

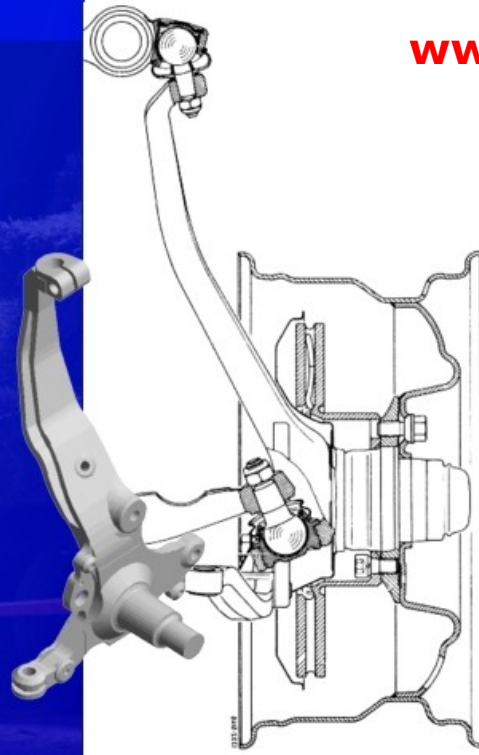


White Paper Series

## Design Validation of Automotive Systems

- Benefits using SolidWorks Simulation

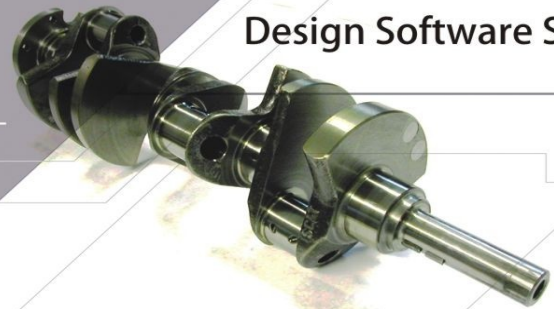
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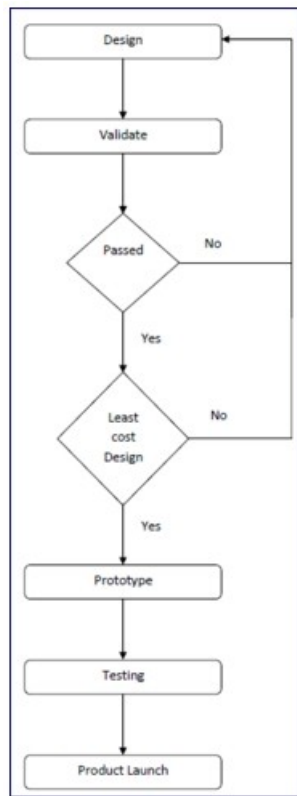
**Head Office:** Old No. 342, New No. 90, Arcot Road, 1st Floor, Kodambakkam, Chennai - 600 024 Tamilnadu INDIA  
Tel: +91 (44) - 2480 3370 / 2372 0265 / 2375 1679. Fax: +91 (44) - 2484 4227. e- mail: [info@egs.co.in](mailto:info@egs.co.in)

**Branch Office 1:** 1/1, B R Nagar, Trichy Road, Opp. Coimbatore Stock Exchange, Singanallur P.O.,  
Coimbatore - 641 005 Tamilnadu INDIA Tel: +91 (422) - 231 0268, 231 4653

**Branch Office 2:** No. 34, Shriram Nagar, II Street, Karumandapam, Trichy - 620001. Phone: 0431-2481443. email : [trichy@egs.co.in](mailto:trichy@egs.co.in)



## Executive Summary



**Integrated CAE approach to Product Development**

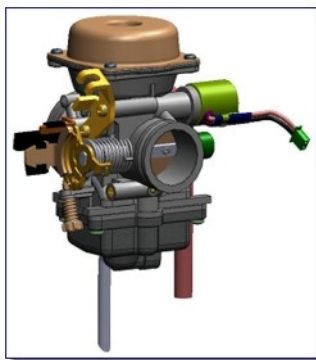
Automotive Industry is constantly looking at ways and means of reducing costs and staying profitable while delivering on time. Common denominator in all these challenges is Design. Companies investing in developing indigenous Design Technologies, emerge successful in the world market and are able to sustain and innovate at a higher pace than the rest of the competition. This is possible on account of the following capabilities:

- Delivering products faster with Up-front Engineering Design Validation as a part of the Product Development Process while compressing the cycle time
- Lean Design by incorporating Value Engineering as a part of the Design Process ensuring evaluation of least cost alternatives before even the first prototype is developed
- Increasing Reliability by Design – an Initiative that will eliminate hidden costs associated with product recall, re-design and/ or replacement of parts

'Valuefacture' of a product ensures product acceptance by Customer while assuring improvement in bottomline profitability. Companies that have identified Design Engineering as a Profit Centre have continued to invest in tools and technologies that augment Design Validation with assured return on Investment.

## Challenges faced by the Automotive Industry

Increasing functional complexity, predatory pricing, compulsive cost reduction commitments, aggressive deadlines, field failures, warranty costs, product recalls are too familiar situations in the automotive sector. Almost all automotive Tier I and II suppliers and their vendors share these common issues.

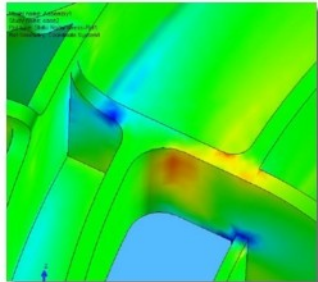


**Design Validation of Automotive Sub-systems**

All cross-functional teams in every organization deal with one thing in common – drawings. A reflection of perfection in design, drawings affect the profitability of any Organization. Perfection in design is achieved only by validating the design concept and continuously refining the design to enhance value and performance.

Imagine what a 10% weight reduction can do to a Company's bottomline profitability. Add to it 10% higher efficiency than a competitive product or technology, the Company's USP just got stronger. Now, choose alternate cost-effective material, the Company has just got the winning combination it needed. All this is possible if the Design department is given Cost Reduction Targets & Performance Enhancement Targets – initiatives that will go a long way in increasing the gap between the Company and its competitors. Such targets are achievable ONLY by Design Validation.

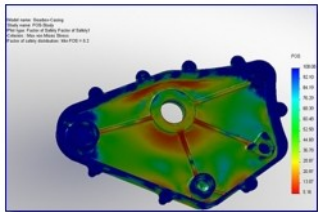
## What is Design Validation?



**Addressing Breakage with Warranty Period using SolidWorks Simulation**

Ensuring the design meets the Fit, Form and Functional requirements specified in the Statement of Requirement for a product, by means of analytical and / or physical testing, is commonly referred to as Design Validation. Analytical methods include Finite Element Analysis (FEA), Computational Fluid Dynamics (CFD), Kinematic Analysis of Mechanisms and Tolerance Stack Up Analysis. Physical testing include deflection measurements, strain gauging, tri-axial vibration testing, measuring fluid flow parameters, temperature measurement, accelerated durability testing, on-road vehicle testing, four-post vehicle testing, frequency response measurements, hot-chamber and cold-chamber testing among others. For physical testing, a set of prototypes (preferred minimum number is 8) conforming to dimensional specifications are necessary. For analytical testing a 3-Dimensional CAD model of the design is sufficient.

## Why Design Validation?



**Gear Box Casing Stress Analysis using SolidWorks Simulation**

Imagine a situation wherein a product needs to be tested for tri-axial vibration response to meet functional requirements. After building a set of acceptable prototypes, the assemblies are tested individually on a shaker table, one direction at a time. At the end of the test, that could last anywhere between a few hours to a few days, if failures are witnessed then design changes need to be effected. What caused the failure in the first place? At the end of the physical testing, one is left with only a failed prototype and not a solution ! Add to this the predicament to deliver on time, tool change, cost implications, loss of confidence and above all, customer trust, we have a complex challenge of monstrous proportions.

On the contrary, if the Design Team had been able to validate the design using analytical methods, evaluate alternatives that are cost-effective and predict the failure modes and ensure fatigue analysis yielded higher cycles than test requirements, the first prototypes would have passed the test, leading to a win-win situation for the Company and its customer.

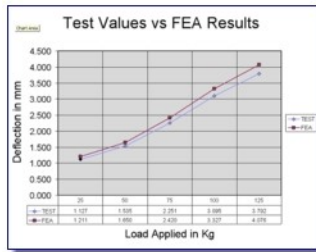


**Full Vehicle Simulation using SolidWorks Simulation**

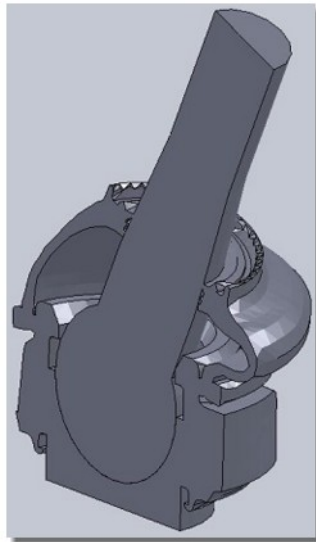
Every Organization needs to give the best to the customer. Every employee needs to give the best to the Organization. Design team has to deliver the best products. This is possible only by constant innovation and design validation.

Basic objectives of any organization in terms of critical business issues are met by Design Validation. Answers to any of the following questions, in affirmative, would emphasize the need for Design Validation as a part of the Design process.

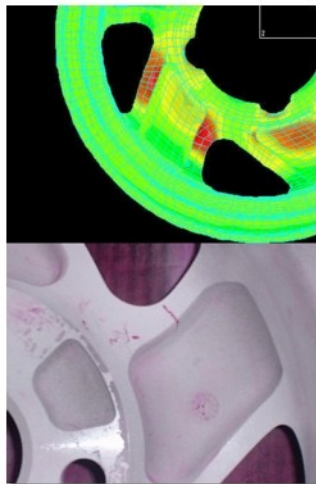
- Is profitability under threat from predatory pricing?
- Have we developed the Best-in-class Cost effective product?
- Is Technology important for product to survive?
- Is there a necessity to improve product performance?
- Is Cost Reduction a mandatory requirement?



**Deflection correlation using SolidWorks Simulation**



**Ball Joint Articulation – Deflection of rubber boot using SolidWorks Simulation**



**High-cycle Fatigue of Alloy Wheel - Correlation between Test and Analysis using SolidWorks Simulation**

## Functional Design Validation for Automotive Components & Systems

### Stiffness & Deflection Analyses:

Stiffness of automotive parts is vital to meet performance criteria, especially in parts such as brackets, mounts, body structure components, machined castings among others. Stiffness studies find immediate relevance in following areas:

- Anti-vibration Mount Design
- Suspension attachment to body structure
- Instrument Panel support structure
- Brackets used in mounting sub-systems such as water pump, oil pump, radiator, cross-member re-inforcements, steering attachment among others
- Machining of casings – to maintain tolerance of straightness, flatness, location and orientation
- Tyre deflection due to inflation and loading – for ride comfort and force transmissibility studies

### Frequency & Buckling Analyses:

It is a well known fact that resonant conditions reduce life of components. Systems designed for limit loads in axially-loaded members need to have buckling calculations done to ascertain safety and reliability. Some of the benefits of Frequency & Buckling Analyses for automotive systems include:

- Natural Frequency calculations for body structures, mounts, support brackets, rotating components including fans, transmission elements, power-train among others
- Limit load calculations using Linearized Buckling analysis for steering systems, suspension components, engine components, brackets and body structure sub-systems

Frequency calculations are a pre-requisite for performing response estimations based on harmonic and random excitations.

### Durability & Fatigue Analyses:

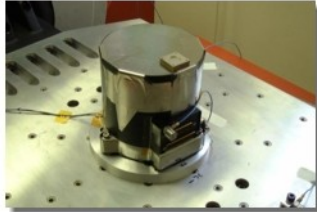
A vehicle is tested on a 4-post shaker system using road-loads as input. At the end of testing components are found to have failed. Since loads transmitted to the failed components would not be known, re-design to overcome the failure is a daunting task. A system level analysis with fatigue calculations would throw light into vulnerable areas in the system and help address the failure issues. This is a powerful approach to solving such issues in addition to predicting possible modes of failure.

Components are subjected to cyclical load testing on test rigs to ensure

required number of cycles are completed without evidence of failure. This requirement can be easily tested on a digital prototype virtually to ascertain zones of failure, cycles to failure and modes of failure.

When this exercise is carried out at the design stage, it is possible to evaluate alternate designs to arrive at least cost designs for higher profitability.

### **Vibration & Dynamic Analyses:**

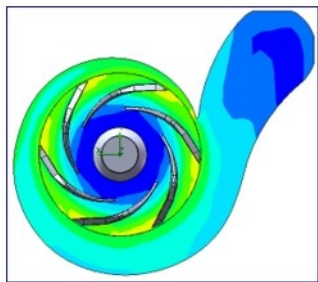


**Tri-axial Shaker Testing**

Accelerated durability testing is conducted by placing automotive sub-systems on shaker tables and subjecting the same to varying base excitations such as fixed-amplitude sine-sweep or random excitations. Life is consumed in these tests rapidly leading to a failure. If no failures are evident after a stipulated duration, the component(s) are said to have passed the criteria.

This can be easily verified on digital designs using Simulation approach first by extracting required number of eigen modes and then performing a post-dynamic analysis for computing the response characteristics.

The advantage of digital simulation is enhanced by performing a combination of what-if scenarios that is generally unavailable in test rigs unless an expensive investment is made for special purpose testing equipments.

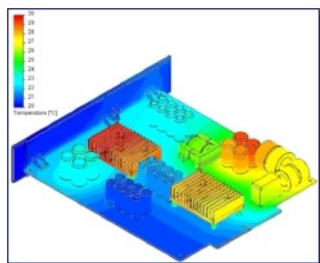


**Velocity Profile Plot of Water Pump using SolidWorks Flow Simulation**

### **Thermal and Fluid Flow Analyses:**

Estimation of temperature, pressure, velocity among other parameters can be computed using Computational Fluid Dynamics Software (CFD) in combination with Finite Element Analysis (FEA) for thermal deformation and effect of pressure on structural side.

Be it electronic thermal management of engine control systems, climate control devices, radiator circuit, fan studies, brake rotor cooling, hot- and cold- chamber testing, Simulation has come a long way in addressing critical performance challenges and optimization of design.



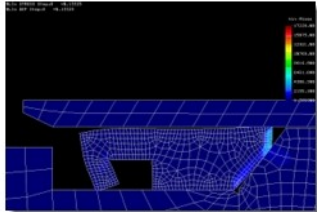
**Electronics Cooling using SolidWorks Flow Simulation**

Several correlations between test and analysis data have revealed the powerful technological advantage a manufacturer enjoys by implementing these solutions effectively.

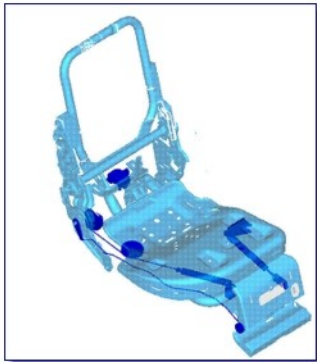
CFD is very useful to estimate characteristics of water pump, oil pump, fuel delivery devices and systems among other sub-systems.

### **Non-linear Analysis:**

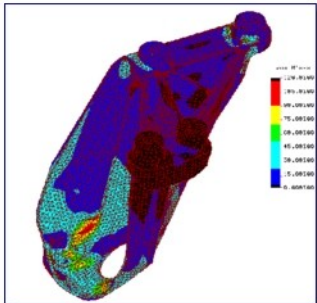
Critical sealing systems, light weight composites, manufacturing process simulations require sophisticated Non-linear analytical treatment. Effectiveness of sealing systems under assembled conditions involving initial deformation can be found using Non-linear Simulation Analysis.



**Rubber Seal Non-linear Analysis using SolidWorks Simulation**



**Seat Actuation Mechanism – Kinematic Analysis using SolidWorks Motion Simulation**



**Engine Mount – Durability & Point Mobility based Optimization**

Large deformation analysis and Large displacement analysis ensure that product safety and performance are not affected during function. Seals, Gaskets, Bellows, Hoses, Weather Beading, Tyre inflation and loading are some of the areas that Non-linear analysis finds application in the Automotive sector.

### **Kinematic Analysis:**

Mechanisms find use in automotive industry extensively. Door Closure, Windows, accelerator, braking, fuel-trap-door opening, transmission gear selection, hood/ deck-lid opening, seat actuation are some of the areas where Kinematic analysis is important to ensure fail-safe actuation and performance. Forces calculated using Kinematic analysis will be used in FEA to estimate stresses and deflections.

### **Summary**

Design Validation, integrated as a part of the Design Process ensures that automotive products and systems produced are Sustainable in the long run, in terms of :

- Technological Ownership
- Cost-effective Product Development
- Increased Reliability and Quality

Additional benefits from Sustainable designs include:

Conservation of:

1. Material
2. Resources
3. Energy

This would necessarily result in Least Cost Designs – Need of the hour.

### **About EGS India:**

EGS Computers India Private Limited, since inception in 1993, has been providing solutions in the areas of Product Design, Validation and Engineering Simulation for customers in India. EGS India is an authorized reseller of SolidWorks Simulation Software Solutions since 1997. Backed by years of expertise in Design, Finite Element Analysis, Correlation to Test data and Software Development, SolidWorks Technical Support Team at EGS India has been delivering Solutions to demanding customer requirements in applications ranging from Automotive, Material Handling, Machinery Development to Power, Process and Allied industries.

### **About SolidWorks Simulation:**

SolidWorks Simulation (formerly known as Cosmos FEA) is a flagship product of SolidWorks Corporation, USA. Reputed as an Easy-to-use Design Validation Software, SolidWorks Simulation is known for its interoperability with contemporary CAD software such as Unigraphics, CATIA, Pro/Engineer in addition to mid-range CAD software such as Autodesk Inventor and SolidEdge.