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INDUSTRIAL PLANTS 2

Chapter three ï part 2
Numerical simulation
Application examples

DOUBLE DEGREE MASTER IN
ñPRODUCTION ENGINEERING AND MANAGEMENTò

CAMPUS OF PORDENONE
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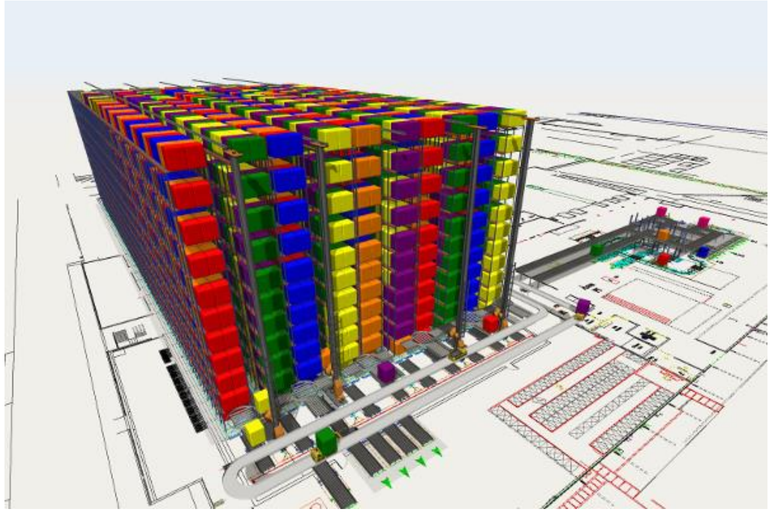
NUMERICAL SIMULATION

Simulation technologies

Due to the complexity of the problems faced in industrial plant engineering, proceeding analytically most of the time does not make it possible to obtain a solution to the problem. Here **simulation** represents a fundamental tool in all these cases, allowing a numerical approach. Precisely for this reason the simulation methods are now applied in the field of plant engineering in the search for the most disparate technical solutions, obtaining, in the majority of cases, extremely interesting results.



NUMERICAL SIMULATION

Simulation technologies

As an example we have:

a) **Simulation technologies to support decisions**:
DSS (Decision Support System);

b) **Simulation technologies to support product design and engineering**:
MBS Simulation (Multibody Modeling);
BEM Simulation (Modeling of boundary elements);
SEA Simulation (Statistical Energy Analysis);
CFD Simulation (Numerical Fluid Dynamicx Analysis);
FEM Simulation (Finite Element Method);

c) **Simulation technologies to support the analysis of processes of manufacturing and process industry**:
CAM (Computer Aided Manufacturing);
CAPP (Computer Aided Process Planning);
Virtual Commissioning.

NUMERICAL SIMULATION

Decision Support System (DSS)

A **decision support system (DSS)** is a computerized program used **to support determinations, judgments, and courses of action** in an organization or a businessthat gathers and analyzes data, synthesizing it to produce comprehensive information reports..
A DSS sifts through and analyzes massive amounts of data, compiling comprehensive information that can be used to solve problems and in decision-making.
Typical information used by a DSS includes **target or projected revenue, sales figures or past ones from different time periods, and other inventory- or operations-related data.**

A decision support system differs from an ordinary operations application, whose function is just to collect data.

NUMERICAL SIMULATION

Multibody simulation (MBS)

Multibody simulation is a useful tool for conducting motion analysis, where systems are composed of various rigid or elastic bodies. Connections between the bodies can be modeled with kinematic constraints (such as joints) or force elements (such as spring dampers).

It is often used during **product development to evaluate characteristics of comfort, safety, and performance**. For example, multibody simulation has been widely used since the 1990s as a component of automotive suspension design. It can also be used to study issues of biomechanics, with applications including sports medicine, osteopathy, and human-machine interaction.

The MBS process often can be divided in **5 main activities.**

1) The first activity of the MBS process chain is theò**3D CAD master modelò,** in which product developers, designers and engineers are using the CAD system to generate a CAD model and its assembly structure related to given specifications.

2) This 3D CAD master model is converted during the activity ñData transferò to the **MBS input data formats**

The ñMBS Modelingò is the most complex activity in the process chain.

3) Following rules and experiences, the 3D model in MBS format, with multiple boundaries, kinematics, forces, moments or degrees of freedom are used as input to generate **the MBS model**. Engineers have to use MBS software and their knowledge and skills in the field of engineering mechanics and machine dynamics to build the MBS model including joints and links.

4) The generated MBS model is used during the next activity ñSimulationò. **Simulations, which are specified by time increments and boundaries like starting conditions are run by MBS Software, to prepare CAD models and visualize results**.

5) The last activity is the **ñAnalysis and evaluationò.** Engineers use case-dependent directives to analyze and evaluate moving paths, speeds, accelerations, forces or moments. The results are used to enable releases or to improve the MBS model, in case the results are insufficient. One of the most important benefits of the MBS process chain is the usability of the results to optimize the 3D CAD master model components.

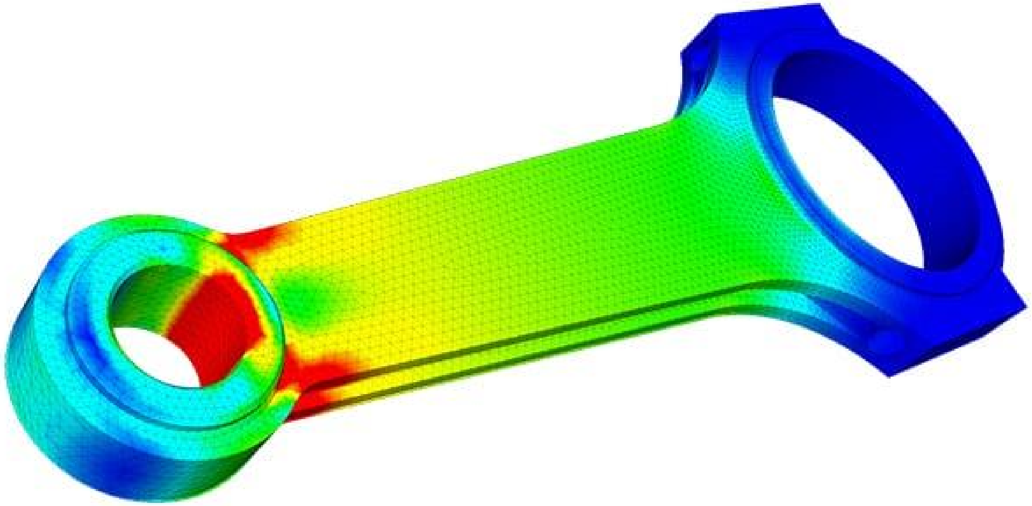
NUMERICAL SIMULATION

Finite Element Method (FEM)

Finite element method (FEM) and boundary element method (BEM) are strong numerical analysis tools for engineers for obtaining numerical solutions of field problems for complex geometries.

In a few words, the two methods diverge on where discretization is applied: in FEM it involves the domain, whereas in BEM the surfaces of the sources, only, regardless the domain.

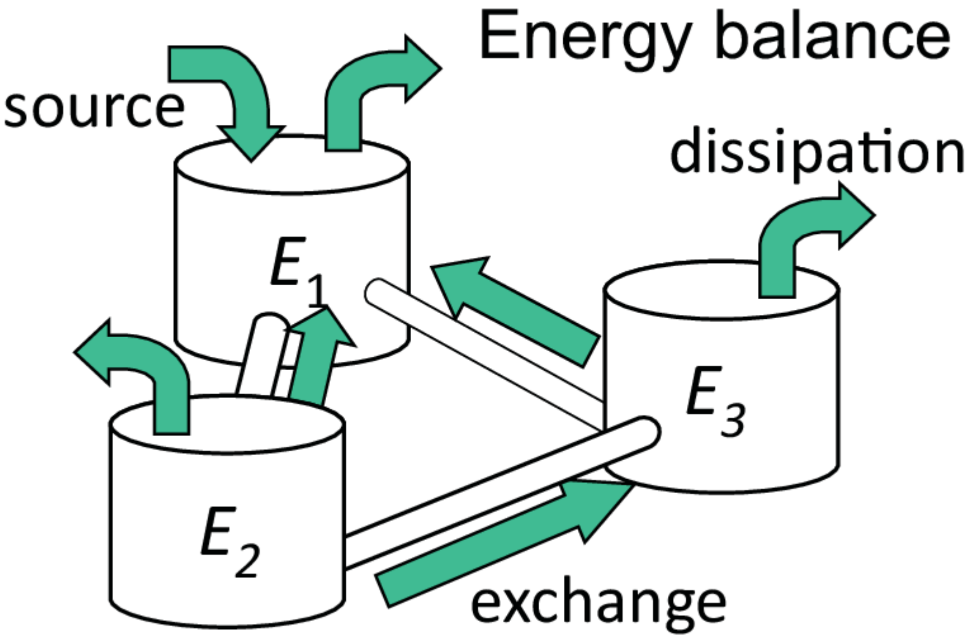
In FEM, the domain, is subdivided into small elements and connected like a grid.
The finite element method started with significant promise in the modeling of several mechanical applications related to aerospace and civil engineering. The applications of the finite element method are only now starting to reach their potential. The most important applications are in fluid-structure interaction, thermomechanical, thermochemical, thermo-chemo-mechanical problems, biomechanics, biomedical engineering, piezoelectric, ferroelectric, and electromagnetics.
In BEM, compared to domain type analysis, a boundary analysis results in a substantial reduction in data preparation and a much smaller system of equations to be solved. Furthermore, this simpler representation of the body means that regions of high stress concentration can be modeled more efficiently as the necessary high concentration of grid points is confined to one less dimension. This ability to model high stress gradients accurately has been the main reason for the method¸s success in fracture mechanics applications



NUMERICAL SIMULATION

Statistical Energy Analysis (SEA)

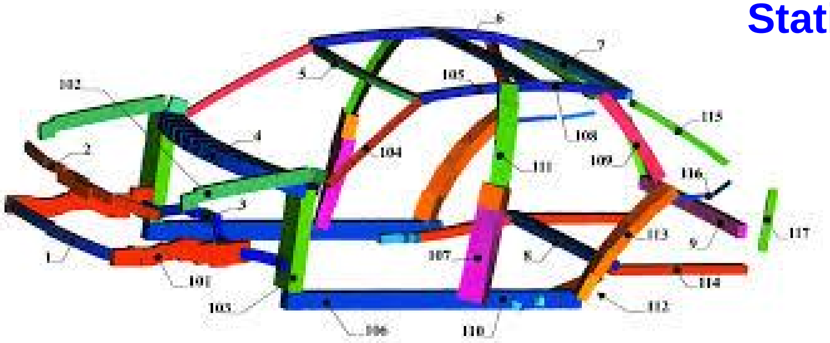
Statistical Energy Analysis (SEA) is the most widely used modelling technique for vibroacoustic problems at high frequencies. It has been applied to building acoustics, in train designs or ships. The reliability of the simulation results depends on many different aspects.
First of all, the SEA hypotheses must be satisfied. Afterwards, the vibroacoustic system must be properly characterised. This implies performing an adequate definition of the subsystems and precisely characterising the **input power**, **the internal loses and the energy transfers between them.** The internal losses of a subsystem are characterised by the **internal loss factor (ILF)**. It can be obtained from tables of material data and experiments. The energy transfers are characterised by the **coupling loss factors (CLF)**. This is probably the key parameter in order to obtain a good SEA model of a vibroacoustic system.

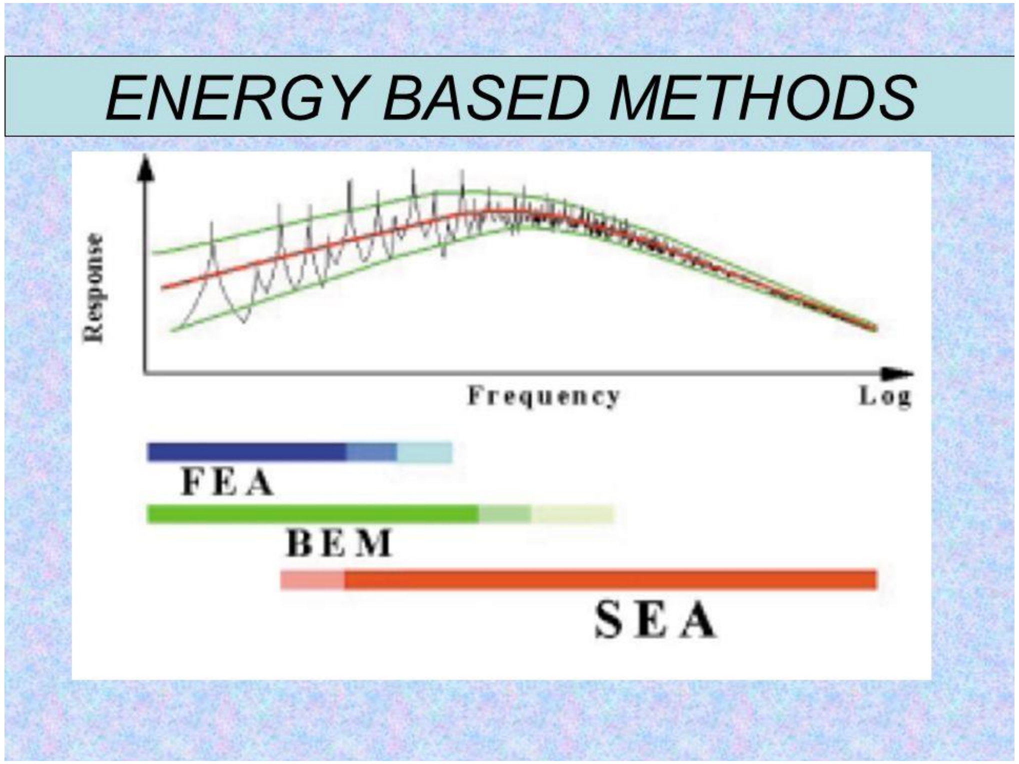


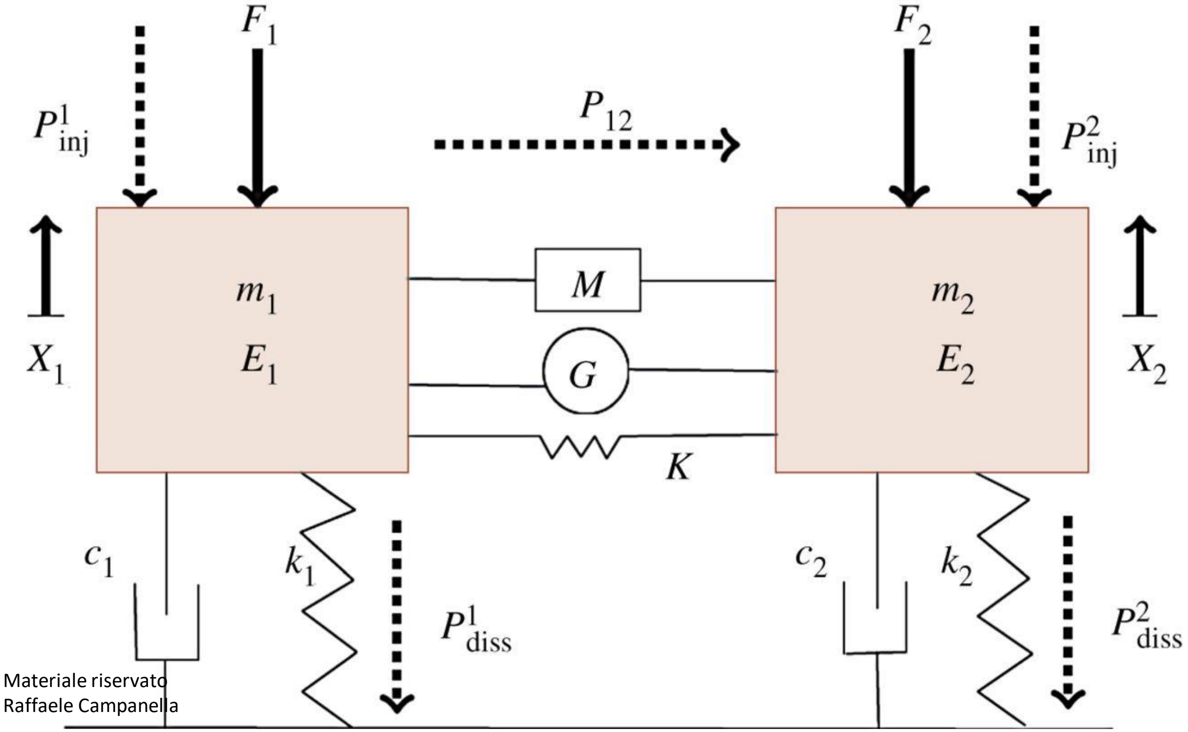
The energies are obtained by means of the Spectral Finite Element Method (SFEM).

NUMERICAL SIMULATION

Statistical Energy Analysis (SEA)



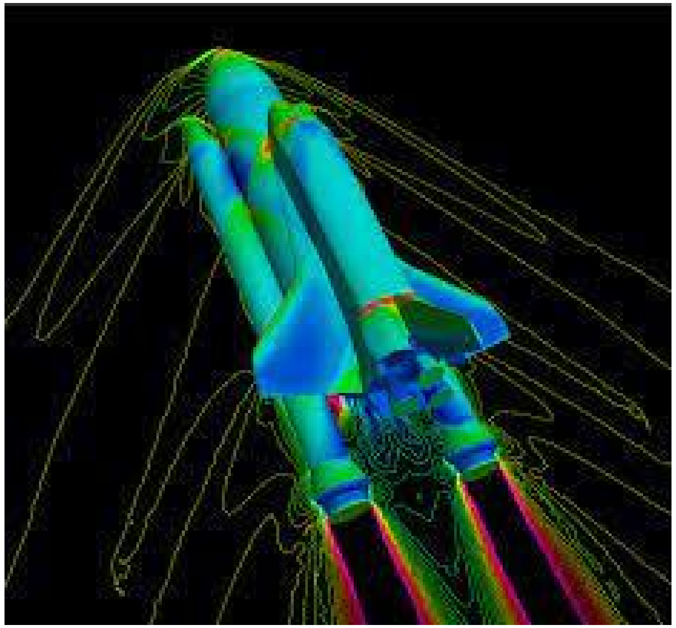


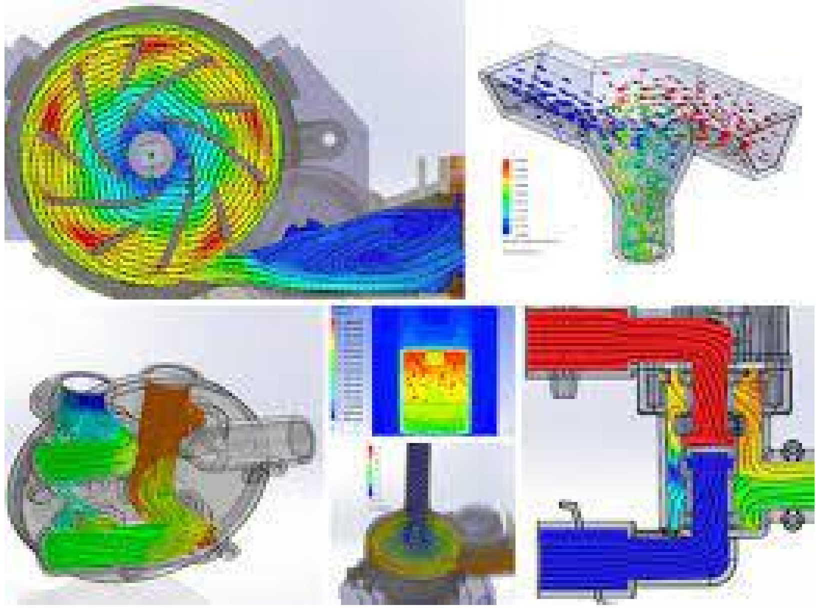


NUMERICAL SIMULATION

Computational Fluid Dynamics (CFD)

Computational Fluid Dynamics (CFD) is the branch of CAE that simulates fluid motion and heat transfer using numerical approaches. CFD acts as a virtual fluid dynamics simulator. CFD software can analyze a range of problems related to laminar and turbulent flows, incompressible and compressible fluids, multiphase flows, and much more.





NUMERICAL SIMULATION

Partial Differential Equations (PDE)

The finite element method (FEM) is a numerical technique used to perform finite element analysis (FEA) of any given physical phenomenon.

It is necessary to use mathematics to comprehensively understand and quantify any physical phenomena, such as structural or fluid behavior, thermal transport, wave propagation, and the growth of biological cells. Most of these processes are described using partial differential equations (PDEs). However, for a computer to solve these PDEs, numerical techniques have been developed over the last few decades and one of the most prominent today is the finite element method.

Firstly, it is important to understand the different genre of PDEs and their suitability for use with FEM. Understanding this is particularly important to everyone, irrespective of the motivation for using finite element analysis. It is critical to remember that FEM is a tool and any tool is only as good as its user. PDEs can be categorized as elliptic, hyperbolic, and parabolic. When solving these differential equations, boundary and/or initial conditions need to be provided. Based on the type of PDE, the necessary inputs can be evaluated. Examples for PDEs in each category include the Poisson equation (elliptic), Wave equation (hyperbolic), and Fourier law (parabolic).

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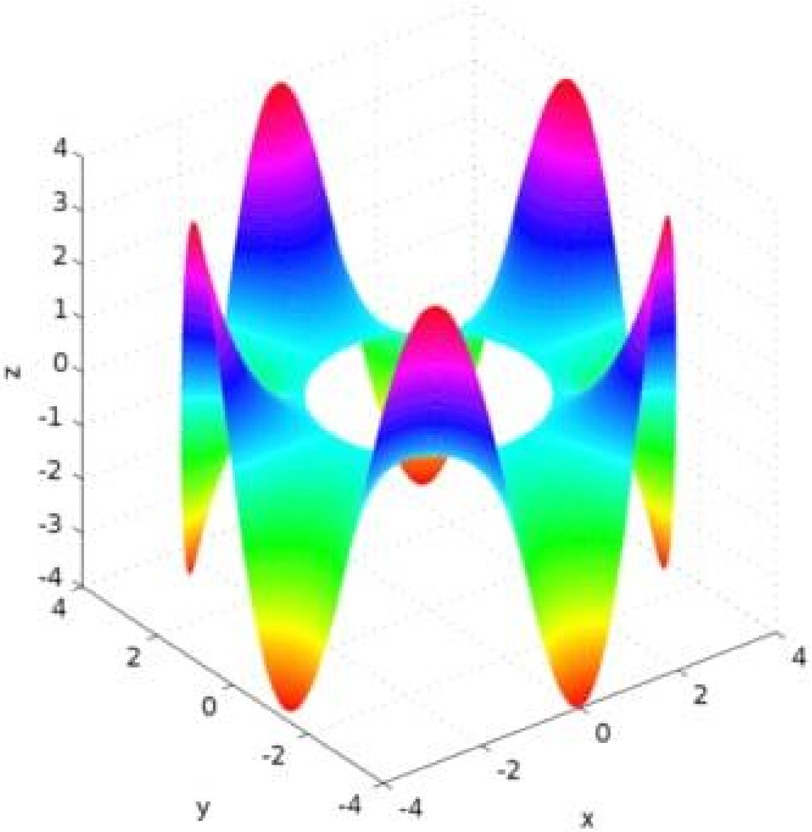

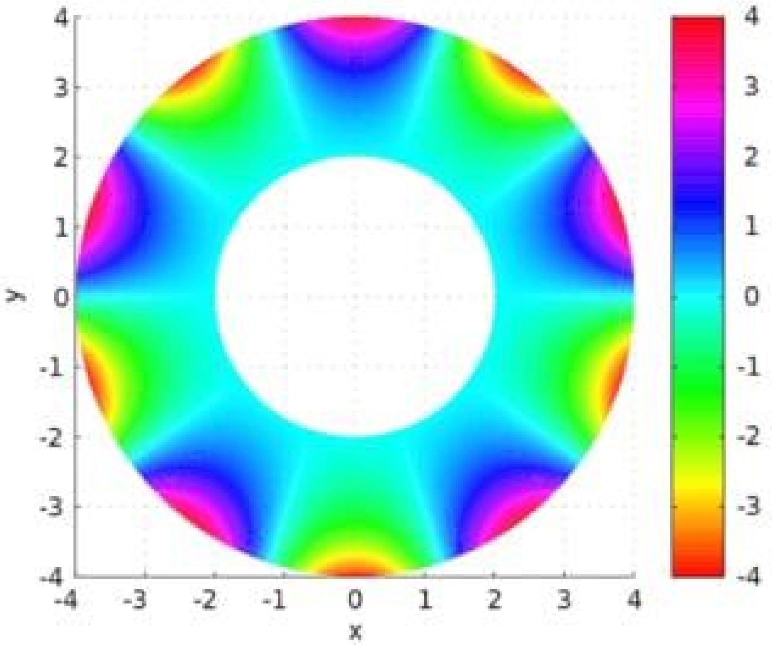

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Partial Differential Equations (PDE)

There are two main approaches to solving elliptic PDEs, namely the finite difference methods (FDM) and variational (or energy) methods. FEM falls into the second category. Variational approaches are primarily based on the philosophy of energy minimization.

Hyperbolic PDEs are commonly associated with jumps in solutions. For example, the wave equation is a hyperbolic PDE. Owing to the existence of discontinuities (or jumps) in solutions, the original FEM technology (or Bubnov-Galerkin Method) was believed to be unsuitable for solving hyperbolic PDEs. However, over the years, modifications have been developed to extend the applicability of FEM technology.

Before concluding, it is necessary to consider the consequence of using a numerical framework that is unsuitable for the type of PDE. Such usage leads to solutions that are known as ñimproperly posed.òThis could mean that small changes in the domain parameters lead to large oscillations in the solutions, or that the solutions exist only in a certain part of the domain or time, which are not reliable. Well-posed explications are defined as those where a unique solution exists continuously for the defined data. Hence, considering reliability, it is extremely important to obtain well-posed solutions.

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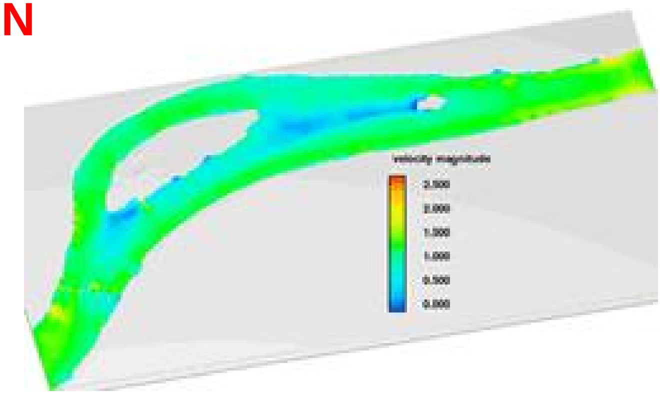
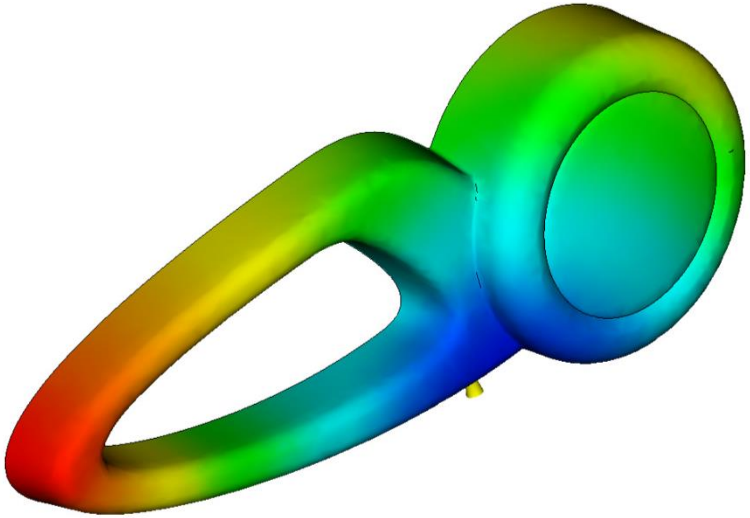
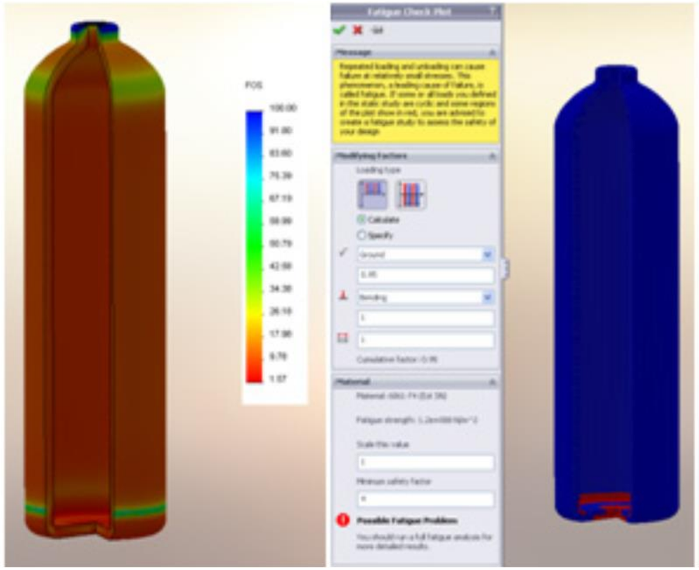
NUMERICAL SIMULATION



In conclusion, every technical issue connected with

- **HEAT DISTRIBUTION**
- **FORGING PHASES**
- **HYDRAULIC FLOW**
- **MOULDING FLOW**
- **ACOUSTIC RADIATION**
- **FATIGUE SIMULATION**
- **é é é .**





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