Design and Performance Analysis of Modern Material used in Shock Absorbers

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Tittle of the Project: **Design and performance analysis of modern material used in shock absorbers.**

OBJECTIVES:

- **To analyze the shock absorber with respective to chosen materials. To perform theoretical analysis of shock absorber.**
- **To reduce amplitude of disturbance. Absorber body to give comfort and smooth ride.**

- ## PROBLEM STATEMENT:

- When a vehicle is travelling on a level road and the wheels strike a bump, the spring is compressed quickly. The compressed spring will attempt to return to its normal loaded length. It will rebound past its normal height, causing the body to be lift. The weight of the vehicle will then push the spring down below its normal load height. This causes the spring to rebound again. This bouncing process is repeated over and over, a little less each time, until the up and down movement finally stops. If bouncing is allowed to go uncontrolled, it will not only cause an uncomfortable ride but will make handling of the vehicle very difficult.

- **Introduction**

A shock absorber or damper is a mechanical device designed to smooth out or damp shock impulse, and dissipate kinetic energy. Pneumatic and hydraulic shock absorbers commonly take the form of a cylinder with a sliding piston inside. The cylinder is filled with a fluid (such as hydraulic fluid) or air. This fluid-filled piston/cylinder combination is a dashpot. The shock absorbers duty is to absorb or dissipate energy. These are an important part of automobile suspensions, aircraft landing gear, and the supports for many industrial machines. Large shock absorbers have also been used in structural engineering to reduce the susceptibility of structures to earthquake damage and resonance. A transverse mounted shock absorber, called a yaw damper, helps keep railcars from swaying excessively from side to side and are important in commuter railroads and rapid transit systems because they prevent railcars from damage station platforms. In a vehicle, it reduces the effect of traveling over rough ground, leading to improved ride quality, and increase comfort due to substantially reduced amplitude of disturbances. Without shock absorbers, the vehicle would have a bouncing ride, as energy is stored in the spring and then released to the vehicle, possibly exceeding the allowed range of suspension movement. Control of excessive suspension movement without shock absorption requires stiffer (higher rate) springs, which would in turn give a harsh ride. Shock absorbers allow the use of soft (lower rate) springs while controlling the rate of suspension movement in response to bumps.

- **LITERATURE REVIEW:**

1. Kim 1993:

An analysis of a twin tube damper with focus on implementation into a vehicle suspension system. Kim's model included chamber compliance and fluid compressibility which yielded a differential equation for the chamber pressures that was solved using the Runga Kutta Method. Incorporating damping data into a quarter car model, the frequency response of the sprung mass and tire deflection were calculated numerically.

2. Ferdek etal 2012:

Designed a physical and mathematical model for a twin-tube hydraulic shock absorber, using oil as the working medium. To analyse the model, methods of numerical integration were incorporated. The basic characteristics of the damping force were also obtained. The velocity sensitive and nominally symmetric hydraulic dampers were considered.

3. Lee 2005:

Suggested a new mathematical model of displacement sensitive shock absorber to predict the dynamic characteristics of automotive shock absorber. The performance of shock absorber is directly related to thevehicle behaviours and performance, both for handlingand ride comfort.

❖ Material Selection:

- Materials such as acryl base resins and silicon base resins with low elasticity are conventionally used as shock absorbing materials. These resin materials have a three-dimensional cross-linking network structure with covalent bonds.

- In contrast, products developed by reference to biological materials have the feature of having a three-dimensional cross-linking network structure that uses low energy bonds.

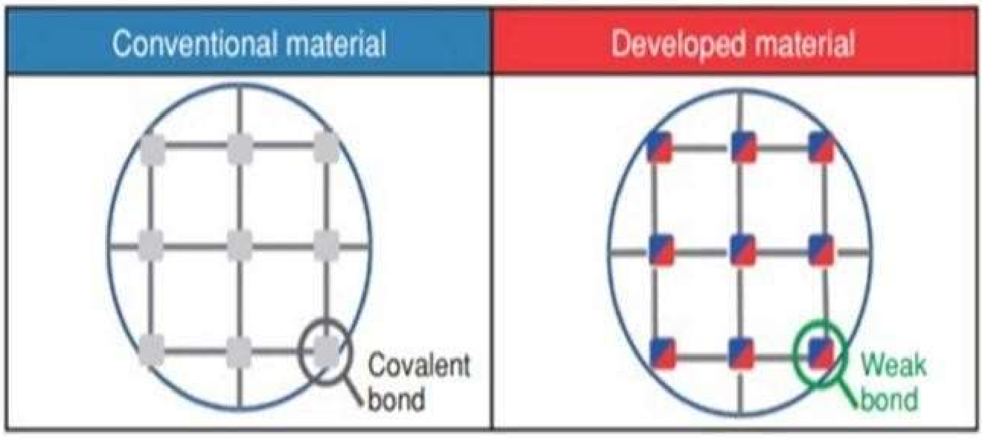

Figure no. 1 Material Bonding [Research Paper 6]

Based on above case we select the following materials:

1) Spring Steel:

- Phosphor bronze is used for suspension in moving coil galvanometer because It has low torsional constant.
- Its restoring torque per unit twist is small. Due to it, the galvanometer is very sensitive.
- It is rust resisting. Hence it remains unaffected by the weather conditions of air in which it is suspended.
- Also, it is non-magnetic and does not oxidize easily.

2) Beryllium Copper:

The copper is high strength with non-magnetic and n-sparking qualities.

It has excellent metalworking, forming and machining properties**.**

3) Phosphorus Bronze:

- Phosphor bronze is used for suspension in moving coil galvanometer because it has low torsional constant.

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- It is rust resisting. Hence it remains unaffected by the weather conditions of air in which it is suspended.

  Also, it is non-magnetic and does not oxidize easily.

4) Titanium:

- Titanium follows logically from high strength, low density and low modulus.
- It has good flexibility.
- It has excellent resistance to corrosion and oxidation.

- Steps Involved in Design Work:

1. Gathering all relative data for the design of Shock Absorber.
2. Generation of model using CATIAV5.
4. Importing the generated model to ANSYS for analysis work Static analysis is carried out on the Shock Absorber to evaluate the performance.

- Designing Factors of Compression Helical Springs

  The design of compression helical spring is dependent on two factors.

- The first factor is the type of material used in its fabrication process. Music wire, stainless steel, or chrome silicon are some common materials used in the construction of these spring.
- The second factor involves the service environment in which the spring operates, which can be either static or cyclic. The design process of the spring is dependent on the application environment in which the spring is used. During the static condition, the spring designer selects the appropriate material, which helps the spring generate stable output force over the given period of time. On the other hand, during cyclic condition,

apart from stable output force, the spring must be able to tolerate harsh conditions without breaking.

The other factors, which influence the design of compression helical springs are as follows:

- Permissible tolerance limit of the given spring
- Environmental conditions such as temperature and pressures
- Space considerations
- Reliability and accuracy of the spring

Generalized Parameters for Helical spring

Material: Spring Steel, Beryllium Copper Mean diameter of a coil D= 64mm

Diameter of wire d = 8mm

Total no of coils n= 15

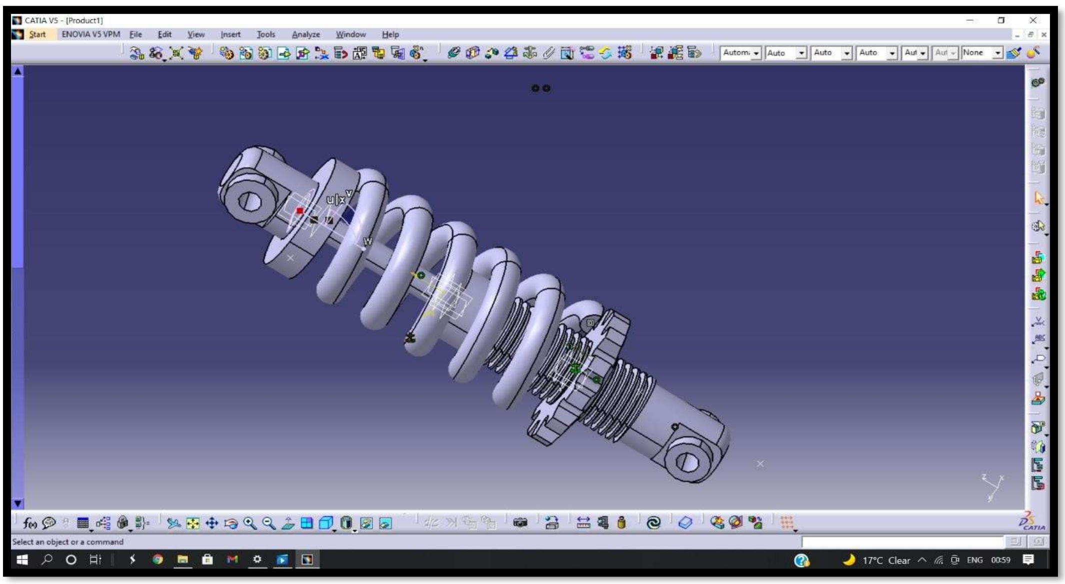
Pitch=14mm

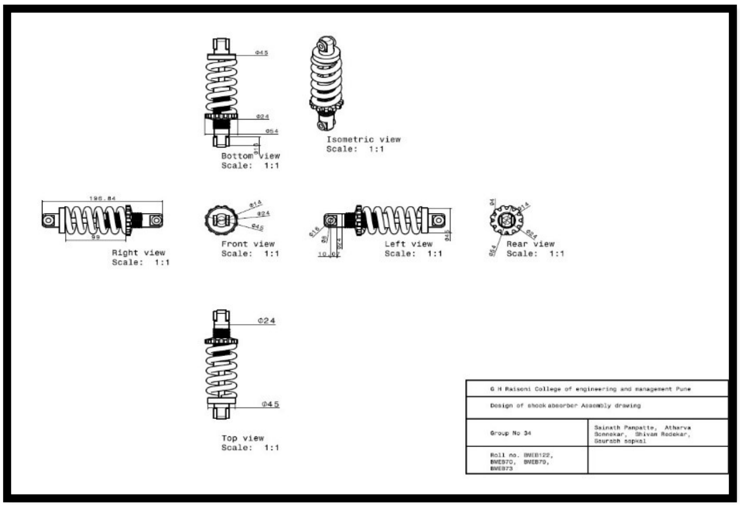
Let weight of bike be 125kgs and Weight of one person be 75Kgs.

Then total weight= weight of bike + weight of person =200Kgs

total load on Shock Absorber = 300 × 9.81 =2943N

Considering Factor of Safety (FOS) = 1.5 Total weight = 200 × 1.5 = 300Kgs Therefore





❖ Design Calculations for Shock absorber

Material: Steel (modulus of rigidity) G = 41000

Mean diameter of a coil D=62mm

Diameter of wire d = 8mm

Total no of coils n1= 18

Height h = 220mm

Outer diameter of spring coil D0 = D +d =70mm

No of active turns n= 14

Weight of bike = 125kgs

Let weight of 1 person = 75Kgs

Weight of 2 persons = 75×2=150Kgs

Weight of bike + persons = 275Kgs

Rear suspension = 65%

65% of 275 = 165Kgs

Considering dynamic loads, it will be double

W = 330Kgs = 3234N

For single shock absorber weight = w/2= 1617N = W

We Know that, compression of spring (δ) = × × /×

C = spring index = = = 7.75 = 8

(δ) = × × × /× = 282.698

Solid length, Ls=n1×d=18×8=144

Free length of spring,

Lf = solid length + maximum compression + clearance between adjustable coils

= + + 0.15 = 144 + 282.698 + 0.15 × 282.698 = 469.102

Spring rate, K = = . = 5.719

Pitch of coil, P = = = 26

Stresses in helical springs: maximum shear stress induced in the wire

τ = K× K = + . = × × + . = 0.97 τ = K× = 0.97 × × × × = 499.519

Buckling of compression springs, = × × Values of buckling factor KB= 7.5 K = 0.05 (for hinged and spring)

The buckling factor for the hinged end and built-in end springs

Wcr=5.719×0.05×469.102=134.139N.

❖ Introduction to Finite Element Analysis

Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variational calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published in 1956 by M. J. Turner, R. W. Clough, H. C. Martin, and L. J. Topp established a broader definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures". By the early 70's, FEA was limited to expensive mainframe computers generally owned by the aeronautics, automotive, defense, and nuclear industries. Since the rapid decline in the cost of computers and the phenomenal increase in computing power, FEA has been developed to an incredible precision. Present day supercomputers are now able to produce accurate results for all kinds of parameters. 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.

Pre-processing

The user constructs a model of the part to be analyzed in which the geometry is divided into a number of discrete sub regions, or elements," connected at discrete points called nodes." Certain of these nodes will have fixed displacements, and others will have prescribed loads. These models can be extremely time consuming to prepare, and commercial codes vie with one another to have the most user-friendly graphical “preprocessor" to assist in this rather tedious chore. Some of these preprocessors can overlay a mesh on a preexisting CAD file, so that finite element analysis can be done conveniently as part of the computerized drafting-and-design process.

Analysis

The dataset prepared by the preprocessor is used as input to the finite element code itself, which constructs and solves a system of linear or nonlinear algebraic equations.

Kijuj = fi

where u and f are the displacements and externally applied forces at the nodal points; The formation of the K matrix is dependent on the type of problem being attacked, and this module will outline the approach for truss and linear elastic stress analyses; Commercial codes may have very large element libraries, with elements appropriate to a wide range of problem types. One of FEA's principal advantages is that many problem types can be addressed with the same code, merely by specifying the appropriate element types from the library.

Post-processing

In the earlier days of finite element analysis, the user would pore through reams of numbers generated by the code, listing displacements and stresses at discrete positions within the model. It is easy to miss important trends and hot spots this way, and modern codes use graphical displays to assist in visualizing the results. Typical postprocessor display overlays colored contours representing stress levels on the model, showing a full field picture similar to that of photo elastic or moiré experimental results.

❖ Material Comparison

Material Graph

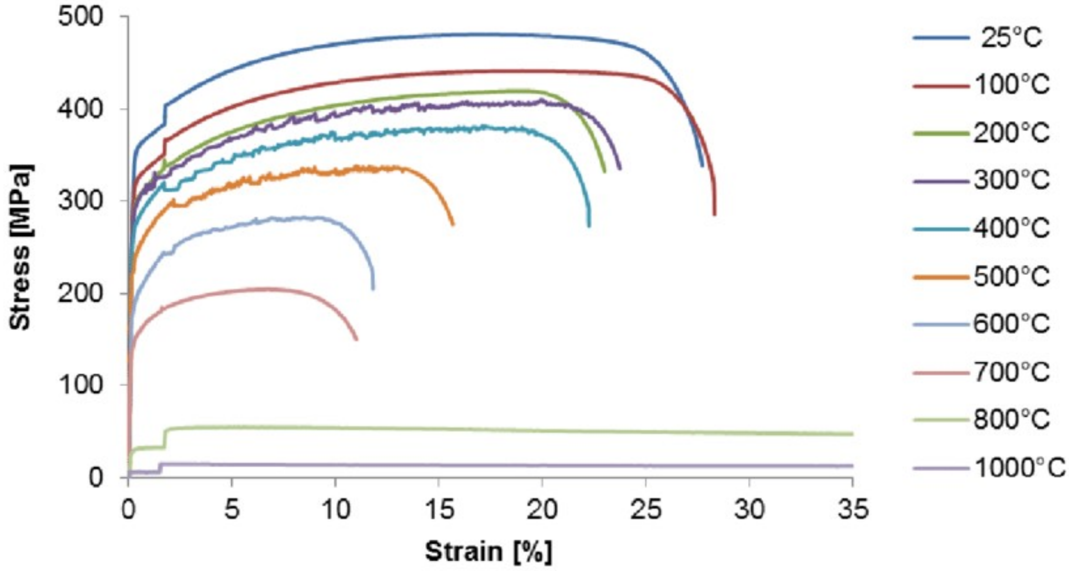
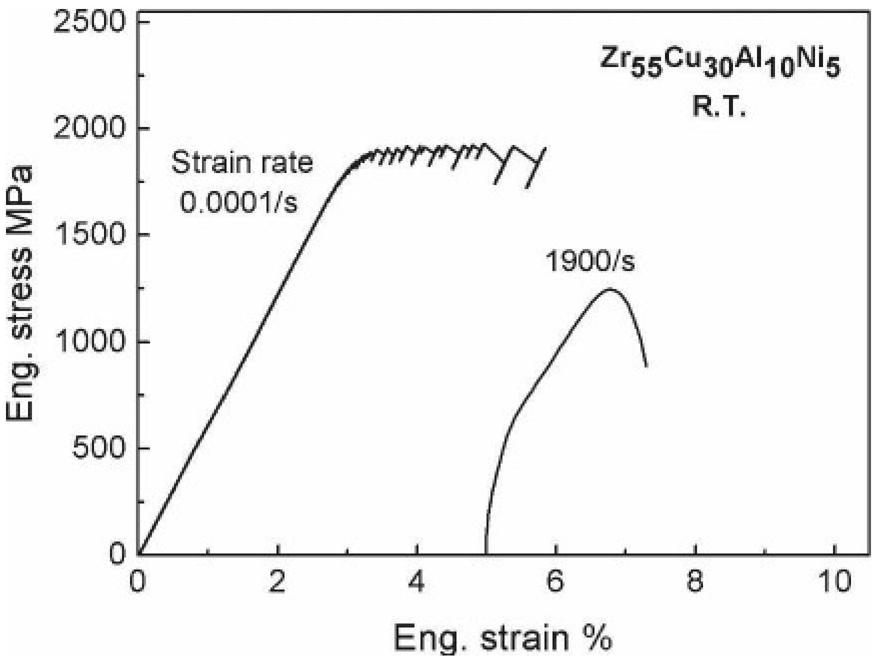
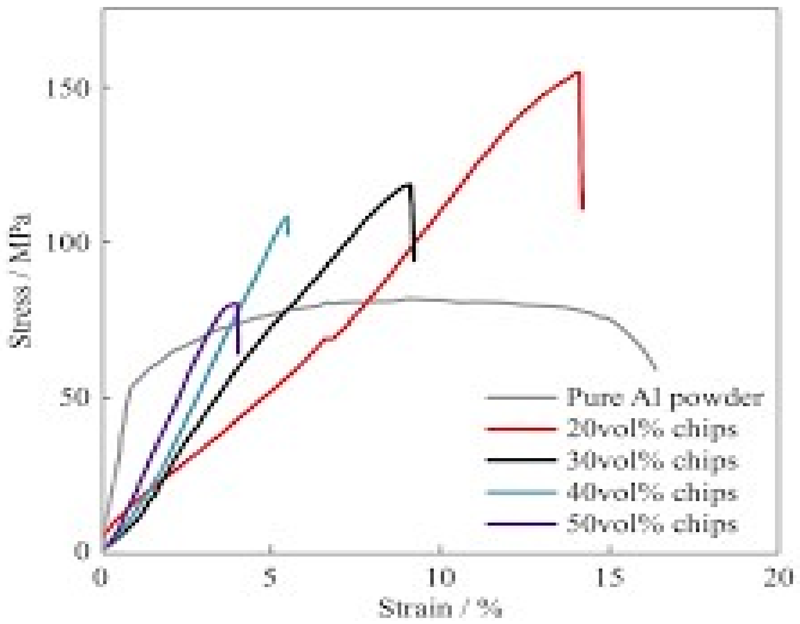


Figure no. 6 Spring Steel [research paper 6]



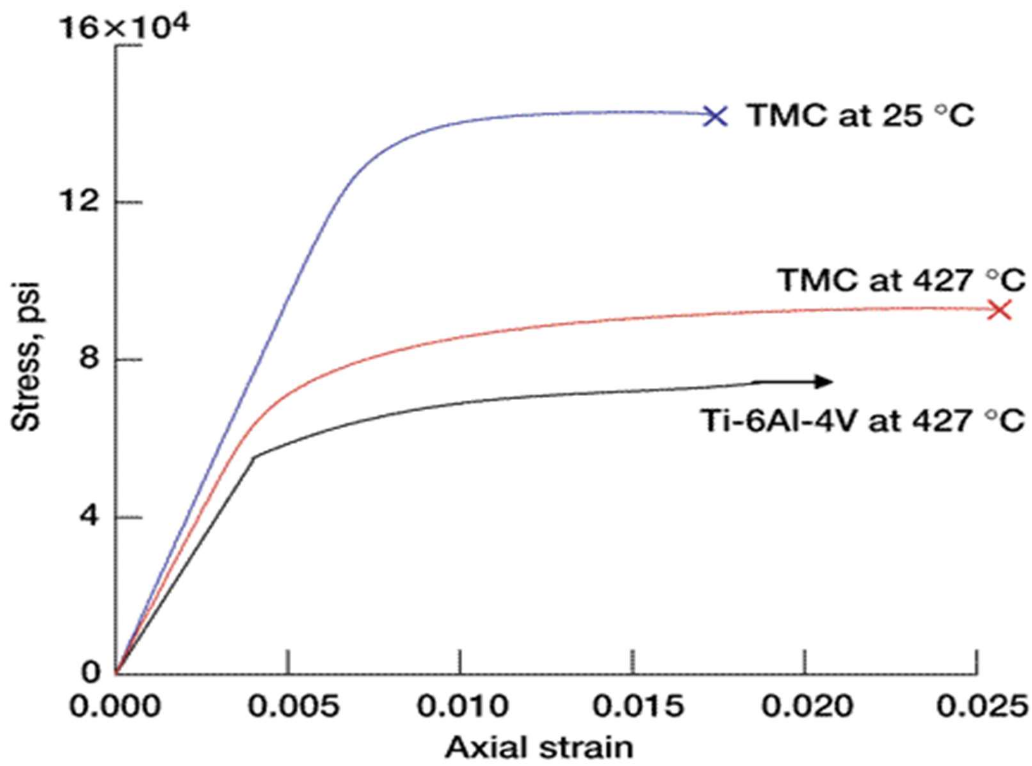
Beryllium Copper

Figure no. 7 Spring Steel [research paper 6]



Phosphorus Bronze

Figure no. 8 Spring Steel [research paper 6]



Titanium Alloy

Figure no. 9 Spring Steel [research paper 6]

Sl.no	Material	Young's Modulus (N/mm^2)	Density(Kg/mm^3)	Poisson's ratio
1	Spring steel	202000	7820	0.292
2	Phosphor Bronze	103000	8160	0.34
3	Copper alloy	130000	8100	0.285
4	Titanium alloy	102000	4850	0.3

Static analysis

Used to determine displacements, stresses, etc. under static loading conditions. ANSYS can compute both linear and nonlinear static analyses. Nonlinearities can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep.

Buckling Analysis

Used to calculate the buckling loads and determine the buckling mode shape. Both linear (eigenvalue) buckling and nonlinear buckling analyses are possible. In addition to the above analysis types, several special-purpose features are available such as Fracture mechanics, Composite material analysis, Fatigue, and both p-Method and Beam analyses

Thermal Analysis

ANSYS is capable of both steady state and transient analysis of any solid with thermal boundary conditions. Steady-state thermal analyses calculate the effects of steady thermal loads on a system or component. Users often perform a steady-state analysis before doing a transient thermal analysis, to help establish initial conditions. A steady-state analysis also can be the last step of a transient thermal analysis; performed after all transient effects have diminished. ANSYS can be used to determine temperatures, thermal gradients, heat flow rates, and heat fluxes in an object that are caused by thermal loads that do not vary over time. Such loads include the following:

- Convection
- Radiation
- Heat flow rates
- Heat fluxes (heat flow per unit area)
- Heat generation rates (heat flow per unit volume)
- Constant temperature boundaries

A steady-state thermal analysis may be either linear, with constant material properties; or nonlinear, with material properties that depend on temperature. The thermal properties of most material vary with temperature. This temperature dependency being appreciable, the analysis becomes nonlinear. Radiation boundary conditions also make the analysis nonlinear. Transient calculations are time dependent and ANSYS can both solve distributions as well as create video for time incremental displays of models.

Model Analysis

A modal analysis is typically used to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component while it is being designed. It can also serve as a starting point for another, more detailed, dynamic analysis, such as a harmonic response or full transient dynamic analysis. Modal analyses, while being one of the most basic dynamic analysis types available in ANSYS, can also be more computationally time consuming than a typical static analysis. A reduced solver, utilizing automatically or manually selected master degrees of freedom is used to drastically reduce the problem size and solution time.

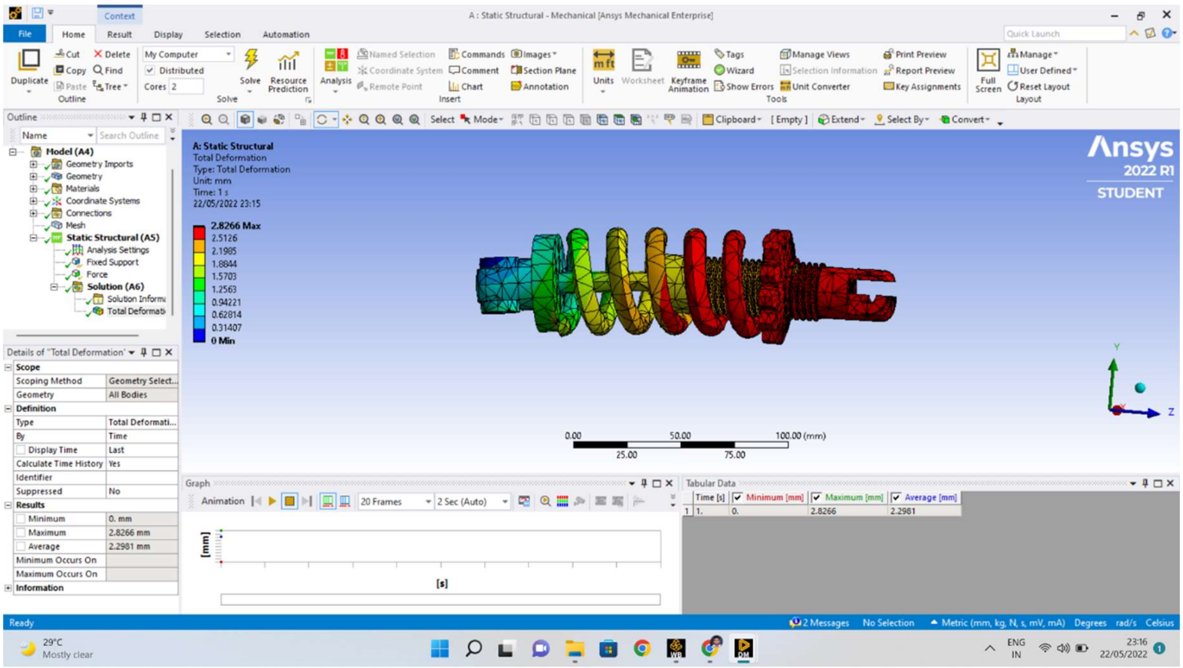


Fig. no 11 Model analysis in ANYS(Failed)

S. No	Parameters	Spring steel	Phosphor bronze	Beryllium copper
1	Deformation (mm)	0.010559	0.019273	0.010117
2	Equivalent elastic stress (N/mm^2)	19.957	21.979	19.836

		SPRING STEEL			BERYLLIUM COPPER		
		BIKE	1P+BIKE	2P+BIKE	BIKE	1P+BIKE	2P+BIKE
	STRESS(N/mm^2)	0.58386	0.91322	12.351	0.58561	0.915956	1.239
	DISPLACEMENT (mm)	$0.189e^{-03}$	$0.184e^{-04}$	0.004562	$0.162e^{-03}$	$0.254e^{-03}$	$0.343e^{-03}$
MODE	FREQUENCY (HZ)						
	DISPLACEMENT(mm)	3.525	3.075	3.075	6.967	6.967	6.967
	FREQUENCY (HZ)						
	DISPLACEMENT(mm)	2.616	2.797	2.797	6.827	6.827	6.827
	FREQUENCY (HZ)						
	DISPLACEMENT(mm)	2.702	1.713	1.713	6.616	6.616	6.616
	FREQUENCY (HZ)	$0.364e^{-04}$	$0.184e^{-04}$	$0.184e^{-04}$	$0.606e^{-04}$	$0.606e^{-04}$	$0.606e^{-04}$
	DISPLACEMENT(mm)	1.997	2.706	2.706	3.66	3.66	3.66
	FREQUENCY (HZ)	2.797	$0.817e^{-04}$	$0.817e^{-04}$	$0.125e^{-03}$	$0.125e^{-03}$	$0.125e^{-03}$
	DISPLACEMENT(mm)	3.38	3.364	3.364	6.325	6.325	6.325

❖ Result Discussion:

In this project the helical spring of a shock absorber by using 3D parametric software CATIA. And also, the analysis was performed by using ANSYS is a general-purpose finite element analysis (FEA) software package.

To validate the strength of the model, the structural analysis on the helical spring was done by varying different spring materials like steel, titanium alloy, copper alloy and Phosphor bronze Modal analysis is done to determine the displacements for different frequencies for Number of modes. The maximum displacements and stress intensities of the respective materials are given below. To validate the strength of our design, we have done structural Analysis

So, we can conclude that as per our analysis using material spring steel for spring is best and also our modified design is safe.

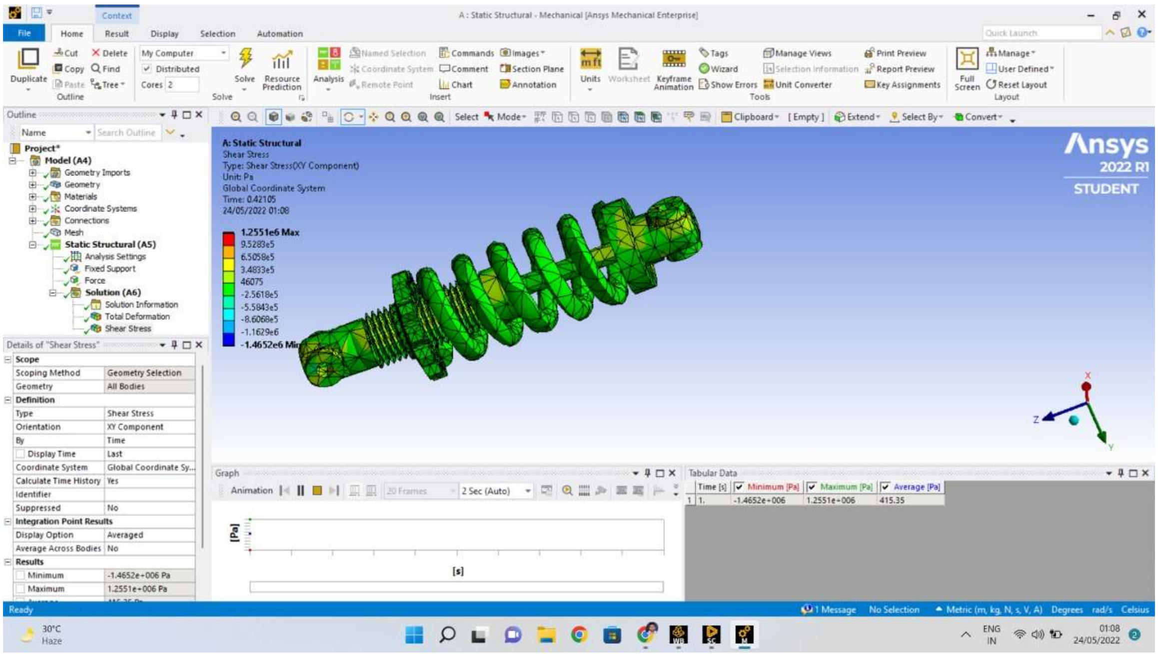


Fig.12Model analysis in ANYS(Success)

❖ Conclusions:

Comparison of above materials we concluded that,

- To validate the strength of our design, we have done structural analysis on the shock absorber. We have done analysis by varying spring materials such as Spring steel, Beryllium Copper.
- By observing the analysis results, the analyzed stress values are less than their respective yield stress values. So, our design is safe.
- By comparing the results for these materials, the stress and deformation value is less for Beryllium Copper than the other two materials.
  Also the shock absorber design is modified by reducing the diameter of spring by 2mm and structural analysis is done on the shock absorber. By reducing the diameter, the weight of the spring reduces.
- So, we can conclude that as per our analysis using material beryllium copper for spring is best.

- To validate the strength of our design, we have done structural analysis and modal analysis on the shock absorber. We have done analysis by varying spring material Spring Steel and Beryllium Copper.

- Also, the shock absorber design is modified by reducing the diameter of spring by 2mm and structural, modal analysis is done on the shock absorber. By reducing the diameter, the weight of the spring reduces. By comparing the results for both materials, the stress value is less for Spring Steel than Beryllium Copper.

- By comparing the results for present design and modified design, the stress and displacement values are less for modified design.

- So, we can conclude that as per our analysis using material spring steel for spring is best and also our modified design is safe

❖ Future Scope:

- By using copper alloy in shock absorber to reduce weight and increase the comfort level by measuring force transmission at both ends of helical compression spring.
- To compare the material property of suspension spring system under low and high weight and time variation.
- Improvement in shock absorber fluid, and additive or substance for increase heat transfer should be obtain
- Once the design and analysis are done, as in this project report, there is always a scope for improvement and optimization of the design based on the available present results. The design can further be optimized and further analysis can be done so as to reduce the overall total stress, deformation and temperature variation. As a result of further optimization in the design, the best possible design can be obtained as a result of dimensional variation and practical application. Once the design and analysis are done, as in this project report, there is always a scope for improvement and optimization of the design based on the available present results. The design can further be optimized and further analysis can be done so as to reduce the overall total stress, deformation and temperature variation. As a result of further optimization in the design, the best possible design can be obtained as a result of dimensional variation and practical application**.**

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