International Journal of Engineering Research
Volume No.5, Issue No.9, pp :749-752
ISSN:2319-6890)(online),2347-5013(print)
1 September 2016

Analysis of a Primary Suspension Spring Used In Locomotives

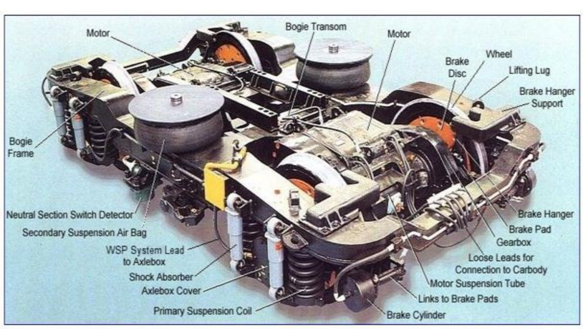
K. Pavan Kumar[1], B. Vinod Kumar[2], P. Gopi[3] and K. Aruna[4]
Dept. of Mechanical Engineering, S.V.U. College of Engineering, Tirupati-517502
Email: karanampa1@gmail.com

Abstract:A spring is an elastic object which is used to store mechanical energy. It can be twisted, pulled or stretched by applying force and returns to its original shape upon release of force. In practice, the spring tends to buckling under the compressive load. Thus, the guiding components are usually used to constrain the buckling deflection, and the spring can continue to work in the normal situation. In these states, the deflection of the spring satisfies the small deformation assumption. This work is helpful in figuring out the behavior of post-buckling of the compressed helical spring. A typical locomotive suspension spring configuration is chosen for this study. This work is mainly concentrated on modeling and analysis of primary suspension spring (20NiCrMo$_2$) and comparing with the earlier conventional steel helical spring (Chrome Vanadium). The objective of this research is to reduce the overall stresses and deflections of the helical spring by using the new material. The buckling analyses of the locomotive suspension spring are performed using ANSYS 14.0 and compared with analytical results. The spring model is done by using Pro/E Wildfire 4.0.

Keywords: Locomotives - Primary Suspension System - Helical spring – Modeling - Static Analysis – Ansys 14.0- Pro E -4.

I. Introduction:

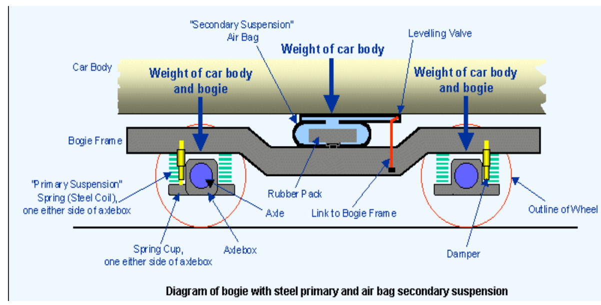
Locomotive is one of the primary transport systems for all classes of people. Mainly a train is divided into two parts, bogie and compartment. Lower part of the train is called bogie and upper part of the train is called compartment. In this study, locomotive primary suspension spring is chosen for analysis. The calculation, design and testing of spring suspension is an important component of the bogie, represent a complex and high engineering task.



(Fig 1.1 Different Bogie Parts)

2. Primary Suspension System:

The natural progression from the rigid framed vehicles used in the early days of European railways to a bogie vehicle brought with it a more sophisticated suspension system. This system was based on a steel plate framed bogie with laminated spring axle box suspension, much as seen on the first vehicles, and with a secondary suspension added between the car body and the bogie. First, primary suspension is considered.



(Fig 1.2 Primary Suspension System)

Figure 1.2 shows a plate framed bogie with the axle box suspension and bolster suspension is left out for simplicity. The bogie carries half the car weight which is then divided roughly equally between the two axles. If the whole vehicle weight was 30 tones, each bogie would carry 15 tones and each axle 7.5 tones. For a civil engineer wanting to know the stresses on structures and track, a 7.5 tone axle load would be given for analysis. Of course, the carrying load of passengers and freight would be included in this calculation. Returning to the primary suspension design, it is seen that the laminated axle box spring is fitted with two "spring hangers" attached to the outer ends of the longest spring plate. Each hanger passes through a hole in a bracket attached to the bogie frame and is screwed to another bracket at the bottom end. Between the two brackets a steel or rubber spring is placed. The weight of the bogie on the axle box is transmitted through the steel laminated spring and the two spring hangers. Each spring hanger and its associated spring carry 1/16th of the total car weight. The height of the bogie relative to the rail level could be adjusted by using the screwed spring hangers. Adjustment is allowed for small variations in wheel diameter.

II Material & Methodology

2.1. Springs:

Springs are elastic bodies (generally metal) that can be twisted, pulled, or stretched by some force. It can return to their original shape when the force is released. In other words it is also termed as a resilient member.

Based on the shape behavior obtained by some applied force, springs are classified into the following ways:

- Helical springs
- Leaf Springs

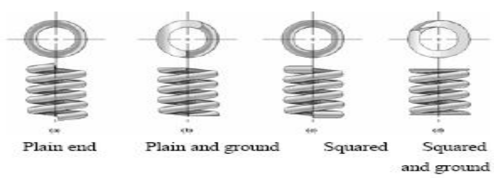
2.2. Helical compression spring:

- The gap between the successive coils is larger.
- It is made of round wire and wrapped in cylindrical shape with a constant pitch between the coils.
- By applying the load the spring contracts in action.
- There are mainly four forms of compression springs as shown in Figure-2.1 & 2.2.

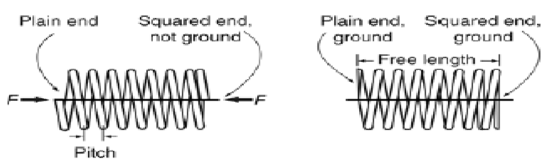
They are as follows:

1. Plain end
2. Plain and ground end
3. Squared end
4. Squared and ground end

Among the four types, the plain end type is less expensive to manufacture. It tends to bow sideways when applying a compressive load.



(Fig.2.2 Compression helical spring)



(Fig.2.2 Compression helical spring)

Applications:

- Ball point pens
- Pogo sticks
- Valve assemblies in engines

2.3. Specification of Helical Compression Spring:
2.3.1 Existing spring: (Chrome Vanadium)
Profile & Material Properties of primary suspension spring:
Dimensions for spring:

Table 2.1 Dimensions of helical spring

Description	**Dimension Value**
Wire dia. (d)	33.5 mm
Outer Dia (D_o)	244.5 mm
Mean Dia (D)	211 mm
Free height (H_f)	360 mm
Test load (W)	19.6 kN (on each spring)
No. of active coils (n)	8
Pitch	63 mm

Table 2.2 Chemical Composition:

C	**Mn**	**P**	**S**	**Si**	**Cr**
0.48-0.55	0.65-0.90	0.04 max	0.04 max	0.20-0.35	0.80-1.0

Table 2.3 Material and it properties

Description	**Dimension Value**
Material	Chrome Vanadium
Modulus of rigidity (G)	79300 MPa
Young's modulus (E)	207000 MPa
Density (ρ)	7860 kg/m^3
Poisson ratio	0.37

2.3.2 Proposed spring: ($20NiCrMo_2$)

Table 2.4 Chemical Composition of ($20NiCrMo_2$):

C	**Mn**	**P**	**S**	**Si**	**Cr**	**Ni**	**Mo**
0.15-0.2	0.7-0.9	0.035 max	0.04 max	0.15-0.3	0.4-0.6	0.4-0.7	0.15-0.25

Table 2.5 Dimension s ($20NiCrMo_2$)

Description	**Dimension Value**
Material	$20NiCrMo_2$
Modulus of rigidity (G)	140000 Mpa
Young's modulus (E)	210000 Mpa
Density (ρ)	8000 Kg/m^3
Poisson ratio	0.28

III. Results and Discussions
3. Analytical Calculations of Helical Spring:
3.1 Calculation Part: (EXSITING SYSTEM)

Critical axial load caused due to bucking $W_{cr} = kxK_BxL_f$

Where k = Stiffness = W/ δ

L_f = Free length of the spring

K_B = Buckling factor depending upon the ratio L_f/D

Now

Stiffness k = W/ δ

= 19600/99.5

= 196.88

Free length of the spring L_f = 360 mm

L_f/D = 360/211 = 1.706 = = 2

From data book

If L_f/D is 2 then buckling factor depending upon the ratio L_f/D = K_B = 0.71

Now

Critical axial load caused due to bucking W_{cr} = 196.88x360x0.71

= 50322.528 N

3.2 Calculation Part: (PROPOSED SYSTEM)

Stiffness $k = W/\delta$

$= 19600/56.39$

$= 347.58$

Free length of the spring $L_f = 360$ mm

$L_f/D = 360/211 = 1.706 = = 2$

From design data book

If L_f/D is 2 then buckling factor depending upon the ratio L_f/D = $K_B = 0.71$

Now,

Critical axial load caused due to bucking W_{cr} = 347.58x360x0.71

= 88841.28 N

3.3. Finite element analysis:

FEA consists of a 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. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

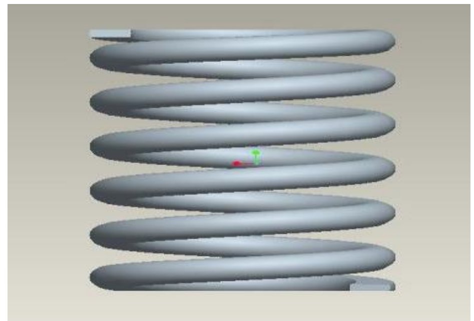
There are generally two types of analysis that are used in industry: 2-D modeling, and 3-D modeling. While 2-D modeling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modeling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively. Within each of these modeling schemes, the programmer can insert numerous algorithms (functions) which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to fracture.

3.4. Analysis of both helical springs:

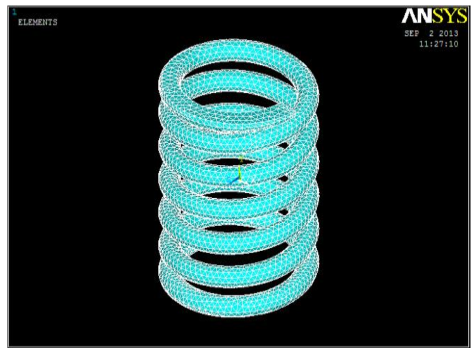
Buckling analysis is used to calculate the buckling loads and determine the buckling mode shape. Both linear (eigenvalue) buckling and nonlinear buckling analyses are possible. Buckling analysis is a technique used to determine buckling loads-critical loads at which a structure becomes unstable-and buckled mode shapes-the characteristic shape associated with a structure's buckled response.

Buckling of spring refers to its deformations in non-axial (lateral) direction under compression. Compression coil springs will buckle when the free length of the spring is larger and the end conditions are not proper to evenly distribute the load all along the circumference of the coil. The coil compression springs will have a tendency to buckle when the deflection (for a given free length) becomes too large and thereby spring can no longer provide the intended force. Once buckling starts, the off-axis deformation typically continues rapidly until the spring fails. As a result, it is important to design compression springs such that their likeliness to buckle is minimized.

3.5. Results:

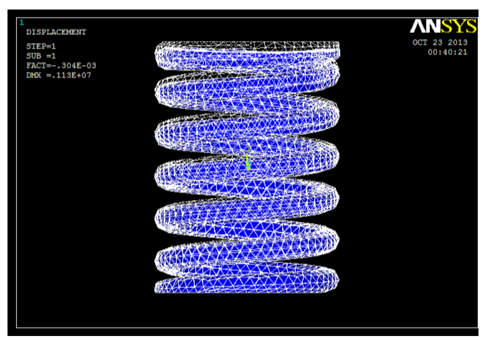


(Fig 3.1 3D Model of spring)



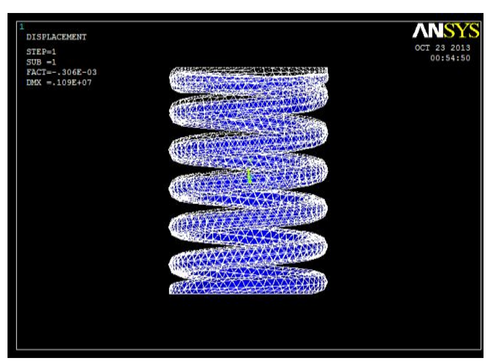
(Fig 3.2 Mesh of Primary Suspension Spring)

Buckling of Existing Spring:



(Fig 3.3 Buckling Analysis of Chrome Vanadium)

Buckling of Proposed spring:



(Fig 3.4 Buckling Analysis of $20NiCrMo_2$)

The above results shows that the $20NiCrMo_2$ is best replacement of Chrome Vanadium and the deflection and stress induced are very less comparative.

Table 3.1: Comparison of results

S. No.	Description	Chrome Vanadium	$20NiCrMo_2$
1.	FACT	-0.304E-03	-0.306E-03
2.	DMX	0.113E+07	0.109E+07

IV. Conclusion:

From the above analysis, and calculations we observe that the proposed spring $20NiCrMo_2$ can bear more load when compared to the existing spring Chrome Vanadium

By replacing Chrome Vanadium with $20NiCrMo_2$ alloy steel maintenance can be reduced. The cost $20NiCrMo_2$ steel materials cheaper in India & International Markets compared to Chrome Vanadium material.

References:

i. *Gaikwad S S and Kachare P S (2013), "Static Analysis of Helical Compression spring Used in Two- Wheeler Horn", International Journa of Engineering and Advanced Technology (IJEAT), Vol. 2, No. 3, ISSN: 2249-8958.*

ii. *"Investigation of Probable Failure Position in Helical Compression Springs Used in Fuel Injection System of Diesel Engines", IOSR Journal of Mechanical and Civil Engineering (IOSRJMCE), Vol. 2, No. 3 (September-October 2012), pp. 24-29, ISSN: 2278-1684*

iii. *Mehdi Bakhshesh and Majid khshesh (2012), "Optimization of Steel Helical Spring by Composite Spring", Department of Mechanical Engineering, Behbahan Branch, Islamic Azad University,Behbahan, Iran.*

iv. *Priyanka Ghate, Shankapal S R and Monish Gowda M H (2012), "Failure Investigation of A Freight Locomotive Suspension Spring and Redesign of the Spring for Durability and Ride Index", Automotive and Aeronautical Engineering, Dept. M.S. Ramaiah School of Advanced Studies, Bangalore 560058.*

v. *Research Committee on the "Analysis of Helical Spring", Transactions of Japan Society for Spring Research, No. 49, P. 35 (2004).*

vi. *Valsange P S (2012), "Design of Helical Coil Compression Spring: A Review", International Journal of Engineering Research and Applications, ISSN: 2248-9622.*