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DESIGN, MODELING & ANALYSIS OF TWO WHEELER SHOCK ABSORBER FOR OPTIMUM PERFROMANCE

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Abstract

Pneumatic and hydraulic shock absorbers are used in conjunction with cushions and springs. An automobile shock absorber contains spring-loaded check valves and orifices to control the flow of oil through an internal piston .One design consideration, when designing or choosing a shock absorber, is where that energy will go. In most shock absorbers, energy is converted to heat inside the viscous fluid. In hydraulic cylinders, the hydraulic fluid heats up, while in air cylinders, the hot air is usually exhausted to the atmosphere. In other types of shock absorbers, such as electromagnetic types, the dissipated energy can be stored and used later. In general terms, shock absorbers help cushion vehicles on uneven roads.

Shock absorbers are basically oil pumps. A piston is attached to the end of the piston rod and works against hydraulic fluid in the pressure tube. As the suspension travels up and down, the hydraulic fluid is forced through tiny holes, called orifices, inside the piston. However, these orifices let only a small amount of fluid through the piston. This slows down the piston, which in turn slows down spring and suspension movement.

All modern shock absorbers are velocity sensitive hydraulic damping devices – meaning the faster the suspension moves, the more resistance the shock absorber provide.

Shock Absorber

There are a number of different methods of converting an impact /collision into relatively smooth cushioned contact.

- . Metal Spring
- Rubber Buffer
- Hydraulic Dashpot
- Collapsing safety Shock Absorbers
- Pneumatic Cylinders
- Self-compensating Hydraulic

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Metal springs

Simply locating metal springs to absorb the impact loads are a low cost method of reducing the collision speed and reducing the shock loading. They are able to operate in very arduous conditions under a wide range of temperatures. These devices have high stopping forces at end of stroke. Metal springs store energy rather than dissipating it. If metal sprint type shock absorbers are used then measures should be provided to limit Oscillations. Metal springs are often used with viscous dampers. There are a number of different types of metal springs including helical springs, bevel washers(cone-springs), leaf springs, ring springs, mesh springs etc etc. Each spring type has its own operating characteristics.

Metal Spring

Elastomeric shock absorber

Elastomeric shock absorber

These are low cost options for reducing the collision speed and reducing the shock loading and providing system damping. They are conveniently moulded to suitable shapes. These devices have high stopping forces at end of stroke with significant internal damping. Elastomeric dampers are very widely used because of the associated advantages of low cost and mould ability together with performance benefits. The inherent damping of elastomers is useful in preventing excessive

vibration amplitude at resonance – much reduced compared to metal springs. However elastomeric based shock absorbers are limited in being affected by high and low temperatures. And are subject to chemical attack. Silicone rubber is able to provide reasonable mechanical properties between temperatures of -50O to +180O deg. C- most other elastomeric has inferior temperature tolerance

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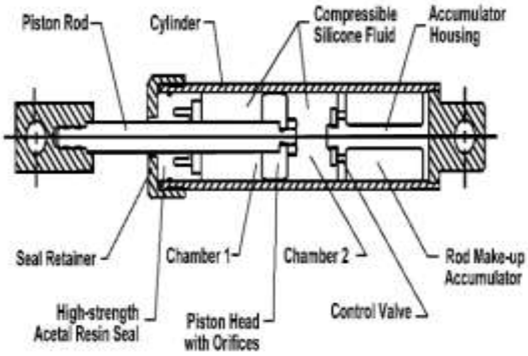
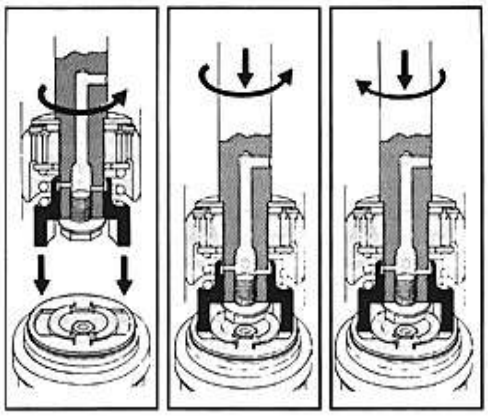
Hydraulic Dashpot



Hydraulic Dashpot

This type of shock absorber is based on a simple hydraulic cylinder. As the piston rod is moved hydraulic fluid is forced through an orifice which restricts flow and consequently provides a controlled resistance to movement of the piston rod. With only one metering orifice the moving load is abruptly slowed down at the start of the stroke. The brakingforce rises to a very high peak at the start of the stroke and then falls away rapidly. On completion of the stroke the system is stable - the energy being dissipated in the hydraulic fluid as heat. This type of shock absorbers are provided with Springs sufficient to return the actuator to its initial position after the impacting load is removed.

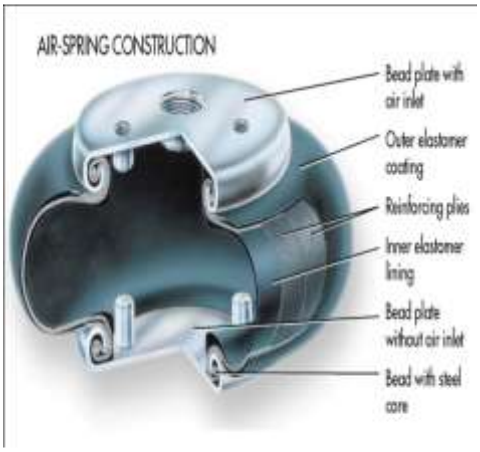
Collapsing Safety Shock Absorbers



Collapsing safety shock absorber

These are single use units which are generally specially designed for specific duties. They are designed such that at impact they collapse and the impact energy is absorbed as the materials distort in their inelastic/yield range. They therefore are more compact compared to devices based on deflections within their elastic range

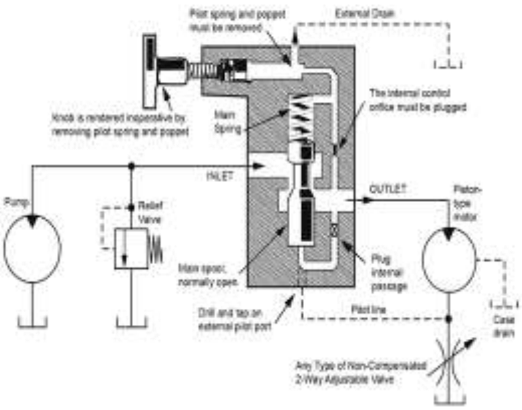
Air (Pneumatic) spring



Air (pneumatic) spring

These devices use air as the resilient medium. Air has a high energy storage capacity compared to metal or elastomeric materials. For duties with high loads and deflections the air spring is generally far more compact that the equivalent metal or elastomer device. Due to the compressibility of air these have a sharply rising force characteristic towards the end of the stroke. The majority of the energy is absorbed near the end of the stroke. The force on an air cylinder buffer is determined by the relation PVn=constant. Air springs require more maintenance than meal or elastomer based springs and the temperature range is restricted compared to metal springs.

Self-compensating Hydraulic



Self-compensating Hydraulic

These devices are similar to the hydraulic dashpot type except that a number of orifices are provided allowing different degrees of restriction throughout the stroke. These devices are engineered to bring the moving load is smoothly and gently to rest by a constant resisting force

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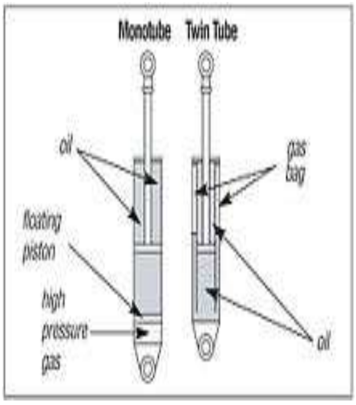
throughout the entire shock absorber stroke. The load is decelerated with the lowest possible force in the shortest possible time eliminating damaging force peaks and shock damage to machines and equipment. These type of shock absorbers are provided with springs sufficient to return the actuator to its initial position after the impacting load is removed.

Types of vehicle shock absorbers

Most vehicular shock absorbers are either twin-tube or mono-tube types with some variations on these themes.

- Twin-tube
- Mono-tube

Twin-tube type :-



Twin Tube Type Shock absorber

Also known as a "two-tube" shock absorber, this device consists of two nested cylindrical tubes, an inner tube that is called the "working tube" or the "pressure tube", and an outer tube called the "reserve tube". At the bottom of the device on the inside is a compression valve or base valve. When the piston is forced up or down by bumps in the road, hydraulic fluid moves between different chambers via small holes or "orifices" in the piston and via the valve, converting the "shock" energy into heat which must then be dissipated.

Types of Twin-tube Shock absorber

Twin-tube gas charged

Variously known as a "gas cell two-tube" or similarly-named design, this variation represented a significant advancement over the basic twin-tube form. Its overall structure is very similar to the twin-tube, but a low-pressure charge of nitrogen gas is added to the reserve tube. The result of this alteration is a dramatic reduction in "foaming" or "aeration", the undesirable outcome of a twin-tube overheating and failing which presents as foaming hydraulic fluid dripping out of the assembly. Twin-tube gas charged shock absorbers represent the vast majority of original modern vehicle suspensions installations

Position sensitive damping

Often abbreviated simply as "PSD", this design is another evolution of the twin-tube shock. In a PSD shock absorber, which still consists of two nested tubes and still contains nitrogen gas, a set of grooves has been added to the pressure tube. These grooves allow the piston to move relatively freely in the middle range of travel (i.e., the most common street or highway use, called by engineers the "comfort zone") and to move with significantly less freedom in response to shifts to more irregular surfaces when upward and downward movement of the piston starts to occur with greater intensity (i.e., on bumpy sections of roads— the stiffening gives the driver greater control of movement over the vehicle so its range on either side of the comfort zone is called the "control zone"). This advance allowed car designers to make a shock absorber tailored to specific makes and models of vehicles and to take into account a given vehicle's size and weight, its maneuverability, its horsepower, etc. in creating a correspondingly effective shock.

Acceleration sensitive damping

The next phase in shock absorber evolution was the development of a shock absorber that could sense and respond to not just situational changes from "bumpy" to "smooth" but to individual bumps in the road in a near instantaneous reaction. This was achieved through a change in the design of the compression valve, and has been termed "acceleration sensitive damping" or "ASD". Not only does this result in a complete disappearance of the "comfort vs. control" tradeoff, it also reduced pitch during vehicle braking and roll during turns. However, ASD shocks are usually only available as aftermarket changes to a vehicle and are only available from a limited number of manufacturers.

Coilover

Coilover shock absorbers are usually a kind of twin-tube gas charged shock absorber around which has been mounted a large metal coil. Though common on motorcycle and scooter rear suspensions, coilover shocks are uncommon in original equipment designs for vehicles, though they have become widely available as aftermarket add-ons. Coilover shocks for cars have been considered specialty items for high performance and racing applications where they allow for significant reductions in overall vehicle height, and though high-quality aftermarket options with wide sturdy springs may provide improvements in vehicle performance, there is dispute over whether or not most aftermarket coilover shocks confer any material benefits to most drivers and may in fact reduce performance over original equipment installations.

1.22 Mono-tube

Hydraulic shock absorber mono tube in different operational situations

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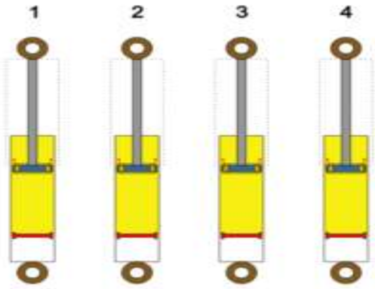

Mono-tube Type Shock Absorber   Mono-tube Shock Absorber

The principal design alternative to the twin-tube form has been the mono-tube shock absorber which was considered a revolutionary advancement when it appeared in the 1950s. As its name implies, the mono-tube shock, which is also a gas-pressurized shock and also comes in a coil over format, consists of only one tube, the pressure tube, though it has two pistons. These pistons are called the working piston and the dividing or floating piston, and they move in relative synchrony inside the pressure tube in response to changes in road smoothness. The two pistons also completely separate the shock's fluid and gas components. The mono-tube shock absorber is consistently a much longer overall design than the twin-tubes, making it difficult to mount in passenger cars designed for twin-tube shocks. However, unlike the twin-tubes, the mono-tube shock can be mounted either way— it does not have any directionality. It also does not have a compression valve, whose role has been taken up by the dividing piston, and although it contains nitrogen gas, the gas in a mono-tube shock is under high pressure (260-360 p.s.i. or so) which can actually help it to support some of the vehicle's weight, something which no other shock absorber is designed to do.

Mercedes became the first auto manufacturer to install mono-tube shocks as standard equipment on some of their cars starting in 1958, manufactured by Bilstein. Because the design was patented, no other manufacturer could use it until 1971 when the patent expired.

I. INTRODUCTION TO ANSYS

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software Implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations. ANSYS is the standard FEA teaching tool within the Mechanical Engineering Department at many colleges. ANSYS is also used in Civil and Electrical Engineering, as well as the Physics and Chemistry departments. ANSYS provides a cost-effective way to explore the performance of products or processes in a virtual environment. This type of product development is termed virtual prototyping. With virtual prototyping techniques, users can iterate various scenarios to optimize the product long before the manufacturing is started. This enables a

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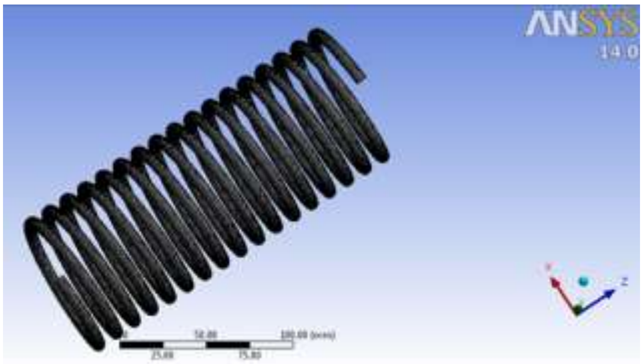
reduction in the level of risk, and in the cost of ineffective designs. The multifaceted nature of ANSYS also provides a means to ensure that users are able to see the effect of a design on the whole behaviour of the product, be it electromagnetic, thermal, mechanical etc.

Geometry Description and Meshing

Geometry of the tube with inserts is modelled in ICEM CFD (Integrated computer aided Engineering and Manufacturing) software. This tool is an advanced pre-processor tool which is used to meet the specific geometry and meshing needs. ICEM CFD is used in order to mesh the components. In this tool the meshing is basically classified in two categories.

1. Hexa meshing
2. Tetra Meshing



Hexa meshing is composed of filling the volume of the geometry with cuboids. The ends of these cuboids can have arbitrary curvatures. These cuboids are called as Hexa elements. These hexa elements are closed with six faces which are called as quad elements. Details of tetra meshing are not discussed as they are not used in the present project.

Ansys-Fluent Setup

The first steps taken after importing the mesh geometry into ANSYS-FLUENT involve checking the mesh/grid for errors. Checking the grid assures that all zones are present and all dimensions are correct. It is also important to check the volume and make sure that it is not negative. If the volume is shown as negative, there is a problem with the grid. When the grid is checked completely and free of errors, a scale and units can be assigned. For this study, the grid was created in mm, and then scaled to meters. Once the grid was set, the solver and boundary conditions of the system were then set and cases were run and analyzed.

Defining the Models

To run the cases, the model properties must be set. Model properties include the internal ANSYS-FLUENT solver settings like air and thermal properties, as well as model operating conditions and grid boundary conditions. The following settings were used to create the model in ANSYS-FLUENT.

1.3D
2. Steady state
3. Enabling energy

Defining the Material Properties
This section of the input contains the options for the materials to be chosen For the shock absorber and the Properties that can be specified in this section are density, viscosity, specific heat, and thermal conductivity. Air is passed through the tube and due to the heat transfer from heating
For natural convection cases, density is the driving mechanism for air motion. In ANSYS-FLUENT different density models can be incorporated. Since for the present project the temperature variations should be there from start point to end point, thus the properties viscosity, specific heat and thermal conductivity are considered varying with temperature. Polynomial curve fit equations are incorporated in ANSYS-FLUENT for varying properties.

Defining the Operating Conditions
The operating conditions include gravity and pressure. Gravity can be entered in values of m/s^2 in x and y and z components. In this project, the geometry was modelled assuming air will be placed on the ground with gravity acting downwards in the Y direction

Executing the Ansys-Fluent Code
Each case must be initialized before the ANSYS-FLUENT code begins iterating toward a converged solution. Initializing the case essentially provides an initial guess for the first iteration of the solution. In the initialization process, the user must specify which zones will be provided with initial conditions. For the modelling performed in this study the option chosen was to compute from inlet. The final initialization step is for the user to enter the maximum number of iterations, after which the simulation begins. For the modelling performed in this study, the number of iterations ranged between 500 and 1000 depending on the case being run and how long it took to converge the solution.

II. DEFELCTION Vs SPRING TAPER ANGLE

The deflection occurred in the shock absorber springs considered for tests are different as shown in fig. Also it is found that the deflection is higher at the inner diameter (surface) compared to the external surface, means the load though assumed to be uniformly distributed at all points theoretically but it is a eccentric load that twist the wire diameter towards center. This is due to the twisting of the wire diameter towards the center from the point of load application towards the other end. Due to this the spring wire cross section of a coil gets in touch to its adjacent coil at the inner surface. Therefore the deflection is higher at the inner surface.

The deflection of the shock absorber spring with application of load at one end and keeping fixed at the other end for all considered springs with different taper (having gradually varying diameter) from one end to the other. The red colour shows the maximum deflection zone, which occurs at free end (loaded end) of the spring and decreases gradually to zero towards the fixed end.
The maximum deflection is observed to be decreasing with increase of taper. The maximum deflection is found to be 0.201, 0.186, 0.174 and 0.16mm for springs with corresponding taper angles of α_1, α_2, α_3, α_4. Results show that there is reduction of deflection by 7.4% by proving α_2 taper angle and it is 13.4% with α_3 it is 20.3% with α_4 compared to the spring without taper (α_1). Finally these results shows that shock absorber with α_4 is good in yielding lower deflection. But

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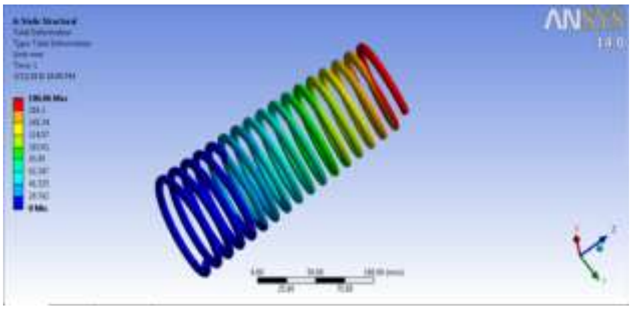
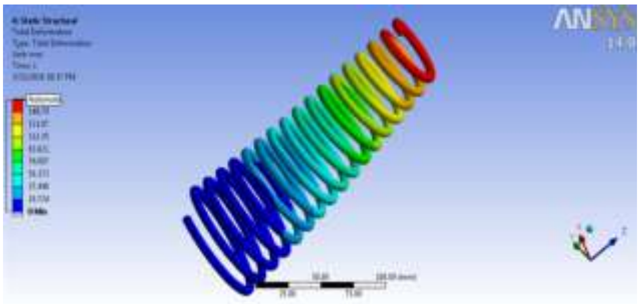
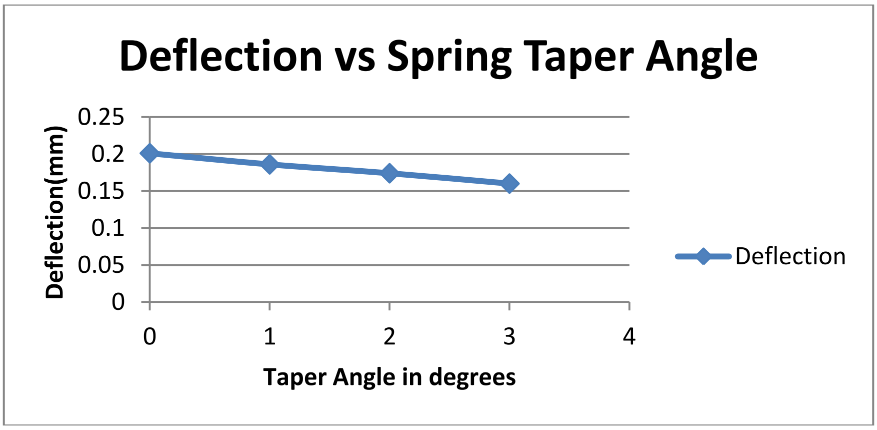
too much increase in taper is not preferred as it reduces the flexibility of providing the spindle assembly.



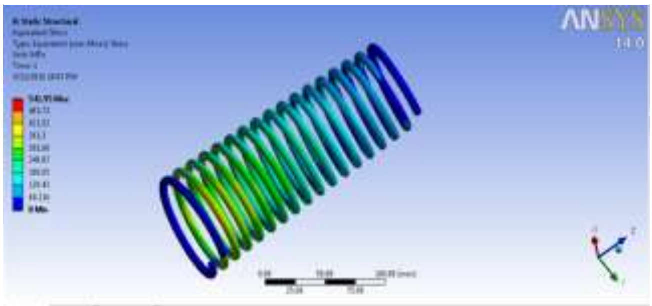


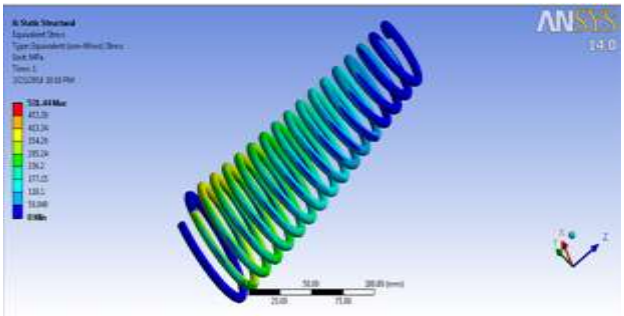
The obtained results show reduction in deflection which gives better performance of the shock absorber by providing taper and also the self weight of the spring reduces due to reduction in the material which in turn reduces the cost (economical).Even the reduction in self weight helps in increasing the vehicle mileage. Also due to irregularities on the road surface the load may not be pure compression which may leads to buckling of the spring that leads to dangerous for the shock absorber to the spring to bear the load (vehicle and persons together). Therefore providing taper supports in making the load to be compression as it tends to pointed to the centre of the spring.



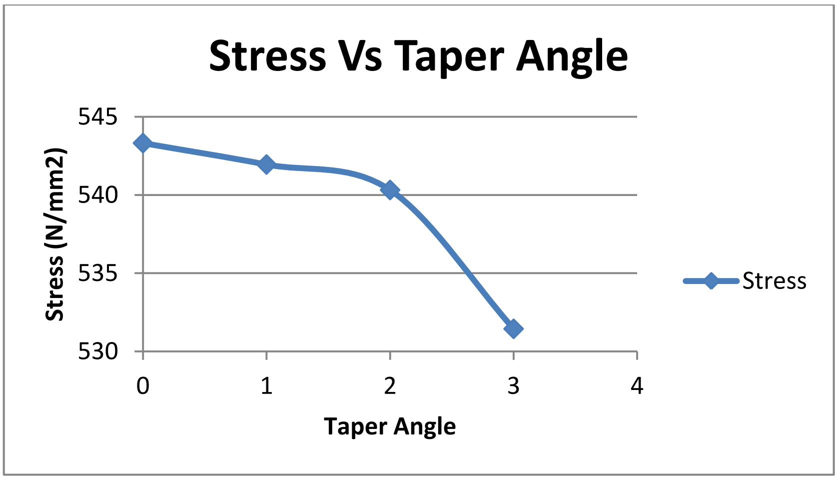
III. DEFELCTION Vs STRESS

The stress development along the spring profile of the shock absorber without and with different level of taper is shown in fig. Both ends of the spring are under minimum stress development and middle part is under action of higher stress values. It is found that the heavily stressed coil is those which are adjacent to the fixed edge and decreases towards free end of the shock absorber spring profile. The maximum stress developed in the spring is found to be 543.32, 541.95, 540.32 and 531.44 N/mm^2 for the spring profile with corresponding taper angles of α_1, α_2, α_3, α_4. From these it is found that the maximum stress is decreasing with increase of taper angle.





The maximum stress developed is reduced by 2.1% by providing a taper of α_4 compared to the spring without taper. Though the maximum stress developed is around 540N/mm^2, it is not clearly visible in the result diagrams because these heavily stressed points are occurred at the inner side of the spring. But the majority part of the spring profile at the external surface is developed by an 393, 388, 384 and 376 N/mm^2. Even though the external surface is developed by stress lower than the stress at the inner surface for the same reason explained in the previous section. But in actual practice the external surface of the shock absorber is exposed to outside atmosphere which results in development of higher stress than expected theoretically (material properties changes). Therefore looking at these stress values developed at the outer surfaces it is found that 4.3% of reduction in stress development occurred by providing taper of α_4.



IV. COMPARISON OF ANALYTICAL AND NUMERICAL RESULTS

Comparing the results obtained through analytical and numerical methods it is found that deflection in the spring is higher calculated through analytical method compared to that of numerical process. The maximum deflection obtained is 3.618mm and 7.8mm for the shock absorber spring through numerical and analytical process. The difference in these values is due to certain assumptions considered in analytical process.

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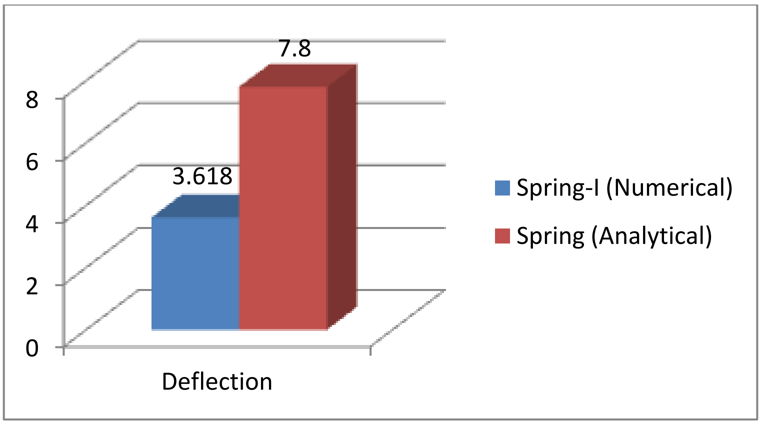
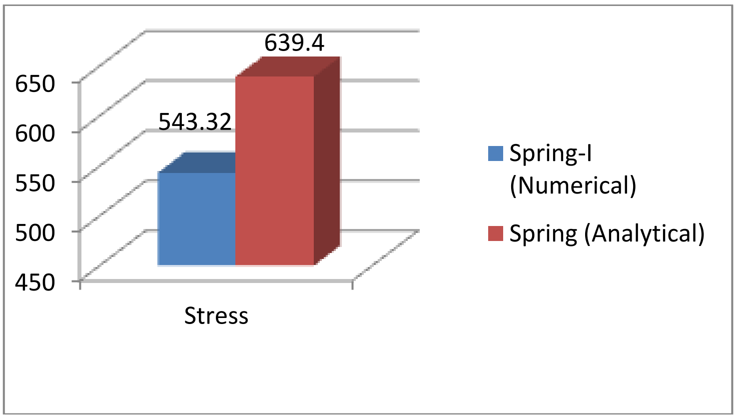


Through the comparison of the stress obtained through analytical and numerical process shows that the maximum stress developed is 639.4 N/mm^2 and 543.32 N/mm^2. There exist 15% of difference in the results obtained comparing analytical and numerical process. These results show that the numerical process is in good agreement to the analytical process.



V. CONCLUSIONS

Carrying series of numerical analysis of the shock absorber spring providing different taper (gradually varying diameter from one end to the other) and also analytical analysis the following conclusions are drawn.

- The deflection in the shock absorber spring reduces with increase of taper angle of the spring. A maximum reduction of 20.3% in deflection is obtained by providing a taper angle of 3^0 to the shock absorber spring.
- The maximum deflection in the spring took place at the internal surface of helical profile of the spring of shock absorber.
- The maximum stress developed in the spring of the shock absorber also decreases with increase of taper angle. A maximum reduction of 4.3% in maximum stress is obtained by providing a taper angle of 3^0.
- The stress is maximum in the coils next to the fixed edge of the spring of shock absorber.

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- The deflection and maximum stress developed in the spring through numerical analysis are valid compared to that of results obtained through the analytical calculations.
- The weight of the spring reduces with provision of taper sized coil for shock absorber that gives an economical product. Also weight reduction improves the vehicle performance in terms of mileage.
- Finally the modified shock absorber spring with 30 is decided to be optimum in occurring of lower deflection and stress values compared to the existing model without taper.

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