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Research Paper

STATIC ANALYSIS OF A PRIMARY SUSPENSION SPRING USED IN LOCOMOTIVE

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A spring is an elastic object used to store mechanical energy. They can twist, pulled or stretched by some force and can return to their original shape when the force is released. Static analysis determines the safe stress and corresponding pay load of the helical compression spring. The present work attempts to analyze the safe load of the locomotive suspension spring with different materials. A typical locomotive suspension spring configuration is chosen for study. In this present work is carried out on modeling and analysis of primary suspension spring ($60Si_2MnA$) is to replace the earlier conventional steel helical spring (Chrome Vanadium). The work is to reduce the overall stress and deflections of the helical spring by using the new material. This work describes static analysis of the locomotive suspension spring is performed using Ansys 14.0 and compared with analytical results. The spring model is done by using Pro/E Wildfire 4.0 software.

Keywords: Locomotives, Primary suspension system, Helical spring, Modeling, Static analysis, Ansys 14.0, Pro E-4

INTRODUCTION

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

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

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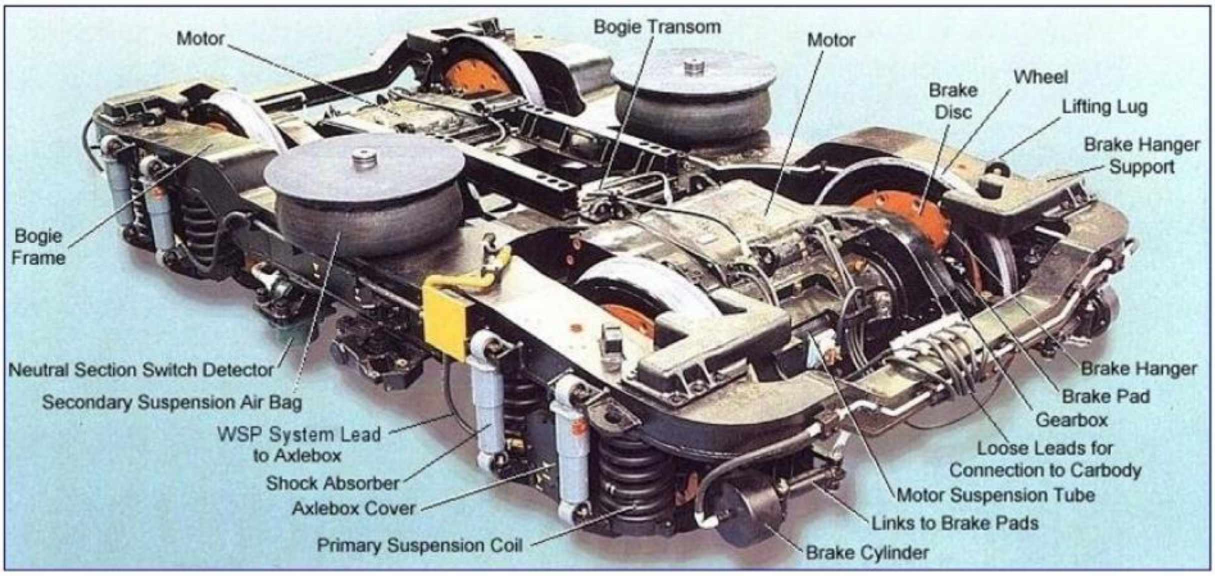
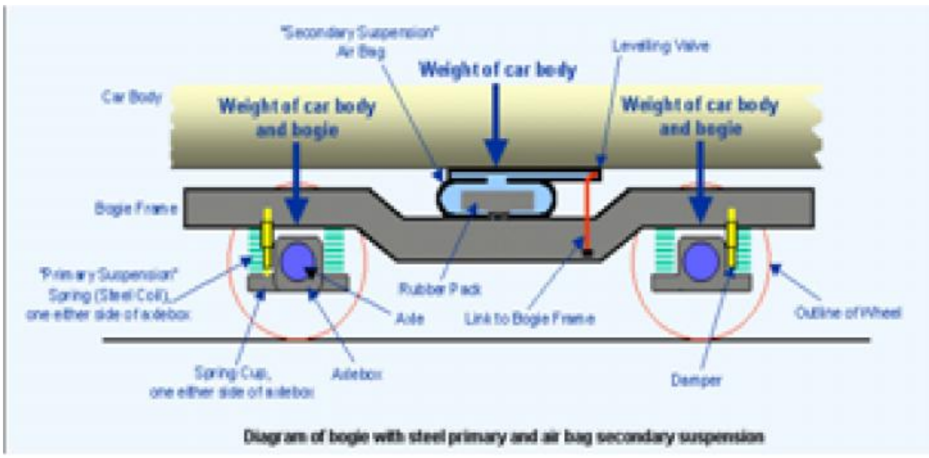
Figure 1: Different Bogie Parts



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, we look at the primary suspension.

The diagram above shows a plate framed bogie with the primary, axle box suspension. The secondary, 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 we said 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 his structures and track, we would tell him we had a 7.5 tone axle load. Of course, we would include the carrying load of passengers and freight in this calculation. Returning to the

Figure 2: Primary Suspension System



primary suspension design, we see 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 into another bracket at the bottom end. Between the two brackets is a steel or rubber spring. 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. The adjustment allowed for small variations in wheel diameter.

SPRINGS

Springs are elastic bodies (generally metal) that can be twisted, pulled, or stretched by some force. They 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:

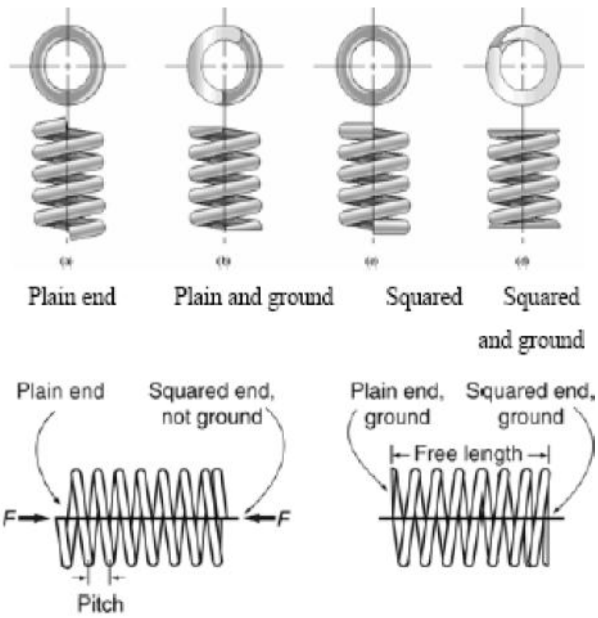
- Helical springs
- Leaf springs

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 3.

Figure 3: Compression Helical Spring



They are as follows:

- Plain end
- Plain and ground end
- Squared end
- 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.

Applications

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

SPECIFICATION OF HELICAL COMPRESSION SPRING

Existing Spring

(Chrome Vanadium)

Profile and Material Properties of primary suspension spring:

Dimensions for Spring

Table 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: 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 3: Material and It Properties

Description	Dimension Value
Material	Chrome Vanadium
Modulus of Rigidity (G)	79300 MPa
Young's Modulus (E)	207000 MPa
Density (°)	7860 Kg/m^3
Poisson Ratio	0.37

Proposed Spring ($60Si_2MnA$)

Table 4: Chemical Composition of ($60Si_2MnA$)

C	Mn	P	S	Si	Cr	Ni
0.56-0.64	0.7-1	0.025 max	0.025 max	1.6-2	0.35 max	0.35 max

Table 5: Dimensions ($60Si_2MnA$)

Description	Dimension Value
Material	$60Si_2MnA$
Modulus of Rigidity (G)	83600 MPa
Young's Modulus (E)	206000 MPa
Density (°)	4820 Kg/m^3
Poisson Ratio	0.3

ANALYTICAL CALCULATIONS OF HELICAL SPRING

Calculation Part (Exsiting System)

Maximum shear stress $T = k(8WD/\text{®}d^3)$

Wahl's stress factor $(k) = \frac{4C-1}{4C-4} + \frac{0.615}{C}$

$C = D/d$

$= 211/33.5 = 6.3$

Now $k = 1.24$

$T = 1.23 \times (8 \times 19.6 \times 10^3 \times 211)/(\text{®}\times 33.5^3)$

Maximum shear stress $T = 347.34$ MPa

Deflection

Deflection of the spring ¢ $= 8WD^3n/Gd^4$

$= 8 \times 19600 \times 211^3 \times 6.75/79300 \times 33.5^4$

$= 99.55$ mm

Calculation Part (Proposed System)

Maximum shear stress $T = k(8WD/\text{®}d^3)$

Wahl's stress factor $(k) = \frac{4C-1}{4C-4} + \frac{0.615}{C}$

$C = D/d$

$= 211/33.5 = 6.3$

Now $k = 1.24$

$T = 1.23 \times (8 \times 19.6 \times 10^3 \times 211)/(\text{®}\times 33.5^3)$

Maximum shear stress $T = 347.34$ MPa

Deflection

Deflection of the spring ¢ $= 8WD^3n/Gd^4$

$= 8 \times 19600 \times 211^3 \times 6.75/83600 \times 33.5^4$

$= 94.43$ mm

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.

ANALYSIS OF BOTH HELICAL SPRINGS

A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time-varying loads. A static analysis can, however, include steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads (such as the static equivalent wind and seismic loads commonly defined in many building codes).

Static analysis is used to determine the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time.

RESULTS

The above results shows that the $60Si_2MnA$ is best replacement of Chrome Vanadium and the deflection and stress induced are very less comparative.

Figure 4: 3D Model of Spring

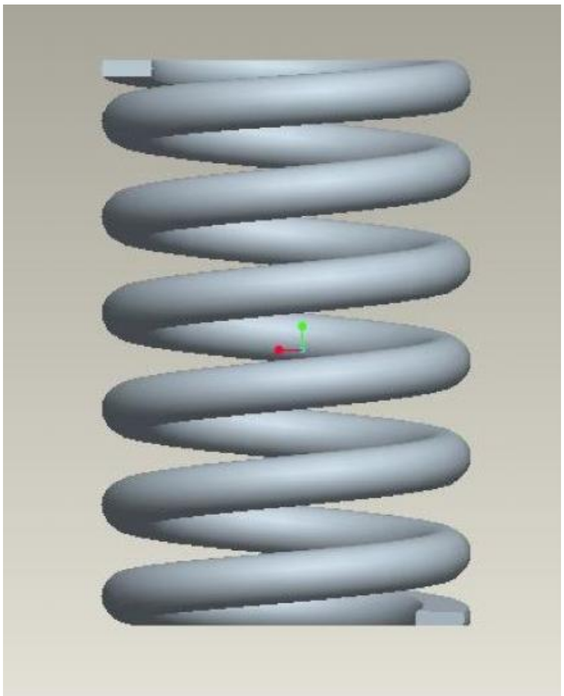


Figure 5: Mesh of Primary Suspension Spring

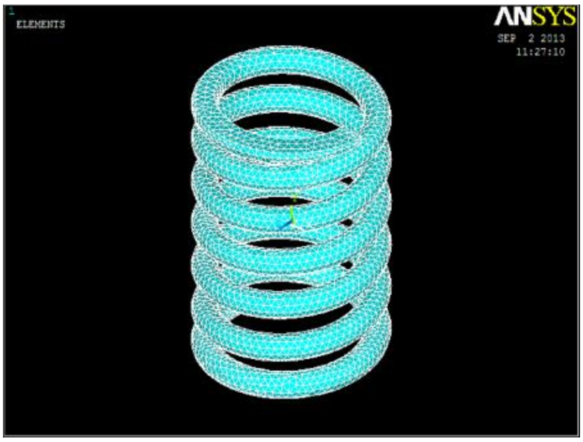


Figure 6: Principal Stress

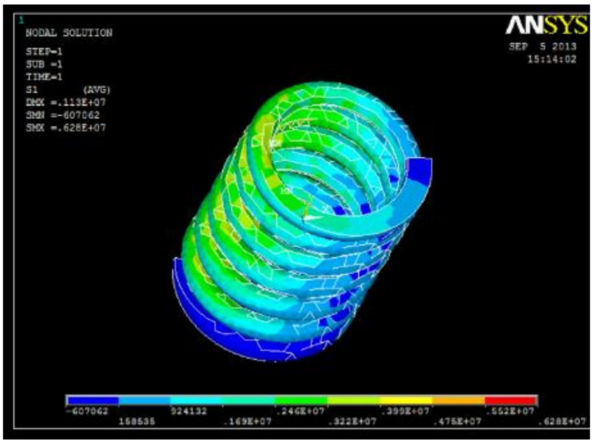


Figure 7: Total Mechanical Strain of Spring

Table 6: Comparison of Results

S. No.	Description	Chrome Vanadium	$60Si_2MnA$
1.	Shear Stress (MPa)	0.259E+07	0.261E+07
2.	Principal Stress (MPa)	0.625E+07	0.542E+07
3.	Total Mechanical Strain	34.26	32.91
4.	Von Misses Stress (MPa)	0.686E+07	0.701E+07

Figure 8: Principal Stress

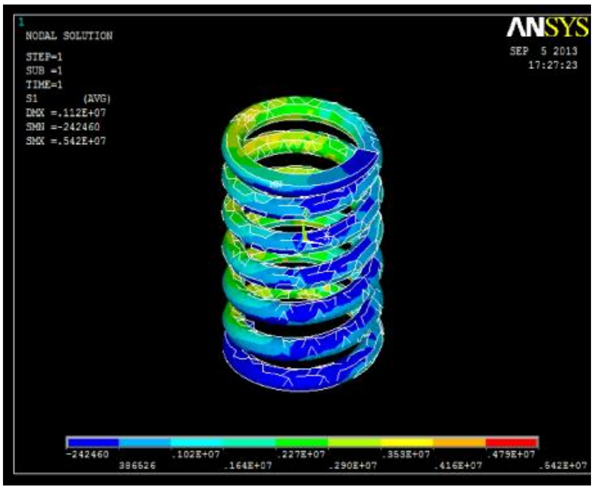
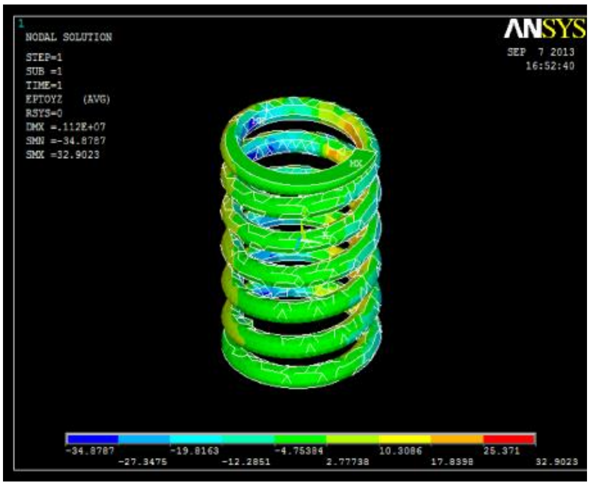


Figure 9: Mechanical Strain



CONCLUSION

From the above analysis, even though the stresses are almost equal, but the deflection of suspension spring is less when comparative to the Chrome Vanadium and it will works efficiently with less maintenance.

Due to the placing of $60Si_2MnA$ steel maintenance can be reduced. The cost $60Si_2MnA$ steel material is cheaper in India and international markets compare to Chrome Vanadium.

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