

Computational Simulation

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Introduction to Computational Simulation

Computational Simulation is the process of using computer models to replicate, predict and analyse the behaviour and performance of vehicles, systems or components under various conditions. These simulations allow engineers to virtually test and optimise designs without the need for physical prototypes or on-track testing.

Computational Engineering

The first phase of design and testing in modern engineering relies heavily on computational methods. This allows for rapid testing of designs without the need for prototype manufacture. The main subsections of computational engineering are:

- **Computer Aided Design (CAD)**
- **Computer Aided Engineering (CAE)**
- **Computer Aided Manufacturing (CAM)**

CAD is a way to digitally create 2D drawings and 3D models of real-world products before they have been manufactured. Typically used in component design, assembly creation, testing tolerance, motion simulation a finite element simulation modelling.

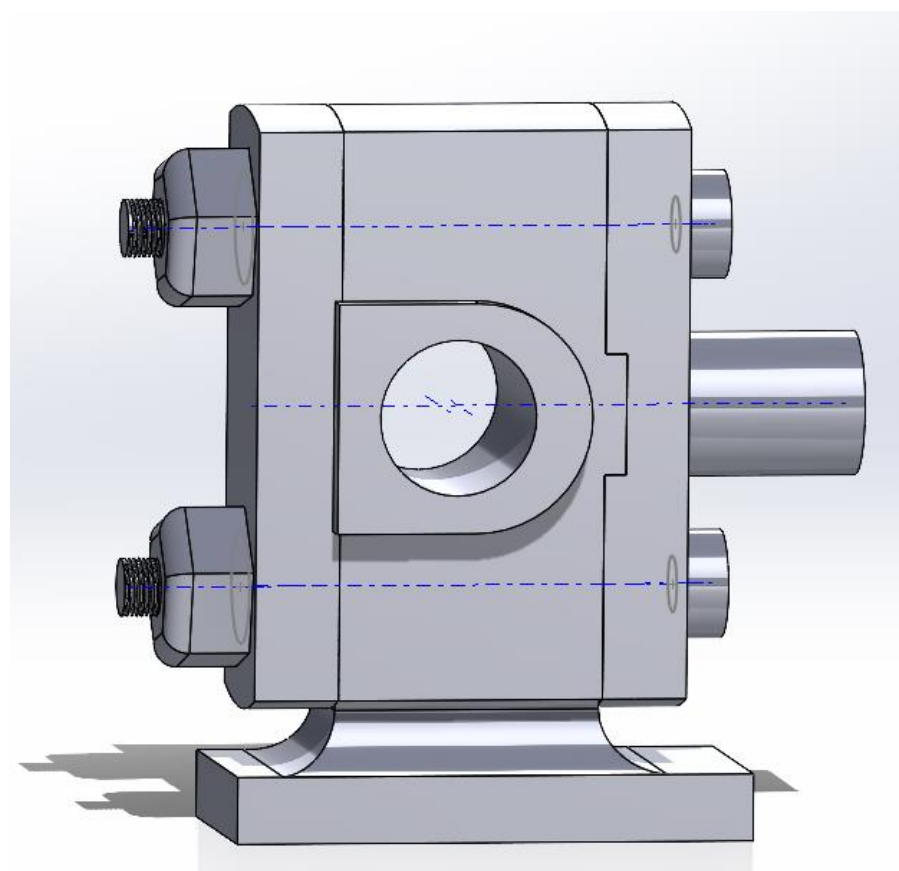


Figure 1: A CAD model

CAE uses simulation software to analyse forces, stresses, deformations, and fluid flow. Uses finite element methods to divide the large problem into many smaller ones, making solving easier.



Figure 2: Photo courtesy of Scan2CAD

CAM Using computer systems to plan, control and manage manufacturing processes

Finite Element Analysis (FEA)

FEA breaks down complex problems into smaller, manageable finite elements for computational solutions, which can be solved easily.

Types of Analysis: linear static, non-linear, thermal, fatigue, crashworthiness and computational fluid dynamics (CFD)

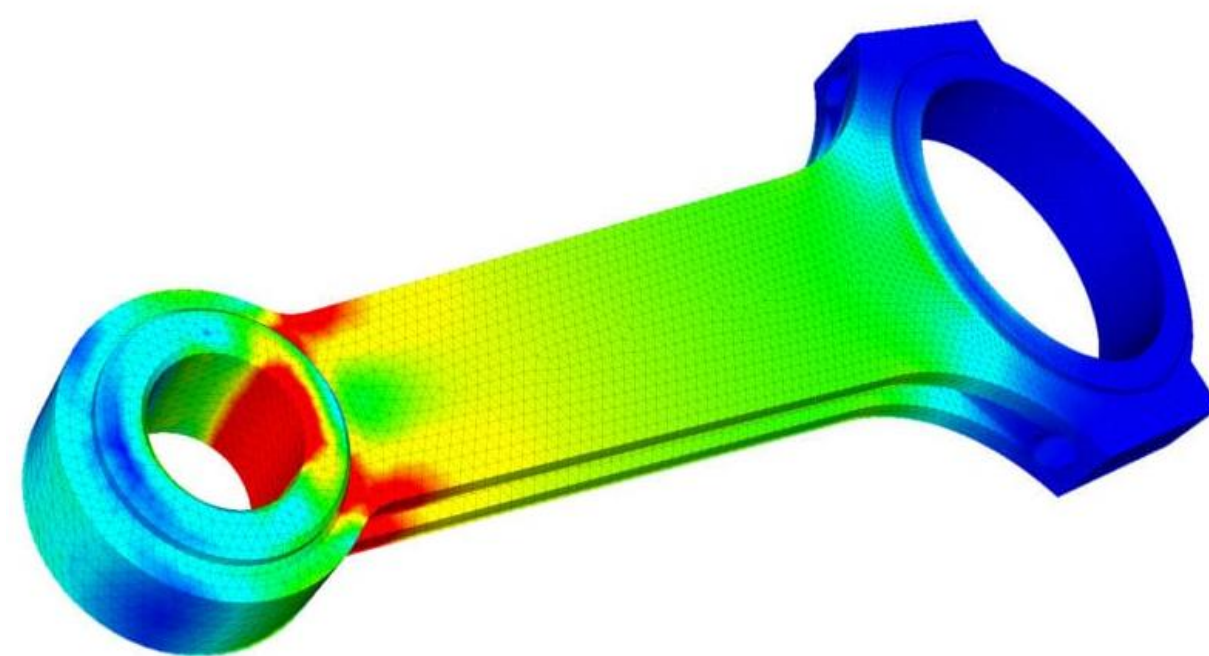


Figure 3: FEA simulation of a piston rod

Validation of Simulations

Validation is the process of determining that the model on which the simulation is based is an acceptably accurate representation of reality (Giannanasi et al. 2001)

Ensures accuracy by comparing computational models with real-world data.

Methods of validation include hand calculations, standard result comparisons and physical validation.

Validation deals with the assessment of the comparison between ‘sufficiently accurate’ computational results from the simulation and the actual/ hypothetical data from the system.

Applications in the Automotive Sector

Crashworthiness: With computer models, engineers can predict the movements of a car in an accident. Crash simulations are the most familiar to the public. **These simulations consider factors including speed, angles at which the crash occurs, and those characteristics of the automobile that includes the materials used in making the car.**

Suspension Kinematics: Simulation helps to address these challenges by enabling engineers to create virtual models of suspension systems, allowing for rapid testing. By simulating real-world scenarios, engineers can explore different design alternatives and fine-tune suspension performance before any physical prototypes are made.

Vehicle Simulations

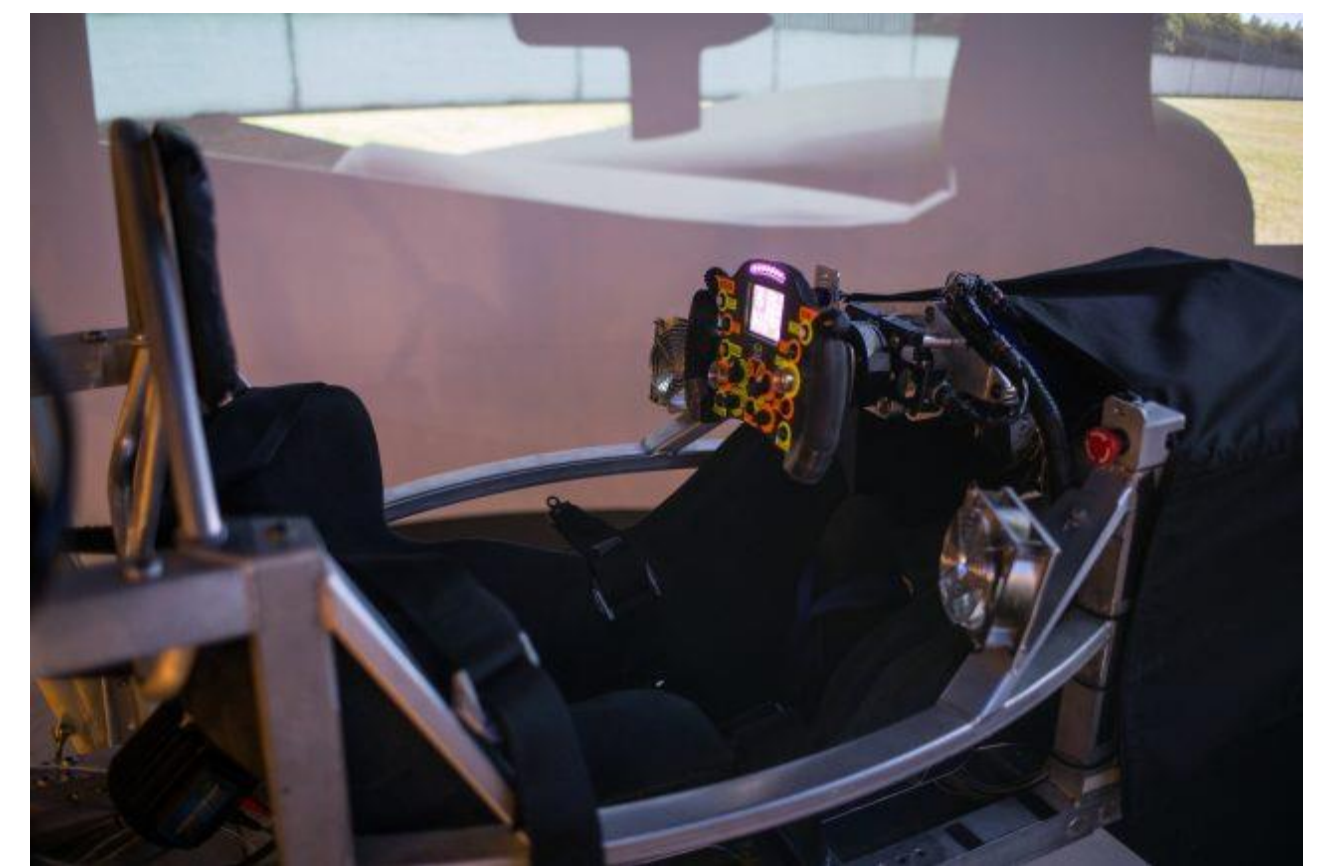


Figure 4: Driver-in-the-loop simulator (Gitlin, 2018)

- **Driver Out of the Loop (DOL):** Uses physics-based models for vehicle design, suspension, aerodynamics, and engine tuning.
- **Driver In the Loop (DIL):** Simulates vehicle dynamics with a human driver; used for motorsports, strategy planning, and real-world testing.
- **Dynamic Simulators:** High-fidelity motion platforms mimic real driving experiences.

References

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