Re-Engineering of Suspension Control Arm Using Aluminum Alloy and Validation Using FEA

[1]Benjamin Shiloh Davidson, [2]Neelakrishnan S

[1]Assistant Professor, [2]Professor
[1]Department of Automobile Engineering,
[1]PSG College of Technology, Coimbatore, India

***Abstract*— Aluminum alloys have high Strength to weight ratio. This feature of this metal has been a matter of study among the engineers for the past few years. The recent manufacturing processes have solved the misery of manufacturing using aluminum alloys. This resulted in a strong eager for aluminum alloy application in all the fields of engineering. The development stages started in aerospace and aircrafts in earlier stages itself. The adaptation into road vehicle is a subject of study. The project here deals with application of aluminum alloy in Suspension components replacing steel with design change accompanying that can improve the material change aggressively.**

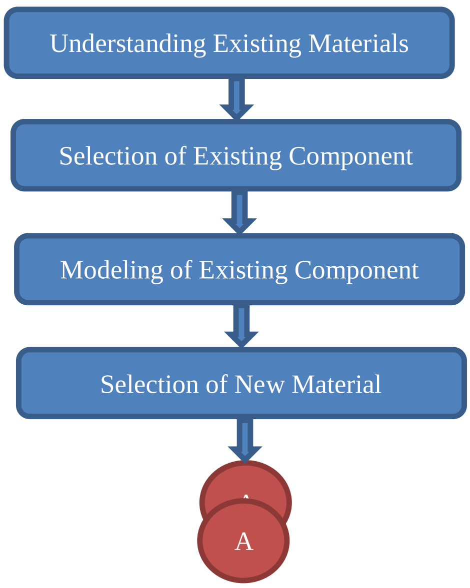
***Index Terms*— FEA, Control Arm, Aluminum, Ansys.**

I. Introduction (Heading 1)

Transportation is a significant source of CO_2 emissions with individual transportation (cars) producing a major share of it. Among the many measures to reduce CO_2 emissions from cars, technological ones (i.e. the ones that are intrinsic to the car and do not depend on driver behavior) are the most reliable. Light weighting is one of the most effective and directly impacts CO_2 emissions, as 100kg saved on the mass of a car is equivalent to a reduction of 9 grams of CO_2 per kilometer. With 2,700 kg/m^3, the density of aluminum is one third of that of steel. But such a weight reduction is seldom achieved since for a large number of parts, it is necessary to increase the average thickness of aluminum compared to steel to achieve the same part characteristics. It should be noted that, since the modulus of aluminum is lower than that of steel, the greater stiffness had to be achieved by improved geometry of the cast aluminum design. Each of the leading automakers are either investigating or actively increasing the aluminum content in their chassis and suspension systems. Thus the aim of this paper is re-engineering the suspension control arm using aluminum, make the design well suited along with the material change and thereby increasing the advantage of new lightweight aluminum material application and validation of this work with help of Finite Element Analysis tools.

II. Objective & Methodology

The main objective involved is to reduce the un-sprung mass of the vehicle thereby obtaining better ride and stability by application of aluminum alloy. The weight reduction helps to solve the existing problem of increase in weight due to Global standards and Safety norms. The design change for alternative material to be used will help in bringing out the best out of it rather than slightly change in material alone.



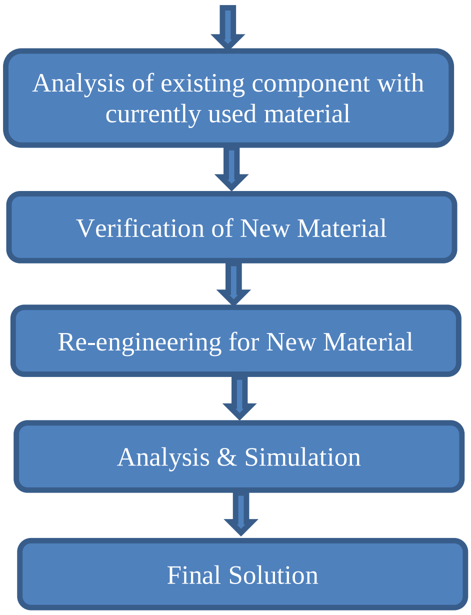


Table 1: Process Flow

III. CAD Modelling of Existing Component

Measurements were taken using Vernier caliper and scale, noted down and based on that the modelling is done for individual parts and then assembled properly using CATIA (Computer Aided Three-Dimensional Interactive Application).

Figure 1: Modeling using CATIA

Figure 2: Modelled Final Assembly

IV. Front Axle Load Calculation

Thus for a deceleration D_x, the front axle load is given by:

$$W_f = \frac{c}{L} W + \frac{h}{L}\frac{W}{g} D_x$$

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The specifications obtained from Users guide & journals gives following data:

W = 2600 Kg L = 2.425m c = 1.007m h = .6m g = 9.81m/s^2

$$W_f = \frac{1.007*2600}{2.425} + \frac{.6*2600*.5}{2.425*9.81} = 1100Kg.$$

So, during braking from 60Km/hr to zero, calculating the load transfer and thereby obtaining the maximum front axle load, W_f obtained as,

W_f = 1100 Kg.

Based on the calculations the maximum front axle load has been calculated and will be equally distributed between the two front wheels. So each wheel will be loaded half the front axle weight. So,

Load acting on the arm = $\frac{Wf}{2}$ = 550 Kg

= 550*9.81

= 5395.5 N

TECHNICAL SPECIFICATION

WEIGHT (kg) : (Tolerances as per INTEREUROPE STVZO)	
Complete vehicle kerb weight as per ISO:1176 (With spare wheel & tool):	: 1820 (FAW- 997 RAW- 823) - For AC / HVAC 1800 (FAW- 987,RAW- 813) - For Non-AC
Gross Vehicle weight	: 2600 (FAW 1080 ,,RAW 1520)
Max. Permissible FAW	: 1100
Max. Permissible RAW	: 1560

Table 2: Specification of Axle Load - TATA SUMO BSIII

The specification data given in the TATA SUMO User's manual also validated the fact that maximum possible load that can be acting on the front axle is 1100 Kg.

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Finally, complete content and organizational editing before formatting. Please take note of the following items when proofreading spelling and grammar.

V. Material identification

The existing material with which the arm is made is unknown. To do the analysis using ANSYS, actual material is to be known. Optical Emission Spectrometer is used to find out the material composition at various parts (as in the figure at 1, 2 & 3).

Figure 3: Material tested zones (1, 2, & 3)

Optical Emission Spectrometry (OES) technique utilizes a high-energy spark created across an argon-filled gap between an electrode and a sample of the material to be analyzed. The spark creates an emission of radiation from the excited sample surface with wavelengths characteristic of the elemental composition.

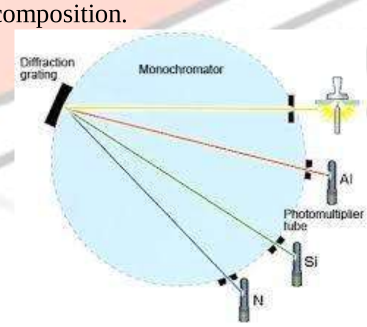

Figure 4: Principle of working of Optical Emission Spectrometry

The spectrum of radiation is separated into the distinct element lines and the intensity of each line is measured. Finally, these are precisely converted into concentration values for each element present. Typical applications involve determination of the alloying content of iron and steel, aluminum, copper, nickel, zinc, lead and many other metals and alloys. Optical Emission Spectrometry continues to be the reference technique for direct chemical analysis of solid metallic samples. Based on the spectrometry study we got the materials as:

- Forged part - ST 25 (at 1 & 2)
- Fabricated part - SAE 1005 (at 3)

VI. Simulation

Considering static load analysis in which the total load acting on the component is half the front axle load. So the analysis is done considering only the axle load. So the other joints are given fixed support boundary condition. The spring mounting is given with the front axle load.

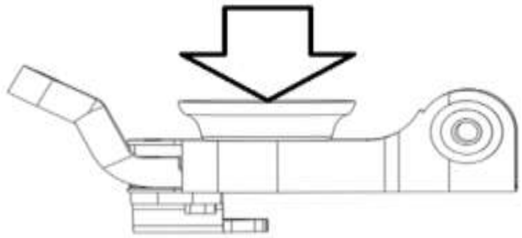

Figure 5: Loading on Lower Control Arm

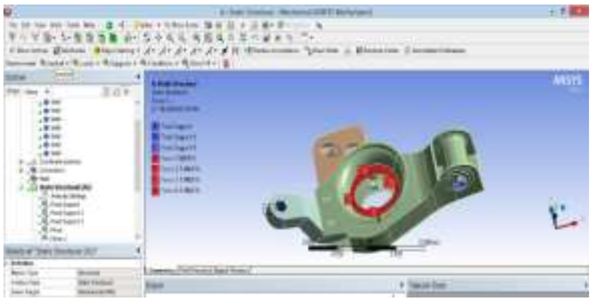

Figure 6: Application of boundary condition and Load

Analysis on Existing Design for SAE 1005 & ST 25

Material Properties

ST 25

Density	7850 kg m^-3		
Young's Modulus	Poisson's Ratio	Bulk Modulus	Shear Modulus
2.e+011 Pa	0.3	1.6667e+011 Pa	7.6923e+010 Pa
Tensile Yield Strength			
2.5e+008 Pa			

SAE 1005

Density	7872 kg m^-3		
Young's Modulus	Poisson's Ratio	Bulk Modulus	Shear Modulus
6.9e+010 Pa	0.33	6.764e+010 Pa	2.594e+010 Pa
Tensile Yield Strength			
3.5e+008 Pa			

Parameters

Volume	7.074e-004 m^3
Mass	5.5603 kg
Nodes	24916
Elements	12253
Force	-5395.5N in Z direction

Analysis on Existing Design for SAE 1005 & ST 25

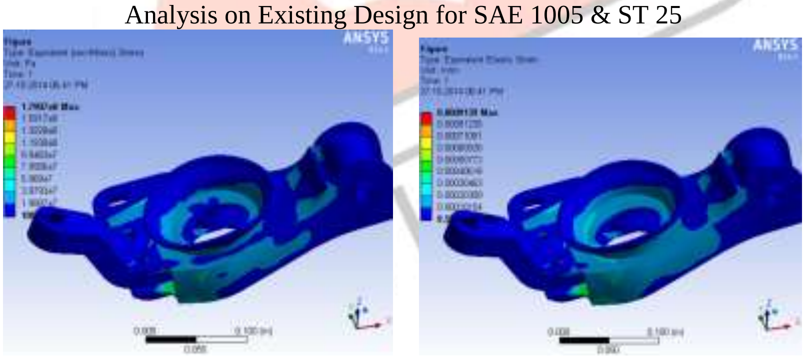

Figure 7: Von-Mises analysis for SAE 1005 & ST 25

Type	Total Deformation	Equivalent (von-Mises) Stress	Equivalent Elastic Strain	Strain Energy
Minimum	0. m	100.54 Pa	8.5879e-010 m/m	9.7952e-015 J
Maximum	1.4888e-004 m	1.7907e+008 Pa	9.139e-004 m/m	1.543e-003 J

Analysis on Existing Design with aluminum 6061 PH

Materials Properties

ALUMINIUM 6061 PH

Density	2700 kg m^-3		
Young's Modulus	Poisson's Ratio	Bulk Modulus	Shear Modulus
6.9e+010 Pa	0.33	6.764e+010 Pa	2.594e+010 Pa
Tensile Yield Strength			
2.76e+008 Pa			

Parameters

Volume	7.074e-004 m³
Mass	1.9673 kg
Nodes	24916
Elements	12253
Force	-5395.5N in Z direction

Analysis on Existing Design with aluminum 6061 PH

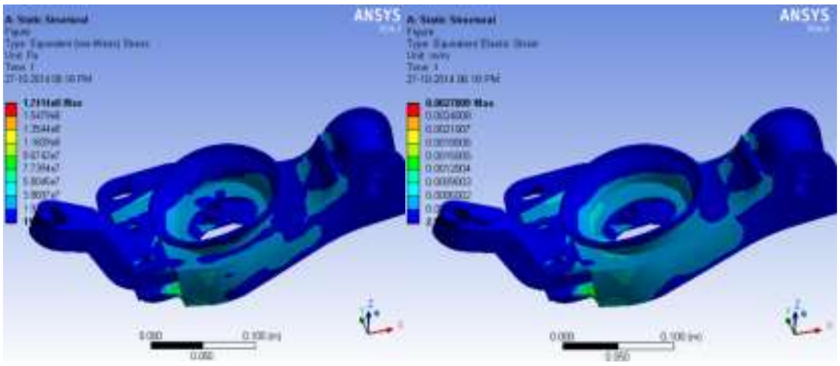

Figure 8: Von-Mises analysis for aluminum 6061 PH

Type	Total Deformation	Equivalent (von-Mises) Stress	Equivalent Elastic Strain	Strain Energy
Minimum	0. m	115.25 Pa	2.9356e-009 m/m	4.1671e-014 J
Maximum	4.4492e-004 m	1.7414e+008 Pa	2.7009e-003 m/m	4.6259e-003 J

Analysis on Existing Design with combination of aluminum 6061 PH & ST 25

Material Properties

ALUMINIUM 6061 PH

Density	2700 kg m^-3		
Young's Modulus	Poisson's Ratio	Bulk Modulus	Shear Modulus
6.9e+010 Pa	0.33	6.764e+010Pa	2.594e+010 Pa
Tensile Yield Strength			
2.76e+008 Pa			

ST 25

Density	7850 kg m^-3		
Young's Modulus	Poisson's Ratio	Bulk Modulus	Shear Modulus
2.e+011 Pa	0.3	1.6667e+011 Pa	7.6923e+010 Pa
Tensile Yield Strength			
2.5e+008 Pa			

Parameters

Volume	7.074e-004 m³
Mass	2.6443 kg
Nodes	24916
Elements	12253
Force	-5395.5N in Z direction

Analysis Existing Design with combination of aluminum 6061 PH & ST 25

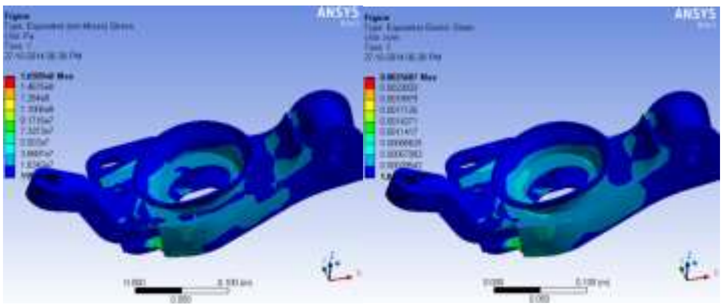

Figure 9: Von-Mises analysis for combination of aluminum 6061 PH & ST 25

Type	Total Deformation	Equivalent (von-Mises) Stress	Equivalent Elastic Strain	Strain Energy
Minimum	0. m	119.67 Pa	1.0482e-009 m/m	1.4877e-014 J
Maximum	4.3614e-004 m	1.6509e+008 Pa	2.5687e-003 m/m	4.5391e-003 J

VII. Proposed Design Evolution

A material change won't provide the complete advantage unless until a design change is provided [1]. So, in order to validate the effect, proposed design was done without effecting the assembly, keeping all constrains and parameters of the total wheel and axle assembly the same and modifying only on the sub-assembly.

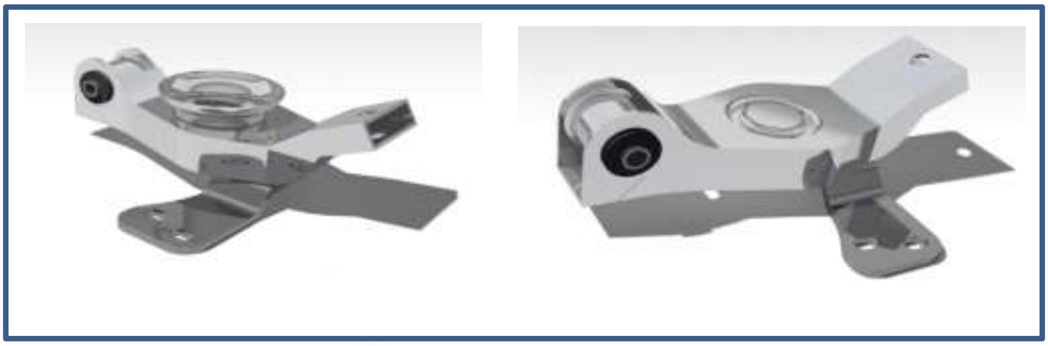

Figure 10: New designed Assembly with & without mounting cap for spring

The proposed design here above consists of the old solid arm eliminated and integrated to the single arm body. The cup in which the spring is mounted is retained in this case and the design is done so with thickness as 4mm for the part. This design in which the cup for mounting the spring has been eliminated and is integrated to the arm body itself. This results in reduced cross section while maintaining the functionality un-affected.

VIII. Proposed Design Simulation

The analysis is done with all the constraints and forces applied same as done for existing one. The material for arm is given aluminum 6061 PH and others the standard materials. The meshing is done and analysis is carried out. The results are published as below.

Analysis on Proposed Design-1 with aluminum 6061 PH

Materials Properties

ALUMINIUM 6061 PH

Density	2700 kg m^-3		
Young's Modulus	Poisson's Ratio	Bulk Modulus	Shear Modulus
6.9e+010 Pa	0.33	6.764e+010 Pa	2.594e+010 Pa
Tensile Yield Strength			
2.76e+008 Pa			

ST 25

Density	7850 kg m^-3		
Young's Modulus	Poisson's Ratio	Bulk Modulus	Shear Modulus
2.e+011 Pa	0.3	1.6667e+011 Pa	7.6923e+010 Pa
Tensile Yield Strength			
2.5e+008 Pa			

Parameters

Volume	7.0135e-004 m³
Mass	3.0843 kg
Nodes	16887
Elements	7918
Force	-5395.5N in Z direction

Analysis **on** New Design-1 with aluminum 6061 PH

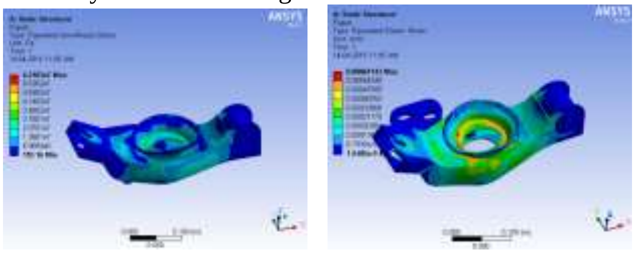

Figure 11: Von-Mises analysis for aluminum 6061 PH

Type	Total Deformation	Equivalent (von-Mises) Stress	Equivalent Elastic Strain	Strain Energy
Minimum	0. m	155.16 Pa	1.5405e-009 m/m	1.8672e-014 J
Maximum	1.9807e-004 m	6.2103e+007 Pa	6.1143e-004 m/m	1.3189e-003 J

Analysis on Proposed Design-2 with aluminum 6061 PH

Materials Properties

ALUMINIUM 6061 PH

Density	2700 kg m^-3		
Young's Modulus	Poisson's Ratio	Bulk Modulus	Shear Modulus
6.9e+010 Pa	0.33	6.764e+010 Pa	2.594e+010 Pa
Tensile Yield Strength			
2.76e+008 Pa			

ST 25

Density	7850 kg m^-3		
Young's Modulus	Poisson's Ratio	Bulk Modulus	Shear Modulus
2.e+011 Pa	0.3	1.6667e+011 Pa	7.6923e+010 Pa
Tensile Yield Strength			
2.5e+008 Pa			

Parameters

Volume	6.8639e-004 m³
Mass	2.3641 kg
Nodes	16432
Elements	7741
Force	-5395.5N in Z direction

Analysis New Design-2 with Aluminium 6061 PH

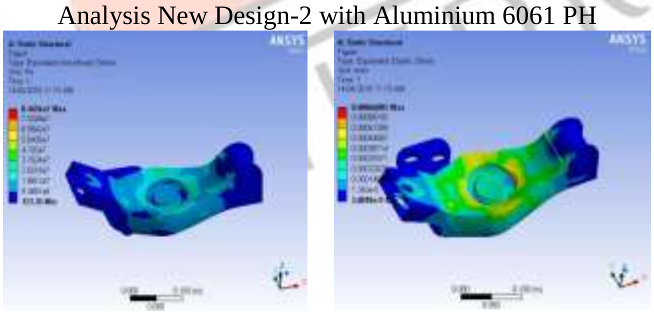

Fig 12: Von-Mises analysis for aluminum 6061 PH

Type	Total Deformation	Equivalent (von-Mises) Stress	Equivalent Elastic Strain	Strain Energy
Minimum	0. m	123.35 Pa	3.0018e-009 m/m	2.7784e-014 J
Maximum	1.6929e-004 m	8.465e+007 Pa	6.6085e-004 m/m	1.6456-003 J

IX. CONCLUSION

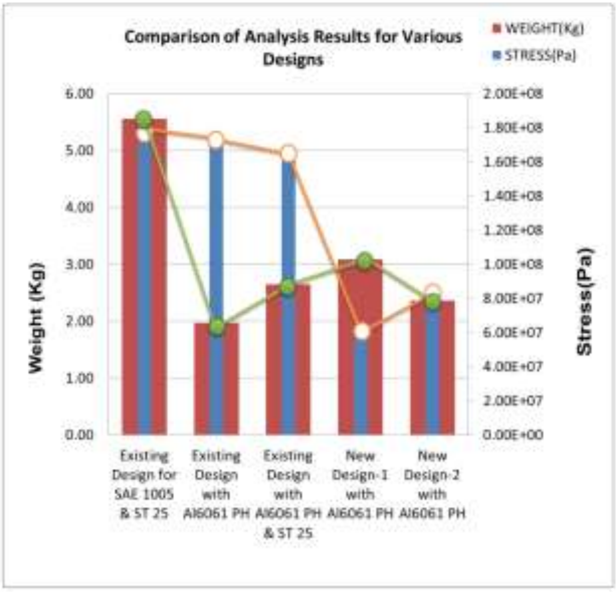

Figure 13: Comparison of Analysis Results for Various Designs

Based on the Ansys study for static conditions, we came across that with cup assembly has stress level and elastic strain the lowest. But when compared with the major factor the weight of the assembly and the stress and strain level corresponding, 2nd design (without cap) is much more acceptable and easy to manufacture. The graph plotted above compares all the 5 designs done. It clearly depicts how the new design along with the material change is favorable.

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