Suspension Calculation for Baja ATV

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Abstract: ***Spring is a key component of any suspension system. In suspension systems, springs are primarily employed to absorb shock energy and to return displaced parts to their original positions to start the specified function. The spring maintains ride height, supports the vehicle's weight, and cushions road shocks. Helical coil compression springs are the type of spring that suspension systems employ the most frequently. The main issue with automobile is that when spring bouncing is out of control, it makes it difficult for the car to handle and causes an uncomfortable ride. In order to have the most efficient suspension system for a BAJA ATV, this paper describes the reverse calculation of the suspension system and ultimately determines the necessary free length, stiffness, and pitch of a helical compression spring. To make the theoretical calculations as accurate as possible, the relevant data is calculated and acquired in order to derive average values for various design parameters.***

Keywords: Suspension Calculation, BAJA ATV, Helical Compression Spring, Spring Design, Spring Stiffness, Spring Index, Wahl's Factor, Max Shear Stress, Spring Deflection, Solid Length, Free Length

1. Introduction

The vehicle suspension system is responsible for driving comfort and safety as the suspension caries the vehicle body and transmits all forces between the body and the road. Semi-active or active components are added to have a good impact on these qualities. These make it possible for the suspension system to adjust to different driving scenarios. Driving comfort and safety are significantly increased when a variable spring is added compared to suspension systems with fixed features. For this method to work, it is necessary to understand both the control behaviour of these components and the laws governing how to modify the free parameters in response to driving excitations. This necessitates a mechatronic design that includes the identification and fault detection of the related components.

1.1 Design of compression spring for suspension system

Design of helical compression spring involves following

1) Should possess sufficient strength to withstand the external load.
2) Should have required load-deflection characteristics.
3) Should not buckle under external load.
4) Should insure comfortable ride.
5) Should provide elastic connection between load carrying systems and the axles.
6) Should damp their vibration
7) Should perform with desired economy
8) Should fit into given space and operate accordingly.

1.2 Spring Stiffness

The amount of mass distributed between the front and rear of the vehicle is taken into account when calculating the stiffness of the front and rear springs independently.

Vehicle Mass (m) = 207 kg
Mass Distribution in Front = 45%
Mass Distribution in Rear = 55%
Mass in Front (m_{front})= (0.45)×(207) = 121.5 kg
Mass in Front (m_{rear})= (0.55)×(207) = 148.5 kg

According to the BAJA 2023 rulebook, the spring's damping frequency must be maintained at a specific level.

Where,
Natural Frequency of Front suspension (F_{front}) = 2.1 Hz
Natural Frequency of Rear suspension (F_{rear}) = 2.3 Hz

Now, Frequency of Front suspension, $F_{front} = \frac{1}{2\pi}\sqrt{\frac{K}{m}}$(Hz)

Rearranging this equation, $K_{front} = (F_{front})^2 \times (2\pi)^2 \times m_{front} = (2.1)^2 \times (2\pi)^2 \times 121.5 = 21131.69\ {}^{N}/_{m} \times$ (Factor of Safety)
= 21131.69 × (1.5)

$K_{front} = 31697.5\,{}^{N}/_{m}$

Similarly for Rear Suspension,

$K_{front} = (F_{front})^2 \times (2\pi)^2 \times m_{front} = (2.3)^2 \times (2\pi)^2 \times 148.5 = 30981.5\ {}^{N}/_{m} \times$ (Factor of Safety)
= 30981.5 × (1.5)

$K_{front} = 46472.2\,{}^{N}/_{mm}$

For Both cases, Factor or Safety is taken as 1.5

1.3 Spring Index

The figures of Mean Coil Diameter and Wire Diameter are taken in accordance with the Baja Rulebook's recommendations.

Spring Index (C) = $\frac{D}{d}$

where,
D-Mean diameter of coil = 80 mm
d-wire diameter = 10 mm

$C = \frac{80}{10} = 8$

C=8

1.4 Wahl's Factor

Axial force is exerted on the spring. The equation for resultant stress, which also accounts for torsional shear stress, direct shear stress, and stress concentration because of curvature, was developed by W. Wahl. C is the spring index where. The Wahl factor offers a quick way to determine the spring's resulting stresses.

Wahl's Factor (W) $= \frac{4C-1}{4C-4} + \frac{0.615}{C} = \frac{32-1}{32-4} + \frac{0.612}{8}$

W= 1.184

1.5 Max Shear Stress

To consider the effect of direct shear stress and stress concentration due to curvature effect,

$\tau = K\left(\frac{8WD}{\pi d^3}\right)$

Where,
W= Load / Force on Spring
= m×g
= 270 × 10 × (factor of safety)
= 2700 × (1.5)
W = 4050N
K = Wahl's Factor

$\tau = 1.184\left(\frac{8 \times 4050 \times 80}{\pi \times 10^3}\right)\frac{N}{mm^2}\ \tau = 977.365\ \frac{N}{mm^2}$

1.6 Spring Deflection

An equation for the axial deflection of a helical spring in terms of the axial load, spring dimensions, and a materials constant may be conveniently determined by equating the work required to deflect the spring to the strain energy in the twisted wire. For close-coiled springs the bending of the wire is small and the strain energy of bending may be neglected.

$\delta = \frac{8WD^3 n}{Gd^4}$

Where,
G-Modulus of Rigidity of Spring = 79241 $\frac{N}{mm^2}$
n- number of Coils = 8

$= \frac{8 \times 4050 \times 80^3 \times 8}{79241 \times 10^4}\delta$ = 167.55 mm

1.7 Solid Length

Solid length is defined as the axial length of a compressed helical compression spring where consecutive coils are in contact with one another.

Solid length (L_s) = n × d
= 8 × 10
L_s = 80 mm

1.8 Free Length

Free Length in Defined as the Axial Length of the Helical Compression Spring in unloaded condition. Here, no external force acts on the spring.

Free Length (L_f) = (n×d) + δ + (δ ×.015)
= (8×10) + 167.5 + (167.5 ×.015)
L_f = 300 mm

1.9 Pitch of the Coil

The pitch of a spring is the distance from the center of one coil to the center of the adjacent coil like threads (lead) on a bolt or screw

Pitch, P = $\frac{Free\ Length}{n-1}$
= $(L_f - L_d) \times \frac{1}{n} + d$
= $(300 - 80) \times \frac{1}{8} + 10$
P = 37.5 mm

1.10 Buckling

When a spring buckles, it means that it deforms under compression in a lateral (rather than axial) manner. When the spring's free length is greater and the end conditions are not suitable to equally distribute the load along the coil's circumference, compression coil springs will buckle. If the free length is more than 4 times the mean diameter and the spring is not adequately directed, buckling may happen in compression springs.

Now,
L_f/D = 300/80 = 3.75
Since, 3.75 < 4. So, no need spring guide to prevent Buckling.

1.11 Analysis and evaluation of a coil spring under Helical Compression

Understanding the behaviour of the material is crucial to enhance the performance of the spring. The fatigue life of springs can be greatly extended by heat and surface treatments.

Different reasons of spring failure analysis are:-

1) Defects in raw materials: The most common raw material flaw is the presence of foreign material, including non-metallic inclusions, inside the steel. In general, inclusions and spinells, which are smaller flaws brought on by alloying elements, are the two main foreign materials that might become trapped inside the steel solution.
2) Surface flaws: During cold drawing, surface flaws might take the form of a small hardening crack, tool markings, or scale embedded to the underlying material. Surface flaws can also be thought of as poorly shot peened surfaces.
3) Poor Thermal Treatment: Prolonged heating can dramatically increase the grain size of earlier austenite. The desired martensite microstructure may become pearlite as a result of improper heat treatment. Another example of incorrect heat treatment is bainetic formation.
4) Oxidation: The most frequent reason for spring fracture is oxidation or corrosion. But modern coating technology has advanced to the point where it can shield a metal from even the hardest cold stone chipping.

2. Conclusion

This article outlines the calculation process for choosing a suspension system for a BAJA ATV. All masses acting at the springs in both static and dynamic situations were taken into account throughout the calculating process. The spring strength is influenced by design parameters, material choice, defects in raw materials, spring geometry, and surface flaws. The operating modes, operating temperature, shot peening, and flaws on the inside of the coil spring are observed to have a direct impact on the fatigue life of the spring. Additionally, when temperature rises, the modulus and torsional yield strength of the spring material drop. Process factors therefore play a crucial influence in spring. The choice of material is crucial for spring design since it allows us to adjust many design factors in accordance with the material and applications to achieve the best design.