# The use of virtual prototyping tools in the design of Generation IV Nuclear Energy Systems

Ansaldo Nucleare is a company fully owned by Ansaldo Energia. The Company has the complete responsibility for the nuclear business and well established in the new international markets. In Italy, Ansaldo Nucleare is recognized as the main industrial company in the nuclear sector.

The product lines of Ansaldo Nucleare are:

*Engineering and Construction of Nuclear Power Plants*

In partnership with world-class established nuclear providers, Ansaldo Nucleare builds Nuclear Power Plants performing systems and main components design, core and thermo-hydraulic calculations, safety and licensing analyses, in field engineering as well as erection, supervision and commissioning. Ansaldo Nucleare has gained an extensive experience both as a supplier of NSSS (Nuclear Steam Supply System) and for architectural engineering in Italy and abroad for more than forty years.

*Development of New Generation Nuclear Reactors*

In the framework of the European and International co-operation, Ansaldo Nucleare develops innovative Nuclear Power Plants, offering enhanced safety features and economic improvements for the electrical production with a view to reducing the radioactive wastes generated by the plants.

*Service to Nuclear Power Plants and Facilities in operation*

Ansaldo Nucleare provides a large range of service activities for systems and components of Nuclear Power Plants aiming at safe operation, system optimization and performance enhancement. The Company can effectively provide these services thanks to its experience and in-depth knowledge gained in the design and implementation of different technologies for Nuclear Power Plants. Moreover, beyond design basis events and associated cliff edge effects assessments are performed to evaluate NPPs capabilities (Stress Tests) also implementing the resulting plant modifications.

*Decommissioning of Nuclear Plants & Facilities*

Ansaldo Nucleare has gained knowledge and experience in this field working since 1999 to pursue the decommissioning of the Italian Nuclear Power Plants and successively performing decommissioning studies and activities on Nuclear Power Plants in Europe. Activities range from the basic design to the management of on-site dismantling, including design and creation of waste management facilities.

*Radioactive Waste Management*

Activities performed by Ansaldo Nucleare in the field of liquid and solid radioactive waste management, cover conceptual and detailed design finalization, components and materials procurement, on-site erection and commissioning of complete systems and plants - including turnkey projects - for operational waste treatment as well as for the primary and secondary radioactive wastes generated during decommissioning process.

# Interview with Fabrizio Magugliani, Sr. Engineer, Aero/Thermo Analytical Design, Ansaldo Nucleare SpA

*Figure 1 - Eng. Fabrizio Magugliani*

### How long have you been using CAE simulation technologies and mathematical modeling in your company?

Since the very beginning of the nuclear industry, CAE simulations and mathematical models have been widespread practice. Ansaldo Nucleare has been one of the first users in Europe of 3D CAE codes. In my archive, I have a couple of documents dated early 1980s mentioning the Harwell-Flow3D CFD 3D code, originally developed at the United Kingdom Atomic Energy Authority, the 'grandfather' of the package currently known as ANSYS CFX. Since then, CAE technologies have been the standard tool for the design and validation of components and the results of the codes have been subjected to extensive V&V by the nuclear regulatory commissions.

### What was the main reason for introducing these technologies?

Two main reasons have been the drivers for introducing and using CAE simulation technologies and mathematical modeling: safety and achieving optimal design. Safety is mandatory in the nuclear industry, and any design and component must be thoroughly validated against stringent safety criteria. Results of numerical simulations in specific and controlled conditions are routinely compared with properly-designed experimental results and, provided that there aren't discrepancies, the model is validated. Achieving optimal design is the other main reason: in a complex 'system of systems' like a nuclear power plant, optimization is critical to make sure that each component performs at its best and all the components together perform at their best, without compromising safety. Last but not least, cost saving is a factor for using CAE simulation technologies.

### What kind of products are you using simulation for?

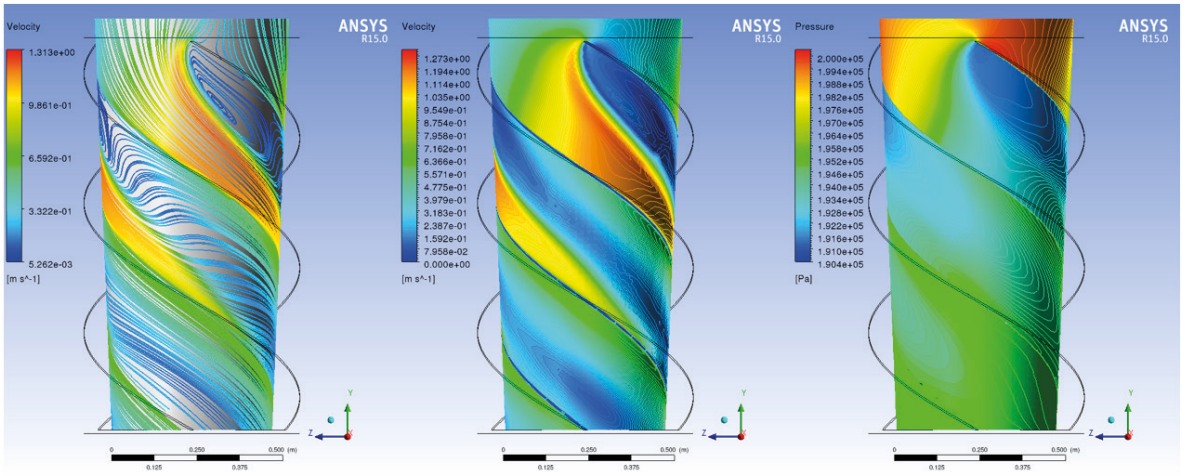
Any components of the reactor and any ancillary equipment are analyzed by itself and as an ensemble. I cannot think of a single component which does not get thoroughly analyzed in detail. The performance and operational life of the Primary Pump, Steam Generator, Decay Heat Removal System and any other components and equipment are analyzed via 3D FEM, CFD and FSI simulations taking into account not only the normal operation conditions but also any potential incidental conditions. Fluid–Structure Interaction plays a key role in the design process, because enables to evaluate the interaction between the liquid coolant and the solid components.

### Why did you decide to introduce mathematical modeling in the design process?

Stringent safety requirements and the availability of versions of the ANSYS suite of packages approved for nuclear design have been the main drivers for using mathematical modelling in the design process. Beyond these drivers, 3D detailed simulations provide invaluable data for enabling the optimization of the single components and of the reactor as a 'system of systems', the assessment of the full compliancy with the safety requirements and the evaluation of the safety margin of the reactor in normal as well as in shutdown condition.

### How does this affect your design process?

Ansaldo Nucleare is currently designing ALFRED (Advanced Lead Fast Reactor European Demonstrator), the liquid lead cooled nuclear



reactor, relying on the seamless integration of CAD/FEA/CFD/FSI technologies. The engineering development of the design of the reactor is dependent upon different kinds of mathematical tools: Design of Experiments, multi-scale, multi-physics modelling, Fluid–Structure Interaction and optimization algorithms. These mathematical tools supplement the data obtained with different methods in experimental campaigns. Moreover, the design team's cumulative knowledge and expertise is the most effective tool, making it possible to interpret and apply the results of 3D simulations for the development of a very effective design, leading to safe and reliable components.

**Are you also thinking about applying mathematical modeling for new products and what expectations do you have?**

We are exploring the merits of introducing advanced techniques for the mathematical modeling of the materials and their interaction with the liquid coolant. The modelling of the interaction between different materials and the coolant will provide invaluable data for assessing the safety of the plant in the long term, as well define the required mechanical properties for the materials to sustain in the long term the demanding environment. As of now, the modelling of the long term interaction between the material and coolant is unviable in term of computer time; my expectations are that in the future such a modeling could become a standard and sustainable design tool.

**What value is EnginSoft providing to Ansaldo Nucleare?**

I keep saying that EnginSoft isn't just a technology supplier but an external associate of the design team. The in-depth knowledge of the features of the FEA and CFD packages used in Ansaldo Nucleare makes EnginSoft an invaluable source of recommendations. We currently rely on EnginSoft to install on Ansaldo's computer systems the updated version of the packages and to keep our main HPC resource (a 244-core cluster) at the highest level of availability and efficiency. Moreover, EnginSoft's wide range of expertise in FEA, CFD and FSI enables a mutually effective interdisciplinary collaboration leading to a faster and error-free progression towards the optimal design of the components. Last but not least, EnginSoft makes available guidelines and real-world examples of best practices used in design environments other than the specific nuclear area that can guide the design process and avoid pitfalls and roadblocks.

**In your perspective do you believe there will be a need for computation codes to handle future challenges?**

There is no question in my mind about the absolute requirement to apply advanced modelling and analysis techniques in the development of current as well as future products or systems. The nuclear industry must comply with very stringent safety rules: every component must be tested and validated for the more demanding conditions and for the entire lifetime of the nuclear power plant. In the future, and according to the lesson learned with the current design practices, I envision a major emphasis on improving the overall efficiency of the nuclear power plant and on a design that allows for an increase of the operational life of the plant. To achieve these objectives, experimental campaign and 3D, FEA, CFD and FSI modelling are required, with a widespread application of Fluid-Structure Integration and material modelling techniques.

**Could you estimate the return on the investment related to these R&D activities?**

It is difficult to attach a monetary value for ROI when using advanced FEA/CFD design practices in the development of a complex and inter-dependent system like a nuclear power reactor. In our view, the value of FEA/CFD design practices goes well beyond any ROI evaluation, and relies on the possibility to designing a safe, reliable and efficient system of systems without having to resort to approximations or mock-up.