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Design Calculation of Leaf Spring for Mazda Jeep

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Abstract- the Suspension System is an essential part of the automobiles. Nowadays several types of automotive Suspension System are used. The better the quality, the more complex the Suspension systems become. Suspension system is the combination of various types of spring which include leaf springs, coil springs, shock absorbers, air springs and torsion bars. These are used in sets of four for each vehicle, or they may be paired off in various combinations and are attached by several different mounting techniques. Therefore, to check the comfort ability of a vehicle we need to find the deflection and stiffness or rate of various types of spring mounted in that car. In this thesis, the deflection and rate of leaf spring of Mazda Jeep are analyzed. This paper deals with the suspension system of road vehicle analyzed. Road vehicles can expend a significant amount of energy in undesirable vertical motions that are induced by road bumps. The objective is to study how much comfortable the occupants when an automobile is in motion on any kind of a road its body and wheels vibrate. It is not complete to emphasize the suspension system without vibration. So, the vibration with two degree of freedom is also calculated.

Indexed Terms- suspension system, springs, vibration

I. INTRODUCTION

The chassis frame supports the weight of the body, engine, transmission and the passengers. The frame, if mounted directly on the axle, would be subjected to serve vibrations due to road irregularities. The basis frame structure, the units mounted on it and the passengers would be seriously affected by these serve oscillations. It has become recognized, as a result of long experience, that all types of vehicles used for location, suspension must be provided with some means of insulating the wheel and axle from the rest of the vehicles, so that the road shock received by the wheel will not be transmitted appreciably to the outer parts. The mechanism fitted between the wheel axle and frame, i.e.., the suspension system, tends to cushion and allows a small vertical movement of the chassis frame. The pneumatic types and the seat cushion are also in the line of deference against road shocks. Springs are an elastic body, which is designed and constructed to give a relatively large elastic deflection under a given load. Although in lost cases the elastic deformation of an engineering body is considered a disadvantage, a spring is usually employed where deflection flexibility is specifically desired. Springs have a variety of applications and made in many different forms. A spring is a flexible element used to exert a force or a torque and, at the same time, to store energy. The force can be a linear push or pull, or it can be radial, acting similarly to a rubber band around a roll of drawing. The torque can be used to cause a rotation, to close a door on a cabinet to provide a counterbalance force for a machine element pivoting on hinge. Springs inherently store energy when they are deflected and retain the energy when the force that causes the deflection is removed. This is the primary design objective. The suspension system has two main basic functions, to keep the car's wheels in firm contact with the road and to provide a comfortable ride for the passengers. A lot of the system's work is done by the springs.

II. THEORY BACKGROUND

Leaf springs (also known as flat springs) are made out of flat plates. 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. Thus, the leaf springs may carry lateral loads, brake torque and driving torque. The most commonly used leaf spring is the semi-elliptic type, consisting of one main leaf, which usually has its ends formed into eyes for connection with the spring brackets. It is built up of a number of plates (known as leaves). The leaves are usually given an initial curvature or cambered so that they will tend to straighten under the load. The spring is clamped to the axle using by means of U-bolts. The upper and the lower surface of the leaf are at maximum tension and maximum compression respectively. Practically the failure of leaf springs occur due to fatigue that always starts on the tension side of the spring leaves because of tensile strength of the material being less than its compressive strength.

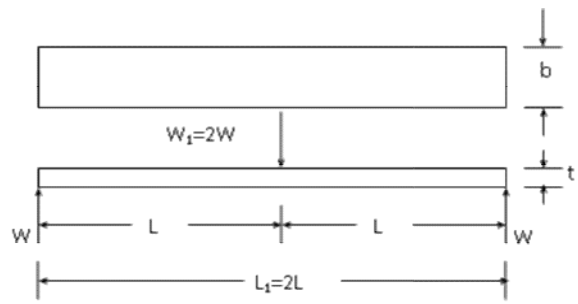

Fig.1 Simply Supported Beam Type

Bending stress,

$$\sigma = \frac{M}{Z} = \frac{W\,L}{b\,t^2/6}$$

$$= \frac{6\,W\,L}{b\,t^2} \qquad (1)$$

Where, σ = bending stress, W = load on spring,
b = width of spring, t = thickness of spring

$$\delta = \frac{W_1 (L_1)^3}{48\,EI} = \frac{(2W)(2L)^3}{48\,EI} = \frac{W\,L^3}{3\,EI} \qquad (2)$$

A. Full length leaves and graduated leaves

There are two types of leaves; full length leaves and graduated leaves. Leaf spring is usual to provide two full length leaves upper the rest graduated leaves as shown in Fig.2.

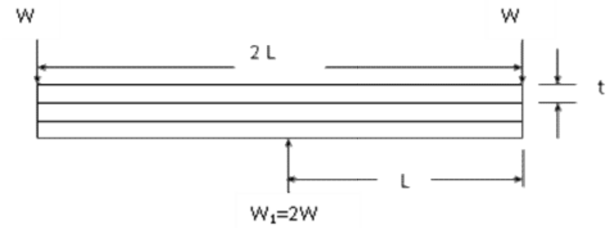

Fig.2 Full Length Leaves
Source: Khurmi and Gupta (2005)

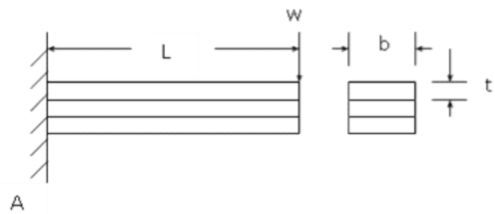

Fig.3 Cantilever Beam of Full Length Leaves
Source: Khurmi and Gupta (2005)

The maximum deflection of a cantilever beam loaded in the end is given by

$$\delta_F = \frac{2\,\sigma_F\,L^2}{3\,E\,t} \qquad (3)$$

Where, δ = deflection of cantilever beam
E = modulus elasticity
n = number of leaf

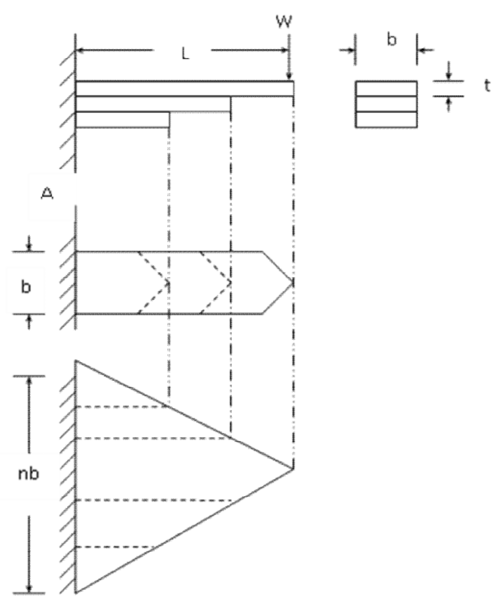

Fig.4 Cantilever Beam of Graduated Leaves
Source: Khurmi and Gupta (2005)

$$W_G = \left[\frac{2\,n_G}{3\,n_F + 2\,n_G}\right]W \qquad (4)$$

$$W = W_G + W_F \qquad (5)$$

Where,
W = Total load on the spring
W_G = Load on graduated leaves
W_F = Load on full length leaves

Equivalent Springs in series,

$$k_e = \frac{k_1 k_2}{k_1 + k_2}$$

Equivalent Springs in parallel,

$$W_e = W_1 + W_2$$

$$k_e\delta = k_1\delta + k_2\delta$$

$$k_e = k_1 + k_2$$

The frequency equation of the system,

$$\omega_{1,2}^2 = \left(\frac{k_1 + k_2}{2m_1} + \frac{k_2}{2m_2}\right) \pm \sqrt{\frac{1}{4}\left(\frac{k_1 + k_2}{m_1} + \frac{k_2}{m_2}\right)^2 - \frac{k_1 k_2}{m_1 m_2}}$$

III. DESIGN CALCULATION OF LEAF SPRING

Table I
Design Implication of Varying Leaf Spring Geometric Variables

Geometric Variable	Design Implication
Leaf Length, L	Use largest possible L L=1100 mm for Front Leaf Spring L=1200 mm for Rear Leaf Spring
Number of Leaves, n	Use n $\leq$ 6 for Front Leaf Spring Use n $\leq$ 9 for Rear Leaf Spring
Leaf Thickness, t	Use smallest 't' that will provide an acceptable value for natural frequency
Leaf Width, b	Use smallest 'b' that will provide an acceptable value for natural frequency

Table II
Specifications of Existing Leaf Spring for Mazda Jeep

	Front Leaf Spring	Rear Leaf Spring
Length, l (mm)	1100	1200
Width, b (mm)	60	60
Thickness, T (mm)	6	6
Number of leaves, n	6	9
Full length leaves, n_F	2	2
Graduated leaves, n_G	4	7
Deflection, δ (mm)	109.7588	101.7164
Spring stiffness k, (N/m)	47872.9900	51658.1600

Standard nominal widths are: 32, 40*, 45, 50*, 55, 60*, 65, 70*, 75, 80, 90, 100 and 125 mm. Dimensions marked * are the most commonly manufactured leafspring widths. Standard nominal thicknesses are: 3.2, 4.5, 5, 6, 6.5, 7, 7.5, 8, 9, 10, 11, 12, 14 and 16 mm.

Table III
Proposed Dimensions for Front Leaf Springs

Number of leaves	6
Length	1100 mm
Leaf Thickness	60 mm
Leaf Width	6 mm
Calculated Spring Stiffness	47872.99 N/m

Table IV
Natural Frequencies for Front Suspension System

	Natural Frequency (Hz)	
	Full load	Empty load
Front Suspension	1.3516	1.7235

Table V
Proposed Dimensions for Rear Leaf Springs

Number of leaves	9
Length	1200 mm
Leaf Thickness	60 mm
Leaf Width	6 mm
Calculated Spring Stiffness	51658.14 N/m

Table VI
Natural Frequencies for Rear Suspension System

	Natural Frequency (Hz)	
	Full load	Empty load
Front Suspension	1.3933	1.7769

IV. CONCLUSION

For the Mazda Jeep, the front leaf springs have natural frequency 1.3487 Hz in full loaded condition and 1.717 Hz in empty load condition. Also the rear leaf springs have natural frequency 1.3902 Hz in full load condition and 1.7708 Hz in no loaded condition. Thus, the natural frequencies of front and rear leaf springs have between frequency 1 Hz and 2 Hz of the ride comfort limit. Moreover, the frequencies of proposed front and rear leaf spring are less than that of existing front and rear leaf spring. Therefore, proposed leaf suspension system is more comfort than existing leaf suspension system. The existing front and rear leaf springs have six and nine leaves. The proposed front and rear leaf springs have five and eight leaves. The proposed design is also economic because of reducing material cost by using less number of leaves than existing design.

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