

DEVELOPMENT AND APPLICATION OF COMPUTER PROGRAM FOR HELICAL SUSPENSION SPRING

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Abstract: *The Automobile Suspension System (ASS) is an integral part of any automobile. It is primarily responsible for Vehicle control and Passenger comfort. A new computational approach was developed to give an insight to proper design of automatic suspension system to meet the current demand of recent automobile. The major components of any Suspension System are the springs and the different characteristics of the Helical suspension spring such as thickness, diameter, spring index, Modulus of rigidity amongst others were studied extensively to model a package in Microsoft Visual Studio (visual basic language) which will be capable of flexible analysis and design.*

This study is focused on development of a computer program for the analysis and design of the springs of an automobile suspension system using the Visual Basic programming language. The developed algorithm consists of deflection derivative, Shear stress induced (Ignoring and considering the effect of curvature), Mean diameter, Pitch and finally drawing the different materials' Load-deflection and Load-Shear Stress graphs.

The developed application has thereby made automobile suspension system an easy one due to automatic plotting and analysis of optimum load to be applied in other to obtain least deflection. The results obtained conform to those of other related packages and that of theoretical calculations for the same set of constants. It also provides a higher degree of accuracy and reduces the rigor and drudgery which is normally accompanied by drawing and calculating manually.

1.0 INTRODUCTION

The Automobile Suspension System is a fundamental component of an automobile. The automobile suspension system consists of springs, shock absorbers and linkages which connect a vehicle to its wheels. The suspension system supports the weight of the automobile from damage and wear also assist in vehicle control and passenger comfort (McMahon *et al.*, 2013). Comfort is provided by isolating the vehicle's passenger cabin from road bumps, vibrations, road noise, e.t.c. Control is achieved by keeping the car body from excessively rolling and pitching, and maintaining good contact between the tyre and road surface. A suspension system must be strong enough to withstand forces encountered by the vehicle during motion. Apart from the linkages, the fundamental components of any suspension are springs, dampers and stabilizer (also called anti-roll) bars. Helical springs are used on the front suspension of most modern light vehicles and in many cases; they have replaced leaf springs in the rear suspension.

There are basically two types of suspension system: an active suspension system possesses the ability to reduce acceleration of sprung mass continuously as well as to minimize suspension deflection, which results in improvement of tire grip with the road surface, thus, brake, traction control and vehicle manoeuvrability can be considerably improved. One of the performance requirements is advanced suspension systems which prevent the road disturbances to affect the passenger comfort while increasing riding capabilities and performing a smooth drive (Ayman, 2012). Passive suspensions can only achieve good ride comfort or good road holding since these two criteria conflict each other and necessitate different spring and damper characteristics. While semi-active suspensions with their variable damping characteristics and low power consumption, on systems offer a considerable improvement. (Ayman, 2012).

To guarantee safety and stability of suspension systems, material selection for the highly stressed components is critical. Firstly ductility of the elements is important. Materials with a breaking strain below 12% must not be applied in suspension systems. Forged steel, cast steel, forged aluminium or squeeze casted aluminium parts are to be preferred. Cast iron or other Brittle materials can only be used at parts with lower strains and of secondary importance. Exotic and costly materials like titanium or composites (e.g. carbon fibre reinforced resin) are only used for super sports and racing cars. Secondly materials with a high Young's modulus (elasticity modulus) like steel (Young's modulus 206 000 N/mm²) ensure less deformation under loads than aluminium (modulus 70 000 N/mm²) or even titanium (modulus 110 000 N/mm²). Thirdly the design has to draw little deformation into the

calculation. Parts with a high section modulus (e.g. tubes instead of rods) are less distorted under bending or torsional loads and are preventing unwanted change of the suspension geometry under high loads (side forces, brake forces, traction forces, vertical forces) (Jurgen, 2006).

The optimal design method of the helical springs of the automobile suspensions according to the criterion of the minimum mass has been established (Aurel, 2009). For this purpose, at a given spring rate, the torsional stress corresponding to the maximum force applied to the spring, the fatigue stress, the buckling stability condition and the constraints relating to the spring index and to the outer coil diameter are considered. It is possible to work on the suspension system to achieve lower weight. The performance of the suspension system fully depends upon the spring stiffness, this could be achieved by reducing the weight of suspension system, then considered the other factors like performance, design constraints, corrosion resistance, fatigue strength of material, cost and the operating environment (Valsange, 2012 & Sourabh *et al.*, 2014).

The main factor to be considered in design of spring is the strain energy of material used. This indicates that the material with lower Young's modulus (E) or density (ρ) will have relatively higher strain energy/deflection under same stress (σ) (Gopinath *et al.*, 2008 & Aher, 2012). Modern passenger vehicles use light coil springs. Light commercial vehicles have heavier springs than passenger vehicles and can have coil springs at the front and leaf springs at the rear. The main objective of the chassis spring is to absorb shocks imparted to the wheels by road obstacles. A spring when fitted between the wheel and the frame isolates the body partially from the axle so that the wheel moves up and down without transferring similar movement to the frame (McMahon *et al.*, 2007 & Sourabh *et al.*, 2014).

In the design of helical spring various factors must be considered for the effectiveness performance, these include the following:

- Space into which the spring must fit and operate.
- Values of working forces and deflections.
- Accuracy and reliability needed.
- Tolerances and permissible variations in specifications.
- Environmental conditions such as temperature, presence of a corrosive atmosphere.
- Cost and qualities needed

(Gopinath *et al.*, 2008).

The designers use these factors to select a material and specify suitable values for the wire size, the number of turns, the coil diameter and the free length, type of ends and the spring rate needed to satisfy working force deflection requirements. The primary design constraints are that the wire size should be commercially available and that the stress at the solid length be no longer greater than the torsional yield strength.

Computer Aided Engineering (CAE) tools provides a cost effective and less time consuming solution in comparison with the experimental testing but the results may vary in the specified range (Vinkel *et al.*, 2011). The predictive capability of Computer Aided Engineering (CAE) tools has progressed to the point where much of the design verification is now done using computer simulation rather than physical prototype testing (Baviskar *et al.*, 2013 & Vinkel Arora *et al.*, 2011). the optimal design method of the helical springs of the automobile suspensions according to the criterion of the minimum mass has been suggested. For this purpose, at a given spring rate, the torsional stress corresponding to the maximum force applied to the spring, the fatigue stress, the buckling stability condition and the constraints relating to the spring index and to the outer coil diameter are considered Aurel (2009).

A helical spring is made from a single length of special wire, which is heated and wound on a former, to produce the required shape. The load-carrying ability of the spring depends on the diameter of the wire, the overall diameter of the spring, its shape and the spacing of the coils. A light commercial vehicle has springs that are robust and fairly stiff. On a small passenger car, they are lighter and more flexible. The coils may be evenly

spaced, or of uniform pitch, or unevenly spaced. The wire can be the same thickness throughout, or it may taper towards the end of the spring.

METHODOLOGY

The proposed Application program should provide an Interface in which the User will input data based on the component of automobile suspension to analyse. After Inputting the data, the program then analyse the spring type and display the Constant values as input in a Visual Basic dropdown. Visual Basic application was used to develop a program that would analyse a suspension system and give the magnitude of unknown values for length, width, diameter, thickness, load and shear stress. The visual basic software would be able to specify the optimum values of length, width, diameter, thickness, load and shear stress to get a safe design and least deflection for automobile suspension system.

- i. Start the Program
- ii. Select Material Type for a suspension type.
- iii. Use drop down box to select constants
- iv. Select Variable values
- v. Click “Calculate” to show results.
- vi. Click “Plot” to plot required graph forms

Running the developed application the user is presented with an interface to select the component of automobile suspension to be analysed, on selecting the component, a form to input the constant data such as load is presented to the user. On specifying, the software computes all the necessary parameters to compute the necessary output such as deflection. Coding the equations below into the algorithm of the program and incorporating other characteristics of springs and dampers, the software is developed using the visual basic application.

Mathematical Model for Spring Construction

1. Solid length: When the compression spring is compressed until the coils come in contact with each other, then the spring is said to be solid. The solid length of a spring is the product of total number of coils and the diameter of the wire. Mathematically,

Solid length of the spring,

$$L_s = n'd \dots\dots\dots(1)$$

where n' = Total number of coils, and

d = Diameter of the wire.

2. Free length: The free length of a compression spring, is the length of the spring in the free or unloaded condition. It is equal to the solid length plus the maximum deflection or compression of the spring and the clearance between the adjacent coils (when fully compressed).

Mathematically,

Free length of the spring,

$$= \text{Solid length} + \text{Maximum compression} + \text{*Clearance between adjacent coils (or clash allowance)}$$

$$L_f = n'd + \delta_{max} + 0.15\delta_{max} \dots\dots\dots(2)$$

The following relation may also be used to find the free length of the spring, i.e.

$$L_f = n'd + \delta + (n' - 1) \times 1mm \dots\dots\dots(3)$$

In this expression, the clearance between the two adjacent coils is taken as 1 mm.

3. Spring index: The spring index is defined as the ratio of the mean diameter of the coil to the diameter of the wire. According to Roymech (2012), the Spring index, C for most helical springs used in automobiles is between 3 to 12, the optimal size being 9. Mathematically, Spring index,

$$C = \frac{D}{d} \dots\dots\dots (4)$$

where $D =$ Mean diameter of the coil, and

$d =$ Diameter of the wire.

4. Spring rate: The spring rate (or stiffness or spring constant) is defined as the load required per unit deflection of the spring. Mathematically,

$$k = \frac{W}{\delta} \dots\dots\dots (5)$$

where $W =$ Load, and

$\delta =$ Deflection of the spring.

In actual practice, the compression springs are seldom designed to close up under the maximum working load and for this purpose a clearance (or clash allowance) is provided between the adjacent coils to prevent closing of the coils during service. It may be taken as 15 per cent of the maximum deflection.

5. Pitch: The pitch of the coil is defined as the axial distance between adjacent coils in uncompressed state. Mathematically **Pitch of the coil,**

$$p = \frac{L_f}{n'-1} \dots\dots\dots(6)$$

The pitch of the coil may also be obtained by using the following relation, i.e.

$$p = \left(\frac{L_f - L_s}{n'}\right) + d \dots\dots\dots (7)$$

(a) The pitch of the coils should be such that if the spring is accidentally or carelessly compressed, the stress does not increase the yield point stress in torsion.

(b) The spring should not close up before the maximum service load is reached

Solid Length,

$$L_s = n'd \dots\dots\dots (8)$$

Free Length,

$$L_f = n'd + \delta_{max} + 0.15\delta_{max} \dots\dots\dots (9)$$

$$L_f = n'd + \delta + (n' - 1) \times 1mm \quad (10)$$

Spring Index,

$$C = \frac{D}{d} \dots\dots\dots (11)$$

Spring Rate,

$$k = \frac{W}{\delta} \dots\dots\dots (12)$$

Pitch,

$$p = \frac{L_f}{n'-1} \dots\dots\dots (13)$$

$$p = \left(\frac{L_f - L_s}{n'}\right) + d \dots\dots\dots(14)$$

Deflection,

$$\tau = K \times \frac{8WD}{\pi d^2} \dots\dots\dots (15)$$

Where

$$K = \left(4C - \frac{1}{4}C - 4\right) + \left(\frac{0.615}{C}\right) \dots\dots\dots(16)$$

Spring rate,

$$\frac{W}{\delta} = \frac{Gd^4}{8D^3n} \dots\dots\dots(17)$$

TABLE 2: PHYSICAL PROPERTIES OF SOME MATERIALS USED FOR HELICAL SPRING

MATERIAL	MODULUS OF Rigidity (KPa x 10 ³)	ALLOWABLE STRESS(MPa)
Music Wire	79.3	1237.95
Hard-drawn wire	79.3	893.6
Oil Tempered	79.3	1005.3
Carbon Valve	79.3	744.75
Chrome Vanadium	79.3	931.05
Chrome Silicon	79.3	931.05
302/304 Stainless Wire	69.0	784.35
316 Stainless Wire	69.0	675.6
Phosphor Bronze Wire	43.1	400
Beryllium Copper	48.3	713.7
Monel 400	65.5	496.4
Incoloy(A-286 Alloy)	71.7	482.65
Inconel 600	75.8	634.4
Inconel 718	77.2	689.6

(ACE WIRE SPRING AND FORM COMPANY, 2005)

4.0 RESULTS AND DISCUSSION

4.1 Numerical Examples on Coil Spring

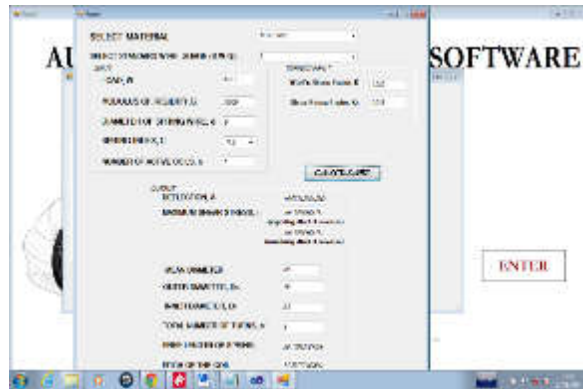
Case study 1: A compression coil spring made of an alloy steel is having the following specifications: Mean diameter of coil = 50 mm; Wire diameter = 5 mm; Number of active coils = 20. If this spring is subjected to an axial load of 500 N; calculate the maximum shear stress (neglect the curvature effect) to which the spring material is subjected.



	THEORETICAL VALUES	COMPUTED RESULT
DEFLECTION	9.98	10.09
SHEAR STRESS FACTOR	534.7	534.69

MAXIMUM SHEAR STRESS	1.05	1.05
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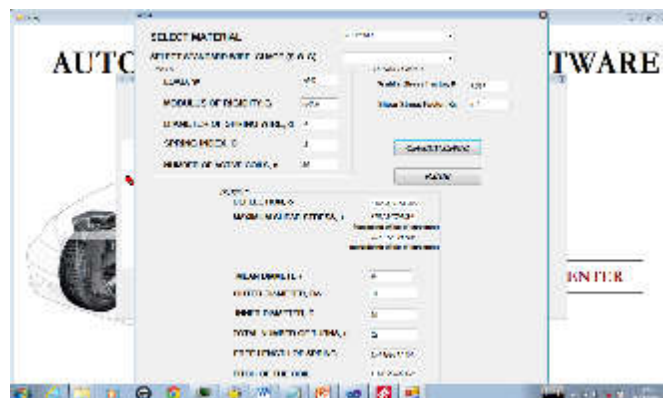
Case study 2: A helical spring is made from a wire of 6 mm diameter and has outside diameter of 75 mm. If the permissible shear stress is 350 MPa and modulus of rigidity 84 kN/mm², find the axial load which the spring can carry and the deflection per active turn.



	THEORETICAL VALUES	COMPUTED RESULT
DEFLECTION(mm)	9.96	10.05
SHEAR STRESS FACTOR	350	350.10

Case study 3

Design a spring for a balance to measure 0 to 1000 N over a scale of length 80 mm. The spring is to be enclosed in a casing of 25 mm diameter. The approximate number of turns is 30. The modulus of rigidity is 85 kN/mm². Also calculate the maximum shear stress induced.



	THEORETICAL VALUES	COMPUTED RESULT
OUTER DIAMETER(mm)	23.25	24
SHEAR STRESS FACTOR	1028.2	1043.13

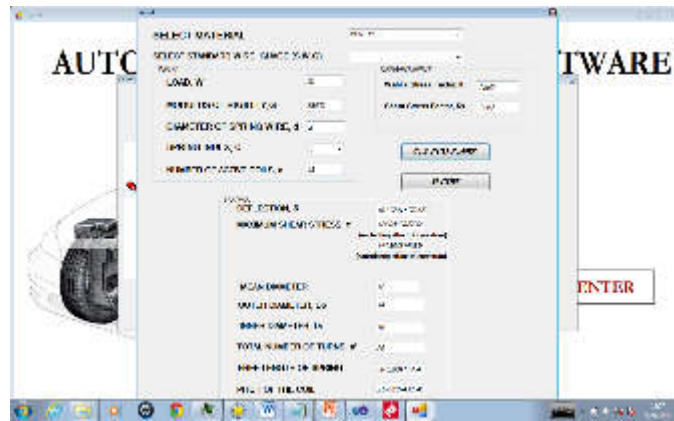
Case study 4

A mechanism used in printing machinery consists of a tension spring assembled with a preload of 30 N. The wire diameter of spring is 2 mm with a spring index of 6. The spring has 18 active coils. The spring wire is hard drawn and oil tempered having following material properties:

Design shear stress = 680 MPa

Modulus of rigidity = 80 kN/mm²

Determine: 1. the initial torsional shear stress in the wire; 2. Deflection;



	THEORETICAL VALUES	COMPUTED RESULT
SHEAR STRESS(N/mm²)	143.5	143.56
DEFLECTION(mm)	11.43	11.44

CONCLUSION

Extensive design and analysis of Automobile Suspension System for Helical Spring has been developed. In the application developed, there are many design combinations, numerous material types available, readily available recommended constants coupled with plotting of graphs (Load against deflection and Load against shear stress) for each material type. The Automobile Suspension Software has justified the need for the continuous development of various software in this area. The developed algorithm consists of deflection derivative, Shear stress induced (Ignoring and considering the effect of curvature), Mean diameter, Pitch and finally drawing the different materials' Load-deflection and Load-Shear Stress graphs.

The developed application has thereby made automobile suspension system an easy one due to automatic plotting and analysis of optimum load to be applied in other to obtain least deflection. This has greatly reduced the rigor and drudgery involved in the theoretical and graphical analysis of suspension systems. The results obtained conform to that of theoretical calculations for the same set of constants. It also provides a higher degree of accuracy due to the use of Visual basic language.

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