ENGIN SOFT Newsletter

Simulation Based Engineering & Sciences

Year 13 n°4 Winter 2016

Numerical simulations for the structural performance assessments: a connecting rod's case study of a Piaggio motorbike

Detecting and mitigating critical flow structures in **water pumping stations**

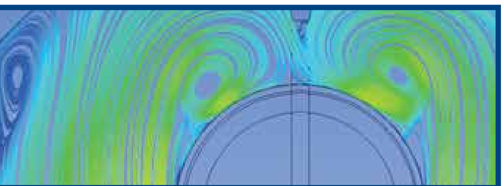
Fluid Dynamics Optimization of **Racing Engine** Inlet Ducts at Aprilia Racing

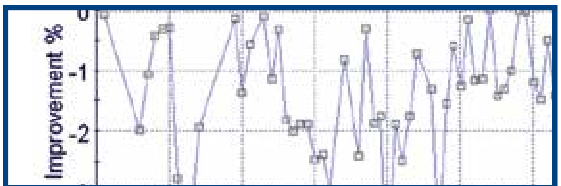
Investigation of **vacuum cleaner** performance through vacuum head modifications

Multibody Simulation of **Forklift trucks** dynamic loads

High Temperature Forging of **Austenitic Stainless Steels**

High Temperature Forging of Austenitic Stainless Steels: Failure Analysis using Numerical Simulations





FLASH

Winter has quickly set upon us again, with another memorable year coming to an end; 2016 has definitely left its stamp. As we brace ourselves for 2017, this year's CAE Conference provided a touch point for how far we have come to improve the environment around us. It certainly struck home over the enriching two days, with over 150 speakers and countless engaging conversations, that simulation is an enabler for all aspects of life – we certainly would not be where we are today without the undeniable determination to do more, better, through simulation.

In the case on page 24, we look at the advancements made by Intelligent Infrastructure Innovation Srl in designing a reliable real time seismic monitoring system to understand the damage state of buildings. This will allow for much better understanding to improve future technical designs in addition to minimize time delays to assess and evaluation buildings to employ recovery efforts.

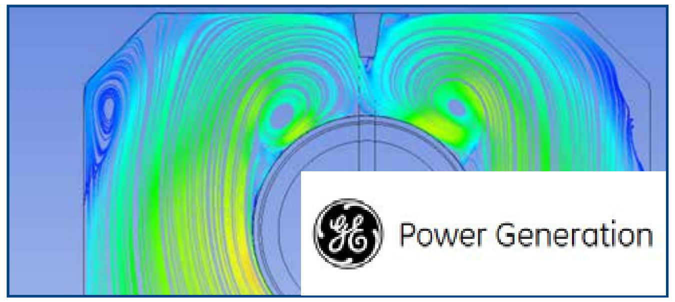
While customer expectations increase, design products are also met with regulations to avoid misleading the end-users. Whirlpool details their use of CFD to meet both the user's expected performance and ErP Regulation compliance in the case on page 13.

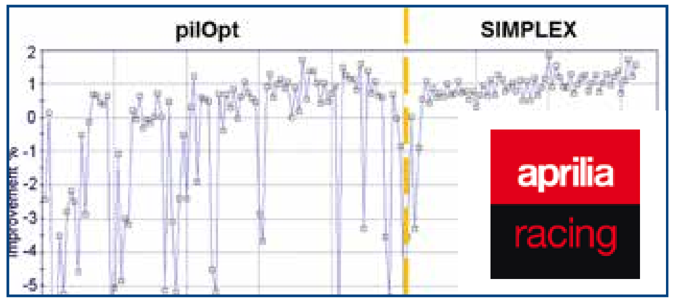
On behalf of everyone at EnginSoft, we thank you all for your contribution and another remarkable year and look forward to continuing this in 2017 with more opportunities to collaborate with many of you. EnginSoft wishes you, your colleagues and families a Merry Christmas and prosperous year ahead.

Stefano Odorizzi, Editor in chief

Contents

OUR ACKNOWLEDGEMENT AND THANKS TO ALL THE COMPANIES, UNIVERSITIES AND RESEARCH CENTRES THAT HAVE CONTRIBUTED TO THIS ISSUE OF OUR NEWSLETTER





Newsletter EnginSoft
Year 13 n°4 - Winter 2016

To receive a free copy of the next EnginSoft Newsletters, please contact our Marketing office at: newsletter@enginsoft.it

EnginSoft S.p.A.
24126 BERGAMO c/o Parco Scientifico Tecnologico
Kilometro Rosso - Edificio A1, Via Stezzano 87
Tel. +39 035 368711 • Fax +39 0461 979215
50127 FIRENZE Via Panciatichi, 40
Tel. +39 055 4376113 • Fax +39 0461 979216
35129 PADOVA Via Giambellino, 7
Tel. +39 049 7705311 • Fax +39 0461 979217
72023 MESAGNE (BRINDISI) Via A. Murri, 2 - Z.I.
Tel. +39 0831 730194 • Fax +39 0461 979224
38123 TRENTO fraz. Mattarello - Via della Stazione, 27
Tel. +39 0461 915391 • Fax +39 0461 979201
10133 TORINO Corso Marconi, 10
Tel. +39 011 6525211 • Fax +39 0461 979218

www.enginsoft.it - www.enginsoft.com
e-mail: info@enginsoft.it

The EnginSoft Newsletter is a quarterly magazine published by EnginSoft SpA

COMPANY INTERESTS
EnginSoft GmbH - Germany
EnginSoft UK - United Kingdom
EnginSoft France - France
EnginSoft Nordic - Sweden
EnginSoft Turkey - Turkey
VSA-TTC3 - Germany
www.enginsoft.com

CONSORZIO TCN www.consorziotcn.it • www.improve.it
Cascade Technologies www.cascadetechnologies.com
Reactive Search www.reactive-search.com
SimNumerica www.simnumerica.it
M3E Mathematical Methods and Models for Engineering www.m3eweb.it

ASSOCIATION INTERESTS
NAFEMS International www.nafems.it • www.nafems.org
TechNet Alliance www.technet-alliance.com

ADVERTISEMENT
For advertising opportunities, please contact our Marketing office at: newsletter@enginsoft.it

RESPONSIBLE DIRECTOR
Stefano Odorizzi - newsletter@enginsoft.it
ART DIRECTOR
Luisa Cunico - newsletter@enginsoft.it
PRINTING Grafiche Dal Piaz - Trento

Autorizzazione del Tribunale di Trento n° 1353 RS di data 2/4/2008

A History of Vortices

GE Power is a world leading supplier of solutions for power generation, from engineering to manufacturing. Detecting and mitigating critical flow structures in water pumping stations is a complex engineering task, that has always been based on experimental activities. Now GE Power can rely also on CFD modelling and on the support of EnginSoft

Introduction

Vortex generation in pumping stations must be prevented or limited to superficial and low intensity vortices, because deep and intense ones can severely damage the pumps or / and affect their performance (flow, head & efficiency) due to non uniform velocity distribution at the pump impeller inlet and their air content. This kind of dangerous vortices might appear in some operational conditions related for example to low water levels or high rotational speeds and high flow rate values.

Vortex generation must be carefully studied and verified during the design phase of pumping stations, and measures aimed at preventing vortices or reducing their intensity must be taken.

One of the key factor to prevent vortices is the submergence, that is the minimum immersion depth required by the pump to prevent vortices. It varies according to the size of the pump and the rotational speed. As an indication, it is typically 2.5 times the diameter of the hydraulic part, but it must be adapted to the pump NPSHr conditions as well as the pump and pumping station geometry since this rule is very general.

Common practice is to build scaled prototypes of a portion of the pumping station, typically one single pump room is built, in order to simulate the real working conditions and to verify the presence and nature of vortices. Vortices are detected visually, from the observation of the free surface curvature and with the support of colored tracers, that can make the flow structures visible and help the classification of vortices according to the HIS vortex classification shown in Figure 1. This classification is essentially based on visual identification and characterization of structures such as swirls, ripples and air bubbles. This kind of activity requires experienced engineers to distinguish between Type1-2, that are not dangerous, and the other types, that must be avoided. The complexity of the classification is also associated to the transient nature of these vortices that tend to be unstable and to appear and disappear. In this frame the use of Computational Fluid Dynamics (CFD) can support and supplement the experimental activities by providing detailed information about the flow behavior in the whole pumping station and about vortices and fluid structures in the proximity of the pumps.

It must be pointed out that also the CFD simulation of pumping stations and pump rooms is not a simple task. The accurate solution of multi-phase flows on complex geometries, with air entrainment and transportation in unsteady conditions requires high quality computational mesh, high order accuracy and parallel computing. Moreover the identification and classification of flow structures requires the definition of quantitative criteria during the post-processing of CFD results.

Nonetheless GE Power and EnginSoft accepted the challenging task of developing and running CFD models of a pumping station with the aim of comparing the simulated vortices with the ones detected during experimental tests on a scaled model. If CFD demonstrated to be able to identify and classify vortices with the same accuracy of experimental tests, it could be used to speed up the design process, for example to detect critical operating conditions or to compare alternative designs to mitigate vortices intensity.

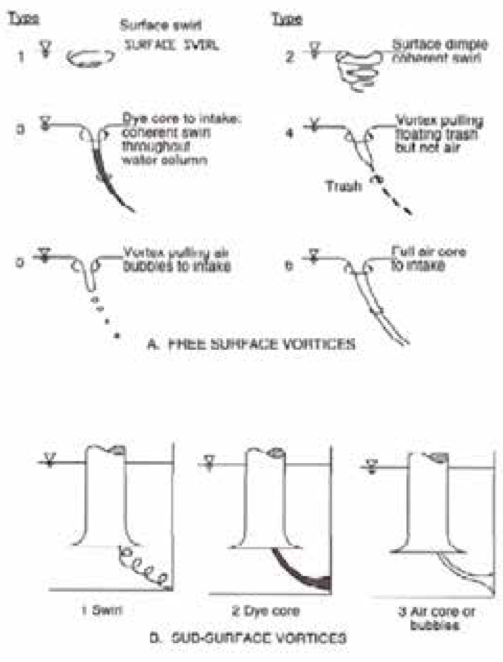


Figure 1 – HIS vortex classification

Pumping Station

GE-Power and EnginSoft developed real and virtual prototypes of the cooling water pumping station for the Narva Power Plant (2 x 300 MW) of Eesti Energia in Estonia. The main cooling water pumps are sized for a nominal flow rate of 19.000 [m3/h] each, while the auxiliary pumps are sized for a nominal flow rate of 1.500 [m3/h]. Figure 2 shows the CFD model of the pumping station, with four main pumps and four water inlets. Considering also the auxiliary pumps and the filters sections, located just downstream the inlets, the resulting flow path includes many disturbances and obstacles from the inlet to the pumps. However the area interested by vortices is close to the main pumps intake, where water velocity is higher than in other areas.

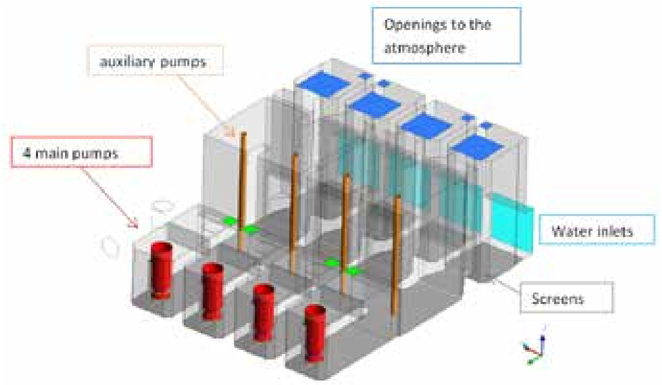


Figure 2 – Pumping station CFD model

For an accurate solution of the free surface and of vortices a fine and high quality hexahedral mesh must be generated. Figure 3 shows the mesh on a section plane of one of the pump rooms, with mesh refinement at the water free surface.

The fact that the pumps are located in separated rooms and that the potential vortex generation takes place locally in proximity of the pumps allows reducing the model to one single pump room. A global CFD model of the pumping station can be used to calculate and visualize the global flow behavior, above all when some of the inlets and pumps are off, but the use of such a large model is not suited for detailed studies related to local vortex generation. Figure 4 shows the CFD model of two different configurations of the same pump room. In the second configuration a skimmer wall is located upstream the pump to break the vortices and reduce their intensity. GE Power made built scaled physical models of the two pump rooms in an external laboratory and verified the beneficial effect of the skimmer wall. The validation and the quality of the CFD results depend on the capacity of the CFD model to simulate the same types of vortices that were detected in the laboratory in the two cases: Case I,

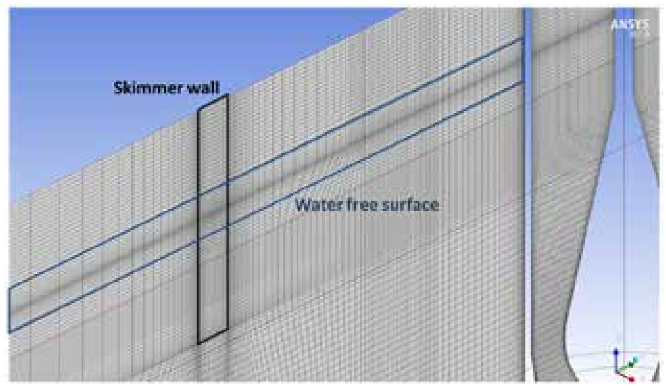


Figure 3 – Mesh on a cut plane

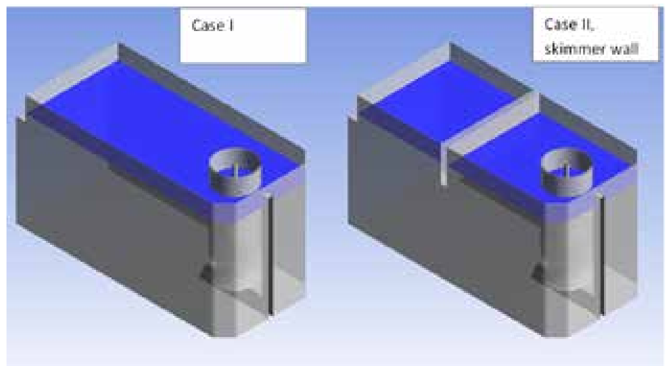


Figure 4 – Pump room CFD model: Case I (left), Case II, with skimmer wall (right)

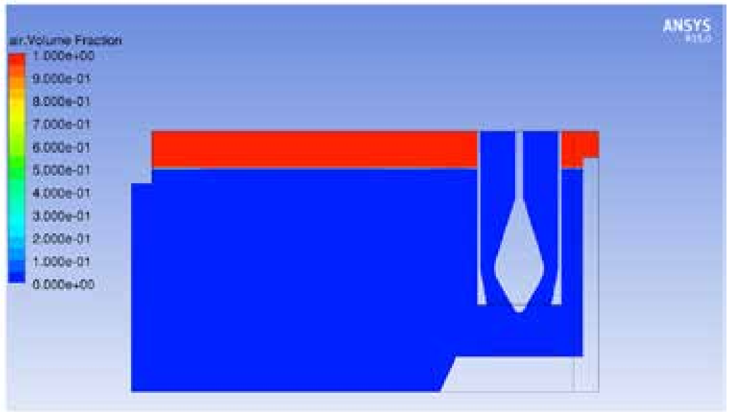


Figure 5 – Contour showing air (red) and water (blue) distributions on mid vertical plane

without skimmer wall and Case II, with skimmer wall.
The CFD procedure is based on two steps: the initial one is a steady state simulation that is used to initialize the flow field, the second one is a transient simulation, about 30[s] of physical time are simulated. The transient simulation is needed to resolve the transient nature of the vortices.
A free surface multi-phase model is used, with water and air. A pressure profile is applied at the inlet of the pump rooms, while a flow rate value is applied at the outlet of the pumps. It must be pointed out that, like in the experimental facility, only the pumps external walls are present, while the impeller and its rotational effect are not present in the CFD model.

Vortex Detection and Classification

Figure 5 shows the air and water distributions on a section plane of Case I (no skimmer wall). At first sight the free surface seems flat and no vortex or other structures are visible. Actually dangerous vortices are there.

In order to detect and classify vortices different ways can be used, the most intuitive one is to create iso-surfaces of the water volume fraction at different levels. Figure 6 shows the water volume fraction at 99.5%. While no structures are visible in Figure 5, Figure 6 clearly shows two vortices on the two sides of the pump. The same vortices are made evident by water streamlines in Figure 7. The two vortices are almost symmetric and located between the pump and the rear wall of the room.
Figure 6 and Figure 7 actually show the solution of the CFD steady state simulations.
The same kind of visualization can be done on the transient CFD results. Figure 8 highlights that the vortices that are initially present tend to disappear, change in depth, position and intensity and then tend to re-appear after about 20 [s].
All these pictures clearly show the presence and unstable nature of the two vortices in Case I. In this case the structures are classified as Type 3 according the HIS vortex classification shown in Figure 1. This type of vortex is dangerous and must be avoided because of its depth and air content. The same kind of structure and classification type are identified using the laboratory testing facilities. Hence CFD demonstrated to be in good agreement with physical testing.
The same kind of CFD analysis is carried out on Case II. Figure 9 shows that in this case a vertical vortex is created just downstream the skimmer wall. The vortex increases the turbulence level locally, breaks other structures and entrains air that tends to re-circulate in a superficial mixing zone.
The skimmer wall prevents the generation of deep vortices of type 3 or higher. Only minor superficial vortices with no air content can be detected in Case II. These vortices are classified as Type 1 or 2 according the HIS vortex classification and they are not dangerous for the pump. Also in this case CFD predictions are in line with experimental tests, thus demonstrating that CFD can be confidently used to identify vortices and to compare the effect of different design solutions.

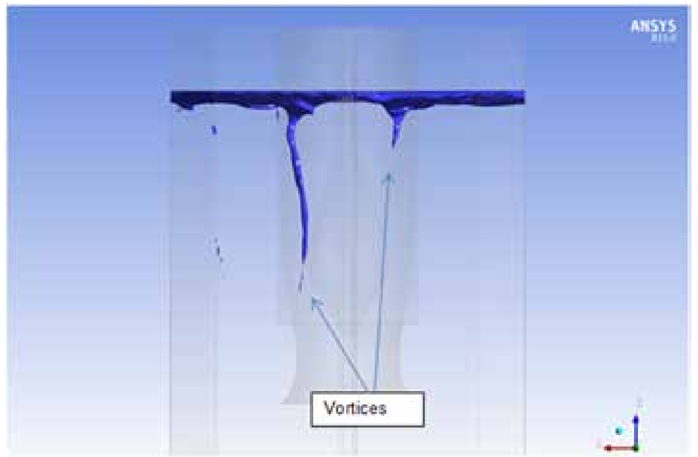


Figure 6 – Isosurface of water volume fraction at 99.5%, lateral view

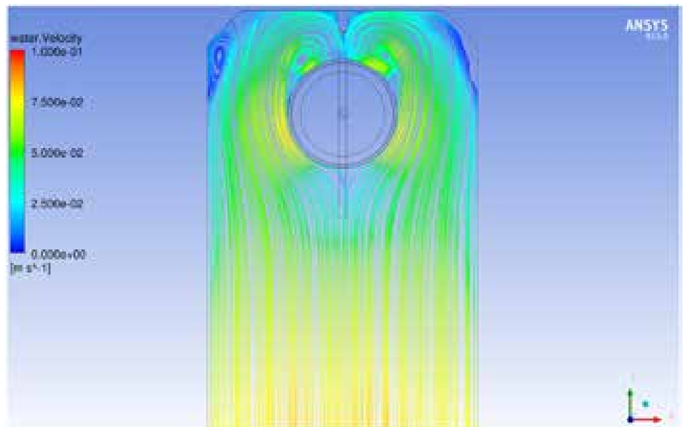


Figure 7 – Streamlines on a plane located 14.5mm beneath the free surface

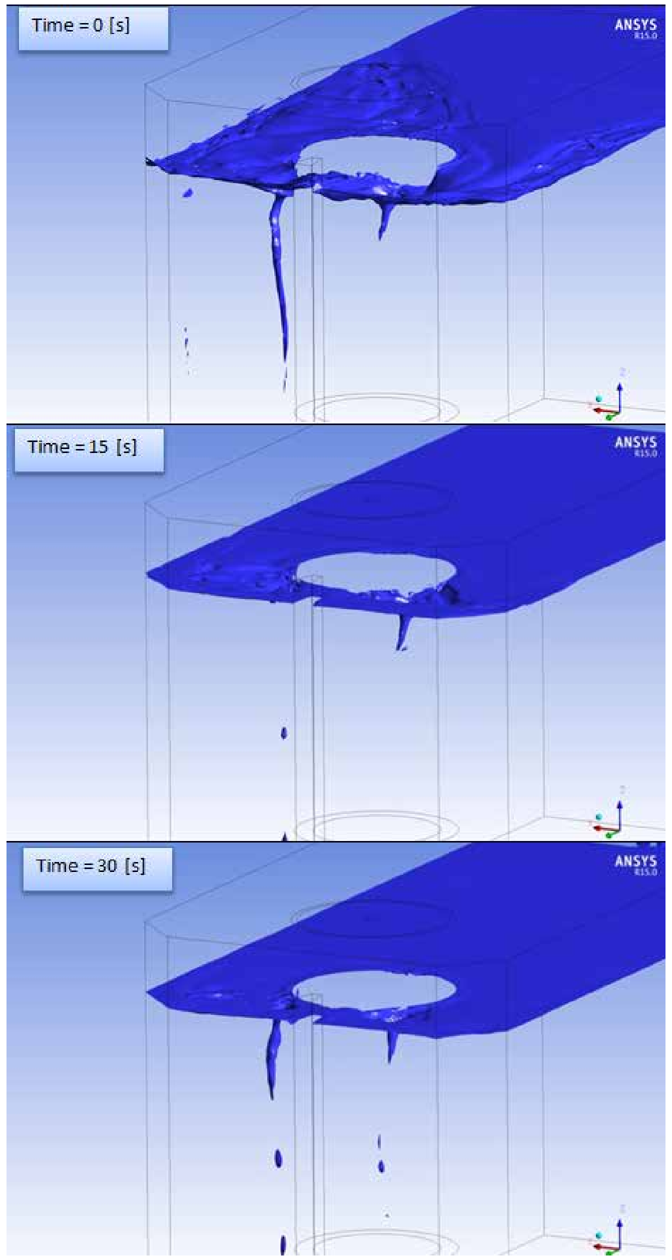


Figure 8 – Isosurface of water volume fraction at 99.5%, at time = 0[s] , 15 [s] and 30 [s]

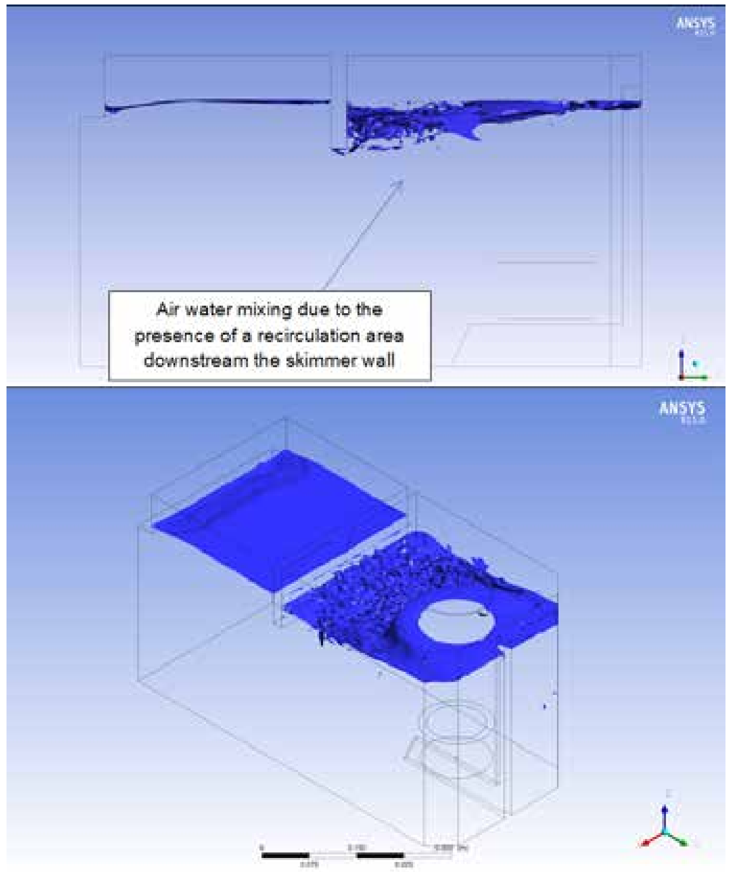


Figure 9 – Isosurface of water volume fraction at 99.5%

Conclusions

GE Power and EnginSoft carried out a validation study on CFD models for the detection and classification of vortices in cooling water pumping stations. The comparison of CFD results and experimental tests demonstrated that the CFD methodology can correctly identify vortices according to the HIS vortex classification.
This means that virtual prototyping can be used both for the study of the global flow behavior in pumping stations and for the detailed study of critical flow structures in the proximity of the pumps. The big advantage of CFD is the insight into the way vortices forms and how to intervene in order to remove them or to reduce their intensity.

Alessandro Arcidiacono, Massimo Galbiati - EnginSoft

For more information:
Massimo Galbiati, EnginSoft
m.galbiati@enginsoft.it

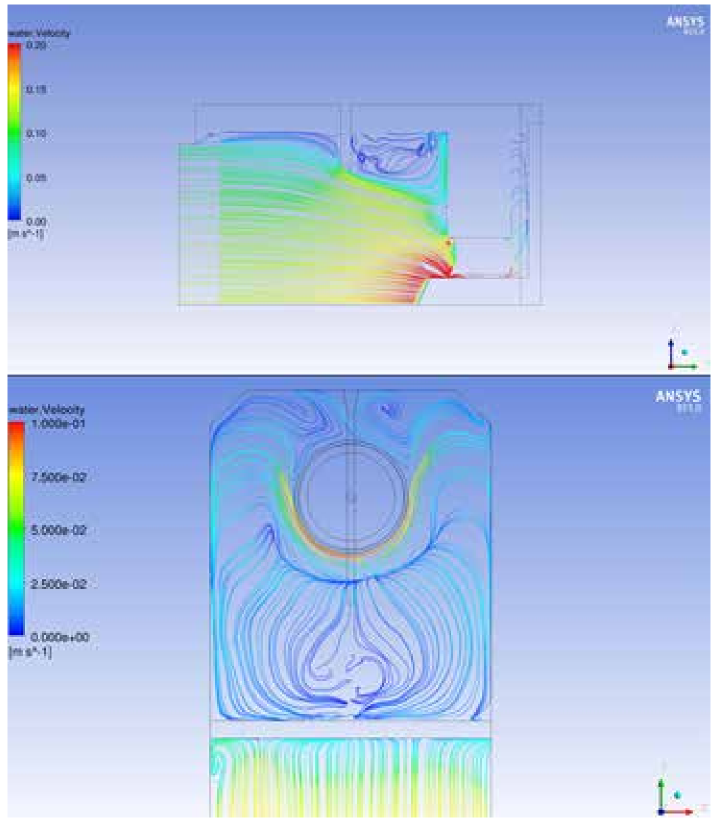
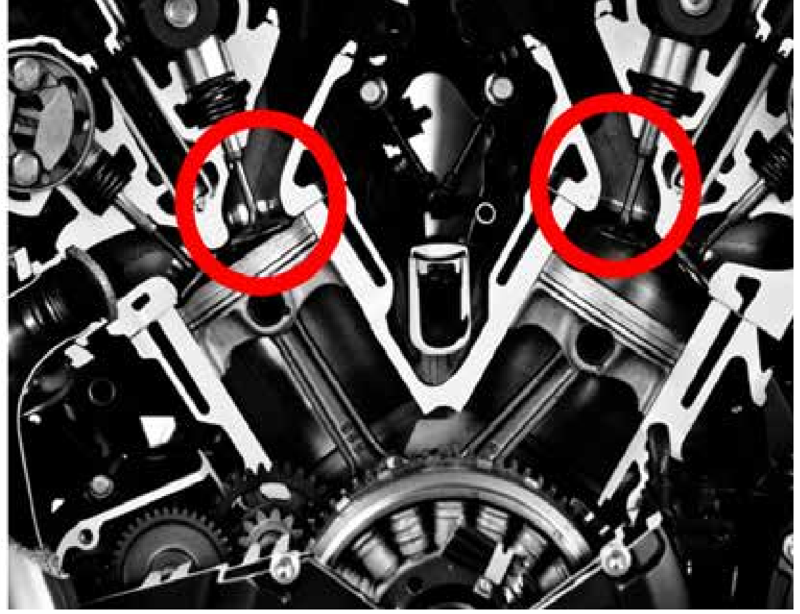


Figure 10 – Streamlines on a vertical plane and on a plane located 16.5mm beneath the free surface.



Fluid Dynamics Optimization of Racing Engine Inlet Ducts at Aprilia Racing

Racing engines are experiencing continuous evolution, allowing them to achieve extraordinary levels of performance and complexity. However, at the same time, regulations are restricting engine development by constraining some of the main design parameters. Consequently, it has become increasingly difficult to improve the engine's performance with traditional design methods, therefore an ever-increasing adoption of new CAE methods is required.

This paper presents a method to optimize the fluid dynamics for the intake valves and ports of the Aprilia RS-GP motorbike. The aim is to develop a procedure in which parametric geometry design, automatic mesh generation and 3D CFD analysis are coupled within modeFRONTIER in order to maximize the efficiency of the valve and port, while guaranteeing design feasibility.

As a result, the discharge coefficient at maximum valve lift of both valve and port has been improved by 1.5% and 2% respectively. These results have been validated through physical experiment with measured improvements of 1.2% and 1.6%, respectively.

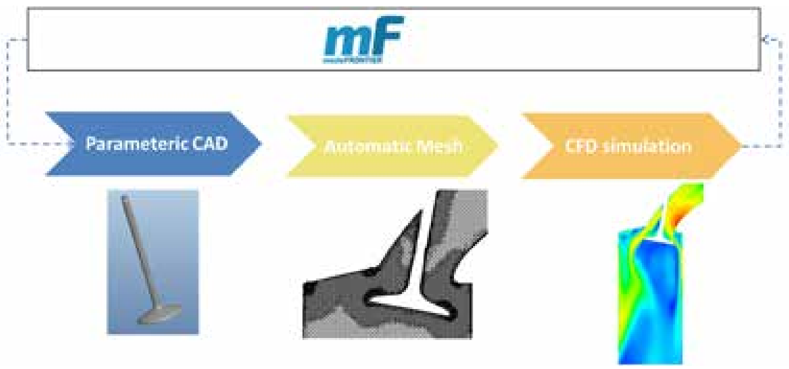


Fig.1 – Optimization process of intake valve and port

1. Improve fluid dynamic efficiency of Intake Valves and Intake Ports of MotoGP motorbike

Every year, MotoGP teams try to enhance the performances of their bikes by working on handling, traction and engine performances. Within this last aspect, effort is focused on several aspects, such as maximum generated power or maximum efficiency and durability.

Due to MotoGP regulations or structural limits, several engine design parameters are fixed or cannot be modified by engineers during development stages. For this reason, the best way to increase power is to enhance the volumetric efficiency of the engine, minimizing pressure losses and thus maximizing the intake mass flow rate.

A two-step optimization procedure was performed starting from the current engine configuration. In the first step, the inlet valve geometry was optimized while in the second, the terminal part of the inlet port was optimized using the valve geometry obtained in the first study.

Both optimizations have been performed using modeFRONTIER, integrating different software tools in an automated process, and applying the available multi-objective optimization algorithms. The parametric geometry has been built with the PTC Creo Parametric. The ANSYS ICEM CFD has been used to generate a structured mesh of tetrahedral elements using the octree algorithm. Finally, to quantify the fluid flow performances of each candidate solution, a full 3D steady state simulation model has been defined in ANSYS CFX. The fluid domain has been modeled in order to replicate the experimental bench used for

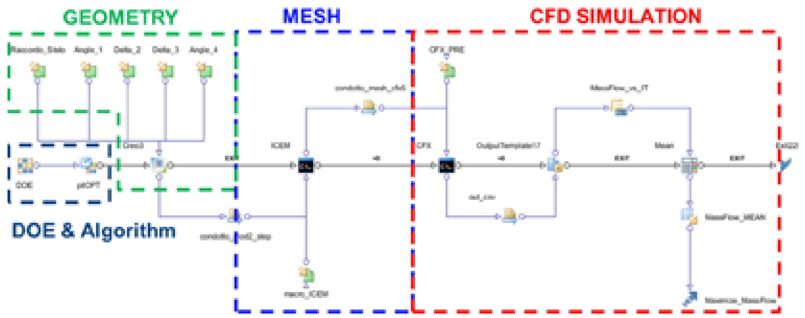


Fig.2 – Optimization workflow in modeFRONTIER

results validation, considering a fixed valve position at the maximum lift and throttle wide open. The two equations k-omega SST model is used to model the turbulent flow inside the cylinder.

2. Intake Valve Optimization

The valve geometry determines the fluid flow characteristics of air entering in the cylinder chamber. The first step is the optimization of the valve's head. In fact, the valve's stem design is fixed due to structural constraints and distribution configuration. The fillet radius and four angles defining the valve's head geometry are considered as input variables, while the maximum valve radius is fixed to avoid interference with the exhaust valve. In fig.2, the workflow created in modeFRONTIER to drive the optimization task is reported, highlighting the sequential phases of the process automation.

Performing 3D CFD simulation is quite demanding in terms of computational resources and time, hence, classical optimization techniques may not be feasible. In this specific case, pilOpt and Simplex algorithms have been combined sequentially to find the best solution. PilOpt is a proprietary hybrid multi-strategy algorithm that combines both local and global search algorithms, speeding up the convergence rate, balancing real and RSM-based designs. Multiple RSMs are automatically trained, validated and used to reduce computational time and achieve better solutions. After running 100 designs using pilOpt, the search has been refined using the Simplex algorithm, with additional 60 design evaluations (fig.3).

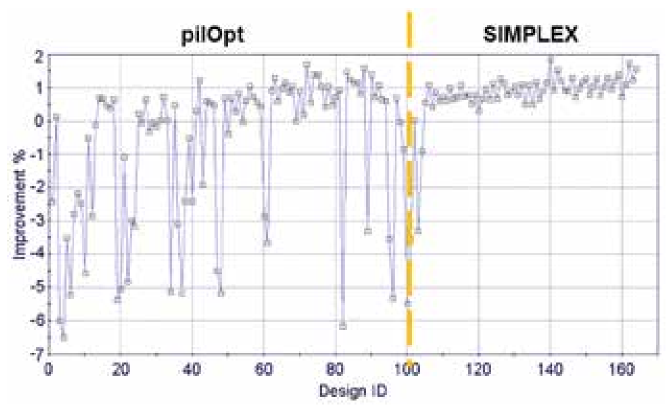


Fig.3 – Optimization results with modeFRONTIER: % improvement of intake overall mass flow rate

The results of the optimization lead to a 1.5% increase of the overall mass flow rate considering the optimized geometry. Looking more in detail to the velocity profiles and fluid streamlines (fig.4), it is possible to note how the optimized geometry enables less deviation and smoother transition of the fluid from the port to the cylinder chamber.

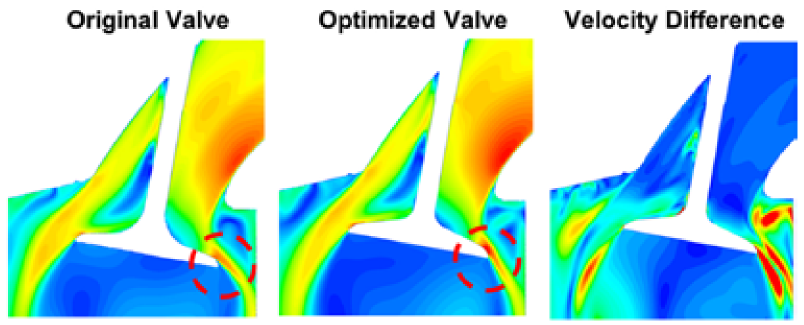


Fig.4 – Velocity field around baseline and optimized valve; velocity difference of baseline and optimized valves

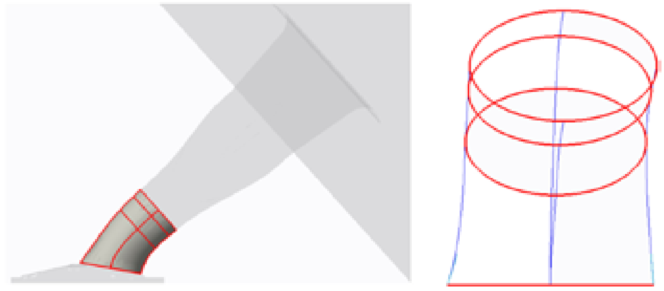


Fig.5 – Sections and splines used for the geometrical parameterization of the intake port

3. Intake Port Optimization

The second activity considered in this work is the optimization of the intake port geometry. The intake geometry is strongly constrained in its position from the intake valve actuation mechanism, the crankshaft displacement and the engine displacement. The major challenge is to define an efficient parameterization of the intake tube limiting the number of input variables, obtaining at the same time robust and accurate geometry variations, while respecting constraints coming from the limited free space.

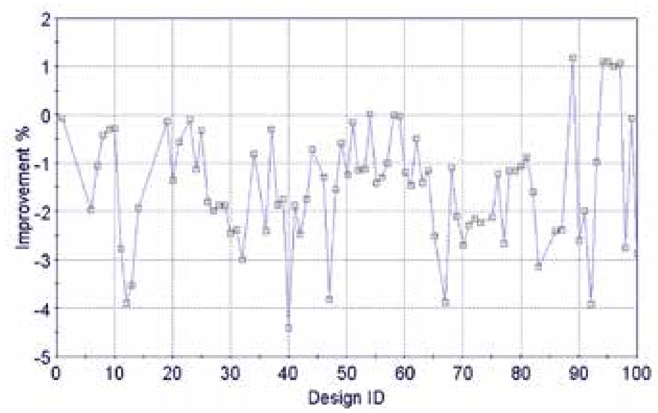
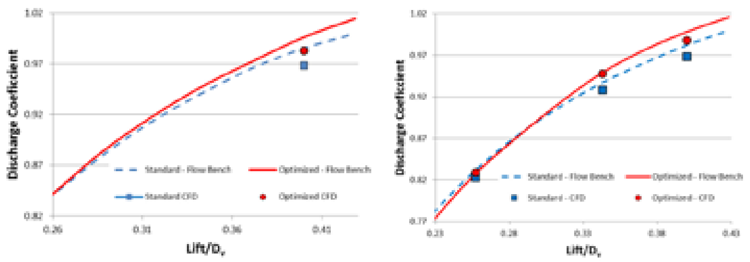


Fig.6 – Optimization results with modeFRONTIER: % improvement of intake overall mass flow rate



Optimized Valve Massflow		
h/D	CFD	Flow Bench
0.4	+ 1.5 %	+ 1.2 %

Optimized port Massflow			
h/D	RSM	CFD	Flow Bench
0.34	-	+ 2 %	+ 1.3 %
0.4	+ 1.45 %	+ 2 %	+ 1.63 %

Fig.7 – Comparison of baseline/optimal solutions found by numerical optimization (left: valve; right: port) with experimental measurements at the bench –discharge coefficient is measured in function of lift/ diameter valve ratio

For these reasons, the port is described by four sections defining the frontal area and four splines defining the longitudinal expansion of the port and the position of the sections (fig.5). The spline shapes have been defined directly in modeFRONTIER using the Bezier curves. This function is implemented in the calculator node and allows the generation of smooth and continuous profiles using a limited number of input variables, namely control points. These are then imported in the CAD software where the 3D geometry is generated. A constraint is defined on minimum volume and, in cases where the constraint is not respected, the CFD simulation is not performed in order to save time.

As for the previous optimization, the Pilopt algorithm has been used with setting a total number of 60 iterations (fig.6). The best design has allowed a 1% improvement of the total mass flow rate compared to the baseline design. This is a satisfying result considering the limited possibility of variation of the port geometry.

4. Experimental validation of optimized results

The optimal results obtained by the numerical optimization have then validated using an experimental test bench, showing good agreement between simulation and experimental results (fig.7). It is interesting to note that the result obtained by the valve optimization approach has carried improvements at even lower valve lift ratios, while the optimization has been carried out only at fixed high valve lift ratio (0.4 h/D). This is essential to keep low computational effort and time and ensure a robust solution at other engine operating conditions.
The results illustrated in this article represent only a preliminary study to adopt proper optimization strategies to improve engine performances. Further steps would consider multiple valve lift values and involve combustion simulations

Alberto Clarich, Giulio Cassio
ESTECO

Investigation of vacuum cleaner performance through vacuum head modifications

Whirlpool Corporation is the number 1 major appliance manufacturer in the world; in 2015 70 million products were sold in more than 170 countries, with 97.000 employees in 70 manufacturing and R&D centers, investing $1 billion in capital and R&D centers annually.
NAR North America, LAR Latin America, EMEA Europe Middle East and Africa, ASIA, are the four major Regions.
Whirlpool's EMEA, whose headquarter is in Comerio (VA) Italy, is the number 1 in the EMEA Region and number 2 in Europe,with 24.000 employees speaking over 40 languages and 15 industrial sites in 8 Countries. In addition to internal manufacturing, Whirlpool is using OEM/ODM for new businesses.
The Company is strongly committed to delivering high performance products to the customer, while being sustainable and environmentally friendly. Over the last year the figures have been outstanding: -27% of water consumption, -11% in energy consumption, -8% of waste production.

Aim of the work

Whirlpool is relatively new to the vacuum cleaner market and is leveraging the Hotpoint brand in EMEA Region. Despite the OEM/ ODM approach for this product, Whirlpool aims to conduct a comprehensive performance analysis of the product's key parts.

Whirlpool

The vacuum head is probably the most important part in assuring the best balance between ErP Regulation compliance, performance in all use cases and a pleasant user experience.
In recent years the ErP regulation has introduced the concept of real performance; moving the customer's attention away from misleading figures like electric motor power (Watts) and suction power (Air-Watts), to performance figures that are closer to the cleaning performance, such as dust pick-up on hard floors and carpets.

The CFD model

Baseline

A 3D numerical model of the vacuum cleaner head was created by EnginSoft based on CAD geometry provided by Whirlpool. Parts were imported into ANSYS CAD/MESHING system and merged together to get an acceptable connectivity. Missing parts,

connections and boundary conditions were also generated.
The ANSYS CFX solver was used to evaluate the system's fluid dynamics.
The CFD model replicates the test conditions according to the above mentioned ErP regulations ;the vacuum head rests on the floor, centered on a 45 degrees inclined guide that contains the dust. A semispherical air plenum surrounding the volume completes the computational domain.
With this approach, the air enters the vacuum head from the semispherical opening (ambient) and is guided along a flexible duct toward the vacuum cleaner's body (not modeled here).
The resulting CFD model is shown in figures 1 and 2.

Every part of the vacuum head is modeled and includes:

- the fully shaped bottom part in contact with the floor. This is an important geometrical detail, since this leakages are the regions where the air can be sucked in by the vacuum cleaner under the blower's action
- the elbowed hood that guides the incoming air into the flexible duct
- the rubber flap in the rear bottom part of the vacuum head
- the flexible connections to the rigid duct

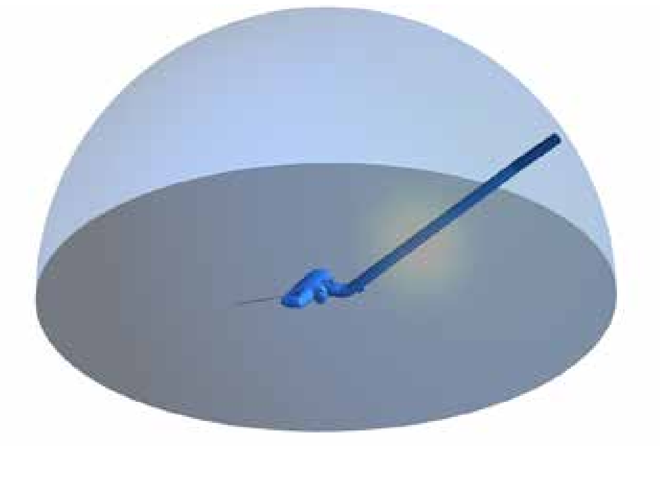


Figure 1 - CFD model of the Valuum Cleaner

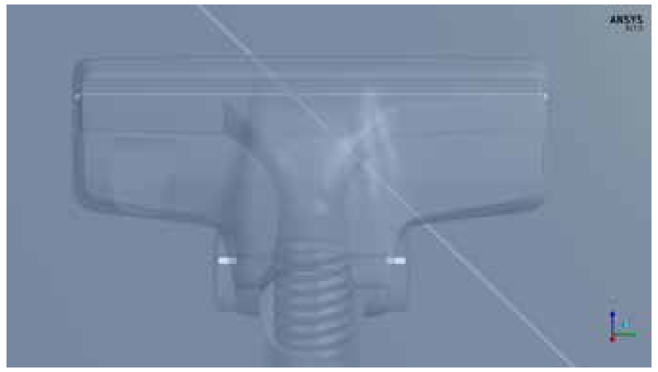


Figure 2 - CFD model of the Valuum Cleaner

Model Tuning

The air motion is generated by a centrifugal blower; In order to account for this effect, the blower's working curve has been implemented in the solver by a 3D region with a momentum source reproducing the blower's working curve.
Also, to properly set the numerical model a 3D porous loss has been considered;given the mass flow rate in the free sucking condition, where the vacuum head is not constrained (rested) on the floor, the resistance coefficient has been tuned in order to meet the supplied mass flow rate.
In other words, the equivalent resistance simulates the rest of the vacuum cleaner, not explicitly modeled. For this reason, this resistance coefficient has been used for all the studied simulations.

Under an imposed pressure drop, resistance and blower curve, the solver outputs the mass flow rate and the fluid-dynamic filed thru the overall computational domain.
The mass flow rate (thus the blower working point), the level of depressurization and the air's flow direction in the bottom region of the vacuum head (floor-vacuum head interaction) are the main objectives to consider in comparing the different designs.

Optimization Results

From the baseline results, three kind of configurations have been studied, corresponding to three geometrical modifications. This was done mainly to investigate the sensitivity of the system's performance to geometric variations.

Modification 1 – new shape of the hood's entrance area (Figure 3)
Given the same available pressure drop, this modification slightly increases the mass flow rate. This effect, although not as strong as expected, still represents useful information about how the system reacts to such modification.

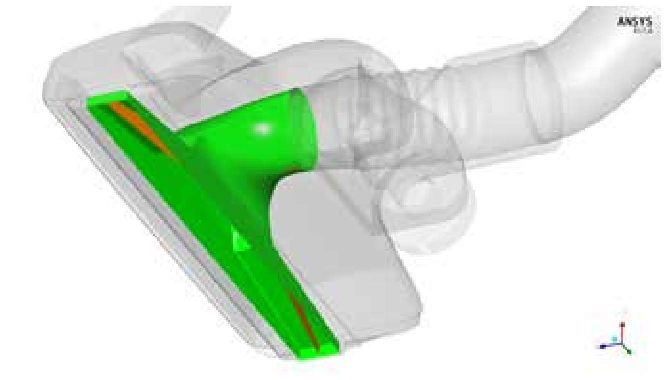


Figure 3 - New shape of the hood's entrance area

Modification 2 – curved shape of the rubber flap (Figure 4)
This configuration has the greatest potential to improve the system's efficiency in the studied scenario.
To best compare the performance of the baseline and modification 2 configurations, they have been simulated with the real blower curve (head-flow rate). The result shows that, although the mass flow rate increase through the hood are similar, the percentage of air captured from the crevice is much higher. This would lead to a better behavior of the vacuum cleaner in the test conditions.

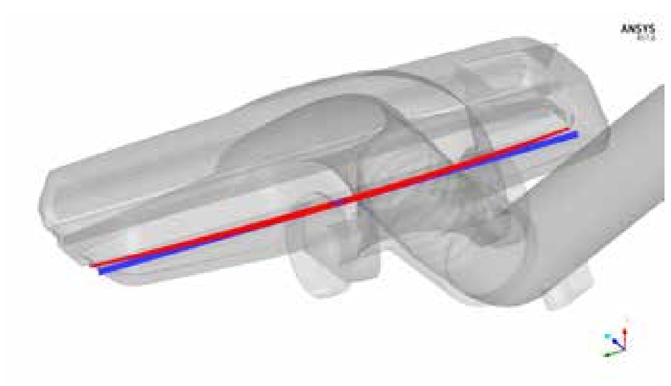


Figure 4 - Curved shape of the rubber flap

Modification 3 – new shape of the hood's elbow (Figure 5)
Given the same available pressure drop, this modification leads to no appreciable increase in mass flow rate. However, there is benefit to the smoothness of the flow when air is sucked from the outside and guided from the vertical to the horizontal direction. Therefore the elbow suffers less back flow.

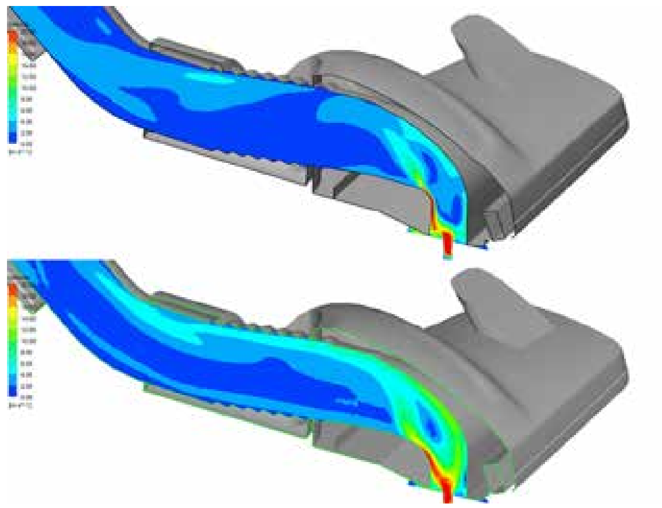


Figure 5 - New shape of the hood's elbow

Conclusion

The approach used, based on the testing scenario, has a general meaning. It is reasonable to consider that similar modifications on different vacuum head might lead to similar responses.
It has to be noted that while modification 2 improves the air flow coming from the crevice, it is a relatively low cost improvement.
Modification 2 appears to be the most promising method to increase the system performance.
Furthermore, a more detailed CFD study could be considered, by introducing the vacuum cleaner's body, the blower system and multiphase effects via the lagrangian approach for dust simulation.

.

Marcello Riderelli Belli - Whirlpool Corporation
Luca Brugali, Anna Rosa Troia – EnginSoft

For more information: Luca Brugali, EnginSoft
l.brugali@enginsoft.it

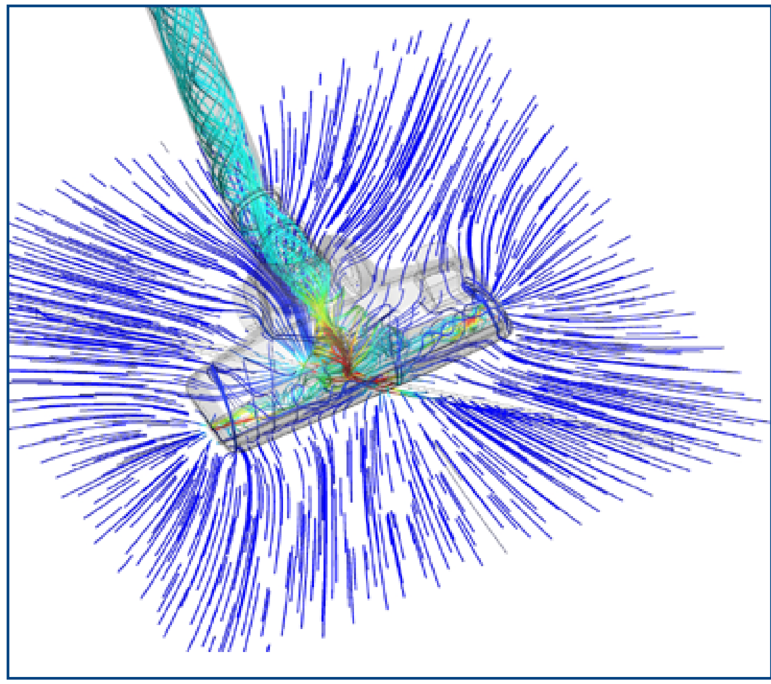


Figure 6 - Qualitative behavior of the air entering the brush

Using ANSYS in Appliances

Consumer expectations for home appliances are high: Users demand that a given product will perform day in and day out — and last for many years. Reputation for reliability and energy efficiency are key product selling points. It is critical that all possible scenarios for a new product's failure be tested before it goes to market. Appliances manufacturers perceive computer based modeling as the most promising if not only way forward.
Though reliability is crucial, consumers have come to expect products easier to use, are smaller in size but operate at maximum capacity, to consume less energy and emit less noise.
By using simulation analysis tools, designers can evaluate alternatives and refine designs early in the process, when it is less costly to make changes. The need for physical prototypes is also reduced, resulting in a shorter development cycle and a quicker to-market time.

Keeping costs in line, maintaining quality and reliability, and striving for continual innovation are key business drivers. ANSYS simulation and modeling tools can help companies meet these consumer challenges in a wide range of sub-industries.

EnginSoft is ANSYS Channel Partner and could support your company in finding the best solution to meet appliance design needs.

Toyota:
“Safety Comes First”

“After an initial testing period with competitor’s simulation systems” - Eng. Bonelli, manager of Advanced technology office in Toyota Material Handling Manufacturing Italy Spa declared - “We asked EnginSoft, as our partner, to carefully evaluate the RecurDyn software solution by setting up a joint pilot project to avoid dangerous risks; this testing period has fully satisfied our needs thanks to the competence of EnginSoft technical staff. For this reason we have chosen RecurDyn, as it fits our needs better than its competitors in terms of both performance and usability “.

“We are confident that the use of this tool will allow us to simulate multi-body analysis and dramatically reduce the product development time, enabling us to evaluate many more design alternatives, improve the quality of our projects and reduce costs.”

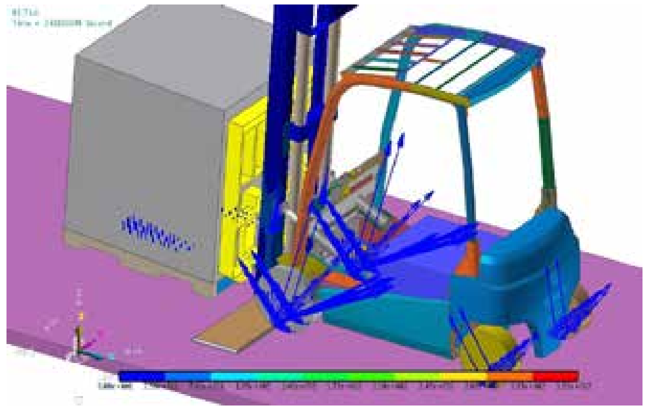
“We fully rely on our decision” – concluded Eng. Bonelli -”and it will prove to be the best solution, in line with the policy of the Toyota Material Handling Manufacturing Italy to invest in the best technologies”.

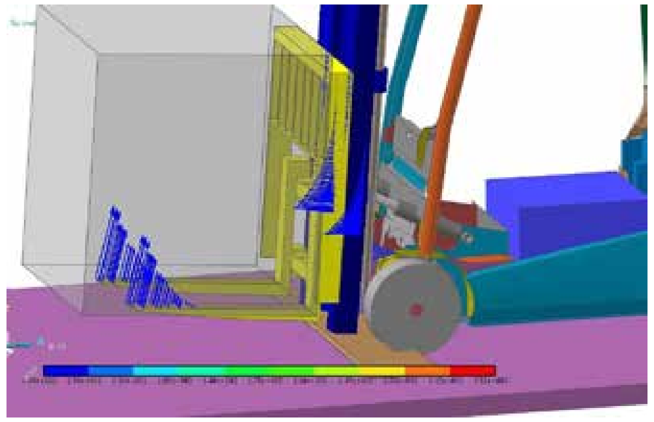
Eng. Giovanni Paolo Bonelli
Advanced Technology Manager
Toyota Material Handling Manufacturing Italy

Toyota Material Handling Manufacturing Italy Spa (TMHMI) offers a complete range of high quality products, services and solutions designed to maximize safety and productivity, thus limiting costs. The wide range of forklift trucks and warehouse equipment of the top brands, Toyota, BT and CESAB, can satisfy every kind of need in loading and unloading operations, in order commissioning, in height storage and horizontal transport.
In particular, the robust and wide range of Toyota counterbalanced trucks, is designed to perform all the operations of loading and unloading, storage, interlocking bays of load and horizontal transport of goods, to be carried both inside and outside of the warehouse.
Thanks to the wide range of electric and IC trucks, the innovative uprights and the forefront technology, Toyota counterbalanced trucks provide a suitable solution for any application requirement.

Using RecurDyn for design

Folklift trucks are vehicles designed to lift and transport loads of considerable mass. In the development process, it’s necessary to consider different types of load, both static and dynamic.
Dynamic loads occur when the vehicle crosses an obstacle, when braking suddenly or in emergency conditions. In all these cases, the inertial effects amplify the internal forces of the loaded structures.
The Multi-body simulation provides a very reliable analysis of these conditions, predicting critical characteristic that would otherwise emerge only in the truck’s testing phase. For this reason, TMHMI



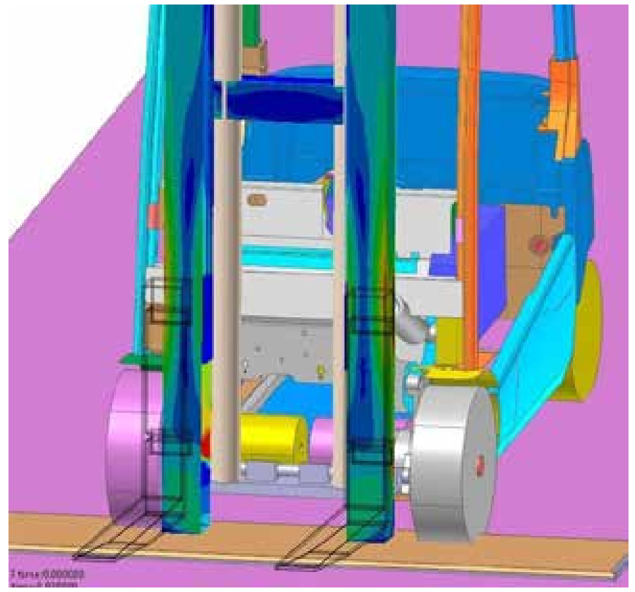


decided to acquire a multi-body software, able to represent the truck in any use condition. The modelling is done through the graphical user interface that allows a virtual truck to be assembled by simply using the mouse. However, such simplicity helps make considerable numerical refinements accessible to the user.

For instance, the interaction of the tire with the road is simulated with different levels of complexity, as a function of the analysis objectives (either elastic non-linear contact or RecurDyn Tire modulus).
Similarly, the interactions between the bodies constituting the truck, can consider both the use of connecting joints and nor linear contacts.

The latter ones are particularly powerful within RecurDyn: Geo-Contact owner technology and the rich library of analytical contacts, allow a level of real physics with incredible results. The analysis performed in the evaluation phase has proved how much the accuracy of the contacts between the load and the forks can affects the final result of the simulation. The remarkable results described above have been achieved with the already powerful configuration of RecurDyn/ Professional. Nevertheless, TMHMI has also decided to equip itself with the RecurDyn Toolkit. They are special modules, which enable the creation of extremely complex subsystems, such as drive chains, the mass-distributed springs, bearings and drive belts.

The Toolkit accelerates the model set-up time, avoiding time-consuming and repetitive operations for the user. The RecurDyn solver represents a further plus for the platform, in fact none of the completed analyses, even the strictest ones, have suffered convergence issues.



RecurDyn V8R5 released

The new version of RecurDyn is available for customers. It includes important updates to speed up modeling and to extend the capabilities of the software. Here is a short list of what’s new.

- G-Modeling fucntion for Multi-Flexible-Body Dynamics (MFBD). This revolutionary technology increases efficiency and productivity, by automating the conversion of bodies from rigid to flexible or from flexible to rigid. This allows the user to convert a body from one type to another while preserving joints, force elements and contact elements on the body itself. G-Modeling invokes the built-in mesher and eigensolver to convert rigid bodies to flexible bodies, and it can convert back a mesh or modal body into a rigid body as well. This unlimited freedom, gives the user the power of testing the same system from different perspectives, without time loss and minimizing the risk of set up errors.
- FE Merge function to create the FFlex bodies with multiple materials. This is really useful, since there is no longer need to create and connect different material bodies.
- More than 100 improvements of the Graphical User Interface. A better interface speeds up the modeling and returns new possibilities in post-processing.
- Great improvements in contact definition: contact set-up time further decreases. Both 2D and 3D Contacts automatically set the contact area. New primitive contacts are available for more accurate analysis
- RFlex Contact pressure and Modal Pressure Load are now possible.
- Improved Post Processor for RecurDyn-Particleworks co-simulation.
- New Expression functions for MTT2D entities.
- Automated creation of PEdge guides.

The development never stops and any new release increases the benefits of the RecurDyn experience!

Numerical simulations for the structural performance assessments: a connecting rod's case study

The Piaggio Group is the largest European manufacturer of two-wheel motor vehicles and one of the world leaders in its sector. The Group is also a major international player in the three-and four-wheel light transport sector.

Project Objectives

The connecting rod is one of the most important components in the powertrain systems, very careful structural analysis are required; its failure implies serious damage to the entire engine. Piaggio is developing a new twin engine for motorbike applications and consequently a particular attention has been paid to the connecting rod development, as shown in Figure 1.

Figure 1 - 3D geometry of the connecting rod

In this project, the design soundness of this component has been investigated through the employment of CAE simulations. Firstly, a multibody model has been implemented to evaluate the dynamic loads over the time and, afterwards, it has been possible to verify the safe design of the part by the followings structural performance assessments:

1. FE analyses to:
   a. investigate buckling issues;
   b. compute the natural mode shapes and frequencies of the system (modal analysis);
   c. perform and analyze the connecting rod's eyes deformation;
2. Durability analysis.

Modelling and simulations
Multibody model

The multibody model has been implemented to simulate the bench test conditions of the powertrain system according to Piaggio's standards. The dynamical behaviour of the system has been analyzed under the effect of the engine's combustion pressure (at maximum torque, maximum power and maximum speed), evaluated using CFD simulations, and the test rig reaction. For each corresponding speed, in stationary conditions, has been computed the load time history acting on the connecting rod (and on the other components). It has also been assessed the maximum tensile and compressive conditions of the connecting rod, used for the following analysis.

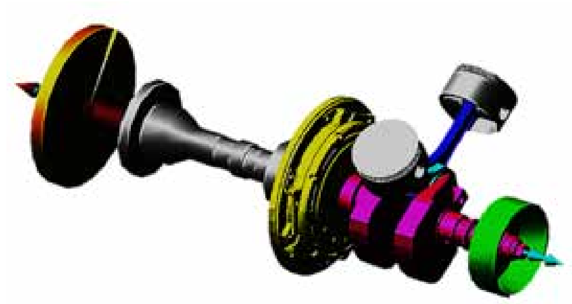


Figure 2 - MBS model of the system

FE analyses
Buckling analysis

The buckling analysis has been performed using a simplified model, with only the connecting rod assembly, without piston, piston pin and crankshaft. The assembly has been constrained with a spherical joint on the big eye, allowing the rotation of the internal surfaces and, on the small eye, locking only the displacements along the transversal directions of the connection rod. An explorative compressive (bearing) load has been applied to the small eye; as output, it has been obtained a load multiplier and consequently the buckling critical conditions. The first buckling critical condition has been compared with the maximum compressive load during the operate. The geometry and boundary conditions are shown in Figure 3.

Figure 3 - Boundary conditions for the buckling analysis

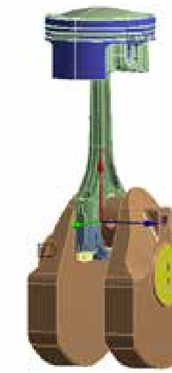


Figure 4 - Constrains for the modal analysis

Modal analysis

The modal analysis has been performed to estimate the mode shapes and natural frequencies of the part, considering all the components of the constrained system. Therefore, the crankshaft, sliced at the main bearing, has been considered fixed on these cutting surfaces, whereas, the piston has been considered free to move along the axial and tangential directions. The first natural frequencies of the system (associated to the twisting, bending, and axial modes) have been assessed.

Figure 5 - Path where deformations have been measured

Eyes deformation analysis

In this analysis, it has been used the same geometry and constrains of modal analysis (Figure 4). Each component's material has been assumed to have linear elastic behaviour, except for the connecting rod (cap and rod) and screws, for which an elastoplastic material with bilinear approximation has been considered. In the interface zones between the components, it has been assumed frictional contacts, considering interferences and clearances. Both static and dynamic loads act on the system. The static load concerning the bolt pretension and the interference on the (frictional) contacts. Regarding the dynamic loads, the maximum tensile and compressive forces have been considered and applied on the piston's upper surface, and the relative acceleration and angular velocity field too. The computing has been performed with a multistep analysis, related to static load condition, maximum tensile condition and maximum compressive condition. In order to ensure the "closure" of the contacts and achieve the convergence, the analysis has required some intermediate steps. The eyes' deformations have been computed on the middle plane of the connecting rod (Figure 5), in the maximum tensile and compressive conditions. The results have been compared with the maximum allowable value according to Piaggio standards.

Durability analyses

The durability analysis has been performed, for each test condition, with two different methods:

- Quasi-static superposition analysis;
- Transient (multistep) analysis.

Quasi-static superposition analysis

This analysis has been performed considering the effective stress tensors time histories during the engine cycle, obtained combining the results of a multibody simulation and another FEM analysis. In particular, It has been implemented a simple model, with the same geometry of the buckling analysis (without piston pin, piston and crankshaft), used in order to compute unit load/stress transfer functions.

The structural continuity has been assumed between the components due to the linearity request of the model. Each transfer function has been computed applying a unit (bearing) load at con-rod interfaces without constraining the system (it has been exploited the Ansys/ Workbench's Inertia Relief feature); it has been considered also the stress field due to angular velocity field. As output, it has been obtained the i-th stress field σ_i (x,y,z) associated to each load channel. The same model, only the variation to consider "frictional" the contacts, it has been used to compute the static stress field σ_s (x,y,z) due to interferences and bolts pretension. Therefore, the stress tensors time histories σ(x,y,z,t) have been obtained with a linear combination of the transfer functions with the associated load time histories F_i (t) (computing and extracting by multibody simulations), added to the (constant) static stress field: $\sigma(x,y,z,t) = \sigma_s(x,y,z) + \Sigma_i(F_i(t) \cdot \sigma_i(x,y,z))$

Transient analysis

The stress tensors time histories have been obtained considering only the maximum tensile and compressive conditions in the transient durability analysis. Therefore, the same FE model of deformation analysis, with the only variation of considering linear elastic materials' behaviour, has been used to estimate the stress field required (possible local plasticity has been taken into account with Neuber's rule, setted in the durability solver parameters). This analysis allows to consider the contacts' nonlinearity and consequently it enables to estimate the performance near connecting rod's eyes area in most severe conditions.

Both the analysis have been performed using the strain life approach and the same solver parameters. The material properties have been defined using the internal Piaggio's procedures. The overall fatigue safety factor has been computed and compared with the minimum allowable value according to Piaggio standards.

Results

For confidentiality reasons, the numerical values of the followings results cannot be provided.

Buckling analysis

By the assessment of the critical buckling conditions P_c and by the evaluation of the maximum compressive load P_{max} acting on the connecting rod, It has been possible to compute the buckling safety factor:

$$SF_{bukcling} = \frac{P_c}{P_{max}(max\ torque)}$$

The minimum of buckling safety factor has shown inline values compared with a similar connecting rod currently operating without criticalities.

Modal analysis

If the frequency of excitation nears with any of the natural frequencies, resonance could occur and it that may result in the mechanical failure of the system. Therefore, once the first frequencies of the first modes has been computed, it has been verified that there is no chance of resonance while operating.

Eyes deformation

Connecting rod's eyes deformation has been computed in the middle plane of the eyes, to the maximum tensile and compressive conditions. On the big eye, it has been also computed the deformation due to static load (interference between the half bearings and the connecting rod) to make a proper appraisal during operation. The results are shown in Figure 6 and Figure 7. These deformations are contained in the Piaggio's standard limits.

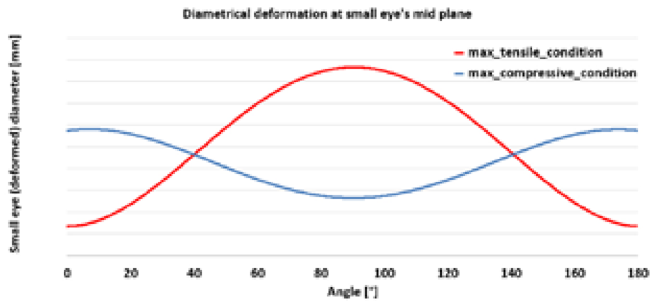


Figure 6.- Diametrical deformation of the small eye

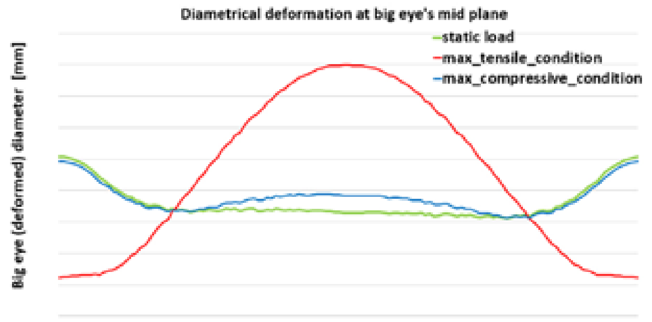


Figure 7 -Diametrical deformation of the big eye

Durability Analyses

The following figures show the results, expressed in terms of safety factor distribution in the most severe condition (maximum speed). The minimum value of safety factor has been turned out above the minimum Piaggio allowables into both analysis.

Conclusions

In the early stages of development of a new idea, the simulation is the only way to correct the design mistakes. In this project, CAE tools have been exploited to predict the mechanical performance of a connecting rod to be used in a new twin engine for motorcycle applications. The implementation of an accurate numerical models, an efficient integration between CAE tools, improve the products competitiveness, speed up the process, reducing, for example, the cycles of physical experimentation saving considerable time and therefore money.

Pasquale Viola
2-Wheeler Product Development - Piaggio Group

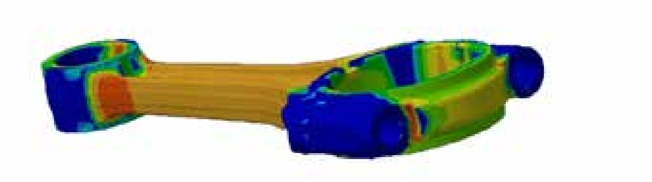


Figure 8 - Safety factor distribution with transient analysis

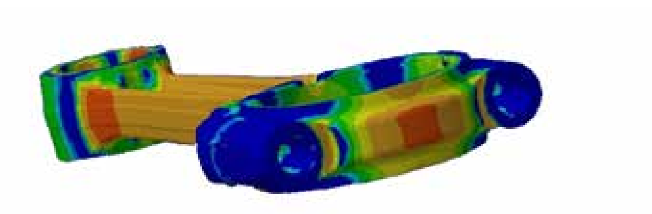


Figure 9 - Safety factor distribution with quasi-static superposition analysis

High Temperature Forging of Austenitic Stainless Steels: Failure Analysis using Numerical Simulations

Due to the increasing demand for higher mechanical properties and geometrical complexity of metallic parts in many industrial sectors, the interest in the optimization of the forging process is remarkable. In this scenario, the Finite Element Method (FEM) has become the best solution to obtain fast and reliable results. However, there are still significant limitations when modelling complex material behaviors, especially when complex phase transformations take place.

The aim of the present study is to develop and implement an effective methodology to first predict and then reduce hot tearing during the closed die forging of austenitic stainless steel.

Firstly, a review of literature was performed to understand the material behavior under forging conditions. Through FEM analysis, the Latham&Cockcroft criterion was chosen as the most representative way to describe the hot tearing process. Finally, through response surface methodology and statistical analysis, a predictive model is proposed.

Introduction

Austenitic stainless steels are known as Low stacking fault energy materials by their metallurgical properties. During hot deformation, the dislocations move by crystal twinning across the face centered cubic (CFC) lattice. If the dislocations are constrained, the energy excess will lead to cracking of the material. These cracks are usually recovered during the recrystallization processes.

On the other hand, for specific strain, strain rate and temperature conditions, the coalescence of these cracks occurs, leading to ductile fracture. Delta ferrite clusters in these materials influence crack propagation: globular clusters are known to slow down the rupture, whereas lamellar layers speed up the rupture. Delta-ferrite cluster topology is influenced by heating time and deformation, because clusters align to the maximum deformation direction. Moreover, a percentage of less than 10% of delta-ferrite causes embrittlement in hot conditions. Experimental tests highlighted that delta-ferrite nucleate along crystal grain boundaries to dissipate the excess of deformation energy in addition of already nucleated metastable ferrite from continuous casting or rolling. Deformation energy is also related to the stress on the material, strain ε, strain rate ε' and temperature T. Further experimental tests have shown that both metastable and twinning nucleated ferrite formation are influenced by the Cr_{eq}/Ni_{eq} ration, which describes the ability of austenitizing elements to prevail on ferritizing ones.

Finally, through the analysis of process maps, AISI316L demonstrated a higher efficiency of recrystallization recovery than AISI304L, reducing voids creation.

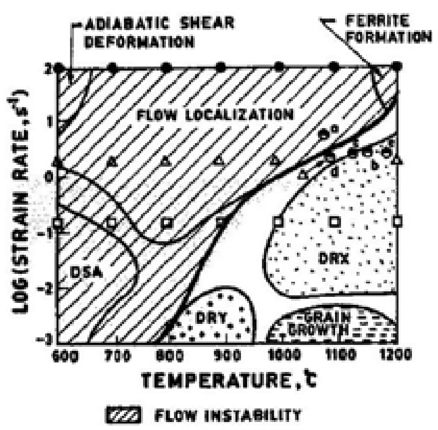


Fig. 1 - AISI 304L Processing Map ε=0.3

The aim of this study is to combine FEM analysis and the Surface Response methodology to predict stress on material; find the most significant variables to analyze; analyze the embrittlement of the material in process conditions.

Forging behavior of AISI 304L – AISI 316L

Analysis of the production process reveals the following:

- the use of mechanical presses (ε' > 10 s^{-1}), forging temperature between 1150 ° C and 1230 ° C and high ε values (due to net shape forging) lead to the deformation of the austenite in twinning conditions;
- the raw material is characterized by Creq/Nieq ≥ 1.6 (due to economic reasons on the alloying element selection), encouraging the formation of ferrite instead of stabilizing the austenitic phase;
- the combination of the previous points implies that the forging cycles are always characterized by the formation of a minimum quantity of delta ferrite;
- the cold shearing of the bars implies that in the fracture area there is a density of dislocations (and strain energy) extremely greater than in the central part of the trimmed portion, promoting the ferrite formation during hot-forging;
- the induction heating of the billet is not able to anneal dislocations in the sheared zone (due to the shape of the inductors and the skin effect), so the risk of crack formation is higher;
- the main reasons of material cracking are: a) wrong die design with subsequent high material deformation, b) excess of metastable ferrite in the raw stock material, c) too high process temperatures.

A process map of AISI 304L was used as a starting point for process parameters analysis of strain rate and temperature:

For typical process conditions, T ≥ 1150°C and ε' ≥ 10 s^{-1}, the process map shows the formation of δ-ferrite. A similar condition was found by FEM simulation, where the cracking area was characterized by strain ε > 0,3, temperature 1100° C < T < 1150° C, strain rate 10 s^{-1} < < 100 s^{-1} and stress 160 MPa < σ1 < 190 MPa.

Hence:

- for strain $\varepsilon > 0,3$, the amount of δ-Fe can be considered constant;
- the process map was created for AISI304L stainless steel with Creq/Nieq=1,66, while the raw material available has a ratio of 1,6÷1,63, with a lower tendency to generate δ-Fe;
- strain rate values are in accordance with the process map even if the temperature range should not allow the δ-Fe generation;
- stress data are only available from FEM simulation.

It should be noticed that the raw material used to create the process map is fully annealed with no inhomogeneity in dislocation or energy density. This means that it is free from localized excesses of dislocations/ deformation energy, related to the history of the process of the sample (e.g. cold shearing). It is therefore supposed that the material which lead to the hot tearing has a different processing map from the aforementioned one, with formation area of delta-ferrite larger than that one traced in Fig.1. This hypothesis would justify the possible formation of delta-ferrite even in the temperature range 1100° C ÷ 1150° C, at constant strain rate (dislocations/deformation energy derived from the cold shearing). The hot tears formation is consequently a combination of void nucleation, brittle phase formation and material flow with $\sigma 1 > 0$. The dimensions of the tears is proportionally with the intensity of these three causes.

Industrial case

Application of the proposed methodology is related to the hot closed die forging of AISI304L-AISI316L flanges for food industry, where cracks are detected at the end of the forging cycle. In this case, the tearing are deeper than the machining allowances, which are approx. 1.5 ÷ 2.5 mm. In Fig.2 the cracks are highlighted with dye penetrant inspection.
The production process starts with cold-shearing of the initial billet. The hot forging is performed by mechanical presses with three different stages. The first stage prepares the preform for a subsequent finishing stage. In the third stage, the flash is trimmed to produce the final part. Process temperatures are set between 1150°C-1200°C to reduce the risk of rupture while keeping formability.

Fig. 2 - Example of cracks on a finished part

Numeric Model

The methodology proposes a multidisciplinary approach based on three steps: metallurgical analysis of the cracking phenomena, FEM process simulation, and statistical analysis of simulation data to identify the most influencing variables. To control the evolution of hot tearing risk during the production process, a damage criteria was chosen. Among the several damage criteria, Rüf performed a comparison between the most common damage criteria. He concluded that the normalized Latham-Cockcroft criteria is the more stable criteria towards the variation of the process parameters:

$$D = \int_0^{\varepsilon_f} \frac{\sigma_1}{\sigma_{eq}} d\varepsilon_{eq}$$

The knowledge of the damage limit for a specific material requires complex laboratory tests. Due to the impossibility to perform these calibration tests, the preliminary simulations of the process were used as reference for a relative comparison.

Process variable selection

After the evaluation of the metallurgical aspects, the identification of key parameters was carried out through FEM analysis. Only geometrical variables have been evaluated, due to their independence by the stochastic process effects:

- H_B: height of the inner part of the lower die, related to the first contact of the material and the die.
- Sf_B: slope of the inner part of the die, the lower the value (measured from the symmetry axis) more the material will be squeezed in the die cavity.
- s_F: thickness of the flash. This variable influences the length of the central part of the upper die. The deformation of the preform increases with this dimension.
- H_C: height of the central part of the preforming die.

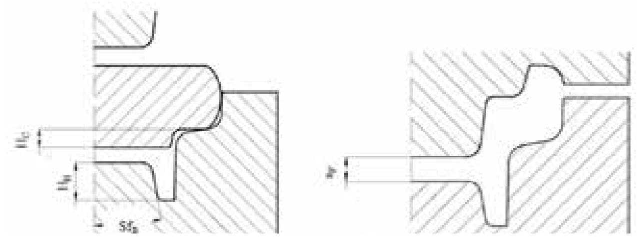


Fig. 3 - Variables HB, SfB, sF and HC

Variable Screenings

Based on the main variables and parameters from the previous analysis, the Surface response method was applied. A Design of Experiment was implemented in FEM simulation and data were analyzed through Analysis of Variance (ANOVA) to evaluate the sensitivity of the variables. This approach allows to not consider the less influencing variables. The most significant variables are reported in the following table for DN32 and DN40 components:

VARIABLE		COMPONENT DN 32	COMPONENT DN 40
H_B	min	3	8
	MAX	9	12
Sf_B	min	8	8
	MAX	12	12
s_F	min	4,5	4,5
	MAX	6,5	6,5
H_C	min	3	0
	MAX	8	5

The chosen face-centered-design DOE is composed by four variables on three levels to have a sufficient number of individuals to describe the curvature of the response surface. The total amount of simulations is given by $2k + 2k + 1 = 25$, where k is the number of variables considered. From an analytical point of view, the response surface has to be modeled within the maximum and minimum value of the chosen variables. From a mathematical point of view, linear equations were chosen to simplify the management of the analysis. This allows the use of the method of the Least Squares for the calculation of equation coefficients. Through the regression analysis, it is possible to assess:

- the consistency of the model: if the regression p-value is lower than 0.05 and the R_{adj} value assumes values greater or equal to 0.7-0.8, the linear model can explain the variance present in the observed data.
- the significance of variables: if the model is valid, a variable with p-value greater than or equal to 0.05 will be regarded as insignificant and therefore may be removed from the model without affecting the accuracy.

This analysis was performed at least with second order response surfaces, while iterations are limited to the same maximum order chosen for the response surface, e.g. HB*HC. The maximum value of Cockroft&Latham normalized damage criterion in a specific cracking zone (Fig.4) was evaluated.

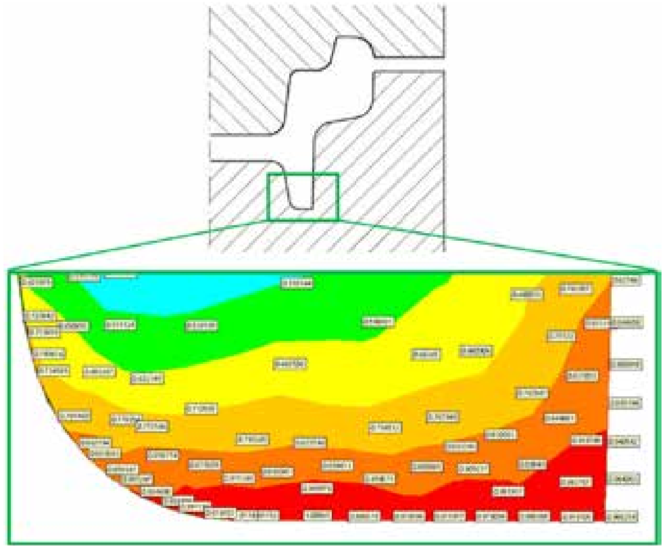


Fig. 4 - Latham-Cockcroft coefficient values (DOE data)

Response Surfaces

Response surfaces of Cockcroft&Latham normalized damage criterion values were generated as function of the most representative variables. Response surfaces for DN32 and DN40 are reported in Fig.5 and Fig.6.
The analysis of the data obtained from DOE for DN32 has highlighted H_B e H_C as most significant variables.
The analysis of the data obtained from DOE for DN40 has highlighted H_B, Sf_B e H_C as most significant variables.
Beside the different number of variables, the same tendency is evident in both cases: higher values of H_B and H_C permit to obtain the greatest reduction of the Latham-Cockcroft damage coefficient and therefore lower probability of hot tears occurrences. From a practical point of view, this means a predominant compression State of Stress.

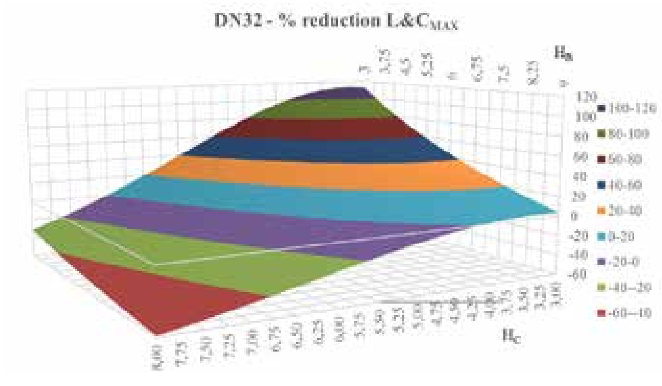


Fig. 5 -Response surface for DN32

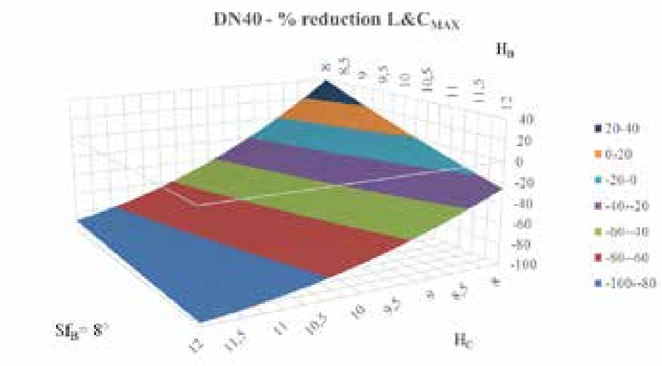


Fig. 6 - Response surface for DN40

Conclusions

The proposed multidisciplinary method is able to evaluate the most critical parameters in hot tearing and covers the following:

- metallurgical evaluation to understand the main causes of the hot tearing phenomena;
- numerical model to analyze a broader range of process conditions, reducing the number of experimental tests;
- mathematical analysis to evaluate the most influencing parameters and to develop specific response surfaces.

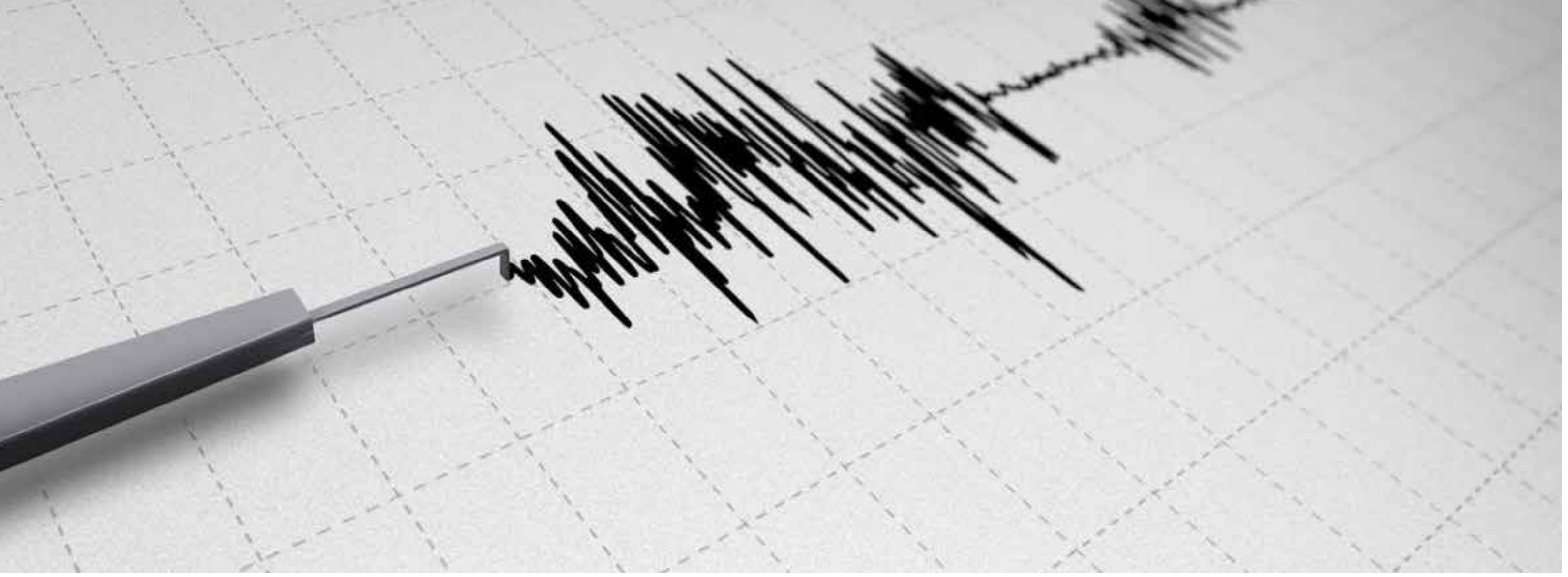
This methodology can be applied to all the high temperature forging cycles where metallurgical transformations will affect the final result (e.g. Ni and Ti alloys).
Furthermore, the proposed multidisciplinary schema is suitable to be extended to other forging processes and to other defects, as function of literature data and process stability.
The proposed approach allows the visualization of how the process changes varying the actually influential parameters, leading to a more effective managing of the forging cycles by combination of metallurgical and production requirements.

Acknowledgement

The authors would thanks OMFA Inox Srl for the support gave to realize this study and EnginSoft for the support gave in the use of FEM codes.

Giulio Gallo, Alessandro Ballan - OMFA
Federico Fracasso, Riccardo Capuzzo - EnginSoft

For more information: Federico Fracasso, EnginSoft
f.fracasso@enginsoft.it



Safequake: real time seismic monitoring of buildings

An advanced seismic monitoring system, able to provide immediate information on structural reliability of buildings struck by non-destructive earthquakes

Company

Intelligent Infrastructure Innovation SRL is an offspring of the University of Trento, established with the aim of developing applications from the knowledge stemmed from academic research in the field of structural health monitoring and asset management.

IKUBED INTELLIGENT INFRASTRUCTURE INNOVATION

Motivation

Despite the notable efforts made to improve the knowledge on seismic events and on the techniques for building protection, earthquakes still have a serious impact on society in terms life and financial losses. The analysis of recent seismic events in Italy led to the following considerations.

- In addition to direct damages, the economic impact is largely due to the interruption of activities caused not only by structural collapses but also by the necessity of assessing the damages. As an example, after the earthquake in Emilia Romagna (Italy), occurred in 2012, the cost of the interruption of the productive activities amounted to approximately 55 % of the total loss;
- the technician in charge of inspecting the structure is often unsure of what the action to take is because they are responsible of the decision and because the uncertainty affecting the assessed structural state of damage is large.

Nowadays, visual inspection is the most used technique employed in post-seismic damage evaluation. The result of this kind of inspections is subjective, and usually not very reliable because of the lack of available resources and time constraints. Furthermore, in many cases visual inspections are not able to detect the damages, especially if the damages are not severe or when the damaged elements are hidden by non-structural elements (e.g. when there are suspended ceilings).

In case of high-magnitude earthquakes, the inspections are carried out using the AeDES forms whose evaluation is time consuming. For example, in the case of the earthquake in Emilia Romagna the total building inspection were about 39000 and were done in more than two months. After these inspections, 37% of the buildings were actually safe, while 17% were put in service after applying short-term countermeasures.

These reasons have led in recent years to a growing interest in seismic monitoring systems, which provide objective real-time data concerning the effects of the earthquakes on the structure useful for reliable damage evaluation.

Seismic monitoring systems of buildings

Nowadays, seismic monitoring is implemented worldwide, particularly in the United States with two programs: the California Strong Motion Instrumentation Program (CSMIP) and the United States Geological Survey (USGS), which has installed and managed seismic monitoring systems on buildings and infrastructures with the primary aim of studying the structural behavior during the earthquakes and improving technical design. In Italy, the Osservatorio Simico delle Strutture (OSS) – managed by the Department of Civil Protection – monitors some public structures and infrastructure such as schools, hospitals, town halls and dams.

Several strategies exist for estimating structural damages caused by earthquakes. The most common are: (1) comparison with the design Peak Ground Acceleration (PGA); (2) measurement of accelerations during the earthquake event and posterior dynamic analyses of the structure with a Finite Element Model; (3) comparison of the values of modal parameters before and after the earthquake events; (4) calculation of the interstory drift, i.e. the relative displacement between two subsequent stories of the building. The choice of monitoring the interstory drift is often the preferred choice and is supported by the literature, academic studies and real-life experience carried out though the USGS program. Experimental tests have evidenced that the interstory drift is the principal indicator of the damage in ductile reinforced concrete elements. Furthermore, this monitoring strategy has the advantage of providing information not only on the damage existence but also on its localization. The method consists of evaluating whether the drift has exceeded a given threshold during the seismic event, linked to the level of damage.

The most used sensors for the measurement of the interstory drift are accelerometers. Accelerometers continuously acquire of acceleration data, which are later cleansed and filtered. Finally, the acceleration are integrated twice for the calculation of the instant displacement between the stories.

SAFEQUAKE

Safequake is a monitoring system developed in order to detect the damages that a building might have suffered as a consequence of an earthquake. It is helpful to decide whether people may be allowed to stay in a building after an earthquake and supplies the data that can be used to assess the structural damages. In case of damages, Safequake helps to plan repair before activities are resumed. The system is made of a network of sensors placed on several sensitive locations of the building and connected to a central unit that processes the information and generates a comprehensive output. The central unit can manage the data coming from several buildings, thus it provides insight on the overall seismic intensity in a large area and the seismic vulnerability of all the monitored buildings.

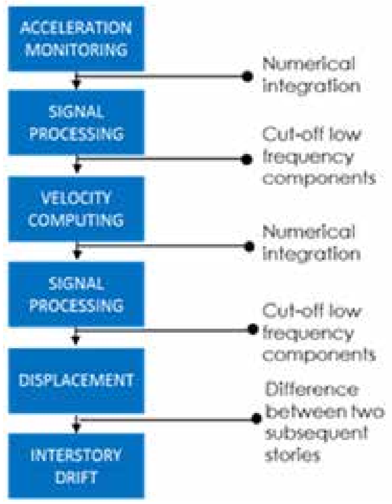


Figure 1 - Algorithm implemented in the local system for the estimation of the interstory drift

The sensors are connected to an acquisition unit which in turn is connected to an industrial PC. An UPS ensures the power supply for 15 minutes – enough to elaborate, save and transmit data – in case the earthquake causes loss of power. The local system is connected through the internet to the asset management system in which data are saved, processed and analyzed. The recorded data are available in real time to the users, who can always visualize them on the specific web application.

The software implemented in the local system does the following.

- The software identifies the seismic event avoiding false positives and false negatives by adopting two strategies:
  - o a local strategy at single node level – an algorithm that is able to identify electric noise and that avoids the transmission of junk data is implemented in the node;
  - o a global strategy at system level – the system is able to identify whether the acceleration signals from a sensor are caused by an earthquake or environment vibration.
- The software registers and processes the data to identify the damage state of the building (see Figure 5).
- The software transmits only the significant data to the acquisition unit.
- The software evaluates the seismic response of the building, estimates the damage state after the earthquake and send the results though emails or text messages in real time. The full data can be downloaded through the web application.

Safequake has been extensively tested in the laboratories of the Department of Civil, Environmental and Mechanical Engineering of the University of Trento. After the tests, it has been installed in several school buildings in the Province of Trento.

Case study: the elementary school of Stenico (Trento, Italy)

The seismic monitoring of the elementary school of Stenico (Trento, Italy) is the first case study in which the Safequake project was applied. The building was completed in the 80s. The main part, in which the monitoring system has been installed, contains the classrooms, the laboratories, offices and – in the basement – a fire station. This part is 480 m^2, divided in 2 floors, an attic and a basement with a maximum height of 10,60 m. From a structural standpoint, the structure of the

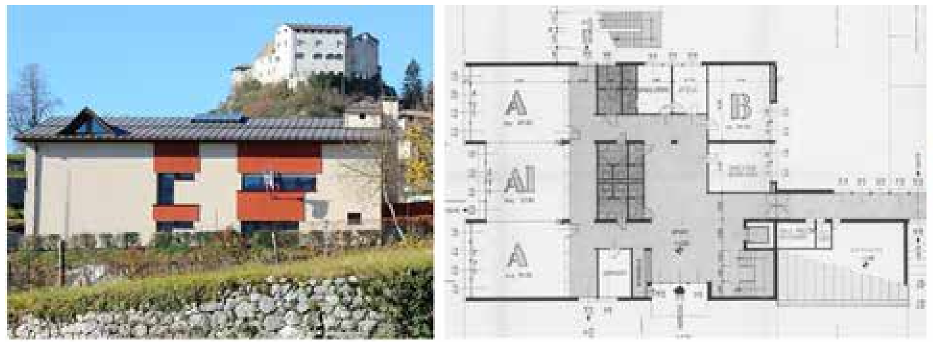


Figure 2 - a) main building and b) FEM of the elementary school of Stenico – south-east view and c) plan of the ground floor

Figure 3 - a) uniaxial accelerometers, b) biaxial inclinometer, c) acquisition unit and UPS, d) an installation of the monitoring system

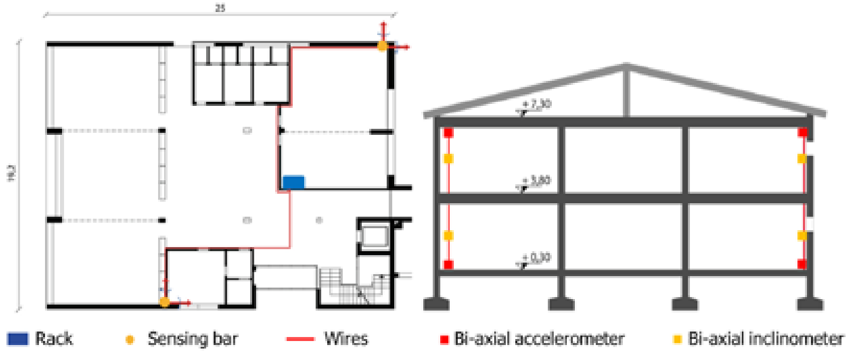


Figure 4 - Scheme of the monitoring system

main building is made of composite masonry walls and concrete columns, concrete slabs and a timber roof.
Before the installation of the monitoring system, a FEM of the main building was made in order to map the sensor measures with the damage state. This analysis is required also to identify the key parts of the structure in which the measurements must be acquired. The FEM was used to perform a non-linear static analysis, in order to determine for each structural element the interstory drift that leads to serviceability (operational) and ultimate limit state. A different 3D FEM was also used to perform a pushover analysis, in which the masonry walls were modeled as mono-dimensional macroelements having elastic-perfectly plastic behavior. In this model, the resistance of the masonry walls was calculated based on the elastic limit of the material, while the ultimate displacement was calculated based on the flexural and shear response.

The Safequake monitoring system is useful not only to measure the accelerations and the displacements in the building during the seismic event, but also to calibrate the FEM of the structure. The results of the analysis were used to design the monitoring system. We installed 8 uniaxial accelerometer (4 on the slab of the ground floor and 4 of the second floor) and 4 biaxial inclinometers (2 between the ground and the first floor, and two between the first and the second floor).

Results

The system has been running since December 2014 and has detected 112 minor earthquakes so far. Table 1 shows a list of the 10 major earthquakes detected by the system in 2016 and Figure 4 the accelerations recorded during the earthquake of Rieti. For all the recorded earthquakes, the system did not find any damage on the structure.
Major earthquakes on the monitored buildings will further validate the system.

Date	Time	Latitude	Longitude	Depth [km]	Magnitude	Epicenter (Province)	Distance from Stenico [km]
03/02/2016	21.37.39	45.7635	10.7383	10.1	3	Brescia	34.53
15/04/2016	03.18.07	45.8353	11.0172	11.2	2.5	Trento	30.12
31/01/2016	22.43.59	47.0998	10.07	10.7	3.4	Austria	145.25
11/04/2016	10.47.23	46.4588	10.0267	10	3.1	Switzerland	102.34
15/12/2015	00.15.48	45.6595	10.2127	2.9	2.9	Brescia	83.49
13/03/2016	00.58.49	46.6697	10.6237	9.3	2.8	Bolzano	73.16
28/05/2016	03.31.40	44.9262	11.2958	5.7	3.1	Mantova	134.25
25/02/2016	20.55.14	44.9622	11.1708	10.2	3	Mantova	125.99
04/05/2016	08.17.47	44.3492	10.8247	33.4	3.2	Modena	189.06
24/08/2016	03.36.32	42.7100	13.2200	4.0	6.0	Rieti	417.69

Table 1 - 10 major earthquakes detected by the system

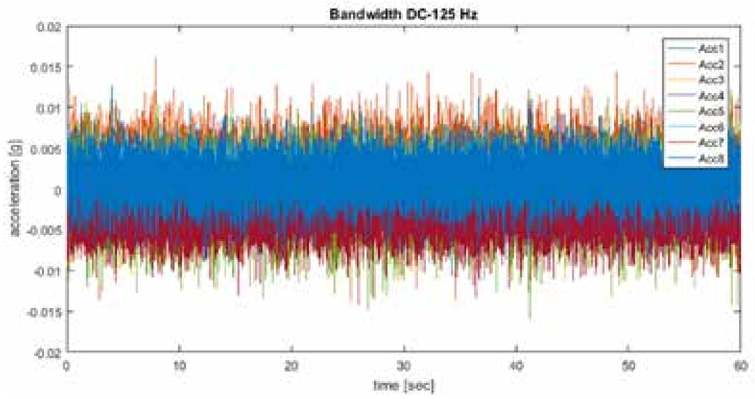


Figure 5 - Accelerations recorded during the earthquake of Rieti 24/08/2016

Emiliano Debiasi, Davide Trapani
Intelligent Infrastructure Innovation srl

Oreste Salvatore Bursi
Full Professor, Department of Civil Environmental and Mechanical Engineering (DICAM), University of Trento

HPDC Foundry Competitiveness
based on Smart Control and Cognitive Systems in Al-Alloy Products

High Pressure Die Casting (HPDC) technology is facing a new global challenge to improve quality. Achievable production rate, process monitoring and control all need to be addressed to satisfy the end-user. The EU-FP7-funded MUSIC Project adds to the competitive landscape. It is probably the biggest research project ever carried out in the field of HPDC, with 16 partners and an effort of about 1000 person-months.
MUSIC developed a totally new Control and Cognitive system, giving an integrated and multi-disciplinary answer to address the issues faced by the HPDC industry: "zero-defect" production, real time process control, understanding the role of process variables, process optimization and real time cost evaluation. The foundations about this new Control and Cognitive system are presented in this article.

Introduction: Factory of Future and Industry 4.0

The so called Industry 4.0 is the industrial revolution based on Cyber-Physical-Systems (CPS). In the context of Factory of Future (FoF), the smart manufacturing, or Factory 4.0, is part of the
Internet of Things (IoT), of Services and People. The well-known digital transformation of the industrial value chain is relevant for smart grids in the field of energy supply, advanced materials, sustainable mobility strategies (smart mobility, smart logistics) and smart health in the realm of healthcare. The new and radically changed processes in manufacturing companies are applied for new technologies such as Sensors, 3D printing and next generation robots or the globalization of the supply chain. The digital innovation is not an exclusivity of new and advanced technology and production processes. The traditional production processes and plants are evolving following this digitalization combining the extensive experience and fast new methods to improve the production efficiency and to accelerate the fine tuning and real time adjustment of the process parameters oriented to the zero defect quality.
Evolution instead of Revolution. The FP7- MUSIC project (funded in the frame of the Call FoF-ICT-2011.7.1 Smart Factories: Energy aware, agile manufacturing and Customization) is giving a new age to the traditional multi-stages production processes such as High Pressure Die Casting (HPDC) and Plastic Injection Moulding (PIM). The use of Sensors, the totally integrated systems, as well as the data mining and cognitive model are the key ingredients of the MUSIC project, to be a reference in the Industry 4.0 scenario.
Having this general context clear in mind, it becomes evident that all project objectives are focused on trans-sectorial production technologies, larger European market, capability of manufacturing site to be flexible, fast and reactive, manufacturing customization and environmental friendliness, management of manufacturing information, ICT application to improve the manufacturing process, new metrology methods and international standardization.

The Foundry Market and HPDC Multi-Disciplinary Process

European non-ferrous foundries are a group of about 2700 companies, which produced more than 4 millions of tons of castings in 2015 (Aluminium castings represent roughly 70% of them). Key players are Germany and Italy, with 55% of total production from Europe (1,221 and 0,900 Million tons for Germany and Italy corresponding to a turnover of 5.743,00 and 4.460,00 Mio of euro) and an average number of employees of 15 in Italy and 96 in Germany (source CAEF). At least 60% of Aluminium alloy castings are produced by HPDC process. Categories of die cast products as thin wall and safety castings (represented in MUSIC project by a shock tower manufactured by AUDI) and Housing and Covers (represented in the MUSIC project by a gearbox manufactured by RDS) are the 75% of the total HPDC production (Fig. 1).

High Pressure Die Casting (HPDC) of light alloys is one of the most representative large-scale production-line in manufacturing fields, which are strategic for the EU industry largely dominated by SMEs. Due to the high number of process variables involved and the non-synchronization of all process parameters in a unique and integrated process control unit, HPDC is one of the most "defect-generating" and "energy-consuming" process in EU industry, showing less flexibility to any changes in products or process evolution. The sustainability issue imposes that machines/systems are able to efficiently and ecologically support the production with higher quality, faster delivery times, and shorter times between successive generations of products. This is the scenario of the MUSIC project, strongly aimed at leading EU-HPDC factories to cost-based competitive advantage through the necessary transition to a demand driven industry with lower waste generation, efficiency, robustness and minimum energy consumption.

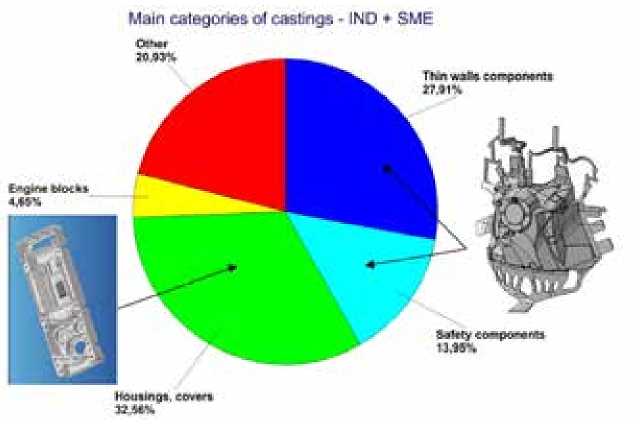


Fig.1 – Main categories of high pressure die casting products

The development and integration of a completely new ICT platform, based on innovative Control and Cognitive system linked to real time monitoring, allows for an active control of quality, avoiding the presence of defects or over-cost by directly acting on the process machine variables optimisation or equipment boundary conditions.
The Intelligent Manufacturing Approach (IMA) works at machine mould project level to optimise the production line starting from the management of manufacturing information. An Intelligent Sensor Network (ISN) monitors the real-time production acquiring multiple layers of data from the different devices while an extended meta-model correlates the input and sensors data with its quality indexes, energy consumption cost function. Data homogenization, centralization and synchronization are the key aspects of the control system to collect information in a structured, modular and flexible database. Process simulation, data management and meta-model are key factors to generate an innovative Cognitive system to improve the manufacturing efficiency.

Challenges and Proposed Solutions
Introducing intelligent manufacturing systems in HPDC, made available by autonomous and self-adaptive devices, changes totally the actual organization and potential of this process.
According to the experience of the MUSIC Partners, which are well established players in HPDC manufacturing scenarios, six main challenges have to be faced for the progress in this field.
These challenges are directly addressed by the MUSIC project's multilevel objectives and answered by several specific outcomes, associated with the main breakthroughs identified as follows:
The innovation aspects introduced by MUSIC project results are referred to process optimization, centralized control of multi-stage production efficiency as detailed in the following list:

Challenge #	Represents the breakthrough
①: leading HPDC/PIM to "zero-defect environment	Quality improved and defects minimised
②: introducing real-time tools for process control	Process data acquired by real-time tools
③: monitoring and correlating all the main process variables	Extent of knowledge of Process data vs. Quality as well as vs. Maintenance
④: making the process set up and cost optimisation a knowledge-based issue	Extension of average die life, Cost reduction in HPDC/PIM production cell, Process efficiency (energy & material) improved
⑤: involving to multi-disciplinary R&D activities	Control & Cognitive System
⑥: impacting on EU HPDC/PIM companies, by dissemination and standardization activities	International standardization

- A new Control and Cognitive system (the "smart Prod ACTIVE" tool) is ready for the market, for use from design chain simulation and process optimization to real-time quality and cost modelling.
- The high-performance production is supported by introducing an advanced Sensors Network and Centralized data management to control all the stages and tools in the production line.
- The process data, recorded in a proper database, are managed and elaborated in real time to predict the Quality and Cost characteristics of single product through advanced and trained process meta-models.
- The Machine operator, the Production manager or Plant director are supported by smart web-based GUI to remotely visualize and navigate their real-time or historical process data.

Pprocess Parameters and Cognitive Predictive Quality Model
The "smart Prod ACTIVE" tool (Fig. 2) predicts the quality, energy and cost of the injection process in real-time, covering 100% of the production processes, and suggests any appropriate reactions to adjust the process set-up and/or mechanism. It works in combination with the real time monitoring system (or Intelligent Sensor Network) to instantaneously use the production data set to create a quality/energy/cost prognosis. The client-server mechanism works in combination with the real time monitoring system (or Intelligent Sensor Network) to instantaneously use the production data set to create a quality/energy/cost prognosis.
The client-server Connections, based on the OPC _ UA protocol is then accepted as the Interface for Industry 4.0, and is collecting all the process data coming from any existing devices and active sensors in a centralized database.
A fundamental innovative characteristic of the "smart Prod ACTIVE" tool is the Cognitive predictive quality model, integrating multi-solution and multi-variate process data, monitored and gathered by an articulated network of sensors by collection across a distributed control system. Advanced models link process variables to specific defect generation mechanisms, new optimization tools and the remote management of production by self-adaptive equipment. The real-time visualization of elaborated data, including safety messages and statistic production diagrams, will be appropriately customized for multiple unique user

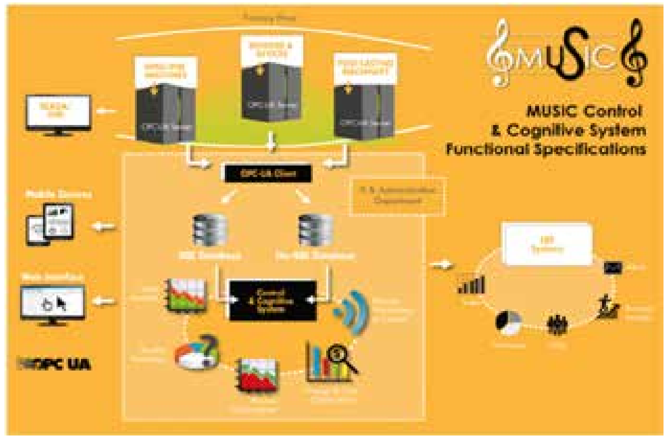


Fig.2 – Introducing the "smart Prod ACTIVE" tool with the client–server structure in the factory floor

interfaces, for machine operators, production managers and plant directors. The standardization Quality classification and investigation methods, as well as the traceability, are fundamental to train the Cognitive model guiding the minimization of relevant indexes affecting the scrap rate. The final tool is a smart web application to visualize, share and communicate the significant data and to support the decision making with proper reactions in real-time (retrofit) based on the captured signals from the process and intelligent elaboration of data by the quality model.

The Expected Impacts
The MUSIC project introduces new ICT technologies to manufacturing plants with the significant potential impacts of: (i) strengthening the global position of the EU manufacturing industry; (ii) larger EU market for advanced technologies such as electronic devices, control systems, new assistive automation and robots; (iii) the intelligent management of manufacturing information for customization and environmental friendliness. Expected benefits are:
- 40% reduction in scrap rate for the involved HPDC foundry,
- -3% in no-quality costs for the involved automotive company,
- up to 40% decrease in the cost of quality control, to be applied only to specifically individuated products,
- 5-10% reduction in energy consumption, due to scrap reduction and increased production efficiency,
- better knowledge and control of the process, resulting in time to market reduction and minimization of trial & error approaches.

Conclusions and Future Developments
Due to the high number of process variables involved and to the non-synchronization of all process parameters in a unique and integrated process control unit, HPDC is one of the most "defect generating" and "energy consumption" processes. Sustainability imposes that machines/systems are able to efficiently and ecologically support production with higher quality, faster delivery times, and shorter times between successive generations of products. The new "smart Prod ACTIVE" tool is a flexible and totally integrated system able to predict the real time quality and the cost. Its extension of application to further multi-stages and multi-disciplinary production lines (e.g. sheet metal forming, forging, rolling, thermoforming, machining, welding, trimming, or the innovative additive manufacturing) is planned to exploit the same methodology in different industrial contexts.

Acknowledgments
This work was developed inside MUSIC Project (MUlti-layers control & cognitive System to drive metal and plastic production line for Injected Components), supported by European Union
(FP7-2012-NMP-ICT-FoF, grant agreement n° 314145).
The authors would like to thank all Partners of MUSIC consortium (www.music.eucoord.com).

ASSOCIAZIONE ITALIANA DI METALLURGIA

Nicola Gramegna – Enginsoft
Franco Bonollo – University of Padova

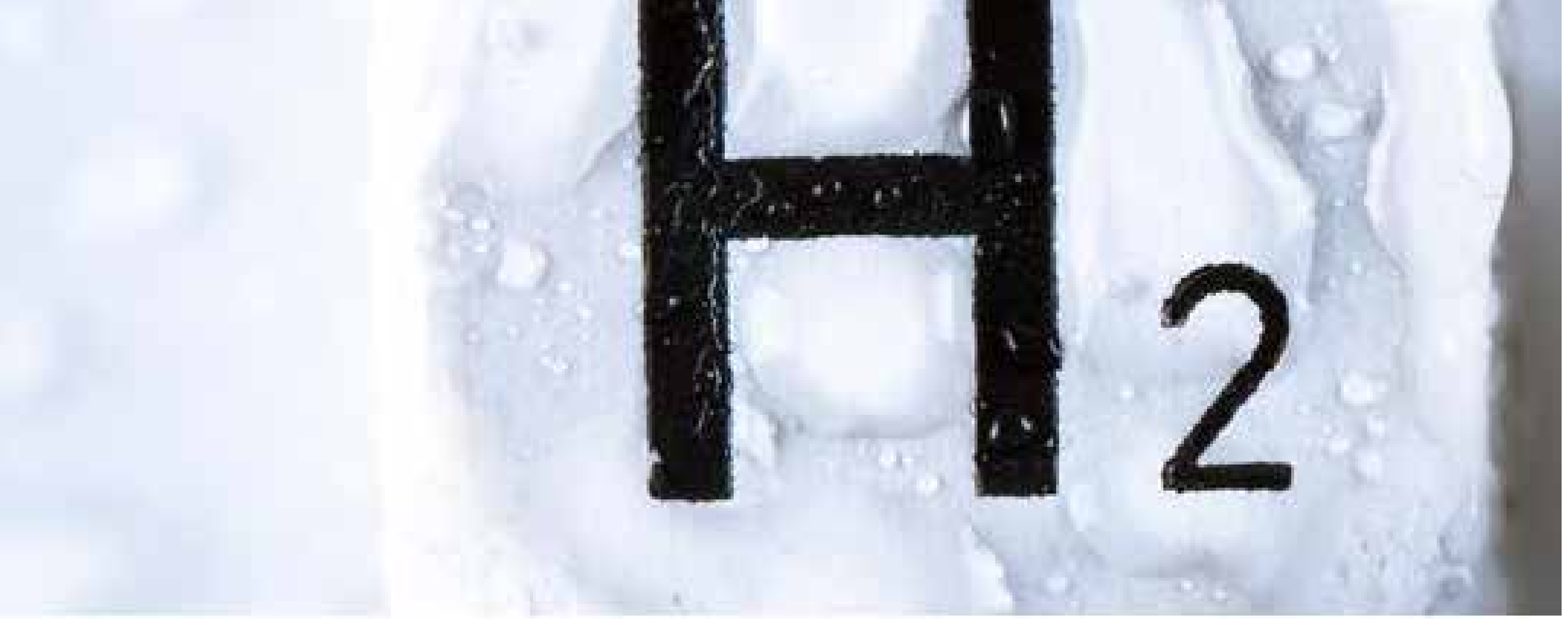
Article published on La Metallurgia Italiana, n. 7/8 Luglio Agosto 2016, pagg. 27-32 Anno 108
ISSN 0026-0843

ExaNeSt

ExaNeSt celebrates its first birthday

The European Exascale System Interconnect and Storage project (ExaNeSt) has already reached its first year of activity, on the path to the development, evaluation and prototyping of a the physical platform and architectural solution for a unified Communication and Storage Interconnect with the aim of delivering European Exascale Systems with a physical rack and suitable environmental structures to be used for HPC applications.
This first milestone provided an ideal pretext to check the evolution of the project and its alignment with its great ambitions, also related to the connection with two other FETHPC projects, ExaNoDe and ECOSCALE. ExaNeSt, ExaNoDe and ECOSCALE are working in close collaboration to develop the building blocks for an Exascale architecture prototype that will put the power of ten million computers into a single supercomputer. ExaNeSt is the project focused on the system level, including interconnection, storage, packaging and cooling, and as the name implies, ExaNoDe is responsible for the compute node and the memory of that compute node and ECOSCALE focuses on employing and managing reconfigurable logic as accelerators within the system.
During last HiPEAC CSW (European Network on High Performance and Embedded Architecture and Compilation), that took place in Dublin in early November, ExaNeSt-ExaNoDe-ECOSCALE had a joint workshop in order to discuss the Memorandum of Understanding that will be signed by the end of 2016 in order to precisely define a global and unified time plan to release the common milestones define a common shared architecture and to avoid risks and delays.
Although the work to be done is huge, the collaboration of the three consortia and the great skill, knowledge and expertise available will ensure a successful evolution of these research activities, bringing to outstanding results for the three projects.
http://www.exanest.eu/

Gino Perna - EnginSoft g.perna@enginsoft.it



Multi-Objective Optimization of a Solar Powered Hydrogen Production process

H_2 production through different solar technologies

H_2 production through different solar technologies

Hydrogen is a fundamental feedstock for many processes and plays a fundamental role in the future sustainability of energy production. Among the numerous processes that have been proposed to produce hydrogen from water, the so-called Hybrid-sulfur (HyS) has shown high potential for industrial application. This process consists of two main steps, summarized in Figure 1: the first, is a low-temperature (<100°C) electrochemical step and the second a high-temperature thermochemical reaction step (>850°C). SOL2HY2 (https://sol2hy2.eucoord.com/) is a research project, ending in November 2016, which aims to address the challenges related to the solar-powered HyS cycle by developing material solutions, demonstrate key components and optimize the whole process. A consortium of 7 European Research Institutions and enterprises (Figure 2) has been working together for 42 months on the project and was funded by FCH-JU within the VII Framework Programme of the European Commission. In the SOL2HY2 concept the thermal energy requirement of the H_2 production plant is fulfilled with different solar technologies: medium-temperature (<550°C) heat is provided using a parabolic trough plant, while the high-temperature (~1000°C) heat required by the sulfuric acid decomposition step is provided with a central receiver system. The first plant is equipped with a sensible heat storage system that allows smooth and prolonged supply of solar heat to the chemical process equipment even after sunset. Different options are considered, either individually or in combination, to fulfil the power demand of the chemical plant: inclusion of a power block to produce electricity from the CST plant, integration with a photovoltaic (PV) plant and use of grid power. The electrochemical reaction has been tested by an SDE (Sulphur Depolarized Electrolizer), the thermochemical one by a catalytic reactor. The catalyst has been tested both in ENEA Casaccia Research Centre and into a 500 kW reactor into the DLR Solar Tower in Jülich (Germany). When an external SO_2 source is available, the plant can be operated in a partial or complete open cycle mode, leading to the co-production of hydrogen and sulfuric acid, which can be sold as a valuable product. Open cycle operation is also possible if a source of elemental sulfur is available: in this case sulfur combustion leads to the simultaneous production of SO_2 and useful heat for the plant. With several operating options, the SOL2HY2 plant concept is therefore highly flexible. Depending on the plant installation location and market conditions, the operating settings that optimize the hydrogen production costs and share of renewables in the energy input may change. Therefore, a multi-objective optimization was carried out in order to identify the best solutions for a selected number of scenarios.

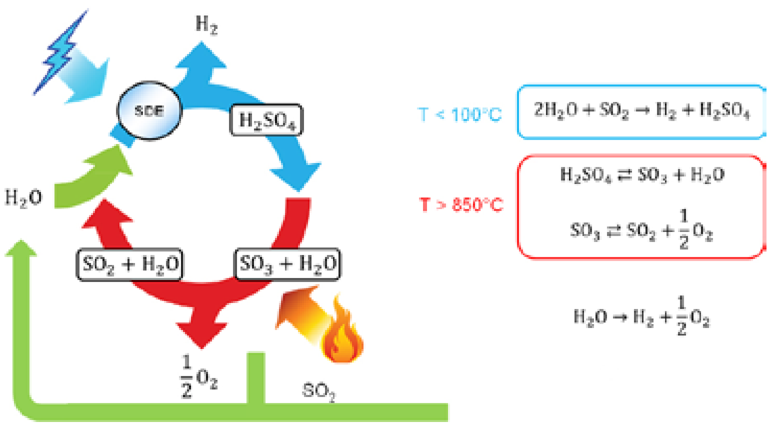


Figure1 - HyS in its closed and open option


Figure 2 - SOL2HY2 research context

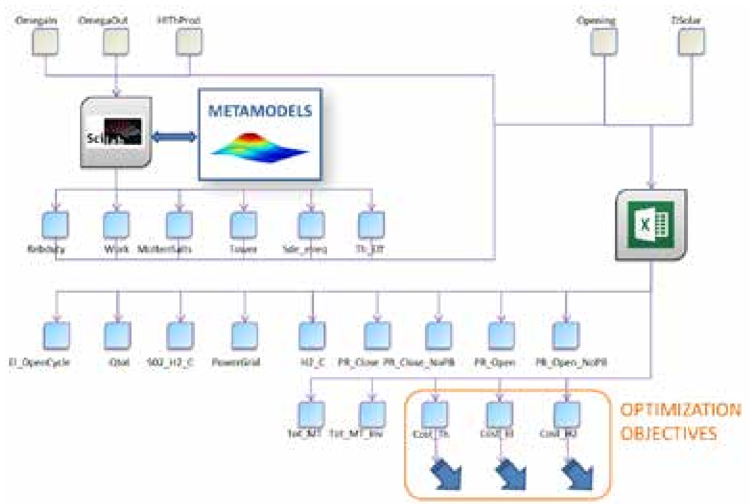


Figure 3 - Flowchart of the simulation process

Multi-objective optimization

EnginSoft developed a new software tool to make a flexible plant design with different share of cycle opening, SO_2 source, solar energy share and, on demand, adjustable hydrogen production. It is capable of estimating the CAPEX/OPEX for any planned location.

An optimization process for the whole plant was created to integrate the simulation spreadsheets and metamodeling techniques, which are useful to deal with the size (scaling) of the solar plant under consideration, with the aim of minimizing costs and maximizing the percentage of renewable hydrogen produced. This tool offers a single interactive and accessible application with a graphical user interface. It is able to display charts to support the simulation analysis and compare different solutions.

Statistical techniques, in particular correlation, are useful in discovering relationships between input and output variables that are often hidden. In this instance is has helped reduce the number of variables to consider and reduce the size of the search space in finding the optimal solutions.

Metamodeling is a method that extracts information from a model that has been developed from knowledge produced by another mode and has been used for handling the SDE data; in this case data was only available at discrete values, therefore an interpolation between these values was performed. This produced a function that allows the SDE parameters to be approximated for all input combinations. In this sense, all results obtained in the optimization activity are the result of metamodeling.

Conclusions

The integration of the HyS process for hydrogen production with different energy technologies (Solar Tower, Solar trough, PV, SDE, S burner…) in different conditions has been investigated. The implemented SW can execute accurate formulation and integration of the economic and environmental aspects and on the adjustment of the post-processing and visualization tools supporting the optimization process. For the longer term, these activities will be used for the development of a new competitive integration and optimization tool that can be in principle decoupled (stand-alone) from the processes of the SOL2HY2, the data coming from the pilot plant demonstrator will be used for a proper validation of the whole solution, including the integration and optimization software.

Luca Turchetti, Raffaele Liberatore,
Mariarosaria Ferrara - ENEA
Anna Bassi - EnginSoft

For more information: Anna Bassi, EnginSoft
a.bassi@enginsoft.it

The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) for the Fuel Cells and Hydrogen Joint Technology Initiative under grant agreement n° 325320

Figure 4 - Scilab GUI of the SOL2HY2 program

Multi-Body & Fluid Dynamics Co-Simulation

Interaction of structure and fluid in the development of industrial products

In developing a product, it is very important to accurately predict its behaviour in the real world, in order to evaluate its strength, stability and safety.
For this purpose the Multi-body dynamics (MBD) software package RecurDyn has been applied to various fields of engineering, including the analysis of kinematics, durability and fatigue of components such as suspensions, engines and joints. While assessing scenarios such as vehicle controllability/safety and strength analysis of construction machinery. In these cases, the influence of fluid must also be considered, e.g. lubricating oil inside a product or a vehicle's buoyancy when driving on a waterway etc... One efficient co-simulation technique is to use RecurDyn and the MPS particle method based CFD software Particleworks, which has been developed to treat such MBD-fluid interaction problems. This co-simulation procedure and its application examples are introduced in this article.

RecurDyn and Particleworks

RecurDyn is a multibody dynamics software that combines a unique MBD solver, developed on the Recursive Formulation theory, and a user friendly GUI. It is designed to efficiently compute large and complex models while coupling to nonlinear elastic models (see Fig.1). Particleworks is an integrated CFD software with an incompressible flow solver based on the MPS (Moving Particle Simulation) method and an intuitive GUI. Particleworks can import CAD data and model the fluid by automatically generating the particles in the specified domain. Since a mesh is not necessary to calculate the flow, complex and intensive change of free surface, splashing and scattering of fluid can be easily tracked.

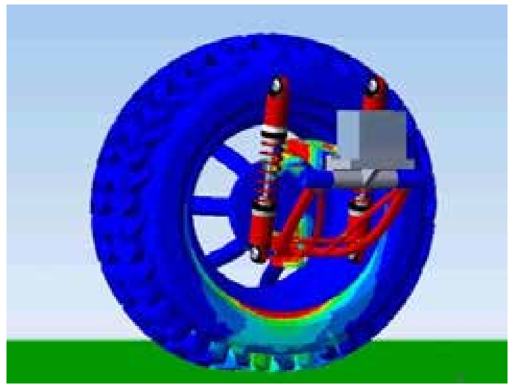


Fig.1 - Example of simulation using RecurDyn: Buggy car suspension system behavior including tire deformation

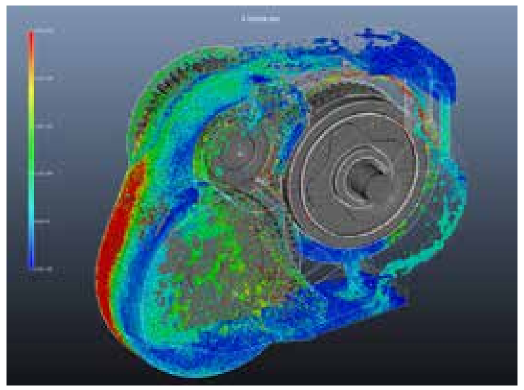


Fig.2 – Example of simulation using Particleworks: Oil lubrication in a gear box

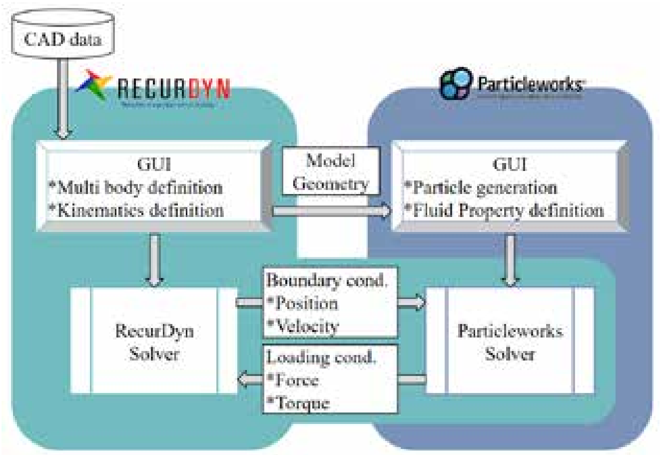


Fig.3 – Schematic flow of MBD-fluid co-simulation using RecurDyn and Particleworks

MBD-fluid co-simulation and validation procedure

The configuration and data flow of the MBD-fluid co-simulation using RecurDyn and Particleworks are shown in Fig.3. The procedure for co-simulation is as follows;

1. CAD data of model geometry is imported into the RecurDyn GUI.
2. Analysis conditions, e.g. Motion of the model, constraint (joints) and so on are defined by the RecurDyn GUI.
3. Parts which interact with fluid are exported by the RecurDyn GUI.
4. Particleworks GUI is invoked and the parts which interact with fluid are imported into Particleworks side.
5. Particles representing fluid are generated in the structure model and material properties of fluid are defined in Particleworks GUI.
6. RecurDyn solver is started through RecurDyn GUI. Particleworks solver is invoked automatically inside RecurDyn solver during the execution as dynamic link library.
7. RecurDyn solver progresses computation receiving fluid force from Particleworks solver. Simultaneously, the Particleworks solver continues the computation for fluid domain using updated position and velocity of structure model.

In this procedure, real time 2-way coupling computation is provided by combining solvers of RecurDyn and Particleworks seamlessly.

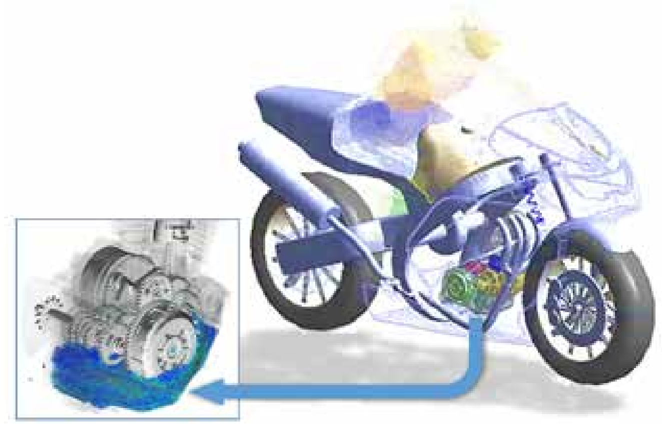
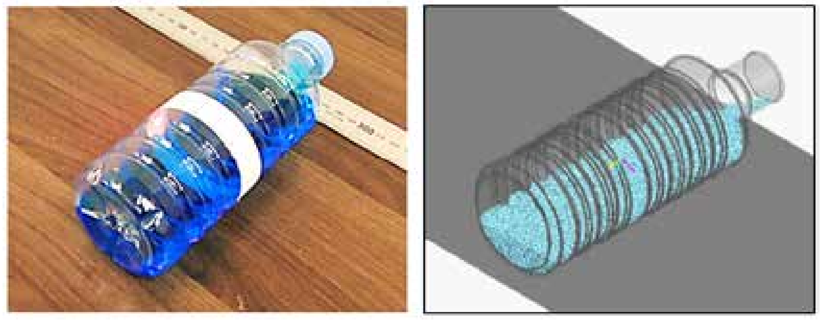


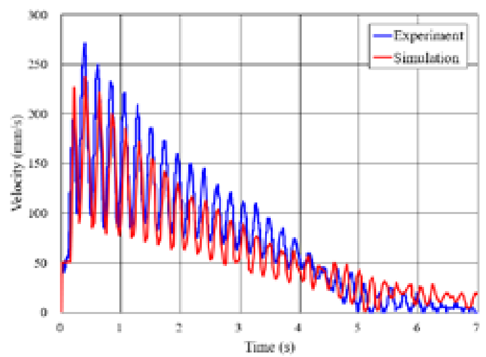
Fig.5 - Simulation of lubrication oil behavior in an engine of motorcycle from start-up to traveling (Courtesy of Thomas Freviller and FunctionBayK.K.)

A simple experiment and a substitute simulation was performed to validate the suitability of this co-simulation technique. A PET bottle containing water is rolled on the plane in this experiment as shown in Fig.4 (a). The translational velocity of the bottle changes periodically and decreases gradually by the effect of the water sloshing and the bottle stopped after seven seconds. The co-simulation was performed under the same condition as the experiment. The comparison of the translational velocity history obtained from the experiment and the co-simulation are shown in Fig. 4 (b). Both of two velocity curves show good resemblance for the period and the amplitude of the velocity change.



(a) PET bottle with water

Fig.4 - Comparison of experiment and simulation of PET bottle rolling Courtesy of FunctionBay K.K.



(b) Translational velocity history

Application examples

Kinematic motion of the structure that is used as the boundary of flow analysis changes dynamically in MBD-fluid co-simulation. There are explicit advantages of flexible and useful modeling by using the particle method in which mesh generation is not required and reduction of computational cost is also expected. For example, when the simulation of oil lubrication in the engine during the period between the start up to the traveling at constant velocity of a motorcycle is executed, realistic condition in motion can be modeled exactly by implementing the the co-simulation procedure as follows (Fig.5);

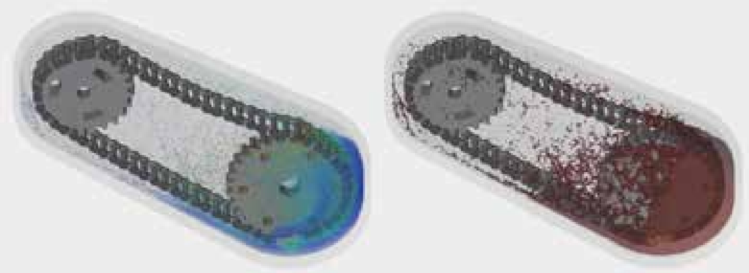


Fig.6 - Lubricant behavior inside the housing of a transmission chain mechanism (Model geometry: courtesy of Amine, member of mechatronics INSAT)

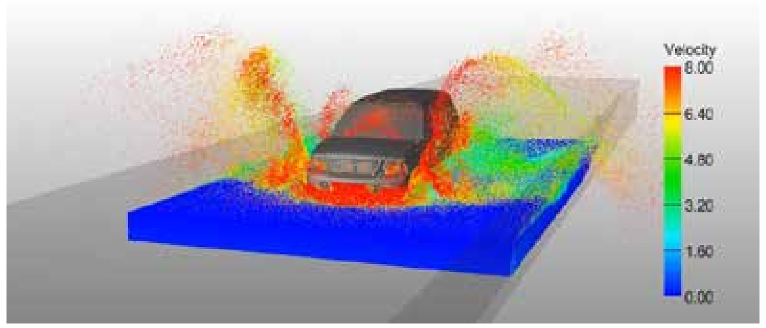


Fig.7 - Waterway driving simulation considering kinematics of vehicle and water resistance (vehicle model : FHWA/NHTSA National Crash Analysis Center)

1. The acceleration and vibration of the engine and rotational velocity change of the gears are computed using MBD analysis
2. The oil behavior is computed using MBD-fluid co-simulation considering the motion of the engine and the gears automatically.

The second example is the simulation of a transmission chain mechanism where a complex interaction of the chain and oil arises in the mechanism. Splashing and dripping of the lubricant caused by shaking and loosening of the chain are shown in Fig.6. In this simulation, the loosening of the chain caused by the lubricant is also treated in the simulation.

MBD-fluid co-simulation capability also supports parallel computing and it enables the computation of a large sized model, like vehicle driving simulation on the waterway (Fig.7). The body of the vehicle driving on the waterway is affected by the resistance force and the buoyancy and the posture of the body changes. In this example model, the suspension mechanism is modelled and the change of the body can be realistically reproduced in MBD analysis. In such simulation, wetting of important devices, volume and flow pass of water flowing into the vehicle body can be predicted.

Conclusions
There are many problems in which the interaction of structure and fluid should be considered in the development of industrial products. These are multi-physics problems involving structural and fluid kinematics, and typically requires a complex interface and special numerical procedure to solve them. In this article, an easy-to-use and seamless MBD-fluid co-simulation technique, applicable for these multi-physics problems, was introduced. This co-simulation technique allows flexibility and can be applied to many practical problems.

This article was written by Prometech Software Inc. in cooperation with FunctionBay K.K.

Sunao Tokura – Prometech Software Inc.

For RecurDyn and Particleworks inquiries:
info@enginsoft.it

modeFRONTIER 2016 Update

modeFRONTIER streamlines the design process with powerful workflows, innovative algorithms and sophisticated post processing tools. Its multidisciplinary design enabling technology, critical to successful new product development today, keeps it at the forefront of engineering technology. modeFRONTIER 2016 Update 1 - What's New?

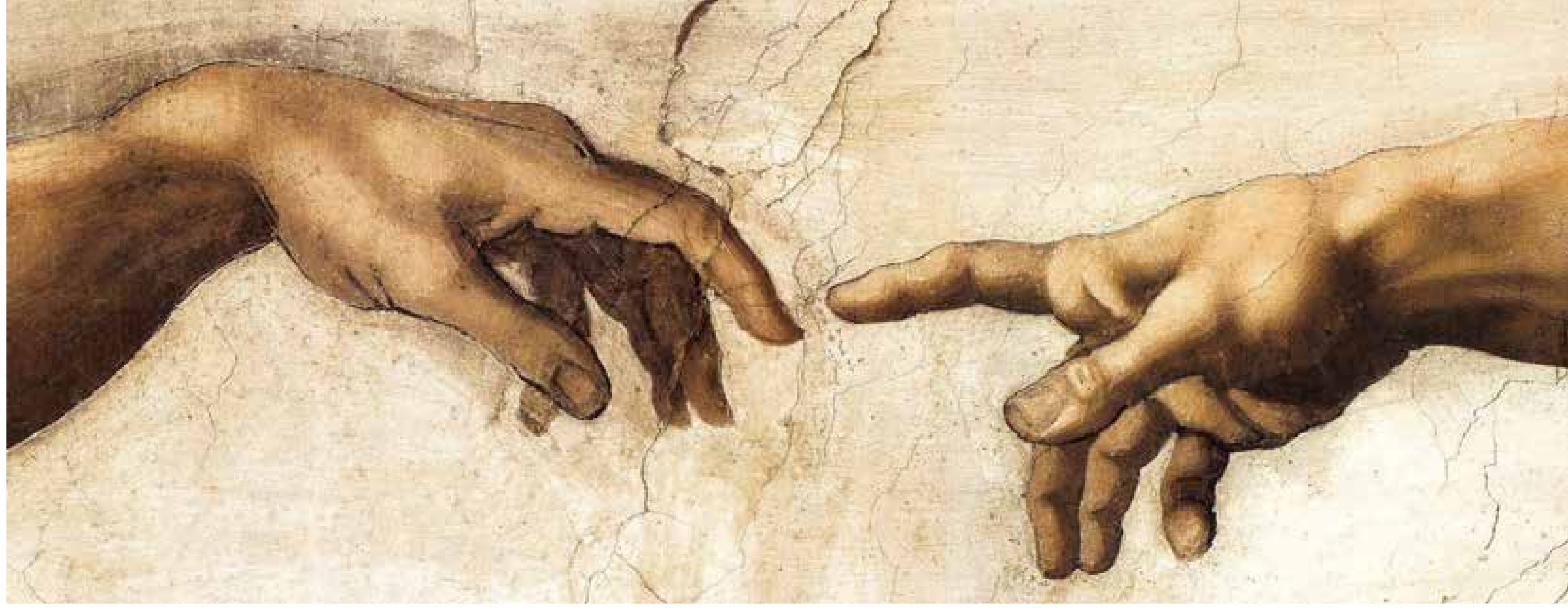
Algorithm Improvements
One-Click Optimization with MOGA-II and MOPSO
modeFRONTIER now enables you to start the optimization of your project with a single click. We have expanded our selection of One-Click Optimizers from the adaptive multi-strategy pilOPT to also include automatic single parameter setup versions of our classic algorithms MOGA-II and MOPSO.

Integration Nodes
New Integration Node - Adams/Car
We developed a new direct integration node coupling modeFRONTIER with the MSC Adams/Car dynamics and motion analysis software.

Run Analysis Improvements
New Interactive Gadget - Design Loader
This new Run Analysis gadget enables you to feed custom designs to the pilOPT optimization algorithm during the project execution, so you can actively learn from pilOPT and contribute to uncovering excellent designs in much less time.

Design Space Improvements
Sensitivity Analysis Tool Improvements
We enriched the Sensitivity Analysis with a new table which shows you at a glance the most important factors and their contributions, taking into account both main and interaction effects.

For more information: Francesco Franchini - EnginSoft
f.franchini@enginsoft.it



Product Lifecycle Quality®
Key to Zero Defect

Background
Every generation faces new technical challenges and needs to review the principles, methods, tools and workflows to ensure they meet future requirements. One way the modern generation is doing this is by embedding artificial intelligence into systems, such as:
- Industry 4.0
- Autonomous Driving
- IOT – Internet of things

requires sensitive audits of applied Methods and Tools to support functional/ legal requirements and sustainability to achieve the ultimate goal:

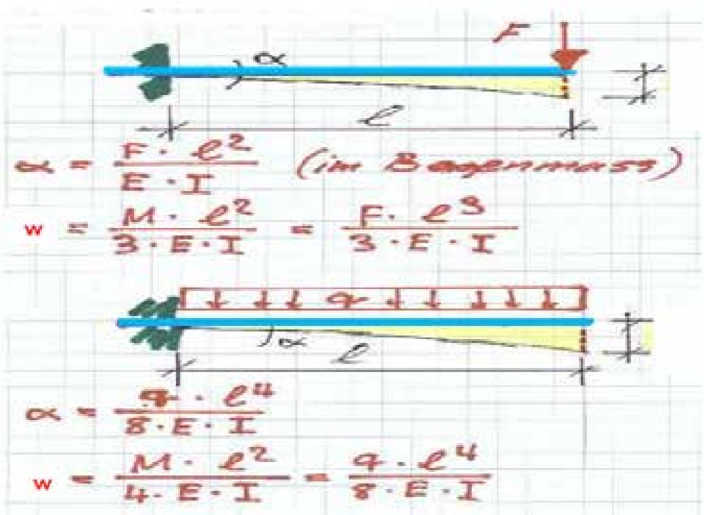
- ZERO DEFECT. 20 years history in Tolerance Management for multiple industry sectors and applications delivered the input to the Product Lifecycle Quality approach, based on the experience
- Never assume anything!

What is Product Lifecycle Quality?
Product Lifecycle Quality (PLQ) is an EnginSoft brand!
It has been registered and protected to stay unique and consistent: In the past there have been terms such as "CIM" that have been poorly specified and leave room for interpretation. The objective of PLQ is to consolidate all aspects of quality definition and associated criteria of fulfillment (measurable / measurements) in a fully documented product specific environment. By applying statistics into the early design phase to simulate the "in use effects" using multi-disciplinary optimization, PLQ delivers an early warning for critical areas of sustainability. Initially we defined PLQ as follows:
- An EnginSoft initiative to make the best use of all skills, methods and tools in providing high quality data for the full product lifecycle.
- The Target is to achieve ZERO DEFECT according to the specifications of the product.
- The Product Lifecycle Quality approach is tailored to products, based on the different functional and legal requirements and specific approvals.

How is the „PLQ“strategy structured?
Product Lifecycle Quality = 4 Layers!

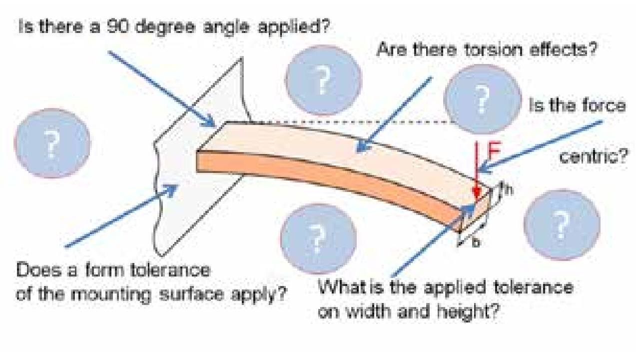
Layer 1 – Interlectual Layer
A new product starts when an idea passes the concept phase, turns into a design, is verified and then optimized to a better function or a smoother process.
Usually it is registered and protected to stay unique and consistent. In the past there have been terms – such as “CIM” – without detailed specification and a lot of space for interpretation.
The target of PLQ is to consolidate all aspects of quality definition and associated criteria of fulfillment (measurables / measurements) in a product specific environment and documentation. By applying statistics into the early design phases to simulate the “in use effects” in combination with multi-disciplinary optimization, PLQ delivers early results to drive management decisions in the direction of:

- Function
- Process
- Quality
- Maintenance
- Legal conformity



Engineering Instinct is a prerequisite to be sensitive for possible cannibalizing effects. Reducing a task to simplify or abstract a problem without communication/documentation the simplification is a high risk.

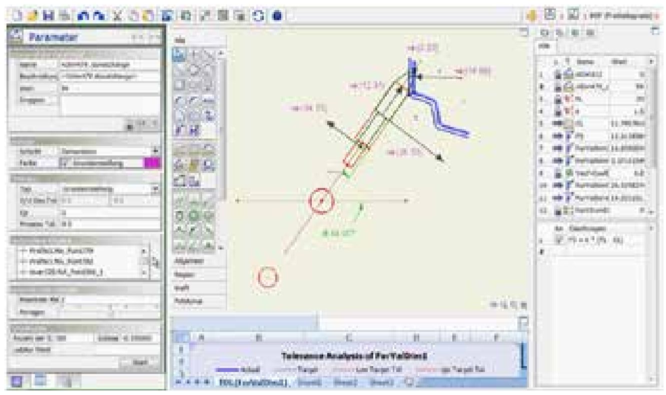
Example:
The calculation of a Beam with the input data can only be considered as an initial check of the required function – Is the layout of the beam in the target zone?
If we consider the beam as subsystem and take into consideration the corresponding environment, we identify, that there are multiple inputs to be verified or taken into consideration:
The bending beam is one of the elementary Design elements in Micro Engineering:



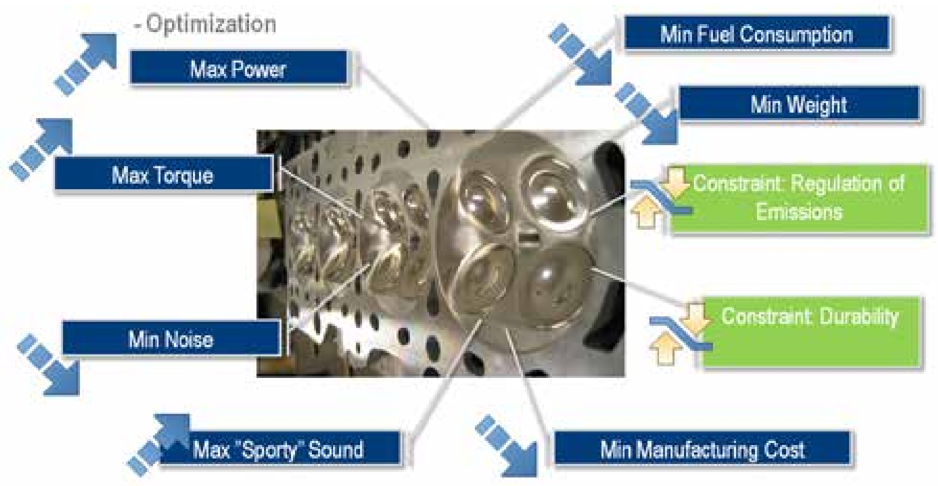
- JOINT / SPRING in Microvalves
- ACCELERATION SENSORS
- GYRO SENSORS
- NON-RETURN VALVES
- ACTUATOR PATTERN
- PIEZO
- BIMETALL

Engineering instinct is also a driver for better engineering solutions!
Comparing “coil springs” vs. “torsion springs” in their specifics shows dedicated advantages for the Torsion spring in multiple applications. The volume of material is one on the advantages.
Take this into consideration in the initial layout, supports a better product from the early beginning.
Engineering Instinct has to be complemented by Engineering skills; basic engineering know how is mandatory to be ready for a proper interpretation of simulation results!
The prerequisite for a proper interpretation and proof of simulation results is the intellectual capability to “pre-calculate” the simulation – in principle… (Do the results make sense?).This supports a proof of concept in the early design phase, where decisions for changes in the project are possible -and acceptable. The result will lead to a Robust Design.

Layer 2 – Method Layer
To standardize the workflow into a reliable and reproducible Methodology proper documentation is required. This can be done by a checklist to prove / verify the operational activities with respect to the Product / Process specification.
Historical methods like Systems Engineering started to implement a kind of Method Layer.
The complexity of actual products and the future project demands like distributed engineering processes, Multiphysics, including flexible production aspects (Industry 4.0) requires a just-in-time documentation to monitor and track the actual project status in a communicative way to avoid parasitic effects.
Templates are required to catch the various data types, synchronize them with the product specification and production requirements. These Templates will be adjusted to the different needs of the application requirements to support a “Best in Class” strategy.
The “Green Book” will carry the product development history, the production requirements and track the quality status and data to deliver the input for a predictive Maintenance process.
Symbol based languages – i.e. GD&T – are used to support dialect free communication and minimize interpretation gaps.



Layer 3 – Tool Layer
Historically there was a plain sheet that collected the ideas, transferred it into a concept, followed by a layout that ultimately ended in a design. This chronology was accompanied by sketches, a formula based basic calculations and 2-D simulation.
Today the engineering workflow starts with a “3D CAD start model”, which creates the topology and hands it over to simulate the design vs. the specifications.
The required input for simulation is much higher and the effort out of balance with respect to the early design phase.
A cascaded strategy starting with calculation followed by simulation balances the effort to the results.
Actually most of the simulation domains rely on the CAD nominal model. Effects like statistics for the manufacturing / production process or wear-out (by use) or fatigue effects are in most workflows not on the “engineering radar screen”. To execute multiple (single domain) simulations in a combination cannibalizes accuracy of the results.
A pragmatic strategy is a chronology of Calculation followed by Simulation and consolidated into Optimization.
EnginSoft is working on multiple projects to implement the PLQ strategy for various applications to support the introduction of statistical effects with the objective to manage the Product Lifecycle with respect to Quality.
Part of this is the inclusion of Tolerances in the Simulations via modeFRONTIER.



This strategy supports Projects that have to deliver solutions for conflicting criteria.
Feasibility is checked on the lowest possible level, lifecycle aspects are monitored and considered in the optimization process as a dedicated criteria of fulfillment.

Layer 4 – Check Layer
The Check Layer manages Specifications, Definitions and Measurements.
Checking starts with a general specification, which is detailed by measurable criteria to manage “Quality gateways” in the Product Development and Production cycle.
Wear-out can be mapped versus the spec to support predictive Maintenance plans.
With the parameter history documented in the “Green Book” the measurements -the product specific criteria of fulfillment-are transparent and individual to the application or (legal) specifications to the various markets.

Appendix – Green Book
The “green book” is a collection of product relevant parameters, specifications, calculations, simulation input, simulation results, Description of Quality relevant Engineering / Production changes as well as criteria of fulfillment to guarantee the proper function (Quality) of the product. The plan is to set it up a workbench that consolidates and crosschecks the important information. We are actually benchmarking software tools to use as Green Book platform.

Dipl.-Ing. Conrad F. Toepfer - EnginSoft
c.toepfer@enginsoft.com

MapleSim user case study:
A parametric approach to designing an industrial pick-and-place robot

Figure 1 - Design of a 3-link pick-and-place robot arm

Challenge
A leading provider of packaging machines wanted to design a pick-and-place robot to be incorporated into a new packaging machine.

Solution
The company chose Maplesoft to develop a high-fidelity parameterized model of the robot. Using MapleSim, the company simulated the robot's design and used Maple to develop the analysis tools needed to optimize performance of the robot.

Result
Not only was the company able to create a fully optimized pick-and-place robot for its intended use, the company realized that by modifying the parameters, Maplesoft's model and analysis tools could be used to optimize the designs of any other pick-and-place robots the company develops in the future.

Case study description
Industrial automation is on the rise, with machines performing more and more tasks every day. Designing these complex industrial machines is a challenging process. Engineers need to ensure that the machine they design meets many different performance objectives, for productivity, workspace, maneuverability, payload, and so on. But at the same time, they also need to develop a design that will minimize both production and maintenance costs, such as using the smallest possible motors and the shortest links for robot arms, and minimizing loading to reduce the wear and tear that leads to expensive repairs and downtime. All these requirements must be taken into account when developing an industrial machine to ensure a high-performing product at the lowest possible cost.
A leading provider of packaging machines wanted answers to questions about the design of their new product, including:

- What is the proper motor sizing for the robot?
- What lengths should the links be to achieve the desired workspace?
- What effect will different combinations of link lengths have on the design?
- What will be the required performance from the motor and gearbox be?

A parametric physical modeling approach was applied to answer these questions. MapleSim, the multi-domain system-level modeling and simulation platform, was used to develop a high-fidelity parameterized model of the desired robot type. Then the advanced computation capabilities of Maple were exploited to develop analysis tools to examine the operation of the system and its dynamic behavior with different sets of parameter values. These analysis tools, together with the high-fidelity model, provided the client with the insight required to determine how to optimize their design, and provided them with a toolset they could easily configure for use in the design of similar products.

Model Development using MapleSim
The robot model is mounted on a reference base, to which three links that form the robot arm are connected. The links are actuated by three servo motors, which provide the rotational motion and control with three degrees of freedom. The end effector consists of a translational component attached to the third link, allowing for the desired pick-and-place action.

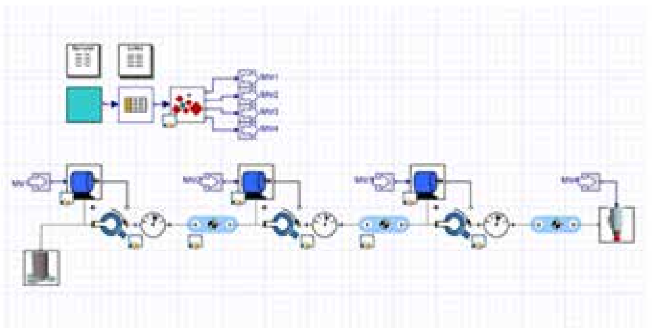


Figure 2 - Model schematic of the system

Each of the link structures includes sensor components to provide force and torque information, which can later be used to determine radial force, axial force, and bending moment at each bearing. The model also includes numerous probes embedded at strategic locations within the design, to monitor performance characteristics such as required motor speed and torque, along with joint angle and constraints.
Initial simulations were run in MapleSim, to observe the behavior of the system, with the probe information presented in various plots. (Fig. 3).

Design Analysis using Maple
After a first analysis of the system was performed in MapleSim, the model was loaded into Maple for in-depth analysis: a set of analysis tools were developed in Maple, to provide the client with insight into the different areas of their design that will help them make design decisions for the final product. Taking advantage of the fully parametric nature of the high-fidelity model developed using MapleSim, and Maple's symbolic computation engine, the tools enabled the client to perform multiple iterations of simulations to determine the best combinations of parameters. The first design tool enabled the client to perform a kinematic analysis. The kinematic analysis allowed them to check the robot's workspace, visualize its motion, and determine any path offsets if required. The robot's motion is affected by whether the robot's elbow is configured to be on the right side or the left side. One of the features of the kinematic analysis tool was to perform the inverse kinematics calculations, and evaluate for both elbow positions. By observing its behavior in both cases, the client was able to make an informed decision about which side to place the elbow – a decision which was then carried forward and applied to all further analyses.

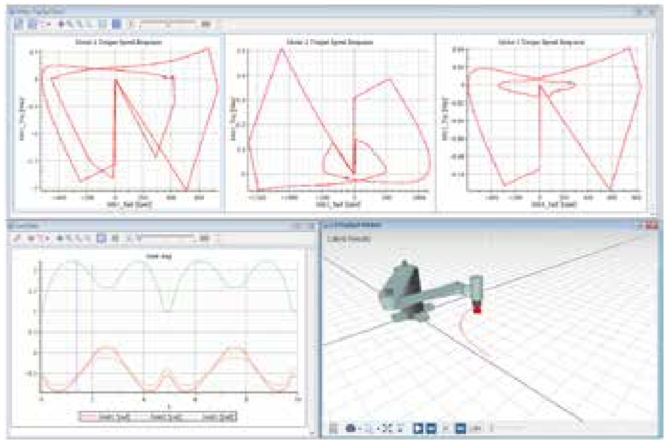


Figure 3 - System behavior insights from MapleSim

The next step was to determine whether the robot was operating within the range of allowable motion, and whether any of the joint angles were exceeding the desired limit.
For each joint, multiple variables including joint angle, angular velocity, and angular acceleration were determined, based on the desired path of the end effector motion. The results showed that the initial end effector design path resulted in large angular acceleration spikes, indicating that the client needed to make some modifications in order to smooth out the motion used to actuate the joints. The adjustment would not only decrease the magnitude of the acceleration spikes, but would also result in a reduced joint load, and reduced motor/bearing operating requirements.

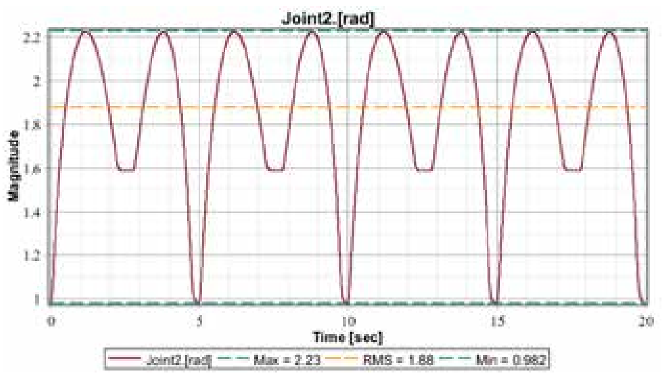


Figura 4 - Joint analysis in Maple

While the client naturally wanted to use the smallest motors possible, they also had to ensure that the motors selected would still meet the robot's performance goals. An analysis tool to assist the client with motor sizing was then developed. The speed, torque, and energy of the motors were determined and plotted, then overlaid onto the manufacturer's performance curves for the targeted motors. The motor performance curves were selected from a list of possible motor data imported into Maple. For each of the motors, the client could then compare simulated results with the data for different motors from the manufacturer's specifications. Using the analysis tool, the client was able to consider different motor configurations capable of performing within the desired range. A similar approach of overlaying the manufacturer's data on simulated data was taken to explore the gearbox limits and the selection of different gear ratios.
Another analysis tool developed for the client was a parameter sweep to observe the effects of different link lengths on the operation of the robot. Simulating the model with different link length configurations within a pre-determined permissible range enabled the client to observe the corresponding effects on performance characteristics such as motor speed, torque, load requirements, and workspace variations. Maple automatically makes use of parallel processing, allowing the user's computer to simultaneously run multiple simulations using different parameter values, and then presents the results overlaid in a visualization window for quick and easy comparison (Figure 5).
Using these, and numerous other tools developed for other specific purposes, the client was able to apply a comprehensive approach to analyzing their design decisions, and arrived at an ideal design for their industrial pick-and-place robot.

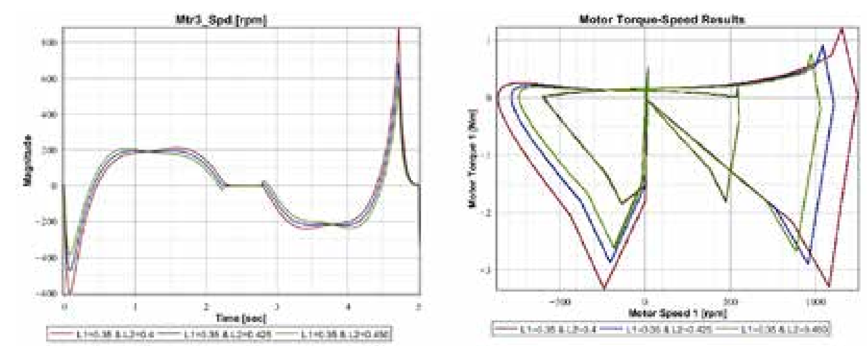


Figure 5 - Example parameter sweep results for varying link lengths

Summary
A highly configurable solution that helped the client address the challenges they were facing when designing industrial pick-and-place robots was developed. Developing a fully parametric system model in MapleSim provided access to all the system parameters required to analyze and optimize the behavior of the system. Maple's symbolic computation engine enabled the development of a wealth of analysis tools that explored the relationships between system parameters, and their effects on the overall performance. This parametric approach meant that not only was the packaging company able to make informed design choices and arrive at the optimum configuration for their targeted application, but that they could reuse the same tools in other contexts. By modifying the parameters, they can use the same model and analysis tools to optimize and validate the designs of other pick-and-place robot products they develop in the future.

For more information: Filippo Furlan, EnginSoft
f.furlan@enginsoft.it

Smart Engineering Simulation Apps

Democratization of numerical simulation through the development and dissemination of expert-designed Smart Engineering Simulation Apps is gaining momentum; however to ensure the level of reliability expected in professional practice, such apps must incorporate solution verification which is an essential technical requirement of Simulation Governance.

What are Smart Engineering Simulation Apps?

Smart Engineering Simulation Apps (Sim Apps) are FEA-based software tools that support standardization and automation of recurring analysis tasks and process workflows for use by non-specialists. They are designed to fit into existing analysis processes, capturing institutional knowledge, best practices and design rules. An example is the aircraft structural bolted joint shown in Figure 1.
Sim Apps can be used and shared by engineering groups in different geographic locations to produce consistent results by tested and

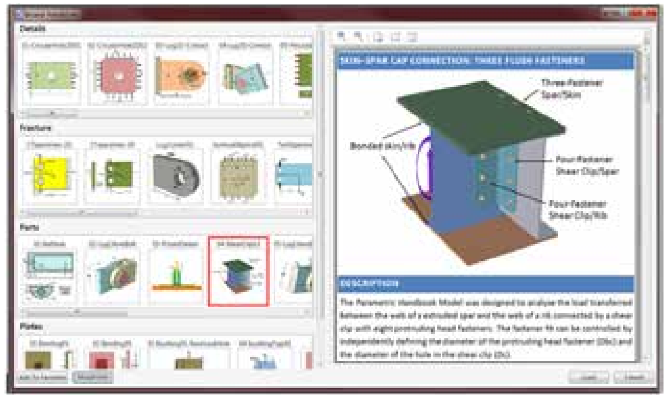


Figure 1 - Sim App example: Parametric model of an aircraft structural bolted joint

approved analysis procedures, regardless of the level of expertise and experience of the user. When they meet the technical requirements of Simulation Governance, Sim Apps are "smart" in the sense that their embedded intelligence enables Simple, Accurate, Fast, Efficient, and Reliable (SAFER) simulations with built-in quality assurance.

Why Simulation Governance?

Simulation Governance is a managerial function concerned with the exercise of command and control over all aspects of numerical simulation through the establishment of processes for the systematic improvement of the tools of engineering-decision-making over time. The key elements of simulation governance are Verification, Validation and Uncertainty Quantification (VVUQ).
Verification is concerned with the accuracy of the numerical solution of mathematical models and encompasses code verification, data verification and solution verification. Whereas code verification is the responsibility of the code developer, data verification and solution verification are among the responsibilities of the users. In the application of established design rules, data verification and solution verification are essential; the goal is to ensure that the data is used properly and the numerical errors in the quantities of interest are reasonably small. Given the growing reliance of simulation-driven design early in the product development cycle, it is simply no longer sufficient to neglect solution verification and only perform validation late in the cycle during physical testing or prototyping.
Engineering simulation apps for standardizing recurrent analysis processes must be developed under the framework of Simulation Governance for users who do not have FEA expertise; they must possess built-in safeguards to prevent use outside of the range of parameters for which they were designed; must incorporate automatic quality assurance procedures; and must be deployed with detailed description of all assumptions incorporated in the mathematical model and the scope of application. Estimation of relative errors in the quantities of interest is an essential technical requirement of Simulation Governance.
One argument often used to justify the lack of error estimation is that rules established by the experts are sufficient, and that the "user can always consult with an expert if the results are wrong". The problem with this argument is that if the assessment of the quality of a solution depends on the subjective opinion of the expert analyst, the same expert opinion is needed to determine when the solution is wrong. A non-expert user is not qualified to make that determination. Having an automatic solution verification feedback for all the quantities of interest however, allows non-expert users to consult with experts when the computed data does not converge to within the prescribed tolerance. Engineering simulation apps should not be deployed without objective measures of quality for all quantities of interest.

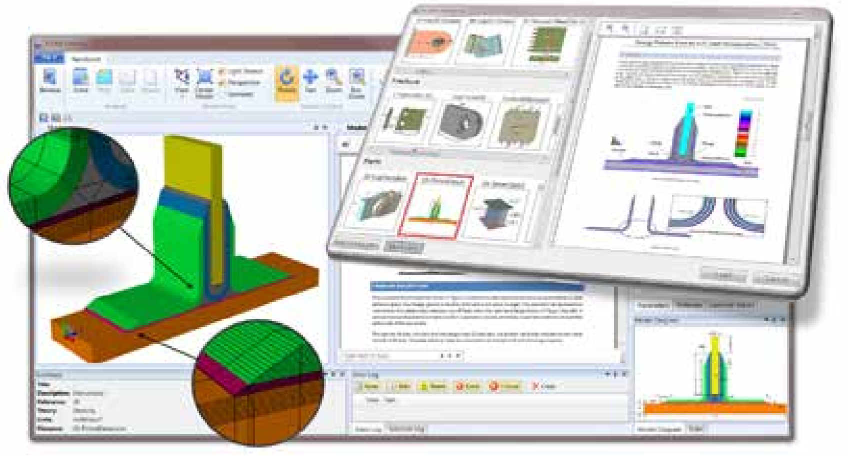


Figure 2 - CAE-Handbook hosting a portfolio of Sim Apps

Why use Simulation Apps?

Proper application of numerical simulation procedures requires expertise in computational engineering that is not widely or readily available. Standardization deployed by means of Smart Sim Apps can leverage this expertise for recurring analysis tasks and process workflows similar to the expertise of specialists in applied mechanics made available through classical engineering handbooks.
Because classical handbooks present results for parameterized problems solved by classical methods, they have limitations in model complexity and scope. FEA-based Smart Sim Apps developed by expert analysts on the other hand deploy verifiable solutions obtained by numerical means allowing models of much greater complexity to be deployed for users who do not need to have the same level of expertise in numerical simulation technology. Thus design engineers earlier in the cycle may begin to harness the power of simulation with less technical risk and greater confidence.

What are the benefits of using Simulation Apps?

The benefits include: (a) making difficult classes of simulation problems easier, faster, and more accurate to solve by the specialist to support increasing complexity of products and the demands of shorter design cycles, (b) making routine design analysis problems solvable by designers and engineers as they did for years when relying on handbooks and design curves produced by methods groups, and (c) empowering new engineers to become productive sooner by providing access to reliable tools that have captured institutional knowledge and best practices of the organization.
An example of Sim App implementation is the portfolio of Simulation Apps shown in Figure 2. The user can examine each model by clicking on an icon on the left panel of the browser while the corresponding detailed information is being displayed on the panel on the right. For each app in the portfolio a simple 3-step operation is required to obtain results: Select – Update – Solve.

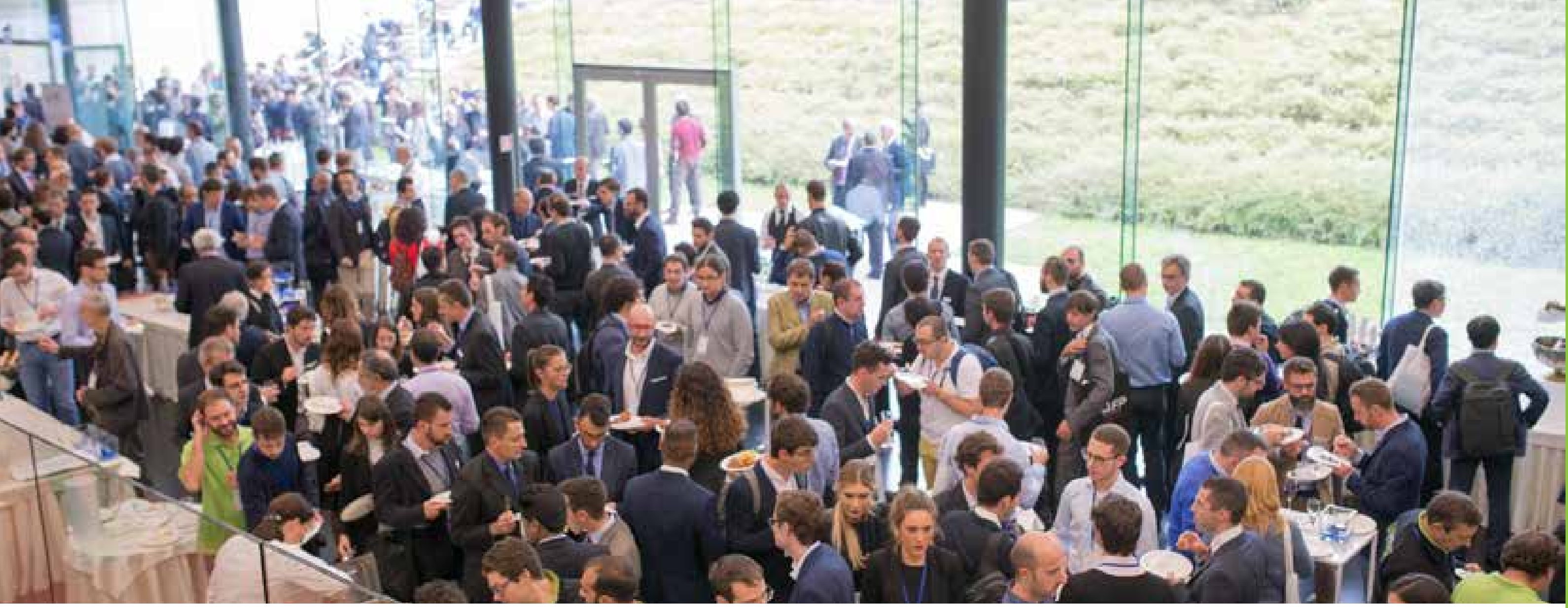
Once a Sim App model has been selected, it is loaded into the user interface of the host program, in this case the CAE-Handbook shown in the figure. The user can update the model by modifying the parameters available for changing dimensions, magnitude and direction of loads, material properties, laminate ply layout, and any other attributes exposed by the Sim App model creator. The e-Handbook checks for consistency of the input parameters and warns the user if any rules were violated. The rules governing the relation among parameters are available for review by the user at any time.
Once the input parameters are entered and verified the user simply performs a pre-defined solution and the results are presented in the form of a report, contour plots and convergence information.
While the above process looks straightforward to implement, it is not. There are numerous challenges with employing traditional finite element analysis tools that will be addressed in a future article on the technical requirements for robust and reliable Sim Apps.

Concluding Remarks

FEA-based Smart Engineering Sim Apps are software tools that standardize and automate recurring analysis tasks for use by non-experts. They are designed to fit into existing analysis processes that capture institutional knowledge, best practices and design rules.
Since the finite element method is a numerical procedure to find an approximate solution of a mathematical model, extreme care must be given to any simulation tool which may be employed by a non-expert. Automating simulation without providing the user with an explicit, objective measurement of the quality of the approximate solution is simply dangerous.
When Sim Apps are designed within the framework of Simulation Governance, they are "smart" because their embedded intelligence enables simple, accurate, fast, efficient, and reliable (SAFER) simulations with built-in quality assurance.

Ricardo Actis, CEO
Engineering Software Research & Development, Inc.

For more information: Luca Marcadent, EnginSoft
l.marcadent@enginsoft.it



International CAE Conference
in the Industry 4.0 Era

Parma, 18th October 2016
The 32nd edition of the International CAE Conference has just drawn to a close at Paganini Congressi in Parma, providing once more an extraordinary focus on the culture of technology and numerical simulation. Many representatives from worldwide have been the protagonists of this event, which has brought together company leaders, academic researchers and scholars of the most advanced public and private labs and the major experts in the world of simulation.

Stefano Odorizzi, Scientific Director of the International Conference, also a researcher and lecturer at the University of Padova, and the CEO and cofounder of EnginSoft, stated: "Thirty years ago, applying simulation to product and process development belonged to a small community. Today, thirty years later, this event mirrors how CAE technologies have become necessary and widely extended to all sectors of life, becoming the essential engine for the development and innovation of products, processes and services in every field: from aircraft to construction, from transportation to energy, to healthcare. Today it is fundamental and inseparable of Industry 4.0".
Odorizzi's words have been supported by the numbers of the event: more than a thousand congress delegates coming from all over the world, with a 15% increase in participants in comparison with previous editions, over 150 speakers in the thematic sessions, more than 50 booths in the exhibition area and "Research Agora" of R&D Projects and studies showcasing the latest news and results from forefront research achieved thanks to the use of simulation.
The two plenary sessions could count on distinguished experts such as Akin Keskin, engineer of Rolls-Royce, and Giovanni Andrea Prodi from the University of Trento.
The research group of Professor Prodi, working on the Italian "Virgo Project", has been the first, in the world, able to record the gravitational waves hypothesized by Einstein and to prove their existence. "A true revolution - the professor said - that has given humanity a new sense of perception of the universe".
In addition, of great importance was the participation of Professor Alberto Broggi, the pioneer in studies of autonomous vehicles, and founder of VisLab, a spinoff from the University of Parma, ceded in 2015 for 30 million dollars to the Americans. The creation of a fully Italian autonomous car began well before Google: "We started not just before - Broggi stated – but much much earlier. In the nineties, when I built the first prototype in Turin, Google did not even exist". And he assured that "…it won't take long before seeing these cars on our roads and highways".
It is also worth mentioning, among the guests, the participation of Alessandro Catanzano of Cimolai, located in Pordenone, as contributor for the fabrication of one of the greatest work in civil engineering of this century: the doubling of the Panama Channel, which opened in June. Cimolai worked with Salini Impregilo to produce the 16 water proof large sliding gates, manufactured in steel and then welded, 33 meters high, 10 meters wide and 58 meters long with over 4 thousand tons of weight. They are necessary to control the water flow to the lifting basins for big ships during transit.

The ICC is not only the place where scientists come together to share experiences. The 2016 edition has also hosted two side events intimately linked to the role of numerical simulation results, confirming its usefulness especially now at the dawn of the Internet of Things and Industry 4.0.
A session of lectures with a final debate has been dedicated to seismic topics; a relevant issue, not just after the recent sad events happened in central Italy, but also considering the earthquakes that damaged and shocked the Emilia Romagna region few years ago.
Such presentations have been enriched by one of the five winning projects prized at the Poster Award competition, which has been reserved for students, doctoral students, researchers and/or teachers of universities and research centres to show the best ideas and applications of simulation. Its authors have elaborated a numerical model that, by exploiting the principles of tomography also used in medicine, is able to produce three-dimensional models of buildings, highlighting their vulnerability and their critical points and allowing targeted anti-seismic consolidation.
The further initiative, embraced by the conference, was a Round Table aimed to focus, more than ever, on the importance of the aggregation among companies, R&D Centres and Universities.
In an increasingly global market, where technological innovations push and enable products and services with increasing complexity, companies are facing new competitive challenges, forcing a radical change in their strategies and even in their business models.
Such competitive challenges affect not only the final product, but also the capability of producing it at a low cost, with ever-increasing requests for functional flexibility (Intelligent Factory, Industry 4.0, Smart Manufacturing, etc.).
In a Global Market, individual companies and above all SMEs (90% of the Italian industries) would not be able to sustain the demands for innovative products and services that require a new business approach. Hence is it clear how the same competitiveness of the Italian system depends on the ability of these companies to understand that competitiveness is no longer related to neighbourhood, but it's a global matter (with more opportunities if you know how to grasp them…) and that it is not only appropriate, but necessary, to try to cluster and work as a system with Research Centres and Universities.

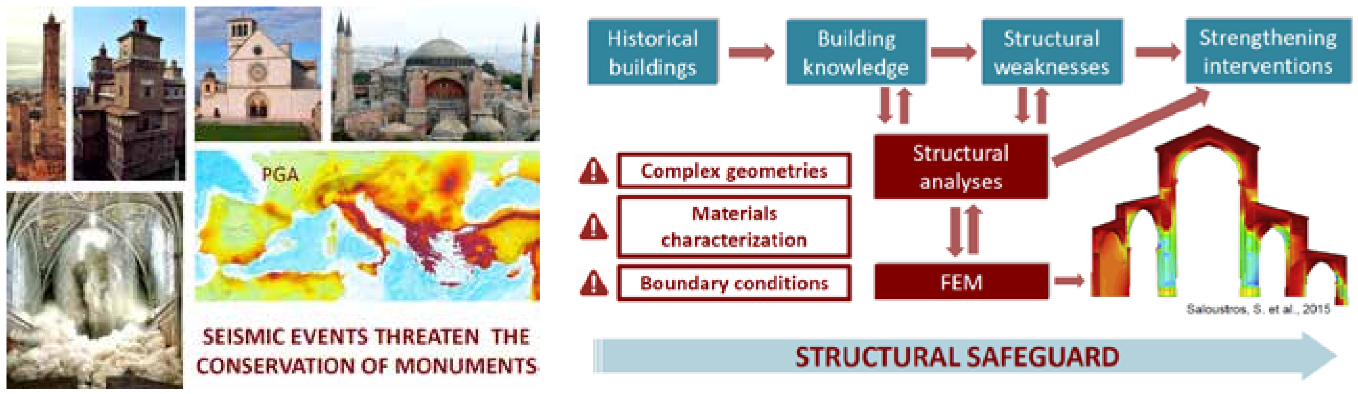
Through the evidence of professionals and managers with leading roles in public and private governance enterprises and with over 80 managers and executives in the room, this initiative was probably the best opportunity to clearly understand features and differences among the different type of aggregations which are officially recognized and financially sustained by the Italian government and by the EU commission.
www.caeconference.com

The Successful fifth edition of the International CAE Poster Award
A prize to the creativity and innovation of young researchers

The fifth edition of "International CAE Poster Award " came to an end with the proclamation of the winners and the delivering of the prize during the award ceremony which took place on October 17th at Paganini Congress Centre in Parma. The award, announced by EnginSoft and supported by the sponsorship of ESTECO, was dedicated to the dissemination of the scientific culture and aimed at creating new opportunities for talented young researchers. The poster award session was planned at the end of the first day of the International CAE Conference, a yearly appointment about "Simulation based Engineering and Sciences", and was presented by Luca Viscardi, well-known radio presenter with the participation of two forerunners of the virtual simulation world: Stefano Odorizzi, CEO of EnginSoft and professor at University of Padova, and Enrico Nobile, founding partner of ESTECO and professor at University of Trieste. Both of them expressed great satisfaction for the growing success of this initiative along the five editions and underlined, on behalf of the Scientific Commission, the quality and originality of the presented works. Among the several presented projects, 52 posters were selected, uploaded for consultation in Poster Award section of the Conference official web-site.
The 5 winning projects and the special mention are presented in the next pages.
For further details about this initiative, please refer to www.caeconference.com, Poster Award section, or contact posteraward@enginsoft.com

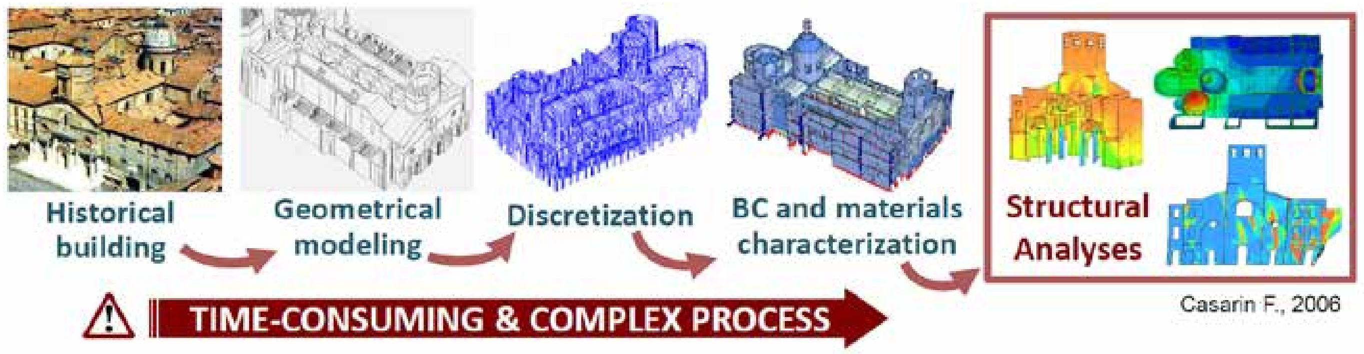
Advanced Numerical Modeling of Historical Monumental Buildings

Conservation of Historical Buildings



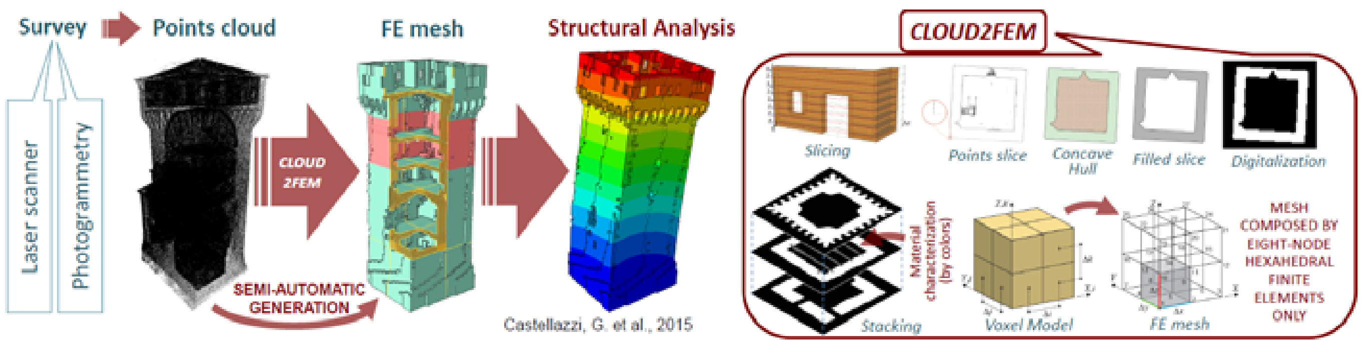
Numerical Modeling: Traditional Approach

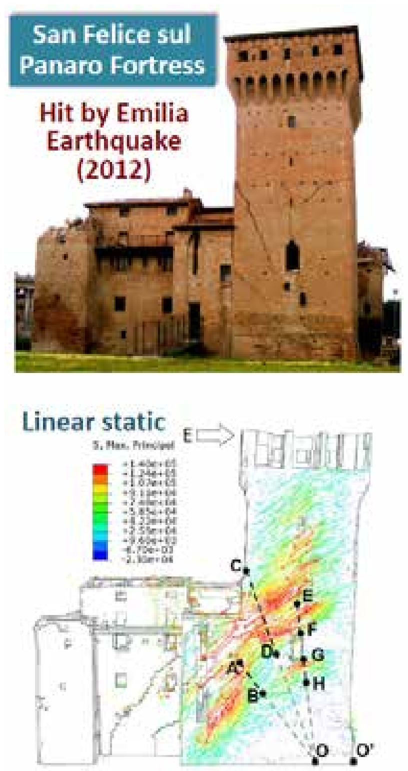
The numerical modeling of historical monumental buildings is a challenging task for contemporary civil engineers. One of the main reasons for this is that, due to the complex geometry of such historic structures, the use of traditional simplified structural schemes is inadequate. Thereby, it is unavoidable to resort to a fully 3D modeling that often is performed using the CAD. In general, CAD based modeling is an expensive and complex process, often manually carried out by the user, which inevitably leads to the introduction of geometric simplifications (Defeaturing) or interpretations.



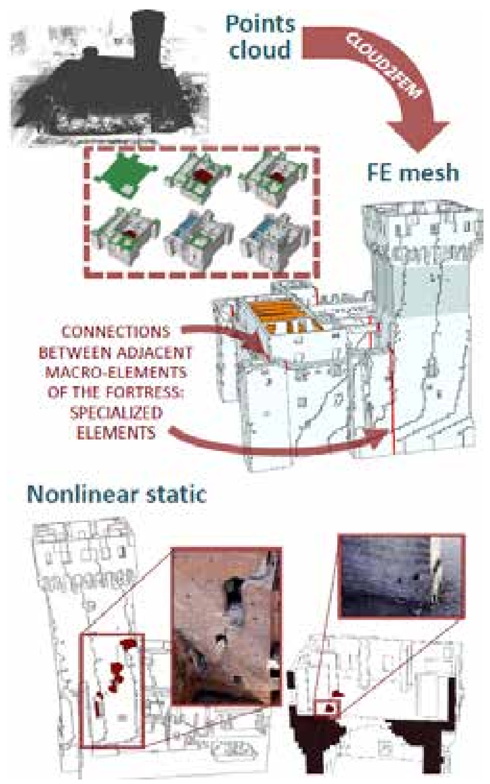
A new Numerical Modeling Strategy

A semi-automatic method (CLOUD2FEM) to transform 3D point clouds of complex objects to 3D finite element models has been developed and validated. The procedure constructs a fine discretized geometry with a reduced amount of time and ready to be used with structural analysis: the resulting finite element model accurately capture the whole 3D structure, producing a complex solid made by voxel elements.





Comparison between linear static analysis results relative to a East directed force and the crack pattern suffered by the structure during the Emilia Earthquake, South front. Segments AB, CD, EF and GH correspond to the major cracks.



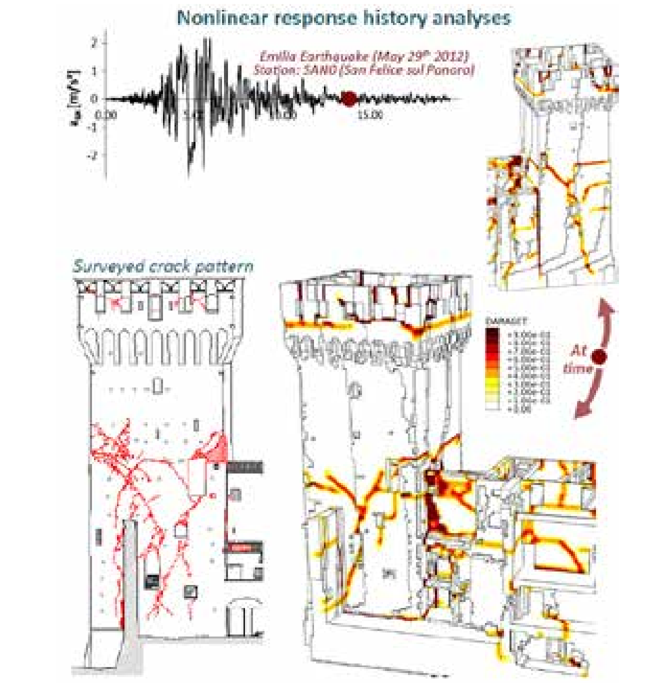
Nonlinear static analysis for a horizontal East directed force, North front. The computed damaged zones are highlighted in red.

A Case Study: The San Felice sul Panaro (MO) Fortress

In order to show the potential of the proposed strategy, the application to the case study of the San Felice sul Panaro (Italy) fortress, hit by the Emilia earthquake in 2012, has been performed. This application aims at validating the numerical strategy according to the requirements of the Italian standards and guidelines about monumental historical buildings.

Several linear and nonlinear static analyses under vertical and horizontal loads, as well as several nonlinear Response History Analyses (RHA) using natural accelerograms have been performed. Much attention has been paid to the modeling of the connections between adjacent macro-elements of the fortress. A comparison between structural analyses results and the crack pattern experienced by the structure during the Emilia Earthquake has been carried out.

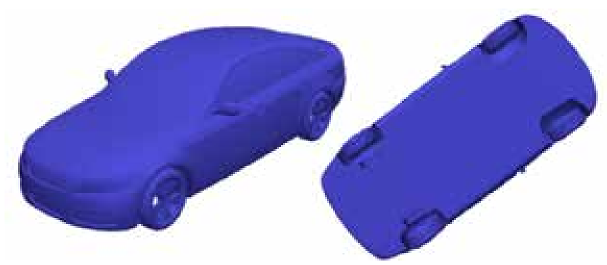
Giovanni Catellazzi, Antonio Maria D'Altri, Stefano De Miranda
– School of Engineering and Architecture, University of Bologna, DICAM Dept. of Civil, Chemical, Environmental and materials Engineering



Constitutive model: Concrete Damage Plasticity (Lee, J. et al, 1998). Analysis type: Dynamic Explicit (Abaqus© 6.11). Plots refer to the tensile damage variable (DAMAGET).

Shape Optimization and CFD RANS Codes: an Adjoint-based Strategy for Drag Reduction in Automotive Applications

Introduction
Looking at the evolving technology trends in CFD-based shape optimization chains, there is a strong request for robust and flexible Adjoint Optimization based solutions. In external aerodynamics shape optimization the most convenient approach relies on the use of some aerodynamics indices as targets (drag for instance). The overall desired effect is to improve aerodynamic efficiency (drag reduction) using the outcomes of an Adjoint CFD RANS simulation to drive the CAD morphing.



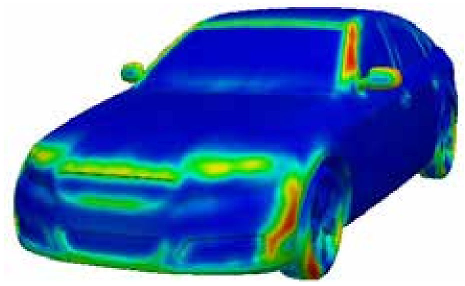
Baseline CAD Definition

Main Targets of the Project
For these reasons, within a Master Thesis, an Adjoint Solver for turbulent external aerodynamics prob-lems has been developed in the open-source CFD Toolbox (OpenFOAM). The main target is to perfrom a single shot. Adjoint CFD computation and verify to which extent Drag re-duction is obtainable.

CAD Definition and Problem selection
As a first application we applied the developed solver to a well-established automotive problem: the 3D DrivAer car model given by TUM.

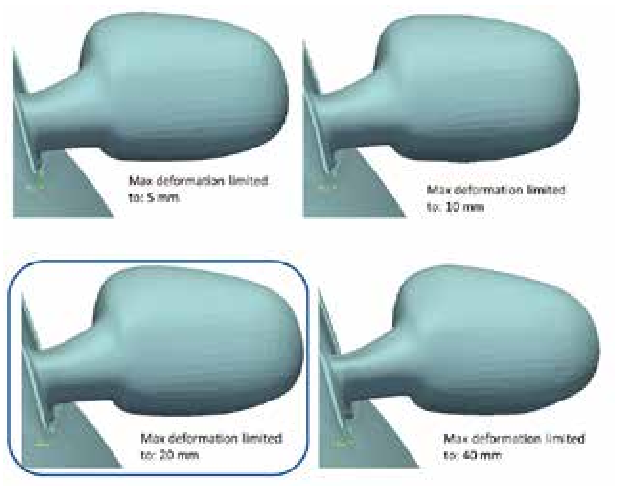
Baseline CFD
The baseline CFD simulation is performed using the CAD definition provided keeping the wheel as fixed as the floor. The velocity of the car is set to 58 km/h and all other physical parameters are related to air at reference conditions. The solver is a steady-state RANS with a k-omegaSST turbulence model.

Adjoint RANS CFD
The outcomes of the baseline CFD solution are used as input to the Adjoint RANS solver. The solver is tailored developed to compute the sensitivity of the whole CAD with the respect to drag changes. The outcome of the adjoint solver is a sensitivity map of the whole car surface points. Red/Blue areas indicates points that should be moved inward/outward to the car surface to reduce drag value. The maximum deformation is a free parameter that designers can tune to obtain a desired morphing of the CAD.



Whole CAD Drag Sensitivity Map
Blue/Red means inward/outward normal deformation

Baseline Design



CAD Deformation According to Drag Sensitivity Map

New Design CFD
The New CAD Design is obtained applying a max deformation of 20 mm starting from the baseline CAD. The New Design CFD simulation is performed using the same settings used for the baseline CFD. The drag reduction obtained is more than 5%.

Discussion&Conclusion
The application presented herein shows how a more than 5% drag reduction can be obtained in a single shot adjoint-driven shape optimization for a state of the art automotive CAD definition. This is a relevant result that could be exploited introducing an optimization engine to drive an optimization loop. The workflow is built on top of an existing HPC platform and is therefore suitable to be exploited on more demanding CFD problems.

Leonardo Palma, Roberto Pieri, Maurizio Quadrio
Politecnico di Milano

Raffaele Ponzini
CINECA

New Design

Innovation under the spotlight

Research Agorà, Parma, Italy | 17th - 18th October

The Research Agorà, brought together another amazing assortment of the most innovative research projects, developed through outstanding international partnerships.
The importance of research projects and collaboration is recognized with the €77 billion European investment in Horizon 2020 which is the biggest EU research and innovation funding program ever, spanning seven years (2014 to 2020).
Horizon 2020 has been designed to open up European research and innovation, by attracting more SMEs, ensuring better use of research results and strengthening research cooperation with other countries.This fittingly reflects the Research Agorà, where projects are given the means to showcase the latest cutting-edge achievements in Europe.
For the fourth year, the Research Agorà provided a platform for innovative materials and nanostructures, additive manufacturing, brain-inspired computing, aeronautical morphed configurations, manufacturing intelligence and exascale-level supercomputers, these are just some of the cutting edge topics represented this year.

The Research Agorà held as part of the International CAE Conference facilitated Project delegates with the exclusive opportunity to highlight their research results to a global influential audience and the occasion to meet a variety of interested business stakeholders and business managers.

Visit http://www.caeconference.com/researchagora.html to see an overview of the projects.
Why not find out how to be part of the Research Agorà in 2017, contact info@caeconference.com
or stay tuned on http://www.caeconference.com/researchagora.html
For more information: Carla Baldasso, EnginSoft – c.baldasso@enginsoft.it

Computational Analysis of the Fluid Dynamics and Drug Delivery Inside the Posterior Chamber of the Eye in Case of Saccadic Movements

Introduction

One of the main ocular diseases related to aging is the age-related macular degeneration (AMD), which is treated with a drug injection inside the eye. The aim of the work is to study the influence of the saccadic movements and the physiological boundary conditions on the drug distribution inside the vitreous humour in a patient affected by AMD and treated with an injection of anti-VEGF (Vascular Endothelial Growth Factor). This problem has been faced with different approaches: Stay et al, 2003 consider the influence of the tissues around the posterior chamber on the drug delivery, but neglect rotations of the eye; on the other side, Modareszadeh et al., 2013 correctly implement the saccadic movements but they don't take into account neither the presence of the anterior chamber nor the Retina-Choroid-Sclera (RCS) complex. The aim of this work is to propose a complete model of the posterior chamber that overcomes the limits of the works in literature and analyse the real impact of the saccadic motions onto the fluid dynamic and drug delivery mechanisms.

Materials and methods

The saccadic movements

The saccade is an involuntary and imperceptible movement performed by the eye during the focusing of an object. The rotation is caused by the external muscles of the eye. The single saccade has been defined by Repetto et al., 2005 as a fifth-grade polynomial:

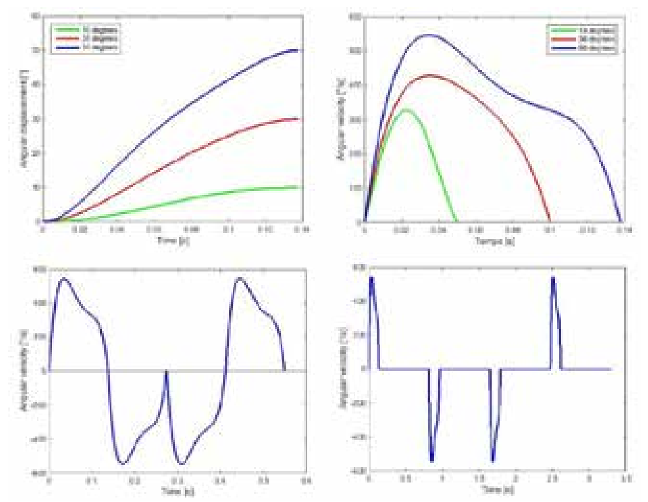


Fig.1 A) Saccadic angular displacement and velocity with different amplitudes. B) Complete cycles of the saccadic movements without and with the rest time.

$$\theta(t) = c_0 + c_1 t + c_2 t^2 + c_3 t^3 + c_4 t^4 + c_5 t^5$$

where the coefficients can be found imposing the following conditions: $\theta(0) = 0, \theta(D) = A, \dot{\theta}(0) = 0, \dot{\theta}(t_p) = \Omega_p, \theta(D) = 0$ and, $\ddot{\theta}(t_p) = 0$ where D is the period of a single saccade, A is the amplitude, tp is the instant of maximum acceleration and Ωp is the peak angular velocity. The saccade can have different amplitudes and frequencies: in this work the movements of 10°, 30° and 50° have been analysed. In order to study different frequencies, a rest time of 5D after each saccade has been added to the complete cycle. The computational analysis has been developed with the software COMSOL Multiphysics®.

Fluid dynamic analysis

The geometry of the posterior chamber is like an hemisphere with an indentation caused by the presence of the lens. The vitreous humor inside the eye is modeled as water, due to the liquefaction occurring in old people. The equations solved in the fluid dynamic model are the incompressible Navier-Stokes ones. The boundary conditions imposed are explained in table (1). In particular, the pressure on

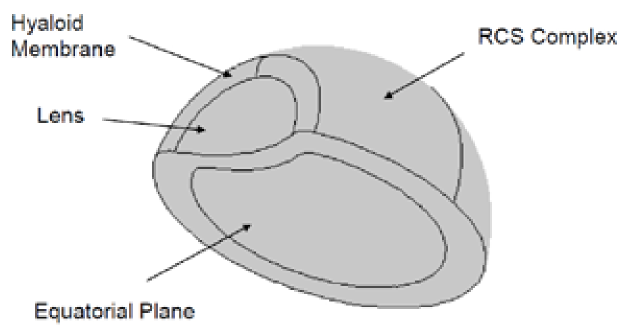


Fig.2 The geometry used for the fluid dynamic model

Boundary	Boundary condition
Lens	*Sliding wall* $u = \dot{\theta}(t) \cdot R$
Equatorial Plane	*Symmetry*
Hyaloid Membrane	*Normal Stress* $p = 2000\ Pa$
Hyaloid Membrane	*Velocity* $u = \dot{\theta}(t) \cdot R$
RCS Complex	*Velocity* $u = K_p \cdot (p - p_v) + \dot{\theta}(t) \cdot R$

Table 1 The boundary conditions implemented in the fluid dynamic model, where Kp is the normalized permeability of the RCS complex (5·10-10 cm/(Pa·s)) and pv is the venous pressure (1200 Pa)

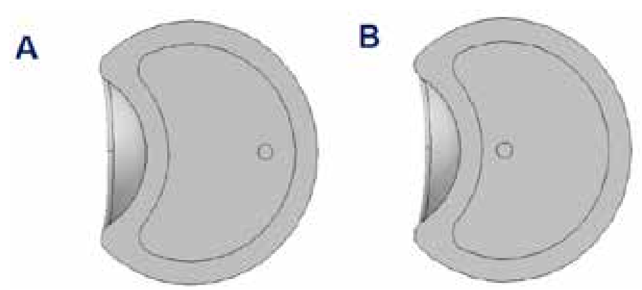


Fig.3 A) The bolus next to the RCS complex B) The bolus at the center of the posterior chamber

Boundary	Boundary condition
Vitreous humour	*Initial Value* $c = 0$
Bolus	*Initial Value* $c = 39.5849\ mol/m^3$
Hyaloid Membrane	*Concentration* $c = 0$
RCS Complex	*Flux* $N = k \cdot c$
Lens	*No Flux* $N = 0$
Equatorial Plane	*Symmetry*

Table2 The boundary conditions added to the drug delivery model, where k is equal to 10-5 cm/s

the membrane is due to the presence of the anterior chamber and the Darcy's law describes the outflow of fluid from the RCS complex. The time-dependent study has been extended till the fifth complete cycle of saccadic movement, when the solution reaches an equilibrium condition in the motion field.

Drug delivery analysis

In order to analyse the influence of the saccadic movements on the delivery of anti-VEGF after the intravitreal injection, the bolus has been considered as a sphere of a known concentration inside the posterior chamber. For this problem, the saccade of amplitude of 50° and without rest time has been chosen. A parametric study on the location of the bolus is presented. The equations, solved and properly coupled in the models, are related to the mass conservation law, the Fick's law and the Navier-Stokes equations. The boundary conditions related to the drug delivery are listed in table (2) and they have been added to the fluid dynamics ones in table (1). In particular, the clearance of the drug has been implemented as an outflow from the RCS complex proportional to the concentration on this boundary.

Results

The equatorial velocity maps related to the steady state condition are shown in fig. 4, while the streamlines averaged on the whole cycle are presented in fig. 5. The distribution of the anti-VEGF on the equatorial plane is shown in fig. 6, for both the bolus locations considered. In order to underline the entity of the saccade on both the motion field and the drug distribution, table (3) presents the averaged values of

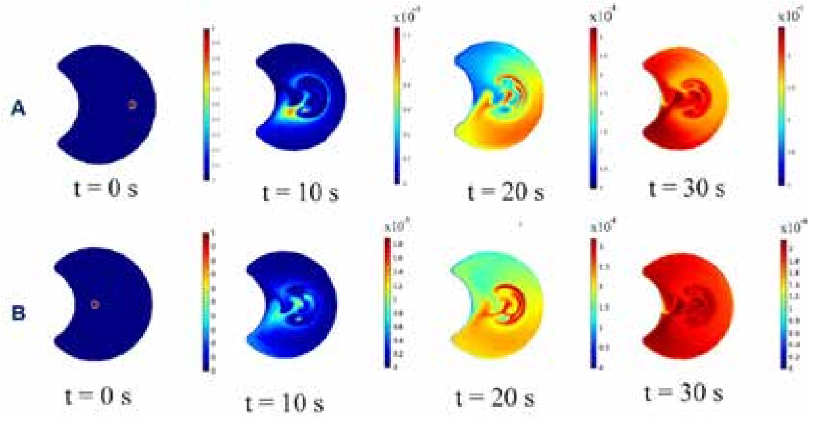


Fig.6 Equatorial map of the normalized concentration for the two different locations considered. Both when the bolus is next to the RCS complex (A) and when it is in the center of the eye the maps are similar and a uniform distribution is reached after 30 seconds from the intravitreal injection. In particular, in the maps related to t = 30 s, the vortexes underlined by the streamlines (fig. 5) can be seen

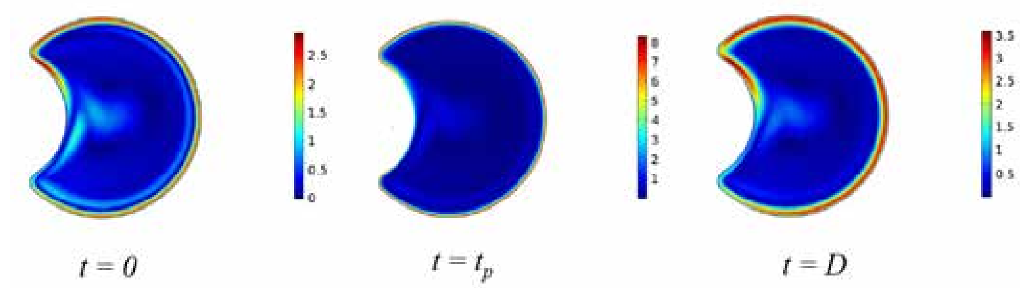


Fig.4 Equatorial velocity maps generated by the saccade with amplitude of 50° in three important instants of the motion [cm/s]

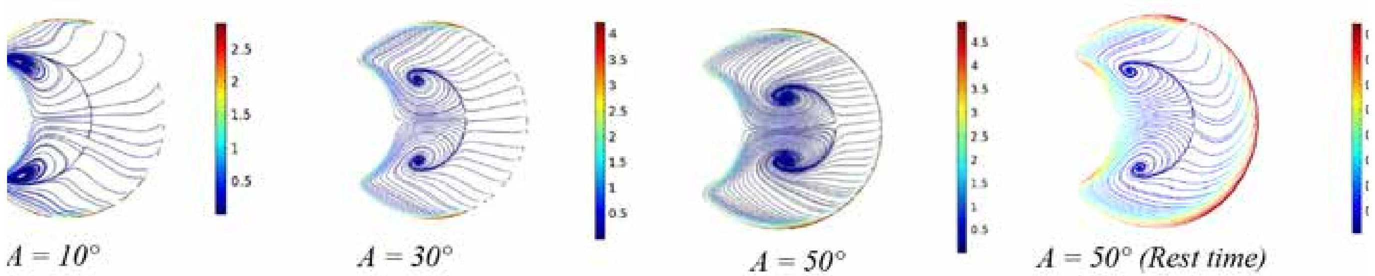


Fig.5 Streamlines related to all the saccadic movements implemented in the model. [cm/s]. It can be noticed that some vortexes are created, mainly because of the presence of the lens. With higher amplitudes, the value of the velocity increases and the location of the vortexes moves to the center of the eye. The streamlines related to the rest time show lower values of velocity

the velocity of the RCS complex and the Péclet number, in case of the saccade of 50° of amplitude and without any rotation. Fig. 7 shows the concentration maps on the equatorial and vertical planes in the motionless case. The exponential decay of the number of moles inside the posterior chamber is presented in fig. 8: the two plots are related to the saccadic movement and to the motionless cases.

Conclusions

This study shows that the saccadic movements cannot be neglected due to their great influence on both the fluid dynamic and the drug delivery mechanism inside the posterior chamber of the eye. A complete characterization of the surrounding tissues is also mandatory in order to consider the changes in permeation across the RCS complex and the specific anti-VEGF consumption nearby the retinal surface.

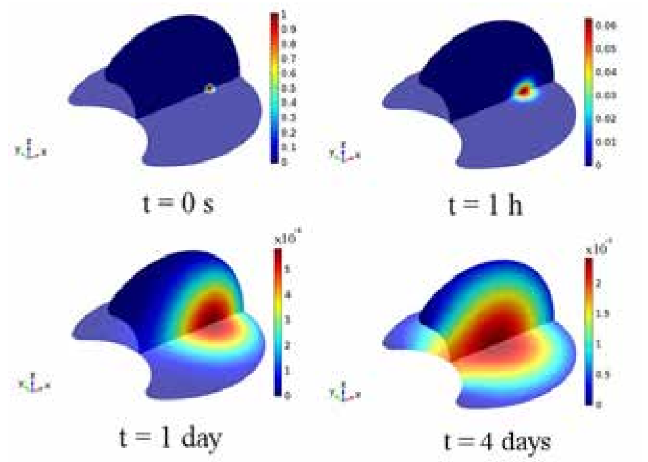


Fig.7 Equatorial and vertical maps of the normalized concentration for the motionless case. It is clear that the timing clearly increases with respect to the saccadic movement case. In addition to that, the uniform distribution is never reached, because the clearance of the drug is faster than its diffusion.

	Motion (A = 50°)	Motionless
Average velocity on the RCS complex	3.72 cm/s	$3.99 \cdot 10^{-7}$ cm/s
Péclet number	$7.56 \cdot 10^{5}$	1.18

Table 3 The average velocity on the RCS complex and the Péclet number are shown in order to underline the great influence of the saccadic motion both on the fluid dynamics and the drug delivery. The drug considered in this work are the anti-VEGF, which have a diffusion coefficient of 7.6·10-11 m2/s but the use of any other molecules don't change the results because the Péclet number due to the saccade is very high

Alessandra Moioli, Elisa Cristina Sganzerla, Marco Ferroni, Federica Boschetti
Politecnico di Milano

Matteo Cereda
Luigi Sacco Hospital, Milan

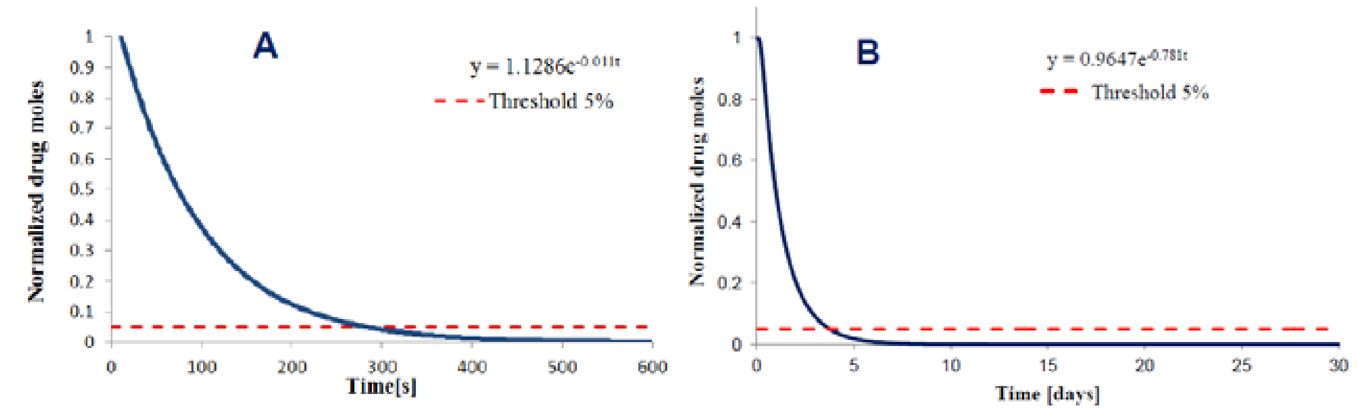


Fig. 8 Time course of the normalized drug moles inside the posterior chamber with the saccadic movement of 50° (A) and without any motion (B). The threshold of 5% of the initial moles has been set in order to consider the drug cleared from the domain. In the first case, the threshold is reached more or less after 300 seconds after the injection, while in the second case 4 days are needed

Multi-design Innovative Cooling Research & Optimization (MICRO): a novel proposal for enhanced heat transfer in DEMO

INTRODUCTION

The project, called Multi-design Innovative Cooling Research & Optimization (MICRO), aims, on one hand, to verify the present solution applied inside the MITICA experiment and, on the other, to perform further improvements in the heat transfer process with an acceptable pressure drop and reliable manufacturing process.

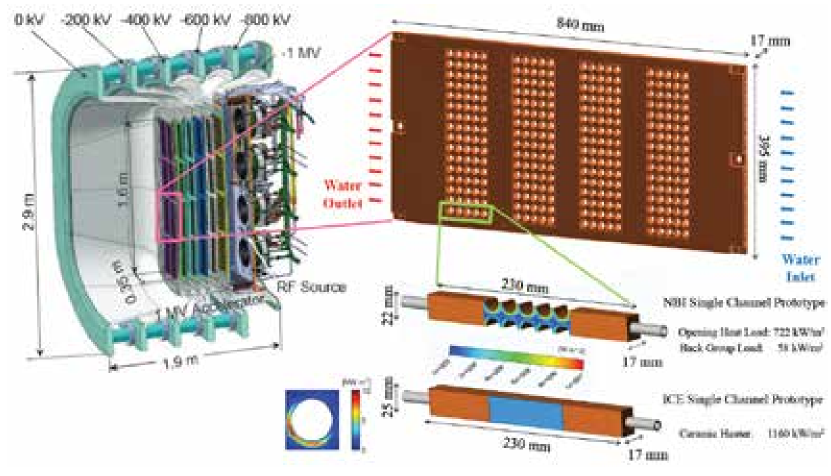
A comprehensive parametric investigation has been carried out with the goal of comparing various design options and establishing a standard approach to apply in several devices, characterized by comparable heat loads both in terms of spatial distribution and amplitude.

The main advantages rely on the possibility to extend the fatigue lifecycle of different high thermal stress components and to investigate the possibility to employ alternative dielectric fluids instead of water.

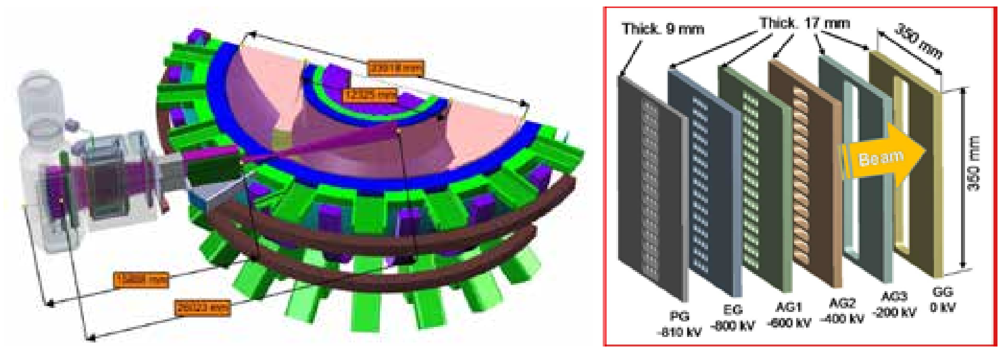
Such design solutions would in fact allow the exploitation of less performing fluids in terms of cooling capability.

Despite the unavoidable deterioration of the cooling performances such approach would represent a significantly advantageous option with respect to the existing ultra-pure water technologies.

This is particularly relevant in view of DEMO and future power plants characterized by higher efficiency and reliability.



Design of the MITICA beam source. A focused view of the overall accelerating grid is shown on the left, while graphical representation of the single channel prototypes (SCP) in NBI and ICE configurations are visible below. On the bottom left a spatial estimation of the heat flux taken in input.



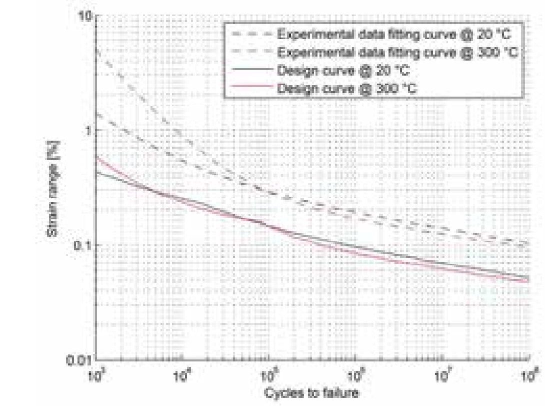
Conceptual CAD of DEMO NBI and under evaluating grids concepts (circular apertures, vertical and horizontal slots, large window)

OBJECTIVES

The main driver for the fatigue life is the different thermal expansion along the grid, leading to a sharp concentration of stress and strain between the aperture area (heated by particle) and the frame area (not heated). The goal is to lower the temperature gradients to the maximum reasonable extent.

DESIGN OVERVIEW

The spatial load distribution is a crucial element for the definition of high performing cooling system design. The focus is now on one of the most challenging cases: the beam halo loads.



Fatigue verification of electrodeposited copper used for the grids. Strain range must be below 0.169% to perform 50000 beam on/off cycles.

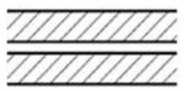
CONSTRAINTS

- Pressure drop: SCPs should not exceed a Δp greater than 1.8 bar (6 bar in segment model).
- Thermo-Mechanical properties: peak temperature as low as possible and in any case lower than 300°C.
- Structural requirements: minimum gap of 1.5 mm (channel wallsheated surface) and 1 mm (cavity or external boundary).
- Vibration and Erosion: water velocity limit on channel walls precautionary set 15 m/s.
- Geometrical constrain: presence of a 6.4 x 4.4 mm cavity hosting the SESM magnets
- Technological limit: required penetration depth (7 mm) limit the mill minimum diameter to 1.2 mm.

NOVEL ENHANCED PROPOSALS

After an extensive CAE campaign, ten innovative design have been considered of technical interest and worth to be manufactured as prototypes. The present MITICA cooling solution acted as the starting point for the development and optimization of the novel proposals. Two parallel guidelines have been followed: approaching the channel walls to the heat load footprint (thus reducing the thermal conducting resistance) and increasing the laminar heat transfer coefficient with the introduction of turbulence. These solutions can be categorized in four classes:

Option A represents the original cooling solution and the most suitable design to test the analytical correlations from literature.

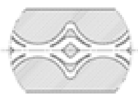

A) Straight Channel

Option B1 is the solution applied inside the MITICA experiment, with a doubling channel in correspondence of the apertures.

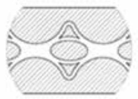

B1) NICE Channel

Options B2, B3, B4, B5 are characterized by an increased streamline curvature (overall bend amplitude is increased from 12 mm to 17 mm) in order to further enhance the coupling with the thermal loads. The cooling solutions differ in the design of the different sub-channels.

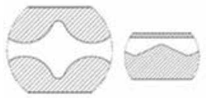

B2) NICE Upgrade

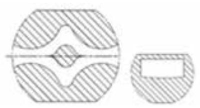

B3) Baffle Channel


B4) Criss Cross Channel

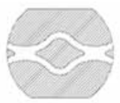

B5) Diverted Channel

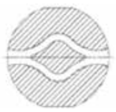
Option C1 and C2 propose a single channel where the increasing channel height is compensated by lowering its depth.


C1) Duned Channel


C2) Duned Drag Channel

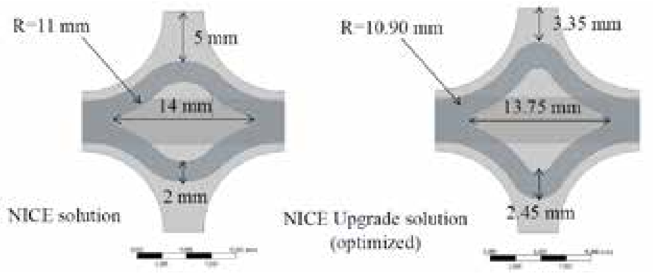
Option D1 and D2 recall the present project solution with the introduction of 11 additional ribs acting as turbulent injector devices.

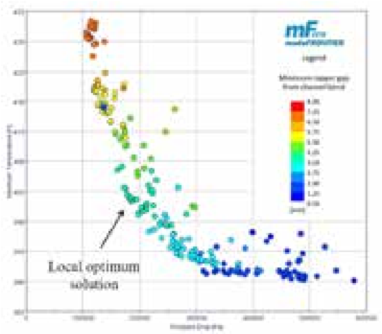

D1) Turbotron Channel


D2) Tilt Turbotron Channel

Details sections of SCP designs (ICE Configuration) along longitudinal plane representing a single cooling module contained between two virtual beam aperture region.

OPTIMIZATION STAGE





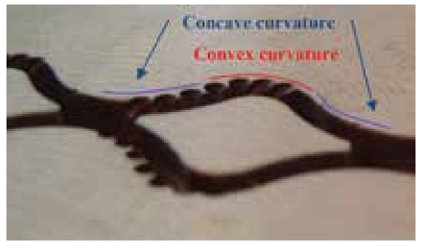
Schematic representation of NICE design pre and post optimization (left), bubble chart showing the pareto region in a Tmax -Δp plot (right).

Once the basic features of the novel designs have been individuated, their geometries have been parameterized in order to perform the optimization of the channel shape aimed at improving the cooling performances while containing pressure drops, fluid velocity and channel topology within the given requirements.

The application of the optimization process to the present project design solution has led to a substantial decreasing of copper maximum temperature (143.48°C to 129.02°C) with a promising improving of fatigue life due to the minimization of temperature gradients.

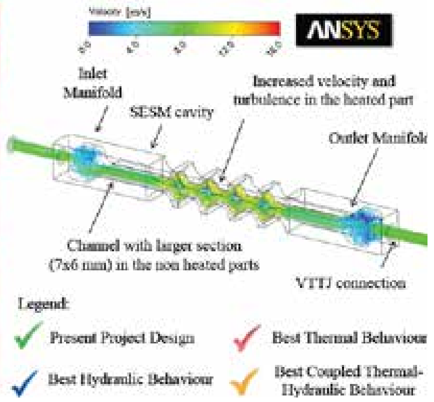
MANUFACTURING

The different SCP prototypes have been manufactured in a single copper slab. All the designs have been realized with high accuracy during the milling operations, demonstrating the technological reliability of the manufacturing process. The realization of the inclined ribs was the only issue due to the employment of a 3-shaft milling rather than a 5-shafts one. The different channel wall curvature encountered by the mill while penetrating the material did not allow the tool to accomplish the design realized on the CAD. The ribs were then eventually realized just in those regions characterized by a curvature that did not turn from concave to convex along milling direction.



SCP copper slab (right) and detailed view of the inclined ribs in Tilt Turbotron concept (left)

	Design Solution	NBI Configuration Δp [bar]	NBI Configuration T_{max} [°C]	NBI Configuration V_{wall} [m/s]	ICE Configuration Δp [bar]	ICE Configuration T_{max} [°C]	ICE Configuration V_{wall} [m/s]
✓	Baffle Channel	1.83	120.86	16.68	1.76	61.75	16.43
	Criss-Cross Channel	1.76	130.02	15.13	1.67	67.32	15.24
	Diverted Channel	1.79	123.54	15.51	1.68	62.95	15.82
✓	Duned Channel	1.56	131.96	14.04	1.49	68.59	13.57
	Duned Drag Channel	1.78	126.44	13.66	1.70	64.89	12.95
✓	NICE Channel	1.29	143.48	12.60	1.22	73.83	12.57
	NICE Upgrade	1.78	129.02	15.06	1.68	66.78	15.47
	Turbotron Channel	1.72	134.91	15.52	1.64	69.48	14.86
	Tilt Turbotron Channel	1.70	133.64	14.67	1.59	68.83	14.42
✓	Straight Channel	0.92	178.31	9.29	0.85	84.58	9.14



Effect of Baffle design on water turbulence and schematic description of SCP concept (above) and table with results obtained with CFD simulations

RESULTS

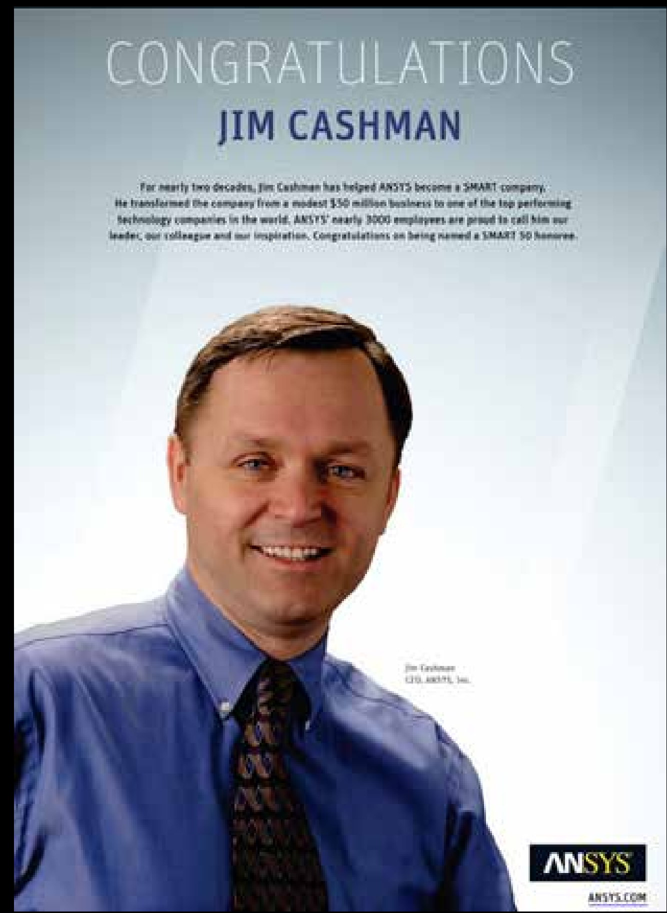
The different proposals have been evaluated in steady state CFD simulations, assessed with sensitivity analyses and compared in term of fluiddynamics characteristics. Particular attention was given to pressure drop, laminar velocity and cooling performances.

Giulio Gambetta
Università degli Studi di Padova

Piero Agostinetti, Piergiorgio Sonato
Consorzio RFX (CNR, ENEA, INFN, Università di Padova, Acciaierie Venete SpA)

JIM CASHMAN - ANSYS among the TOP EXECUTIVES

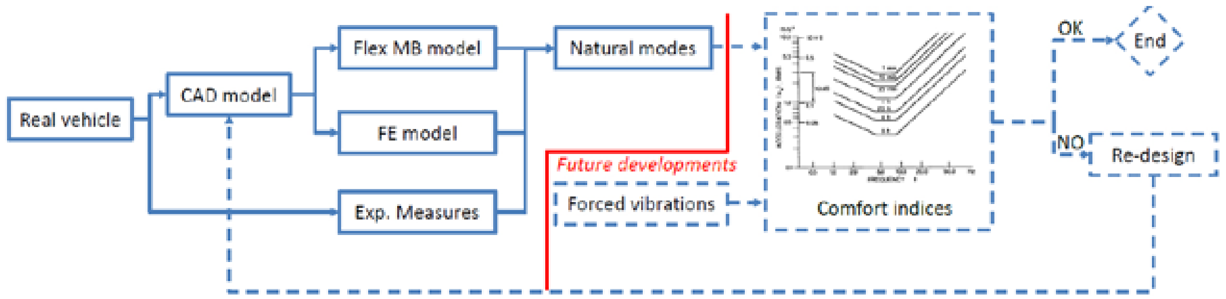
If you've seen a rocket launch, flown on an airplane, driven a car, used a computer, touched a mobile device, crossed a bridge or put on wearable technology, chances are you've used a product where ANSYS software played critical role in its creation. James E. Cashman III joined ANSYS Ing. in 1997 as the senior vice president of operations. He became president and CEO three years later. Today, thanks to his technical and business acumen, ANSYS is the largest engineering simulation company with the world's leading technology in all fields of product development. In 2000, many analysts thought the market for engineering simulation was saturated. Cashman had a contrary view that is proving to be true. Cashman helped ANSYS grow through his innovative ideas about the extended possibilities and scope of solutions that engineering simulation could offer to product development engineers. He also helped reinvent the sales and marketing efforts and inspired ANSYS employees to greater productivity and creativity.



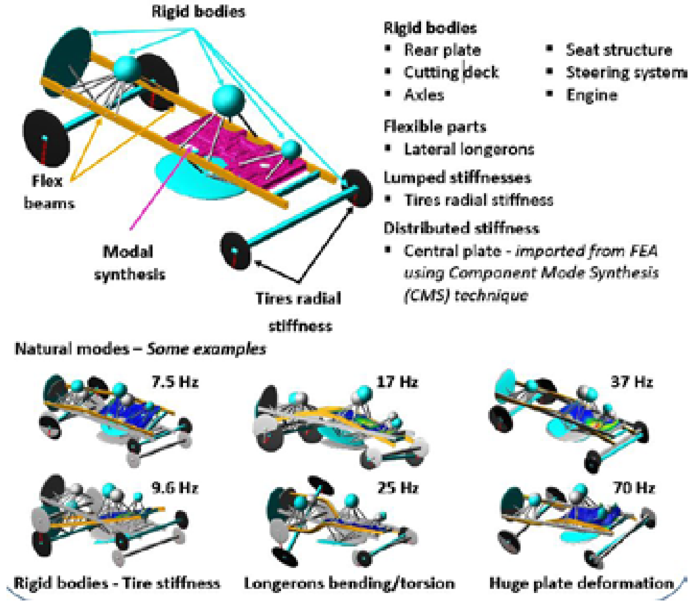
Multilevel Approach for Vibration Characterization of a **Lawn Tractors through Numerical Tools and Experimental Analysis**

Introduction

The activity was originated in the framework of a collaboration between University of Pisa and Global Garden Products (GGP). The goal of the activity was to develop multilevel simulation and experimental tools aimed at characterizing the vibration behavior of a Lawn Tractor and of its components, in the frequency range of interest for human comfort. These tools can be used to improve the comfort of the driver of the tractor and to avoid components resonance due to engine and blades excitations.



Tools development was based on analyses of the parts composing the real vehicle. Masses, flexible components and joints driving the vibrational response were identified. CAD geometries were also cleaned for mesh generation.

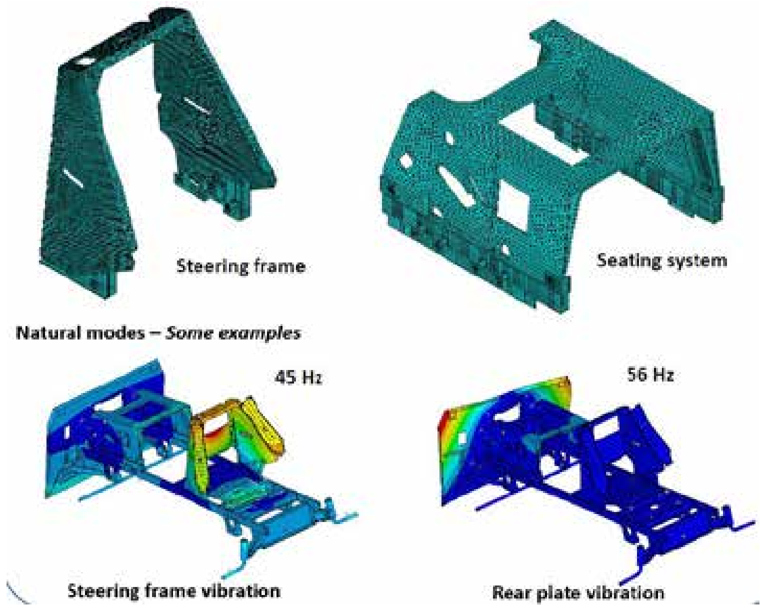


Semi-flexible MultiBody model (SMB)

A multilevel approach was used to develop the multibody model. The inertia properties of the most rigid parts were imported from CAD as rigid bodies and the flexible parts were identified and imported as lumped or continuous elements.

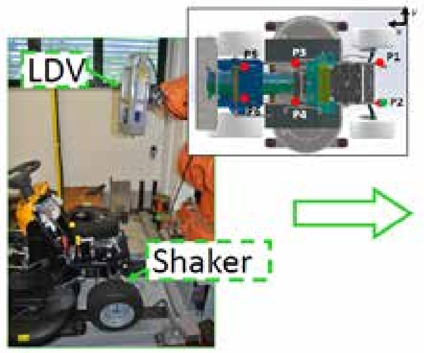
Finite Element Modal model (FEM)

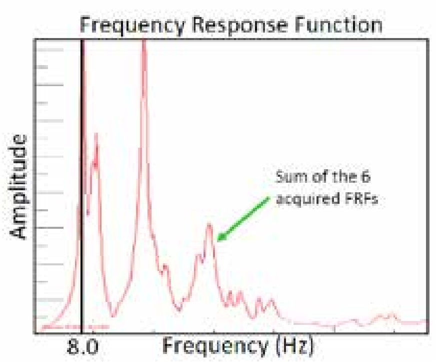
Finite element method was used to develop the modal model. Engine, transmission, cutting desk and tires were implemented as concentrated mass and inertia whose values were derived from CAD geometries. The structural components were implemented by meshing the previously cleaned CAD geometries using 3D structural brick elements. Joints were implemented in order to reproduce the effective structural continuity and kinematics of the parts in the real vehicle.



Experimental modal analysis

Single input (electrodynamic shaker) – multi output (Laser Doppler Vibrometer): 6 measurement points were chosen on the chassis. High precision sensor positioning was achieved through an ABB anthropomorphic robotic arm.





Leonardo Bertini, Francesco Bucchi, Bernardo Monelli, Paolo Neri
Università di Pisa

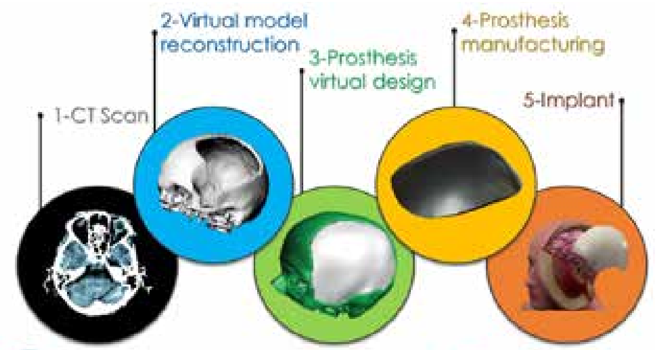
Results and conclusions

A fairly good agreement was verified comparing the first natural frequencies and the mode shapes found with SMB, FEM and Experimental modal analysis. Further modes related to higher frequencies are obtained by FEM model considering also single-part vibrations.

Natural frequencies (Hz)			
EXP	**MBS**	**FEM**	**Shape**
8.0	7.5	7.8	Roll
8.3	8.0	8.1	Heave
10.0	9.6	10.1	Pitch
18.5	17.0	18.9	Bending
29	25	27	Torsion 1
35	39	37	Torsion 2

Innovative stamping process for fully-customized prosthetic implants

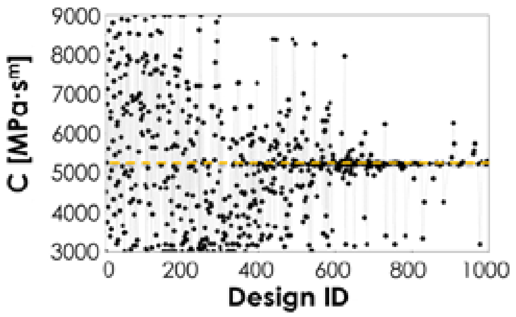
BioForming Project
The research project "BioForming" (www.bioforming.it), funded by the MIUR, aims at the realization of titanium alloy custom-made prostheses by means of unconventional sheet metal forming processes such as SuperPlastic Forming (SPF) and Single Point Incremental Forming (SPIF); in particular, in the SPF a metal sheet is deformed using the action of inert gas in pressure at a high temperature and in the SPIF a tool rotating at high rpm deforms the sheet locally.

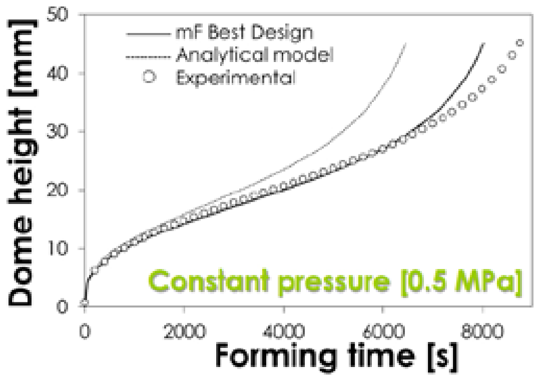


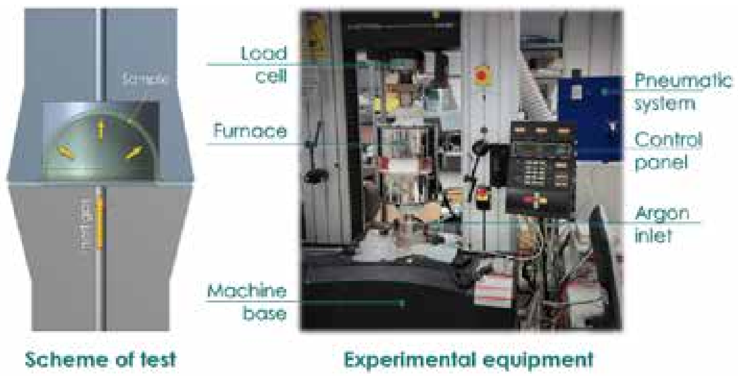
Politecnico di Bari · POLITECNICO MILANO 1863 · UNIVERSITÀ DELLA CALABRIA

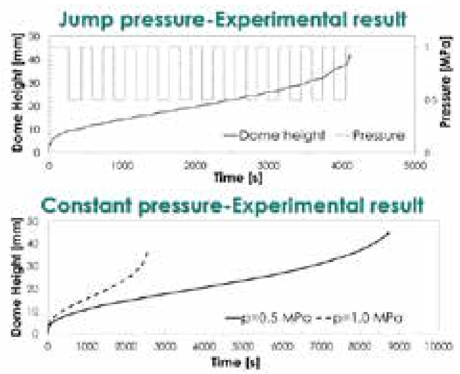
Background
When it is necessary to ensure complex geometries or integrated structure, SPF is reported to be the most suitable manufacturing process. Numerical simulation plays a fundamental role in the process design, and reliable results can be obtained only if a proper material characterization is carried out. The characterization of the superplastic behaviour of the Ti6Al4V-ELI alloy was carried out by means of free- inflation tests.

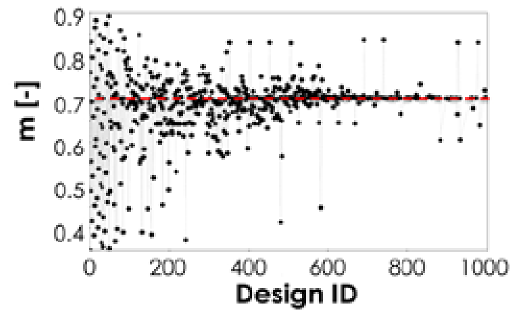
Methodology
Circular Ti blanks (D=80mm, s=1mm) were deformed at high temperature (T=850°C) by the action of pressurized argon according to both a constant value (0.5 and 1.0 MPa) and a pressure profile based on jumps between 0.5 and 1.0 MPa. Evolution of the dome height with the time was recorded and subsequently adopted for the inverse analysis approach.

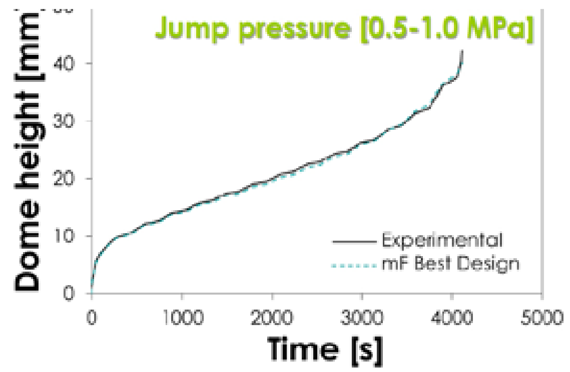


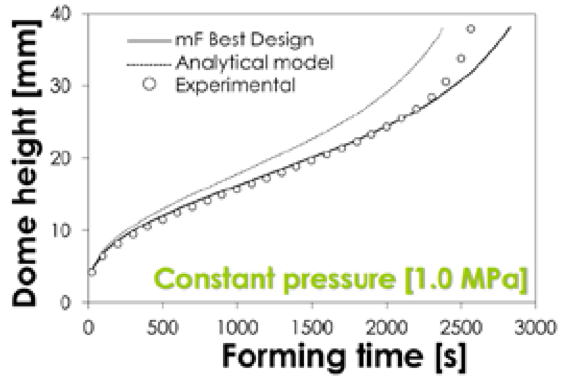












modeFRONTIER

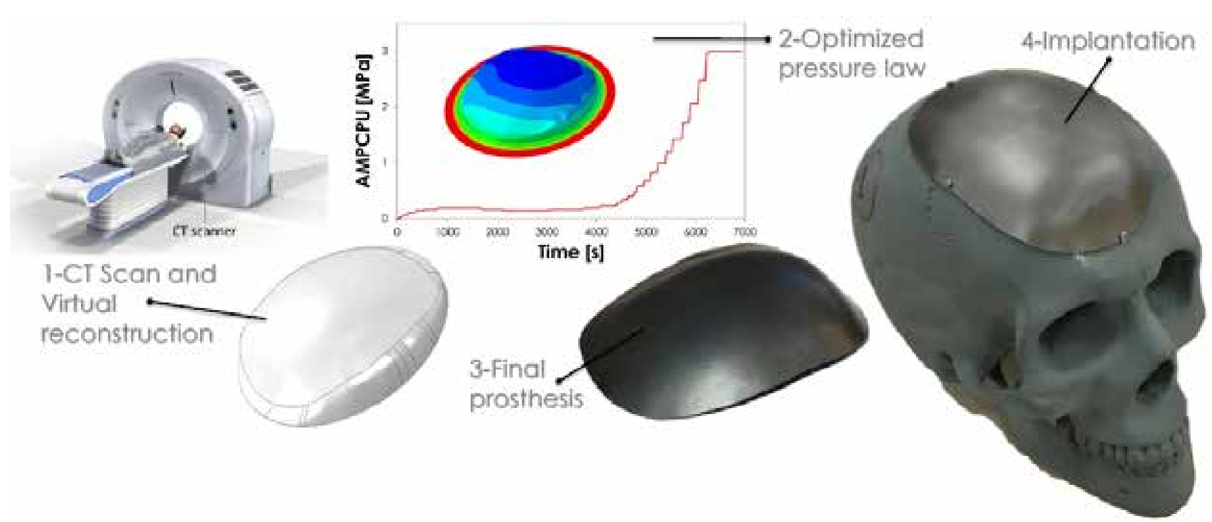
Inverse analysis
Experimental tests conditions were re-created within a CAE environment with a 2D FE model. Material elasto- viscoplastic behaviour was modelled according to Backofen law $\sigma = C\varepsilon^m$. The values of the strength coefficient C and the strain rate sensitivity index m able to minimize the error between the numerical and the experimental dome height evolution with time were obtained coupling the 2D model with modeFRONTIER within an optimization procedure driven by the MOGA-II algorithm. A total number of 1000 designs (20 successive generations, each composed of 25 designs) were run on a Xeon 3.47 GHz dual processor with 40 GB RAM installed. The whole optimization procedure took less than one day to get completed.

Validation
The material constants obtained from the inverse analysis were validated with further numerical simulation regarding free inflation tests under constant levels of pressure equal to 0.5 and 1.0 MPa. Comparison with experimental data confirmed the accurateness of the determined constants even when compared with those determined with the analytical model.

Prosthesis manufacturing design
Once properly determined the material constants, the design for the skull prostheses manufacturing can be carried out by means of numerical simulations. Prostheses geometry is virtually re-constructed from CT scans (1), then the optimized pressure law is obtained by means of FE simulations (2). The final geometry of the prostheses is thus obtained by means of 3D laser cut (3) and finally implanted on a demonstrative skull (4).

Gianfranco Palumbo, Antonio Piccininni, Pasquale Guglielmi, Luigi Tricarico
Politecnico di Bari

Donato Sorgente
Università degli Studi della Basilicata



EnginSoft and modeFRONTIER at the 6th International Conference on Laser Peening and Related Phenomena

For the first time, The International Conference on Laser Peening and Related Phenomena was held in the "motherland", South Africa, for the sixth conference in the series, from 6th – 11th November 2016.

This conference, with its workshop-style approach of a single session and an emphasis on discussion and networking, was enriched with a dedicated section on industrial problems and applications, alongside the basic phenomena of materials behavior and the development of laser systems for the future. The conference also hosted a workshop on the optimization of laser peening modelling using Finite Element software integrated in a multi-objective optimization platform, modeFRONTIER, in recognition of the intensive efforts made to optimize the application of laser peening to an increasing range of industrial materials and components.

During the session on Processing Modelling and Simulation, several application cases and applied research studies were presented. One of these was awarded the best paper of this session and its author Mohammad I. Hatamleh, a research assistant at The University of Texas at Dallas was awarded membership access to the ESTECO Academy, which includes a one year modeFRONTIER license, on-line training and dedicated events about optimization, with the opportunity to get closer to the world of Multi-disciplinary Optimization (MDO). Below is the prize giving in perfect "Kruger Park" Style!

The conference started in Gauteng ("Place of Gold") Province, the financial capital of Africa, where the University of the Witwatersrand welcomed the delegates in the vibrant "urban forest" of Johannesburg and for the last few days moved to the world-class destination of the Skukuza Conference Centre in the spectacular Kruger National Park.

In addition, an interesting program of events were arranged around the conference, including exciting safari game and an unforgettable Bush Dinner Gala evening experience.