Design Analysis and Comparison of Aluminium Alloy Based Leaf Springs with Conventional Steel Springs

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Abstract— In order to conserve natural resources and economize energy, weight reduction has been the main focus of automobile manufacturers in the present scenario. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. The suspension leaf spring is one of the potential items for weight reduction in automobiles as it accounts for 10% - 20% of the unspring weight. This achieves the vehicle with more fuel efficiency and improved riding qualities. The introduction of metal alloys was made it possible to reduce the weight of leaf spring without any reduction on load carrying capacity and stiffness. Since, the aluminium alloy has more elastic strain energy storage capacity and high strength to weight ratio as compared with those of steel, it can used as the leaf springs for automobiles. Casting and comparison of the aluminium alloy-2219 leaf spring with steel will be done in this project.

Keywords: Leaf Spring, Steel Springs

I. INTRODUCTION

A leaf spring is a simple form of spring commonly used for the suspension in wheeled vehicles. Originally called a laminated or carriage spring, and sometimes referred to as a semi-elliptical spring or cart spring, it is one of the oldest forms of springing, dating back to medieval times.

A leaf spring takes the form of a slender arc-shaped length of spring steel of rectangular cross-section. The center of the arc provides location for the axle, while tie holes are provided at either end for attaching to the vehicle body. For very heavy vehicles, a leaf spring can be made from several leaves stacked on top of each other in several layers, often with progressively shorter leaves. Leaf springs can serve locating and to some extent damping as well as springing functions

A leaf spring can either be attached directly to the frame at both ends or attached directly at one end, usually the front, with the other end attached through a shackle, a short swinging arm. The shackle takes up the tendency of the leaf spring to elongate when compressed and thus makes for softer springiness. Some springs terminated in a concave end, called a spoon end (seldom used now), to carry a swivelling member.

II. DESIGN OF LEAF SPRING

In order to have an idea of working principle of a leaf spring, let us think of the diving board in a swimming pool. The diving board is a cantilever with a load, the diver, at its free end. The diver initiates a to and fro swing of the board at the free end and utilizes the spring action of the board for jumping. The diving board basically is a leaf spring.

The leaf springs are widely used in suspension system of railway carriages and automobiles. But the form in which it is normally seen is laminated leaf spring.

$$\sigma_{max} = \frac{3FL}{bh^2}$$

$$\delta_{max} = \frac{2FL^3}{Ebh^3}$$

III. MATERIALS FOR LEAF SPRING

Materials for leaf spring are not as good as that for the helical spring.

Plain carbon steel, Chromium vanadium steel, Chromium- Nickel- Molybdenum steel, Silicon- manganese steel, are the typical materials that are used in the design of leaf springs.

Standard sizes of leaf spring

Width (mm): 25-80 mm in steps of 5mm

Thickness (mm): 2-8 mm in steps of 1mm, 10-16 mm in steps of 2mm

$$\delta_{max} = \frac{\delta_c qFL^3}{ENb_N h^3}$$

Where, correction in deflection, δ_c is given as,

$$\delta_c = \frac{1.0 - 4m + 2m^2\{1.5 - \ln(m)\}}{(1.0 - m)^3}$$

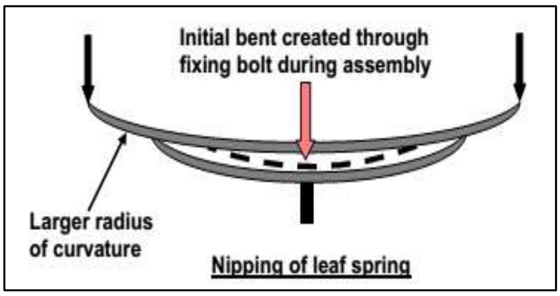
where,

$$m = \frac{N_f}{N}$$

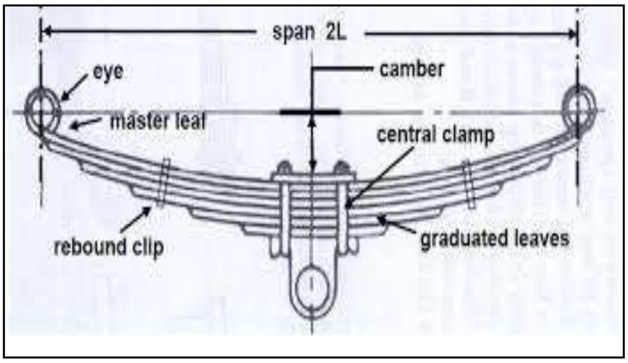
N_f = Number of full length leaves

N = Total number of leaves in the spring

The master leaf has a larger radius of curvature compared to the additional leaf that is placed below so obviously a gap will be created between the two leaves as indicated in the figure. Now, an initial bent is created during assembly by tightening the central bolt. Therefore, some amount of compressive stress will be produced at the inside curvature of the master leaf. Similarly, at the outside curvature of the master leaf tensile stress will be produced. Both these stresses are initial stresses in the master leaf.



However, due to same nature of initial stress and loading stress, the additional leaf is stressed more compared to the master leaf. But, it is to be noted that the higher stress on the additional leaf is actually shared between all other leaves than the master leaf. This practice of stress relief in the master leaf is known as Nipping of leaf spring. As a matter of fact, all the leaves of a laminated leaf spring do have certain amount of nipping, so that there will be gaps between the leaves, as a result the stresses will be uniformly distributed and accumulated dusts can also be cleaned.



Existing Material used for steel leaf spring is 55 Si 2 Mn 90 steel
Length 2L = 700 mm
Width b = 40 mm
Thickness t = 6 mm
Here Weight and initial measurements of four wheeler "TATA ACE" Light commercial vehicle is taken.
Weight of vehicle = 700 kg
Maximum load carrying capacity = 1000 kg
Total weight = 700 + 1000 = 1700 kg;
Taking factor of safety (FOS) = 2
Acceleration due to gravity (g) = 9.81 m/s
Therefore; Total Weight = 1700*9.81 = 16677
Since the vehicle is 4-wheeler, a single leaf spring corresponding to one of the wheels takes up one 4^{th} of the total weight.
$\therefore$ 16677/4 = 4169 N,
But 2F = 4169 N. $\therefore$ F = 2084 N.
Span length, 2L = 860 mm, $\therefore$ L = 430 mm.
Now the Maximum Bending stress of a leaf spring is given by the formula
Bending Stress, $\sigma_b = 6FL / nbt^2 = (6*2084*430) / (3*60*8^2) = 466.84$ MPa
The Total Deflection of the leaf spring is given by

Observation and Calculation: -

Area of indentation $A = ¶\times d/2(D-\sqrt{D^2-d^2})$
$= ¶\times 4.6/2(10-\sqrt{10^2-4.6^2})$
$= 8.098$
BHN = Load Applied (kgf.)/ Spherical surface area indentation (in mm.)
$= 3000/8.098$
$= 370.46$

$\delta_{max} = 6FL^3 / Enbt^3 = (6*2084*430^3) / (2.1*10^5*3*60*8^3) = 51.38$ mm

IV. Conclusion

This study explains the various characteristics and properties of the aluminium alloy. By means the literature survey it is well clear that the aluminium alloy is best suitable for its properties. This project describes the latest and strongest alloy automobile leaf spring. This work will show that successful fabrication of an aluminium alloy. Solid particle characteristics and strength of these were analyzed.

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