Development of Porous Aluminium Foam for Making Commercial Vehicle Leaf Spring

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***Abstract* - The automobile industry has shown increased interest in the replacement of steel spring with different materials like aluminium foam, fibreglass, composite leaf spring due to high strength to weight ratio. This research work describes about the development of porous Aluminium foam for making commercial vehicle leaf spring made of Aluminium. The Aluminium foamed leaf spring has stresses much lower than steel leaf spring and weight of aluminium foamed leaf spring was reduced upto 20%. Using FEA stress and deflection is analysed.**

Key words:- Aluminium foam, Sand balls, Foamed Leaf spring Finite Element Analysis.

1.INTRODUCTION

The rear axle leaf is used in the suspension system of a vehicle it is used to prevent the vibration made by a vehicle on an irregular road [5]. This provides safety to the engine and for the transmission unit. It helps to drive the vehicle in a controlled manner. The leaf spring is one of the main component, it provides a good suspension and it plays a vital role in automobile application. It carries lateral loads, brake torque, driving torque in addition to shock absorption. The advantage of leaf spring over helical spring is that the ends of the spring may be guided along a definite path as it deflects to act as a structural member in addition to energy absorbing device. The suspension leaf spring is one of the potential items for weight reduction in automobile [14]. This helps in achieving the vehicle with improved riding qualities. It is well known that springs are designed to absorb, store energy and then release it [12]. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. Hence, the strain energy of the material becomes a major factor in designing the springs [13].

It can be easily observed that material having lower modulus and density will have a greater specific strain energy capacity. The introduction of aluminium foams was made it possible to reduce the weight of the leaf spring without any reduction on load carrying capacity and stiffness [9]. Since the aluminium foam have more elastic strain energy storage capacity and high strength-to-weight ratio as compared to those of steel[1].

In this research work the rear axle leaf spring is designed with 3 leafs which is varying in length. All the strips are clamped using u-clamps. The spring is supported on the rear axle with one end of the spring is mounted on the frame using a simple pin and the other end is connected with a shackle.

2. LITERATURE SURVEY

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Foamed aluminium is very efficient in sound absorption, impact energy absorption, electromagnetic shielding and vibration damping [1]. This unique structure possesses unusual combination of properties, such as low thermal conductivity, high impact energy absorption capacity, very high specific toughness and good acoustic properties, especially in the case of interconnected porosity[5]. Moreover, this exceptionally light weight material is inflammable, ecologically harmless and easily recyclable.

There are two basic preparation methods: The first method is mixing a foaming agent (metal hydride e.g. TiH_2) into a molten aluminium or aluminium alloy. The foaming agent decomposes at the melting temperature of aluminium, releases gas (e.g. hydrogen) and blows up the melt [1]. Second method is heating of gas-tight precompacted mixture (preform) of aluminium or aluminium alloy powder with powdered foaming agent above the melting point of the metallic matrix, the foaming agent decomposes and expands the preform into porous cellular solid [3]. Various techniques based on both principal methods have been investigated to achieve the uniform cellular structure of the foam at reasonable costs[7].

In these research method foamable precursors is kept in the desired hollow mould to achieve required shapes. The main benefit of this method is the possibility to use the same foaming material of simple performs (e.g. wire, sand balls, etc.) for different shapes to be foamed. Using this method diverse parts made from foamed aluminium (flat-, rod-, or 3D-shapes), as well as integral foams can be produced; i.e. foams connected with bulk metal sheets (e.g. sandwich structures), or hollow metallic profiles filled with the foamed aluminium [2]. The *density* of foamed aluminium lies typically in the range of 0.4-0.8 g/cm^3 [5]. The porosity is essentially spherical and closed, although an interconnected porosity can be achieved as well [1]. Foamed aluminium depend also on the shape, size, and uniformity of the pores distributed throughout the matrix, they are greatly influenced by apparent density of the foam [10]. There is a fairly close relationship between density and mechanical and physical properties. This dependence obeys the power-law function

3. DESIGN PARAMETER OF STEEL LEAF SPRING

Parameters of the steel leaf spring used in this research work are shown in Table 1.

Table 1. Parameters of steel leaf spring

S.No	Design parameters	Values
1.	Material Selected	55Si2Mn90
2.	Young's modulus E(N/mm2)	2.1 x 10^5
3.	Design stress (σb) (N/mm2)	653
4.	Total length (mm)	900
5.	Breadth (mm)	60
6.	Thickness(t) (mm)	7
7.	Spring weight (kg)	6
8.	Deflection (mm)	90

4. DESIGN AND FABRICATION OF ALUMINIUM FOAM LEAF SPRING

Parameters of the aluminium foam spring used in this research work are shown in Table 2.

Table 2. Parameters of aliminium foam leaf spring

S.No	Design parameters	Values
1.	Material Selected	Aluminium
2	Young's modulus E(N/mm2)	0.345*10^5
3.	Design stress (σb) (N/mm2)	653
4.	Total length (mm)	900
5.	Breadth (mm)	50
6.	Thickness(t) (mm)	25
7.	Spring weight (kg)	5
8.	Deflection (mm)	90

4.1. TESTING OF ALUMINIUM FOAM LEAF SPRING

The aluminium foam leaf spring is tested by deflection test rig shown in fig.1. The spring is loaded from zero to the prescribed maximum deflection and back to zero. The load is applied at the centre of the spring, the vertical deflection of the spring's centre is recorded in the load interval of 9.81N. The deflection test results are shown in table 3.

Fig.1.Leaf spring deflection test rig.

4.2. FABRICATION OF ALUMINIUM FOAM

The Porous Aluminium leaf spring is produced by casting metal around granules method [5]. The silica sand with bentonite mixture and silica oil is used for making sand balls. The prepared balls are dried in the room temperature, the picture of sand balls is shown in fig 2. Then the Aluminium metal is melted above the melting temperature by using the furnace. The molten metal is poured into the pattern which consists of sand balls filled. The poured mould was knocked off, separated from the gating system and shot blasted.

The same procedure is followed up for the preparation of required aluminium foamed pieces. Prepared aluminium foam piece is shown in fig 3.

Fig.2.Sand balls.

Fig.3.Aluminium foam piece

Then this aluminium foam piece is inserted into the aluminium hollow tubes. The finished leaf spring is shown in fig 4

Fig.4.Aluminium foam leaf spring

5. FINITE ELEMENT ANALYSIS

FEA consists of computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design and existing product refinement. Here it is used to analyze the foamed spring structure.

To design leaf spring, a stress analysis was performed using ANSYS software. This is like a cantilever beam. Hence solid45 is selected as element type and brick 8node45 was chosen, the stress and deflection test results are shown in fig.5and fig .6.The following assumptions are made in this analysis, spring eyes and shackles are not modeled and no inter leaf friction was considered, only the vertical pay load was considered.

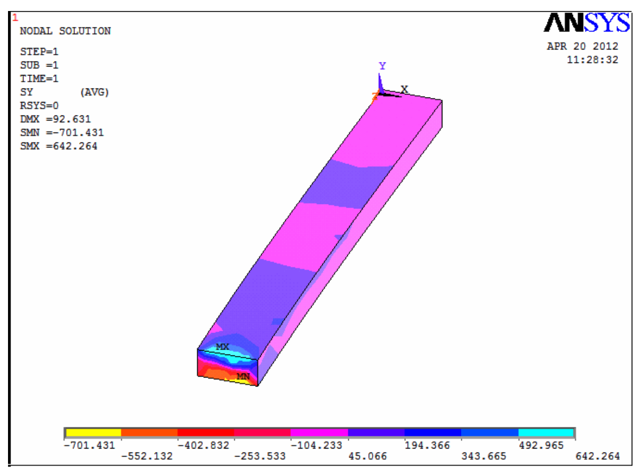

Fig.5. Deflection along y direction

Table No-3

<u>DEFLECTION TEST OF ALUMINUM FOAM LEAF SPRING</u>

SI.NO	LOAD (W)		DIAL GAUGE READING IN DIVISION		ACTUAL DEFLECTION (δ) 'MM'	STIFFNESS (k) N/mm	YOUNG'S MODULUS (E) N/mm²
	kg	N	LOADING	UNLOADING			
1	1	9.81	6	6	0.06	163.5	$0.326*10^5$
2	2	19.62	12	13	0.125	156.96	$0.342*10^5$
3	3	29.43	19	19	0.19	154.89	$0.332*10^5$
4	4	39.24	25	26	0.255	153.88	$0.335*10^5$
5	5	49.05	31	32	0.315	155.71	$0.336*10^5$
6	10	98.1	63	64	0.635	154.49	$0.339*10^5$
7	15	147.15	94	95	0.945	155.71	$0.340*10^5$
8	20	196.2	125	125	1.25	156.96	$0.343*10^5$

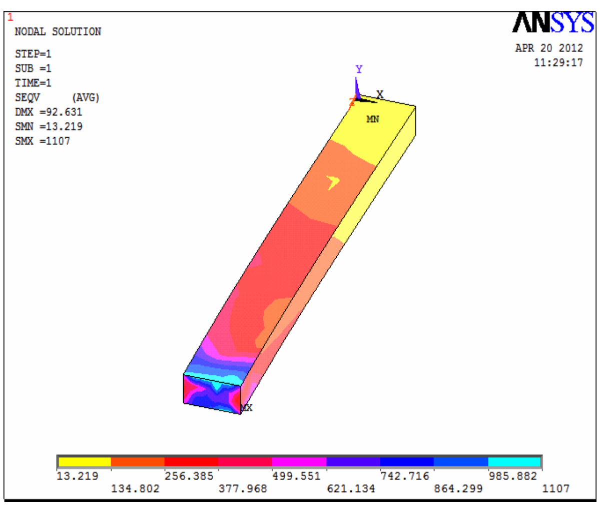

Fig.6. Stress maximum and minimum

6.RESULTS AND DISCUSSION

The steel leaf spring was replaced with an aluminium foam leaf spring. The objective was to obtain a spring with minimum weight which is capable of carrying given static external forces by constraints limiting stresses and displacements. The weight of the leaf spring is reduced considerably about 20 % by replacing steel leaf spring with aluminium foam leaf spring. Thus, the objective is achieved to a larger extent. The stresses in the aluminium foam leaf spring are much lower than that of the steel spring. The following table.4. gives the comparison results of steel and aluminium foam leaf spring.

Table No-4

Comparison results for steel and Aluminium foam leaf spring

S.no	Materials	Parameters	FEA	Experimental
1	Steel	Load (N)	4000	4000
		Deflection (mm)	90	91
		Stress N/mm2	653	656
		Weight (kg)	6	
2	Aluminium foam	Load (N)	7000	7000
		Deflection (mm)	92	90
		Stress N/mm2	642	640
		Weight (kg)	5	

CONCLUSION

- Porous aluminium foam is prepared using Casting around granules method with the help of sand balls

- The Aluminium foam leaf spring is able to withstand the maximum static load of 7000 N
    - The deflection test and FEA analysis for aluminium foamed leaf spring gives 92mm.
    - The weight of the foamed leaf spring is reduced considerably about 20 % by replacing steel leaf spring with Aluminium foamed leaf spring.
    - Thus, the objective of the unsprung mass is achieved to a larger extent.

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