The Simulation Based Engineering & Sciences Magazine

Newsletter

Year 18 n°1

Spring 2021

The PaCMan project: Cultivating plants to support life in space

Optimizing the performance of antennas installed on avionics platforms

A natural remedy for hot-spot stresses

Using advanced mesh morphing to seamlessly perform bio-inspired structural shape optimization

Thermo-structural analysis and implosive collapse in the fire prevention field

Flash

A year after the Covid pandemic saw Italy shutdown for the first time to combat the number of contagions and deaths, and to stall the exponential demand for patient hospitalization and intensive care, Italy is now slowly emerging from its third lockdown. The outlook varies from cautiously optimistic, to pessimistic to stoic, depending on who you talk to. But one thing is certain, as engineers we have been required to innovate not only in our own disciplines but, in most cases, also our place of and approach to work and our methods of collaboration.

The consensus is that the pandemic has massively accelerated some existing and emerging business and technology trends and that these will continue to speed up as we begin contemplating a new reality of cohabiting with Covid while controlling its effects through public health initiatives.

Digitalization is obviously the trend that has accelerated most of all, but there are substantial roadblocks, which has important financial consequences. According to the MuleSoft 2021 Connectivity Benchmark Report, 77% of respondents say that a failure to complete digital transformation projects will affect their revenue in 2021. 87% of organizations reported that IT integration is the biggest obstacle to digital transformation since an effective project requires the connection of systems, applications and data. Data silos (90%) and legacy IT infrastructure (60%) are cited as some of the biggest challenges. For further information about the report, which also reviews the top technology investments planned in 2021, see the footnote [1].

In this edition of the Newsletter we wished to reflect on not only the current situation, but to look at how simulation based engineering sciences have evolved in the past thirty years, as well as attempting to do some crystal ball gazing and examine the short-to-medium-term future prospects. To assist us, we contacted some long-standing colleagues and associates and the interviews conducted with them have been compiled into a very interesting article, which is the main feature of this edition.

Other highlights include case studies from Elettronica, Prometech, TNSE, and Digital Product Simulation. We have a number of interesting articles regarding European projects, the GAP project and several new product updates. All in all, there is much to digest in this edition of the Newsletter, and I hope you find it as interesting as I did.

Stefano Odorizzi
Editor in chief

[1] https://www.mulesoft.com/lp/reports/connectivity-benchmark

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At this particular moment in time, the "Newsletter" editorial team wished to reflect on the evolution of CAE and simulation in an effort to present a big-picture view when most of us are daily dealing with all the devil in the details in every aspect of our lives. We approached some long-standing business friends in engineering simulation from various regions around the world to help us in this task. The contributors come from different countries in Europe, the USA, Brazil, and Korea. Each had as different an early beginning as can be imagined considering the differences geographically, economically, technologically, and culturally.

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Correction: In the winter 2020 issue of the Newsletter the article "Enabling safe and efficient human-robot collaboration across Europe with the ROSSINI project" was published on page 46 with the incorrect subtitle referring to numerical simulations of heat radiation. The subtitle should have been: "Test cases to ensure broad adaptability and applicability across industry sectors". The Newsletter regrets the error.

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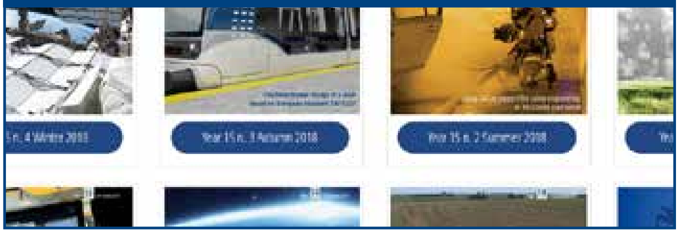

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Taking stock: the evolution of simulation around the world pre- and post-Covid-19

From its earliest days through to future post-pandemic perspectives

by Kathleen Grant and Marisa Zanotti
EnginSoft

At this particular moment in time, the "Newsletter" editorial team wished to reflect on the evolution of CAE and simulation in an effort to present a big-picture view when most of us are daily dealing with all the devil in the details in every aspect of our lives. We approached some long-standing business friends in engineering simulation from various regions around the world to help us in this task.

The contributors come from different countries in Europe, the USA, Brazil, and Korea. Each had as different an early beginning as can be imagined considering the differences geographically, economically, technologically, and culturally. They all began their careers in technical roles as users of finite element simulation, after which their careers developed into management positions in various technical and consulting capacities that saw them involved in the deployment and application of the different generations of these advanced technologies over a period of thirty years.

This, therefore, provides an interesting snapshot of the evolution simulation has had and we hope it will stimulate further debate and thought as we move into the future.

As Roberto Gonella, Director of Corporate Strategic Initiatives at EnginSoft, explains, "Among friends we can allow ourselves to speak frankly, to compare and discuss the experiences and challenges that have seen us participating as protagonists for a long time, albeit in different cultural contexts. This background makes us, somehow, veterans of engineering simulation."

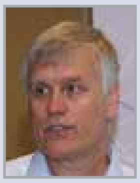
"The term veteran comes from Latin. In ancient Rome, the "veteranus" was a soldier who, after having served for a certain number of years, was retained in a special division (vexillum veteranorum) of the legion. He was released from regular service but obliged to fight in case of war, since the skills he had acquired were still necessary when important decisions had to be made that could potentially alter the outcome of a battle itself," he says.

"Inspired by the teachings of the ancients and with the intention of creating a type of virtual agorà (like the public square in Ancient Greece that welcomed public debate to reconcile the prospective vision of the future with past experiences), this feature will attempt to make a balanced comparison of the past, present, and future in different regions and try to glimpse the future of simulation on the horizon," states Gonella.

Looking back: the Asian dawn

Jinwook Shim, Ph.D, today is joint-CEO of South Korea-based CAE service provider TAE SUNG S&E (TSNE), but he first began his career in a shipbuilding company in 1984. One of the pioneering companies in Korea, Shim's employer used finite element method (FEM) to check the structural integrity and fatigue life of crude oil carriers and offshore drilling rigs. "It was the first time I came across the terms FEM and CAE," he notes. "At that time, FEM was a state-of-the-art technology only accessible to a few designers because the company did not have many computers or software. Designers could run small-sized models consisting of roughly several thousand elements and nodes which were manually constructed in a painfully time-consuming way on the mainframe computer in the computer room," Shim recalls. "And the postprocessing work, such as plotting stress contours and displacement contours, which looks so simple today when viewed on a monitor, was only possible on an A0-sized physical drawing that was printed by a big X-Y pen plotter on a roll of paper."

Contributors (in alphabetical order)



Dave Conover | Ansys
Chief Technologist for Mechanical Products (Retired), and Corporate Fellow
40-year veteran of FEA software development: elements, materials, nonlinear, dynamics, and additive manufacturing.

Markus Dutly | CADFEM (Suisse) AG
CEO
Achieved a bachelor's degree in mechanical engineering from ZHAW, then worked as calculation engineer at Maag Zahnräder (Zurich), after which he transitioned to support, consulting, training, and sales at CADFEM GmbH (Munich). He then became Managing Director of CADFEM Switzerland where he is also head of sales.

Roberto Gonella | EnginSoft
Director of Corporate Strategic Initiatives
With a degree in Aeronautical Engineering from Pisa, he worked at Italcae, where he participated in the development of the "Black Shark", a state-of-the-art heavy torpedo, the detailed design of the Arane 5 boosters, and the dynamic dimensioning of the powertrain system of the 8-cylinder Ferrari engine. Once Italcae was incorporated into EnginSoft, engineer Gonella, in the role of Director of Presales and special projects, is responsible for all the technical activities that govern the engineering software proposition within companies, and the management of special projects, including a nuclear site in Cadarache (France) and Castorone with Saipem.

Marco Perillo | EnginSoft
General Manager
Enamored with FEM since graduating in mechanical engineering in the mid-nineties. Follower of explicit time integration methods for dynamic high velocity problems, especially concerning composite structures. Devoted to discovering emerging methods and technologies to boost CAE application in industry.

Marcus Reiss | ESSS Brazil
Vice President
Marcus Reis was involved in various activities from his early days at ESSS (a Latin American pioneer in the field of numerical simulation). He started as a software developer, but soon migrated to CFD consulting. Over time, he has built a team of technical specialists working in various disciplines of computational modeling (CFD, FEA, EMAG, MDO, and DEM). He has participated in more than 100 projects for key customers from several industry segments, ranging from automotive, appliances, and aerospace, to mining and oil&gas. Concurrently, he also set up and developed the ESSS marketing and sales division with a key focus on Ansys software for LATAM and Iberia. More recently he has been responsible for the global business development of Rocky DEM software.

Jinwook Shim, PhD | TAE SUNG S&E (South Korea)
Ph.D, joint CEO
Studied marine engineering at Pusan National University and began his career at Daewoo Shipbuilding in South Korea. Deeply impressed by the beauty of CAE, he continued his studies earning master's and doctoral degrees. He began working for TSNE in 1997 as a support engineer, devoted to Ansys consulting and support for major companies in South Korea.

Erke Wang | CADFEM Germany
Managing Director
Joined CADFEM in 1988, my life is simulation.

Shim's company used CAE to decide the thickness of the steel to be used for the ship hulls. While the classification societies provided standard guidelines for scantling the hull thickness, shipbuilding companies used FEM software to determine the minimum thickness possible within the guideline criteria, or to cut down the overabundant safety margin: "Obviously, reducing the thickness was key to making more profits by saving on materials, manufacturing, dead weight and fuel, Shim says. In Korea, some government institutions, large enterprises, and first began using simulation software from the early Eighties, "OEM companies for shipbuilding, power plants, and the automotive and defense industries were the early adopters," he explains, "Later, those OEM companies began requiring their contractors to submit their simulation reports, which led to the expansion of CAE technology more widely into smaller companies."

"Since 2000, simulation technology has been widely used by electronics, electrical and semiconductor companies to investigate reasons for failures and to find solutions. Among end users, its use has expanded from a limited group of highly qualified experts to widespread use among normal designers and consequently the role of simulation has changed from merely assisting to improve designs or solve specific engineering problems to playing a key role as an adviser to enhance and maximize the performance of their products," Shim states.

The European beginnings

In Switzerland, when Markus Dutly, today CEO at CADFEM Suisse, started his career, simulation tools like Ansys were also only available on mainframe computers that were reached via a modem and client/server software, "This scenario is being duplicated now: today's cloud applications look very similar," he says, "Although the performance, speed and graphics are not comparable. Back then, my models contained a maximum of 5,000 elements. A job was sent in the evening and you hoped it would be processed by the next day. The costs were also remarkably high – around $500 per night," he explains. "For this reason, only large companies could simulate seriously."

Like in Korea, simulation was used mainly by professors and doctors and began in the established industries such as oil and gas, hydro power, nuclear power, and plant engineering with applications for generators, turbines, compressors, and pipelines. He states, "It was all about safety assessments and proof of standards. I estimate that there were less than 30 companies in Switzerland that used simulation in 1980."

When the first PCs came onto the market in 1990, smaller companies were able to enter the market, Dutly says, "Ansys PC LINEAR or Ansys FULL were popular products for small and medium-sized companies and design engineers were targeted for the first time in 1995. All the marketing and sales messages focused on the software having to be "easy to use", and, to this day, one can argue about what "easy to use" should be in engineering simulation. Some CAD manufacturers' marketing hammered the message that 'anyone can simulate' into

The Beginning of Simulation

Simulation method	FEA/FEM with hand-crafted node and element meshes
ICT environment	Mainframe computer with modems, terminals, line printers, and pen plotters
Users	Professors, PhDs, technical experts at state institutions and large enterprises
Industry sectors	Shipbuilding, oil&gas, power plants, aerospace, automotive and defense
Applications	Structural integrity, fatigue life, understanding failure or damage, assessment of standards, model parameter extraction
Model size	A few thousand elements

customers heads." But Dutly recalls, "John Swanson, the founder of Ansys, said at the time that he would never get into an aircraft that had been calculated by a designer who was simulating just 5% of his time."

Dutly states, "The recipe for the successful use of simulation is not the software alone, but its correct application: it takes a good engineer with good knowledge of numerics and physics and their practical relevance, and he must also be proficient in Ansys. These requirements have not changed since the beginning."

Erke Wang, Dutly's colleague at CADFEM Germany, where he is Managing Director today, elaborates, "Most companies used simulation to understand the reason for damage to a product after it had broken. The knowledge they gained from simulation helped them to improve the products. The time, costs and limitations of testing compared to simulation began to become obvious, so companies began realizing that using more simulation during the development process could save them on time and costs and help them better understand their products. So, while simulation was initially used for validation, it evolved into being used for simulation-driven product development."

According to Wang, the CAD interface and TET mesh features allowed simulation to become mainstream. "From 2D CAD to 3D CAD, companies realized that the value of the 3D model was in more than just its geometry, but that it could also be used for simulation. This is when the CAD-FEM interface became a business opportunity," he recalls, "The automatic TET mesh was the natural step to making the 3D CAD model available for simulation and this, simultaneously led to two important changes in simulation: it provided the experts with more time for advanced simulation and enabled non-experts to begin to use it," he states. "Another technological change that helped to expand the use of simulation was the move from the command-driven interface to the graphical user interface (GUI). Only dedicated experts were able to use the command-driven simulation software tools, whereas the GUI greatly increased the accessibility of the software, broadening the user community and making simulation an engineering tool for engineers too."

In Italy, the adoption of advanced simulation by industries was driven by technical expertise and a deep understanding of finite element methods from the late 1990s to the mid-2000s, according to Perillo. "An understanding of physical phenomena, governing equations and condition modeling, and FEM numerical techniques were necessary conditions to use engineering simulation software. While knowledge and familiarity with meshing capabilities, matrix generation options, and numerical techniques for solving systems of nonlinear equations all ensured stable solutions, accurate results, and a viable use of the expensive computational resources."

He adds, "Any design department that was incorporating CAE technologies for product development had to have an exceptional, respected technical expert on hand to direct the blinking cursor or the input decks with well-known procedures and precise commands."
"In the meantime, the reduction of product time to market in major industries drove the expansion of simulation to solve all physics by using huge, accurate models managed by the HPC systems available at that time. The principal supplementary problems to be solved by contemporary players in industry then were thermal, magnetic, acoustic, fluid dynamics, and crash issues - plus any combination of these," Perillo explains. "In those days, the constant refrain in the market was for CAD translation, defeaturing, and simplification, with automated meshing capabilities to create "single" multi-purpose simulation models. It certainly was the tech-driven era of CAE technologies."

Early forays across the pond

Marcus Reiss, today Vice President of ESSS in Brazil, recalls that in the early days in Brazil too, only super technical experts would deal with the few R&D users here and there, and with advanced product design groups. "Today's advances in both hardware and software, especially in usability, are leading to much greater adoption and a true democratization of physics-based 3D modeling and simulation," he says, "Today, the technology is no longer a 'nice to have' product. For most companies, it is a must-have if they want to remain competitive in their respective industries."

Dave Conover, Chief Technologist for Mechanical Products (retired) and Corporate Fellow at Ansys, says that in the USA, FEA was only used by the PhDs in the analysis departments of a few companies in aerospace, automotive and nuclear when he started at Ansys 40 years ago. "Today, it is used in almost all industries throughout the companies' engineering and design groups, and by engineers just starting out (who almost always encountered it in their undergraduate studies) as well as by the traditional FEA experts who now lead and guide these young engineers," he comments, "Certainly simulation is much more widespread today as a way of designing and validating design. While affordable compute power and software ease-of-use have contributed to this expansion, there has also been a thrust to solve increasingly complicated problems – more physics, more nonlinearities, more assembly models – rather than just simple part models. Industry has evolved from using FEA to augment testing to, in many cases, completely replacing testing; from "why did it fail?" to "the design is good, go to manufacturing"," Conover says.

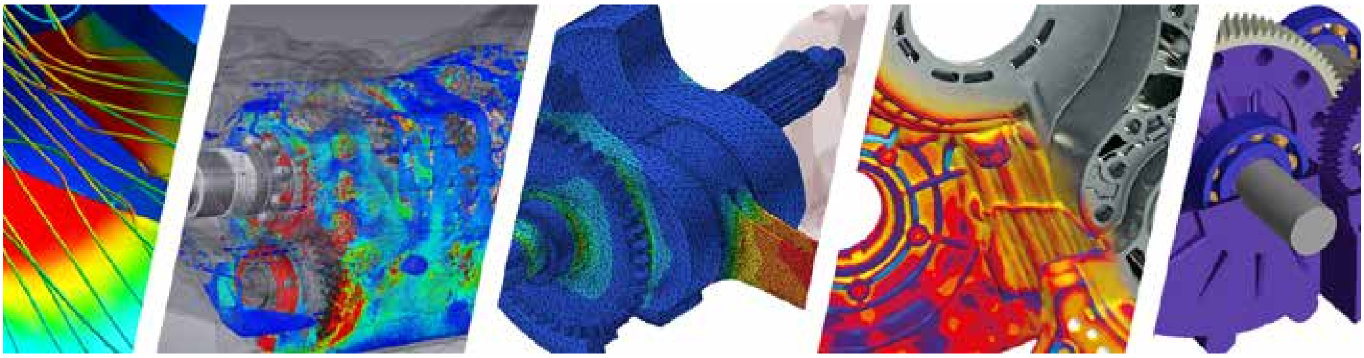
The Covid-19 Tsunami

At the tail end of 2019 and the beginning of 2020, Covid-19 made its appearance on the world stage, totally disrupting every aspect of life around the world, not least work dynamics, and customer relations. Reiss explains that in Brazil they suddenly found themselves locked at home. Business development activities, which until then had been happening through face-to-face visits that resulted in heavily loaded travelling calendars, all moved online. “As a result, we had to significantly increase our digital presence, improve customer support, become more proactive, and really engage with our market and its priorities. From our customers’ point of view, the inability to be on-site (in their factories and labs) helped to demonstrate how important modeling and simulation were to their processes,” he says. “As a result, digital transformation has increased in pace even in this complex and difficult time.” He adds, “It should not be forgotten that Latin America also has local territorial challenges, including unstable politics and high exchange-rate fluctuations, both of which usually make it much more difficult for companies to maintain the pace of their technology investments, meaning that it usually has to be a long-term strategy.”

Conover agrees that online meetings in Zoom, Microsoft Teams, Google Meet and Cisco WebEx certainly enabled continued – and even more – interactions with clients both in the USA and overseas since time frames and travel became irrelevant constraints, while the ability to record and replay meetings and events also offers advantages.

Early Evolutions of Simulation

Simulation method	FEA from 2D and 3D CAD with TET meshing, CAD-FEM
ICT environment	PCs on Local Area Networks, limited HPCs
Users	Design engineers at large enterprises, but also medium-sized companies
Industry sectors	Shipbuilding, oil&gas, power plants, aerospace, automotive and defense
Applications	Product development, performance improvement, thermal, magnetic, acoustic, fluid dynamics, crash issues and combinations of these
Model size	10-100K elements



However, he adds that they are not the best replacement for face-to-face interactions with customers, “Without body language and eye contact, it is difficult to know whether you have really connected with your audience – especially when so many in engineering are from different backgrounds and cultures. The difficulty in asking and answering questions is also somewhat limited in this virtual environment, so supporting users can be hard.”

In Switzerland, Dutly says Covid-19 had a yo-yo effect throughout 2020: “First, business dynamics went steeply downhill, but, at the end of the year, there was an almost complete recovery. Fortunately, we were able to switch our seminars to online operation overnight and the software came from the cloud directly to the customer’s home office. Nevertheless, there was a sharp downturn in the market because customers were on short-time work meaning that training had suddenly become too expensive.” He says that it had been hoped that this digitalization would also capture decision-makers’ thinking, but that this unfortunately was rarely the case and that trial and error continues to be the greatest enemy.

“Today, we use Microsoft Teams and Zoom to see our clients. Our employees spend less time travelling and more time in front of a screen, but we no longer have a bottleneck in pre-sales activities because we can use our human resources more effectively. Our sales expenses have dropped dramatically, and we are questioning whether to revert back to the old model in the future,” Dutly explains, “At the moment it is uncertain where 2021 will take us, but one thing is certain: simulation is necessary to produce high-tech products. Simulation will also become more important to save valuable resources and energy and to stop climate change, so there will definitely be more simulation in the future!”

In Germany, however, Wang says that the transition to online business and the new work dynamic was seamless for his company as a result of their IT infrastructure: “Microsoft Office 365, softphone (VoIP telephony), a virtual private network (VPN) and our CADFEM Cloud enable us to work anywhere and we maintained communication with all our customers from day 1. We were also able to immediately offer our full training program online from day 1. The CADFEM cloud especially enables us to maintain the same quality of support for our customers. Digital communications have demonstrated their true value – our webinar attendance is up by 60% compared to 2019.”

Greater momentum to digital transformation

Perillo is more conservative regarding the situation in Italy, which was one of the countries worst affected by the Covid-19 pandemic, ranking in the top 10 countries worldwide both for total number of deaths and for number of deaths per 100,000 people[1]: "Gaining a reliable picture of the present is not easy. Certainly, the global pandemic is accelerating digital transformation trends in every area and consequently in CAE as well. Even before the pandemic, the need to bring to market Industry 4.0-ready solutions at competitive operational and production costs was generating an increasing demand for the creation of a systemic view within which to create virtual prototypes that both emulated functional and physical behaviors, and supported decision making in all product lifecycle scenarios. Regardless of developments around this disease, there is likely to be an increase in the demand for simulation to address novel product lifecycle management," he states.

"Hundreds of millions of people have had to live and work through the lockdowns. The pandemic is driving profound social and organizational changes and has normalized working from home, which will likely result in a "hybrid" approach to work in future. There is an opportunity for us to embrace the possibility of designing contactless processes to connect the work contributions of remote teams to greater value and outcomes for the remote customer. In this context, CAE remains a technology domain driven by humans using proven simulation methodologies combined with diverse connection technologies that are extended to any area and function of the organization. The ability to build on the lessons learned during this crisis to create a new ecosystem that appropriately leverages potential resources and saves money will be vital to successfully implementing new remote processes to design, plan, and manage next-generation contactless customer relationships," says Perillo.

In Korea, Shim agrees that Covid-19 accelerated digital transformation. But he believes the change was even more dramatic in Korea where working resources were centralized and face-to-face collaboration had been compulsory prior to the pandemic as opposed to the US situation where distributed working environments were more normal, "Koreans got a huge shock and didn't know what to do," he states. "They were asking questions like, "How can I run a big CFD simulation from home? How can I get Ansys training with practice? How can I provide enough technical support if I don't visit my customers? What can we replace our offline seminars and conferences with to generate leads?" Shim explains. He says that TSNE was fortunate because they had been developing their own cloud platform and e-learning/virtual class systems for the previous three years, "These played a tremendous role in preventing the disconnection of our communication with our customers. Currently remote support systems, web meetings, e-learning and virtual classes are believed to be compensating for most of the communication losses caused by social distancing and lock-downs."

Shim says that the major markets for CAE business in Korea now are semi-conductor, HF antenna and automotive. "On the back of the exceptionally fast internet infrastructure, we expect to see exponential growth in three areas: education platform technologies based on VR/AR/MR; no-latency bi-directional communication technologies based on 5G/6G/mmWave; and technology convergence services based on the edge technology for the cloud. At TSNE, we have less direct contact with our customers, but we are getting more proficient in remote support, online training and digital content generation."

Looking to the future

Shim states, "Everyone has accepted by now that we will never go "back to normal" after the pandemic. The customers' desire for diverse experiences, infinite information sharing, the transition to an open society, and the revitalization of the sharing economy will lead us to find more efficient and shorter times to market, with differentiated and cost-effective production. Simulation technology will be an important part of analysis, decision making and control through feedback. Therefore, artificial intelligence (AI), machine learning (ML), and Big Data will not now be added to CAE but will instead be incorporated into CAE which will be developed as a "systems-based multi-physics CAE + service". Beyond the existing CAE space, we can expect multidisciplinary convergence technologies related to e-mobility, healthcare, telemedicine diagnostics, bio/health/beauty, wireless and mobile communications, and sensors to become the major drivers of next-generation CAE."

With regards to the Korean market, he says, "In the near future, the semiconductor business will grow faster in Korea and the demand for highly complex semiconductor simulation will increase. Companies are more likely to use cloud services without maintaining local computer servers. If cloud usage fees begin to decline, more companies will build servers in the cloud. As working from home and online support become normalized in the simulation services industry, sales and subscription support will increase. While the

Future Developments in Simulation

Simulation method	FEA (mixed with boundary elements, meshless methods, and other numerics) of complete assemblies and systems
ICT environment	Cloud-based, edge technologies, HPCs, IoT, Augmented Reality
Users	Designers, engineers, manufacturing
Industry sectors	All
Applications	Besides traditional mechanical parts, 5G sensors, autonomous platforms – robotics, vehicles, construction equipment
Model size	10M-100M elements

References

[1] The Visual and Data Journalism Team. BBC News, "Covid map: Coronavirus cases, deaths, vaccinations by country," BBC News, 15-Mar-2021. [Online]. Available: https://www.bbc.com/news/world-51235105. [Accessed: 18-Mar-2021].

number of sales staff will probably decrease, there is likely to be an increase in paid support services offered by professional engineers and delivered over social networks."

In Europe, Perillo believes that a five-year forecast could generate fragile, unreliable scenarios and suggests referencing the dimensions of Ansys' long-term technology strategy instead. "Focusing on our domestic market, Italian companies are mainly small and medium-sized manufacturing companies and, in 2019, the country still ranked seventh in the world for added value, fourth for production diversification and second for export competitiveness. It is quite clear that information and communication technologies will merge with industrial processes to meet the new challenges and they will play an active role in shaping both established and innovative technologies to permanently grow businesses and profits."

He adds, "CAE simulation technologies will evolve to continue to "aid" engineers to make the right choices at the request phase of the decision processes with sound and reliable background information and data. The synthesis of all the simulation models that combine to represent an entire product – both physically and functionally from a systemic, multidisciplinary perspective – in the real world must be fast, dynamic, and consistent with its alternative uses. An evolutionary execution of collaborative simulation models of differing scale and nature – connected to real-time edge data – will be the natural progression of today's Digital Twin concept to support either predictive operations or new pay-per-use models. This will be one of the characteristic elements of the business-driven new era for CAE technologies."

Dutly thinks that many European countries will have a similar approach: "The complexity of products is constantly increasing, and they are getting smarter. Electronics and embedded software are everywhere. In the past, it was linear statics of individual components; today, it's systems interacting with other domains, being controlled, and containing multiple physical effects. Teams are required to do this because the superhuman who understands it all is rarely found. Complexity can be mastered. That is positive. The question is: who masters the complexity? Only the big players? Is it worth it for an SME to provide that capacity? And that brings us back to EnginSoft and CADFEM. Today and five years from now, we can lead the customers to where they can get the maximum benefit. In the future, simulation will continue to be much more than just software," he concludes.

According to Wang, in the next five years, simulation will replace most of the testing that is used today. "Many companies currently only simulate single physics because Multiphysics simulation is still difficult for product engineers, yet products are becoming smarter and include more physical domains, so efficient process integration and design optimization (PIDO) will make product simulation available to more engineers. PIDO however generates much more data during product development. If that data is managed systematically, its value can be scaled across the enterprise. This will lead to simulation process and data management (SPDM) becoming the standard. Artificial intelligence will make simulation more accurate and create more innovation, while SPDM will increase the quality and use of

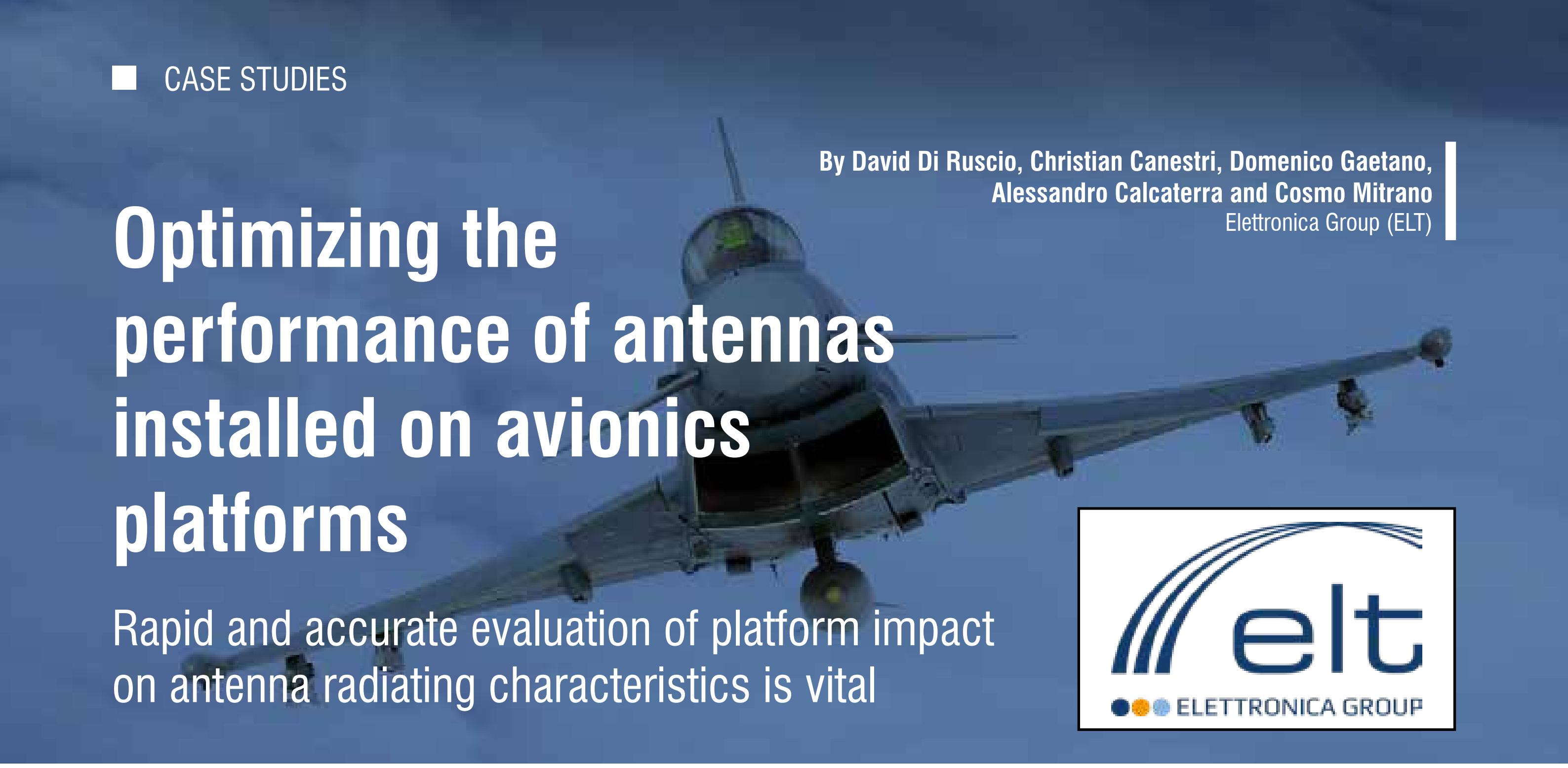
AI in simulation. Cloud computing will become cheaper and more powerful, making simulation available everywhere and even enabling in-product simulation. All of which, combined, will give more engineers, doctors, architects, designers, salespeople and managers access to simulation," he says.

Across in Brazil, Reiss too strongly believes that simulation will become more and more important, even for small to medium-sized businesses, "We share the vision that it will move out of R&D and product development and into large design groups, meaning that it will also move to earlier stages of product development," he states. "In terms of new applications, we see companies increasingly looking to improve the modeling and simulation of production and manufacturing processes (i.e., their production lines). In this regard, additive manufacturing has an obvious place in the future, and that goes hand in hand with the early application of simulation technology."

Conover says that using simulation for the full product lifecycle – from design (where it is now), to manufacturing (where it has some application), to product usage (think digital twin), to end-of-life (think disposal and recycling) – will become more the norm in engineering, "This will entail more physics, including chemical reactions, and more focus on materials," he states, and adds, "The second area of opportunity is inserting more of the human into the product design and usage. The use of AI to help define ergonomics, possible use cases (and abuse cases!), repairability, etc. will evolve quickly, particularly because the development of autonomous vehicles is pioneering this AI, human-centered approach!"

Constant evolution and broader application at a faster pace

For our industry veterans, it would seem that even in the post-pandemic world CAE and simulation technologies and techniques will continue to become easier to use and more widely available, and they will be applied across a broader spectrum of the business, not just to technical product design to assist companies to reduce costs, increase efficiency and useful life, but also to innovate new products and services to improve overall product longevity and business profitability, while improving staff and customer experiences and reducing environmental impact. To conclude with a literary reference, what has been one of the worst of times across the world, augurs to be the start of the best of times for the future of CAE and simulation.



By David Di Ruscio, Christian Canestri, Domenico Gaetano, Alessandro Calcaterra and Cosmo Mitrano
Elettronica Group (ELT)

Optimizing the performance of antennas installed on avionics platforms

Rapid and accurate evaluation of platform impact on antenna radiating characteristics is vital

Electronic Warfare (EW) tactics seek to obtain control of the electromagnetic (EM) spectrum to disrupt the performance of enemy systems that use electronic sensing devices to operate. One of the passive tactical measures used are electronic support measure (ESM) systems, comprised of antennas that are installed on a naval, avionics or terrestrial platforms and which analyse incoming radio frequency (RF) pulses to provide the direction of arrival (DoA) and other characteristics of the received electromagnetic waves. However, EM interactions with the platform can create deformations in the shape of the antenna's radiating beam, resulting in both amplitude and phase unbalances between the independent channels of the receiver, thereby reducing the accuracy of the estimation. It is therefore fundamental to evaluate these pattern deformations during design and this is most commonly done using specific EM solvers. The large dimensions of the platform on which the antenna is installed relative to the wavelength means that full-wave solvers and required to solve linear algebraic systems involving many millions of unknowns, dramatically increasing the computational burden. This article discusses the use of the Ansys HFSS SBR+ method for wave propagation analysis that is based on specific EM propagation formulations (commonly referred to as Asymptotic Methods), and which offers an effective alternative in terms of solution accuracy and computational cost. The method's effectiveness is demonstrated in this case study that considers the analysis of an ESM sinuous antenna installed on an avionics platform.

The main scope of Electronic Warfare (EW) is to obtain control of the electromagnetic (EM) spectrum and to minimize the effectiveness of enemy systems that rely on electronic sensing devices to operate. To achieve these ends, several measures are usually required:

- Electronic support (e.g. threat alert, direction finding, fingerprinting, etc.)
- Electronic attack (e.g. EM jamming, chaff decoys, directed energy weapon, etc.)
- Electronic protection (e.g. spectrum management, emission control, etc.)

Systems implementing the above techniques usually cooperate in the vast and complex electronic warfare scenario.

Tactical knowledge of the distribution of hostile electromagnetic sources over an area or around a protected platform is necessary for both defensive responses (i.e. self/mutual protection) and for electronic offensive operations (jamming missions).

Tactical interceptions refer to two main operations: radar warning receiver and electronic support measures (ESM). The former allows the detection of radar signals, identifying the presence of known emitters and terminal threats. The latter handle tasks of medium/high complexity and analyse the incoming radio frequency (RF) pulses (e.g. frequency, pulse width, modulation, time of arrival), providing the direction of arrival (DoA) of received electromagnetic waves [1].

Several techniques have been developed to process emitter RF signals and estimate the relative DoAs; each technique has specific pros and cons. In addition, it is usually possible to install more than one direction finding (DF) receiver on the same platform.

The main DoA techniques are:

- Amplitude comparison DF, in which the Goniometric Function (GF) is the different weighting of the incoming signal amplitudes from the gains of different antennas in the array;
- Phase comparison DF, in which the phase information is exploited, and the GF is represented by the phase difference between two antennas;
- Correlative DF, which is based on the correlation of the phase responses for a given direction of arrival;

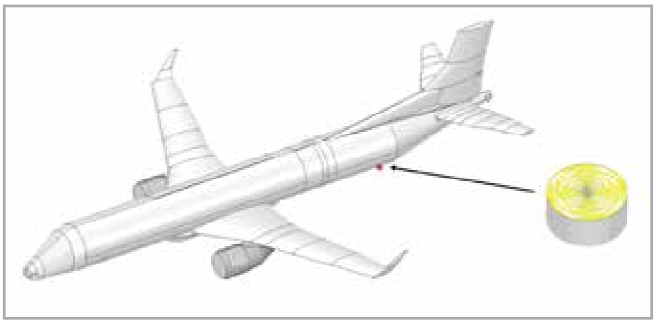


Fig. 1 – Avionics platform considered for the analysis. The antenna is positioned at the rear of the aircraft.

- Differential Time of Arrival DF, which exploits the difference in time of arrival between two antennas for a given angle of the incoming radiation.

The direction finding techniques described are based on the use of arrays of two or more antenna elements that intercept the incoming EM wave and transfer it, in the form of an electrical signal, to the receiver. The signal is then processed to estimate the corresponding goniometric function. Typically, the DoA estimation algorithms implemented in the receiver refer to arrays that are located away from external interfering objects, thus achieving the highest accuracy in terms of root mean square angular error.

Therefore, in practical installations of ESM systems on a specific platform (naval, avionics or terrestrial), it is critical to evaluate the pattern deformations of the installed antenna's sensors. Deformations in the shape of the antenna's radiating beam, caused by EM interaction with the platform, result in both amplitude and phase unbalances between the independent channels of the receiver, thereby reducing the accuracy of the DoA estimation.

For more information about electronic defense and related techniques please visit [2].

It is common practice to analyze the pattern deformation of installed antennas using specific EM solvers. Unfortunately, as a consequence of the large dimensions of the platform relative to the wavelength, full-wave solvers have to solve linear algebraic systems involving millions (and even hundreds of millions) of unknowns. This increases the computational burden enormously. However, specific EM propagation formulations (commonly referred to as Asymptotic Methods) offer an effective alternative in terms of solution accuracy and computational cost.

In this context, the Ansys Electronics Desktop portfolio provides SBR+, a general-purpose method for wave propagation analysis based on a high-frequency asymptotic electromagnetic solver. The method is based on the ray tracing technique and enables EM interaction in an electrically large and geometrically complex platform to be rapidly and efficiently evaluated.

Geometrical optics rays are launched from the phase center of the transmitting antenna towards the structure, evaluating the induced surface currents. The scattered field is then calculated by integrating these currents using physical optics methods. The first bounce zone is then established. Subsequently, several incident rays are reflected towards other zones of the platform, resulting in the second bounce zone and so on. In this way, SBR+ implements the so-called multi-bounce scattering process. To further refine the accuracy of the result, the SBR+ technique exploits Physical Theory of Diffraction (PTD) wedge correction, Uniform Theory of Diffraction (UTD), edge diffraction ray sources and creeping wave physics [3].

In the following, the basic steps of pattern deformation analysis on an installed antenna are described. An avionics platform is considered and the antenna was positioned a few meters behind the trailing edge of the wing, as shown in Fig. 1.

The first step is to design the antenna in a free-space environment. An antenna used in an EW system is commonly required to operate over a wide frequency bandwidth. Several types of UWB antennas have been developed over the years [4]. One such example is the sinuous antenna [5]. It belongs to the class of frequency-independent antennas. It is usually printed on a dielectric substrate in a printed circuit board (PCB) and in many applications is supported by a conductive cavity. Its basic principle of operation is to radiate localized currents at specific frequencies in the so-called "active regions" of the circuit (see Fig. 2).

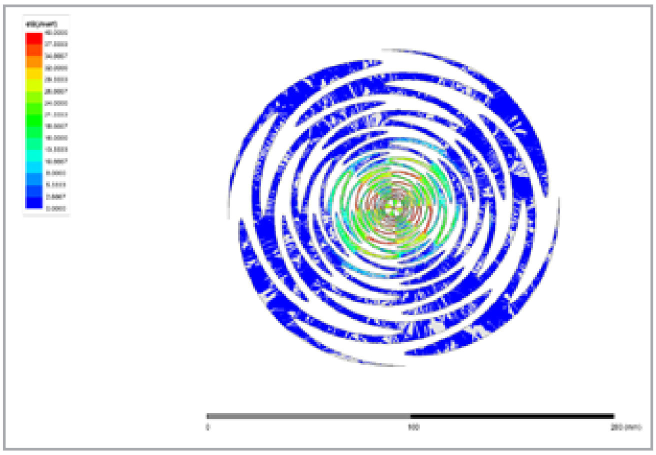


Fig. 2 – Surface currents on sinuous antenna at 3GHz. The active region is identified by the high-value currents.

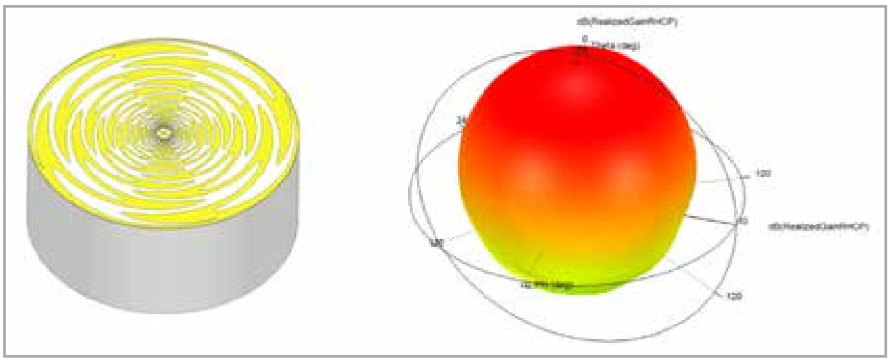


Fig. 3 – Cavity Backed Sinuous antenna. 3D free-space radiation pattern at 3GHz.

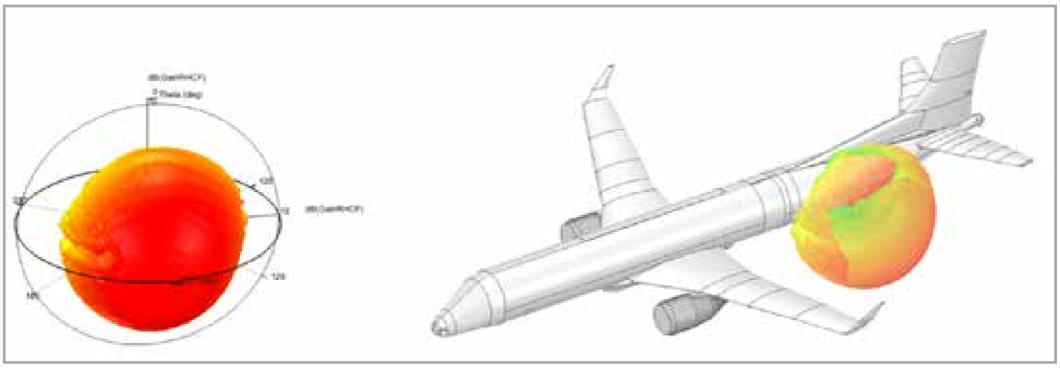


Fig. 4 – 3D Radiation pattern of the installed antenna at 3 GHz

Fig. 3 shows the far-field pattern at 3GHz in a free-space environment. One can see that the pattern has good azimuthal symmetry as is expected from this type of antenna in free space.

Once the 3D model of the antenna has been simulated and the 3D pattern fully characterized, the second step in the analysis is to export the near field box of the antenna. The solver calculates the equivalent electric and magnetic currents on each geometric surface of the box.

About Elettronica

ELT (a.k.a. ELETTRONICA) Group is a global leader in the business of Electromagnetic Spectrum Operations with a complete portfolio of state-of-the-art solutions to satisfy the most challenging requirements of modern operational scenarios. ELT is an Italian Company, established in 1951, share-held by Leonardo, Thales and, for the majority, by a private owner, with an order book of 1.2 B€ and revenues of 250+ M€ per year.
The solutions designed and manufactured by ELT cover a wide range of applications and missions:

- Intelligence-Surveillance-Reconnaissance
- Self and Mutual Protection
- Electronic Attack, Escort, Stand-in and Stand-off Jamming
- Convoy Protection and Prevention
- Homeland Security and Border Surveillance
- Cyber EW and intelligence

ELT solutions are integrated in several kind of platforms (aircrafts, helicopters, fighters, UAVs, Surface ships, underwater vessels) and manage information in air, land, sea and cyber domains. The record include military, military supported and intelligence missions where the Company solutions have been tested and proven in operations by European and non-European Countries worldwide. ELT widen its competence and offers by means of two sister Companies:
ELT GmbH, which is a Centre of Excellence in Homeland Security, Test Validation Systems and Video Digital Boards Design and Production. CY4GATE, which provides Governments with software and hardware solutions to support the full cycle of intelligence and to succeed in Cyber operations in the electromagnetic environment, communications, operating systems and wired networks.

Once the current samples have been memorized, they can be imported to a specific position on the platform of interest, as illustrated in Fig. 4.

The HFSS SBR+ solver processes the surface currents to evaluate the installed far -field pattern of the antenna. In the installation considered, the greatest impact on the radiated electric field relates to the shadowing effect of the wings, as shown in Fig. 5. In this figure, the green curve indicates the far-field pattern of antenna in free space and the red curve indicates the far-field pattern of the installed antenna in the azimuthal plane (i.e. elevation=0 degrees). The directivity of the antenna is shown and the masking effect of the wing can be seen for azimuthal angles less than Φ = -30 degrees, which corresponds to Azimuth = -30 degrees. The pattern deformation could severely affect the overall performance of the system (e.g. DoA estimation) and must be taken into account in the development of the design.

A rapid and reasonably accurate evaluation of the platform's impact on the antenna's radiating characteristics is therefore of primary importance for optimizing the performance of the installed antenna.

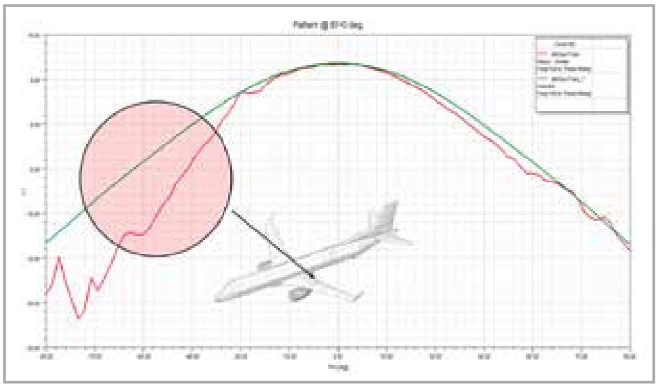


Fig. 5 – Comparison of the far-field pattern in the azimuthal plane at 3GHz. Green curve: free space. Red curve: installed antenna.

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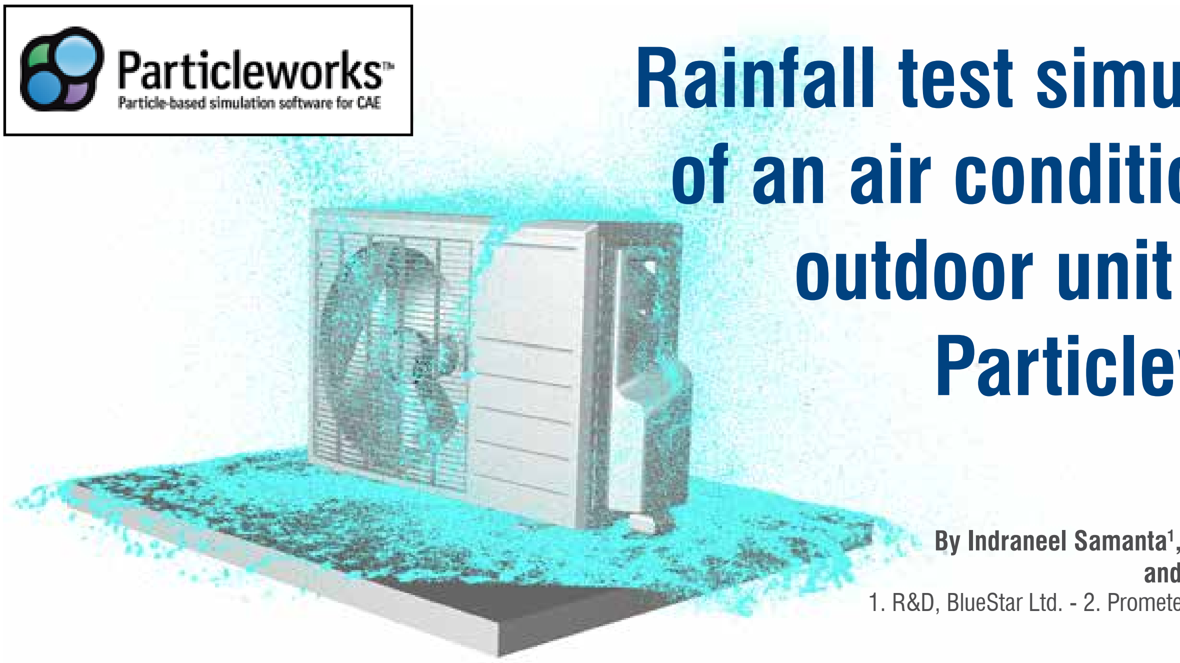


Rainfall test simulation of an air conditioner's outdoor unit using Particleworks

By Indraneel Samanta[1], Sunao Tokura[2] and Akiko Kondoh[2]
1. R&D, BlueStar Ltd. - 2. Prometech Software, Inc.

Today, many outdoor installations of electrical appliances are increasingly exposed to extreme weather patterns, particularly torrential rainfall, resulting from climate change. Typically, these appliances undergo a rain test during design to determine the potential for water penetration and damage to important internal components. However, these tests usually do not reveal where the water penetration occurs. Numerical simulation can predict rainwater penetration and its penetration path to inform relevant design changes and waterproofing measures for improved product performance. Such studies represent complex free-surface phenomenon simulations for which Particleworks is particularly well-suited. This article presents the simulation of rainfall on the outdoor unit of an air conditioner as a concrete example of this approach.

Many electrical appliances around the world are installed outdoors where they are continuously exposed to the elements. In designing these appliances, a rain test is performed in a shower to evaluate the effectiveness of the waterproofing and to examine the possibility of water penetration and damage to important internal components.

However, while these tests can determine whether water has penetrated the product, it is not easy to determine where it entered. In order to develop these products more efficiently, numerical simulation can be used to predict the intrusion of rainwater and its path into the product so that appropriate design changes can be made and waterproofing measures can be taken before prototyping to improve product performance.

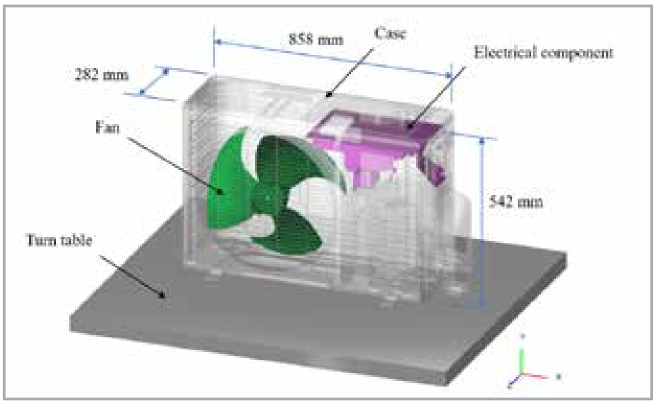
Rainfall or the flow of agglomerated raindrops on a product represent a complex free-surface phenomenon. Particleworks, a particle-based computational fluid dynamics (CFD) software that can efficiently process water droplet behavior and free-surfaces, is well suited to simulating such problems.

In this article, we will introduce a simulation of precipitation on the outdoor unit of an air conditioner as a concrete example of dealing with such a problem. Initially, the problem was posed as a challenge by the manufacturer, Blue Star Limited in India, where it often rains heavily. In recent years, torrential rains, which are considered to be an abnormal weather condition resulting from climate change, have occurred every year in many parts of the world. As a result, appliances installed outdoors need to be more waterproof than ever before.

These waterproofing measures extend the life of the product by preventing critical electronic components from being exposed to water, compromising product functionality and also prevent corrosion of internal components if they are exposed to water. For outdoor units, this includes reducing the ingress of water through the large front grille openings used to control airflow as much as possible. Numerical simulations play an important role in detailing the behavior of these raindrops, identifying the path of water penetration into the product, and using this information for waterproofing measures.

Fig. 1 shows the actual precipitation test. Assuming torrential rain, the amount of rainfall is set to 80mm per hour. The turntable on which the

Fig. 1 - Rainfall test



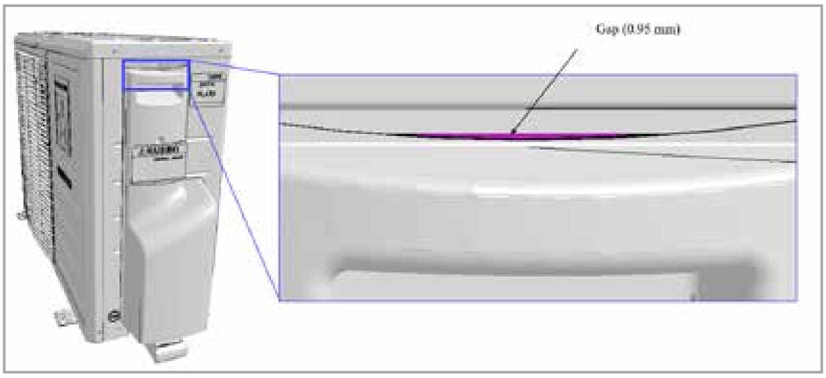


Fig. 2 - Geometry of the simulation model

product is placed rotates slowly, allowing raindrops to hit the product from all directions, while two blowers behind the test chamber constantly blow strongly. Fig. 2 shows the model geometry prepared to evaluate the product by simulation under these conditions.

Overall, the dimensions of the product are approximately 860mm wide, 540mm high, and 280mm deep. Although the actual product is composed of many components, the simulation models only the major components that affect raindrop behavior: enclosure, fans, turntables, and electronic components to be assessed for water damage.

Particleworks does not require meshing and the CAD data itself can be used directly for simulation, so there is no need to spend a lot of time on pre-processing. Importantly, the product has a small gap above the handle through which raindrops may enter. The width of the opening is only 0.95mm, but since it is close to the electronic components, the possibility of raindrops entering from here cannot be ignored.

The water sprinkling from the shower was set as an analysis condition. In the test, three rows of showerheads were installed at a height of about 2 meters from the product. However, only the water from two rows of showerheads had an effect, so eight showerheads were modeled for the two rows that would be needed for the simulation.

In Particleworks, we created an inlet above the showerheads and set a flow rate of 80mm per hour, similar to the test. Considering the precipitation and the area of the sprinkler holes, we defined the flow velocity as 2,000mm/s. As boundary conditions, the fan speed inside the outdoor unit was set to 3,600rpm, and the turntable speed was set to 2.3rpm, estimated from the test video.

We also had to consider the effect of airflow. In order to reproduce the actual rainfall test, we had to consider the effects of the airflow generated by the fan and its rotation on the trajectory of the raindrops inside the outdoor unit. Such an airflow field can be obtained by modeling the air around the outdoor unit with particles, but this is not efficient in practice due to the large number of particles.

In this study, the results of the airflow field calculated by general CFD software were imported into Particleworks as a set of spatial coordinates and velocity vectors in CSV format, and the airflow field was examined as shown in Fig. 3. This airflow field can be used to calculate the state of the raindrops under the influence of wind as a so-called one-way coupling simulation.

The water falling on the entire outdoor unit of the air conditioner was modeled with 2mm diameter particles for practical reasons of calculation time. However, this model geometry has a 0.95mm gap above the handle, so a smaller particle size had to be set to model the particles passing through this gap.

Particleworks provides a feature called "zooming" that allows the spatial resolution, or particle size, of certain areas within the analysis space to be fine-tuned. The zooming function is also intended to reduce the computational load. As shown in Fig. 4, in this simulation, a single particle with a diameter of 2mm that reaches the vicinity of the gap is replaced with approximately 500 particles with a diameter of 0.25mm, and a high-resolution

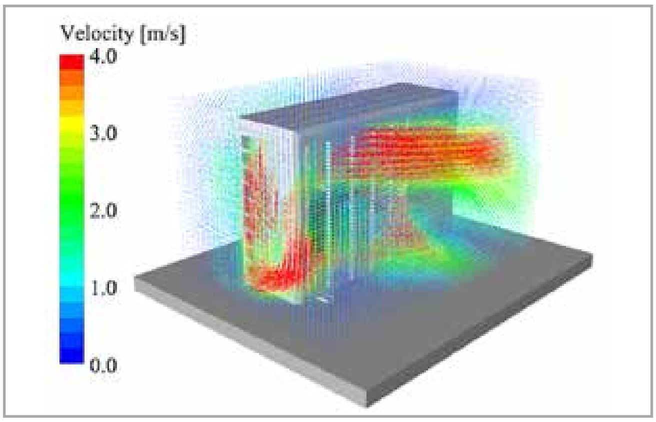


Fig. 3 - Air-flow field inside and outside the outdoor unit

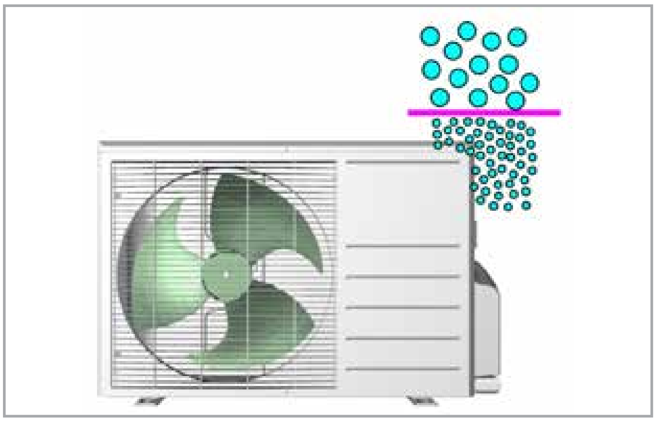


Fig. 4 - Zooming function to fine-tune the particle size

Fig. 5 - Comparison between the test and simulation results

Here, we plotted the streamlines of several particles and found that there are two major infiltration paths. One is the path shown by the green line, where particles entering the enclosure through the front grille hit the rotating fan blades and are blown away towards the top of the electronics box. The other is the path indicated by the pink line, where the fan's airflow also blows particles entering through the grille up towards the electronics.

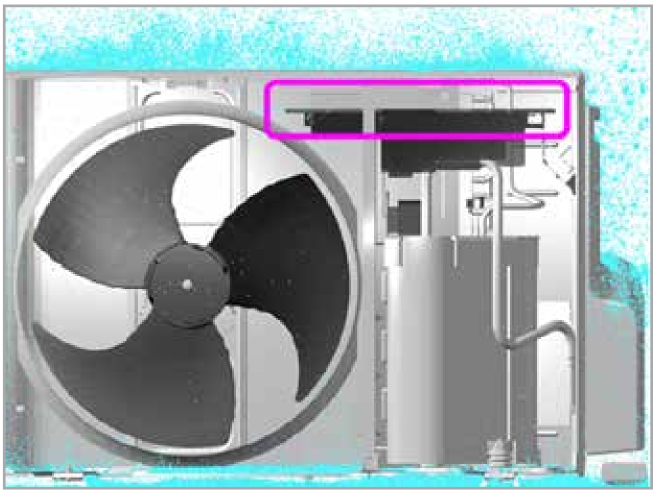


Fig. 6 - Raindrops in the outdoor unit

calculation without partial increase in the number of particles in the entire analysis space is performed.

Fig. 5 shows the simulation results. Water was sprinkled from the eight showerheads and fell onto the outdoor unit. The test confirmed that the surface of the electronic component box was covered with water. The simulation also shows that water droplets adhere to the box.

As shown in Fig. 6, the raindrops that penetrated the outdoor unit reached the top of the electronic component box and flowed through. Using the post-processing function, it is possible to visualize the infiltration path of the raindrops more clearly by plotting the streamlines of the raindrop particles that reached the top of the electronic component box (Fig. 7).

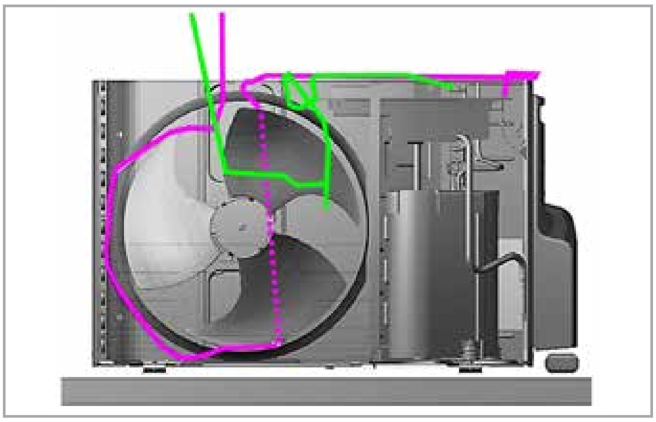


Fig. 7 - Plotting the streamlines of the main paths of the raindrop particles entering the unit

Next, we focused on the behavior of the raindrops around the small gap. As mentioned earlier, we used the zooming function here to create particles with a 0.25mm diameter. Looking at the aperture from the inside, we could see that raindrops were entering through the gap, as shown in Fig. 8.

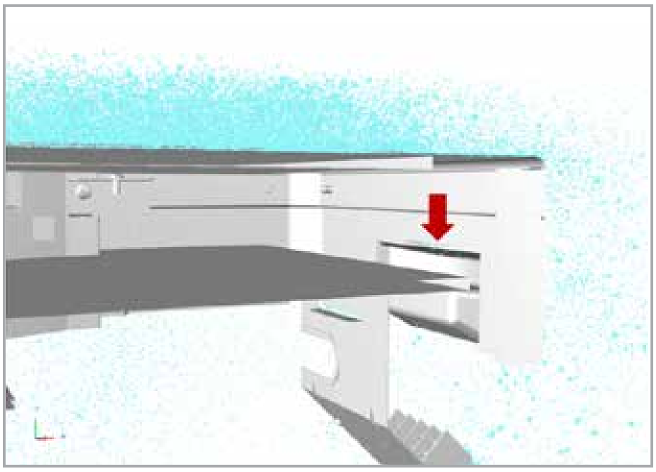


Fig. 8 - Raindrops entering through the gap

Therefore, the ability to visualize the ingress path of the raindrops, which is difficult to observe in the actual test, is a great advantage of simulation.

As mentioned earlier, it is not easy to identify the path of water penetration into the product simply by testing the actual product and then applying waterproofing and water damage countermeasures in the early stages of design.

Fluid simulation with Particleworks can be applied to the design and development of various home appliances to apply waterproofing and water damage countermeasures more accurately and efficiently.

The simulation presented in this paper uses the 3D CAD data of the outdoor unit of an air conditioner, actual test results, and photographs provided by Blue Star (India). This study was also presented at the International CAE Conference held in November 2020.

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A natural remedy for hot-spot stresses

Using advanced mesh morphing to seamlessly perform bio-inspired structural shape optimization

This paper demonstrates how the biological growth method, studied by Mattheck in the 1990s, can be easily implemented for structural shape optimization finite element method (FEM) analyses using advanced radial basis functions (RBF) mesh morphing. We use the same mechanism observed in tree trunks: hot spots of higher stresses promote material growth as well as reducing the stress itself thanks to the added thickness. Mesh morphing is a key enabler in adapting the desired shape, calculated over the surface of the finite element analysis (FEA) mesh, to the entire solid domain. According to the same principle, material can be also removed allowing for lighter structures. We first explain the method by studying a tree trunk and then through a variety of successfully addressed structural optimization challenges.

Industrial design seeks to shape parts optimally to minimize both costs and risk of failure. Nowadays, designers can benefit from the introduction and widespread adoption of numerical simulation, which allows them to virtually test different configurations using FEM. Finding an optimal shape, however, requires the designer to build a numerical model for each variation to be tested, and this can become a very time-consuming task especially when complex-shaped components are being analyzed.

Mesh morphing allows a shape variation to be analyzed while maintaining the same model: only the nodal positions of the FEA mesh are updated enabling the new design to be represented and evaluated using a high level of automation and mesh node control. Such node control is paramount for the implementation of parameter-less methods, such as the one presented in this paper, in which the shape evolves driven by the numerical results.

The biological growth method (BGM) is a bio-inspired approach based on the behavior observed in biological tissue under stress: areas of higher stress usually promote a high growth rate so that stress peaks can be mitigated. This method can be successfully used to optimize the shape of mechanical components and can be flexibly controlled according to the current manufacturing process.

The full complexity of the resulting organic shapes can be achieved using additive manufacturing, unleashing the full expressiveness of this method and obtaining maximum benefit; in the case of traditional machining, manufacturing constraints can be added to the shape optimization process so that feasible solutions can still be realized.

Technical and scientific background

BGM is a shape optimization method whose driving force is the magnitude of surface stresses on structural components. This method is based on the observation that biological structures, such as tree trunks and animal bones, actually add layers of biological material to the surface areas affected by activation stress. In the 1990s, Mattheck proposed extending this concept to CAE and structural part design by adding material to surfaces with high stresses and/or removing it from surfaces where stresses were low. A volumetric growth ε based on the actual von Mises stress $\sigma_{von\ Mises}$ and a reference activation stress σ_{ref} was proposed:

$$\dot{\varepsilon} = k\left(\sigma_{von\ Mises} - \sigma_{ref}\right)$$

The optimization behavior (add/remove material) is controlled by setting the reference stress value σ_{ref}. The method proposed in this study is based on a more versatile and evolved version of the Mattheck model and prescribes displacing the node in the direction normal to the surface:

$$S_{node} = \frac{\sigma_{node} - \sigma_{th}}{\sigma_{max} - \sigma_{min}} \cdot d$$

where σ_{node} is the stress evaluated at each node, σ_{th} is a threshold value for the stress defined by the analyst, and σ_{max} and σ_{min} respectively are the maximum and minimum stress values in the current set. *d* is the maximum offset between the nodes on which the maximum and the minimum stresses are evaluated; this parameter is defined by the user to control the displacement of the nodes whilst limiting the possible distortion of the mesh. Nodes on the surface to be optimized can either be moved inward, if the stress on node is less than the threshold value, or outward, if the evaluated stress is greater.

The proposed BGM implementation can be guided by a variety of stress/strain definitions (such as maximum principal stress, maximum plastic strain, accumulated equivalent plastic strain, etc.), so that the method can be tailored to the specific design requirements.

Propagation to the full computational mesh of the BGM field calculated on the surfaces can be achieved using radial basis functions (RBF) mesh morphing. RBFs were introduced in the early 1960s to interpolate scattered multidimensional data and to allow interpolation of a scalar field anywhere in the defined space from known values at discrete points called source points.

Since the data to be interpolated at x comprises scattered scalar values at N source points Xs_i, the interpolating function s(x) can be obtained as

$$s(\boldsymbol{x}) = \sum_{i=1}^{N} \gamma_i \varphi(\|\boldsymbol{x} - \boldsymbol{Xs}_i\|)$$

by summing the interactions at the probe location x with all the source points that have been computed by weighting all the radial interactions (calculated as Euclidean distances between each source point) with γ_i coefficients, and the probe location transformed by the radial function $\varphi(r)$. The N unknown γ_i are calculated by imposing the passage of the s(x) function through all the (known) source points.

In mesh morphing, the source points are the surface mesh nodes over which the displacement is controlled, whilst the entire set of nodes within the mesh is updated by receiving the interpolated deformation field. Individual RBFs interpolate the three components of the displacement. The above mesh morphing technique and BGM can be successfully coupled in an optimization approach consisting of the following steps:

1. The baseline geometry is discretized into finite elements; load and constraints are applied, and the FEM solution is evaluated;
2. From the FEM solution, the nodal stress on the surfaces to be optimized are retrieved, σ_{th} and *d* are set by the user and S_{node} displacement along the surface normal for each node is evaluated for each selected node;
3. The evaluated displacements are used to configure the RBF problem by imposing them as values to be interpolated (values on source points), the user can optionally set additional source point values to complete the morphing configuration (i.e., points to maintain fixed);
4. The FEM model mesh is morphed, and the FEM solution is evaluated again;
5. The stress values on the surface to be optimized are analyzed: if the new stress levels can be further optimized, the procedure is iterated from step 2; otherwise, the geometry can be considered optimized.

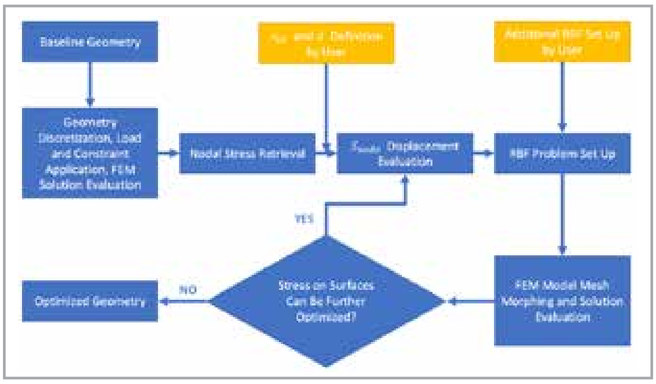

Fig. 1 - Surface sculpting procedure obtained by combining BGM and mesh morphing.

In the methodology described above, the stress analyst must set two BGM parameters: the threshold stress σ_{th} and the maximum displacement d. The first parameter represents the stress level value on which the optimization procedure will try to converge; the second parameter represents the maximum displacement allowed within a single iteration of optimization: the lower its value, the greater the number of iterations that will be required to reach the optimum, and the lower the risk of mesh distortions that could invalidate the FEM model will be.

Software implementation

The proposed approach has been implemented using the RBF Morph line of software. The RBF Morph ACT extension for Ansys Mechanical provides Ansys FEA users with a comprehensive advanced mesh morphing toolkit, and the BGM-based parameter-less shape

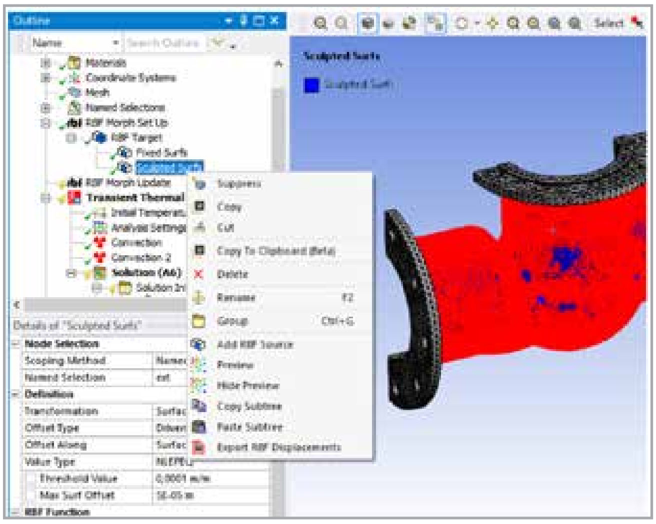

Fig. 2 - The RBF Morph ACT extension for Ansys Mechanical allows you to define the desired mesh morphing configuration directly in the tree. In this example, the wall of a valve subject to TMF is controlled by BGM using accumulated non-linear equivalent plastic strain (NLEPEQ) as the driving function.

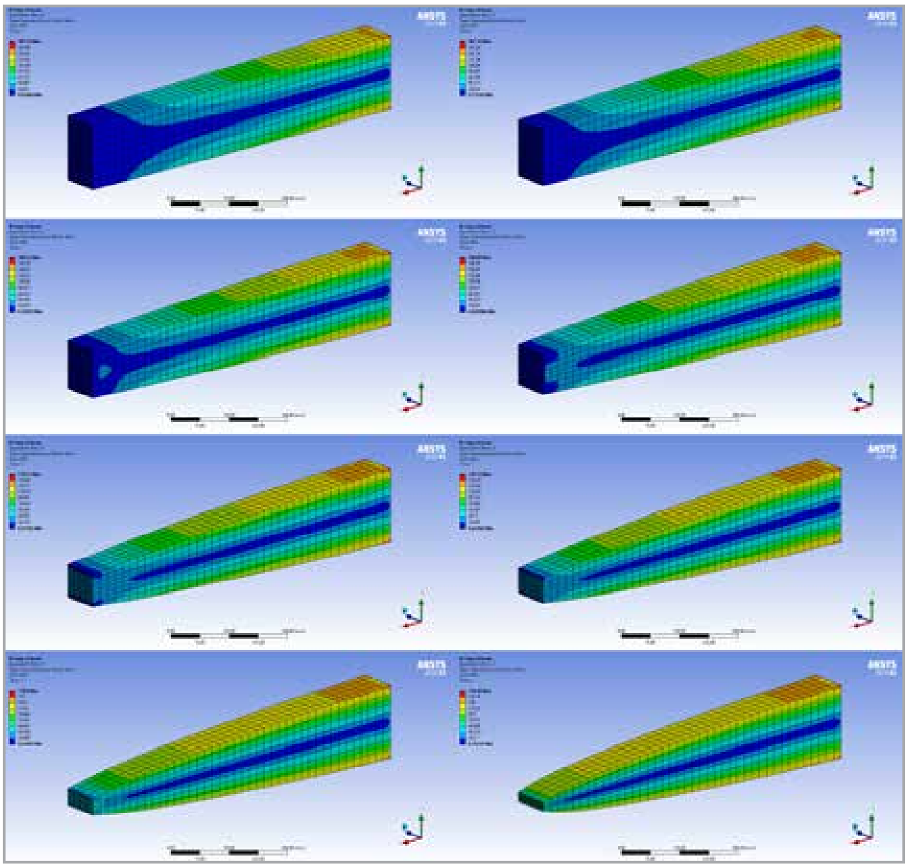

Fig. 3 - Evolution of the shape of a cantilever beam: the final shape has a parabolic profile and the stress levels on the external surface are uniform.

optimization workflow is among these. This specific feature has undergone intense development driven by successful applications obtained from academic and industrial users. As shown in Fig. 2, the user is asked to specify the areas to be reshaped according to the BGM method and the maximum desired action within each iteration.

Overall optimization is then achieved by simply defining the required number of intermediate iterations as individual design points in Workbench. The complete table will then be populated automatically with time depending on the cost of a single FEA run. For complex industrial applications, such as the nonlinear thermomechanical fatigue (TMF) case in the example in the image, full optimization may take several hours. Typically, a dozen FEA solutions are required to obtain a good refined optimal shape.

Applications

The proposed approach has been used for a variety of purposes that demonstrate how BGM

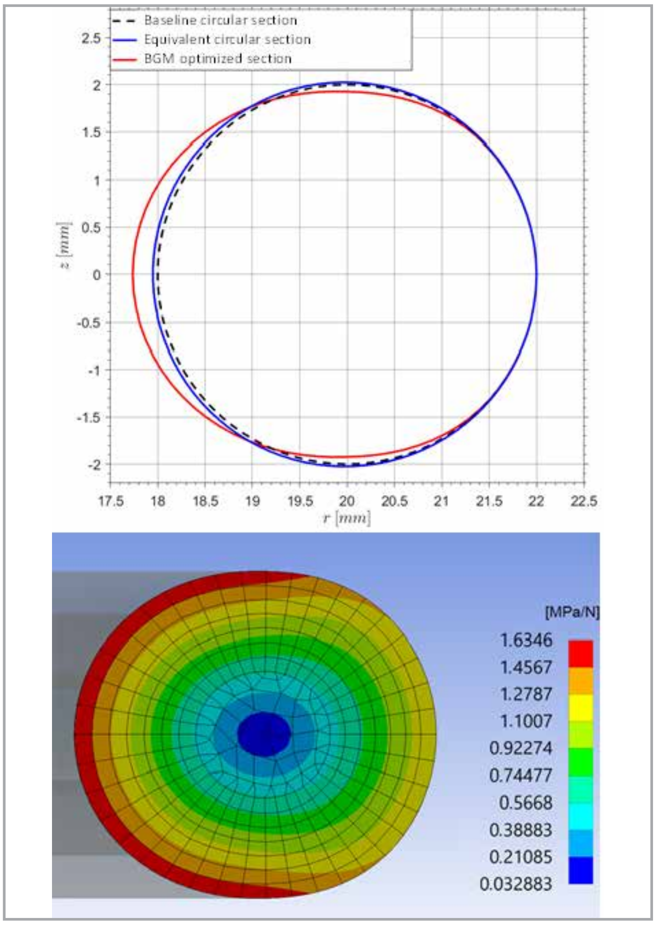

Fig. 4 - Optimized cross-sectional shape of a coil spring. The stress levels on the inner surface are uniform and the optimized shape leads to higher spring efficiency and lower maximum stress.

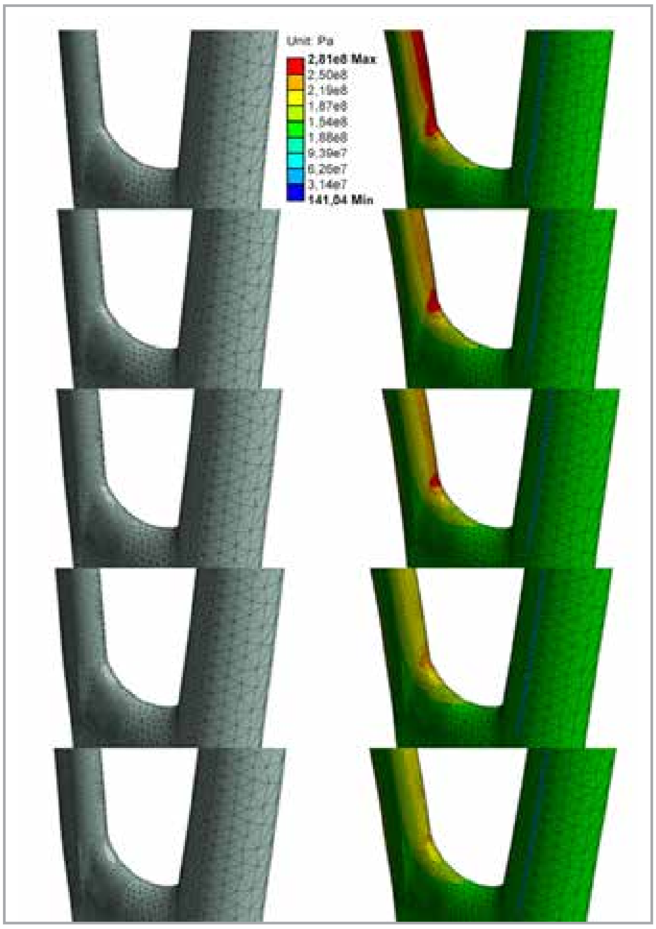

Fig. 5 - Tree trunk evolution study: based on Mattheck's work in the 1990s, it was possible to reproduce the same shape evolution in a 3D model, highlighting the reduction of the hot-spot stress level

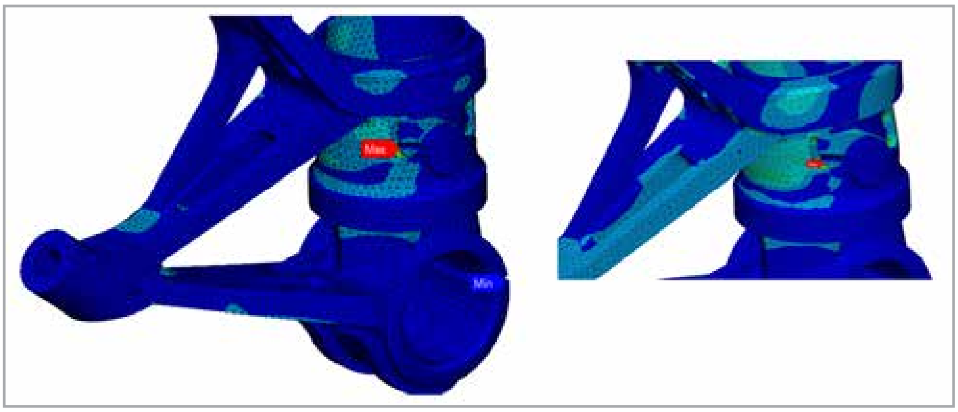

Fig. 6 - Original baseline configuration and optimized configuration after 10 iterations: maximum stress level reduced by 20.8%, increasing whole volume by 2.5%

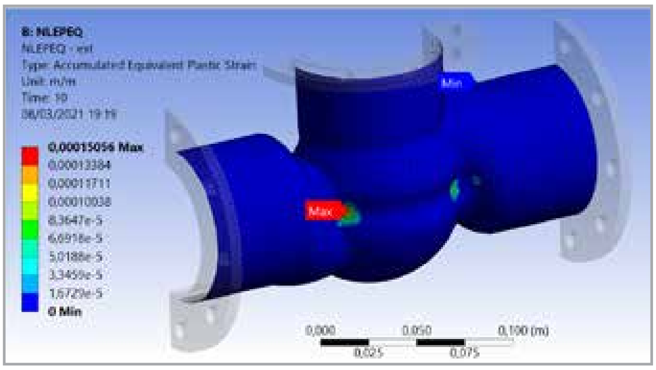

Fig. 7 - Final configuration of the valve subject to thermomechanical fatigue, which resulted in a 49% reduction in NLEPEQ.

can be useful – not only for minimizing von Mises stress, but also for obtaining lighter parts and mitigating more complex results, as in the case of accumulated non-linear equivalent plastic strain (NLEPEQ), so that component life optimization can be effectively achieved.

Firstly, the algorithm's reliability is evaluated for simple benchmarks that are thoroughly explored in solid mechanics textbooks: a cantilever beam (Fig. 3) and a coil spring (Fig. 4). It is worth noting that a bio-inspired automatic method can adequately address even quite simple engineering problems with straightforward but not obvious solutions.

Fig. 5 shows the study of the evolution of a tree trunk explored by Mattheck in 1990. After 30 years, the simple 2D model originally proposed was replaced by a detailed 3D model that takes into account the wood's orthotropic behavior. The predicted shape corresponds very well with previous FEA calculations and with the experimentally observed evolution of the real tree.

Fig. 6 shows an industrial automotive application to optimize an aftermarket motorcycle part (the Motocorse San Marino's wheel hub for the Ducati Panigale V4); in this case, manufacturing constraints were imposed to maintain the full shape of the bracket and of the central cylindrical part of the hub.

Fig. 7 shows a TMF case that demonstrates the workflow in use at SVS FEM for a variety of automotive applications, including thermal fatigue of high-performance turbocharger housings, on a valve model.

Conclusions

This paper presents a new approach to parameter-less optimization, starting with the observation of the method used by nature to reduce surface stress at hotspots. This approach employs two mathematical tools: BGM and RBF-based mesh morphing. When combined, they provide an effective and reliable surface sculpting tool that can simultaneously optimize both stress levels and material utilization.

This parameter-free method requires less effort from the user, since there is no need to define shape modification parameters: optimization is driven by the actual model's FEM results, evolving the shape towards the optimal one. In summary, structural analysts are offered a bio-inspired "natural remedy" for hot-spot mitigation.

About Università di Roma – Tor Vergata

The University of Rome "Tor Vergata", established in 1982, counts 39,000 students, 1,362 professors, 985 administrative staff and technicians and 600 hectares of university campus. The Department of Enterprise Engineering is composed by 90 full time employees and 80 contract researchers.

The research team, from the Machine Design Group, is involved in national and international research projects focused on: structural and fluid dynamic shape optimization (automotive, nautical, aerospace, biomedical); static and dynamic fluid structure interaction; advanced use of RBF; large-scale high-fidelity numerical simulations of flows in complex geometric configurations; Reduced Order Models and Digital Twin.

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Thermo-structural analysis and implosive collapse in the fire prevention field

By Fabio Rossetti,
Marco Spagnolo,
Mariarita De Rinaldis
EnginSoft

New fire prevention regulations issued by the Italian Ministry of the Interior require engineering evaluations of structural collapse to be based on objective thermo-structural analyses. In this regard, numerical simulation is indispensable for designers, who can use it to virtually generate fire conditions and then optimize thermo-structural performance to comply with the regulatory guidelines. This article explains how.

The new directives in fire prevention

The Italian Ministry of the Interior, through the Ministerial Circular DCPREV 9962 of July 24, 2020 (https://www.pro-fire.org/images/Soluzioni_alternative_di_resistenza_al_fuoco.pdf), has provided clarifications and application guidelines regarding design solutions for assessing a structure's fire resistance.

The document complements and clarifies the Decree of August 3, 2015 ("Approval of technical standards for fire prevention") and warns against some design practices used thus far – defined as simplistic and hasty – in the field of thermo-structural verification and the study of the dynamics of the collapse of structures affected by fire.

The SBES solution

Ministerial Circular DCPREV9962 requires engineering evaluations of structural collapse to be based on thermo-structural analyses that represent the actual failure conditions and resulting mechanical behavior of the structures being studied.

These thermo-structural analyses therefore can no longer avoid a computer-aided approach and require dedicated engineering procedures to be performed using typical Simulation Based Engineering and Science (SBES) tools. Within this context, two simulation environments must be used, the first of which is dedicated to CFD simulation, necessary to predict the evolution of the fire within the considered domain (e.g. the propagation of a fire in a warehouse) and to sample the temperature maps over time.

The second environment, for FEM, calculates the structural response of the system to the thermal load and to the contemporaneous working loads. Assuming that the heating of the structure will not affect the fire's evolution, we can consider the interaction between CFD and FEM environments to be one-way. However, it is also necessary to verify – without changing the CFD dynamics – that the deformation of the structure does not significantly worsen the structure's exposure to the fire; if this is not the case, a two-way implementation is required.

The FEM study must necessarily be carried out in two phases. The first concerns the calculation of the tension and deformation states up to the incipient collapse (performed with an implicit code); the second aims at predicting the evolution of the collapse (with an explicit code) starting from the last "photograph" obtained in the first phase (in terms of temperature, stress, and deformation). One example of the implementation of this procedure can be found in the studies carried out following the collapse of the World Trade Center in New York (September 11, 2001) [1].

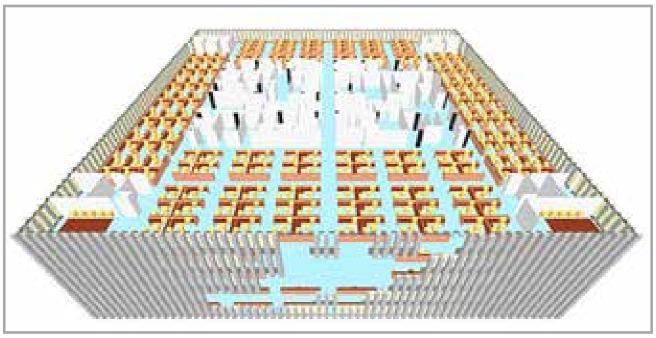

Fig. 1 - Layout of the model of the north tower of the World Trade Center used for the simulation in FDS (Courtesy K. McGrattan)

Numerical methodologies to simulate implosive collapse

Below is an example of how the procedure described above can be implemented:

CFD + FEMImplicit + FEMExplicit

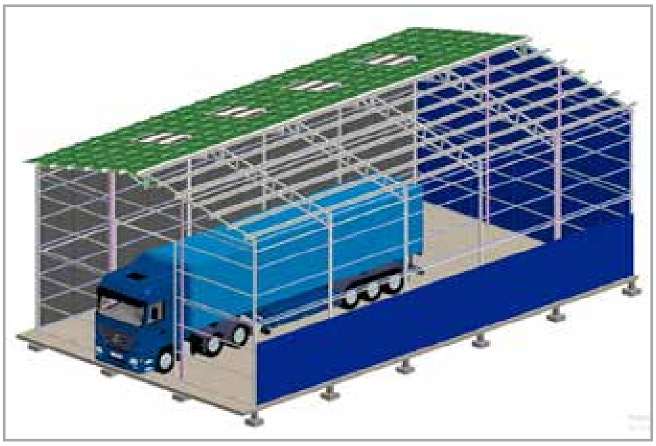

Fig. 2 - CAD model used for simulation of implosive collapse using FDS-Ansys-LSDYNA

CFD Fire Dynamics Simulator (FDS), developed by the National Institute of Standards and Technology, USA (NIST), is a software universally recognized for its reliability in the field of fire simulation. It enables users to also conduct an evolutionary fire simulation, defined as a situation in which the Heat Release Rate (HRR) curve is not known in advance since it depends on the boundary conditions (e.g. presence or absence of ventilation) and on the location of fire load within the domain.

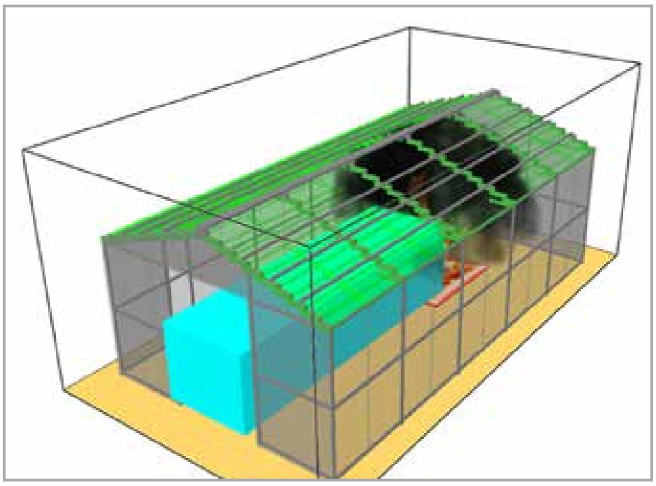

Fig. 3 - Fire simulation (FDS) inside a warehouse

FDS allows the temperature fields to be exported via text files that are easily imported from any FEM code, making it a great option for fire simulation, which is why it was chosen.

With respect to the implicit FEM code, the Ansys Workbench Suite proved to be the most effective solution, by virtue of its known flexibility, reliability, and accuracy in terms of:

- defining the geometry of the structure being studied and the relative inertial properties for each structural element;
- defining the elasto-plastic properties of the structure's materials as a function of temperature;
- importing the temperature maps obtained from the transient simulation of the fire performed in FDS, and the thermal loading for the thermal-structural FEM model;
- executing the transient thermo-structural analysis up to the condition of incipient structural collapse;
- identifying and exporting the structure's data under the condition of incipient collapse, for the explicit FEM code.

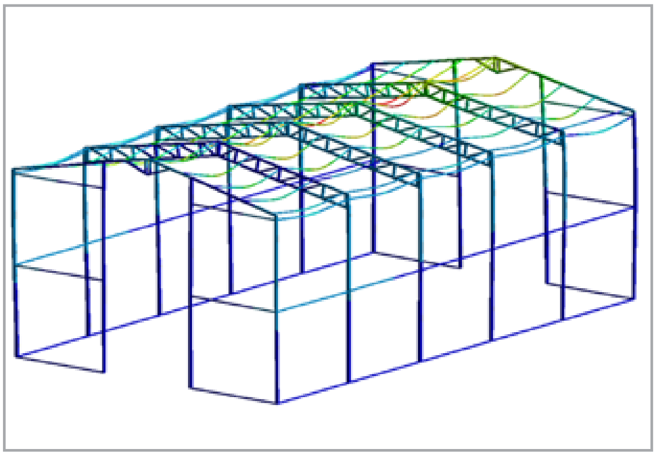

Fig. 4 - Condition of incipient collapse of the structure caused by the degradation of the structural rigidity due to a fire

As far as the explicit FEM code is concerned, LS-DYNA represents the reference technology standard for explicit dynamic simulation.

The recommendations provided by the Ministry of the Interior's Ministerial Circular once again sanction the key role of simulation in the design of structures subjected to a fire incident. This branch of engineering is naturally affected by the limited applicability of real prototyping; moreover, the Ministerial Circular DCPREV 9962 emphasizes the fact that certain evidence related to the thermal response of the system cannot be used to estimate the structural integrity. For these reasons, simulation is no longer merely a recommended option, but becomes an indispensable tool.

If you would like more information or would like a personalized consultation, please contact us and one of our experts will be happy to answer all of your questions.

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By Young soo Choi
TSNE

Analyzing 77GHz-band radar antennas for use by the ADAS in autonomous-driving vehicles

Advanced driver assistance systems (ADAS) are become an increasingly hot topic in the automotive industry. ADAS include several systems such as lidar, radar, cameras, sensors, etc. This article introduces a method for analyzing the performance of an in-vehicle radar antenna for an ADAS.

Advanced driver assistance systems (ADAS) use advanced detection sensors, GPS, communication, and intelligent imaging devices to enable the vehicle to recognize certain situations while driving, assess the nature of the situation, and then either control the vehicle or inform the driver about the risk factors in advance by using sound, headlights, vibration, etc. Fig. 1 describes the functions of ADAS.

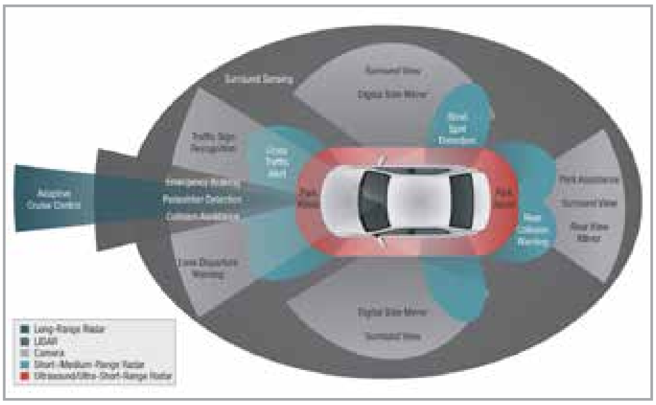


Fig. 1 - Functions of advanced driver assistance systems
Source: TI(Texas Instruments) white paper: Making cars safer through technology innovation by Roman Staszewski and Hannes Estl

The process of designing a 77GHz-band radar antenna to be used in the adaptive cruise control (ACC) system of the ADAS is as follows: firstly, design the array antenna; secondly, conduct a simulation by inserting the array antenna into a radome; thirdly, connect the radome-with-antenna to the vehicle's bumper grille to study any performance changes.

Design the 77-GHz array antenna

The array antenna for an automotive radar is designed in the 77GHz (78.5GHz to be precise) band using a printed circuit board (PCB)-type series-fed patch antenna. Fig. 2 shows the structure and the specifications of the series-fed patch antenna.

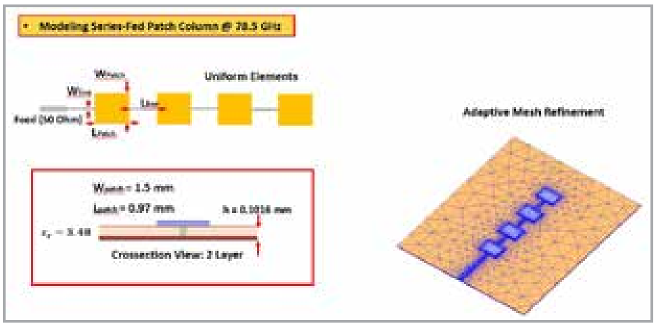


Fig. 2 - Series-fed patch antenna design

The specifications of a series-fed patch antenna board are as follows:

- dielectric constant = 3.48
- thickness = 0.1016mm
- patch size: W = 1.5mm, L = 0.97mm

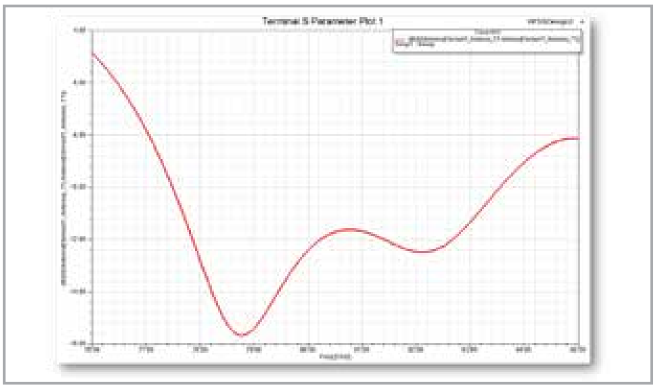


Fig. 3 - S-parameter of the series-fed patch antenna

Four patches were used in the array. The patch shape is uniform, and the impedance of the feed line is 50 Ω.

The high frequency structure simulator (HFSS) solution was performed as a driven terminal and the port was designated as a lumped port. For the antenna parameters, the gain characteristics were confirmed as S-parameters, 2D radiation patterns, and 3D radiation patterns. Fig. 3 shows the S-parameter characteristics.

Fig. 4 shows the contents of the 3D gain plot with a peak gain of about 12.5 dBi.

The simulation is performed by creating an array using multiple series-fed patch antennas. The 77GHz-band vehicle antenna comprises six receivers and two transmitters designed on the same PCB, as shown in Fig. 5.

All conditions, such as permittivity, thickness, and the patch size of a single antenna are common for array antennas. As can be seen in Fig. 5, the total number of antennas is eight and for the RX part, the two antennas indicated by dashed lines are 50 Ω term. In this analysis, we examined how the gain pattern changed when TX1 was operated alone.

It was found to be similar in the radiation pattern, but the side and main lobe antenna gain increased.

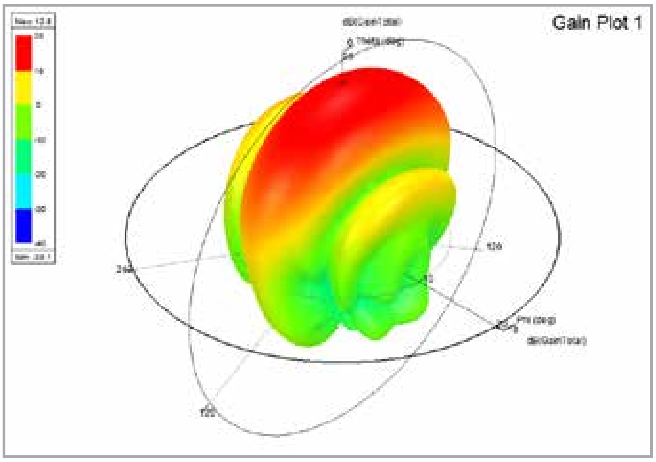


Fig. 4 - 3D gain plot of series-fed patch antenna

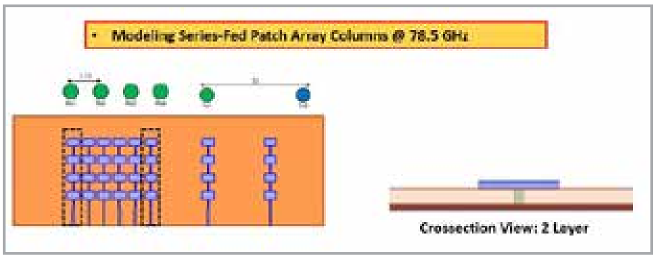


Fig. 5 - Design of TX & RX array antennas

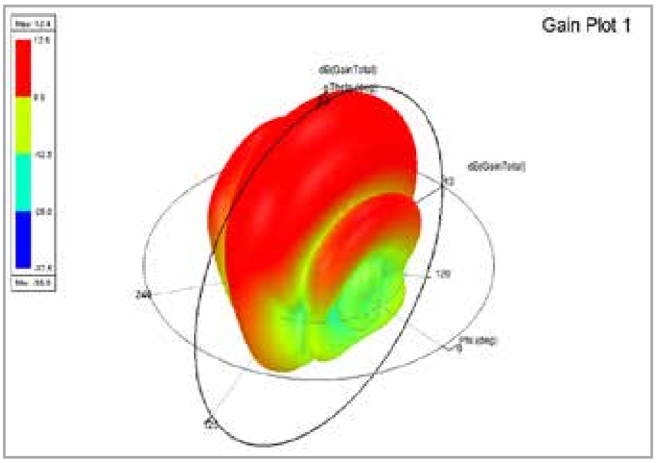


Fig. 6 - 3D gain plot of series-fed patch array antenna

Radar radome antenna design

First of all, the array antenna is designed with air permittivity; once the results are obtained, it is placed into the radome to assess how the radiation pattern of gain changes.

The first step is to insert the antenna into the simplified radome and check the result. Fig. 7 shows the simplified radome structure. The structure is simple. The radome is 80mm long, 35mm wide, and about 1.16mm thick. These dimensions are taken separately from the simulation of the radome.

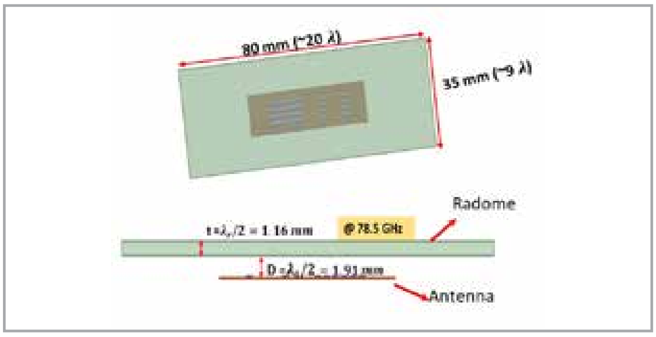


Fig. 7 - Simplified radome array antenna design

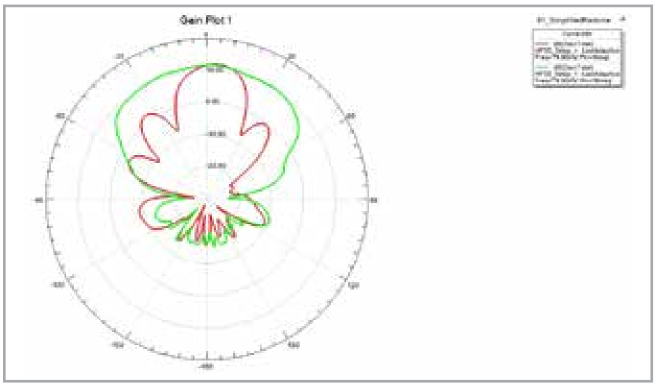


Fig. 8 - 2D gain plot of radome antenna in array

The dimensions of the PCB line and radome change rapidly as the frequency increases. Therefore, for more accurate conditions, the radiation conditions were analyzed as perfectly matched layer (PML) conditions.

Fig. 8 shows the 2D gain plot. The condition of this result was confirmed after configuring the far-field radiation sphere setup for an azimuthal condition.

The gain is slightly reduced and the back lobe is increased due to the radome.

At this point, insert the antenna into the actual radome and check the resulting waveform. Fig. 9 shows the actual radome structure.

The thickness of the radome is 1.16mm and the distance between the antenna and the radome is 1.91mm. The simulation was performed in the same manner as for the simplified structure.

Fig. 10 shows the result of the antenna only, the result with the simplified radome structure, and the result with the actual radome structure.

The overall antenna results were compared by plotting them on the azimuth and elevation planes. Both planes are widely used as indicators of antenna performance. On the azimuth plane, you can see that the Theta angle is wider in the absence of the radome, and narrows due to the presence of the radome. However, we are able to confirm that there are no problems with the operation of the antenna. Furthermore, the elevation plane produced almost the same results except that the angle was shifted slightly in the case of the radome. Fig. 11 compares the time, RAM usage and cores usage for the three simulations.

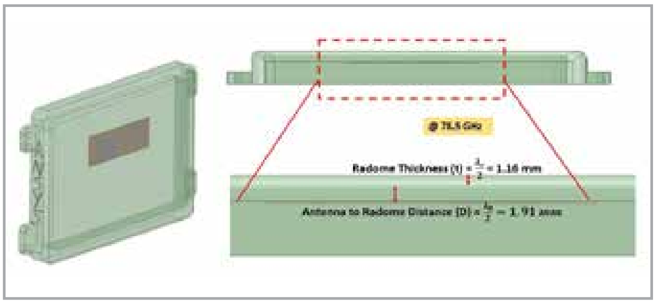


Fig. 9 - Actual radome in array antenna design

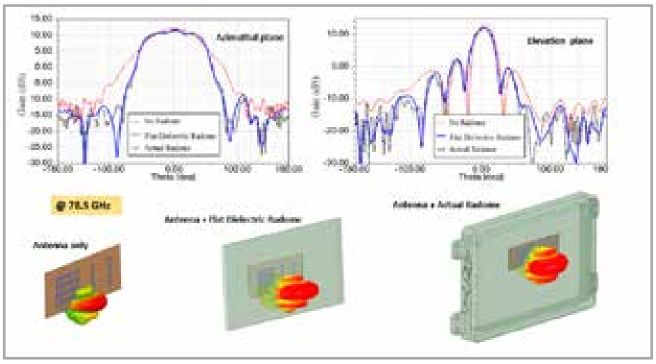
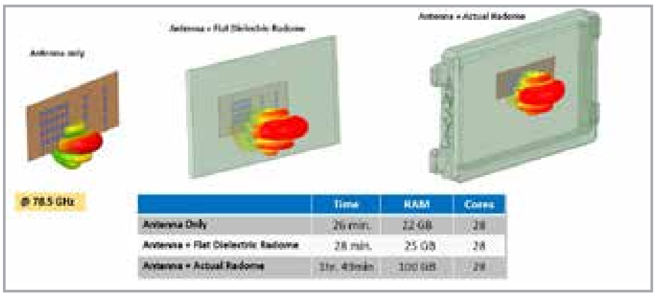


Fig. 10 - Comparison of overall antenna results



	Time	RAM	Cores
Antenna Only	26 min.	22 GB	28
Antenna + Flat Dielectric Radome	28 min.	25 GB	28
Antenna + Actual Radome	1hr. 49min	100 GB	28

Fig. 11 - Comparison of analysis time by antenna structure

The analysis time for the antenna-only structure was 26 minutes; for the simplified radome structure it was 28 minutes, and for the actual radome structure it was 1 hour 49 minutes. All CPUs were using 28 cores.

Analysis of the radar radome module on the vehicle's front bumper grille

Finally, a simulation was conducted after inserting the antenna into the vehicle's front bumper grille (fascia).

In Fig. 12, the simulation was performed by positioning the antenna inside the grille on the lefthand side of the vehicle's front bumper.

It took too long to run the simulation on the whole vehicle, so we simply removed the grille from the vehicle to run the simulation. Fig. 13 shows the process of simulating the grille and antenna in Ansys HFSS.

When simulating a vehicle or a large body, HFSS uses the IE Region and FEBI Region (Hybrid Region) to shorten the analysis time.

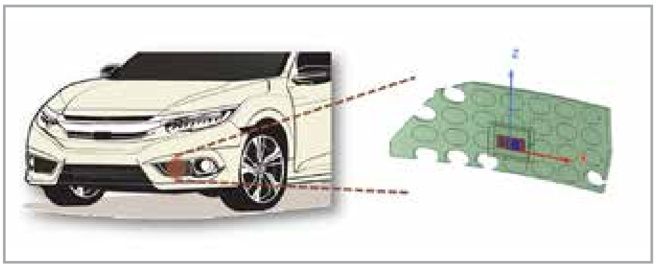


Fig. 12 - Array antenna's position in the grille (fascia)

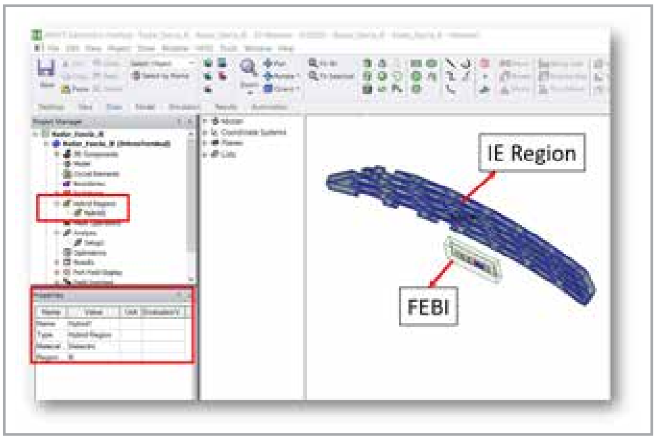


Fig. 13 - The HFSS hybrid region setting

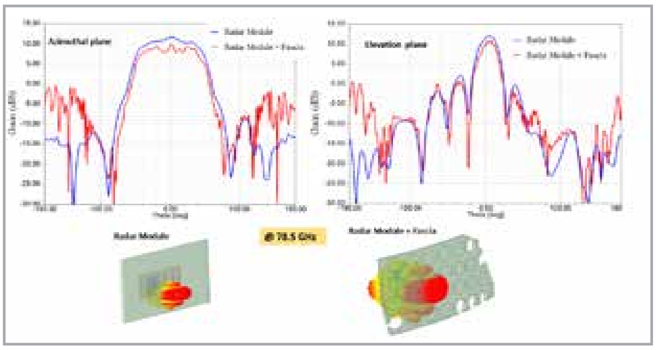


Fig. 14 - Comparison of the results with and without with grille (fascia)

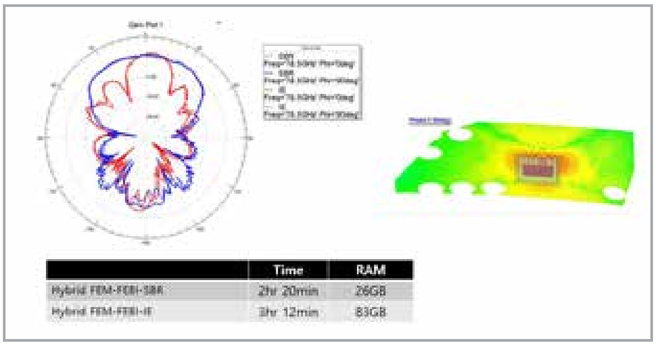


Fig. 15 - Comparison of FEBI+IE and FEBI+SBR+ results

The analysis results of the structure within the grille were compared to those of the simplified radome.

The analysis results confirmed the azimuth and elevation planes, and the difference between the presence or absence of the grille (fascia) showed a slight reduction in gain. However, there were no criticisms of the performance.

Moreover, SBR+, one of the functions of Ansys HFSS, was used to conduct the simulation. SBR+ is the acronym for Shooting and Bouncing Rays, and is an analysis technique that can accelerate the analysis of large objects; it differs from the general techniques use in finite element method (FEM).

About TSNE

Since established in 1988, TSNE has been a CAE specialized company dedicated to deliver engineering programs and services to customers in Korea. The goal of Tae Sung S&E (TSNE, in short) is the "One Stop Total CAE Solution Provider (OSTS)" both in domestic and global markets.

With its CAE experts and largest business capabilities in Korea, TSNE serves customers from a variety of industries (aerospace, automotive, civil engineering, biomedical, shipbuilding, electrics and electronics, energy, defense, chemical industries and etc.), and is expanding its business scope to researching innovative technologies and applying them to the field. We are striving to become a global engineering company and raising our potential to become a sustainable engineering company. Tae Sung S&E is the partner of all engineers striving to solve their challenges. Tae Sung S&E will be with you for NO PROBLEM, BE HAPPY.

Fig. 15 shows the speed of analysis using SBR+ and demonstrates that there is no difference in the result.

Conclusion

With the growing development of autonomous-driving vehicles, the analysis of in-vehicle radar antennas is becoming mandatory. For installation at the front of the vehicle, the dielectric constants of the radome and the front bumper grill (fascia) must be considered to achieve accurate radar performance.

In future, the simulation of vehicle radar antennas using Ansys HFSS can be expected to increase rapidly.

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Tackling the complex process of modeling bio-inspired systems that adapt spontaneously

Introducing OSCAR: Optimal System-in-system Control and Architecture

Long-term space missions require a reliable life support system including food supply, gas generation and waste management. To this end, the Micro-Ecological Life Support Alternative (MELiSSA) concept was conceived as an ecosystem of micro-organisms and higher plants that was intended to serve as a tool for understanding the behavior of artificial ecosystems and for developing the technology for a future biological life support system. Modeled on an aquatic ecosystem, the MELiSSA loop comprises four microbial compartments, a higher plant compartment and the crew (see Fig. 1).

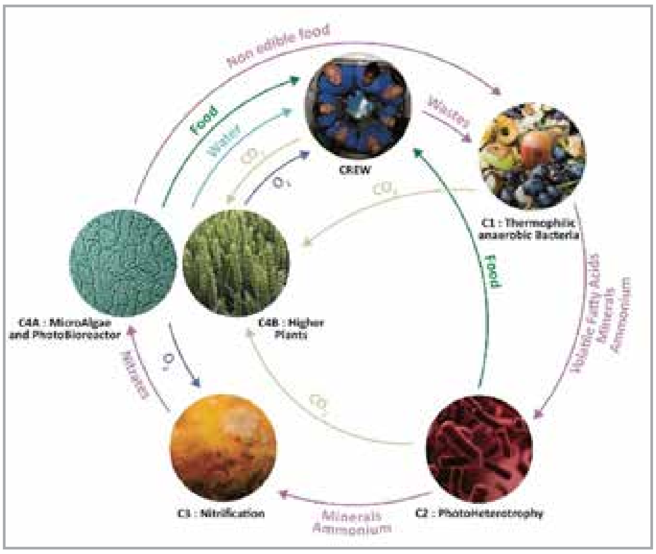

Fig. 1 - MELiSSA loop

The main driver is the recovery of food, water and oxygen from waste, including faeces, urine, inedible plant matter and CO2, in order to limit the amount of excess on-board resources and mass buffers. The overall structure of the MELiSSA loop, developed from a natural ecosystem, has been determined. However, the detailed structure evolves depending on the application and the context (e.g. the BIORAT program, see https://www.melissafoundation.org/).

A key guideline of MELiSSA projects has been a generic approach and the development of a general methodology for tackling so-called circular systems. Under this framework, each compartment must first be analyzed individually for indepth understanding and is translated into mathematical models. In a second step, the complete loop must be integrated by linking the different compartments with respect to gas, liquid and solid phases.

This involves studying the waste degradation, water recycling, atmospheric revitalisation and food production systems from the same perspective, with the same degree of accuracy and using the same language and concepts, following the integration of knowledge-based control models, built on multiple hierarchical levels with a decision system interface to the human environment. The development of accurate mathematical models is highly relevant in this context. The intelligence of the system is based on the adequacy of the models to represent each single

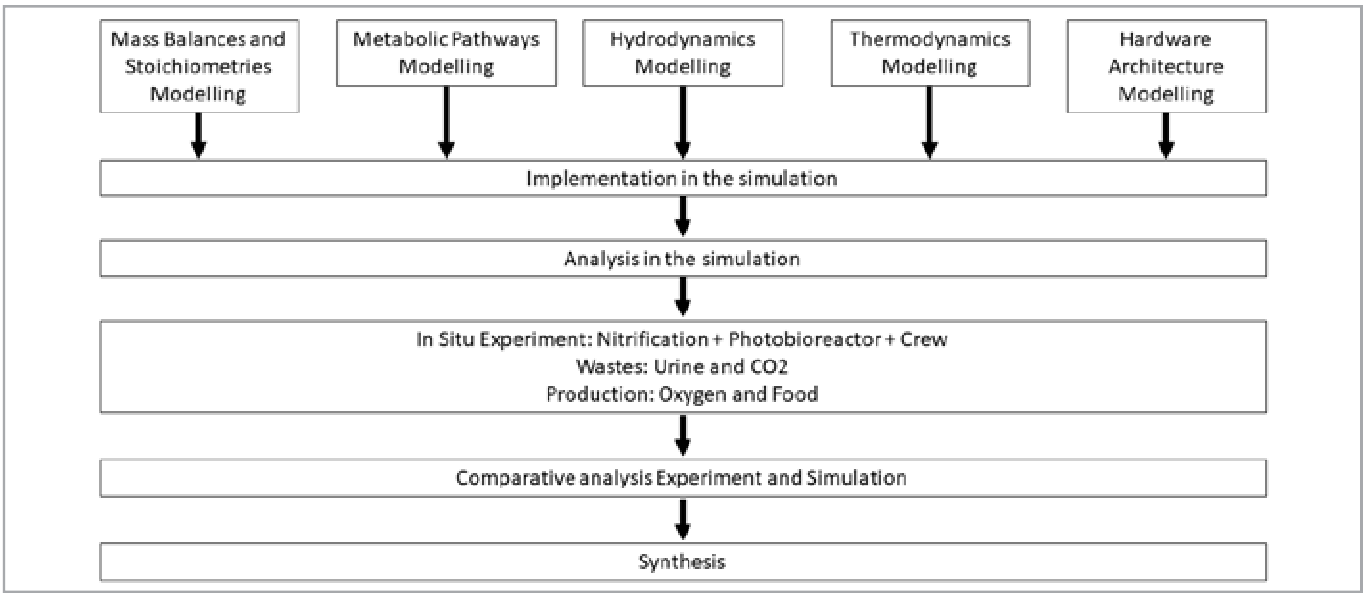

Fig. 2 - Modelling and Control approach of ECLSS developments

component's operations and their interrelationships with a suitable degree of accuracy and an appropriate range of model validity to implement a hierarchical control strategy.

EnginSoft has been collaborating with the European Space Agency on the MELiSSA program for the past fifteen years. The company is a member of the MELiSSA consortium and is actively working on life support systems for space applications. The Optimal System-in-system Control and ARchitecture (OSCAR) is the latest of many projects that have been developed by EnginSoft within the MELiSSA framework over this period:

- Advanced Life Support System Evaluator – ALISSE
- Food Characterization Phase 1, HVAC at MPP – FC1
- Scaling of Life Support System – SCALISS
- Greenhouse Module for Space system – GMSS
- Hydroponic Sub System Engineering – HYSSE
- ENergy Resources Utilization Mapping – ENRUM
- Air and Canopy Sub–compartment analysis – ACSA
- Atmospheric SubSystem Engineering – AtSSE
- Operation and integration of the MELiSSA Pilot Plant – MPP – CCN5
- PlAnt Characterization unit for closed life support system – engineering, MANufacturing & testing – PaCMan

Biological systems, or bio-inspired systems, are notoriously complex to model, due to their nonlinearity, very high dynamic range, susceptibility to the environment and potential for self-adaptation (i.e. progressive or instantaneous changes in behavior), at the cellular or community level.

Owing to their complexity, these evolutionary characteristics are often presented as a vulnerability, but they can also be seen as an interesting self-adaptation and, therefore, a high resilience capacity to stressors. Many studies have addressed the modelling of complex and potentially evolving systems. Unfortunately, however, they are generally very theoretical and do not consider, for example, the challenge of the associated hardware, which is rarely able to evolve. Understanding and controlling these potential evolutions requires significantly more characterization, understanding and modelling of the processes than conventional ones (for instance, one process equal one stoichiometry), as well as the incorporation of the hardware specificities into the modelling approach.

Figure 2 presents the overall logic of the modelling and control of Environmental Control and Life Support System (ECLSS) developments.

Drawing on the experience of the three partner entities (EnginSoft, UCA and Sherpa Engineering) in modelling, simulation and control, the OSCAR study aims to chart the main paths towards the bioprocess modelling and predictive control of a complex life support system, such as MELiSSA. It strives to combine the emerging tools in synthetic biology, various classes and complexities of balanced models of microbial growth and bioconversion, process simulation and control and, ultimately, system-level evaluation into one coherent approach.

The challenge is to extend the approach to include the system's own self-adaptation. The activities, developed over a twenty-month period, are divided into three consequential tasks. The first task is the development of the modelling requirements for bio-inspired systems. The second task will be the identification of the modelling limitations and criticalities. The third task will then be to apply the models to a real coupling of three compartments (C3, C4a and C5) of the MELiSSA loop to determine their accuracy and application in a case study.

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By Claudia Quadri
EnginSoft

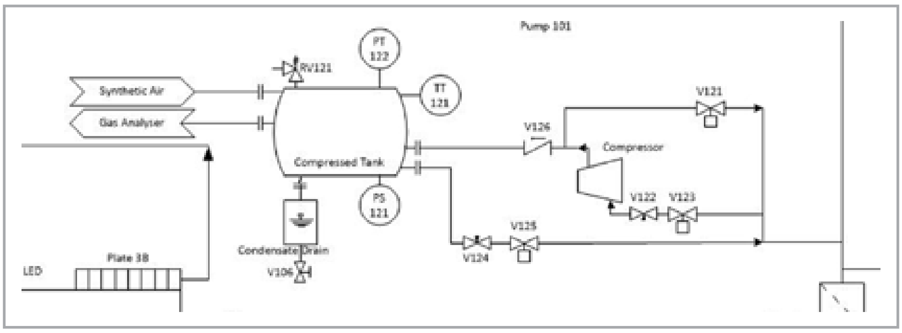
The PaCMan project: Cultivating plants to support life in space

The European Space Agency (ESA) aims to land its first crew on Mars by 2050, and the PaCMan project is part of the scientific effort necessary to accomplish this goal.

The European Space Agency's ambitious aim to land a crew on Mars by 2050 is being powered by an enormous, multi-faceted scientific effort. One aspect of this undertaking is the PaCMan project, part of the MELiSSA program to develop space-based agricultural systems to support life during space travel, space sojourn, and sojourn on other planets, and thus make human missions to Mars possible.

The program's goal is the creation of a bioregenerative artificial ecosystem that will produce food, regenerate the atmosphere, recover water, and recycle all waste. The PaCMan project, funded by ESA and coordinated by EnginSoft, has now developed the first European laboratory, and one of the few in the world, dedicated to the characterization of plants for regenerative life support systems, controlling and monitoring how plants behave in off-Earth conditions. This article presents the PaCMan project and its achievements to date.

At present, the International Space Station (ISS) is in orbit, astronauts take turns on board, and considerable scientific research is being carried out. However, living in space requires food, water, and energy, which are currently being provided to the



Implemented pressure compensation system

ISS crew from Earth. In particular, the astronauts' food is produced in Italy, but it is pre-cooked, dehydrated, vacuum-packed and obviously unlike the food we are used to in taste and appearance. Furthermore, a large amount of food will be required for the interplanetary missions planned for the future. For example, it takes six months to reach the Red Planet and this means that more than 30 tons of raw materials such as oxygen, water and food would be required – with extremely high transportation costs. This is just not feasible.

For many years, ESA has been working on the MELiSSA program to develop agricultural systems for outside the Earth that will be able to support life on other planets and make human missions to Mars possible. Their goal is to develop bioregenerative systems that will allow production of food, regeneration of the atmosphere, recovery of water, and recycling of all waste in an artificial ecosystem.

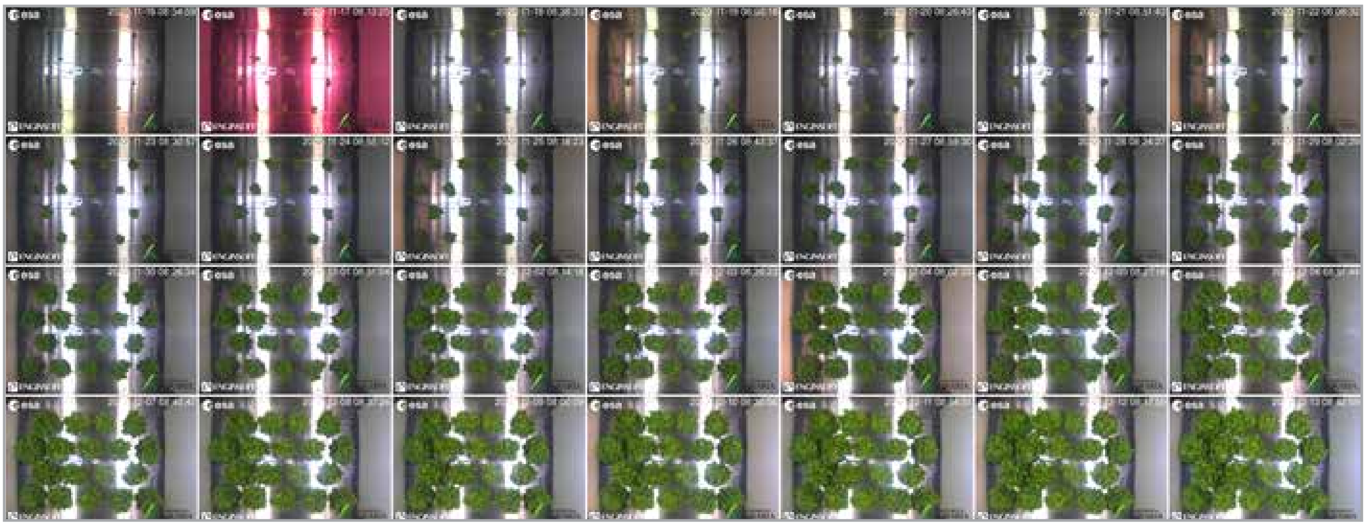
This requires controlling and monitoring how plants behave in conditions different from the Earth: the objective is to grow fresh vegetables, especially necessary for supplying nutrients. To do this, "salad machines" for the controlled cultivation of vegetables, such as arugula (rocket) and lettuce, have been created. However, humans also need carbohydrates and proteins and so the cultivation of tender and Durum wheat, rice, soybeans and potatoes is also being tested.

Within this extensive and complex research scenario, the PaCMan project has now developed the first laboratory in Europe and one of the few in the world, entirely dedicated to the characterization of plants for regenerative life support systems. The project was funded by the European Space Agency (ESA) as part of the MELiSSA program and involved various European partners coordinated by EnginSoft.

At the heart of the laboratory is the Plant Characterization Unit (PCU), a growth chamber equipped with sophisticated sensors and environmental control systems specific to plant growth. The main objective is to quantify oxygen production, CO_2 consumption, and water renewal, and to characterize the effects of different parameters such as temperature, light intensity, and nutrient composition on plant behavior in order to enable the development of an artificial ecosystem.

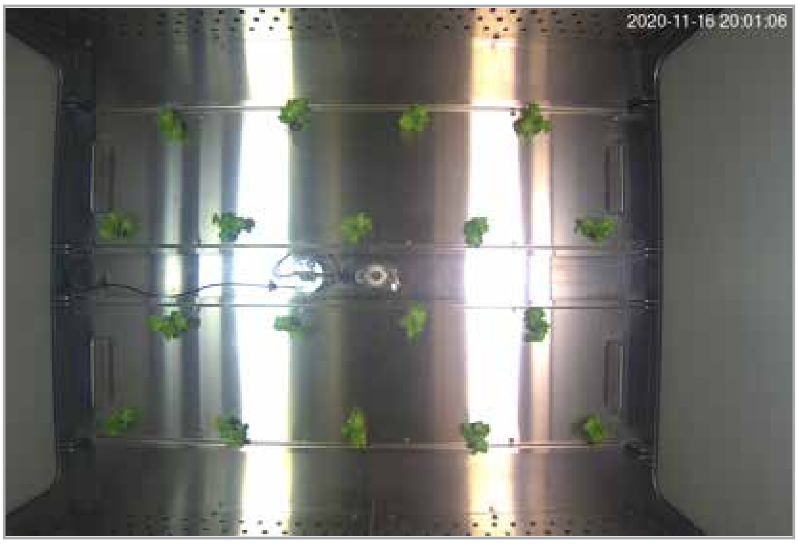
The PCU was designed as a composite of two modules: the atmospheric system and the hydroponic system.

The atmospheric system provides a homogeneous circulation of air in the growth chamber, while controlling and monitoring the environmental parameters and air quality. The hydroponic system recirculates the nutrient solution while controlling its



pH and composition. Particular attention was paid to ensuring homogeneous environmental conditions, both in the root zone and in the chamber. Several engineering challenges were addressed, with a focus on the low leakage rate required to calculate mass balances. The required loss rate (0.05% volume per hour) is considerably lower than typical industrial standards. Several techniques were implemented to achieve this.

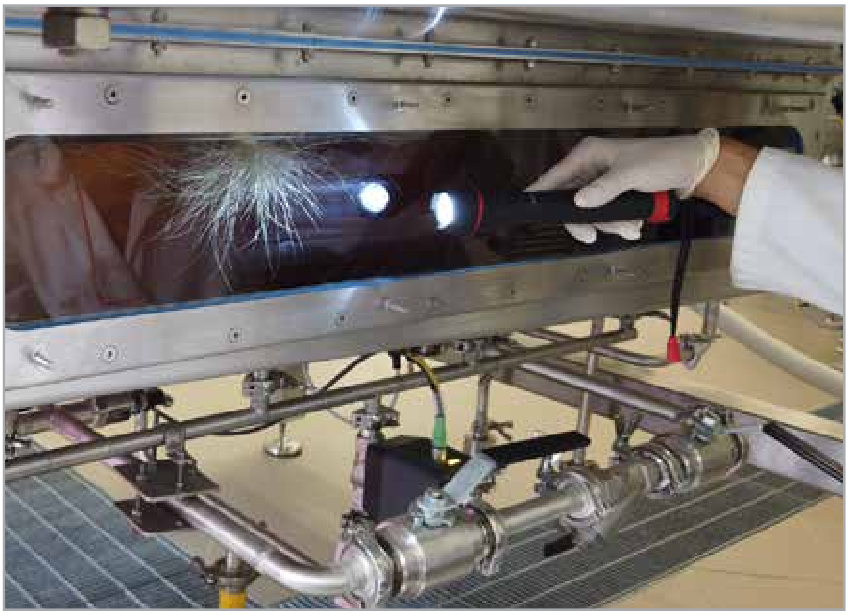
Various phenomena such as external weather conditions, or temperature changes in the chamber which simulate diurnal and nocturnal cycles, produce pressure variations. Therefore, the pressure inside the chamber must be continuously controlled to limit the gradients between the external environment and the chamber. An active pressure compensation system was developed: a compressor extracts air whenever the pressure has to be reduced and stores it in a tank, which is then used to reinject air when the pressure has to be increased.



In addition, special care was taken in designing the connections between the components. For example, the airtight closure of the door was achieved by using inflatable seals.

To verify the airtightness of the system, static pressure decay tests were performed. This test consists of pressurizing the system and measuring the rate of pressure decay over a certain period. The leakage rate is affected by the pressure level, but the pressure compensation system allows the pressure level to be controlled and, under working conditions, the measured leakage rate is within the requirements and comparable to nuclear industry standards.

An advanced nutrient delivery system enables the composition of the nutrient solution and its pH to be controlled. Acid, base and eight stock solutions are dosed from 10 side tanks, each equipped with a peristaltic pump and a scale to calculate the dosage volume. This system ensures high flexibility in formulating the nutrient solution recipe and is supported by state-of-the-art sensors. EC, pH, and temperature are controlled as standard parameters. In addition, the dissolved oxygen and CO2, and concentrations of NO_3-, NH_4+, Ca_2+, K+, Na+, Cl-, Mg2+, $HPO_4$2- are also monitored to improve understanding of uptake by the roots.



During the life test, plant photosynthesis increased the O_2 concentration to 24.57% on day 21; therefore, the system was aerated because the high concentration of accumulated O_2 posed a safety risk. The air was renewed, and the mass balance computation was reinitialized. After seven days, the concentration again reached 24.24%. Whereas plant photosynthesis consumed CO_2 during the day, the respiration phase at night produced CO_2. The control system ensured a minimum concentration of 1000ppm at all times. The CO_2 concentration observed during the life test exhibited the characteristic saw-tooth pattern.

Mass balances were calculated daily to estimate the plants' O_2 production, CO_2 consumption and H_2O evapotranspiration.

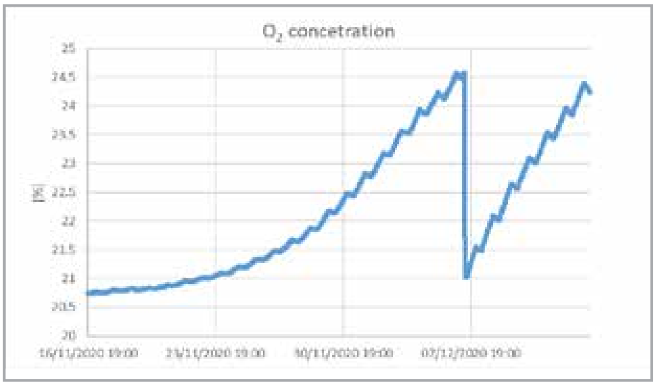
The PCU design was validated and the implemented functionalities were tested by conducting a first test-of-life: a lettuce crop was successfully cultivated from a batch culture. The system's ability to collect the data required to calculate mass balances, such as CO_2 consumption and O_2 production, was demonstrated.

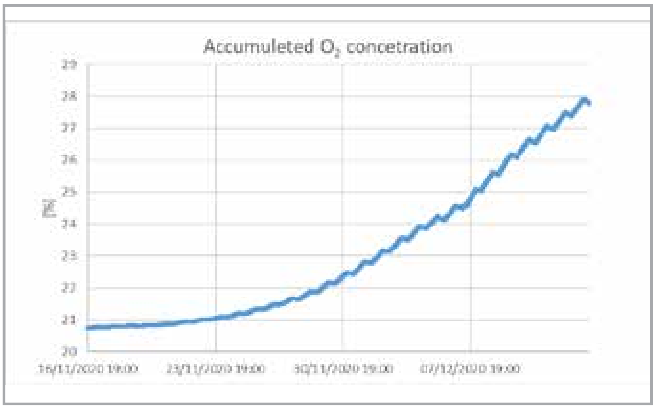
The seeds were sown and were transplanted into the chamber after nine days. The lettuce cultivation experiment was conducted between 16 November and 14 December 2020 and yielded a harvest of eighteen 37-day-old lettuce plants.
The system ran continuously for 28 days.

This first experiment demonstrated that two of the regeneration objectives among the diverse goals of the MELiSSA program had been achieved and were considered to have been highly successful: oxygen production and carbon dioxide absorption, and water recycling.

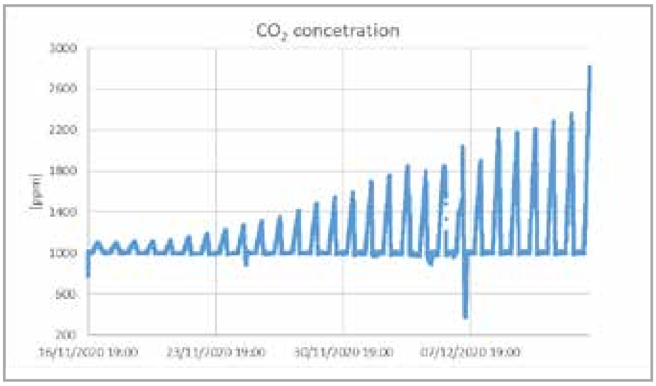
Oxygen

The eighteen lettuces cultivated produced 6,300 grams of biomass and 500 grams of oxygen. The oxygen concentration increased and could have reached 28% if not for the venting procedure performed for safety reasons. The oxygen was produced by a photosynthetic

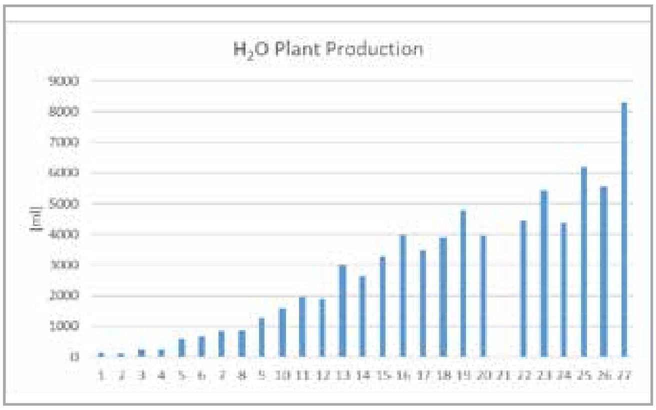




O_2 concentration variations during the life test and the accumulation that would have occurred without the aeration.



CO_2 concentration variations during the life test.



Water production during the life test.

process and will allow future astronauts to generate additional oxygen supplies, reducing the need to carry additional oxygen tanks for long-term space missions.

This outcome demonstrates the airtightness of the system and the reliability of the scientific data, permitting the plant behavior to be characterized. Furthermore, the advanced functions implemented enable the impact of different environmental conditions, e.g. wide ranges of temperature and humidity to be assessed, or the effect of CO_2 toxicity limits to be evaluated.

Water

Another great achievement is the water that was produced and the ability to measure it. The special design of the system isolates the root zone from the aerial part of the plants, enabling the contribution of the plants' evapotranspiration to be distinguished from the evaporated water. This allowed us to measure and calculate the water produced by the lettuces, which can then be recycled for use as drinking water by the astronauts. During the experiment, the eighteen lettuces recycled 75 liters of water.

Understanding and recreating an ecosystem in which humans can survive would benefit people living in extreme environmental conditions that lack clean water or air. Even the urban environment, where the water cycle is often compromised, can be defined as an extreme environment.

Earth, therefore, is one of the possible application areas for the technologies being developed in space research. For instance, subterranean hydroponics projects are foreseen in Arabia, where the desert environment is an obvious limitation; a greenhouse system has been tested in Antarctica to produce food in extreme conditions; and vertical farming in skyscrapers for future overpopulated urban environments is being explored using the same waste recycling and water and oxygen regeneration concepts as the MELiSSA artificial ecosystem.

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Preparatory testing for Ireland's first space mission, EIRSAT-1, is underway at ESA's Hertz antenna test chamber in Noordwijk, Holland. © ESA

The launchpad for great ideas

By Barnaby Lewis
ISO.org

If you have ever had the feeling that the more you find out, the more you realize you do not know, then spare a thought for those exploring space. For them, the only thing expanding as quickly as the universe itself are the data generated along the way.

The upside is that the complex engineering behind space exploration requires a lot less trial and error than at one time. By making use of modelling techniques, engineers can test their designs for craft, probes, and vehicles pre-launch. ISOfocus looks at how one Norwegian company, Jotne IT, is contributing its expertise to building the vehicles that help us chart the unknown. We speak to Vice-President Kjell Bengtsson to find out what it is like taking part in Europe's most advanced space program.

Growing up in an innovation incubator

From his earliest days, Kjell was surrounded by engineering. His childhood was spent in the Swedish manufacturing and port city of Gothenburg, home to Volvo cars. As a young man, there was little doubt in his mind that technology was his future. "Already at that time, I started to play around with programmable calculators, created my first Basic programs on teletype telex machines and, of course, had one of those Sinclair computers," Kjell recalls.

Sure enough, Kjell began his career at Volvo. He proved himself in chassis development, a department that, in his words, "was the best place for an engineer to find themselves". He was deep into the problems of vehicle dynamics when the road took an unexpected turn. It was the early eighties and Volvo made a bold move to pilot computer-aided design, or CAD.

These systems were in their infancy at the time and Kjell was chosen to help them through their teething troubles. He threw himself into this new area and computer-aided modelling and design became central to his work, propelling him towards a life at the cutting edge of tech. He may have changed country and company a few times since then, but he's stayed at the cutting edge: "I continued working with these systems, at General Electric, which is what brought me to Norway. A few years later, I began working for a company called Jotne."

What don't they do?

Jotne is a highly diversified, and innovative, company headquartered in Norway. Their main activities are spread across rail, IT, steel fabrications such as stairways and gratings, and real estate development and management. Whilst they may have a large constellation of businesses, they are mostly in down-to-earth sectors. So how did the company end up contributing to both space exploration and standardization? And how did one of the top managers of a Norwegian IT company become both a user and a developer of standards?

Kjell starts out with a surprise: "It actually begins with standards!" Homing in on the role of computing and the related tech that piqued his interest early on, Kjell points out that "a big part of my career has been about engineering data exchange – sharing and archiving processes". His expertise in these areas drew him into the R&D activities of the US Department of Defense and, in a roundabout way, to contributing to some of ISO's most widely used industrial standards.
ISO standards combine clarity of purpose with flexibility of approach.

Work in innovative sectors relies on a foundation of standards.

What do the right to privacy and Google Street View have in common?

Well, more than you might think: the shared ancestor is DARPA, the agency of the United States Department of Defense responsible for the development of emerging technologies. Founded at the beginning of the space race, with the goal of accelerating US technology, DARPA has undertaken programs that, ultimately, have been responsible for the first weather satellites, portable GPS, and the origins of the Internet itself.

Among these innovations were the data projects that progressed to form part of the work of ISO's technical committee on automation systems and integration (more specifically, the group dedicated to industrial data, ISO/TC 184/SC 4). One of the cornerstones of its work is the ISO 10303 group of standards.

While the first of these was published back in 1994, Kjell points out that they are more relevant than ever. "Today, more than 80% of all CAD and product life-cycle management data exchanges use ISO standards. That's a major achievement."

For many, working on the research that led to these standards would have been enough, but not for the future VP. "At the same time, around 1991, we started PRODEX, an EU-funded scientific project that offers institutions and industry the chance to work on European Space Agency experiments. Sometime later, we were able to turn that into a viable company: Jotne IT."

Bringing it all together

Where some of the companies and experts who contribute to ISO's work see standards as an "extra", for Jotne IT they are foundational. Kjell highlights the wide applicability of the ISO standards for product data representation and exchange (that's the previously mentioned ISO 10303, which is commonly known as "STEP"), as well as Open BIM (Building Information Modelling) standards.

Pointing to a surprisingly wide variety of industries whose work is built on STEP ("aeronautics, space, defense and built environments are some of the most prominent sectors"), Kjell explains that "Jotne supports large organizations like Airbus, Leonardo, BAE Systems, Lockheed Martin, but also software vendors like Autodesk, PTC, Aveva, Graphisoft and many more."

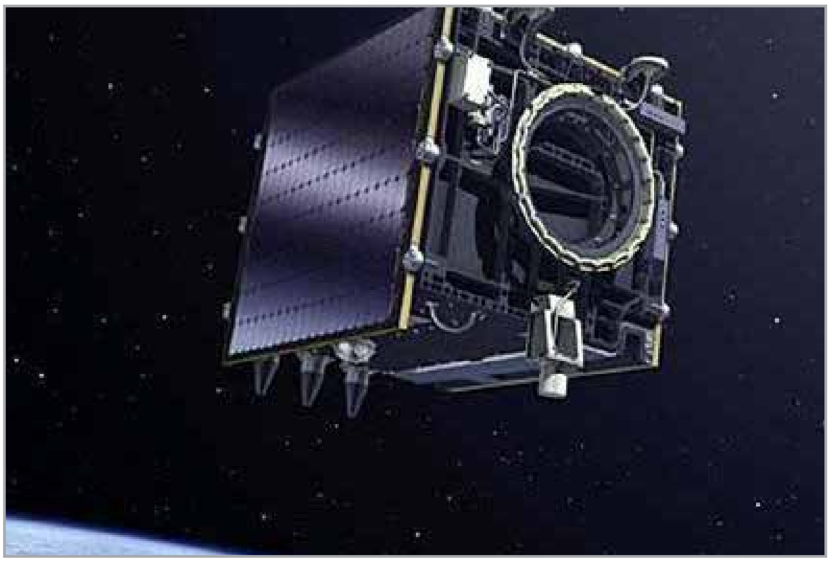
From multinationals to independents to government departments, work in innovative sectors relies on a foundation of standards. There is a straightforward explanation as to why. In providing a clear way of doing things, standards set a level playing field that enables wide participation. As Kjell says, "Participation is widened when standards are used, since collaboration runs on common processes rather than the ideas or processes of a single company", pointing out that Jotne IT offers product life-cycle management and BIM end-user tools, as well as advanced cloud-based interoperability platforms, tailored to a wide variety of industries.

About STEP

ISO 10303 (STEP, STandard for the Exchange of Product Model Data) is a standard for the electronic exchange of product life-cycle data. It enables the representation of product model data in a computer-sensible way, allowing the exchange of data between different computer systems without human intervention.

The innovation space

For Jotne, the name of the game is collaboration. For projects that rely on combining the contributions of individuals and specialized



ESA's Proba-V minisatellite uses semiconductor technology to chart Earth's vegetation, routinely returning mission imagery to the ground. © ESA companies, shared systems for working together are the only way. The role of standards here is to ensure that, when all the various inputs come together, they match up, thus underpinning projects that are literally "out of this world" – such as Jotne's contributions to European Space Agency (ESA) programs.

The ESA runs many of its projects from the European Space Research and Technology Centre in Noordwijk, Holland. Given the enormous costs attached to putting anything into space, it is clear that much of the work done involves highly complex simulations long before launch. Carried out in purpose-built test chambers, everything from a spacecraft's ability to handle extremes of temperature to its structural integrity is tested and modelled.

© ESA

Kjell indicates the scale of the challenge: "In the process, vast quantities of data are generated, shared, modified and analyzed." With teams focused on specific areas of expertise, these data come from multiple sources and often use different file formats. So, while "this approach makes the best use of resources, it has to be carefully managed", he tells me, adding that "beyond achieving immediate development goals, the information generated can also play a part in mission control and has the potential to contribute to future projects". The importance of thorough documentation and coherent archival processes is key here, and it is in these areas of simulation and modelling that Jotne's expertise really shines through.

The name of the game is collaboration.

The definition of teamwork

The DEFINE project, which focuses on "multidisciplinary 3D digital models for AIT (assembly, integration, testing) environments" is one of Jotne and ESA's biggest collaborations to date. Kjell tells me that their partnership "will bring benefits to all parts of ESA's extra-planetary exploration from design and construction of spacecraft to integration and test procedures". At the center of his work, once again, is the ISO 10303 standardized format. Adapted to digital models and simulation data for spacecraft development, Jotne is making full use of what is known as AP 209: Application protocol: Multidisciplinary analysis and design.

The life cycle of a product from conception to use (and, beyond this, replacement, and recycling) is usually broken into distinct phases to facilitate conceptualization and management. Application protocols describe the procedures that are carried out during each of these phases.

The use of ISO standards, and application protocols like AP 242/209, put traceability and accountability at the heart of the approach. Kjell has already highlighted the primary advantages: information that can be reliably accessed and shared; a clear record of what has been done, and by whom; and the ability to apply the information to other projects.

But in addition to this, he tells me, "there are regulatory requirements to maintain test data, especially when it comes to highly regulated sectors like civil aviation or space launches". Providing a solid platform on which companies like Jotne and organizations like the ESA can work together, ISO standards combine clarity of purpose with flexibility of approach. Such versatility is something to be cherished. After all, partnerships like ESA and Jotne's are answering some of the biggest questions about both the origins, and the future, of life on our planet. Answers that give rise to further questions...

Whilst it is likely that none of us will ever see the whole picture, it is reassuring to know that standards provide a frame around a workable canvas, bringing order to impossibly large projects, and transforming them into blocks that can be shared and built upon. That is good news for people like Kjell, and companies like Jotne, who just cannot keep themselves from innovating.

A special thanks to Barnaby Lewis and Kjell Bengtsson for their collaboration and to the ISO.org website, which first published this article online on September 15th, 2020.

About ESA

The European Space Agency (ESA) is Europe's gateway to space. Its mission is to shape the development of Europe's space capability and ensure that investment in space continues to deliver benefits to the citizens of Europe and the world.

The European Space Agency portal features the latest news in space exploration, human spaceflight, launchers, telecommunications, navigation, monitoring and space science. www.esa.int.

An advanced virtual approach: the study of tin segregation in the diecasting process

Integration of numerical simulation and industrial tomography reveals cause of porosity

Fig. 1 - The concurrent architectures for the EMA

By Giampietro Scarpa
EnginSoft

Virtual analysis already plays a leading role in process-product design. Experience alone does not suffice and therefore virtual technology is used to maximize and optimize a project's quality, performance, and efficiency. In this paper, the study described confirms the reliability of virtual simulation methods for predicting potential defects in the diecasting process, and also discusses how it significantly advances the prediction of tin segregations.

While the integration of two three-dimensional techniques – numerical simulation and industrial tomography – further increases process control, it can also stimulate the investigation of heretofore unexplored aspects to better understand certain defects and their origin. Funded research plays a critical role in this process, enabling studies that go the extra mile to discover new solutions that can then be integrated into industrial design and production processes. This funded research case study concerned the production of a bushing, an essential component of gear pumps, using alloy L91 (AlCu4Sn3) in a die-casting process with a multi-cavity mold.

Today, virtual design techniques and tools are fully integrated into the design and decision-making processes. In addition, the extraordinary potential of integrating numerical simulation and industrial tomography, both three-dimensional techniques, the former being numerical in nature and the latter physical-structural, further increases process control. However, this integration sometimes prompts the investigation of unexplored aspects and terrain in order to understand certain defects and their origins better and more closely.

Funded research projects serve this very purpose, going the extra mile to discover new solutions that can then be integrated into design and production processes.

The study results described in this article articulate the innovation introduced thanks to the "Ghise e leghe di Alluminio ad elevate Prestazioni per componenti innovativi" (GAP), or "Cast iron and high performance aluminum alloys for innovative components", research project approved by the Veneto region as part of the Italian POR-FESR 2014-2020 program's Axis 1, Action 1.1.4: "Sostegno alle attività collaborative di R&S per lo sviluppo di nuove tecnologie sostenibili, di nuovi prodotti e servizi" (Support for collaborative R&D activities to develop new sustainable technologies, products and services).

The Case

The case being studied concerns the production of a bushing, a small yet essential component of gear pumps. The part is produced by RDS Molding Technology using alloy L91 (AlCu4Sn3) in a die-casting process with a multi-cavity mold, as shown in Fig. 1.

The production process of these components ends with a T6 heat treatment of the casting to give the bushings the necessary mechanical characteristics. In accordance with best design practices, both the process and the product have undergone a series of interventions, assisted by virtual technology, to optimize the casting system and process parameters, and to guarantee maximum component quality in "as cast" conditions [1]. As a result, scrap has been kept below 5% for the components produced, but a surprise emerged after heat treatment was completed. The qualitative analysis, conducted by the University of Padua, revealed that the component showed porosity, generated during the treatment phase (Fig. 2).

The first hypothesis considered the possible presence of air inclusions at the end of the diecasting production process, which subsequently expanded during the solubilization phase of the T6 heat treatment [2], generating the porosity detected.

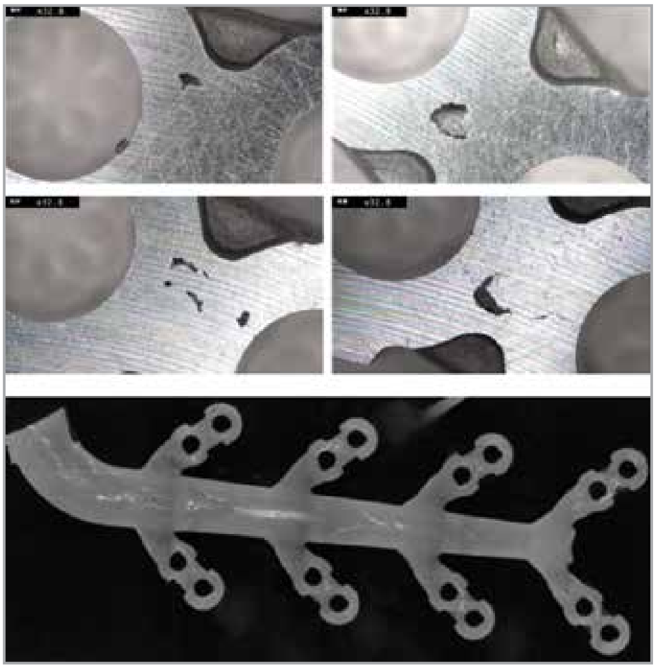


Fig. 2 - Porosity defects detected after heat treatment.

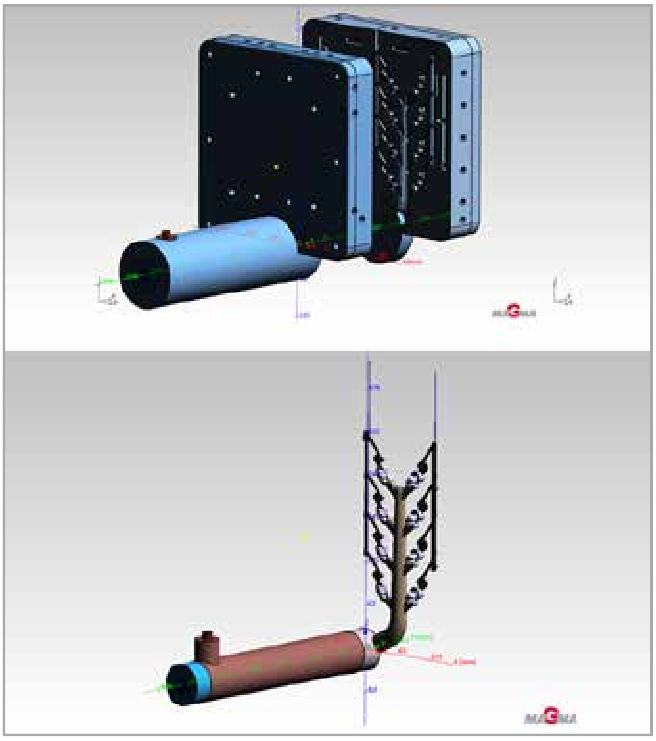


Fig. 3 - Geometries of the molds and of the castings

To this end, a highly detailed simulation considering all phases of the cycle with maximum precision was performed at thermal regime [3-4]. In order to analyze the defect in the component in the most minute detail, it was necessary to simulate the process by considering the geometry of the molds (Fig.3), the thermoregulation circuits (Fig.4), and all the cycle times and parameters that characterize it. The latest release of MAGMASOFT software, version 5.4.3, was used for this analysis, as it allows such a meticulous study to be configured.

The fluid dynamics of the thermoregulation circuits and the efficiency of the circuits themselves were considered (Fig.

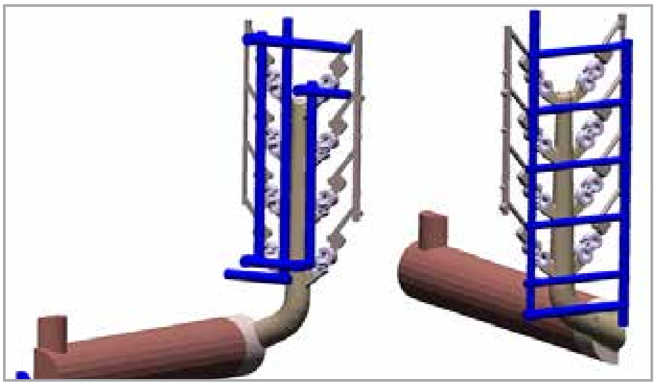


Fig. 4 - Fixed and movable temperature control circuits

	Circuit Position	Diameter (mm)	Medium (Water/Oil)	Flow Rate (l/min)	Operating Temperature (°C)
1	Cover Die	10 mm	olio	35	250
2	Ejector Die	10 mm	olio	35	250

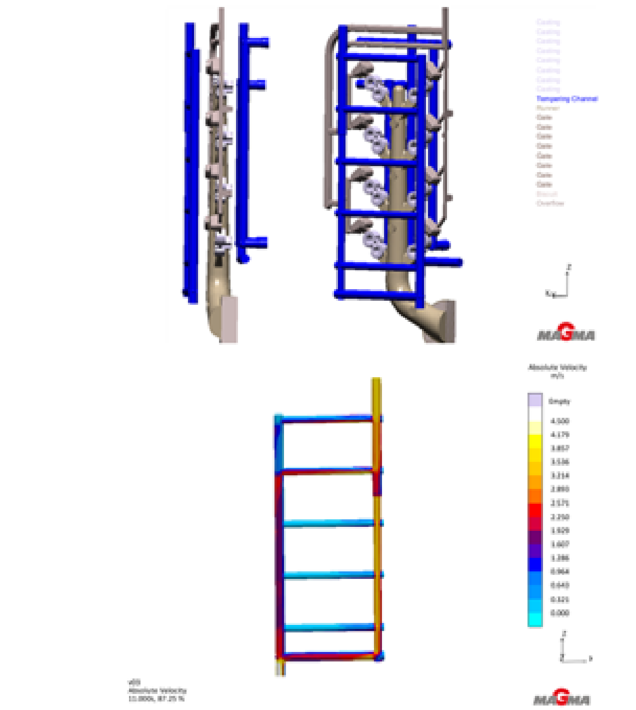


Fig. 5 - Defining the functions of the thermoregulation circuits.

5) in order to achieve maximum representativeness of the process, and to ensure that the temperature distribution across the molds was comparable to that of real production. An innovative software module was also used for the lubrication and blowing phase, which allows the lubricators' movement to be simulated while taking into account the

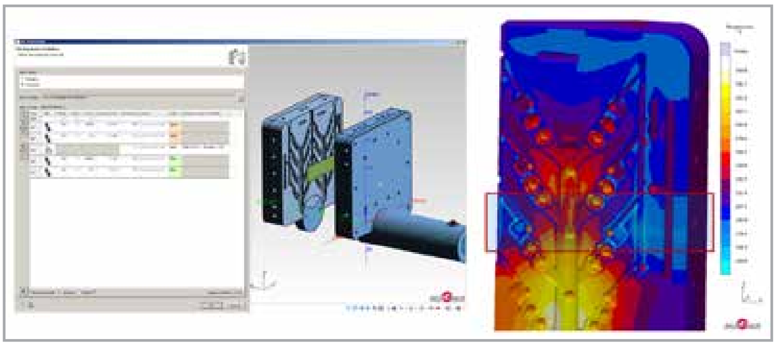


Fig. 6 – Definition of lubrication and blowing phases.

effects of distance and overlapping of the lubrication cones and shadow areas (Fig. 6), all to enhance the reliability of the virtual calculations.

The simulation configurations also considered all the boundary conditions concerning the mutual thermal exchange among the various parts, the machine, and the surrounding air. The realism and reliability of the diecasting process simulation found that the level of criticality of the defects identified was not uniquely related to the level of air incorporation within the bushings (Fig. 7) but to an effect induced by the segregation of tin [5].

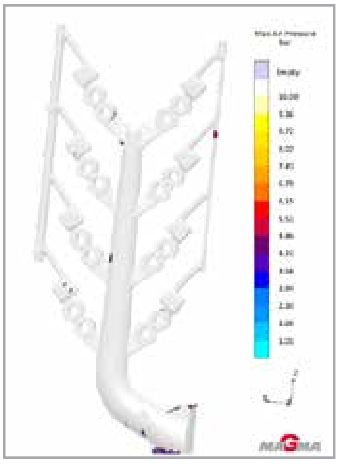


Fig. 7 - The air incorporated in the casting.

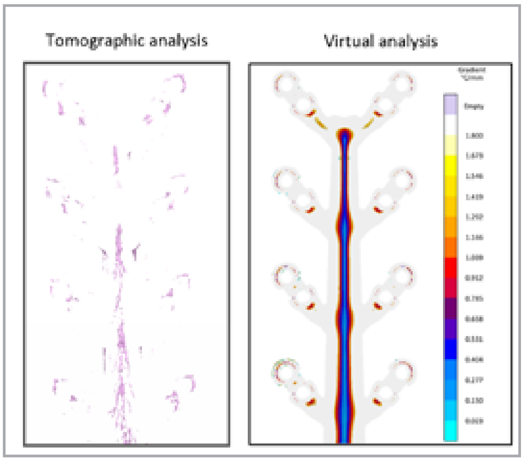


Fig. 9 - Analysis of segregations in the second sampling.

The segregations and their analysis

The origin of tin segregation lies in the different melting points of tin and aluminum alloys. Tin in fact has a melting point of about 230°C while aluminum melts at about 660°C. Clearly, therefore, during the solidification phase and starting at the same melting temperature, aluminum will solidify before tin.

In Alcu4Sn3, the alloy used in the project, which contains 4% tin, the course of solidification and cooling can cause a different concentration of tin depending on the cooling rate. These segregations lead to the formation of the porosity that occurs with the subsequent heat treatment.

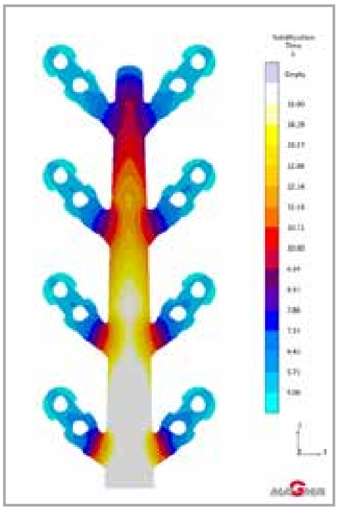


Fig. 8 - Casting solidification times

At first, the solidification times of the total melt were evaluated (Fig. 8). However, analyzing this result did not yield exhaustive information since it showed a progression of solidification from the smaller zones to the more solid ones (i.e., from the components to the casting). While this dynamic explains the higher concentration of tin segregations in the casting branch compared to the parts, it does not explain the segregation in the bushings. In fact, the tin in the casting branch segregates more easily and in larger quantities than in the parts due to the highly differentiated and extended solidification times.

Therefore, in order to identify and isolate the zones in the components that present tin segregation, the thermal gradient criterion was used. This criterion allows the zones that release heat more slowly to be verified, thereby facilitating the segregation of the low melting tin. The thermal gradient filter obtained from the simulation enabled the zones that drastically reduce thermal exchange with the outside to be highlighted and demonstrated that the zones identified in tomography can also be evaluated in a virtual calculation.

The comparison between the mold tomography, conducted by the laboratory involved in the research (UNILAB Laboratori Industriali s.r.l.), and the criterion mentioned above allowed both the simulation's and the hypothesis' veracity to be verified (Fig.9).

Conclusions

Virtual analysis is now perfectly integrated into the process-product design and development chain. The level of precision achieved, and the contribution provided by virtual analysis to the cause is indisputable. It is becoming increasingly important to go the extra mile and consider previously uncharted territories, virtually speaking, in order to provide designers and developers with increasingly effective and precise instruments.

The case study on segregations in die castings shows that the potential of simulation tools is in constant evolution, capitalizing on basic fluid and thermal results with increasingly advanced and intelligent approaches. Research projects make an especially important contribution in this regard by stimulating and funding innovation towards new frontiers as shown in the project above.

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Developing virtual sensors for real-time quality assessment in continuous production

by Giovanni Paolo Borzi
EnginSoft

The ForZDM research and innovation initiative has been created to identify, develop, and implement methods, processes and technologies aimed at achieving zero defect manufacturing (ZDM). The project is developing and testing an innovative ZDM methodology for production and quality control in multi-stage manufacturing systems. This methodology integrates multi-level systems modelling (both simulation- and data-based), big data analysis, Cyber Physical Systems (CPS), and real-time data management. This article presents the case study of application of this methodology to the extraordinarily complex production of angioplasty micro catheters on behalf of ENKI, a leading Italian producer and assembler of medical devices.

Common trends affecting the entire European manufacturing industry, such as shorter product lifecycles, increased complexity in design and manufacturing, higher demands for customization, and growing demand for traceability and cost reduction, are challenging classical approaches to quality management. These approaches, established in the 1970s, are generally focused on single production stages and applied sequentially and are therefore ill-suited to small batches and customized production runs.

These limitations and the pursuit of continuous improvement and innovation have motivated ENKI, a leading Italian producer and assembler of medical devices such as micro catheters for angioplasty, to partner with the ForZDM research and innovation initiative to identify, develop and implement methods, processes and technologies aimed at achieving zero defect manufacturing (ZDM).

The ForZDM project aims to develop and test an innovative ZDM methodology for production and quality control in multi-stage manufacturing systems. This methodology is based on the integration of multi-level systems modelling (both simulation- and data-based), big data analysis, Cyber Physical Systems (CPS), and real-time data management.

Fig. 1 - The ForZDM consortium and roles

The ENKI case: the extrusion of three-layer microtubes

The production of microcatheters is a complex process that begins with the procurement, inspection, and classification of polymeric materials. The polymer grains are inspected, their physical properties measured, and then they are dried and stored in special containers to preserve their quality and safety, after which they are checked into the warehouse according to strict quality procedures. The materials are checked out of the warehouse against required production batches and then inspected again.

While other catheter components are injection molded, microtubes are obtained by extrusion. Extrusion represents the core and one of the most critical operations. It has a highly variable setup time before the desired quality – and full production – is reached. Further inspection and assembly complete the process.

ENKI microtube extrusion exemplifies the challenges typical of continuous production processes. Oftentimes such processes require lengthy setups and product quality can only be gauged by sampling. This is also the case in processes where appropriate sensor technology does not yet exist or is not reliable enough to provide real-time quality data. In such a scenario, when a quality problem is identified by inspection, entire production batches may be scrapped or necessitate further costly inspection campaigns.

The following paragraphs will focus on the specific design of a three-layer microtube. This tube, with an overall diameter of less than 1mm, consists of three layers of different polymers, each with widely different physical properties so that the microtube meets specific requirements (e.g., drug compatibility, mechanical properties, etc.). The dimensional and geometric tolerances have been specified: some of the critical quality measures are the inner and outer diameters and the thickness of each layer.

ENKI's goal is to achieve product quality while minimizing process setup time. Machine setup is a manual process: the machine is configured according to nominal process data and production is started. Over time, ENKI has evaluated different sensors and technologies for directly measuring quality, albeit

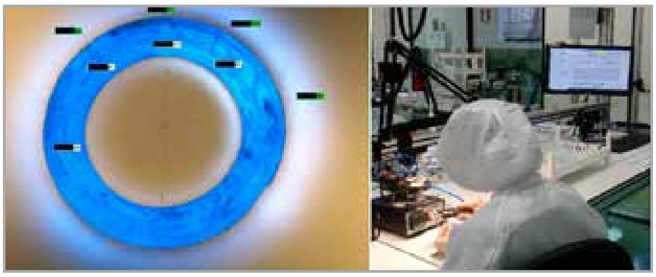


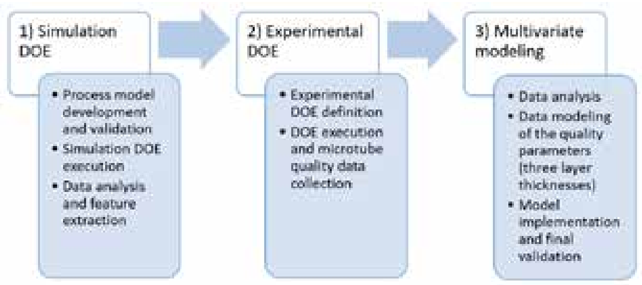
Fig. 2 - Quality inspection (manual process, some details are masked)

that, to date, no single technology or approach is able to provide all the necessary measurements in real time. While it is possible to accurately measure the overall outer and inner diameters in real time, it is not possible to obtain a reliable reading of the thickness of each layer owing to the characteristics of the materials. The production process is therefore carefully tuned until the correct measurements are achieved. Thereafter, and throughout the production of the entire lot, samples are collected, and quality control manually inspects the required measurements.

Virtual sensors development

EnginSoft has developed virtual sensors to improve the management of ENKI's extrusion process and assist with its quality control. Virtual sensors provide an estimate of physical values through data-driven or simulation-based models that run in real time as Digital Twins.

In the ENKI extrusion case, the virtual sensors are based on mathematical models obtained through multivariate data analysis techniques. Although the models are data-driven, simulation played an important role in developing the models. The model development process consisted of three main steps, detailed in the figure below.



Step 1: Simulation DOE

The 3D CAD models of the extrusion die, the flow paths of the three materials, and the process parameters, were used as the starting point for modeling the extrusion process, which was performed using ANSYS Polyflow. Appropriate viscosity data (dependent on material shear rate and temperature) was obtained and applied. A series of simulations was performed, together with refinements of the simulation, and model validation, in an iterative process in order to obtain the best match with the data measured from the actual process. The calibration of the model involved accurate observations of the material behavior, such as wall slippage due to high shear rates. The process parameters were analyzed and a virtual DOE was defined and executed with the primary goal of improving the understanding of the relationships between the input variables (e.g., material pressures and temperatures) and the output variables (e.g., tube diameters and layer thicknesses).

Careful validation of the simulation and model prerequisites by process experts produced useful information about the behavior of the extrusion process, including a range definition for all the process variables and a preliminary identification of the main variables affecting the process. The DOE simulation helped determine which physical sensors, in addition to those already available, should be considered for collecting useful process data. Applying data science modeling techniques made it possible to create a model based on the simulation data, which was instrumental in properly defining the experimental DOE.

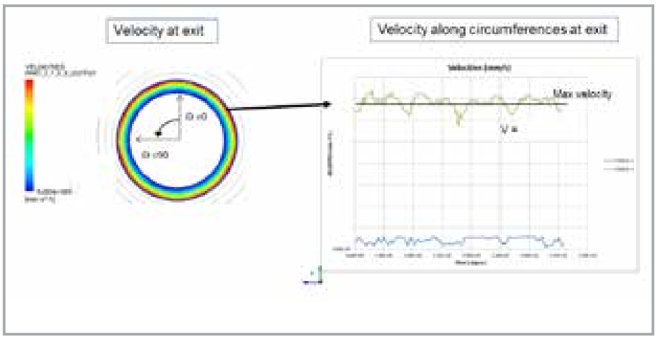


Fig. 3 - Ansys Polyflow simulation of the extrusion process: sample results (data has been masked)

Step 2: Experimental DOE

Two separate DOEs were planned by EnginSoft. The first DOE was aimed at further validating the production process insights obtained from the DOE simulation, while the subsequent DOE was designed to collect experimental data about product quality in order to create the necessary predictive models.

A team consisting of ENKI, the Politecnico of Milan, and EnginSoft researchers conducted the experimental DOEs, which applied

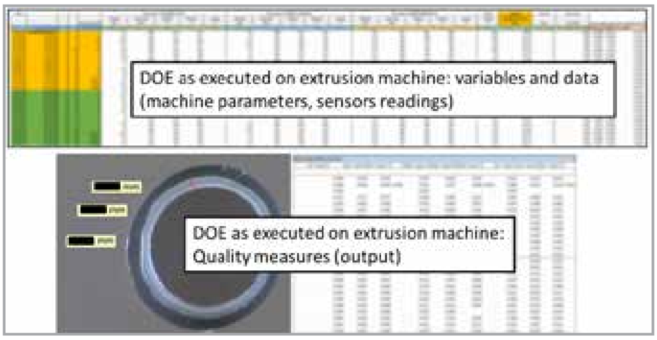


Fig. 4 - DOE as executed: input and output (quality measurements). (Data has been masked.)

Fig. 5 - ForZDM researchers from ENKI, Politecnico di Milano and EnginSoft executing the experimental DOEs on the ENKI microtubes.

metrological and statistical considerations and other appropriate techniques to ensure the quality of the data. It should be noted that the samples collected during the DOEs were used only for the quality measurements and data collection, and were then scrapped.

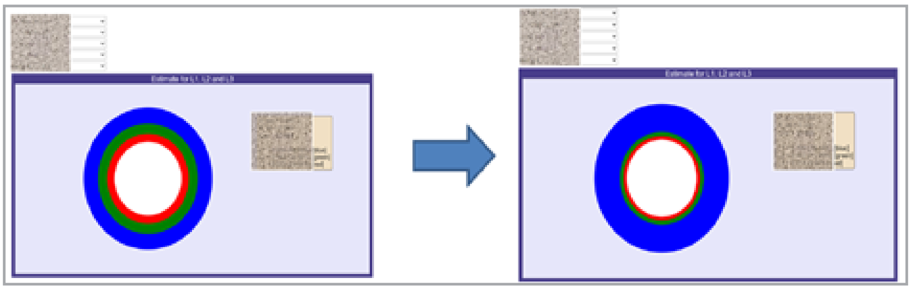


Fig. 6 - Mock-up of the operator GUI of the virtual sensors: changing process variables provides immediate insight into their effect on product quality.

Fig. 7 - The virtual sensors being used in production.

Step 3: Multivariate modeling

Multivariate analysis studies the interdependence between variables providing additional information compared to univariate analysis and enabling mathematical modeling of complex processes. Multivariate analysis techniques can be divided into:

- Classification: a classification study examines observations and determines how similar or dissimilar these observations are to one another. In other words, it determines the distance between observations.
- Dimension reduction: dimension reduction is applied to problems with a large number of variables where the variables cannot be addressed simultaneously. It reduces the number of variables in some logical way so that the problem can be addressed more effectively. The most commonly applied methods for dimension reduction are Principal Component Analysis (PCA), and factor analysis.
- Cause-effect relationship studies: and potentially save a vast amount of valuable production (on the interval between actual production and quality measurement by traditional methods). Commonly applied methods include analysis of variance (ANOVA), multiple analysis of variance (MANOVA), regression (multivariate, meaning more than two variables are involved), etc.

By applying advanced regression methods, the EnginSoft team was able to perform variable (feature) selection (extraction) using a regularization strategy to make the prediction of the output variable(s) robust to statistical error. Many variables and their combinations (i.e., more than 30) could be inserted and then returned a prediction, the associated prediction reliability score, and each variable's weight on the prediction. These methods enabled a reliable prediction of ENKI's product quality based on a relatively small number of observations and variables. The resulting models are appropriate for real-time use, since the quality prediction calculation can be performed at the edge.

Real-time virtual sensor implementation and final validation

EnginSoft created a prototype user interface for a virtual sensor intended to assist the extrusion machine operator during production. The mock-up allows the operator to change relevant input variables and immediately visualize their effect on the quality of the microtube. The models and interface have been integrated at the edge of the machine as a web application, thus permitting complete flexibility in the actual deployment of the interface in the production environment. Data is sent from the sensors to the predictive models using MQTT protocol, with very low latency times, allowing the machine operator to react quickly and potentially save a vast amount of valuable production (on the interval between actual production and quality measurement by traditional methods).

Conclusions

This case study shows how it is possible to:

- effectively use FE/CFD simulation to power a physical DOE strategy;
- collect the right data from a continuous production process;
- apply advanced mathematical modeling techniques to small datasets to obtain accurate and robust models;
- develop tools (virtual sensors) to predict in-line product quality in real time.

Zero Defect Manufacturing methodologies are expected to contribute significantly to achieving near-zero defect levels across all European manufacturing sectors, with an emphasis on process improvements for high-value, high-performance parts.

Acknowledgements

I gratefully acknowledge ENKI Srl, Politecnico di Milano and their researchers for the valuable contribution to this achievement.

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A medical digital twin to prevent and treat aneurysms

Analyze thousands of clinical records to build a model of the human body parts affected by aneurysms: this is the purpose of MeDiTATe, a project to build an IT platform to develop personalized cardiovascular medical procedures for patients.

This technology will be made available to universities, hospitals and industry to increase the accuracy of aneurysm diagnoses. The project, coordinated by the University of Rome "Tor Vergata", will use an innovative approach consisting of the construction of a "digital twin" of the affected part by integrating the following cutting-edge technologies:

- Clinical and imaging data;
- Computer-aided engineering (CAE) Multiphysics simulation with radial basis function (RBF) mesh morphing, finite element method (FEM), computational fluid dynamics (CFD), fluid-structure interaction (FSI), inverse FEM;
- Real-time interaction with the digital twin via augmented reality, haptic devices, and reduced order models (ROM);
- High performance computing (HPC) tools, including graphic processing units (GPUs) and cloud-based paradigms for fast, automated CAE processing of clinical databases;
- Big data management for the patient population's imaging data and high-fidelity CAE twins;
- Additive manufacturing of physical mock-ups for surgical planning and training.

MeDiTATe comprises a consortium of 24 members including universities, research institutions, hospitals and companies from eight different countries. The partners are providing their know-how in the field of digital services, simulation and prototype construction.

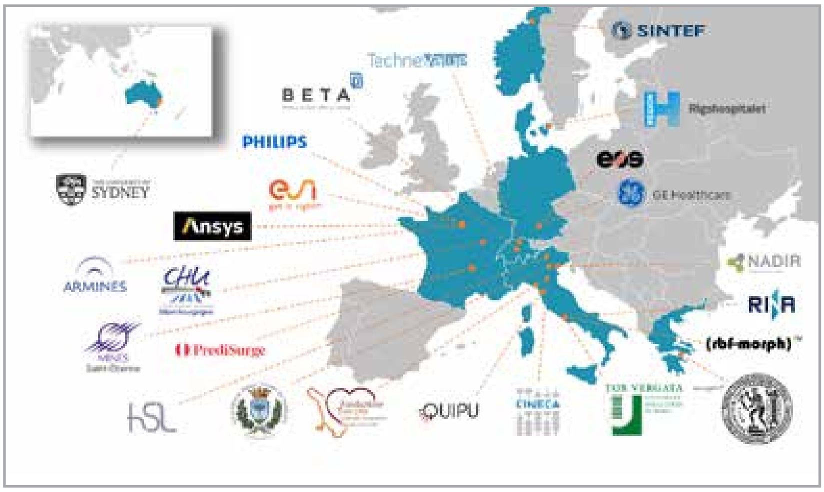
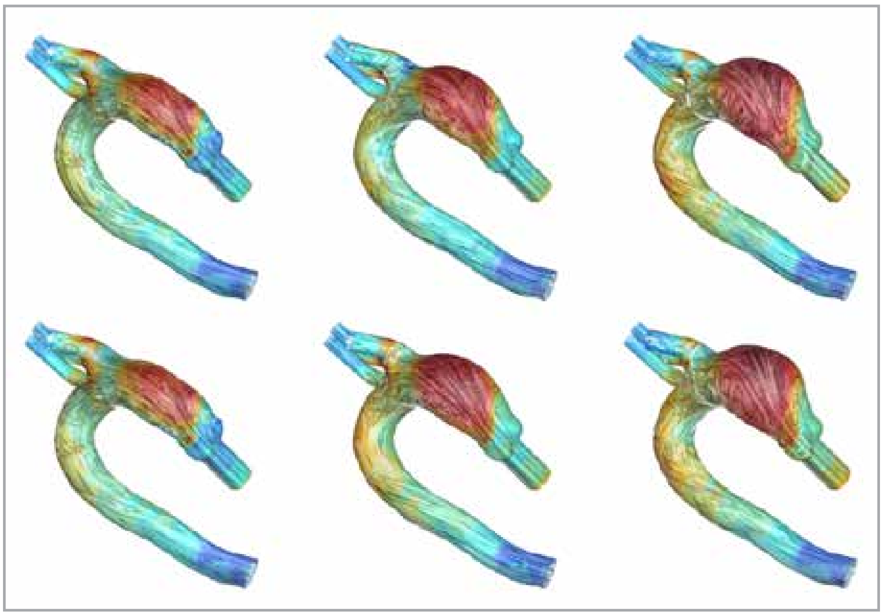


Fig. 1 - The concurrent architectures for the EMA



Simulation of an aneurysm.

The objective is to provide a comprehensive framework of simulation and imaging technologies, for industrial and clinical translation, to accelerate the process of personalised cardiovascular medical procedures, which have been validated by an integrated experimental programme to ultimately improve patient care. The central idea is to make the Digital Twin available as "a service" to everyone in academia, hospitals and industry. The 14 researchers will become the high-profile scientists that have been trained to introduce this innovative concept into the daily routine of healthcare.

Fourteen young researchers will be involved in 14 individual research projects:

1. Combined use of mesh morphing, force-feedback devices and static ROMs to achieve a real-time hemodynamic solution on geometric changes
2. Combined use of mesh morphing, force-feedback devices and dynamic ROMs to achieve a real-time hemodynamic solution on geometric changes
3. 3D modelling and printing for intracranial aneurysm surgery
4. HiFi flow solvers for fixed walls, running on GPUs, and ROMs for aneurysm studies
5. HiFi flow solvers for flexible walls, running on GPUs, and Big Data analytics for aneurysm studies
6. Uncertainty quantification, using polynomial chaos expansion, of CFD predictions for aneurysm studies
7. Patient-specific prediction of aneurysm growth and rupture in the ascending thoracic aorta
8. Simulation of endovascular aortic repair toward evaluation of long-term treatment implications
9. Clinical image processing and Big Data analysis
10. Tissue characterization and endo-vascular aortic repair in a mock circulatory loop
11. Image-guided navigation technology in endovascular interventions: AM-generated mock-ups
12. Image-guided navigation technology in endovascular interventions: advanced CAE tools and mesh morphing
13. Personalized ultrasound-based mechanical characterization of abdominal aortic aneurysm (AAA)
14. Personalized ultrasound-based hemodynamic simulations of the diseased abdominal aorta

The researchers will join the doctoral courses at the University of Rome "Tor Vergata", the National Technical University of Athens and the University of Lyon. In addition to high-level training and a scholarship, students will have the opportunity to gain hands-on experience in the field by working in industry for half of the courses' duration.

We live in a digital age and many answers lie hidden in the sheer volume of data. MeDiTATe aims to take a big step forward in finding these answers in the prevention and treatment of aneurysms. MeDiTATe is funded by the European Union's Horizon 2020 Marie Skłodowska-Curie research and innovation program under Grant Agreement 859836.

Visit: meditate-project.eu

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AFC4Hydro – Design, implementation, and validation of active flow control systems

The Project

Europe is currently confronted with the ever-increasing development of global warming. The earth's capacity to absorb greenhouse gas emissions is exhausted and humanity must meet this challenge by promoting a long-term structural change in the energy system. Hydropower plays a central role in the EU's energy transition to renewable power generation. It is, therefore, necessary to develop solutions to reduce the costs and increase the performance of hydropower, which the AFC4Hydro project is designed to address.

Hydraulic turbines are currently limited in their operating range, so a new component is being developed to allow efficient use in off-design operations as well as during the ramp up and ramp down phases. Specifically, AFC4Hydro aims to design, implement, and validate a novel Active Flow Control for Hydropower system to improve the performance of large-scale hydraulic turbine prototypes of any size, capacity, or design. Through AFC4Hydro, we will achieve particularly important goals:

1. Accelerate the integration of renewable energy technologies into the energy system.
2. Reduce the costs of existing hydroelectric units.
3. Provide a secure supply of hydraulic energy to the grid.
4. Reduce the negative impacts of climate change.

To this end, we established an international consortium comprising two universities, Universitat Politècnica de Catalunya-BarcelonaTech and Luleå Tekniska Universitet; two large energy companies, Vattenfall and Statkraft; and a small-to-medium-sized enterprise, Flow Design Bureau.

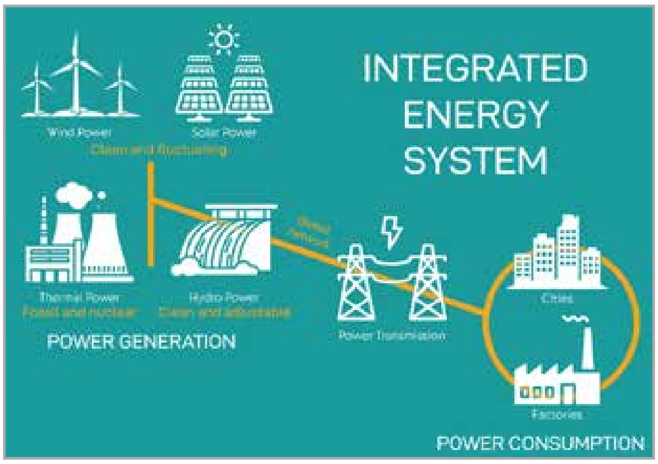

Fig. 1 - Hydropower in the context of the European integrated energy system with the main generation and consumption actors.

The project name suggests a focus on active flow control for a specific type of flow system. The active part of AFC4Hydro also reflects a focus on quantifying the deleterious effects, or structural health monitoring (SHM), of unwanted or secondary flow fields in the hydro turbine and using this quantification to guide an appropriate response by the flow control techniques being exploited. The techniques cover active flow control by pulse or injection of pulsating momentum (IPM). Semi-active flow control involves jet or injection of continuous momentum (ICM). For reference, the project will also apply a passive flow control solution using rods extending into the flow field. SHM, IPM and ICM form separate work packages (WPs) in the AFC4Hydro project, but will merge into a fourth WP when applied to and validated on the project's turbine units.

The work plan consists of a series of experimental and numerical tasks to develop the ICM and IPM technologies, for pressure pulsation attenuation and control, at various scales. Reduced model experiments and numerical simulations will be performed at Luleå university of technology (LTU). Laboratory validation will be performed at a certified state-of-the-art facility at Vattenfall Research and Development in Älvkarleby, Sweden, which allows testing of hydraulic turbine models under stable and transient operating conditions. The complete system will also be tested on a 10 MW Kaplan turbine at the Porjus power plant in Sweden, and on a 200 MW Francis turbine at the Oksla power plant in Norway.

We hope that with the collaborative effort of all the partners in the near future we will see how existing hydraulic turbines can operate safely and with reduced costs in a wider operational range, which will be extremely beneficial for the actual European energy sector and for all the citizens.

Although AFC4Hydro focuses on one set of solutions, several other flow control techniques can be applied. One benefit of AFC4Hydro and similar technologies is that the market will primarily consist

Fig. 2 - 3D model of Oksla Power Plant (205MW). Tests planned for 2023.

Fig. 3 - 3D model of Porjus Power Plant (10MW). Tests planned for 2022.

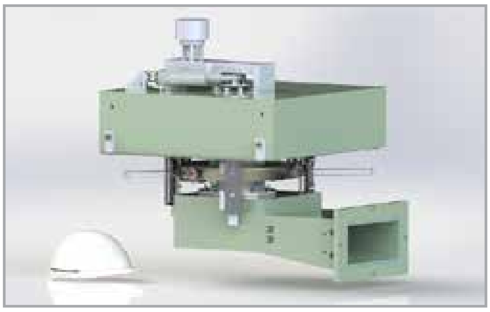

Fig. 4 - 3D model of Luleå Test Rig. Testing starts in spring of 2021.

Fig. 5 - 3D model of Vattenfall-Älvkarleby Test Rig. Testing starts in autumn of 2021.

Fig. 6 - The project has received funding from the European Union's Horizon 2020 research and innovation programme.
Testing starts in autumn of 2021.

of existing hydropower units. If, as a first estimate, we assume an average unit size of 50 MW, this results in about 25,000 hydro turbine units worldwide using 1,205 GW as the total installed capacity (numbers according to IEA statistics). Furthermore, if 10,000 of these machines are candidates for AFC4Hydro or similar technologies at purchase prices in the range of € 150,000 per unit, the total potential market for new upgrades is € 1,500M world-wide. This amount can be significantly larger if AFC4Hydro succeeds in manufacturing kits for small hydro units and pumps.

Experience at the Agorà

Participating in the Research Agorà allowed us to introduce our research project to a wide, competent audience. Since the conference was online this year, a virtual booth was prepared. This was a good opportunity for us to experiment with this new digital format, which we believe will be maintained in the future as well, with virtual sessions parallel to in-person conferences.

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- Project Start: 1 June 2019
- Project End: 31 May 2023
- Project Coordinator: Universitat Politecnica De Catalunya

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S4ALLCITIES

At a glance

S4AllCities is a research project funded by the European Union's Horizon 2020 Research and Innovation Programme, with an aim to revolutionize the way smart cities become more protected, prepared and resilient to both physical and cyber attacks on City soft targets, smart spaces and critical infrastructure networks. This is done by greatly augmenting City Spaces Situation Awareness with intelligence, context and evaluated real-time cyber and physical security threat levels.

The project has a total budget of 9.7 Million Euros and duration of 24 months (1 September 2020 – 31 August 2022). It brings together a consortium of 28 partners from 9 EU countries, including leading European research/academic institutions, SMEs from the software and security domains, and end-users represented by Smart Cities, Law Enforcement Agencies & Transport Operators.

The S4AllCities approach is centered about three modular digital twins, designed to ingest large amounts of data from edge-computing sensors deployed within the Smart Cities, appropriately fuse the information received to establish a recommended course of action, and present the relevant operators with timely and concise actionable information.

Goals & Objectives

The goal of S4AllCities technology is to revolutionize the way smart cities become more protected, prepared and resilient to both physical and cyber-attacks on City soft targets, smart spaces and critical infrastructure networks.

The main objectives of the project are:

- To complement legacy monitoring systems with the adaptation of state of the art and beyond low cost surveillance technologies and solutions that enhance Smart City preparedness and defense capacity in both cyber and physical space.
- To design and develop an open platform for sharing and managing information, while providing intelligence with unprecedented situational awareness and decision support, while enhancing European city resilience, without compromising citizens' fundamental rights and privacy.
- To design and develop intelligent communications architecture that ensures the interconnection and integration of city smart systems while supporting security practitioners
- Significantly impact collaboration across smart cities' stakeholders while engaging citizens towards more secure and safe cities.

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- S4ALLCities Project

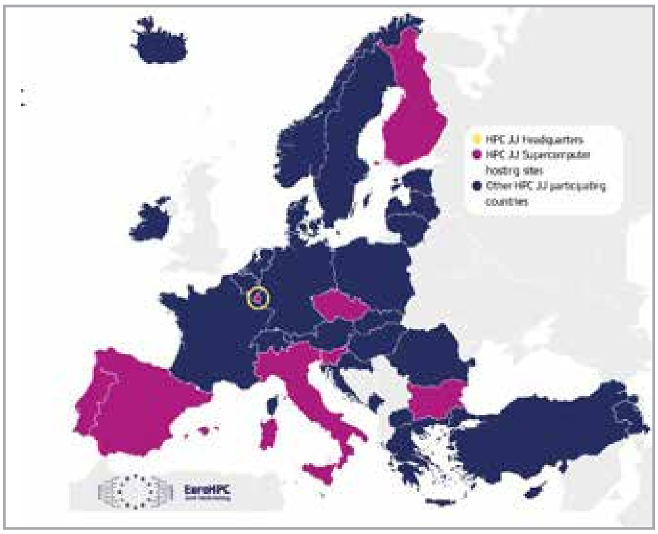
The project has received funding from the European Union's H2020 research and innovation programme under Grant Agreement No. 883522.

Pictures Source: EuroHPC JU website - eurohpc-ju.europa.eu

by **Pascale Bernier-Bruna**
ETP4HPC Office

Looking back on EuroHPC's achievements in 2020

As the EuroHPC JU is entering a new phase, let's look back on its tremendous achievements in the past year, despite the tough context. EuroHPC now pulls together the resources of the EU and of 32 countries, including some non-EU member states, and also includes two private members, ETP4HPC and BDVA. Reaching agreement between so many countries makes the European approach very challenging, but this is what the EU is all about: ensuring that all participating countries get more out of it than they would have if they were acting alone. In 2020, the focus was on infrastructure, on procuring eight supercomputers, with the objective of having all eight operational by the end of 2021. The year also saw the launch of the first three EuroHPC-funded projects; the first 19 Research and Innovation projects were selected, and calls were launched for three advanced pilot systems and for the continuation of the European Processor Initiative.



European map presenting the 32 EuroHPC participating countries, its supercomputer hosting entities and headquarters

Procuring eight EuroHPC Supercomputers

In 2020, the priority was to procure, jointly with the eight hosts and consortia selected in 2019, five petascale systems and three pre-exascale machines. The first EuroHPC JU procurement contract was signed in September 2020 for Luxembourg's MeluXina, and many others have followed. The systems selected will introduce a diverse technology base across the EU, with a variety of architectures excelling for different types of workloads.

Launching the first 3 EuroHPC Projects

The first three EuroHPC-funded projects, resulting from call EuroHPC-04-2019, started in September 2020, are EuroCC, CASTIEL, and FF4EuroHPC. All coordinated by HLRS in Stuttgart, those projects seek to boost European HPC knowledge and opportunities. EuroCC aims to bring the participating European countries to a common high level in HPC and AI. It will establish national competence centres in the participating countries. Its Coordination and Support Action CASTIEL links together the national centres throughout Europe to ensure successful collaboration. FF4EuroHPC aims to expand the use of high-performance computing among SMEs in Europe, building on the successes of the previous Fortissimo projects.

EuroHPC pre-exascale supercomputers

1. LUMI, a 375 petaflops (sustained) system from HPE is under construction at CSC's datacentre in Kajani (Finland). The LUMI Consortium gathers Finland, Belgium, the Czech Republic, Denmark, Estonia, Iceland, Norway, Poland, Sweden, and Switzerland.
2. Leonardo, a 250 petaflops (sustained) machine from Atos, will be located in the new datacentre of CINECA in Bologna (Italy). The hosting consortium also includes Slovenia, Slovakia, Austria, Hungary, and Greece.
3. MareNostrum5 will be hosted by the Barcelona Supercomputing Centre (Spain).

EuroHPC petascale supercomputers

1. MeluXina, a 10 petaflops (sustained) system from Atos, is under construction at LuxProvide in Luxembourg. It will be the first national supercomputer in Luxembourg.
2. VEGA, a 6.8 petaflops (sustained) machine from Atos, is under construction at the Institute of Information Science in Maribor (IZUM) in Slovenia.
3. Karolina, a 9.13 petaflops (sustained) system from HPE, is being installed at the IT4Innovations National Supercomputing Centre in Ostrava (Czech Republic).
4. PetaSC, a 4.44 petaflops (sustained) machine from Atos, will be installed at the Sofia Tech Park (Bulgaria).
5. Deucalion, a 7.7 petaflops (sustained) system from Fujitsu and Atos, will be hosted by the Minho Advanced Computing Centre (MACC) in Portugal.

Preparing the launch of 19 R&I Projects

The EuroHPC JU selected 19 projects during the evaluation of its first Research and Innovation call (EuroHPC-2019-1), out of 38 proposals received. All of them are starting in the first months of 2021. Nine selected projects address the topic "Extreme scale computing and data-driven technologies". They will focus on the performance and efficiency of future exascale systems and leverage ongoing European efforts. Five selected proposals address the topic "HPC and data-centric environments and application platforms". They will focus on the development of energy-efficient HPC software and demonstrate significant use cases and pilot systems. Five selected proposals address the topic "Industrial software codes for extreme scale computing environments and applications". They will further develop, adapt, and optimize HPC software for applications in European industry, while exploiting synergies with existing solutions. Two of those projects, LIGATE and SCALABLE, actually started in January 2021[1].

Signing ceremony of the Hosting agreements of the 8 first EuroHPC supercomputers, November 2019 in Strasbourg.

Photo with representatives of the EuroHPC JU, of the 8 hosting entities and Commissioner Gabriel in middle, in a meeting room.

Calls for three pilots and for the continuation of EPI

Finally, EuroHPC launched two new Research and Innovation calls. ETP4HPC, in its role within EuroHPC's Research and Innovation Advisory Group (RIAG), was instrumental in identifying the research priorities implemented in these calls.

Call EuroHPC-2020-1 included two topics. "Advanced pilots towards the European supercomputers", which closed on 15 September 2020, aims to demonstrate the integration of European technology building blocks developed, for example, in previously-funded EU Research & Innovation (R&I) actions (European Processor Initiative and others) into fully-integrated pilot supercomputing systems aiming at exascale performance. Two complementary pilot supercomputing systems will be supported under this topic: one leveraging the efforts on European low-power general-purpose processing technologies, and one leveraging the efforts on European open hardware solutions. The second topic "Pilot on quantum simulator ", which closed on 28 July 2020, aims at deploying a quantum simulation infrastructure based on European technology, accessible to the European scientific and industrial user community. Call EuroHPC-2020-02, "Framework Partnership Agreement in European low-power microprocessor technologies (Phase 2)", opened on 18 August 2020. It is a follow-up to the Specific Grant Agreement that established the European

References

[1] https://eurohpc-ju.europa.eu/news/new-projects-supporting-drug-design-response-pandemics-hpc-software-european-key-industries

Partners of the OPTIMA Project

Processor Initiative (EPI) in 2018. It addresses the second phase of the research roadmap defined in the Framework Partnership Agreement and will provide the means to turn the most ambitious part of the European HPC Research and Innovation agenda into a reality.

Looking ahead to EuroHPC "Phase 2"

Two years after its establishment, the EuroHPC JU became autonomous on 24 September 2020. As of that day, the EuroHPC JU ceased to be under the supervision of the Directorate-General for Communications Networks, Content and Technology of the European Commission (DG CNECT), although the European Commission remains a member of the EuroHPC Governing Board (50% of all votes). The EuroHPC JU is now solely responsible for its own operations and has the capacity to implement its own budget, under the direction of Mr. Anders Dam Jensen, its Executive Director.

EnginSoft wishes to acknowledge the 2020 ETP4HPC Annual Report as the source for the text of this article.

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OPTIMA

One of the selected proposals addressing the topic "Industrial software codes for extreme scale computing environments and applications" is OPTIMA, the acronym for "Optimizing Industrial Applications for Heterogeneous HPC systems". It is an SME-driven project aiming to port and optimize several industrial applications as well as a set of open-source libraries. These will be used in at least three different application domains on two, novel HPC systems populated with field-programmable gate array (FPGA) integrated circuits and using several innovative programming environments.

In order to support the growing demands for processing power from emerging HPC applications, within a pragmatic energy envelope, future HPC systems will incorporate accelerators. A promising approach, to this end, is the use of FPGA integrated circuits. These devices can be reconfigured at will to tailor application accelerators and their principal advantage is their energy efficiency and/or performance, which, in most cases, is far superior to that of CPUs and GPUs. The applications and libraries are expected to run on these heterogeneous HPC systems with significantly greater energy efficiency, as described by the Energy Delay Product (EDP) metric. In particular, the EDP of OPTIMA applications and libraries running on targeted FPGA-based HPC systems is expected to be more than ten times greater than those on CPU-based systems, and more than three times higher than those on GPU-based systems.

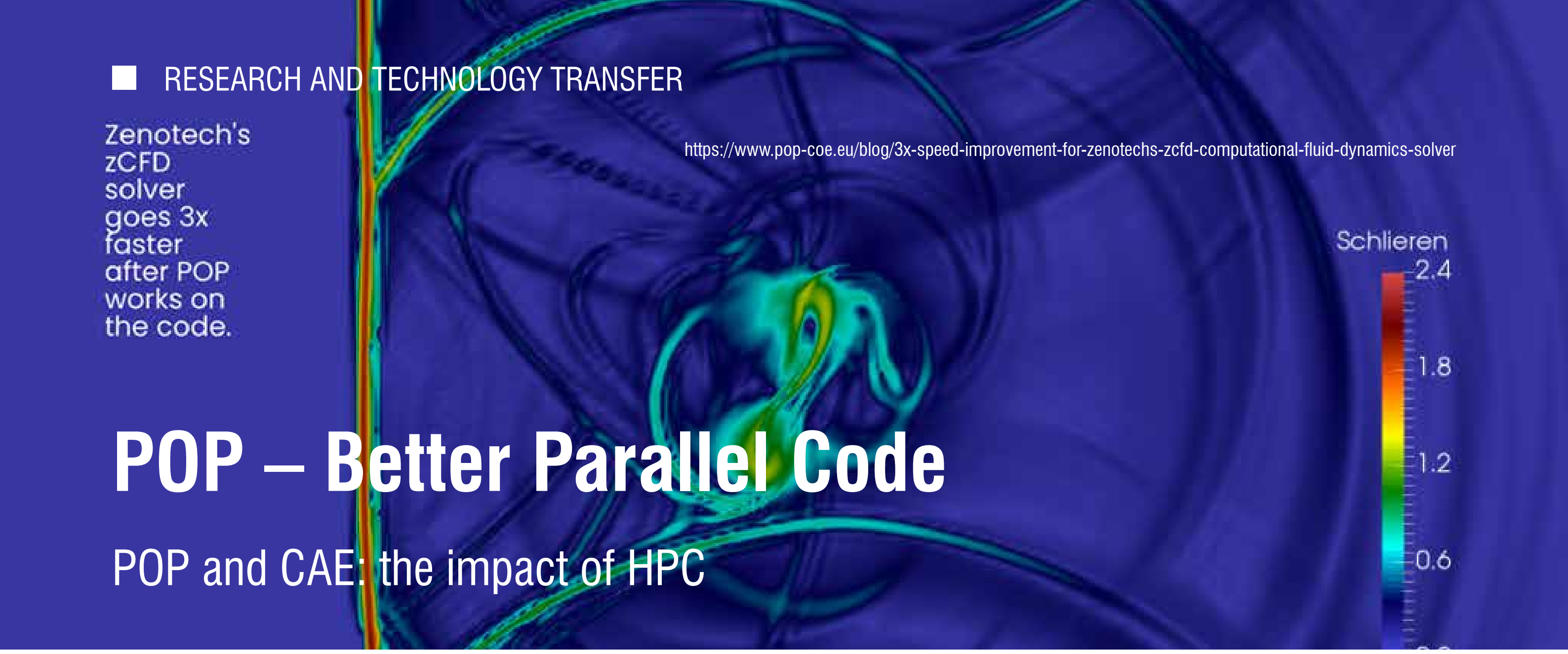
OPTIMA's main outcomes will be:

a) that participating SMEs will gain a significant advantage from being able to run their applications much more efficiently than their competitors;
b) to further demonstrate that Europe is at the forefront of developing efficient FPGA-based HPC systems and the applications/libraries leveraging them;
c) the development of open-source libraries and applications that will allow third-party application developers to easily port to FPGA-based HPC systems;
d) an open-to-use HPC infrastructure supported by a specially created sustainability body.

Started on 1 March 2021, OPTIMA will run for a 33-month period. Horizon 2020 will cover around €1.7 million of the total €4.1 million needed. The project, coordinated by the Greek Telecommunication Systems Institute, brings together ten participants from five EU countries, and Switzerland.

Acknowledgements

This project has received funding from the European High-Performance Computing Joint Undertaking Joint Undertaking (JU) under grant agreement No 955739. The JU receives support from the European Union's Horizon 2020 research and innovation programme and Greece, Germany, Italy, Netherlands, Spain, Switzerland.



Zenotech's zCFD solver goes 3x faster after POP works on the code.

https://www.pop-coe.eu/blog/3x-speed-improvement-for-zenotechs-zcfd-computational-fluid-dynamics-solver

POP – Better Parallel Code

POP and CAE: the impact of HPC

In recent years, HPC facilities have become more widely used where intensive and large-scale simulations are required to control product quality and the production chain. At the International CAE Conference 2020, we were particularly excited to attend the track of talks about commercial software running on HPC machines.

Discussions highlighted the benefits of proper design choices and algorithmic selection. EnginSoft's "best practice" initiative is an outstanding example, created to guarantee effective workflows, thus increasing engineering efficiency. The POP Centre of Excellence, funded by the EU under the Horizon 2020 Research and Innovation Programme, complements the existing efforts in the community and fills an existing gap by providing code performance optimization services.
POP puts the world-class HPC expertise of eight commercial and academic partners at your disposal. POP has the tools and expertise to analyze all aspects of parallel performance, from codes running on a small number of cores, to those on tens of thousands of processors. We work with programs written across a plethora of programming languages including C++, Fortran, Python and Julia, not to mention the many parallel paradigms, such as MPI, OpenMP, CUDA, OpenCL and OpenACC. If you are a European firm looking to improve the performance of your parallel software, you are eligible for free services from POP.

The POP workflow is designed to accommodate the constraints of commercial HPC users and be flexible around their individual needs. Your IP is fully protected, and confidentiality is assured.

Performance Optimisation and Productivity

Our analysis will identify issues such as memory bottlenecks, communication inefficiencies and load imbalances. This enables a better understanding of program efficiency and the identification of target kernels for code refactoring. We can work on these computational kernels and advise on how to roll out improvements to your whole application.

In addition to reducing run-times, greater efficiency can also reduce power consumption and cloud computing costs. After investigating 34 codes used by commercial organizations, we have, on average, reduced their time to solution by more than 50%.

Subscribe to our Newsletter and stay up to date with POP news, developments, events, and live webinars.

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Introducing KARREN: Data intelligence for collaborative engineering

An electromechanical actuator use case

By Nathan Marguet
Digital Product Simulation (DPS)

The complexity of today's highly engineered products requires efficient collaboration between specialized disciplines. One of the big changes in 2020 was the stunning increase in home working, requiring more stringent work allocation and improved communication. KARREN, a new software tool created by DPS, provides a unique instrument for the collaborative design of complex systems. The aircraft Electromechanical Actuator (EMA) use case described below illustrates the design of such a system using KARREN.

KARREN is a web- or cloud-based agnostic framework to support agile engineering and the trade-off processes. It offers flexible and powerful capabilities to define, share and trace key information, such as the engineering parameters of a project, between users and disciplines. It uses a collaborative, multi-disciplinary engineering process to achieve convergence and integration of products at the workgroup or enterprise level.

"3-bar" system with a screw-type cylinder	
"4-bar" system with a crank and rod	
"Direct-drive" system	

Fig. 1 - The concurrent architectures for the EMA

A pilot uses EMA, a simple yet complex system, to flip the wing ailerons to generate an aircraft's rotation of roll. This case study explains the pre-design work done on this system and compares three different system architectures.

Project knowledge and connection diagram

The engineering teams responsible for development of the EMA begin by gathering the key project data (product knowledge) to be integrated by KARREN, thus creating a new model.

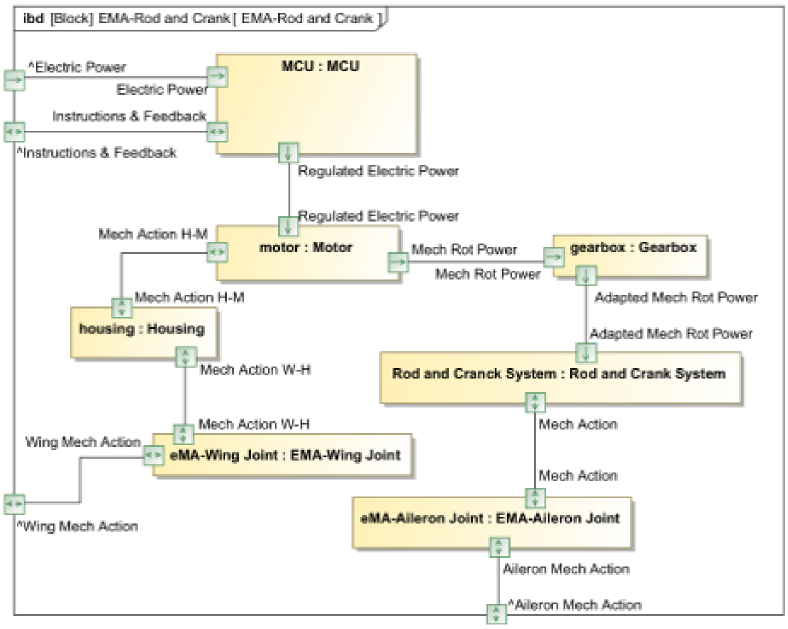


Fig. 2 - SysML diagram of the 4-bar architecture block

Fig. 3 - KARREN Project treeview

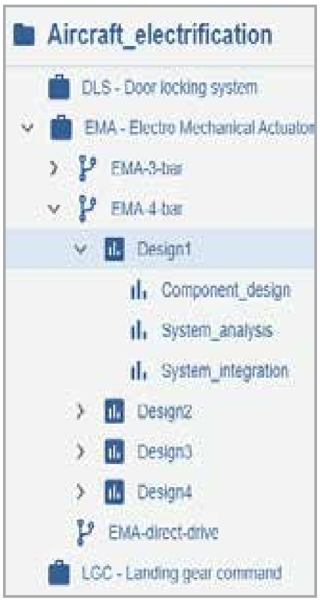


Fig. 4 - EMA treeview

The EMA project requirements are translated into easy-to-understand parameter-based constraints and objectives (e.g. System.Mass < 5kg [CSTR]; Minimize Mass [OBJ]). These parameters are inserted into an object called Activity.

Activity includes as many Branches as there are architectures to be studied (three in this case). In each Branch, the product structure (components and design parameters) is defined to describe the architecture and to correspond to the disciplines involved (CAD study, 0D-1D system analysis, etc.).

The teams then define a mapping between all of these elements and build a model of their Connections. This connection map will serve as the basis for the upcoming collaboration.

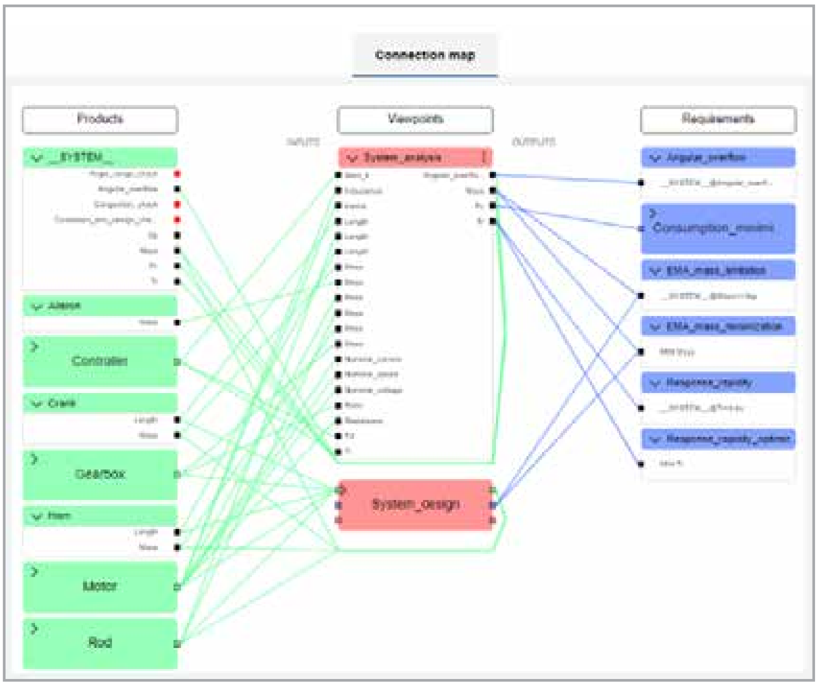


Fig. 5 - Connection map of the 4-bar Branch

From this point, KARREN automatically generates the Candidates: these are spaces dedicated to interdisciplinary collaboration. Each Candidate represents a viable solution proposition for the EMA system. A Branch may have many Candidates. The more there are, the better the design space is covered, increasing the likelihood of discovering a solution that significantly boosts performance.

Collaboration

The Connections between the parameters, disciplines and requirements are clearly defined. Data sharing is instant, and the models are all consistent. At this point, KARREN begins to work its “magic”: the iterative work to achieve product convergence can occur in a truly collaborative way.

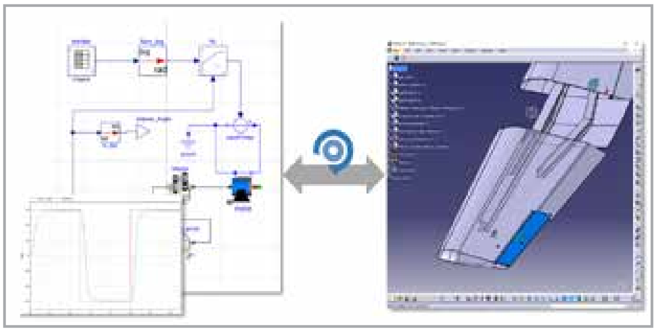


Fig. 6 - 0D/1D analysis engineers work in parallel with CAD integration specialists

The engineers continue to work in parallel as they always have. Fresh data updates the design, and Viewpoints integrate each engineer’s work (products and requirements used, simulation model/tool, result value, etc.). Each alternative Candidate is simulated, and its overall impact can be evaluated without additional efforts. KARREN does not require any fundamental change in the teams’ work habits; moreover, it strengthens them.

The project leader regularly assesses progress towards design convergence using the Consolidation panel built by KARREN. Any inconsistencies due to errors or bad design choices are apparent early on. They trigger immediate rework and iteration. Once all alternative solutions are completely consolidated, KARREN displays indicators to verify, validate, and compare their simulated performances. This is an agile process that saves EMA design teams additional time and costs.

With regard to the EMA with the 4-bar Architecture, the simulation detected weaknesses arising from one of its features, wing penetration: four out of six Candidates show penetration conflicts. In the Direct-drive Architecture, however, the power needed to drive the aileron requires costly equipment (motor/gearbox). Therefore, despite the difficulties of implementing a 4-bar EMA system design, one of its Candidates appears to be the most balanced with a low industrialization cost, reduced mass, and a rapid response to pilot commands. Further design studies can be conducted on the 4-bar design.

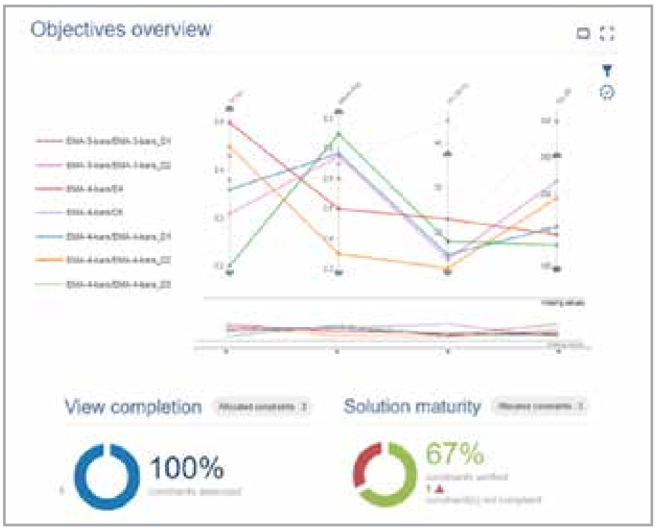


Fig. 7 - KARREN Dashboard: Solutions compared

Conclusion

Higher specialization in engineering disciplines is making collaboration between disciplines more and more difficult.
In this example of using KARREN to design an EMA, the overall complexity of the project is managed by mapping the products, requirements, and engineering studies, creating a solid foundation for intelligent and efficient collaboration.

Each alternative is analyzed and evaluated without additional effort using a traceable process. The product vision and business objectives are achieved by easily identifying the optimal trade-off (e.g. weight vs. cost). KARREN secures product maturity, convergence, and multidisciplinary integration at the workgroup or enterprise level.

For more information:
www.dps-karren.com

About DPS

INDUSTRY LEADER. Since 1997 DPS is a player in digital continuity recognized for its know-how integrating simulation within the process of the design of industrial products. We have solid expertise in CAD/CAE integration, process automation, system modeling & simulation and design optimization.

CONTINUOUS INNOVATION R&D is key to our strategy and contributes greatly to the drive to propose innovative solutions to our customers. For the past 10 years 'Le Lab' at DPS has been exploring new scientific and technological ideas in fields such as Industry 4.0, data mining, data analytics, A.I.

STRONG OFFER IN SERVICES DPS offers services including consulting, technical support, training, software customization and editing… With a strong background in mechanical engineering, our teams are experienced in domains such as stress, electrical, electronics, firmware/software, thermal & fluid dynamics, CEM modeling and optimization.

Using sensitivity analysis to reduce the complexity of design space exploration

Engineering problems can involve a large number of design variables, but not all inputs have an equal effect on the output. Taking all the design variables into consideration can dramatically reduce the efficiency of the Design of Experiments (DOE) or optimization studies. It can also create difficulties in building Response Surface Models (RSM).

It is highly likely that your dataset includes unnecessary parameters that are making your RSM training needlessly more complex. On the other hand, your team of CAE optimization engineers and analysts may disagree about which parameters have the greatest effect on your design problem if these decisions are made manually. Since the human mind can manually grasp up to several of the key effects driving a system, this can lead to uncertainties about the interactions between the design variables and some lower or minor effects in the system.

Defining the influence of the parameters on the outputs of your simulation model before undertaking design space exploration studies can reduce the complexity of your task. Excluding input variables with negligible effects allows the size of the design space to be reduced, and enables the intelligent algorithms to find optimum solutions faster, without sacrificing model accuracy or reliability.

> Understanding how design parameters affect responses before performing optimization enables you to reduce the complexity and find optimal solutions faster.
>
> Danilo Di Stefano
> modeFRONTIER product manager, ESTECO

However, sensitivity analysis itself can be very time consuming and potentially requires many design evaluations. Variable screening methodologies can extract sensitivity information using a relatively small number of sample points, thereby reducing the computational cost of a sensitivity analysis.

Rank the parameters in your engineering design problem

Sensitivity analysis allows the key independent variables that affect the performance metrics, and the quantitative nature of their impact, to be identified. If an independent variable does not strongly impact any of the performance metrics, it can be set to a nominal constant value, thereby increasing the efficiency of your exploration and optimization efforts.

How do you practically investigate the robustness of the model predictions? The process automation and design optimization software, modeFRONTIER, comes with advanced simulation data analysis tools, including sensitivity analysis. It helps you explore the design space in a meaningful way and evaluate the statistical significance of the results obtained from dedicated experiments.

Sensitivity Analysis interface in modeFRONTIER

About Esteco

ESTECO is an independent software company, highly specialized in numerical optimization and simulation process and data management. With a 20-year experience, ESTECO supports over 300 international organizations in excelling in their digital engineering experience, accelerating the decision making process and reducing development time. ESTECO is the owner of VOLTA, the collaborative web platform for Simulation Process and Data Management and design optimization, and modeFRONTIER, the comprehensive solution for process automation and optimization in the engineering design process.

For more information: info@esteco.com

Use modeFRONTIER to perform sensitivity analysis

modeFRONTIER's sensitivity analysis tool includes methodologies based on SS-ANOVA and polynomial chaos expansions (PCE):

- Smoothing Spline ANOVA (SS-ANOVA) is a statistical modeling approach based on a decomposition of functions similar to the classical analysis of variance (ANOVA) decomposition and the associated notions of main effects and interactions. Each term –main effects and interactions – shows the extent of its contribution to the global variance (hence its relative significance). SS-ANOVA is suitable for detecting important variables in a given dataset.
- PCE-based sensitivity analysis is a variance-based approach based on Sobol indices that determine how much of the variability in the model's output depends upon each of the input parameters – either a single parameter or an interaction between different parameters. Polynomial chaos expansion is used to reduce the number of samples needed to calculate the Sobol indices.

Filter out unimportant factors with the Effects Table chart

Effective visualization of the contributions can play a significant role in sensitivity analysis, especially when many factors are involved. modeFRONTIER's new Effects Table dashboard shows all the information needed to make informed decisions in one place.
The effects table chart shows the relative significance of the different terms, i.e., the percentage contribution of each term to the overall variance, and allows you to select and adjust a screening filter to exclude less important terms. Bar charts quickly display the relative contributions of the factors, while sliders help to identify the most promising overall conditions by quickly displaying lateral changes between the factors.

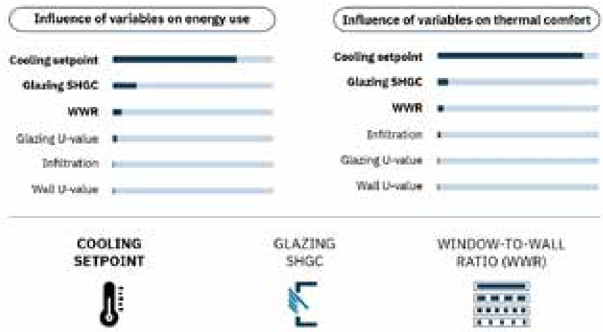
Sensitivity Analysis: new Effect Table Chart

As you apply the filter to the chart, it is saved in the sensitivity model, which is then automatically ready to use in modeFRONTIER for:

- RSM training, to automatically exclude unimportant inputs from the training of RSM models for each output.
- Input domain definition, to transform unimportant input variables into constants.

Sensitivity analysis is available for a wide range of industry-specific engineering problems

The benefits of combining design space exploration with sensitivity analysis are clear: the automotive, aerospace, and other industries use this approach to reduce the complexity of engineering problems, and consequently development time, across a wide range of use cases.

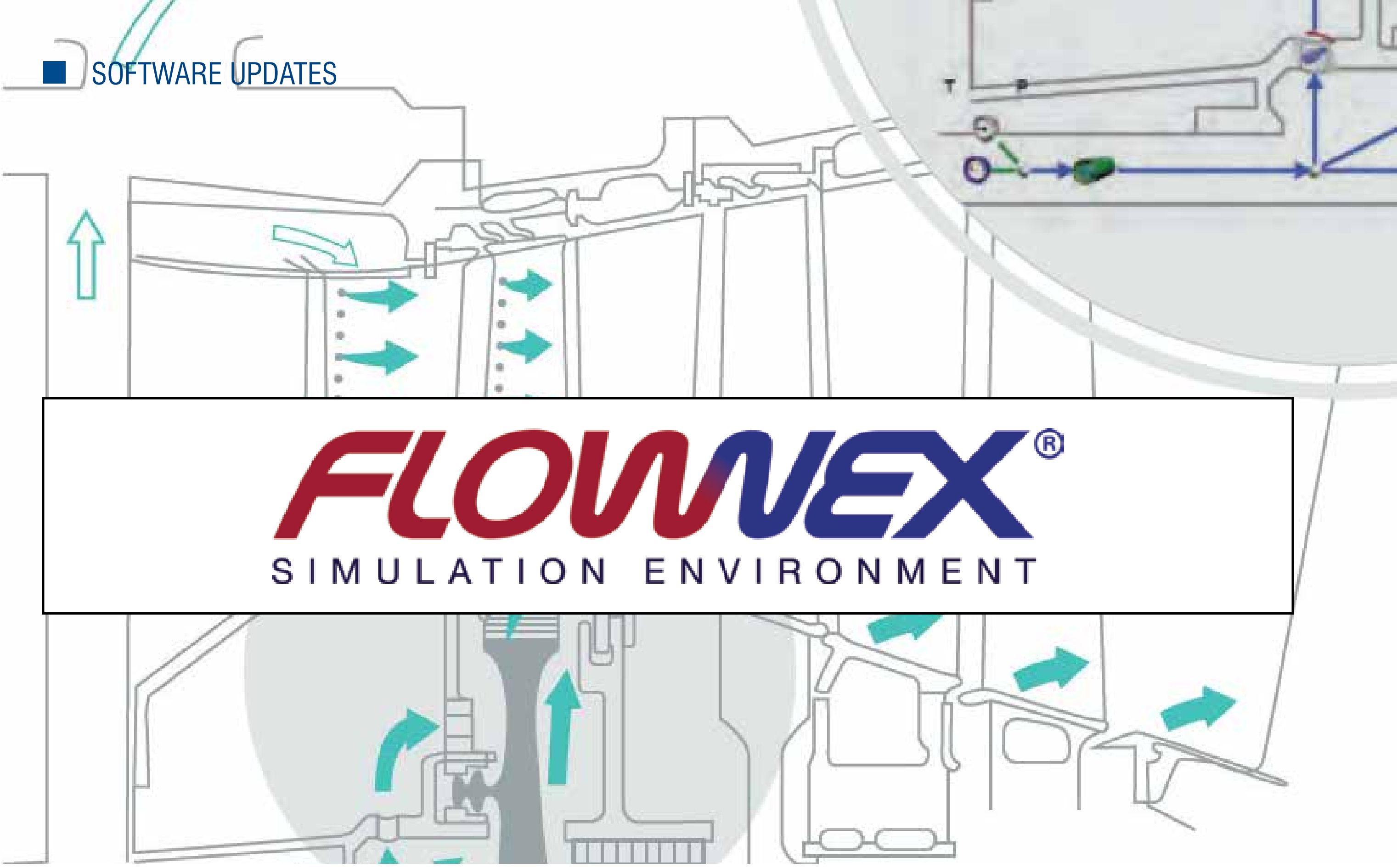


Impact of the construction parameters

In parallel to the spread of simulation to other less "traditional" sectors like architecture and construction, sensitivity analysis can also be applied here. For example, researchers from the Delft University of Technology performed a sensitivity analysis with modeFRONTIER to define which construction parameters have the highest impact on annual energy demand and thermal comfort for an almost zero-energy office high-rise. From modeFRONTIER's sensitivity analysis dashboard, it was possible to visualize the impact of the variables on both energy use and thermal comfort.

The sensitivity analysis showed that the cooling set-point has the highest influence, followed by the Solar Heat Gain Coefficient (SHGC) and the Window to Wall Ratio (WWR). The glazing U-value, infiltration rate, and wall U-value all appear to have little influence on the objectives. These assessments make the optimization strategy more efficient when investigating the influence of building parameters that may have conflicting effects on cooling, lighting, heating energy loads, and facade orientations.

In summary, when tackling an engineering problem, it is advisable to use sensitivity analysis to reduce its complexity. It allows you to reshape a more rational design space, thus improving the quality of the results obtained from DOE, RSM training, and optimization studies.



Enhancements in the latest Flownex release

Flownex is advanced technology to define and calculate 1D fluid-dynamic networks. With its large library of components, Flownex can simulate complete systems: it converts geometrical aspects into lumped parameters to characterize the fluid-dynamic aspects of each specific component.

It reproduces both compressible and incompressible flows and also considers thermal aspects and phase change phenomena, such as cavitation, boiling and condensation.

The latest Flownex release includes the following principal enhancements:

- System resistance graphs
- Force calculations and CAESAR II integration
- Trace elements
- Ansys Mechanical interface

System resistance graphs

A parametric run is automatically configured and executed at the click of a button to easily generate an accurate system resistance graph (see Fig. 1). This can be exported as a CSV file and can also be plotted on a pump chart allowing the user to quickly determine the operating points at different pump speeds.

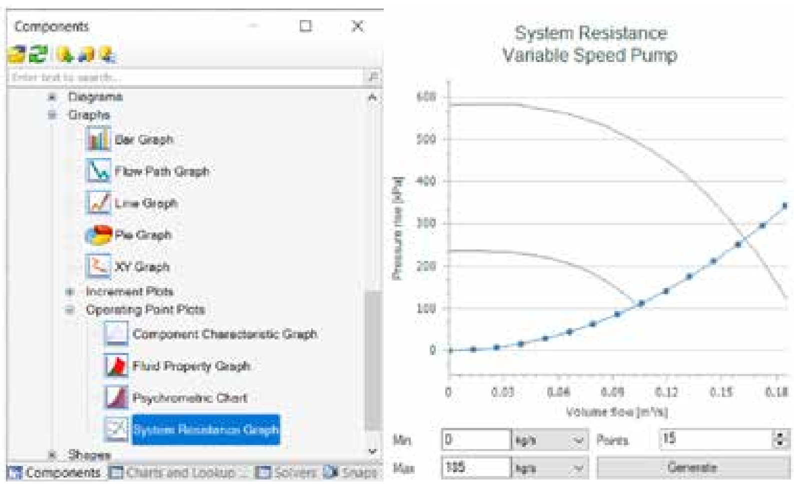


Fig. 1 - System resistance graph

Force calculations and CAESAR II integration

Flownex already allows transient scenarios such as water hammer or pressure surge analyses to be simulated. In the latest release, enhancements enable the calculation of the axial pipe force for both steady state and transient simulations. This allows users to easily simulate the pipe forces and then export the results to structural codes such as CAESAR II. Pipe sections for net force calculations can also be effortlessly defined in the “Force Calculation Piping Sections” dialog, accessible from the Results menu.

A specific user interface enables the dynamic loads from water hammer cases or pressure waves to be calculated: firstly, the user has to import the geometry for the piping system from CAESAR II directly into Flownex. Secondly, the piping sections are simply selected and the net forces will be calculated. These calculated forces can then automatically be exported as a time series that can then be imported into CAESAR II for pipe stress simulation (see Fig. 2).

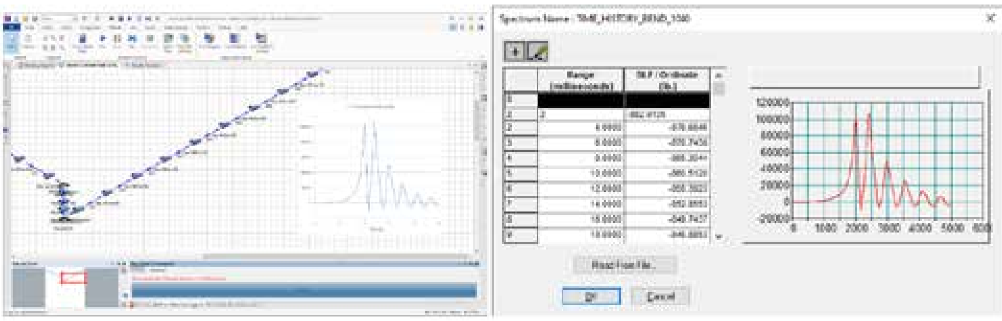


Fig. 2 - CAESAR II integration

Trace elements

The trace element modelling capability has been significantly expanded. Where previous versions only allowed homogeneous mixing of trace elements on nodes, users now have the following additional capabilities:

- Filtering trace elements from the network.
- Specifying selective throughflow of trace elements between nodes, thus conducting non-homogenous mixing of trace elements within nodes.
- Specifying trace element sources and sinks on nodes without the precondition that they enter or leave the system via mass sources or sinks defined for the carrier fluid.
- Modelling trace element decay during transients using the trace element decay constant.
- Filtering and selective throughflow of trace elements are specified on flow element components and sources, or sinks and decay are specified on node components, as seen in Fig. 3.

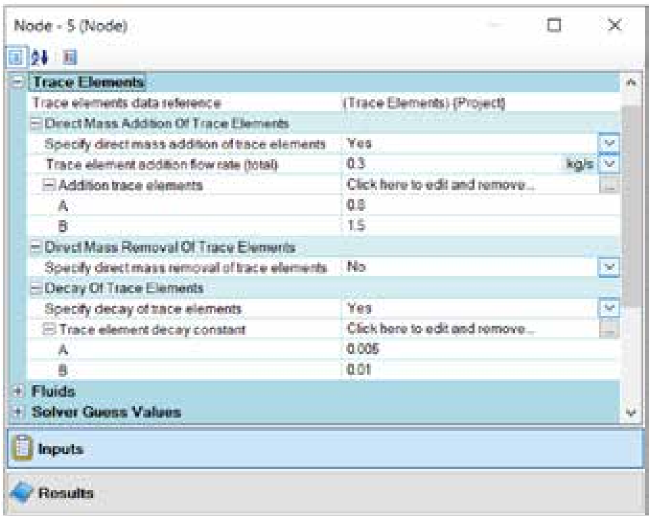


Fig. 3 - Trace elements control panel

Ansys Mechanical coupling

As an Ansys Software partner, Flownex has improved interoperability and ease-of-use with Ansys tools.

In this case (see Fig. 4), the Ansys Mechanical Flow Solver Coupling component has been expanded to allow the simulation of complex 3D conduction and stress in Ansys Mechanical tied to a flow and heat transfer simulation in Flownex. This enhancement includes the addition of a deep solver coupling between Flownex and Ansys Mechanical, allowing data exchange between iterations, full transient co-simulation functionality, and unit integration.

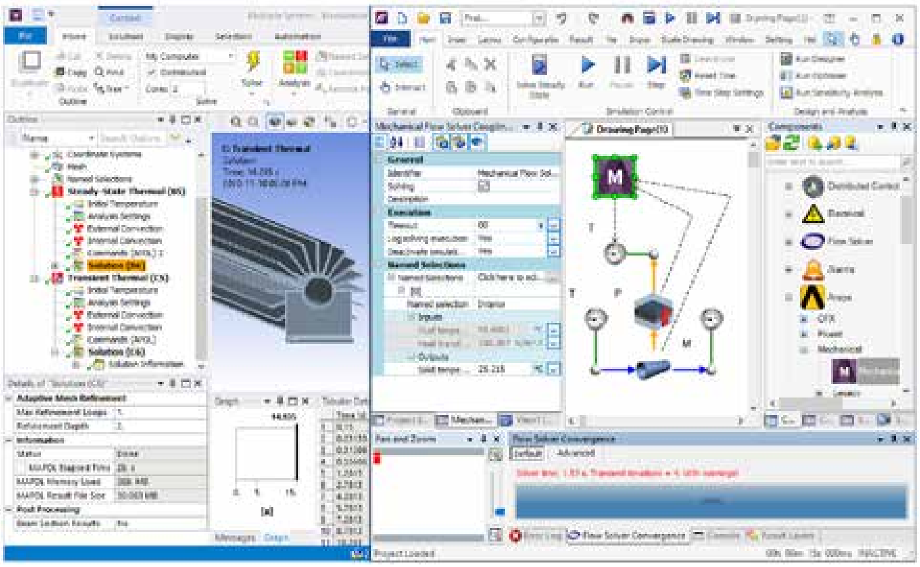


Fig. 4 - Ansys Mechanical coupling

Flownex is already integrated with Ansys Workbench and has dedicated components for co-simulation with Ansys CFX or Ansys Fluent.

For more detailed information regarding these and other enhancements, visit the Flownex website: www.flownex.com

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Ansys 2021 R1: CFD release highlights

By Alessandro Arcidiacono, Diana Magnabosco, and Fabio Villa
EnginSoft

Design products faster than ever thanks to the major physics and productivity enhancements.

Ansys 2021 R1 significantly improves its simulation technology and computing power to help engineers in all industries to reimagine product design and achieve product development goals that were previously thought impossible. This article describes the key new characteristics of the latest release, providing an overview of the pre-processing tools for mesh generation and the CFD solvers.

Ansys pre-processing with Fluent Meshing.

Ansys Fluent Meshing is a mesh generator that allows a high-quality unstructured mesh to be produced, based on a streamlined workflow that guides the user, step by step, through the entire procedure.

In 2021 R1, the Watertight Meshing Workflow (WTM) and the Fault Tolerant Meshing Workflow (FTM) are enriched with useful features including parallel capabilities, mesh transformation and extrusion, graphical usability, and sizing controls.

With regard to usability, a **graphical clipping plane** can be enabled and placed in any arbitrary direction. It is no longer constrained to the global axis, but can be translated, rotated, or moved using the graphical clipping triad.

In both workflows, users can **transform the volume mesh** and replicate it to exploit translational or rotational periodicity. This allows the mesh to be generated for only a portion of the domain after which it can be copied to reproduce the entire configuration.

Another manipulation enables a portion of the mesh to be **extruded**, thus extending the domain to a proper position for the boundary conditions (Fig. 1).

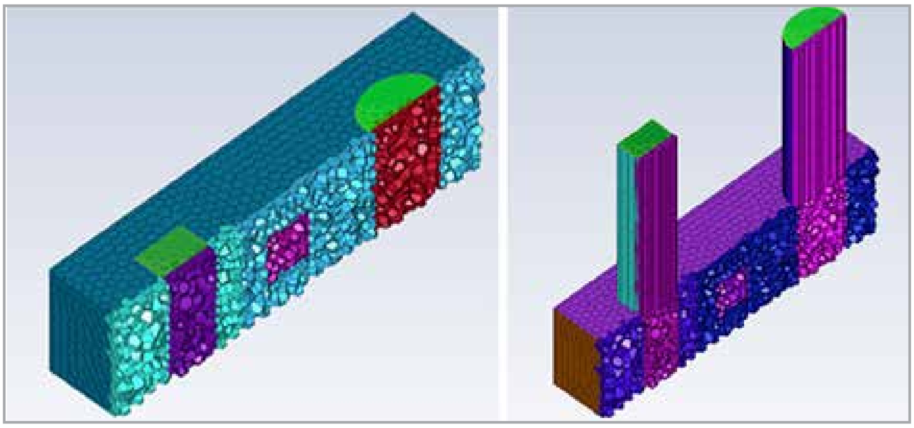

Fig. 1 - Extrusion of surface mesh

The FTM workflow's **Local refinement region** has also been added to the WTM workflow, making it possible to add a Body of Influence shaped like a box or an offset surface. This is useful for automatically refining the volume where high gradients occur. In the WTM workflow, it is also possible to import a **mesh file** (surface or volume mesh or case file), in addition to the classic CAD file. Therefore, third-party meshes can now be read and used to generate a volume mesh.

One of the most important capabilities that has been added is **parallel support for polyhedral meshing**, which speeds up the generation of high-quality meshes that exploit polyhedral shapes to reduce the number of elements and to improve accuracy.

The FTM workflow now supports all volume mesh types **(Tet, Hexcore, Poly and Poly-Hexcore)** for both fluid and solid regions, providing the same capabilities already present in WTM. In addition, the ‘Update Boundary’ task, present in WTM, can now also be found in FTM.

The **Part Management Task** and the Leakage patching task have both been improved, too. The leakage in all fluid/solid/void regions can be specified and leakage sizes can be updated from the update regions settings directly.

When the beta-features are turned on in **Workbench**, and when the ‘Geometry’ component is connected to the ‘Mesh’ cell of ‘Fluent (with Fluent Meshing)’ component, the user is able to initialize the FTM workflow by selecting the ‘Fault-tolerant Meshing (Beta)’ item from the drop-down menu. In the initialized workflow, the ‘Filename’ and ‘Units’ values in the ‘Import CAD and Part Management’ are evaluated based on the geometric path and the units selected in the ‘Geometry’ component in Workbench.

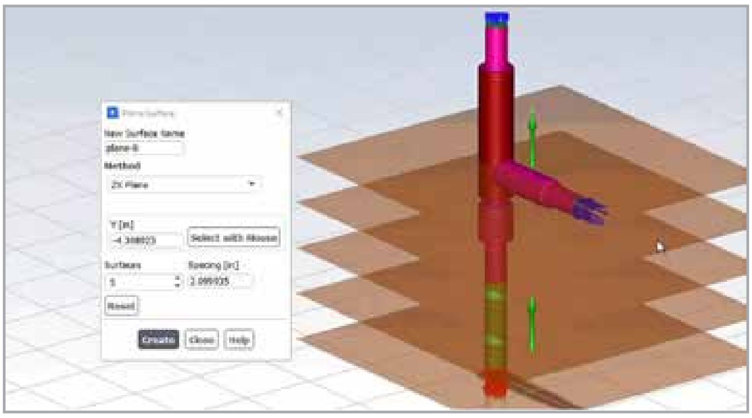

Fig. 3 - Dynamic plane generation in Ansys Fluent 2021 R1

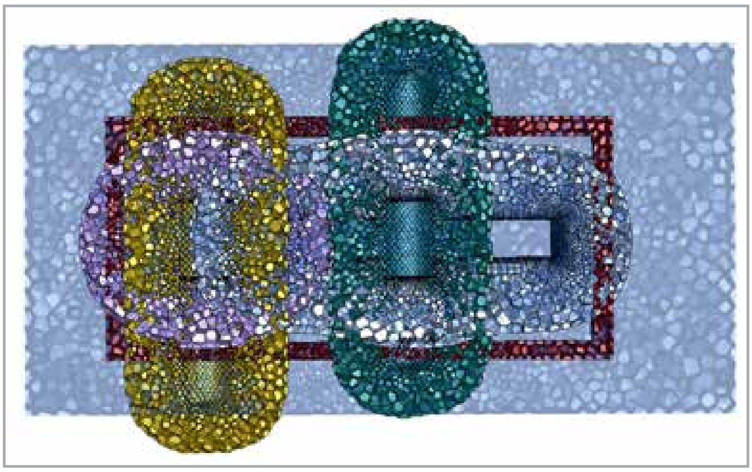

Fig. 2 - Overset mesh

Finally, a particular procedure has been added to this workflow to automatically generate a mesh for the **Overset** technique present in Fluent. This procedure guides users to obtain the correct mesh through task-based workflows, generates proper overset component and collar meshes with different mesh algorithms, creates overset mesh intersections, and diagnoses the mesh (Fig. 2).

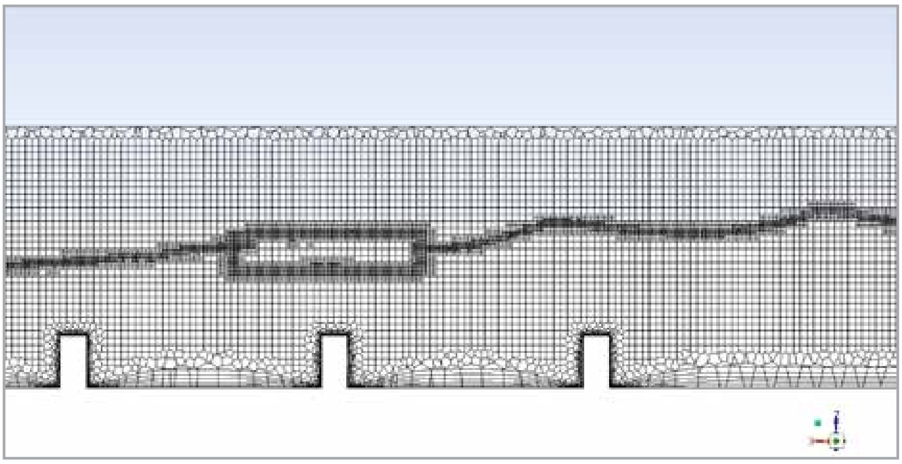

Fig. 4 - Application of overset mesh and polyhedral unstructured mesh adaption

Ansys Fluent

Ansys has announced the fresh release of FLUENT R2021 R1 with new capabilities and enhancements for a more comprehensive approach to product design. The new features are described below.

Ansys Fluent: expression, post-processing, and reports

New **Reduction Functions** have been introduced to simplify the calculation of the key function value at specified locations. To mention a few examples, there are now expressions for vector operations, force, and momentum. The visualization of these expressions is now possible in graphic tools such as contours and vectors, making it easier to check their correct definitions. Their readability is also improved via a dialog that presents a list of all the Named Expressions with corresponding details (such as dimensions, parameter, and status) and with syntax highlights in different colors. Finally, profiles can be used within an expression allowing manipulation and scaling.

Multiple iso-surface and plane are now easier to create in one shot at intervals of field value (Fig. 3). Plots, graphs, or visualizations can be included in embedded sub-windows, so that images and animations contain more personalized information. A new capability allows the automatic generation of customized results **reports**: the simulation output can be post processed, analyzed, and organized into an interactive report, in which sections can be expanded or closed, and one can zoom into/pan within plots. Scenes are available as 3D interactive images when the HTML report is viewed in an external browser.

Ansys Fluent: physics modeling

Solution-based adaption is an important tool for efficiently solving many problems such as free surface flows; now the Polyhedral Unstructured Mesh Adaption (PUMA) technique has been extended for overset problems. This specific adaption automatically reduces orphan cells and cell-size jumps and enables overset-specific adaption to be combined with solution-based adaption criteria. Regarding this area of moving mesh and overset, other remarkable improvements include: overset interface update optimizations, segregated pressure-based solver availability, simplified remeshing frameworks for triangular and tetrahedral elements, and continuous improvement of sliding mesh scalability.

Two new approaches for accelerating **Conjugate Heat Transfer** (CHT) simulations are now available: Accelerated Solid Time-step with Time-Averaged Explicit Coupling and Loosely Coupled Multi-Domain Simulation. The new default mesh interface enhances usability, performance, and diagnostics, reducing the time required to create them. Fluent indeed will automatically detect and create one-to-one interface pairs for any selection of wall/interface zones. Surface-to-surface clustering can now be used with Non-Conformal Interfaces (NCIs), allowing faster view factor creation and solver performance for cases with large numbers of mesh interfaces.

In the field of **multiphase models**, a lot of work has been done to improve the robustness of Volume of Fluid (VOF) simulations of Free Surface Flows (Fig. 5).

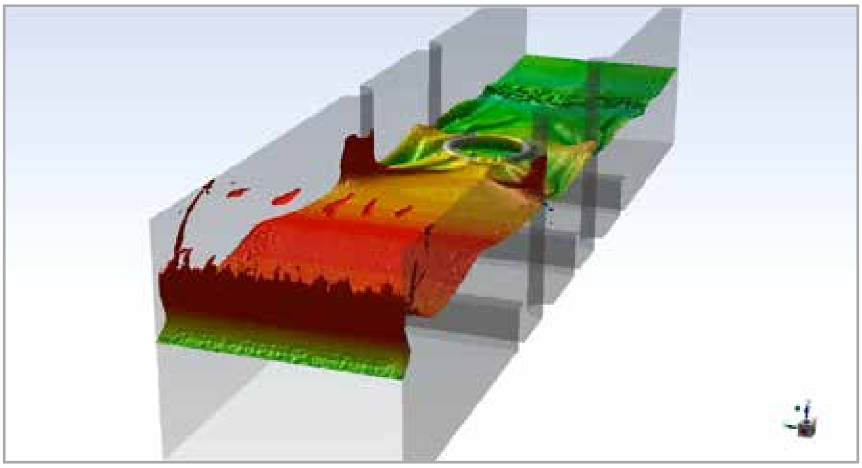

Fig. 5 - Volume of Fluid application

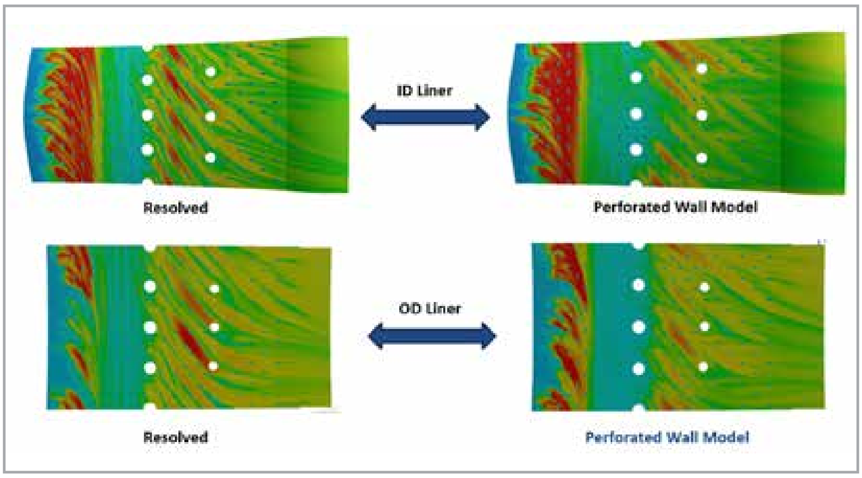

Fig. 6 - Comparison of temperature fields between resolved and perforated wall models

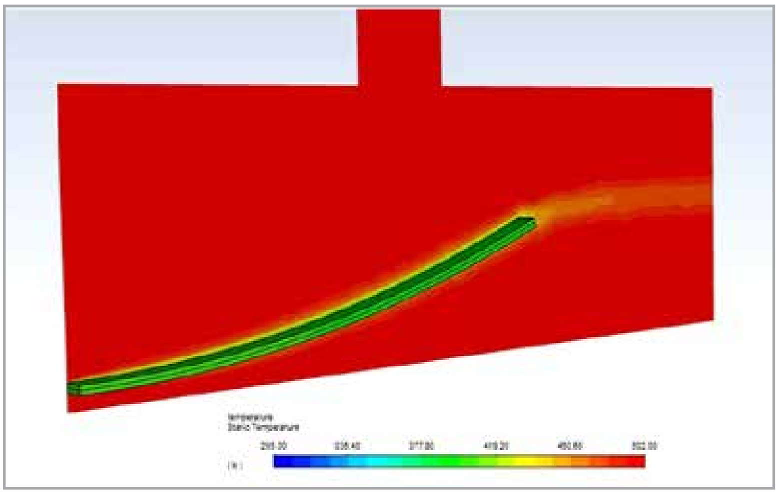

Fig. 7 - Thermo-elastic analysis simulation of a beam

There are enhancements for explicit high-fidelity solutions, especially for high-speed moving mesh applications such as gearboxes, oil-cooled motors, etc. Improvements can be also found in adaptive/variable time stepping, which now considers several different time scales. The Geo-Reconstruct interface tracking has gained in accuracy, allowing larger time-steps to be used and resulting in faster solutions, especially for moving meshes.

In addition to the transition from Volume of Fluid to Discrete Phase Model (VOF-to-DPM), the opposite transition from **DPM to VOF** is also supported. DPM particles falling back onto a free liquid surface now transition back into the VOF formulation, specifically mass-point particles are replaced by mesh-resolved VOF liquid. The high-resolution tracking algorithm has been extended to include compatibility with Overset Meshes.

Within the **combustion models**, the Perforated Wall Model simulates holes without resolving them in the mesh (Fig. 6). Large numbers of small orifices make it impractical to resolve all the details in the mesh discretization.

The benefit is an accurate prediction of pressure drop, back flow margin, mass flow splits and liner wall temperature, while keeping a reduced number of grid elements. Edit Flamelet and Probability Density Function (PDF) for Flame Generation Manifold (FGM) Combustion is now also simpler.

The recent **structural model** integrated into Fluent has an enhanced strain formulation that captures all three mode-shapes very well in comparison to System Coupling results and the previous results. Thermo-elastic analyses are now available in one-way/two-way and Linear/non-linear deformations (Fig. 7).

Ansys CFX

CFX and Turbo Tools

Ansys is constantly developing new capabilities to help customers conduct accurate turbomachinery simulations. Here the main improvements of the 2021 R1 release are presented.

Ansys BladeModeler has been integrated with Ansys DesignModeler to deliver complete 3D geometry modeling capabilities and allow any number of geometric features, such as hub metal, blade fillets, and cut-offs and trims to be added.

The Neutral Data File import to BladeEditor now supports equation-driven thickness, allowing parametric workflows to drive the NDF file without requiring BladeGen in the parametric loop.

Ansys TurboGrid software includes novel technology that targets complete automation combined with an unprecedented level of mesh quality for even the most complex blade shapes. Hybrid meshing can now be used to create conformal meshes for blade tips to account for motion due to flutter, and for secondary flow paths and axisymmetric cavities.

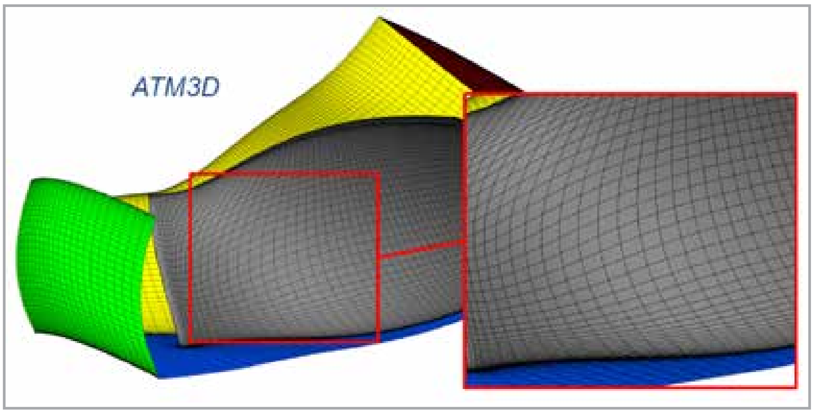

Fig. 9 - Automatic topology meshing

An evolution of Automatic Topology Meshing, called ATM3D, based on a 3D Elliptic Smoother that delivers improved mesh quality in a spanwise direction, has been added in 2021 R1.

Ansys CFX is a high-performance computational fluid dynamics (CFD) software tool that delivers reliable and accurate solutions quickly and robustly across a wide range of CFD and Multiphysics applications. CFX is recognized for its outstanding accuracy, robustness and speed when simulating turbomachinery, such as pumps, fans, compressors, and gas and hydraulic turbines.

Conformal Hexcore Meshes from Fluent Meshing now provide efficient meshes for the CFX solver. Hexcore meshing in the WTM workflow has a new option to avoid hanging nodes (1-to-8 transition avoidance), producing meshes that are compatible with the CFX solver.

Hexcore meshes deliver reduced cell counts for the same mesh resolution compared to Tet/prism meshes, with 30% faster solution times and improved convergence observed.

The **Blade Film Cooling** model provides an efficient and practical way to model an array of cooling holes and the injected film cooling flow on turbine blades. The model does not require the mesh to resolve the holes and is fully compatible with periodic and moving boundaries. In 2021 R1 it is possible to enter injection positions in "user defined turbo coordinates", which define the mapping from the user's preferred coordinates to Cartesian coordinates. It is also possible to parameterize the user-defined locators so the parametric Blade Film Cooling model can be used with Operating Maps and Workbench design points. As an example, injection location can be used as an operating point parameter. This allows the user to run design variations and assess blade performance.

Improved Acoustic Non-Reflective Boundaries. In 2021 R1 particular attention has been given to non-reflective boundary conditions. The first option is the Absorbing Boundary, which

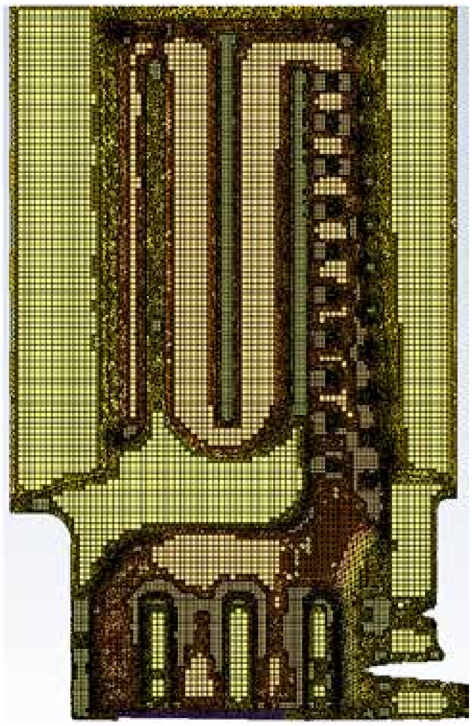

Fig. 8 - Hexcore Mesh with 1-to-8 transition avoidance

prevents boundary reflections in transient/harmonic simulations by damping out the unsteady fluctuations in a buffer region. If the inflow/outflow boundary is close to a blade/object, the Absorbing Layer option is recommended to damp the acoustic reflections.

The second option is the Non-Reflective Boundary, with improved numerics specifically for turbomachinery boundary conditions. Robustness improvements focused on total quantity-based boundary conditions (e.g., Total Pressure), with improved linearization for the Total Pressure inlet.

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Ansys Discovery: a completely renewed interface for entry-level simulation

Beginning with the 2020R2 release, Ansys has completely revamped the Discovery product suite. The main weakness of the former Discovery suite (Discovery Live and AIM) was its poor connection and integration with the Ansys flagship products. For this reason, the Ansys entry-level simulation products, namely the Discovery suite, were not well integrated with the flagship products, such as Fluent or Mechanical, seeming to belong to a different world.

Ansys has made a major effort to improve this connectivity and has developed a revamped product that includes many of the simulation capabilities included in AIM and Discovery Live, all with one user-friendly interface. The new Discovery can be easily connected to Fluent and Mechanical, which is extremely useful in many cases:

- Companies that already use Ansys products for simulation can now implement real-time simulation capabilities, which are particularly useful in the early-design phase. Models developed with Discovery can be shared with Fluent and Mechanical to complete in-depth analyses.
- Companies that are not using Ansys simulations can now get started with an easy-to-use interface that can be used by any type of engineer with no expertise in numerical simulation. If there is a need to increase simulation capabilities in the future, it is quite easy to share the model already developed.

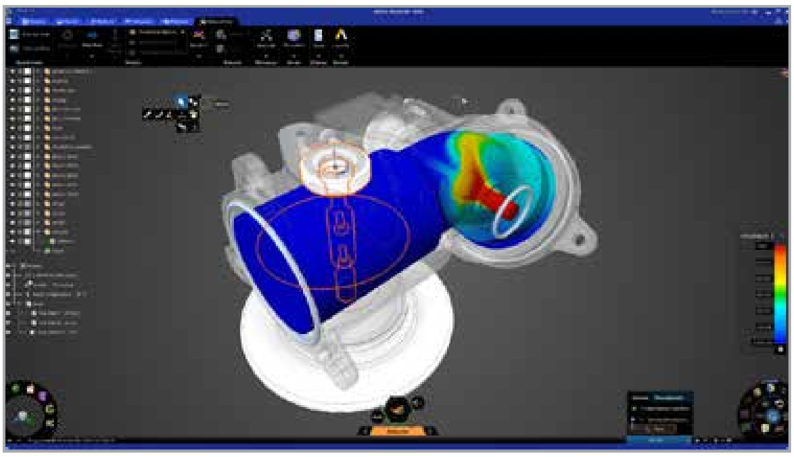

Fig 1 - Thermo-fluid dynamic analysis on an exhaust gas recirculation

Three ways to use Discovery

Discovery works in three different modalities, both for fluid-dynamics and structural analyses:

MODEL Geometry preparation & editing	EXPLORE Structural, Thermal, Fluid	REFINE Structural, Thermal, Fluid
• Geometrical simplifications & defeaturing • Geometrical repairing & cleaning • Fluid volume extraction • Parameter generation for what-if studies	• Rapid exploration of design space • Interactive real-time simulation • Fast geometry modification during physical field visualisation • Fast test setup	• Selection of different physics for in-depth analyses • Global and local mesh method control • Focus on details • Performance validation with high-fidelity results

- ***MODEL mode*** is enabled with the Discovery License and takes advantage of a similar interface to Ansys SpaceClaim. The user can work with the main SpaceClaim tools to make any type of direct modification to the CAD model before entering the analyses. Additional features of SpaceClaim Direct Modeler, which are not included in the Discovery interface, are accessible in the stand-alone version of SpaceClaim, also using the Discovery license.

- ***EXPLORE mode*** is also enabled with the Discovery License and is the environment in which the user can perform CAE analyses using the real-time solver. The results of the numerical analyses, whether on fluids or solid structures, can be viewed as the design engineer creates and modifies the CAD model. Data from the physical analyses is immediately available, leading to a revolutionary way of designing: the time required to prepare the geometry, configure the analysis, and perform the calculation is reduced to almost zero.

- ***REFINE mode*** can be enabled with the CFD-Pro or Mech-Pro license. The user can perform mesh-based simulations using the Ansys Fluent solver for CFD and the Ansys Mechanical solver for structural and thermal analyses. This mode is suitable for engineers with a limited background in numerical simulation; thanks to the well-guided workflow, the user can achieve an accurate and detailed solution to study product behavior.

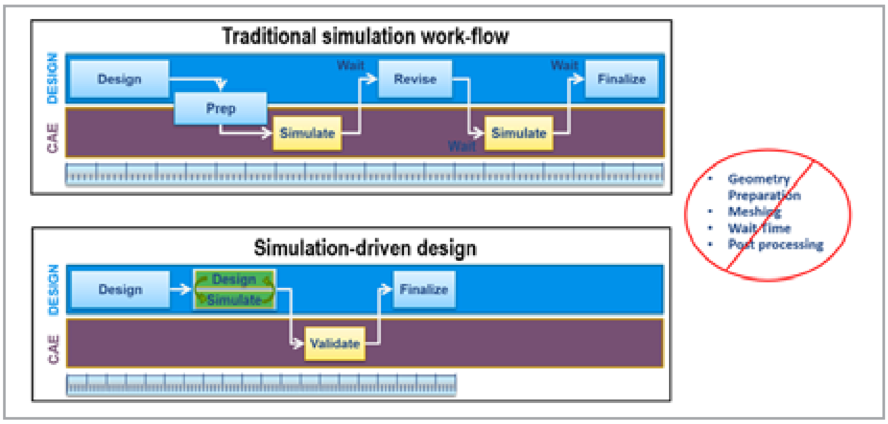

Fig. 2 - Traditional vs simulation-driven workflow

Explore mode: a revolutionary way to design

One of a design engineer's most difficult tasks is to combine product functionality, technical constraints, and performance. Often, the possibility of investigating alternative designs or configurations is not allowed by the upcoming deadlines.

Created a few year ago, real-time simulation is a highly innovative technology that is revolutionizing the field of Computer Aided Engineering. It is based on computer graphics technologies and takes advantage of the workstation's Graphics Processor Unit (GPU) instead of standard processors. The solver uses 3D voxels to automatically discretize geometries with a Cartesian grid. The real-time solver can perform several types of numerical analyses in just a few seconds.

In Discovery it is possible to perform:

- fluid dynamics analysis
- static structural analysis
- thermal analysis
- conjugate heat transfer (CHT) analysis
- modal analysis
- topology optimization analysis

Results, such as Von Mises stresses, total pressure drop, or natural frequencies, can be visualized while the design engineer creates and modifies the CAD model. This alternative workflow dramatically reduces the time required to prepare the CAD, the model, analyze the results and implement changes. By integrating CAD modelling and simulation, all of these iterations are eliminated, leading to **true simulation-driven design.**

With real-time simulation, most of the traditional steps of a CAE analysis are no longer necessary. There is no need to simplify the geometry because the discretization performed by the voxels simply disregards smaller features. The mesh does not need to be constructed because it is created automatically by the voxels. The solver takes seconds to achieve convergence and the results, both quantitative and qualitative, can be examined instantly.

The results can be viewed with a variety of processing tools. For CFD analyses, there are volumetric and surface contour plots, streamlines, particle tracking, iso-surface, and others. For structural analyses, the user can navigate through the results with contour plots, the deformation tool, or iso-surface plots. In addition to the qualitative post-processing, monitors enable the user to quantify performance: pressure drops, maximum stresses, average temperatures, flow rate distributions, etc.

Since the mathematical model is considerably different to the standard mesh-based solver, the accuracy of the solution is lower. The user should bear this in mind when using this tool. Nonetheless, the real-time solver is particularly useful for comparing different solutions and understanding a trend of variations. Once the designer has determined a rough configuration, they can validate the performance with the mesh-based CFD solver included in Discovery.

Refine mode: In-depth thermo-fluid dynamics and structural analyses

Thermo-fluid dynamics

Discovery's Refine mode is an invaluable tool for first-time CFD design engineers who need software with well-guided workflows and great ease of use.

After importing the CAD in neutral (step) or native format, the interface guides the user to extract the fluid volume needed to perform the analysis. The user can decide to simulate the whole assembly or to focus on a limited region.

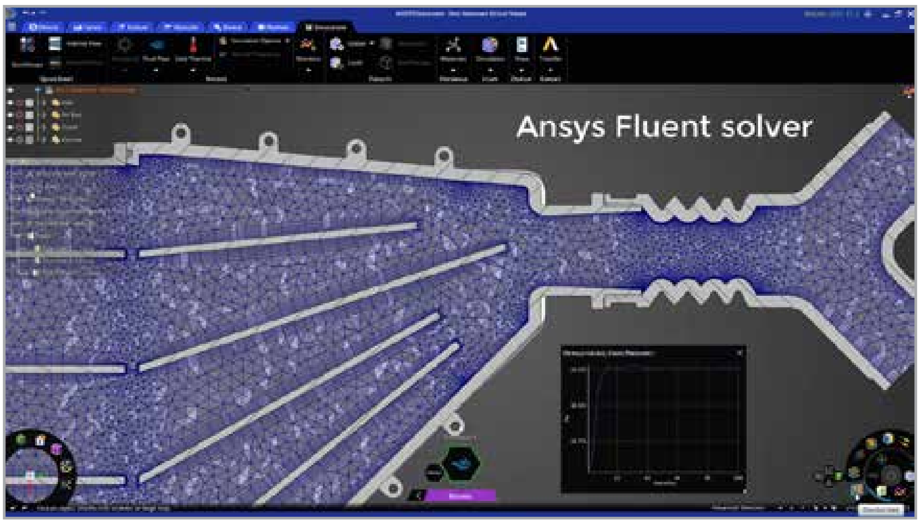

Fig. 3 - CFD analysis in Refine mode

The mesh is tetra-prismatic and is generated using Workbench's meshing algorithms; the user can control global sizing methods (such as curvature, proximity, etc.), local sizing to refine the grid around small details, and also the mesh properties for boundary layers.

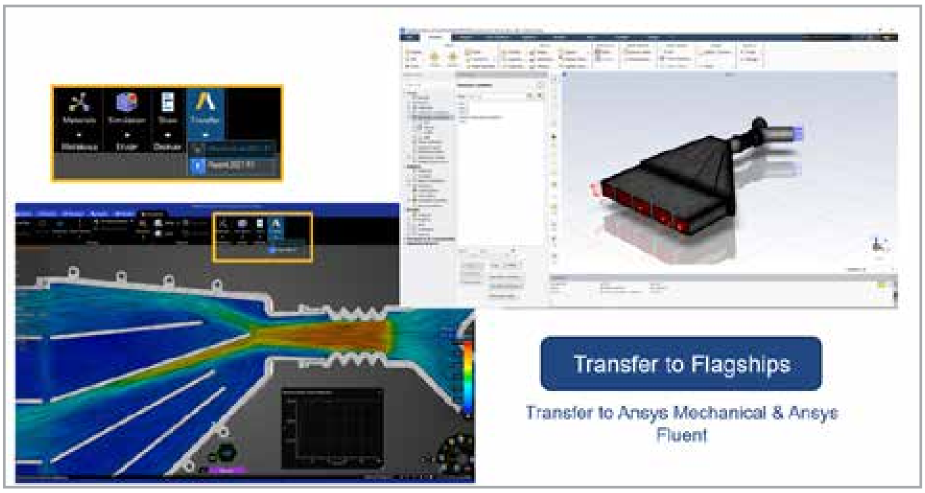

Fig. 4 - Model sharing from Discovery to Fluent

CFD analysis can be configured for many different applications:

- liquid or gas modeling using the internal library (incompressible approach)
- turbulent or laminar
- steady-state analysis
- different types of boundary conditions (pressure, velocity, and flow rates)
- gravity effects
- thermal boundary conditions
- Conjugate Heat Transfer analysis (thermal analysis on fluids and solids together, to model convection and conduction effects)
- Many types of monitors to investigate performance or detailed data (pressure drop, flow rates, forces, velocities, average or maximum temperatures, etc.)

To analyze the data obtained from the calculations, all post-processing capabilities available in Explore mode can also be used in this mode. All models are easily transferable to the Fluent interface.

Refine mode for CFD requires the add-on CFD-Pro license. CFD-Pro is a new Ansys license that can also be used standalone and permits usage of the Ansys Fluent interface.

Fluent licensed this way is a new Ansys product that enables additional simulation capabilities beyond Discovery, such as compressible flow, fan, and pump simulations, multi-species flows, and many other types of CFD analysis.

Structural and thermal analysis

In-depth analysis is enabled by traditional Ansys solvers (Mechanical and Fluent licenses) in Refine mode.

This approach enables the user interested in structural problems to investigate some nonlinear behaviors of the model or more specific aspects of the analysis, such as non-linear contact or large deflection. In Refine mode, unlike Explore mode, the user must create a traditional mesh. In addition to Explore mode, the Discovery environment provides the user with the reliability of traditional solvers and new capabilities.

The Refine mode of structural analysis allows the user to simulate these additional tasks:

- Large deflection
- Non-linear contact
- Pre-tension bolts
- Pre-stressed modal
- Thermal boundary conditions
- Remote displacements

It should be noted that mesh generation can be fully automated or manually defined, depending on the user's experience or expertise. Furthermore, contact detection can also be automated and contact behavior can be defined with standard settings or customized by the user.

Refine mode for structural analyses requires the MECH-Pro add-on license. The MECH-Pro Ansys license can also be used standalone and allows Ansys Mechanical to be used inside the Workbench interface.

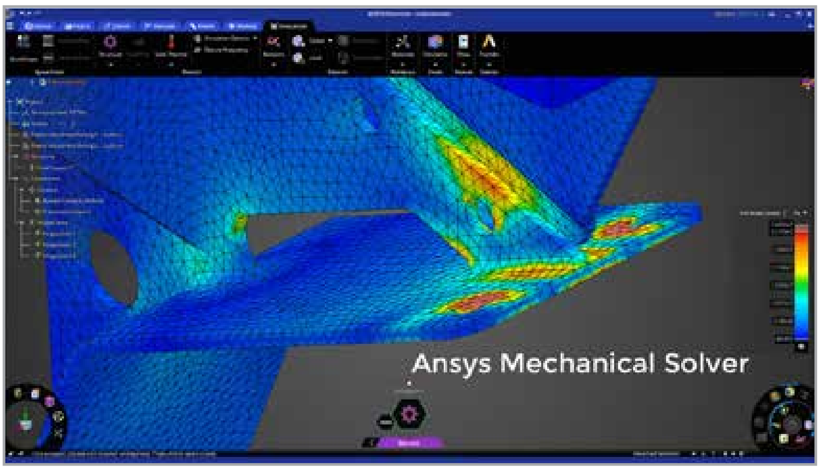

Fig. 5 - Structural analysis in Refine mode

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