ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Design and Analysis of Wave Spring for Automobile Shock Absorber

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ABSTRACT:

Among the many types of springs, wave springs have attracted considerable attention this kind of long and reliable source of long lasting durability and considerable effectiveness than rest of the springs.

An analytical model for stamped ring wave springs is proposed, Because of the particular shape of the spring in the undeformed configuration, the load deflection curve is found to be appreciably bilinear in character. A similar but less pronounced behaviour is displayed also by the relationship between load and internal stresses. The analytical results are compared to earlier theoretical findings and are shown to correlate well with experimental measurements.

Wave springs are used to reduce the height of the spring and to produce the same end effect end that of a coil spring .these were first developed by SMALLEY Industries U.S.A in 1990's. These also obey the principles of Hooke's law discovered by Robert Hooke. So on taking the above basis wave spring application on suspension system is made.

Suspension is the term given to the system of springs, shock absorbers and linkages that connects a vehicle to its wheels and allows relative motion between the two.

In this project we will develop a wave spring which can be replace the coil spring in present automobiles and test it using Ansys workbench, dimensions and other variables are taken from previous papers and works, for design purpose we will use Catia v5r20.

INTRODUCTION

A spring is an elastic object used to store mechanical energy. Springs are usually made out of spring steel. There are a large number of spring designs; in everyday usage the term often refers to coil springs.

When a spring is compressed or stretched from its resting position, it exerts an opposing force approximately proportional to its change in length (this approximation breaks down for larger deflections). The rate or spring constant of a spring is the change in the force it exerts, divided by the change in deflection of the spring. That is, it is the gradient of the force versus deflection curve. An extension or compression spring's rate is expressed in units of force divided by distance, for example lbf/in or N/m. A torsion spring is a spring that works by twisting; when it is twisted about its axis by an angle, it produces a torque proportional to the angle. A torsion spring's rate is in units of torque divided by angle, such as N•m/rad or ft•lbf/degree. The inverse of spring rate is compliance, that is: if a spring has a rate of 10 N/mm, it has a compliance of 0.1 mm/N. The stiffness (or rate) of springs in parallel is additive, as is the compliance of springs in series.

Springs are made from a variety of elastic materials, the most common being spring steel. Small springs can be wound from pre-hardened stock, while larger ones are made from annealed steel and hardened after fabrication. Some non-ferrous metals are also used including phosphor bronze and titanium for parts requiring corrosion resistance and beryllium copper for springs carrying electrical current (because of its low electrical resistance).

History of springs

Like most other fundamental mechanisms, metal springs have existed since the Bronze Age. Even before metals, wood was used as a flexible structural member in archery bows and military catapults. Precision springs first became a necessity during the Renaissance with the advent of accurate timepieces. The fourteenth century saw the development of precise clocks which revolutionized celestial navigation. World exploration and conquest by the European colonial powers continued to provide an impetus to the clockmakers' science and art. Firearms were another area that pushed spring development.

The eighteenth century dawn of the industrial revolution raised the need for large, accurate, and inexpensive springs. Whereas clockmaker's springs were often hand-made, now springs needed to be mass-produced from music wire and the like. Manufacturing methodologies were developed so that today springs are ubiquitous. Computer-controlled wire and sheet metal bending machines now allow custom springs to be tooled within weeks, although the throughput is not as high as that for dedicated machinery.

DESIGN CALCULATIONS AND MATERIALS

Mathematical Calculations

Base data
Load calculations
Weight of bike = 150 Kg
Let weight of 1 person = 75 Kg
Total Weight (Wt.) = Weight of bike + Weight of 1 persons
= 150+75
= 225 Kg

Rear suspension = 65%
65% of 225Kgs = 146 Kg

Considering dynamic loads it will be double
Wt. = 292 Kgs
= 2864 N

For single shock absorber weight (W)

$$= \frac{W}{2}$$

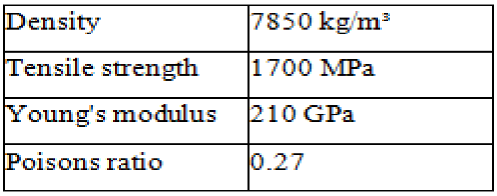
$$= \frac{2864}{2}$$

$$= 1432 \text{ N}$$

Material Properties

Spring steel is a low alloy, medium carbon steel with a very high yield strength. This allows objects made of spring steel to return to their original shape despite significant bending or twisting.

DIN 17221 spring steel (67SiCr5)



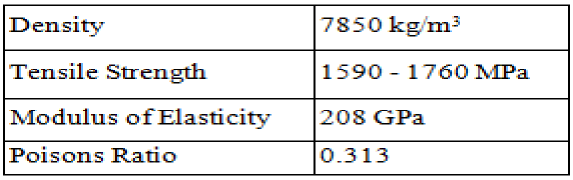
Density	7850 kg/m³
Tensile strength	1700 MPa
Young's modulus	210 GPa
Poisons ratio	0.27

Mechanical properties of DIN 17221 spring steel

ASTM A228 Spring Steel

Cold drawn. High tensile strength and uniform mechanical properties. Music wire springs are not recommended for service temperatures above 121°C (250°F).

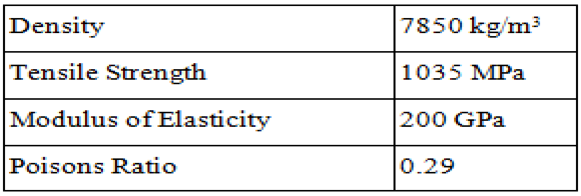
Applications: High quality springs and wire forms subject to high stresses or requiring good fatigue properties.



Density	7850 kg/m³
Tensile Strength	1590 - 1760 MPa
Modulus of Elasticity	208 GPa
Poisons Ratio	0.313

Mechanical properties of ASTM A228 spring steel

AISI 9255 spring steel



Density	7850 kg/m³
Tensile Strength	1035 MPa
Modulus of Elasticity	200 GPa
Poisons Ratio	0.29

Mechanical properties of AISI 9255 spring steel

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
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ANALYSIS

PRE-PROCESSING

Geometry

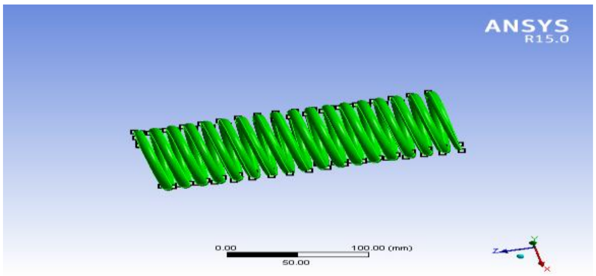

Fig 1 Modelling of Basic model

Meshing

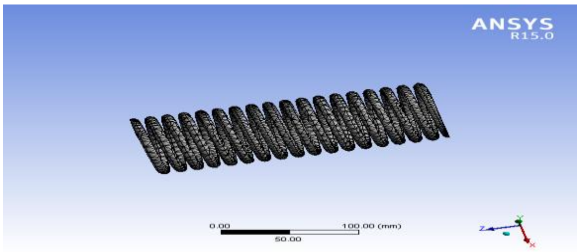

Fig 2 Meshing of Basic model

Boundary conditions

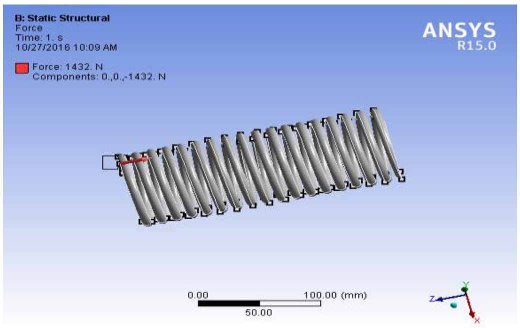

Fig 3 Boundary conditions of Basic model

Structural Analysis of Wave Spring Model 1 Made With DIN 17221 Spring Steel Grade

Total Deformation (mm)

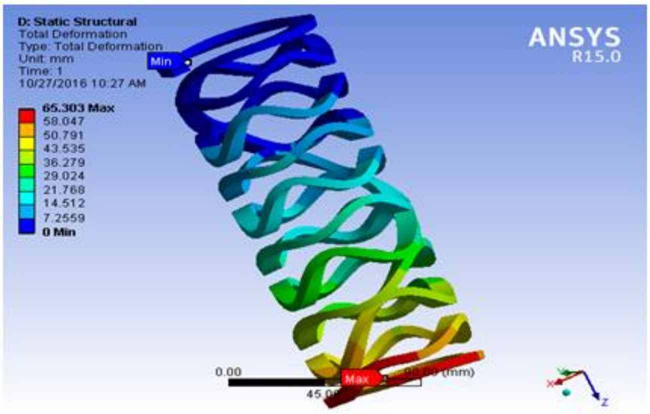

Fig 4.30 Deformation of Model 1with DIN 17221

Equivalent Elastic Strain (mm/mm)

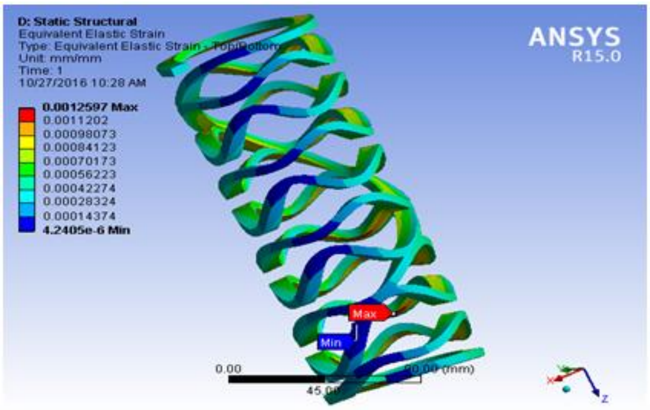

Fig 4.31 Strain of Model 1with DIN 17221

Equivalent (von-Mises) Stress (Mpa)

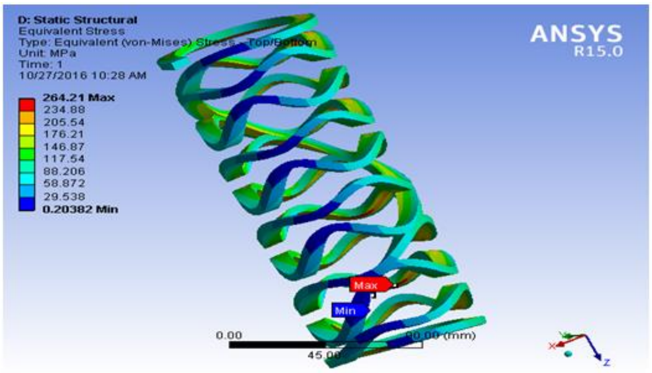

Fig 4.31 Stress of Model 1with DIN 17221

4.9 Model Analysis of Wave Spring Model 1 Made With DIN 17221 Spring Steel Grade

Mode 1

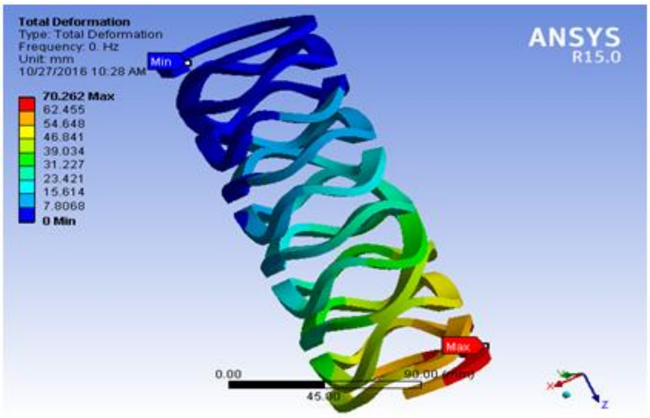

Fig 4.32 Mode 1 of Model 1with DIN 17221

Mode 2

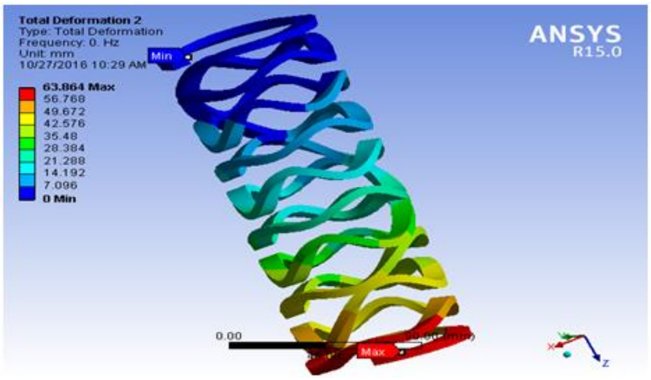

Fig 4.33 Mode 2 of Model 1with DIN 17221

Mode 3

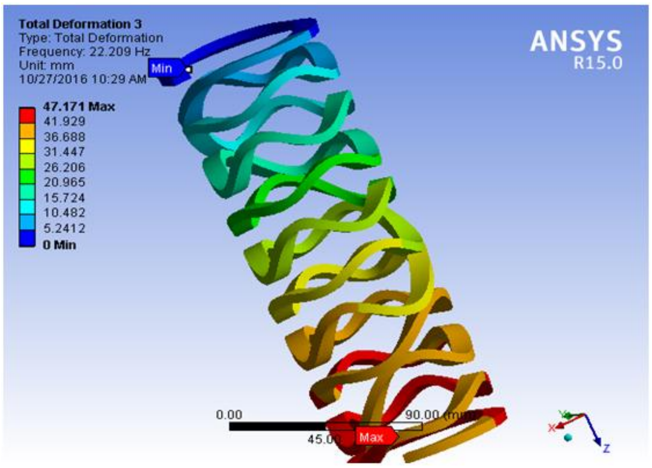

Fig 4.34 Mode 3 of Model 1with DIN 17221

Mode 4

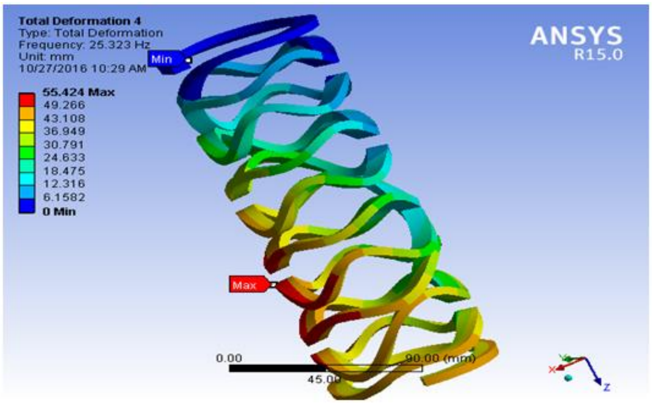

Fig 4.35 Mode 4 of Model 1with DIN 17221

Mode 5

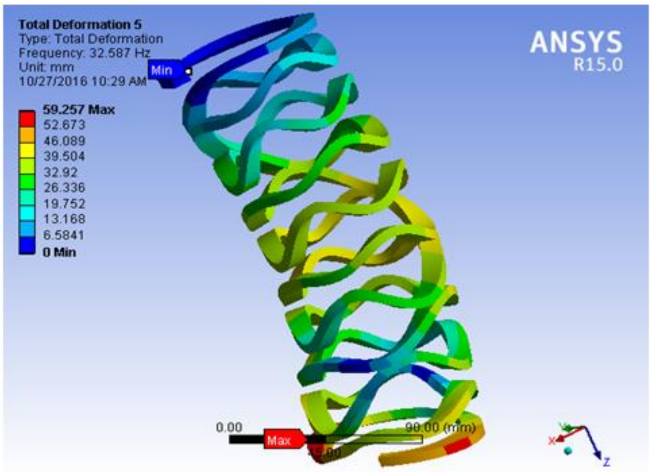

Fig 4.36 Mode 5 of Model 1with DIN 17221

Mode 6

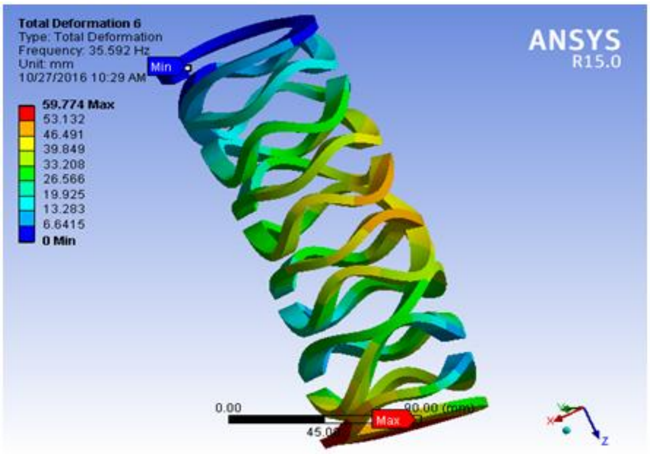

Fig 4.37 Mode 6 of Model 1with DIN 17221

TABLES

Structural Analysis of Suspension Spring Basic Model

Basic Model	Total Deformation (mm)		Equivalent Elastic Strain (mm/mm)		Equivalent (von-Mises) Stress (Mpa)	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
DIN 17221 spring steel	0	54.139	2.55E-11	1.28E-03	3.25E-06	257.13
ASTM A228 Spring Steel	0	52.455	6.28E-11	9.67E-04	1.31E-05	185.63
AI SI 9255 spring steel	0	57.384	3.65E-11	1.31E-03	4.58E-06	252.43

Table 1 Structural Analysis results for Basic Model

Model Analysis of Suspension Spring Basic Model

Basic Model	Frequency [Hz]		
	DIN 17221 spring steel	ASTM A228 Spring Steel	AI SI 9255 spring steel
mode 1	0	0	0
mode 2	0	0	0
mode 3	17.42	17.781	16.872
mode 4	19.451	19.807	18.994
mode 5	27.231	27.947	26.248
mode 6	27.418	28.165	26.45

Table 2 Modal Analysis results for Basic Model

Structural Analysis of Wave Spring Model 1

wave 5mm	Total Deformation (mm)		Equivalent Elastic Strain (mm/mm)		Equivalent (von-Mises) Stress (Mpa)	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
DIN 17221 spring steel	0	65.303	4.24E-06	1.26E-03	0.20382	264.21
ASTM A228 Spring Steel	0	65.295	2.32E-05	1.06E-03	1.3954	220.08
AI SI 9255 spring steel	0	77.698	2.76E-05	1.27E-03	1.4607	253.86

Table 3 Structural Analysis results for Model 1

Model Analysis of Wave Spring Model Made 1

wave 5mm	Frequency [Hz]		
	DIN 17221 spring steel	ASTM A228 Spring Steel	AI SI 9255 spring steel
mode 1	0	0	0
mode 2	0	0	0
mode 3	22.209	22.548	21.849
mode 4	25.323	25.465	23.727
mode 5	32.587	32.735	31.491
mode 6	35.592	35.295	34.57

Table 4 Modal Analysis results for Model 1

Structural Analysis of Wave Spring Model 2

wave 6mm	Total Deformation (mm)		Equivalent Elastic Strain (mm/mm)		Equivalent (von-Mises) Stress (Mpa)	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
DIN 17221 spring steel	0	39.65	1.57E-05	7.56E-04	0.99907	158.65
ASTM A228 Spring Steel	0	40.707	1.61E-05	7.65E-04	1.1429	158.9
AI SI 9255 spring steel	0	41.96	1.67E-05	7.94E-04	1.065	158.76

Table 5 Structural Analysis results for Model 2

Model Analysis of Wave Spring Model 2

wave 6mm	Frequency [Hz]		
	DIN 17221 spring steel	ASTM A228 Spring Steel	AI SI 9255 spring steel
mode 1	1.7848	0.95923	0
mode 2	4.7856	4.603	4.3581
mode 3	26.019	25.5	25.192
mode 4	29.906	29.466	28.777
mode 5	39.796	39.267	38.567
mode 6	41.257	40.746	40.083

Table 6 Modal Analysis results for Model 2

Structural Analysis of Wave Spring Model 3

wave 7mm	Total Deformation (mm)		Equivalent Elastic Strain (mm/mm)		Equivalent (von-Mises) Stress (Mpa)	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
DIN 17221 spring steel	0	26.855	1.14E-05	5.77E-04	0.96605	121.17
ASTM A228 Spring Steel	0	27.594	1.17E-05	5.84E-04	1.0476	121.37
AI SI 9255 spring steel	0	28.43	1.21E-05	6.07E-04	1.0027	121.26

Table7 Structural Analysis results for Model 3

Model Analysis of Wave Spring Model 3

wave 7mm	Frequency [Hz]		
	DIN 17221 spring steel	ASTM A228 Spring Steel	AI SI 9255 spring steel
mode 1	5.8277	5.6288	5.3711
mode 2	7.0203	6.8614	6.6603
mode 3	28.526	27.964	27.631
mode 4	32.37	31.96	31.265
mode 5	45.288	44.695	43.939
mode 6	46.392	45.809	45.072

Table 8 Modal Analysis results for Model 3

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
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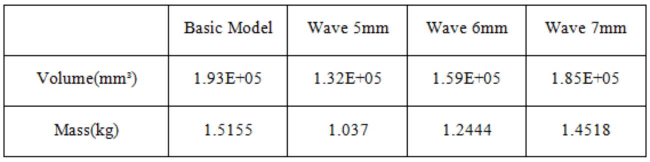
Volume and Mass Comparison of Various Models



	Basic Model	Wave 5mm	Wave 6mm	Wave 7mm
Volume(mm^3)	1.93E+05	1.32E+05	1.59E+05	1.85E+05
Mass(kg)	1.5155	1.037	1.2444	1.4518

Table 9 Volume and mass comparison among different models

CONCLUSION

From the results the following conclusions are made:

1. Wave springs have much stiffness when compared with spiral springs
2. Deflections and stresses can be minimised up to 30% using wave springs
3. Up to 20% material can be saved using wave spring
4. Spring life improves significantly

Hear there is a need for development for manufacturing technique to manufacturing technic. From the results if normal spiral spring is replaced with model 2 (6 mm thick) we can save upto 20% of material, 40 % less stress and 20 % less deflections

FUTURE SCOPE

This study can be further extended by performing experimentations and developing suitable manufacturing methods, the above study includes only rectangular cross section wave springs, considering various cross sections may also help in improving the stiffness of springs

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