Business-friendly Solutions

CAE SIMULATIONS FOR AN OPTIMAL & COST EFFECTIVE AUTOMOTIVE CHASSIS DESIGN

The Backbone of Automobiles

Chassis, the base unit of an automobile, forms the frame that supports the sub-assemblies and other components of the vehicle. It also provides stability to the car, protecting it from the various forces and impacts, which it must continuously withstand.

Basic functions of a chassis;

- Carry all the stationary loads attached to it, along with the load of passengers and cargo carried in the vehicle
- Withstand and control the torsional vibration caused by the movement of the vehicle
- Withstand the centrifugal force caused by cornering of the vehicle
- Withstand bending stresses due to rise and fall of the front and rear axles

Chassis Classification:

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Conventional chassis or full frame chassis

- Specifically used in commercial vehicles like Trucks, Buses, SUVs and Off-highway vehicles
- Conventional chassis handles higher load capacity and has higher strength
- This, though, comes with a drawback of providing lower levels of handling and refinement, along with the tendency of body vibrations

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Non-conventional or frameless chassis

- Offers the advantage of less rattles and squeaks. It also provides good handling due to higher body rigidity and weight
- Load carrying capacity is lower and is not safe in accidental conditions
- Used mostly in hatch back and sedan cars

Chassis Development:

Modern chassis design has come a long way. At the inception of automotive industry, the chassis structures were made of a wooden frame, with wooden body panels mounted on it. Since 1900, chassis are developed from steel and aluminum sheets enabling the designers to create shapes with more freedom.

It is extremely important that the chassis design is sturdy, reliable and durable. Today, the engineering industry is equipped with skills to optimize the weight and size of the chassis. Engineers use industry standard tools, such as Computer Aided Engineering (CAE), which enable them to simulate the design to create a prototype.

The effects of chassis input conditions can easily be estimated, with minimum experimental cost, with the help of simulation tools like the finite element (FE) modelling. The main objective is to determine the static loads defined in pay load and vehicle weight acting in the form of reaction forces that was adopted for static load condition.

Finite Element Method helps in understanding:

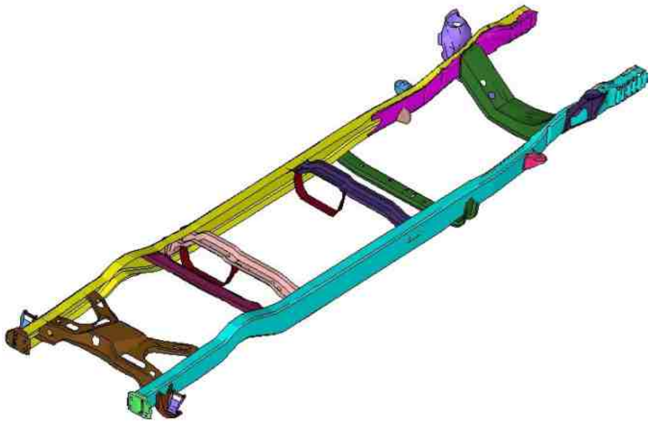
- The physical behavior under various applied loads
- To predict the performance and design feasibility
- To calculate the safety margin
- To identify the weakness of the design, if any
- To identify the optimal design

Typical FE analysis of chassis consists of following steps:

- FE modeling
- Modal Analysis
- Strength/stiffness analysis
- Vibration
- Optimization
- Durability study

FE Modeling:

Before proceeding with the analysis, the basic step involved is the FE modeling. The chassis parts such as the long member, cross member, suspension brackets are meshed with shell elements (2D Mesh) and solid mesh (3D mesh). Bolt connections are represented by the BEAM elements and welds are represented with shell mesh. Appropriate thickness and material properties are specified to the respective components of the chassis.

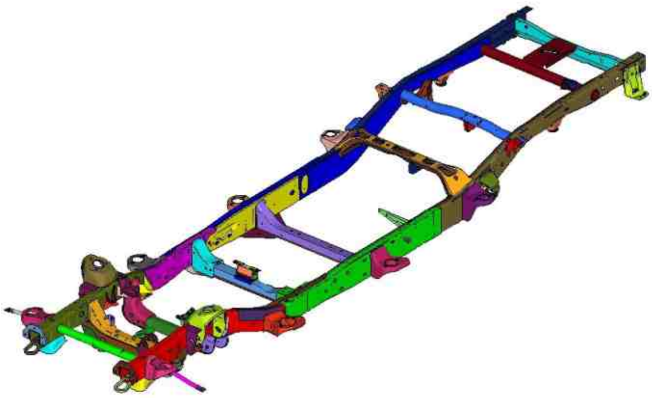


Modal analysis:

Modal analysis is carried out to understand the mode shapes and the 1st natural frequency of the system. For any chassis assembly, there is set of desired mode shapes required to make the design feasible. Modal analysis helps in identifying the unconnected regions and free elements.

Stiffness analysis:

Static Structural Analysis is performed to derive insights about the behavior of the assembly under various loading conditions. It assists the engineers in determining high stress developing regions, leading to deformation, and provides the opportunity to modify the design accordingly. A chassis must have high structural stiffness in order to have minimum deformations upon loading. As a structure that houses various vehicle systems, this attribute ensures that the chassis is stable for these systems to consistently perform.



This basically involves three types of evaluation;

- Torsional, bending and lateral stiffness
- Specific loads are applied as per the type/class of the vehicle and stiffness values are calculated
- The geometry or material thickness or reinforcements are added/removed to get the desired stiffness in all three directions

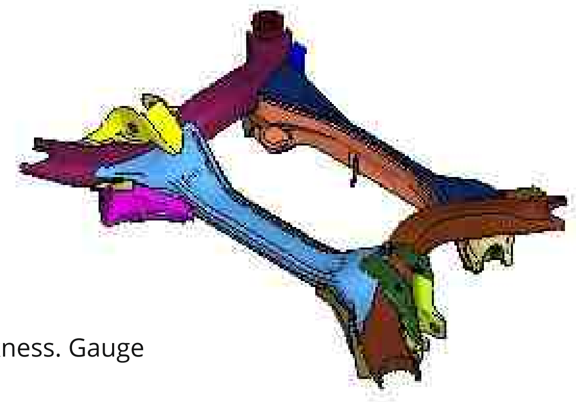
Vibration Analysis:

Vibration analysis of chassis assembly is carried out as per JIS-1601-D prescribed methods. This analysis is performed to understand the behavior, resonance frequency of the assembly, response of the structure under influences like engine type and road conditions. To start with, FE model of respective chassis assembly is modelled with appropriate bolt and welding connections. Springs are represented by 1D elements with spring stiffness properties. A vibrational acceleration of 4.5G OR 3G, for commercial and passenger vehicle respectively, is applied at the wheel centers.

Along with this Random vibration analysis is also performed to determine the structure response under random loading. The power spectral density (PSD) spectrum is used as load input for the random analysis. Power spectral density is a kind of probability statistics method, and is the root mean square value of random variables, including a measure of the random vibration energy and frequency information. Power spectrum that can be displacement, velocity, acceleration or force power spectral density and other forms.

Optimization:

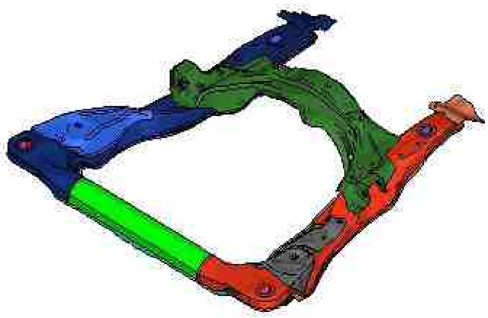
It is the discipline of adjusting a process, to optimize some specified set of parameters, without hampering the performance of the system. The most common goals are minimizing weight and maximizing efficiency.



Following are the types of optimization processes:

- Topology optimization
- Topography optimization
- Size/gauge optimization
- Shape optimization
- Free-shape optimization

Chassis are basically made up of sheet metal with varying gauge thickness. Gauge optimization is the best suite to optimize the chassis assembly.



Typical gauge optimization process follows the below steps:

- Meshing of the chassis/cradle assembly (front and rear cradle)
- Assigning the respective thickness, material properties, boundary condition
- Objective is set as minimizing the Volume for the static and modal analysis load case
- Responses are set as Static displacement and 1st Natural frequency
- Design variable is assigned to selected parts of chassis member, with upper and lower bound. Also the existing part thickness is mentioned in the design variable.
- With the above parameters, optimization will be carried out arriving at the output in the form of optimized gauge thickness for the given parts of the chassis members. These thickness values are rounded off to the nearest gauge thickness and the static and modal analysis are re-run to achieve the desired output.

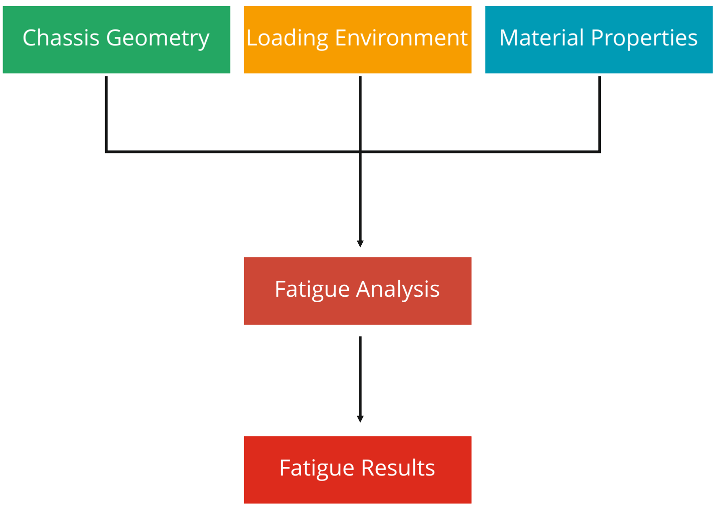
The gauge optimization is basically performed to validate and improve the existing chassis design. But there are some other options like topology optimization, wherein an engineer can create a new chassis design from the given design space, that might have possible constraints. An output from such optimization can be further fine-tuned by the designers and reiterated by CAE engineers to come up with the final optimal design.

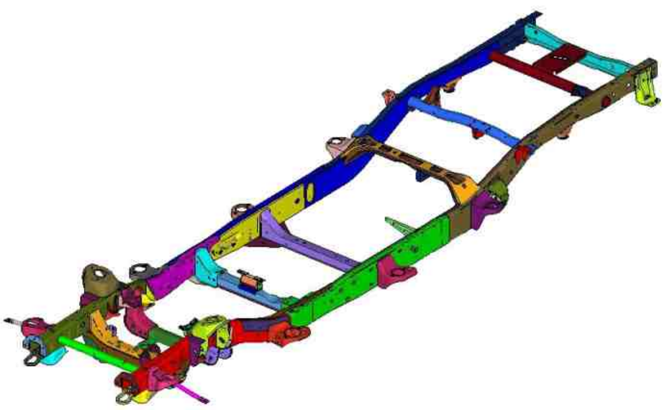
This process will help organizations to improve the quality, lead time and can test diverse designs without going for prototyping, which intern reduce the cost of development of the project.

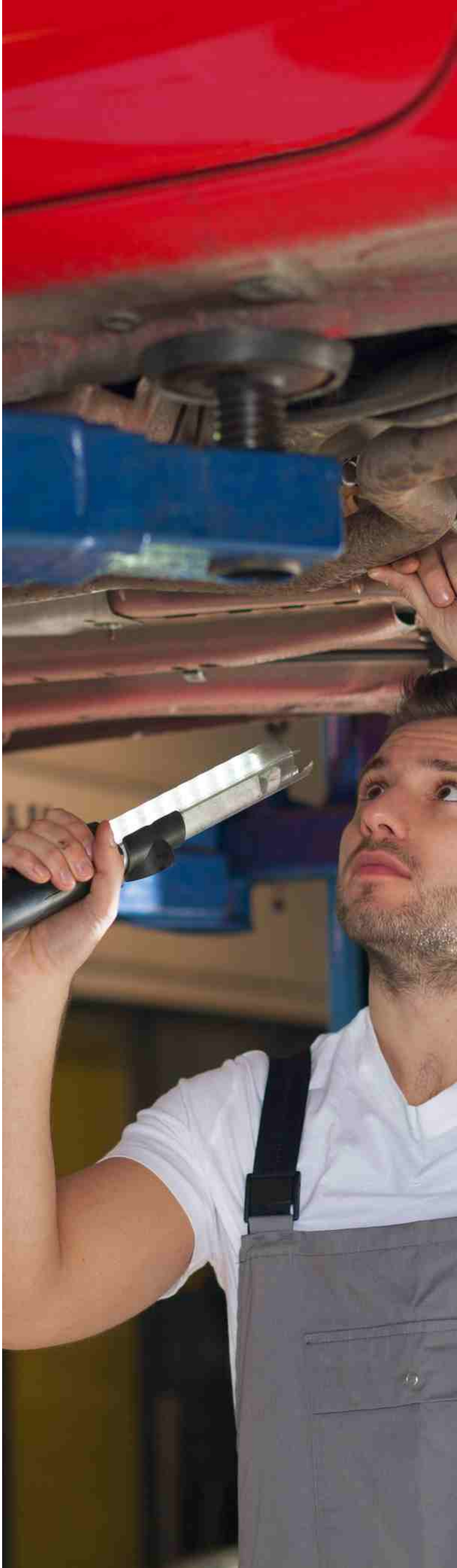
Durability Study:

The structural components such as chassis assembly might be strong enough to withstand a single applied load. But what happens when the part operates over and over, day after day? To predict component failure in such cases requires what's called fatigue or durability analysis. Computer simulations determine how well parts will hold up during cyclic loading. There are many tools like nCode, FEMFAT, MSC Fatigue etc.

Fatigue is generally referred as the weakness in the metal caused by the repeated variation of stress. Fatigue cracks are caused by the cyclic loading. A part can fail even though the stress are low. Fatigue cycles are defined by the change of stress or strain. Figure shows the typical fatigue analysis roadmap:







Durability analysis of a chassis is performed from gathering the road load data for the physical tests. This data is incorporated in the fatigue analysis of chassis. Furthermore, the fatigue life can be predicted through two methods. Stress Life (SN) approach and Strain Life (EN) approach.

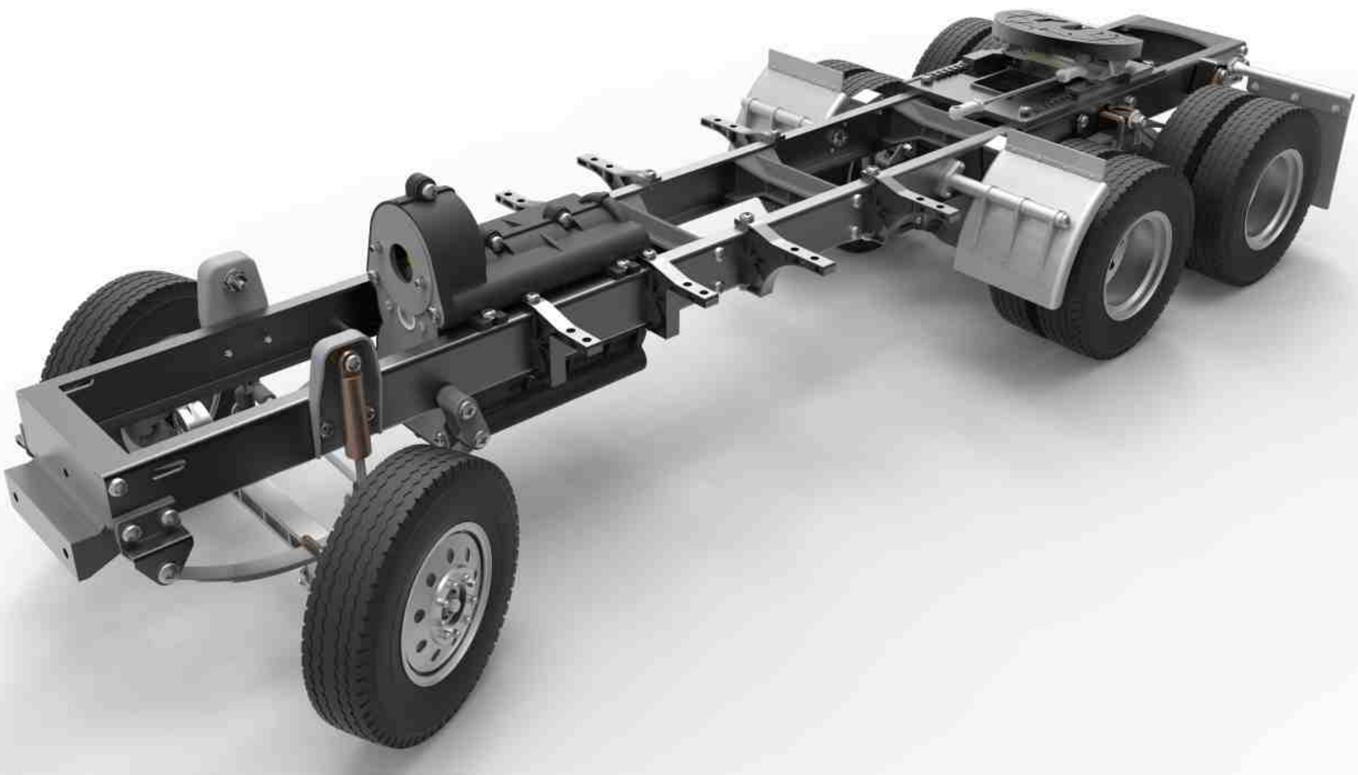
Stress Life approach, components subjected to stresses less than yield do not experience plastic deformation and have relatively long lives. This type of loading is commonly referred to as high-cycle fatigue. For ductile metals, high-cycle fatigue is generally considered to be greater than 100,000 cycles of operation.

Alternately **Strain Life (EN) approach** components subjected to stresses greater than yield experience plastic deformation and have relatively short lives. This type of loading is commonly referred to as low-cycle fatigue. For ductile metals, low-cycle fatigue is generally considered to be between 100 and 100,000 cycles of operation.

Chassis Material:

The material used for the construction of the chassis is usually carbon steel, but aluminum alloys are also gaining popularity considering its light-weight characteristics. The chassis comprises of several I, C and U sections of steel. Operations such as folding, pressing and rolling are done to incorporate various chassis members. Press blanking and bending are important stages in the chassis production.

The next process in the production line is Welding. Welding provides rigidity, uniformity and high strength to the chassis. Metal Inert Gas (MIG), and Tungsten Inert Gas (TIG), or even a combination of both, are used to achieve the desired characteristics. Finally, surface treatment is done for anti-corrosion, damage and wear prevention, improving hardness etc. The coating and plating processes are also performed to prevent the chassis from corrosion.



Conclusion:

This paper explains the various types of CAE processes that are performed on chassis system. FEA tools can be used extensively to simulate the automotive chassis accurately for validation and development purpose. It is easier to represent the actual scenarios with the CAE tools, which will help in predicting the behavior of the structure, failure mode, and developments required to improve the design of the chassis. These tools not only helps in design and development, but also reduces overall cost and lead time.

Author Profiles

Swanand Jawadekar has more than 20 years of experience in Computer Aided Engineering, project execution, training, deep dive technical studies, and offshore consulting. With clients like Ford and JLR, Swan and has played key customer facing roles when developing solutions over the long term. He has also been a key Account Manager and Business Transformation catalyst for major global customers, enabling value creation by providing solutions and services with a focus on the Automotive, Aerospace, and Industrial Machinery sectors.

Prasad Balgaonkar is a Mechanical Engineer with over 12 years' experience in the areas of CAE Analysis for Full Vehicle and BIW &System Level Validation plans. Experienced in Crash Simulations and NV & Durability Analysis, he has been engaged in various automotive vehicle programs such as Seating System, Instrument Panel, BIW Development, Front Fascia Exterior Development, etc. His key competencies in CAE Driven Design Validation &Optimization, Test-FE correlation, and Crash Simulations have enabled him to work with domestic and international clients including Tata Motors and Chrysler, as well as some European OEMs.

Nikhil Shirgurkar - Nikhil Shirgurkar is a Mechanical engineer with over 12 years of experience in areas of Computer Aided Engineering (CAE). He has worked extensively on structural analysis of chassis, cradles, NV and Durability study. He has also worked on vehicle programs such as Chassis and Load body optimization, simulation of Seating Systems for FMVSS regulations, Instrument Panel, BIW development, etc. Nikhil has his key Competencies and working experience in CAE driven design validation & optimization, and Test-FE correlation. He has worked with Domestic and International customers like Tata Motors, Lear Corporation and European OEMs.

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