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Modelling and Structural Optimization of Upper Control Arm Using FEA

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Abstract
In the quest for reduced vehicle mass without sacrificed integrity, Computer Aided Engineering (CAE) topology optimization software was investigated and utilized in the design of the Indian Formula 1vehicle as a means to determine the optimum material distribution within a component for a given set of loading and boundary conditions.

This paper looks at the design of a rear suspension control arm component using modern topology optimization techniques and compares the end product to that of the 2005 model control arm component, which was designed using more traditional techniques.A hydraulic load cell system was created to simulate the vehicle suspension forces and was used to physically test the original and optimized parts to failure. Through the use of Altair OptiStruct® topology optimization software, the same hydraulic loads are applied to the virtual component and checked the results.

Control arm is designed in 3d modeling software then imported in to Altair Hypermesh for preprocessing; to solve Altair Radioss is used. Altair Optistruct is used for optimum material distribution in the component to get weight reduction. After getting reduced component from Optistruct again modified model is analyzed by using same loads and constraints. First step will solve static analysis and second step is to reduce the weight of the component topology optimization methodology is used with the help of Altair Optistruct software. After optimization a weight savings of 42% coupled with an increase in yield strength of 29.7% was realized in the optimized design of the Control Arm.

INTRODUCTION:

A control arm is defined as a type of lever whose two arms form a right angle, or nearly a right angle, having its fulcrum at the apex of the angle .It received the name from its first use which was to change the vertical pull of a rope into a horizontal pull on the striker of a bell. Control arms can also be found in the suspension system of formula-style race cars. Because formula-style vehicles have their suspension control arms exposed by protruding through the body panels, there are aerodynamic reasons for relocating the spring and damper assembly to a location on the vehicle that is contained within the bodywork. This set-up is distinctly different from that of a standard production car (where the springs and dampers are traditionally attached directly to the suspension control arms), and requires the use of a push or pull rod and control arm to transmit the suspension forces from the control arm to the spring and damper.

The objectives of this study are:

1. To determines the static analysis and torsion analysis of the Control arm by using Optistruct software.

2. Weight reduction of control arm component by changing the geometrical dimension and structural properties. This design is given by topology optimization.

3. Compare the base run analysis and optimized analysis.

Topology Optimization

Topology optimization is a relatively new numerical method used to determine the optimum shape and distribution of material within a given design space for a given set of design constraints based on responses obtained from a finite element analysis. For structures under static loading, the basic finite element equation that is solved can be expressed as

$$KD = f$$

Where, K is the effective stiffness matrix of the structure, d is the displacement vector, and f is the load vector as applied to the structure.

MODELLING OF CONTROL ARM

In this project 3d model is designed using CATIA V5 R20 Software. This software used in automobile, aerospace, consumer goods, heavy engineering, etc. CATIA V5 R20 is very powerful software for designing complicated 3d models.

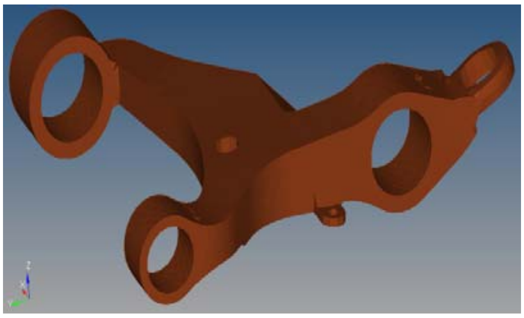

Fig1: model of control arm

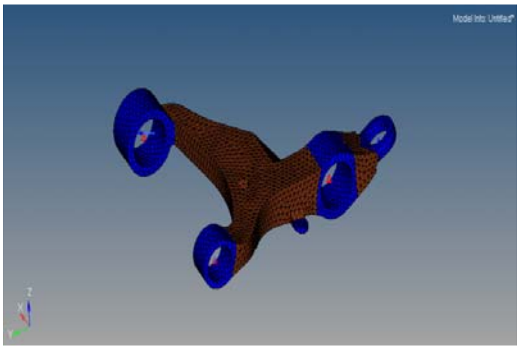

Fig2: Meshing of Control Arm with Tetra elements

ANALYSIS OF CONTROL ARM

Steps to be followed in the analysis of control arm

- Torsional analysis
- Static Analysis
- Structural Optimization

LOADS OF CONTROL ARM

Force at three locations is different based on the physical effect to control arm force and moments are applied.

In first load condition steering rod load and torque are considered and in the second load condition load and torque are applied on the control arm.

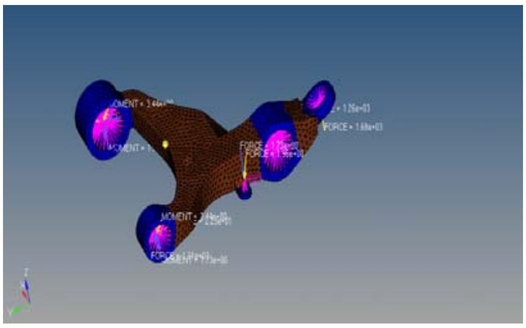

Fig3: Forces and moments applied to control arm

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Displacement of control arm at Load condition1

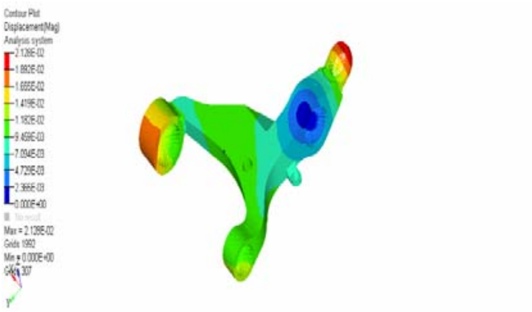

Fig4: Displacement of control arm at load condition1

Displacement of control arm at Load condition2

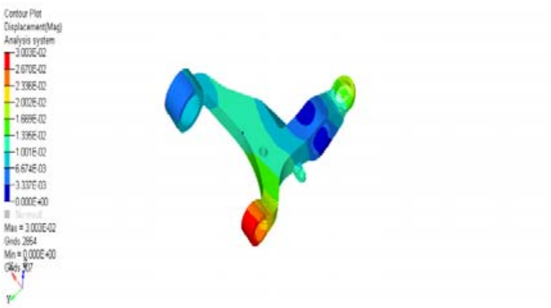

Fig5: Displacement of control arm at load condition2

TOPOLOGY OPTIMIZATION USING OPTISTRUCT

Topology optimization is a method which distributes the density of an initially homogenous volume to achieve a certain objective function while observing the defined constraints. Minimize volume is usually considered as an objective function, while the stress acts as a constraint and with manufacturing constraint such as draw direction.

The optimized models performance in the form of stiffness and strength evaluation is done and linear static analysis is carried out using OPTISTRUCT according to fulfill the design and testing standard values.

The total optimization process is followed as in below flowchart.

Find out the loads acting on the bracket

↓

Test and FEA results of the base

↓

Define design domain and non-design domain

↓

Topology optimization
(Define design variables, constrains and design objective)

↓

CAD modelling & finite element analysis for optimized model

↓

Final Optimized Design

Fig6: Flow chart for Optimization

OPTIMIZED MODEL RESULTS OF CONTROL ARM

Optistruct after consecutive iterations gives the contours for removing material in the given design area. Model in the Figure gives the optimization area of control arm.

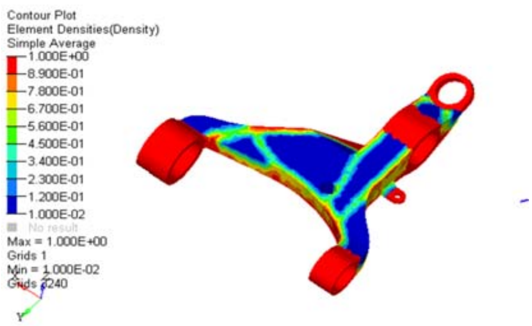

Fig7: Model showing the Optimization(material to be removed) area

OPTIMIZED MODEL AFTER REMOVING MATERIAL OF CONTROL ARM

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This is Complete Optimized Model given by the software after removal of the huge material from the main geometry with consecutive iterations, by this unnecessary material has been removed as shown in Figure

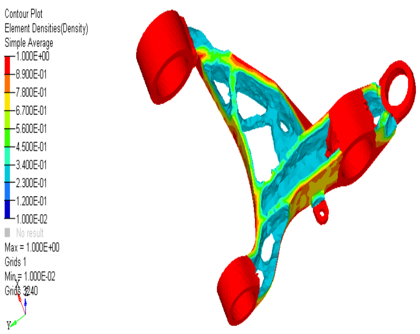

Fig8: Complete optimized model after removing the material of control arm

NEW DESIGN OF CONTROL ARM USING CATIA

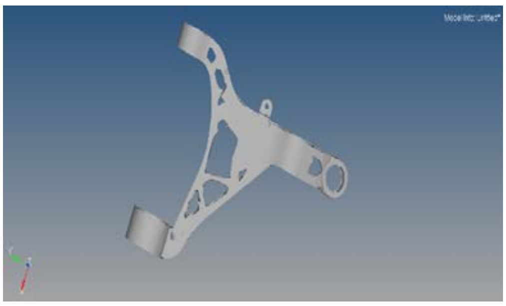

Fig9: New design for optimized result of control arm is designed in CATIA

STRESS COMPARISON FOR TWO MODELS OF CONTROL ARM

BASE MODEL LOAD CONDITION	OPTIMIZED MODEL LOAD CONDITION
Case 1 14 MPA	Case 1 21 MPA
Case 2 8 MPA	Case 2 11 MPA

DISPLACEMENT COMPARISON FOR TWO MODELS OF CONTROL ARM

BASE MODEL LOAD CONDITION	OPTIMIZED MODEL LOAD CONDITION
Case 1 0.021 mm	Case 1 0.040 mm
Case 2 0.030 mm	Case 2 0.051 mm

WEIGHT REDUCTION COMPARISON FOR TWO MODELS OF CONTROL ARM

MODEL TYPE	WEIGHT OF THE CONTROL ARM
Base Model	21.63 kg
Optimized Model	12.59 kg
Percentage of Verification	9.04/21.63 *100 42% Reduction

CONCLUSION

Hence, in this project the weight is reduced by 42% through the usage of the optimized aluminium material. The component (Aluminium made) has further undergone the structural optimization using the Hyper works 12.0 software the observation made from the results stated that the weight of the control arm has been reduced from 21.63 kg to 12.59 kg.

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