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Design and Analysis of Leaf Spring Bracket in Air Suspension Vehicle Using FEA

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ABSTRACT: This paper presents the technique of the fatigue analysis of spot-weld joints to predict the lifetime and location of the weakest spot-welds due to the imposed loading conditions. A simple model was used to illustrate the technique of spot-weld fatigue analysis. Finite element model and analysis were carried out utilizing the finite element analysis commercial codes. Linear elastic finite element analysis was carried out to predict the stress state along the weld direction. It can be seen from the results that the predicted life greatly influence the sheet thickness, spot diameter and loading conditions of the model. Acquired results were shown the predicted life for the nugget and the two sheets around the circumference of the spot-weld at which angle the worst damage occurs.

KEYWORDS: spot-weld joints, Linear elastic, damage occurs

I. INTRODUCTION

The suspension system supports the weight of the vehicle and provides for a smoother ride for the driver and passengers. But suspension systems also protect your vehicle from damage and play a critical role in maintaining safe driving conditions. A well functioning suspension system shields a vehicle from excessive wear and potential structural damage associated with prolonged exposure to bumps and pot holes but also keeps the wheels pressed firmly to the ground for traction. Sprung mass (weight) refers to vehicle parts supported on the suspension system, such as the body, frame, and engine. The sprung weight typically includes the body, frame, the internal components, passengers, and cargo. By contrast, unspring weight refers to the components that follow the road contours, such as wheels, tires, brake assemblies, and any part of the steering and suspension not supported by the springs. The suspension system isolates the body from road shocks and vibrations which would otherwise be transferred to the passengers and load. It also must keep the tires in contact with the road. When a tire hits an obstruction, there is a reaction force. The size of this reaction force depends on the unspring mass at each wheel assembly.

In general, the larger the ratio of sprung weight to unspring weight, the less the body and vehicle occupants are affected by bumps, dips, and other surface imperfections such as small bridges. A large sprung weight to unspring weight ratio can also impact vehicle control. Vehicle ride and handling can be improved by keeping unspring mass as low as possible. When large and heavy wheel assemblies encounter a bump or pothole, they experience a larger reaction force, sometimes large enough to make the tire lose contact with the road surface. Wheel and brake units that are small, and light, follow road contours without a large effect on the rest of the vehicle. At the same time, a suspension system must be strong enough to withstand loads imposed by vehicle mass during cornering, accelerating, braking, and uneven road surfaces. Unspring weight is largely a function of the design of a vehicle's suspension and the materials used in the construction of suspension components. Beam axle suspensions, in which wheels on opposite sides are connected as a rigid unit, generally have greater unspring weight than independent suspension systems, in which the wheels are suspended and allowed to move separately. Heavy components such as the differential can be made part of the sprung weight by connecting them directly to the body (as in a de Dion tube rear suspension). Lightweight materials, such as aluminum, plastic, carbon fiber, and/or hollow components can provide further weight reductions at the expense of greater cost and/or fragility. Forces to be considered regarding the design of bracket for leaf springs are spring rate, roll couple percentage, weight transfer, unspring weight transfer, damping, camber control, roll center height, jounce, rebound, wheel hop, ride steer, spring oscillation, instantaneous center, anti drive and anti squat, wheel unit location, the roll of axles, beam axle, dead axle and plain axle.



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II. PROBLEM IDENTIFICATION

The schematic diagram of the Air suspension system is shown in the fig 1. It consist of four no of parts, these components are mounted in the chase except leaf spring. The component of bellow, shock absorber and bracket is mounted on the chases of the vehicle. The other end of the bellow and bracket is connected by using double stand leaf spring. The other end of shock absorber is fixed along with axel. This is the fixing arrangement of air suspension system. Whenever force exerted on the system the shock absorber and bellow absorb the force by means of leaf spring. One end of leaf spring is mounted below the bellow and other end is fixed with bracket. So whenever force exerted on the system it is also absorb by the bracket. The same process repeated when the vehicle is moving in the road due to road irregularity. Due to which bracket under goes fatigue load. So it leads to bend in the bracket and crack formation.



Figure 1 Air suspension system

The failure component is shown in the fig. Fig 2 shows the bending over the leaf spring fixing area



Figure 2 Crack formation

Fig 3 shows the crack formation in the bracket at fixing with chases.



Figure 3 Deformation



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III. PROBLEM ANALYZING TECHNIQUE

To identify the real time problem we can use the Failure mode effect analysis (FMEA). Failure Modes and Effects Analysis (FMEA) is methodology for analyzing potential reliability problems early in the development cycle where it is easier to take actions to overcome these issues, thereby enhancing reliability through design. FMEA is used to identify potential failure modes, determine their effect on the operation of the product, and identify actions to mitigate the failures. A crucial step is anticipating what might go wrong with a product. While anticipating every failure mode is not possible, the development team should formulate as extensive a list of potential failure modes as possible.

IV. ANALYSIS OF EXISTING SYSTEM

For analyzing the system we need to consider the dynamic forces which are acting on the bracket. The main forces are acting on the body is listed below. Each of the forces is consider as the individual cases and results to be obtained. In all the cases are calculated individually. For calculation purpose the following parameters are considered.

Total wt. of vehicle (With	out loaded cond.)	:10360 Kg	
Total wt. of vehicle (With	loaded cond.)	: 15660 Kg	
Front axle weight		: 650 Kg	
Rear axle weight		: 1020 Kg	
Unspring weight = Front	axle weight + Rea	ar axle weight	
	= 650 + 1020		
	= 1670 Kg		
Total sprung weight	= Total weight -	Unspring weight	
	= 15660 - 1670		
	= 13990 Kg		
	C		
	f1		f2
	N1		<u>b2</u> ► N2
		VV V	

Figure 4 Total body diagram

h

- 15660 Kσ
= 15000 Kg
= 1827 mm
= 2523 mm
= 975 mm
= 0.2
= 0.5

The two normal forces, gravity, and the braking forces, along with the horizontal braking forces of the roadway on the tires, are displayed in fig 1 If one labels the normal forces acting on the front and rear tires as N1 and N2 respectively, and lets W represent the weight, or force of gravity, then Newton's law equation is: N1+N2-W = 0

Since there is no appreciable forward rotation for a vehicle, Newton's laws require that the sum of the torques (lever arm times force) must also add to zero. If the CG is used as the point of rotation, then the roadway's vertical, or normal, force on the front tires produces a clockwise torque with lever arm b1 as shown in the figure, while the normal force on the rear tires produces a counterclockwise torque with lever arm b2 (note that b1 + b2 = B, the wheel base). The braking forces on both the front and rear tires produce counterclockwise torques with lever arm h, the height of the



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CG from the roadway. Adding clockwise torques and subtracting counterclockwise torques (where f1 and f2 are coefficients of friction):

$b_1N_1 - b_2N_2 - hf_1N_1 - hf_2$	$N_2 = 0$	
For creating the bump load calcula	ting we need to consider following parameters.	
Total length of leaf spring	: 930 mm	
Radius of spring	: 5307.8 mm	
Height of the spring	: 30 mm	
Nominal thickness	: 6.5 mm	
Material density	$: 1.7 \text{ g/cm}^3$	
Flexural strength	: 400 MPa	
Flexural modulus of elasticity	: 86 GPa	
Modulus of shear rigidity	: 35 MPa	
Coefficient of compressibility	: 160 MPa	
Load due to bellow:		
Total load exerted by bellow	$: 30 \text{ bar} => 75 \text{xE}^5 \text{ N/m}^2$	
So total load due to bellow	: 30 X E ⁵ * Area (3.14 X : 1.473 E ⁵ N	0.125 X 0.125)

Consider vehicle is going 100 km/hr, and you applied the brakes and dropped to 25 km/hr in 3 seconds, and you assumed a constant braking force, we could calculate that force (given the weight of the vehicle, and ignoring air resistance and miscellaneous frictional decelerators).

Initial speed	= 100 Km/hr = 27.78 m/sec				
Final speed	= 25 Km/hr = 6.94 m/sec				
Time taken	= 3 Sec				
Deceleration (a)	= (Initial speed – Final speed) / Total time taken	= (27.78 – 6.94) /3			
	$= 6.94 \text{ m/sec}^2$				
Braking force	$= m^*a$				
$m \rightarrow Mass of the body (C)$	CG)				
a> Deceleration					
Braking force	$= 15660 \ge 6.94$				
	$= 108680.4 \text{ Kg m/Sec}^2$				
	= 108680.4 N				
	= 108.68 KN				
The results are obtained us	sing working model 2D. The final results are given below. Refe	er fig 3, 4 & 5			
1. Bump Loading Force	= 14980N				
2. Brake Loading Force	= 25500N				
3. Bump Couple Force	= 273165Kg mm				
	= 2731650N mm				
	= 2731.650N m				
Couple	= Force X Distance				
Force	= Couple/Distance				
	= 2731.651/.2				
	= 13658.255N				
4. Corner Couple Force	= 1483700Kg mm				
	=14837000N mm				
	= 14837N m				
= 14837/.2 = 7418	85N				
5. Corner with Pretension	= 25500N + 350Nm				
	= 350/.2= 1750N				
	= 25500N + 1750N				
	= 27250N				



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V. PROCEDURE FOR ANALYZING

PREPROCESSING

• The required modal for analyzing is designed in CAD model and it is transferred to ANSYS. The model is developed in CATIA and Converted in IGES Format and then that IGES format is imported ANSYS.

• For analyzing in ANSYS we need to discrete the imported model in to no of elements. Since for our analyzing process we are using Solid 45.

The brief introduction about element is follows.

SOLID45 ELEMENT DESCRIPTION

SOLID45 is used for the 3-D modeling of solid structures. The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. Figure 6 shows the Geometry of SOLID45



Figure 5 Geometry of SOLID45

MATERIAL PROPERTIES

In our bracket we are using following technical terms for arriving solutions.

Material	: CARBON STEEL C25
Yield Stress	$: 280 \text{ N/ mm}^2$
Youngs Modulus	$: 2.05 \text{ E}^{5}(\text{N/mm}^{2})$
Posion Ratio	: 0.3

In our model we are using 3D model. So we no need to select the Real constant. Because generally we use real constants for 2D model only.

MESHING

We used free meshing for analysis and the element used is Solid 45. The element type is discussed already. Total no of Element used for meshing is 72902. and the node is 583216.

LOAD

For analyzing the displacement is given as all degree of freedom in the mount hole of the bracket. And the boundary conditions are applied for the each cases individually. As already calculated forces are applied individually. The forces applied for the cases of Loads of Bump & Brake, and couple forces of Bump & Corner also Pretension-Corner. And the results are taken individually. **Solve**-After applying all the boundary conditions the component is sent in to get the solution. So each and every element is solved individually and the results are plotted.

POST PROCESSOR

After solving all the elements the results are shown in all the various type of stress. We can obtain all the results by post processing. To get the solution we have to go Plot result – Contour Result- nodal solution –Stress – Von misses stress. In that display shows the stress concentration on different areas.



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RESULT OF AN EXISTING SYSTEM

As per the procedure all the parameters are given in the ANSYS and the results are obtained for different type of cases. The results are shown below and Refer Fig 7 to 11

Cases	Stress value(N/mm ²)
Braking load	251.617
Bump load	71.979
Bump couple	192.821
Corner couple	272.388
Corner pretension	266.869

Table 1 Stress Value of the Existing Bracket



Figure 6 Existing Bracket



Figure 7 Deflections Due To Braking Load



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Figure 8 Deflection due to bump load



Figure 9 Deflection due to bump couple



Figure 10 Deflection Due To Corner Pretension



Figure 11 Deflection Due To Corner Couple



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VI. IMPROVEMENT IN EXISTING DESIGN

For improving the existing model we need to reduce the stress vales in the leaf spring bracket. For that we can go for the material change. But if we suggested for new material then the concern have to maintain some inventory for the new type of material. Also we should not disturb the existing process flow. And the new development can be fitted for the existing operation and the existing vehicle. By considering the stress strain distribution in the product we need to improve the section modulus of the bracket. To reduce the stress strain in the bracket first we attack to increase the bellow diameter and increase the pressure inside. So that we can distribute more amount of force while load is acting upon the bracket. But the space is not enough for to keeping such a bulky bellow. So the bellow changing idea also dropped. On the other case the load which are transferred to the bracket from leaf spring can be minimize by adding highly damping capacity rubber between leaf spring eye to bracket tension bolt. But even high shore hardened rubber material has the low life cycle so couldn't use such type of material. Also if the rubber failed then there will be a gap between both leaf spring and bolt. So it also makes unwanted noise.

With out changing the process and the material, by the addition of ribs in the side faces are giving better stress strain distribution on the leaf spring bracket. In this concept analyzing is started for the product. Firstly we produce 50 mm of bracket from the fixing area. But we don't get optimum result. So we checked the same for different type of lengths. Also we have constrains to produce the stiffener. Because all the areas are covered by fasteners. If the stiffeners inserted in between the holes then it will hinder while bolt tightening. So stiffeners provided on the optimum places. The stiffeners height is finalized and the analyzing is done for that too as like the existing bracket analysis. All the parameters are already determined and the input condition is common for both cases. So existing values can be used for the same process also.

Result of the proposed studiet		
Cases	Stress value (N/mm ²)	
Braking load	231.991	
Bump load	53.873	
Bump couple	177.836	
Corner couple	247.776	
Corner pretension	229.031	

-

TABLE 2 Stress Value of the Proposed Bracket

Figure 12 Meshing



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Figure 14 Deflection Due To Bump Load



Figure 15 Deflection Due To Bump Couple



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Figure 16 Deflection Due To Corner Pretension



Figure 17 Deflection Due To Corner Couple

FACTOR OF SAFETY

Factor of safety is a figure used in structural applications that provides a design margin over the theoretical design capacity. Also known as the safety factor, the factor of safety allows for uncertainty in the design process, such as calculations, strength of materials, duty and quality. The factor of safety is equal to the strength of the component divided by the load on the component. The number chosen as the safety factor depends on the materials and use of the item. Industry standards for design and engineering usually specify the allowable stress, or ultimate strength of a given material divided by the factor of safety, rather than use an arbitrary safety factor. This is because safety factors can be misleading and have been known to imply greater safety than is the case. A safety factor of two does not mean that an appliance can carry twice as much as it was designed for.

Loading	Existing bracket		Proposed bracket	
condition	Stress N/mm ²	FOS	Stress N/mm ²	FOS
Braking load	251.617	1.11	231.991	1.2
Bump load	71.979	3.89	53.873	5.19
Bump couple	192.821	1.45	177.836	1.57
Corner couple	272.388	1.02	247.776	1.13
Corner pretension	266.869	1.04	229.031	1.22

	-				
FOS =	Yield	Stress	/ Working	Stress	

Table 3: Comparison of Existing and Modified Bracket



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VII.CONCLUSION

The life cycle of the existing bracket is arrived using Finite Element Analysis. Various possibilities of improving the life cycle of the bracket is studied finally the addition of stiffeners in the bracket gives the increment in the number of cycles in the bracket without disturbing the Fit, Form and Function.

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