"Design and Perfomance Analysis of MR Twin Tube Shock Absorber Damper of Semi-Active Suspension System"

Ravindra S. Lahane, Mahendra J. Sable

***Abstract:** A shock absorber suspension system of vehicle and bicycle in automobile during travelling on a road surface leads jerky, bound and rebound motion a bicycle or vehicle due to this problem by shock and vibration creates discomfort and unsafely to driver and passenger. The vibration coming from vehicle leads to pain, discomfort and dissipated heat and energy which impact on reduction in efficiency shock absorber on semi active suspension system. Comparison method of actual and design Shock absorber by reductions spring stiffness, use falling tube viscometer method for finding efficient fluid mixture for reducing shock and vibration amplitude of theoretical and experimental method. In this research more shock absorbent and energy efficient Shock Absorber Damper is developed for Splendor two wheeler to controlled the vibration of semi active suspension system of vehicle. The fluid greatly increases its viscosity and result in large damping force, less power consummation, fast and smooth response, and cost effective design and environmentally friendly. The damping force increase and decrease in leads to bounce and renounces.*

***Keywords:** Optimization of spring, Piston Valve, Fluid, transmissibility ratio, Vibration Control, Comfort, Reliable, Efficient.*

I. INTRODUCTION

Shock absorber while traveling on roads surface vibration courses excessive vibration due to excitation incase renounce of spring in compression mode leads more stress is designed to absorbed vibration and shock coming from the ground or machines and dissipates kinetic energy into heat energy. This heat energy absorbed by the fluids inside the cylinder and piston of damper used in the shock absorber. Fluid for shock absorber is main research area for performance improvement in automobile applications. In a bike, shock absorber tries to absorb all the forces coming on the from passenger and ground and at the same time tries to damp and reduced the spring oscillation and increase in comfort, safety, reliable and quality ride by reducing the amplitude of vibration instabilities.

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In this research, performance is improved by reducing damping force by reducing viscosity by using energy efficient fluid, by reducing spring stiffness which ultimately reducing transmissibility of shock absorber damper 33-35 % which leads control vibration and shock of suspensions system.

Shock absorber gives comfortable rides to passenger as rider which shock coming in the form of jerky and bounce motion from tire.

Performance of twin tube Shock absorber is decided by

Shock spring, valve of piston and cylinder and fluid inside the damper effects on changes viscosity temperature and damping force, flow velocity. Force transmissibility is the measure how the force gets transfer to the passenger at constant weight. So, by designing the new spring, and the piston valve and prepared good fluid efficient cluster have to decrease the overall transmissibility of designed shock absorber system.. The suspension also, to satisfy the damping value up to possible extent for the designed spring, with advent fluid used the vegetable oil as the main damper fluid with some of quantity of silicon oil in it.

Shock Absorber Damper performance is decided by spring, piston cylinder arrangement of damper (Spring-Mass-Dashpot) and Fluid inside the cylinder. Shock Absorber absorb the shock coming from tire and gives comfortable ride to the passenger (rider). [1-12]. Recently some investigations done on analytical modeling and optimal design of MR damper with power generation by Xiaocong etal. [13], some researcher worked on experimental study on MR material and its damping dynamics characteristics by Enli. etal.[14], jijun Xue etal. Worked on and find out control system for magneto rheological suspensions system for all domestic all- terrain bike and vehicle [15], Bhau k. kumbhar etal. worked on MR Fluid synthesis for brake application and its impact on characteristics[16],D.S. Yoon investigated an effect of the time response of MR damper to vehicle suspension performance [17],M. Cheng investigates Meandering Magnetic Circuit of MR damper design , analysis and experimental performance to improve shock absorber damper[18]. From the above discussions, it is concluded that Magneto rheological (MR) fluids have been investigated by many researchers as their material properties can be changed through an applied electro- magnetic field. Specially, they are capable of reversibly changing from a linear Newtonian fluid to a semi solid with in a fraction of the milli seconds and the yield strength of these semi solids controllable. No one in his study developed shock absorber damper to improve the performance of semi active suspension system and to optimize the MR damper parameter.

Also no one addressed on synthesis the MR fluids properties to absorbers the energy and control shock of valve, seal and piston scratch geometric parameter of shock absorber damper by combing effect finite element methods a as thermal analysis and C.F.D. analyses of flow simultaneously.

II. MODELING OF SYSTEM

As Fig.2 shown Twin Tube Damper and its designed valve is which is going to mount on the piston rod through metal lock nut. Shock absorber is twin tube shock absorber. Above the valve there is one plate that restricts the flow in rebound condition. And also the spring shown in the structure is going to absorb the impact force in case of full rebound. Above that there is one cap which allows the fluid to pass through inner cylinder to the outer cylinder design main valve with. After that the seal is press fitted into the outer cylinder so that oil will leak outside the shock absorber. And lastly the spring get mount on the damper. Twin Tube Damper is design in CATIA V5 R21 Version.

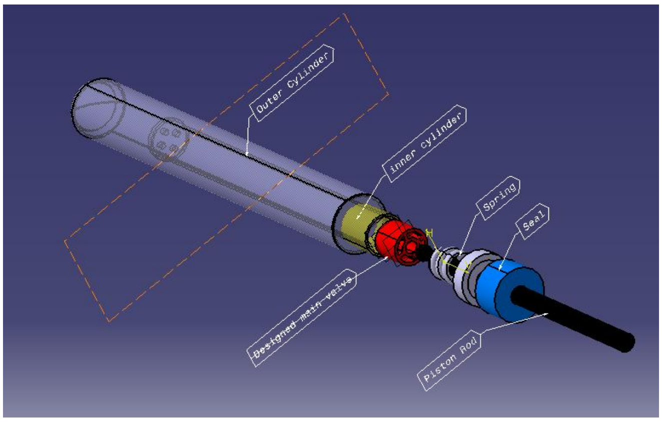

Fig.2: CATIA Modeling of Twin Tube Damper

III. PROCESS METHODOLOGY

The methodology of research is shown in stepwise process In following Fig. 3.

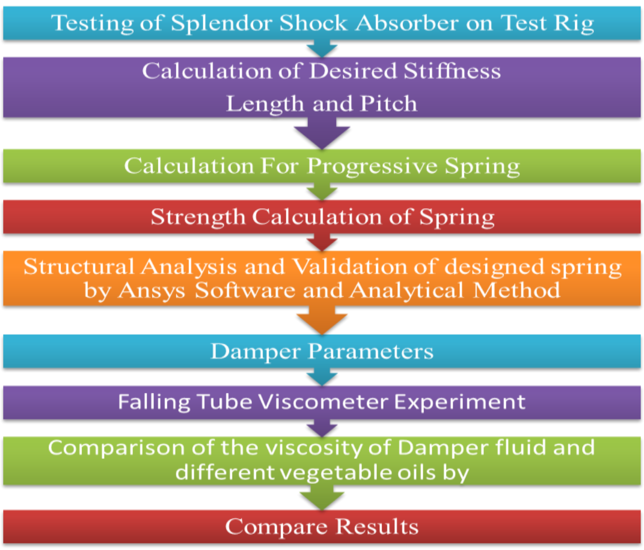

Fig. 3: Stepwise Process of work methodology

IV. STOCK SHOCK ABSORBER EXPERIMENTATIONS

The experiment conducted on Shock Absorber Testing Machine to calculate the various values of force transmissibility in term of force transmitted to foundation to force immerses by foundation is calculate the performance of shock absorber of various damping condition as follows fig.4;

Fig.4: Shock Absorber Test Rig setup.

The experimental results are taken on shock absorber test rig.

4.1. Aim: to find Damping characteristics of splendor (original damper)

4.2. Specification:

the following specification and observation done form Shock absorber test rig machine

Cam lobe diameter = 46mm

Cam base diameter =51mm

Lift of cam =21 mm

Spring Stiffness=12732.8 N/m

Weight on Shock Absorber plats= 45 kg

Table-I: Experimental Reading of Original Shock Absorber damper

Sr. No	Voltage (V, Volts)	Current (I, Amp)	Speeds (N, Rpm)	Length of Travel (L, mm)
1	51	3.66	31.51	40
2	44	3.78	59.88	44
3	50	3.58	80.45	35
4	64	2.76	98.19	30
5	78	2.20	115.6	18
6	89	1.89	140.9	11
7	98	1.86	150	10

From above table –ii it is conclude that voltage is increases current is decreases also speed is increases length of travel of shock absorber is decreases.

4.3 Result and Discussion:

From Experimental result on Shock absorber test rig machine

It is found that shock absorber transmissibility is very large is near about 0.8.

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Aim of this research is to reduce the transmissibility. Force transmitted to the passenger and chassis minimum then rider get safe, reliable and comfortable ride if force transmitted is control upto acceptable limit.

4.4. Actual spring Design in Catia:

Now, we know the stiffness for spring which is actually a progressive spring design for Splendor in CATIA Software as shown in the fig.5

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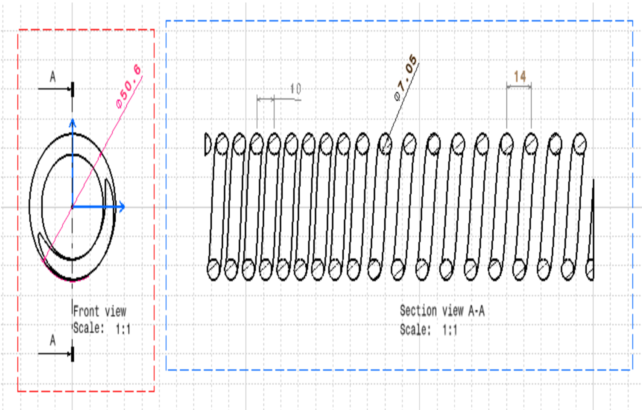

Fig.5: Original Shock Absorber Spring Dimension

4.5. Designed spring specifications

4.5.1 Calculation for Designed Spring:

4.5.1. How to decrease force transmitted is shown below:

The current scenario that we have considered is to split the spring in the two halves consisting of the two stiffness. The first part consists of the spring of less stiffness and the second part consists of the spring of greater stiffness than the first. The logic behind this is to absorb the small amount of shock by the first spring and the large amount of force by the second spring when the first spring is displaced completely by that load. Now, we know that the absolute displacement is given by the formula:

$$X = Y\sqrt{\frac{1+(2\xi r)^2}{(1-r^2)^2+(2\xi r)^2}} \quad \text{--------- (1)}$$

And relative displacement is given by the equation

$$Z = \frac{Yr^2}{\sqrt{(1-r2)2+(2\xi r)2}} \quad \text{------------ (2)}$$

Now, if consider the velocity of the bike as V=40 km/hr =11.11 m/s., M=50 kg, From above formula Absolute displacement(X), Sinusoidal amplitude (Y) and Relative Displacement(Z) is calculated in following Table-II.

Table –II: Result Calculations of Shock Absorber

Sr. No.	Values of K (N/mm)	Values of Cc (Nsec/mm)	Value of damping Ratio	Value of Z (mm)	Value of X (mm)	Value of Y (mm)
1	**18000**	**1894**	**0.8**	**85**	**250**	**200**
2	**15000**	**1549.19**	**0.8**	**211**	**239**	**200**

If we take the value of ξ=1.3 then X2=0.219 mm. Form above Table-II it is observed that if stiffness of suspension system is decreases values of relative amplitude of semi active suspension systems going to increases.

Now calculation for C,

We have a formula $C = \frac{12*\mu*l_p*A_p2}{\pi*d_m*e^3}$ Ns/m

(This formula is only for damper with clearance (e) between piston and cylinder)

Thus factors affecting the damping coefficient

1. Viscosity of fluid.
2. Clearance between the cylinder and the piston.
3. Length of piston
4. Diameter of piston
5. Mean diameter of annular area between the piston and cylinder

As all the values except viscosity are constant as the shape is not going to change. By adjusting the value of the viscosity we can change the value of the coefficient of damping.

In this case damping coefficient decreases from 758.4 Ns/m to 619.67 Ns/m. So the value of the viscosity should also be change in such manner that the C becomes 758.4 Ns/m.But in case of high bump more force come on the shock absorber. So to resist the more force more stiffness of the spring is required which will not affect the performance of the less stiffness spring.

Consider k_n =18000 N/m, m=50 kg, $C_C = 2\sqrt{km}$ = 1894.28 Nsec/m (at 50 kg)

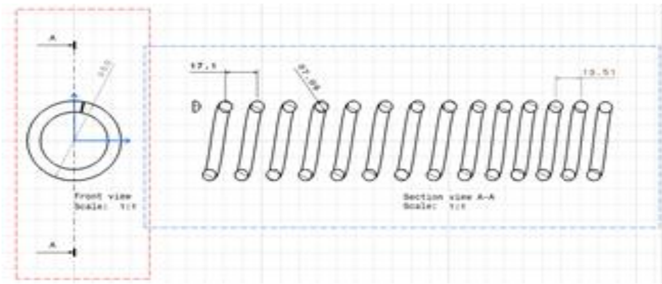

Fig.6: Designed spring of shock Absorber

V. RESULT AND DISCUSSION

5.1. Analysis Results:

5.1.1 For Original Spring (Stock spring)

Fig. 7: Result 1: deformation of splendor spring for 1000 N Axial force

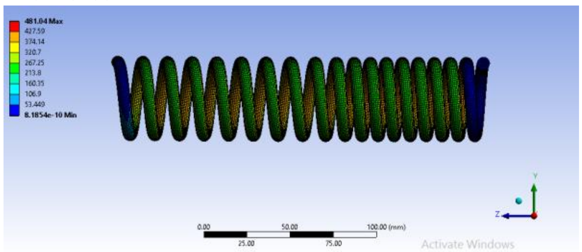

Fig 6: Result 2: Maximum shear stress in Splendor Spring for 1000N.

From above results the stiffness of the spring is coming 17.8 N/mm for 1000 N force applied. That is close to hand calculated value which is equal to 18 N/mm and maximum shear stress generated is 481.91 MPa.

5.1.2 for Designed Spring

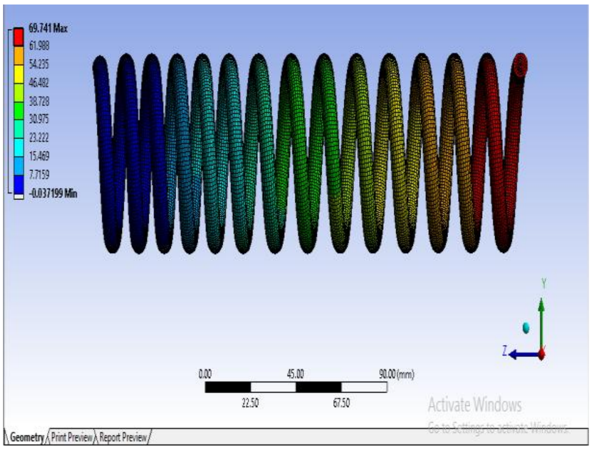

Fig.7: Result 3: Deformation of designed spring

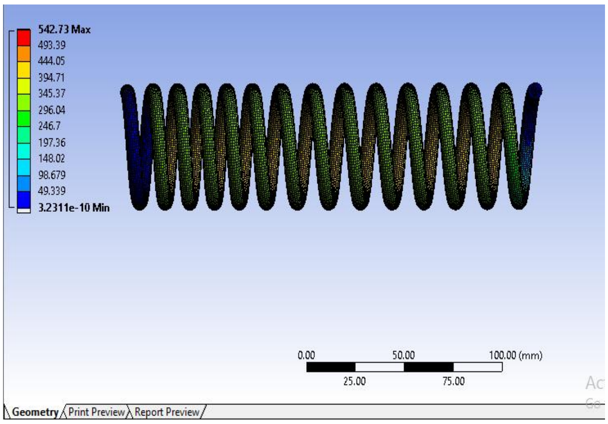

Fig.8: Result 4: Maximum shear stress

From above analysis it is clearly seen that the calculate value of stiffness is very close to results. Calculation value of keq = 15.823 N/mm and analysis result value is 14.5 N/mm. And also calculated value for maximum shear stress is 445.4 MPa, and analysis result value is 542 MPa.

5.1.3 Softer spring part of designed spring

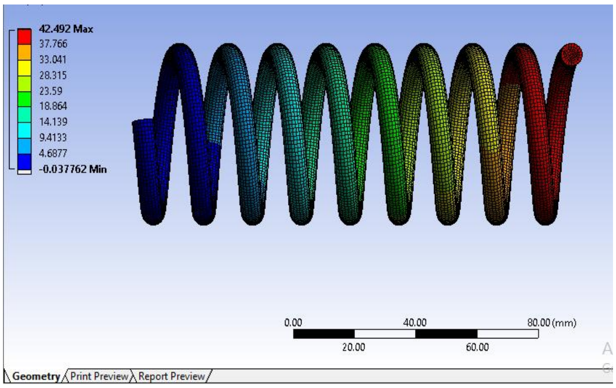

Fig. 9: Result 5: Deformation of designed spring

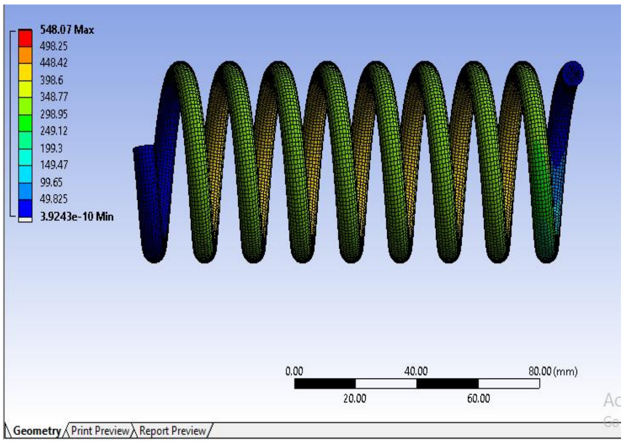

Fig.10: Result 6: Maximum shear stress

Calculated spring stiffness is 25 N/mm
Analysis result spring stiffness is 23.8 N/mm
Calculated maximum shear stress is 445 MPa
Analysis result maximum shear stress is 548 MP.

5.1.4 Softer spring part of designed spring:

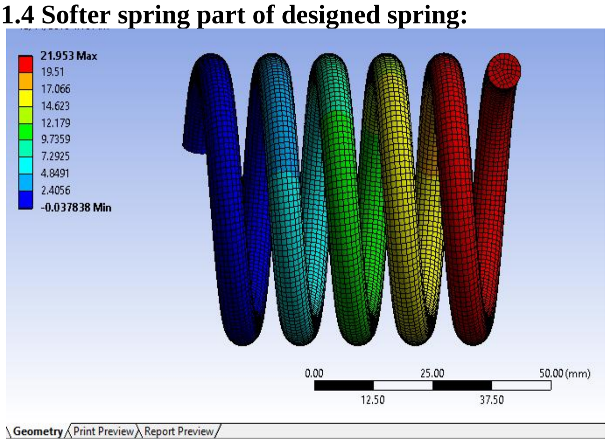

Fig. 11:Result 7: Deformation of designed spring

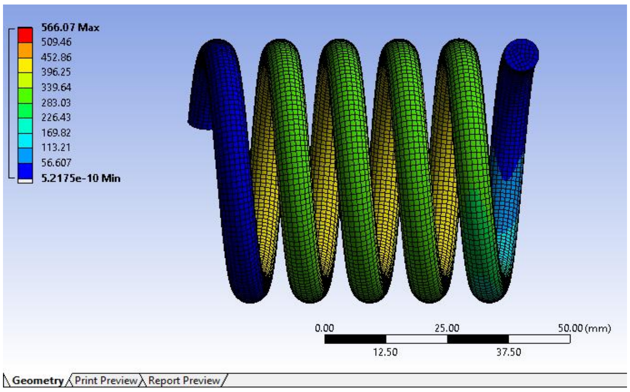

Fig.12: Result 8: Maximum shear stress

Calculated spring stiffness is 43 N/mm
Analysis result spring stiffness is 45 N/mm
Calculated maximum shear stress is 445 MPa
Analysis result maximum shear stress is 566 MPa
Therefore percentage decrease in Transmissibility of shock absorber:
Original shock absorber Transmissibility: 0.75
Designed shock absorber Transmissibility: 0.49
Percentage decrease in Transmissibility= **34.66%**

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Result and Discussion:

From above experiment it is found that the transmissibility for the designed shock absorber is 0.49 and the transmissibility for actual shock absorber was 0.75 therefore the force transmitted to the mass or the passenger has decreased by 34.66 % means, the force reaching the passenger has decreased and therefore the passenger comfort increases. Because of decrease in the spring stiffness from 18000 N/mm to 15400 N/mm and reduction in the damping coefficient in case of compression from 230.3278 Ns/m to 60 Ns/m, more force get absorbed before reaching the passenger. Means the force reaching the passenger has decreased and therefore the passenger comfort increases.

5.2 Comparison of the viscosity of Damper fluid and different vegetable oils, & Change in viscosity with respect to change in temperature for given damper oil by falling tube Viscometer Experiment.

From viscosity versus temperature Fig.13: **Damper Oil** viscosity at temperature 25 ° is 68 μcp to 150° is 37.5 μcp.

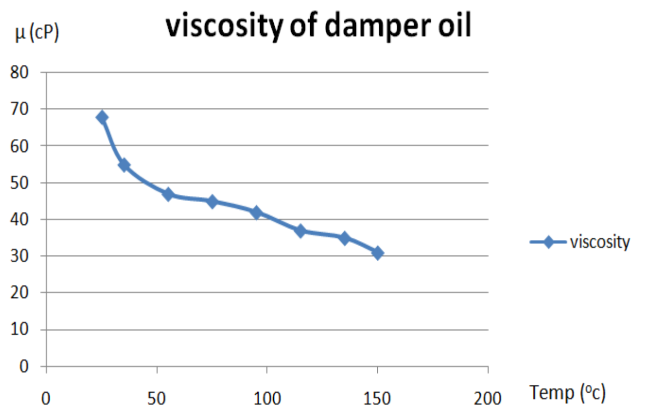
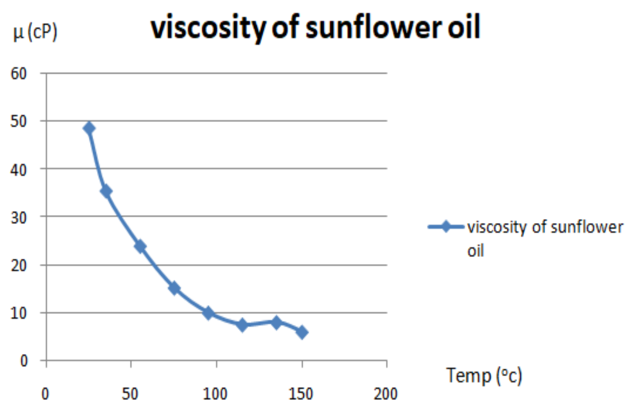


Fig.13: Damper Oil

From Fig.14: Sunflower Oil viscosity versus temperature graph viscosity at temperature is 25° is 48.5 μcp to 150° is 6μcp.



Graph no: 10.3.2.2 Sunflower Oil

From Fig.15: Soybean oil viscosity versus temperature graph viscosity at temperature is 25° is 43 μcp to 150° is 5 μcp.

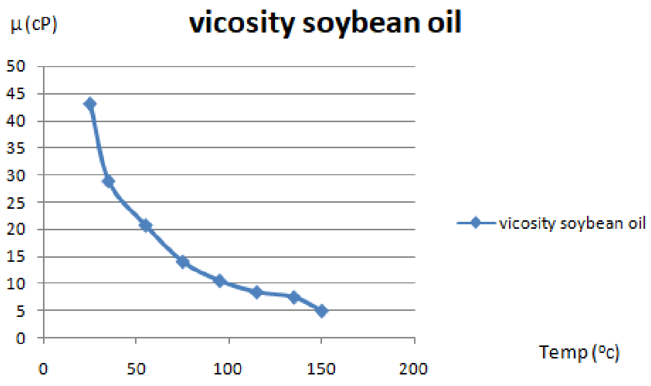
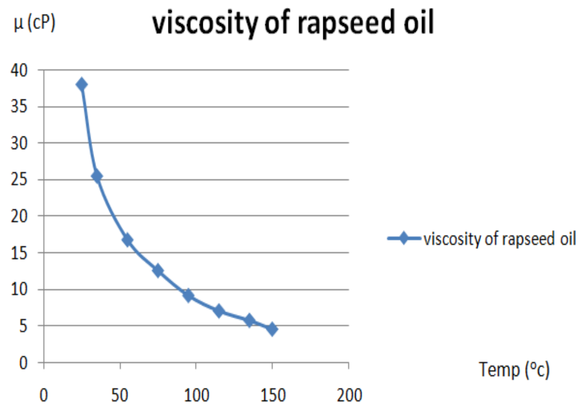


Fig.15: Soybean oil

From Fig.16: **Rapeseed oil** viscosity versus temperature graph viscosity at temperature is 25° is 38 μcp to 150° is 4.6 μcp.



Graph no: 10.3.2.4 Rapeseed oil

From Fig.17: **Corn oil** viscosity versus temperature graph viscosity at temperature is 25° is 46.2 μcp to 150° is 7.7 μcp.

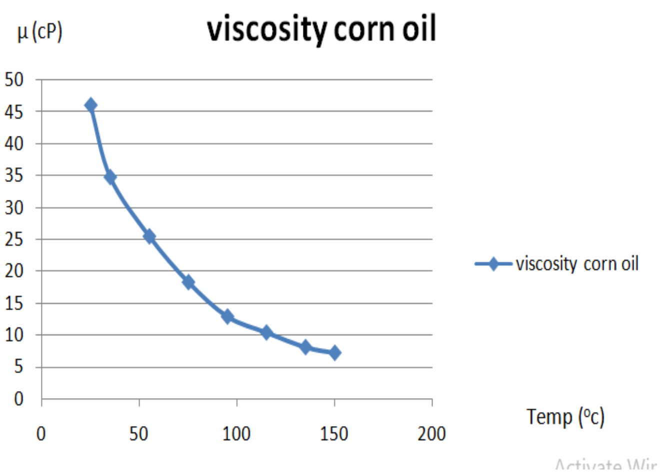


Fig.17: Corn oil

From Fig.18: **Cornola oil** viscosity versus temperature graph viscosity at temperature is 25° is 56 μcp to 150° is 4.6 μcp.

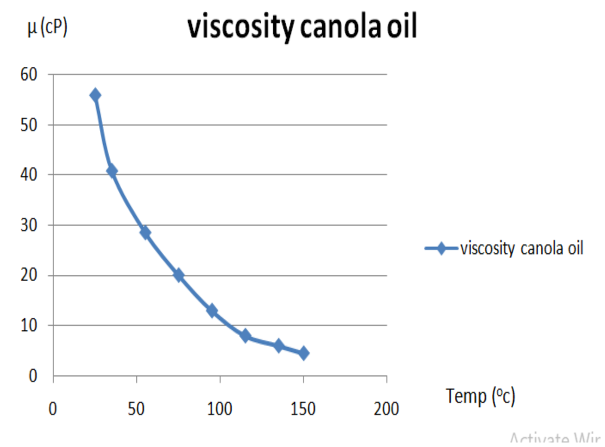


Fig.18: Canola oil

From Fig.19: **Peanut + Silicon oil mixture**

For Peanut + 10 % Silicon oil mixture viscosity versus temperature graph viscosity at temperature is 25º is 58 µcp to 150º is 15 µcp.

For Peanut + 20 % Silicon oil mixture viscosity versus temperature graph viscosity at temperature is 25º is 66.4 µcp to 150º is 20 µcp.

For Peanut + 30 % Silicon oil mixture viscosity versus temperature graph viscosity at temperature is 25º is 80 µcp to 150º is 41.5 µcp.

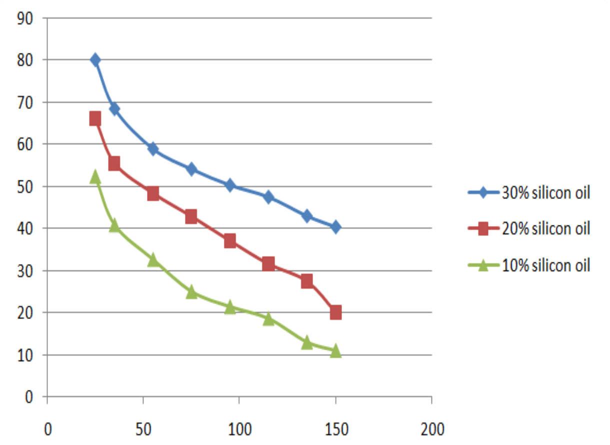


Fig.19: Peanut + Silicon oil mixture

The following table shows comparison of actual and selected fluid for shock absorber damper of bicycle.

Table –II: Comparison of Actual Fluid and Selected Fluid:

Actual Damper fluid	Selected Damper fluid
Density = 890 kg/mm^3	Density = 910 kg/mm^3
Viscosity = 0.065 Ns/m	Viscosity = 0.08 Ns/m

Result and Discussion:

From above graphs viscosity of damper oil is about 65 cP at room temperature and also the viscosity of canola oil is 56 cP. Which is very close to the damper oil also the viscosity of peanut oil is 52.3 cP at room temperature. So we have chosen the peanut oil as it is easily available and cost is also less. After this by adding some amount of silicon oil in the peanut oil we can increase the viscosity of resultant mixture as the viscosity of silicon oil is approximately 100 cP. Also silicon oil has high value of thermal capacity; hence they can help in reducing the working temperature at same condition.

At 30% of silicon oil of total mixture by mass, the viscosity of oil at room temperature is 80 cP. This is greater than the damper oil used in original shock absorber.

The Vegetable oil as the main damper fluid with some amount of silicon oil to increase its viscosity and heat capacity. Also the Vegetable oils can be reproduced; therefore dependency on the mineral oil will be decreased

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National Conference: 10.