Optimization of Steering Knuckle using DOE

Mahendra Shelar
Assistant Professor, TCET
Email: mahendra.tcet@gmail.com

Abstract—A major issue in vehicle industry is the presence of variability in the physical properties and manufacturing processes. Deterministic approaches are unable to take into account these variabilities without leading to oversized structures. The necessity of assessing the robustness of a particular design requires a methodology based on durability and design optimization through probabilistic models of design variables (DOE).

In general it is identified the steering knuckle which is one of the critical components of vehicle which links suspension, steering system, wheel hub and brake to the chassis. We have identified the above problem the process of optimizing the design using a methodology based on durability and design optimization through probabilistic models of design variables (DOE).

Index Terms—Optimization, FEA, DOE

I. INTRODUCTION

Knuckle is an important part on the car, its main function is to load and steering, which support the body weight, transfer switch to withstand the front brake torque and braking torque so on. Therefore, the shape of the structure and mechanical properties knuckle, there are strict requirements. According to models, can be divided into heavy-duty vehicles knuckle, knuckle midsize car, light vehicle steering knuckles, mini-cars Knuckle, knuckle and passenger cars knuckle six categories; press materials and manufacturing methods

Aluminum and cast iron steering knuckles three sections; their characteristic shape into pole class knuckle, knuckle class center hole and casing class. Pole class knuckle mainly composed of the stem portion, flanges and branches rights, and more generally for large Mid-sized cars and buses in; center hole category mainly consists of the base knuckle, flange and right branches, the base center hole, a Generally used for driving the car in which the front axle; casing class knuckle mainly by pole, sleeve and flange composition.

II. IMPLEMENTATION

PHASE 1:
- It is a pre-processing phase
- Creation steering knuckle Geometry
- Finite Element Modelling (Meshing)
- Materials & element properties
- Load and boundary conditions under static and dynamic conditions

PHASE 2:
- It is a processing phase

Knuckle will be subjected to static and dynamic load conditions where I will be performing linear static structural analysis, model analysis (Frequency or Eigen value), Transient structural response analysis and the critical parameters of knuckle affecting the response will be listed down for design of experiments considering manufacturability

PHASE 3:
- Post processing and Design of Experiments using Methodology mentioned below
- Visualization of results and (methodology)

PHASE 4:

III. OPTIMIZATION

From the second and third phases I will collect all the input parameters affecting the output parameters and there by generating the response surface and there by generating the optimized model.
3.1 METHODOLOGIES USED

3.1.1 FEA

FEM is best understood from its practical application, known as finite element analysis (FEA). FEA as applied in engineering is a computational tool for performing engineering analysis. It includes the use of mesh generation techniques for dividing a complex problem into small elements, as well as the use of software program coded with FEM algorithm. In applying FEA, the complex problem is usually a physical system with the underlying physics such as the Euler-Bernoulli beam equation, the heat equation, or the Navier-Stokes equations expressed in either PDE or integral equations, while the divided small elements of the complex problem represent different areas in the physical system.

FEA is a good choice for analysing problems over complicated domains (like cars), when the domain changes (as during a solid state reaction with a moving boundary), when the desired precision varies over the entire domain, or when the solution lacks smoothness. For instance, in a frontal crash simulation it is possible to increase prediction accuracy in “important” areas like the front of the car and reduce it in its rear (thus reducing cost of the simulation). Another example would be in numerical weather prediction, where it is more important to have accurate predictions over developing highly nonlinear phenomena (such as tropical cyclones in the atmosphere, or eddies in the ocean) rather than relatively calm areas.

3.2 DOE

Design of experiments is a series of tests in which purposeful changes are made to the input variables of a system or process and the effects on response variables are measured. Design of experiments is applicable to both physical processes and computer simulation models.

Experimental design is an effective tool for maximizing the amount of information gained from a study while minimizing the amount of data to be collected. Factorial experimental designs investigate the effects of many different factors by varying them simultaneously instead of changing only one factor at a time. Factorial designs allow estimation of the sensitivity to each factor and also to the combined effect of two or more factors. In a highly competitive world of testing and evaluation, an efficient method for testing many factors is needed.

IV. DESIGN OPTIMIZATION FLOW

4.1 LOADING CALCULATIONS

<table>
<thead>
<tr>
<th>LOADING CONDITIONS</th>
<th>Proportionality</th>
<th>Total</th>
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<tbody>
<tr>
<td>Braking Force</td>
<td>1.5G</td>
<td>22200</td>
</tr>
<tr>
<td>Lateral Force</td>
<td>1.5G</td>
<td>22200</td>
</tr>
<tr>
<td>Steering Force</td>
<td>Steering effort of 50 N</td>
<td></td>
</tr>
<tr>
<td>Load on knuckle hub in X-Direction</td>
<td>3G</td>
<td></td>
</tr>
<tr>
<td>Load on knuckle hub in Y-Direction</td>
<td>3G</td>
<td></td>
</tr>
<tr>
<td>Load on knuckle hub in Z-Direction</td>
<td>1G</td>
<td></td>
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</table>

There are two types of load acting on knuckle i.e force and moment. This knuckle is designed for vehicle of 2960 kg so breaking force acting on it produces moment:

\[
\text{Moment} = \text{force} \times \text{perpendicular distance} \\
= 1.5G \times 78 \text{Nmm} \\
= 1.5 \times (2960/4) \times 10 \times 78 \\
= 865800 \text{Nmm}
\]

5.1 Static Analysis

![Fig. 5.1 Model for analysis](image)
5.2 Dynamic Analysis

Table 5.1 Max/Min Solid Safety Factor

<table>
<thead>
<tr>
<th>Result Type</th>
<th>Element ID-Pos.</th>
<th>Safety Factor</th>
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<tr>
<td>MaxFactor of Safety Calculation</td>
<td>166303-Center</td>
<td>1.44448e+004</td>
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<tr>
<td>MinFactor of Safety Calculation</td>
<td>160583-Center</td>
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Graph 5.1 Transient responses for Dynamic loading

DYNAMIC ANALYSIS FOR CYCLIC LOADING

<p>| | | |</p>
<table>
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<td>NUMBER OF EQUATIONS</td>
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</tbody>
</table>

Fig. 5.6 Dynamic Loading

Fig. 5.5 SOLID STRS VON MISES

Fig 5.6 SOLID STRS VON MISES (Max: 0.00000e+000)
VI. RESULT AND DISCUSSION

A major issue in vehicle industry is the presence of variability in the physical properties and manufacturing processes. Deterministic approaches are unable to take into account these variabilities without leading to oversized structures. The necessity of assessing the robustness of a particular design requires a methodology based on durability and design optimization through probabilistic models of design variables (DOE).

Optimization method used in this project gives 8.195% mass reduction and maximum stress has not changed significantly with no change in material properties.

When optimized model is compared with initial model, 8.195% Reduction in weight has been achieved with stress and deflection change within range and not exceeding above the Project target limits.

FUTURE SCOPE

Other vehicle components also can be optimized so that to have less overall vehicle weight in similar way also when there will be change in material of knuckle significantly more mass reduction can be achieved by keeping stress and deflection values within control limits.

REFERENCES


