

Design and Analysis of Lower Control ARM

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ABSTRACT: The main objective of this paper is to model and to perform structural analysis of a LOWER CONTROL ARM (LCA) used in the front suspension system, which is a sheet metal component. LCA is modeled in Pro-E software for the given specification. To analyze the LCA, CAE software is used. The load acting on the control arm are dynamic in nature, buckling load analysis is essential. First finite element analysis is performed to calculate the buckling strength, of a control arm. The FEA is carried out using Solid works stimulation package.

The design modification has been done and FEA results are compared. The influencing parameters which are affecting the response are identified. After getting the final result of finite element analysis optimization has been done using design of experiment method. Taguchi’s design of experiments has been used to optimize the number of experiments. By reducing thickness of the sheet metal and by suggesting the suitable material the production cost of lower control arm is reduced. This leads to cost saving and improved material quality of the product.

KEYWORDS: lower control arm, FEA,

I. INTRODUCTION

The suspension system carries the vehicle body and transmit all forces between the body and the road without transmitting to the driver and passengers. The suspension system of a car is used to support its weight during varying road conditions. The suspension system is made of several parts and components. These include the front and rear suspensions, the shock absorbers, and the Macpherson strut system.

The suspension system is further classified into two subgroups, dependent and independent.

These terms refer to the ability of opposite wheels to move independently of each other.

1.1 TYPES OF SUSPENSION SYSTEM

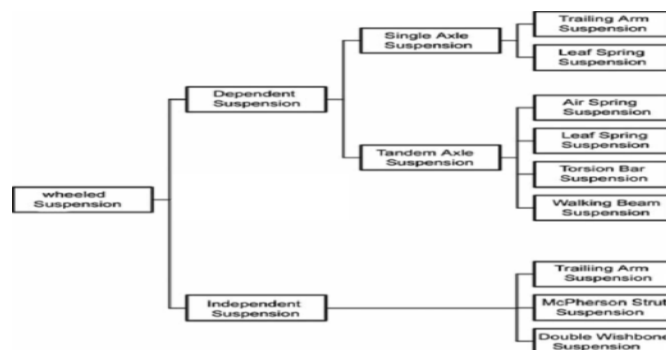


Figure .1.1. Types of suspension system

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II. LITERATURE REVIEW

Dr.J.Mahishi, Nonlinear static and analysis of automotive lower control arm, Ms&M Engineering Inc, Farmington Hills, MI, USA. This study was a part of a series that focused about the types of failure in materials; this article discussed about metallurgical failures. Failures are always caused by humans errors, according to this, errors were classified into three main categories, errors of knowledge, performance and intent. Finite element analysis is a very powerful tool in analyzing mechanical structures because it deal with the whole structure as a huge number of segments on each a mathematical solution is performed in order to know the state of each element of them, then they are summarized together to give the whole status of the structure.

Kang, B., Sin, H.-C., & Kim, J. (2007). Optimal shape design of lower control arm considering dynamics effect. International Journal of Automotive Technology, 8(3), 309-317. Fracture mechanics science is involved in putting the failures due to fracture and cracks into a mathematical frame so it can be understood and explained; it related the defect size and the crack's principal initiation to the subjected stresses and the fracture toughness of the material. The size of the defect that the material can handle without any further growth can be calculated from the equation; this equation will allow for determination of the allowable flaw size, minimum stress required for sudden failure, applied load when failure occurs, determination of materials used in manufacturing and decide if the design of a certain component was satisfactory or not.

Nawar A. Al-Asady, Dept of mechanical Engineering. UKM, Malasiys Automobile body reinforcement by finite element optimization. Finite Elements Analysis (FEA) is the mathematical representation of complex engineering problems to obtain a unique solution for each segment of the system; it can be used to obtain structural, heat transfer, static and various other engineering systems solutions. FEA is based on approximating the mechanical and physical behaviour of each tiny segment of the system by a mathematical representation. This paper dealt about simple FEA for a truss (rod).

Sritharan. G, Deign and mass optimization of independent multi-link suspension for ride performance GM India Pvt, Ltd., ITPB, Whitefield Road, Bangalore. This study was conducted to compare the results obtained by the FEA and the experimental for an automotive suspension part. The part was a lower suspension arm for a 2000cc sedan car. Variable stress, strain and fatigue tests were performed on the part to obtain the critical point's location, loading and part life prediction. The strain distribution obtained from experimental results was found to be compatible with the FEA relative to the complexity of the geometry of the part, but onthe other hand, the data collected from the road test was very different from that obtained by FEA.

Miguel Crashworthiness, Simulation of Lower Control Arm SAE journal Date Published: April 2005. The purpose of FEA was to determine the critical points on the part. CATIA simulation software was used to generate the model, MSC Nastran for strain analysis and MSC Fatigue for fatigue analysis.

IiM. M. Noor and M. M. Rahman, Fatigue Life Prediction of Lower Suspension Arm Using strain-life approach, © Euro Journals Publishing, Inc. 2009. FEA analysis must be compared with experimental data to validate it to ensure its accuracy in order to maximize their advantages in the future, Strain analysis data were reasonably correct by the FE model and helped researchers to identify the exact position where the strain gauges must be fixed, Component (part) data should be collected experimentally, Even though fatigue damage occurred at low cycles range, it was justified by the great number of the cycles

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Roy, R. K. (2001). *Design of Experiments Using the Taguchi Approach*. New York, New York, United States of America: John Wiley & Sons, Inc. This paper dealt about the importance of employing computerized FEA, technology and techniques in the automotive industry. It presented examples of how the results obtained by FEA software were compatible with these collected from expensive, time consuming experiments. The paper also presented a model of a structural design iteration process that is cost effective and can provide a huge useful data.

III. EXISTING SYSTEM OVERVIEW

3.1 Dependent suspension system:

A dependent suspension normally has a beam (a simple 'cart' axle) or (driven) live axle that holds wheels parallel to each other and perpendicular to the axle. When the camber of one wheel changes, the camber of the opposite wheel changes in the same way (by convention on one side this is a positive change in camber and on the other side this a negative change). De Dion suspensions are also in this category as they rigidly connect the wheels together.

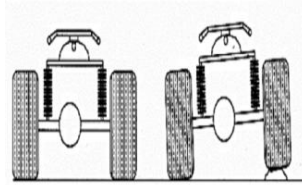


Figure .3.1. Dependent suspension system

Example: Hotchkiss suspension and trailing arm suspension comes under this Category.

3.2 Independent suspension system:

An independent suspension allows wheels to rise and fall on their own without affecting the opposite wheel. In this case, the wheels are connected through universal joints with a swing axle. Suspensions with other devices, such as sway bars that link the wheels in some way are still classed as independent.

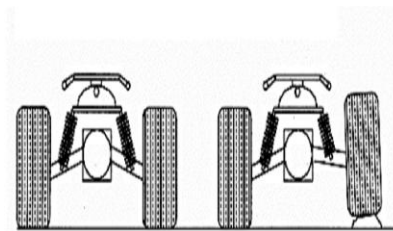


Figure.3.2. Independent suspension system

Example: The two important types of independent systems are Macpherson strut and Double wishbone system.

3.3 TYPES OF INDEPENDENT SUSPENSION SYSTEM:

3.3.1 Double wishbone:

The double wishbone suspension can also be referred to as double 'A' arms, and short long arm (SLA) suspension if the upper and lower arms are of unequal length. A single wishbone or A-arm can also be used in various other suspension types, such as McPherson strut and Chapman strut. The upper arm is usually shorter to induce negative camber as the suspension jounces (rises). When the vehicle is in a turn, body roll results in positive camber gain on the inside wheel. The outside wheel also jounces and gains negative camber due to the shorter upper

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arm. This is especially important for the outer tire because of the weight transfer to this tire during a turn.



Figure.3.3. Double wishbone

Between the outboard ends of the arms is a knuckle with a spindle (the kingpin), hub, or upright which carries the wheel bearing and wheel. Knuckles with an integral spindle usually do not allow the wheel to be driven. A bolt on hub design is commonly used if the wheel is to be driven. At the knuckle end, single ball joints are typically used, in which case the steering loads have to be taken via a steering arm, and the wishbones look A- or L-shaped. A L-shaped arm is generally preferred on passenger vehicles because it allows a better compromise of handling and comfort to be tuned in. The bushing in line with the wheel can be kept relatively stiff to effectively handle cornering loads while the off-line joint can be softer to allow the wheel to recess under for a impact loads.

For a rear suspension, a pair of joints can be used at both ends of the arm, making them more H-shaped in plain view. Alternatively, a fixed-length drive shaft can perform the function of a wishbone as long as the shape of the other wishbone provides control of the upright. This arrangement has been successfully used in the Jaguar IRS. In elevation view, the suspension is a 4-bar link, and it is easy to work out the camber gain (see camber angle) and other parameters for a given set of bushing or ball joint locations.

3.3.2. Trailing arm suspension:

The trailing arm system is literally that a shaped suspension arm is joined at the front to the chassis, allowing the rear to swing up and down. Pairs of these become twin-trailing-arm systems and work on exactly the same principle as the double wishbones in the systems described above.



Figure.3.4. Trailing arm suspension

The difference is that instead of the arms sticking out from the side of the chassis, they travel back parallel to it. This is an older system not used so much anymore because of the space it takes up, but it doesn't suffer from the side-to-side scrubbing problem of double wishbone systems. If you want to know what I mean, find a VW beetle and stick your head in the front wheel arch - that's a double-trailing- arm suspension setup.

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3.3.3. Macpherson struts:

The McPherson strut is a type of car suspension system which uses the axis of a telescopic damper as the upper steering pivot, widely used in modern vehicles and named after Earle S. McPherson who developed the design.



Figure.3.5. Macpherson struts

It consists of a wishbone or a substantial compression link stabilized by a secondary link which provides a bottom mounting point for the hub or axle of the wheel. This lower arm system provides both lateral and longitudinal location of the wheel.

The upper part of the hub is rigidly fixed to the inner part of the strut proper, the outer part of which extends upwards directly to a mounting in the body shell of the vehicle.

The McPherson strut required the introduction of unibody construction, because it needs a substantial vertical space and a strong top mount, which unibodies can provide, while benefiting them by distributing stresses. The strut will usually carry both the coil spring on which the body is suspended and the shock absorber, which is usually in the form of a cartridge mounted within the strut. The strut also usually has a steering arm built into the lower inner portion. The whole assembly is very simple and can be preassembled into a unit; also by eliminating the upper control arm, it allows for more width in the engine bay, which is useful for smaller cars, particularly with transverse-mounted engines such as most front wheel drive vehicles have. It can be further simplified, if needed, by substituting an anti-roll bar (torsion bar) for the radius arm. For those reasons, it has become almost ubiquitous with low cost manufacturers. Furthermore, it offers an easy method to set suspension geometry.

3.4 Lower Control Arm:

The lower control arm is the most vital component in a suspension system. There are two control arms, lower control arm and upper control arm. Lower control arm allows the up and down motion of the wheel. It is usually a steel bracket that pivots on rubber bushings mounted to the chassis.



Figure.3.6. Lower control arm

The other end supports the lower ball joint. Significant amount of loads are transmitted through the control arm while it serves to maintain the contact between the wheel and the road and thus providing the precise control of the vehicle. There are many types of control arms are available. The selection of the arm is mainly based on the type of suspension system.

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4.2 PROCESS CHART LAYOUT

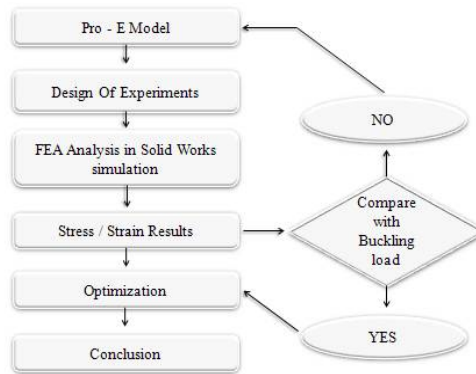


Figure.4.1. Process chart

V. MODELING OF LCA

5.1 Part modeling

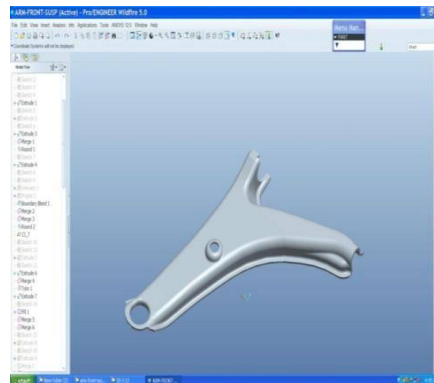


Figure.5.1. Profile

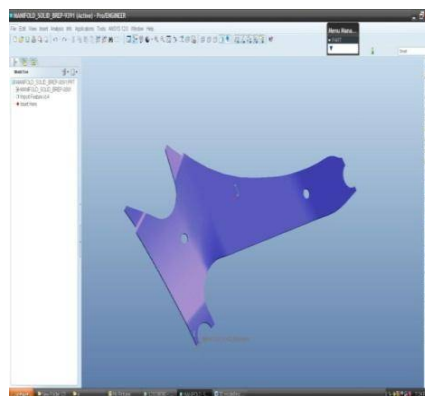


Figure.5.2. Reinforcement plate

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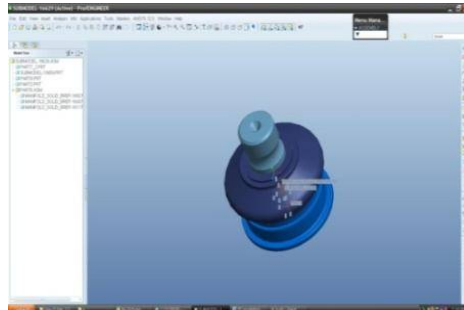


Figure.5.3. Ball joint

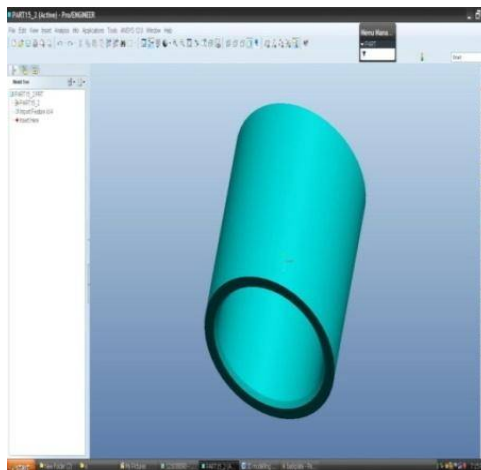


Figure.5.4. Sleeve

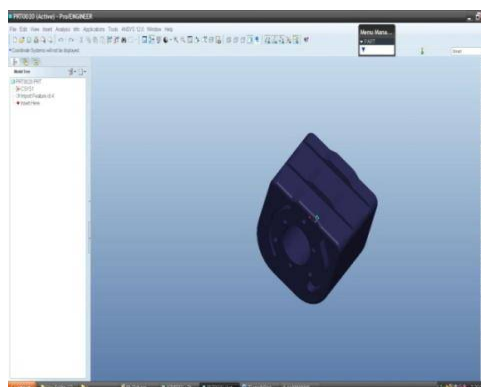


Figure.5.5. Bush

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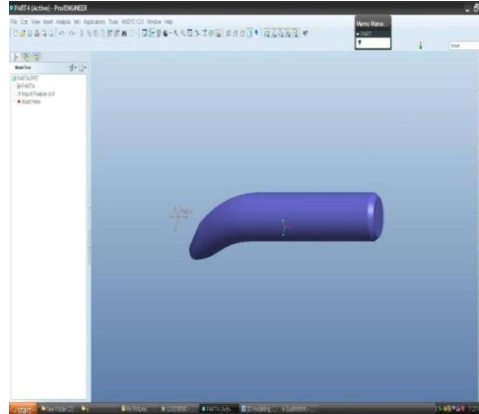


Figure.5.6. Rod

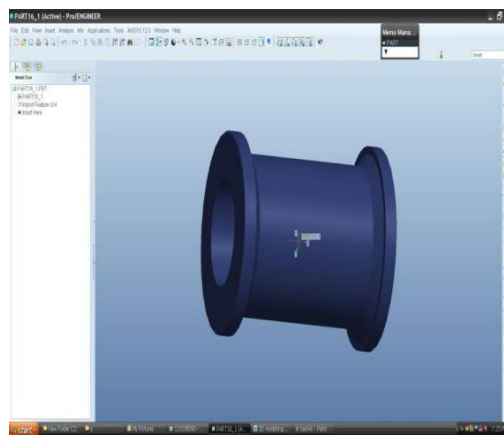


Figure.5.7. Bush sleeve

5.2 Assembly view of LCA:

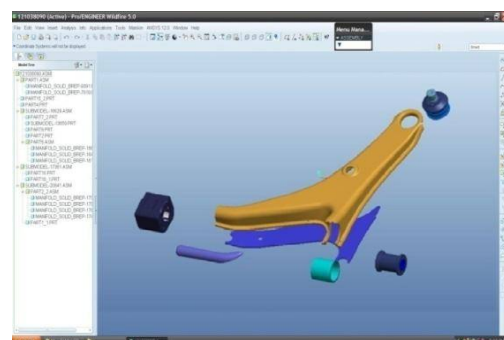


Figure.5.8 Assembly view of LCA (a)

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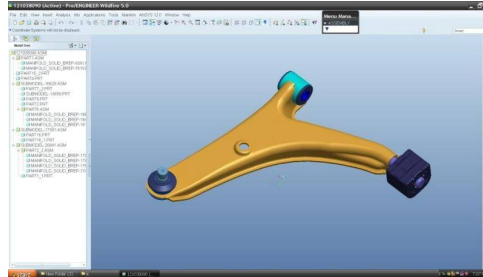


Figure.5.9. Assembly view of LCA (b)

6.1 SHEET METAL (IS 513)

The profile of lower control arm is a sheet metal which is made up of IS 513. This material is in **existing** component. The **IS 513** is 'COLD DRAWN'. It has following characteristics. These properties are taken from MATERIAL STANDARDS.

Table.6.1. Sheet metal (is 513)

IS: 513					
MATERIAL STD	C%	Mn%	Y.S (N/mm ²)	T.S (N/mm ²)	
IS: 513 'O'	0.15	0.6	-	-	cold drawn
IS: 513 'D'	0.12	0.5	280	270-410	
IS: 513 'DD'	0.1	0.45	250	270-370	
IS: 513 'EDD'	0.08	0.4	220	270-350	

6.2 Characteristics of cold and hot rolled:

Table.6.2. Characteristics of cold and hot rolled SAE 1020

	Cold rolled	Hot rolled
Grain size	fine	high
Recrystallation temp	50° C	Above 1000 ° C
Forming	Best	Size reduced (thickness)
Cost & strength	High	

6.3 SHEET METAL (SAE 1020):

Material for lower control arm profile is **modified** and suggested material is standard SAE 1020 (cold rolled). It has following characteristics.

Table: 6.3. Sheet metal (SAE 1020)

SAE: 1020 / AISI								
MATERIAL STD	C%	Mn%	P%	S%	SP%	Y.S (N/mm ²)	T.S (N/mm ²)	
SAE: 1020 / AISI	0.18-0.23	0.3-0.6	0.04	0.05		210	300	Hot Rolled
	0.18-0.23	0.4-0.6	0.03	0.03	0.05	350	460	Cold Rolled

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VII. DESIGN OF EXPERIMENTS

7.1 Introduction to DOE:

The study of most important variables affecting Quality Characteristics & a plan for conducting such experiments is called “The Design of Experiments (DOE)”

Design of Experiments are the tools for obtaining inexpensive & timely process / products’ understanding, without affecting production schedule & incurring time consuming ways of obtaining process information.

The techniques involved in the Design of Experiments were originally implemented in the Agriculture field and later found a lot of applications in the Industrial Field. The various techniques can be broadly classified into the following segments:

- Classical Methods
- Taguchi Methods

Mesh information	IS 513	SAE 1020
Mesh type	Solid Mesh	Solid Mesh
Mesher Used:	Curvature based mesh	Curvature based mesh
Jacobian points	4 Points	4 Points
Maximum element size	2.5 mm	0mm
Minimum element size	0.833325 mm	0mm
Mesh Quality	High	High
Total Nodes	36744	57804
Total Elements	22480	30312
Maximum Aspect Ratio	13.248	135.68
% of elements with Aspect Ratio < 3	96.1	84.2
% of elements with Aspect Ratio >10	0.205	1.06

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VIII. ANALYSIS RESULT

8.1 Mesh of Assembly:

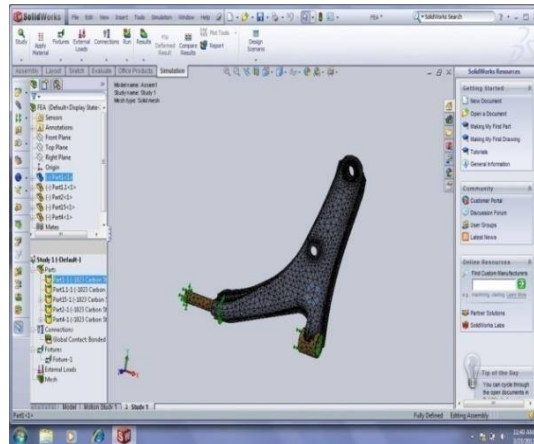


Figure.8.1. Mesh of assembly

Table: 8.1. Meshing information table

Mesh information	IS 513	SAE 1020
Mesh type	Solid Mesh	Solid Mesh
Mesher Used:	Curvature based mesh	Curvature based mesh
Jacobian points	4 Points	4 Points
Maximum element size	2.5 mm	0mm

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Minimum element size	0.833325 mm	0mm
Mesh Quality	High	High
Total Nodes	36744	57804
Total Elements	22480	30312
Maximum Aspect Ratio	13.248	135.68
% of elements with Aspect Ratio < 3	96.1	84.2
% of elements with Aspect Ratio >10	0.205	1.06

8.2 Stress Analysis Results:

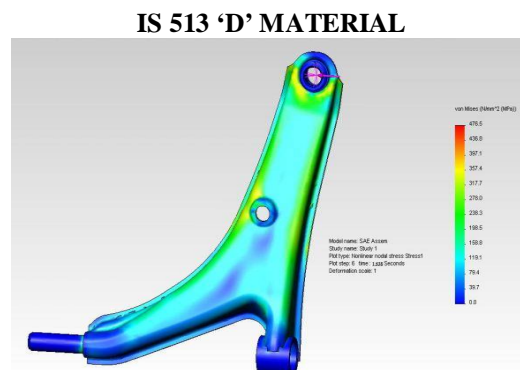


Figure.8.2. Stress analysis results

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The stress analysis plot in solidworks stimulation of lower control arm is shown in VON MISES STRESS PLOT.

Inference from the result that

BUCKLING LOAD CALCULATION:

10,000 Kgs =10 SECONDS(1 seconds

=1000 kgs) Then for stress result for IS 513

'D' it shows 1.612 seconds = 1.612*1000

=1612 Kgs IS THE MAXIMUM BUCKLING LOAD .

'SAE 1020' MATERIAL

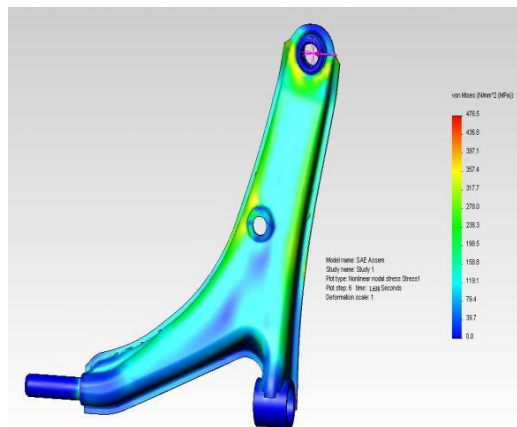


Figure.8.3. Buckling load analysis

The stress analysis plot in solidworks stimulation of lower control arm is shown in VON MISES STRESS PLOT.

Inference from the result that BUCKLING LOAD CALCULATION:

10,000 Kgs =10 SECONDS(1 seconds

=1000 kgs)

Then for stress result for SAE 1020 it shows

1.538 seconds = 1.538*1000 =**1538 Kgs Is the maximum buckling load.**

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8.3 Displacement Result: IS 513

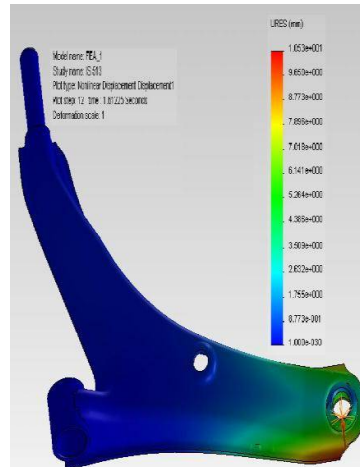


Figure. 8.4. Displacement in IS 513

SAE 1020 `D`

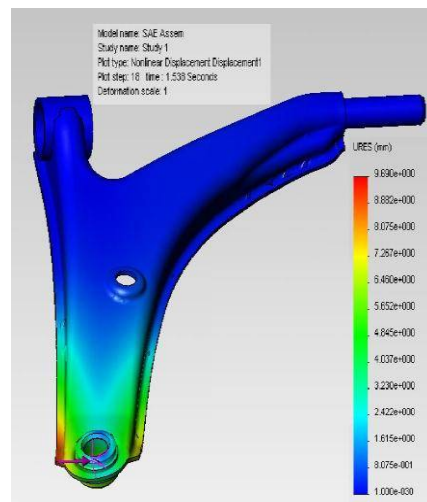


Figure.8.5 Displacement in IS 513

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The displacement result of lower control arm due to the BUCKLING LOAD By URES = Resultant displacement plot.

Table: 8.2 Results comparison

S. No	Material	Cost / kg	Total mass of sheet metal
1	IS 513`D` (for 3.6mm thickness)	Rs.52.00	2.46 kg
2	SAE 1020 (for 3mm thickness)	Rs. 50.00	2.12 kg

Table: 8.3 Cost analysis of materials

FEA RESULTS	IS 513`D`	SAE 1020
Maximum Buckling load	1612 Kgs	1538kgs
Maximum stress by (VON MISES) stress plot	412.5 N/mm ²	476.5 N/mm ²
Maximum Displacement	10.53 mm	9.69 mm

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8.4 Cost Analysis of Materials:

Optimization of lower control arm results lead to two important following characteristics, they are:

1. Cost reduction.
2. Strengthening the lower control arm.

Comparing the above two values the difference in the total mass / product is (2.46kg – 2.12kg = 0.34 kg). Since by reducing the thickness we saved 0.34 kg of material / product & their corresponding cost is (0.34 * 50 = Rs.17) is reduced from the existing one.

When considering in **batch production**

(Assuming for one month)

(1 Batch = 2000 product), 17 * 2000 = **Rs.34,**

000 is saved.

8.5 Strength analysis:

Optimization of lower control arm by suggesting better material than existing leads to **Strengthening** the LCA.

S.NO	Existing material IS 513'D'	Modified material SAE 1020
Yield stress	280 N/mm ²	380 N/mm ²
Tensile stress	350 N/mm ²	460 N/mm ²

Table: 8.4 Strength analysis

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Stress strain curves:

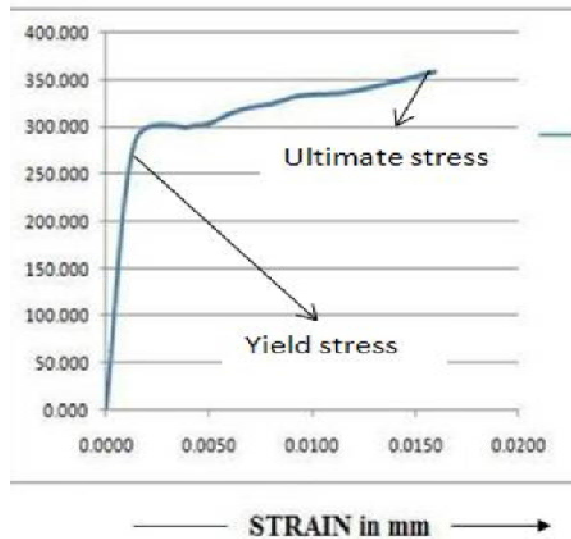


Figure: 8.6 stress strain curve of IS 513

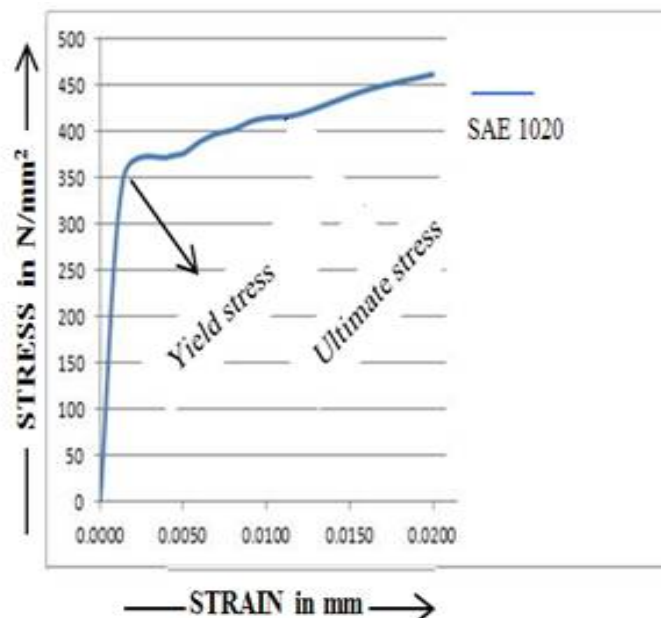


Figure: 8.7 stress strain curve of SAE 1020

IX. CONCLUSION

The existing design has been modified, by reducing the thickness of the existing profile and the reinforcement plate has been proposed. The optimization of lower control arm is done by applying the DOE method. The parameters are identified. The FEA is done on LCA and the buckling load has been compared with the existing component. The sheet metal thickness of the new design has been reduced from 3.6 mm to

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3mm, and material is modified from low carbon steel of IS513 to SA1020. For the mass production the cost has been reduced to Rs.34000 for 2000 products in a batch as assumed. For the modified design the structural rigidity has been increased for the LCA, when compared to the existing design. Finally mass of the control arm has been reduced up to 13.8 % when compared with existing model.

X. SCOPES FOR FUTURE WORK

This project can be extended to satisfy the following requirements as the key objectives:

- ✚ Implementing new design changes in the existing model can be done
 - ✚ Identifying more materials for the proposed design and new design
- Increasing the number of levels of the response

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