A Study on the Damping Characteristics of SAE Oil Containing Suspended Nano Ferrous Oxide (Fe_2O_3) Particles

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Abstract: ***Recently, in a wide range of applications, there has been a need for advanced lubricants. Several materials can be added to a lubricant to produce or improve the required properties. A good lubricant is one that has low friction coefficient; low wear coefficient and good damping properties. In recent times, there are many problems being faced due to the lack of the aforementioned lubricant properties, which in turn causes high maintenance of machines. The purpose of the present research is to study lubricant properties by adding ferrous oxide nano-particles and subjecting it to magnetic flux. The addition of nano-particles to SAE 40 engine oil is expected to reduce friction and wear coefficient and thus, increase the damping properties. Hence, the machine is protected while providing reliability and optimal speed.***

Keywords: SAE 40 engine oil; Ferrous oxide; Lubricant properties; Magnetic flux

1. Introduction

It is known that conventional SAE oil, which is used extensively in automobiles, has less damping characteristics. This disadvantage can be improved by using Magnetorheological/Electrorheological fluids. A Magnetorheological fluid (MR fluid) is a type of smart fluid in a carrier fluid, usually a type of oil. When subjected to a magnetic field, the fluid greatly increases its apparent viscosity, to the point of becoming a semi-solid. Importantly, the yield stress of the fluid when in its active state can be controlled very accurately by varying the magnetic field intensity. The advantage is that the fluid's ability to transmit force can be controlled with an electromagnet, which gives rise to its many possible control-based applications. This improves efficiency and provides several advantages in particular, improving viscosity and damping coefficient.

Thus, by improving damping characteristics, a high degree of vibration control can be achieved.

Few applications are shock absorbers, dampers and clutches. If the shock absorbers of a vehicle's suspension are filled with magneto rheological fluid instead of a plain oil or gas, and the channels which allow the damping fluid to flow between the two chambers is surrounded with electromagnets, the viscosity of the fluid, and hence the critical frequency of the damper, can be varied depending on driver preference or the weight being carried by the vehicle - or it may be dynamically varied in order to provide stability control across vastly different road conditions. This is in effect a magneto rheological damper. Magneto rheological dampers are under development for use in military and commercial helicopter cockpit seats, as safety devices in the event of a crash. They would be used to decrease the shock delivered to a passenger's spinal column, thereby decreasing the rate of permanent injury during a crash. Magneto rheological dampers are utilized in semi-active human prosthetic legs. Much like those used in military and commercial helicopters, a damper in the prosthetic leg decreases the shock delivered to the patient's leg when jumping, for example. This results in increased mobility and agility for the patient.

2. Literature Survey

There have been many studies conducted on the damping properties of oil and methods of improving it.

One study titled "Experimental evaluation of engine oil properties containing Copper Oxide nanoparticles as a Nano additive" involved studying the properties of lubricants. They are mainly the result of adding a material for improving or producing the required properties.[1] Different materials with various nanostructures are used as new additives which, because of their unique properties, are used for improving the lubricant's properties. The purpose of this research was to add copper oxide (CuO) nanoparticles to engine oil and evaluate the produced changes in some of its properties. Also, viscosity, pour point, and flash point of Nano lubricants, which are made at different concentrations (0.1, 0.2, and 0.5 wt.%), and also their thermal conductivity coefficient as four quality parameters which are effective in the functionality of engine oil were evaluated. Among the different methods which have been used for dispersing nanoparticles inside the base oil, using planetary ball mill was determined as the most important method for stabilization of nanoparticles inside SAE engine oil.

Another study titled "Experimental Investigation of Tribological properties of Engine oil with CuO nanoparticles" showed one of the most effective factors of the Nano fluid properties is the rate of dispersion and stability of nanoparticles inside the base fluid.[2] When dispersion of particles inside the base fluid is not good, it is possible that agglomeration and precipitation of nanoparticles occur; which may cause damage of the frictional surfaces. In this research, to disperse nanoparticles inside the base oil, oleic acid was used as surface modifier and by preparing lubricant samples in concentrations of 0.2 wt. %, 0.5 wt. %, 0.75 wt. % and 1wt. % using an ultrasonic probe for 45 min. These concentration values were obtained from the results of bibliographic research, where concentration of nanoparticles is in the range 0.2-1 wt.%. The results confirm that the existence of the surface modification layer can effectively prevent the agglomeration of Cu nanoparticles and provide good oil-dispersion ability.

Also in "A study on vibration characteristics of engine oil based magneto rheological fluid sandwich beam" it was shown that a key feature of Magneto rheological fluids is that their rheological properties will change on the application of magnetic/electric field.[3] The ability to change from liquid to semi solid can be used to provide a good damping effect. Using this concept a cantilever beam structure was fabricated. It consisted of three layers of which the top and bottom layers were of aluminium plates and between the plates an MR Fluid was sandwiched. This experimental study investigated the controllability of vibration characteristics such as natural frequency, amplitude of vibration, damping factor and demonstrated the vibration suppression capabilities of MR fluids in structural elements. MR Fluid was prepared in the laboratory using Engine oil as carrier oil, Nickel as magnetic particles and oleic acid as a surfactant. Two samples were prepared in the laboratory on the basis of weight. Silicone rubber is used at the edges to prevent leakage of the MR fluid. The influence of MR fluid increases with increase in magnetic field. The MR fluid changes from liquid to semi solid state on the application of magnetic field. This causes increase in the stiffness of the beam and hence there will be a shift in natural frequency of the beam. It was found that the peak amplitude of vibration decreases as the magnetic field intensity increases. This indicates that presence of MR fluid can be used to reduce vibration in system.

3. Research Gap

The properties of SAE oil have been studied and attempts have been made to improve the viscosity and damping property by adding nanoparticles. The nanoparticle which has been added in present studies includes Copper Oxide. No study has been conducted with the addition of Iron Oxide (Fe_2O_3) as a Nano additive.

Further, after the addition of nanoparticles, the effect on viscosity and damping factor was studied without subjecting the Nano fluid to a magnetic field. Thus, the effect of Nano additives on the damping property and viscosity when subjected to magnetic flux has not been extensively studied. The Iron Oxide particles will react to an external magnetic field and hence further study can be conducted on behaviour of Nano fluid containing Nano additive under the effect of a magnetic field.

4. Objective

The aim of our project is to immerse Iron Oxide nanoparticles into SAE oil, and study its effect on damping characteristics. The nanoparticles will be added to the oil and proper mixing will be carried out to ensure a stable Nano fluid. The change in the damping characteristics of the oil will then be calculated. Further, the percentage of Fe_2O_3 in the fluid will be varied and the effect on damping property of Nano fluid will be calculated. Also, the strength of magnetic flux is varied, by changing the current flowing through the coil to check effect on the damping properties of Nano fluid.

5. Experimental Setup

The test rig setup consists of a cast iron frame on which a thin rod of diameter 0.01m made of spring steel is suspended. The spring steel rod is attached to a disc of diameter 1m and weight 10kgs. The rod is coupled to the disc such that it provides torsional twisting motion. The motion of the disc is converted to oscillatory motion of the pen and this is used to obtain a graph plot. The graph sheet is placed around the drum, which is rotated by a motor. Thus, the motion of the disc and the number of oscillations it makes is accurately recorded in the form of a graph. Based on the viscosity and damping property of the oil the disc will take a longer or a shorter time to come back to mean position and hence damping property of the oil can be found out.

6. Experimental Procedure

The Nano fluid was first prepared by diffusing Fe_2O_3 nanoparticles into SAE 40 oil. 600ml of oil was taken and nanoparticles in the concentration of 0.5 wt. %, 1 wt. % and 1.5 wt. % were added to the oil to form a Nano fluid. The mixture, which was formed, was then transferred to the container in the test rig. A Copper coil through which current was passed to generate magnetic field surrounded this container. Magnetic field of varying intensity could be obtained. The oil was then subject to the damping test, which showed the damping properties of the oil by means of a graph plot. The experiment was repeated for different concentrations of Fe_2O_3 particles in the fluid. Further, for each concentration of nanoparticles in the fluid, the strength of the magnetic field was varied to check for effects on the damping properties.

In conclusion, the experiment was used to determine at which concentration of Fe_2O_3 particles and at which particular magnetic field strength, the damping property of the oil was maximum.

7. Discussion

It was seen that there was an improvement in the damping property of the oil due to addition of Fe_2O_3 Nano particles. Further, an improved effect is seen on the damping properties of SAE oil when the concentration of Fe_2O_3 Nano additives is varied.

7.1 For 0.5% concentration of nano-additives

Table 1: Logarithmic Decrement

Logarithmic Decrement	Trial 1	Trial 2	Trial 3
Without mag flux	0.3102	0.4055	0.3365
With mag flux x tesla	0.3365	0.3365	0.3102
With mag flux y tesla	0.3365	0.3102	0.3102

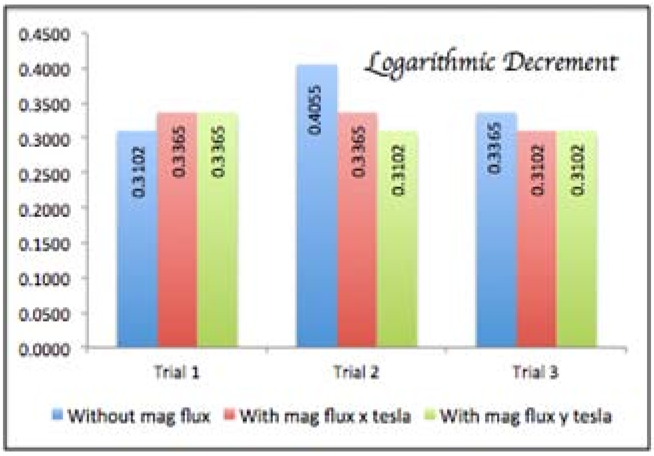

Figure 1: Logarithmic Decrement

Table 2: Damping Ratio

Damping Ratio	Trial 1	Trial 2	Trial 3
Without mag flux	0.0493	0.0644	0.0535
With mag flux x tesla	0.0535	0.0535	0.0493
With mag flux y tesla	0.0535	0.0493	0.0493

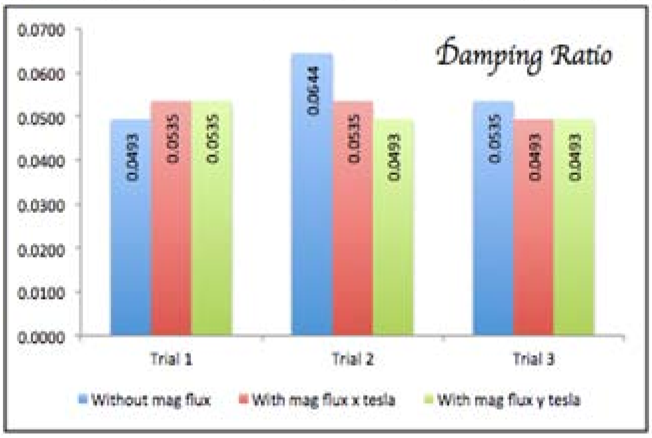

Figure 2: Damping Ratio

Table 3: Damping Coefficient

Damping Co-efficient	Trial 1	Trial 2	Trial 3
Without mag flux	0.0006	0.0008	0.0007
With mag flux x tesla	0.0007	0.0007	0.0006
With mag flux y tesla	0.0007	0.0006	0.0006

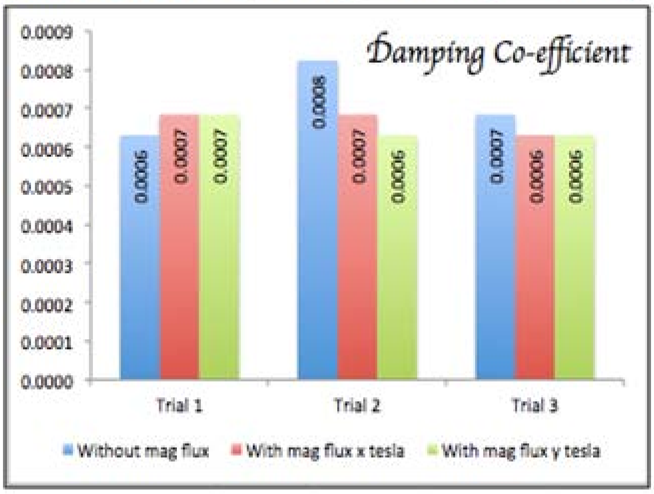

Figure 3: Damping Coefficient

7.2 For 1% concentration of nano-additives

Table 4: Logarithmic Decrement

Logarithmic Decrement	Trial 1	Trial 2	Trial 3
Without mag flux	0.3677	0.3365	0.3567
With mag flux x tesla	0.3677	0.3677	0.3365
With mag flux y tesla	0.4418	0.4418	0.4418

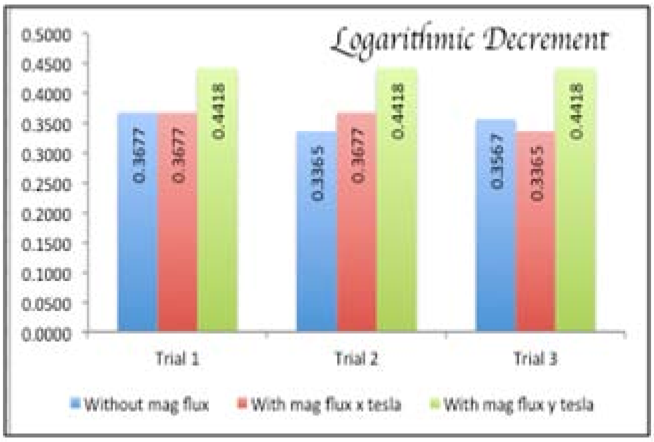

Figure 4: Logarithmic Decrement

Table 5: Damping Ratio

Damping Ratio	Trial 1	Trial 2	Trial 3
Without mag flux	0.0585	0.0535	0.0567
With mag flux x tesla	0.0585	0.0585	0.0535
With mag flux y tesla	0.0702	0.0702	0.0702

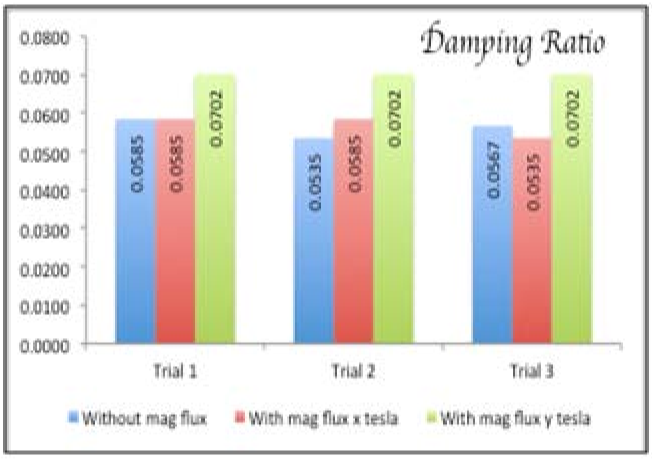

Figure 5: Damping Ratio

Table 6: Damping Coefficient

Damping Co-efficient	Trial 1	Trial 2	Trial 3
Without mag flux	0.0009	0.0007	0.000748
With mag flux x tesla	0.00075	0.00075	0.00063
With mag flux y tesla	0.00075	0.00068	0.00090

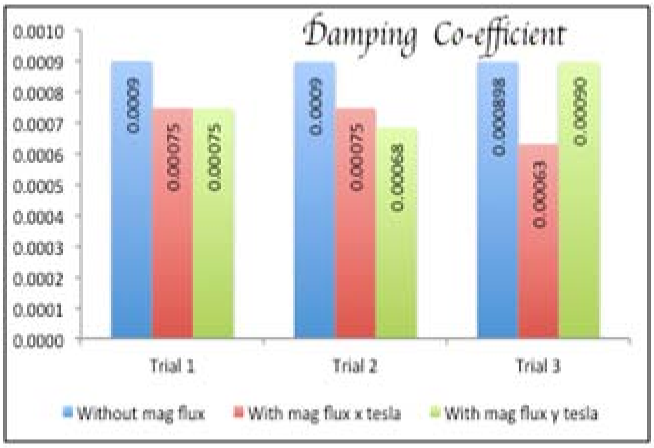

Figure 6: Damping Coefficient

7.3 For 1.5% concentrations of nano-additives

Table 7: Logarithmic Decrement

Logarithmic Decrement	Trial 1	Trial 2	Trial 3
Without mag flux	0.3677	0.3365	0.3567
With mag flux x tesla	0.3677	0.3677	0.3365
With mag flux y tesla	0.4418	0.4418	0.4418

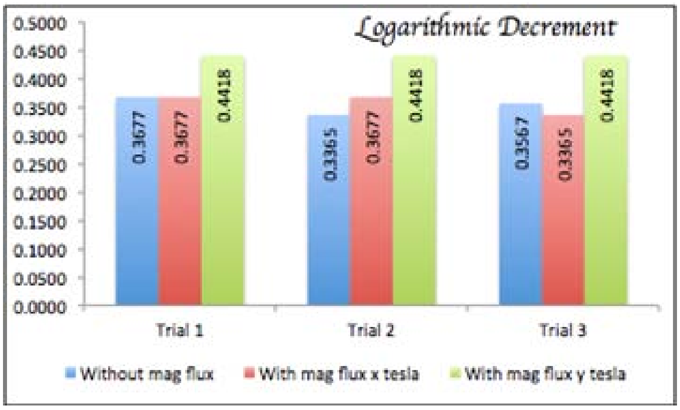

Figure 7: Logarithmic Decrement

Table 8: Damping Ratio

Damping Ratio	Trial 1	Trial 2	Trial 3
Without mag flux	0.009	0.009	0.009
With mag flux x tesla	0.009	0.009	0.011
With mag flux y tesla	0.009	0.01	0.009

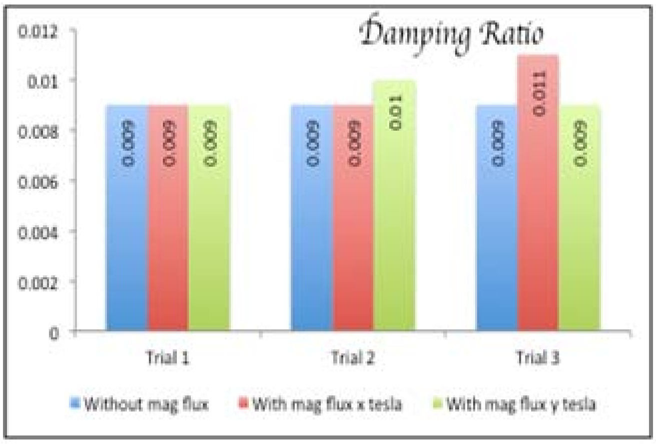

Figure 8: Damping Ratio

Table 9: Damping Coefficient

Damping Co-efficient	Trial 1	Trial 2	Trial 3
Without mag flux	0.00075	0.00068	0.00073
With mag flux x tesla	0.00075	0.00075	0.00068
With mag flux y tesla	0.00090	0.00090	0.00090

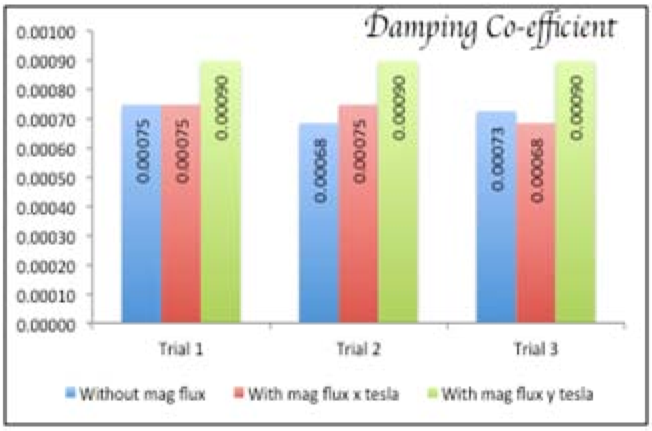

Figure 9: Damping Coefficient

Lastly, the effect on damping properties was studied when the strength of the magnetic field was varied for each concentration of Fe_2O_3.

7.4 Effect of addition of Fe_2O_3on damping properties without magnetic flux

Table 10: Without magnetic flux for each concentration

Concentration	NIL (Oil)	0.5%	1%	1.5%
Logarithmic Decrement	.3199	.3507	.3536	.4418
Damping Ratio	.0509	.0558	.0562	.0702
Damping Co-efficient	.0007	.0007	.0007	.0009

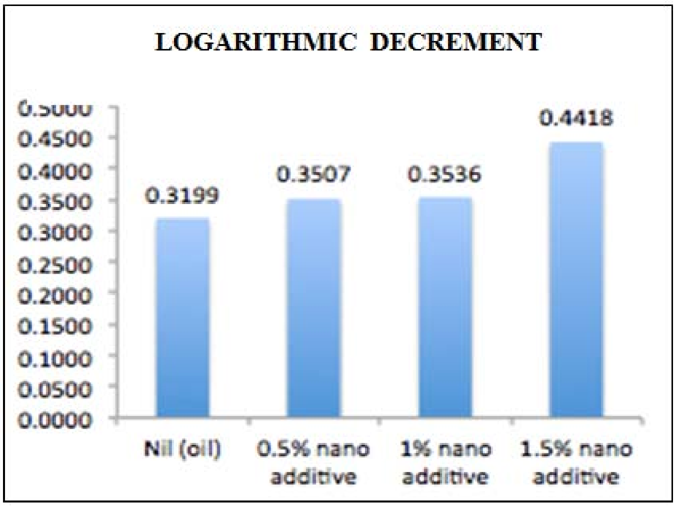

Figure 10: Logarithmic Decrement without magnetic flux

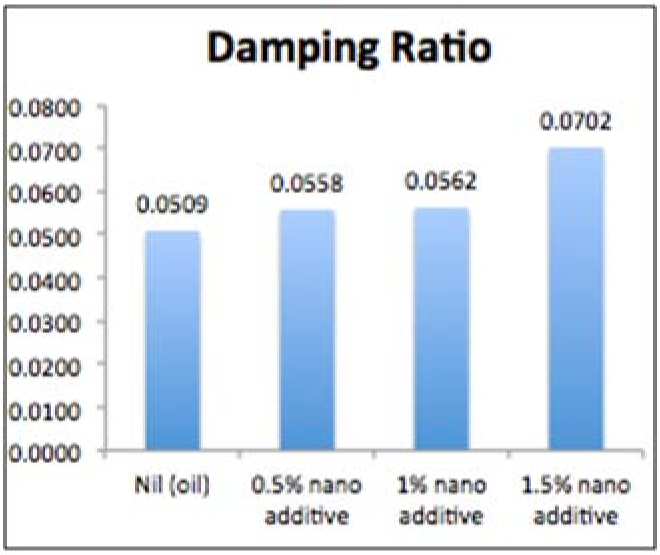

Figure 11: Damping Ratio without magnetic flux

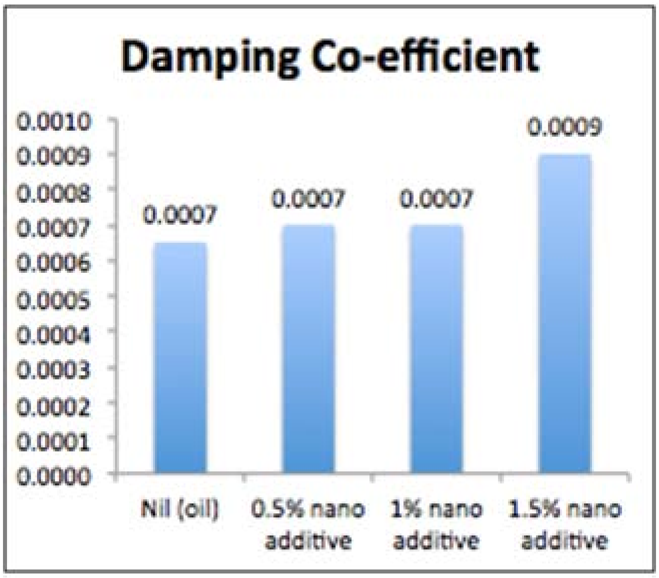

Figure 12: Damping Coefficient without magnetic flux

7.5 Effect of addition of Fe_2O_3on damping properties with magnetic flux of 4.96 x 10^{-4} Tesla (X Tesla)

Table 11: With magnetic flux of 4.96 x 10^{-4} Tesla

Concentration	NIL (Oil)	0.5%	1%	1.5%
Logarithmic Decrement	.3199	.3277	.3573	.3485
Damping Ratio	.0509	.0521	.0568	.0554
Damping Co-efficient	.0007	.00067	.00073	.00071

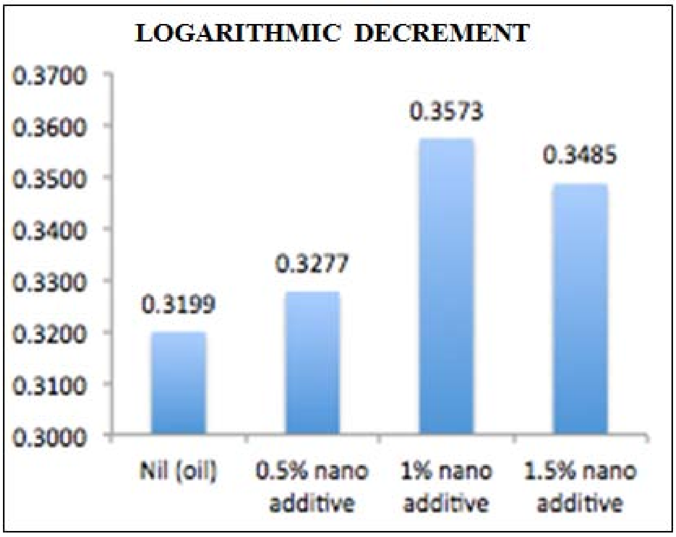

Figure 13: Logarithmic Decrement with magnetic flux of 4.96 x 10^{-4}Tesla

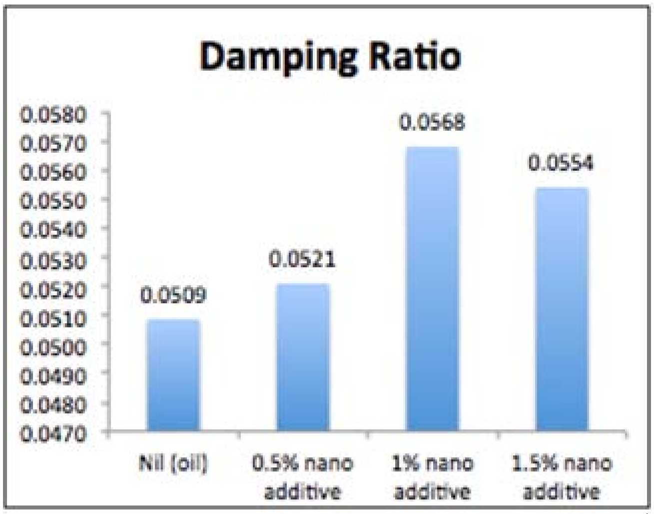

Figure 14: Damping Ratio with magnetic flux of 4.96 x 10^{-4} Tesla

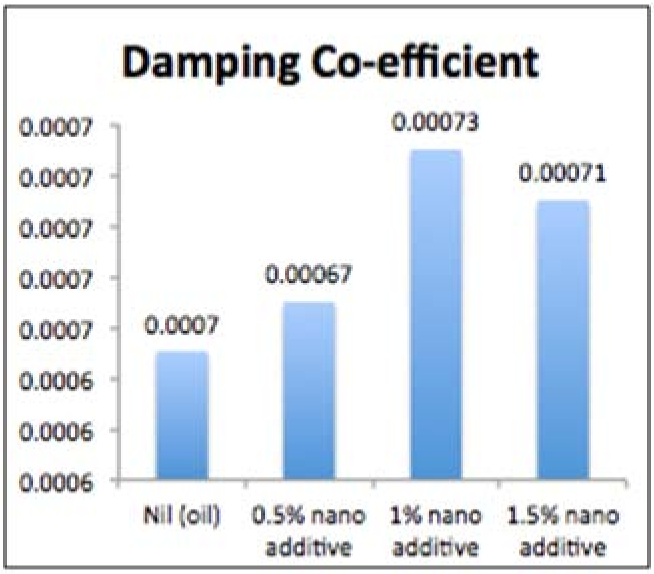

Figure 15: Damping Coefficient with magnetic flux of 4.96 x 10^{-4}Tesla

Effect of addition of Fe_2O_3on damping properties with magnetic flux of 3.44 x 10^{-4} Tesla (Y Tesla)

Table 12: With magnetic flux of 3.44 x 10^{-4} Tesla

Concentration	NIL (Oil)	0.5%	1%	1.5%
Logarithmic Decrement	.3199	.3189	.4418	.03820
Damping Ratio	.0509	.0507	.0702	.0607
Damping Co-efficient	.0007	.00065	.00089	.00078

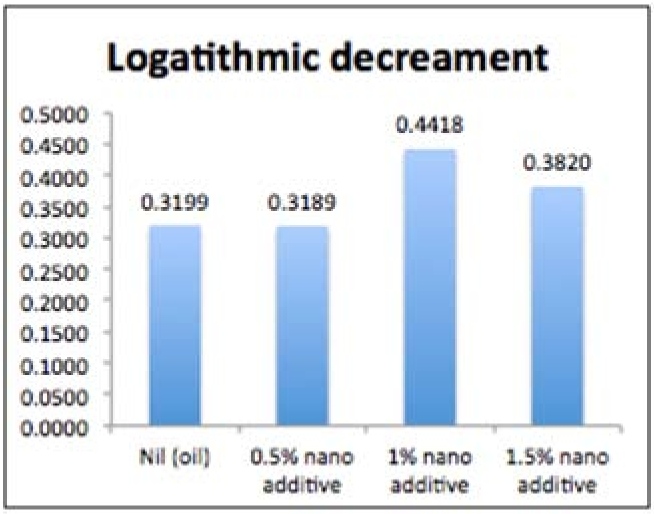

Figure 16: Logarithmic Decrement with Y Tesla

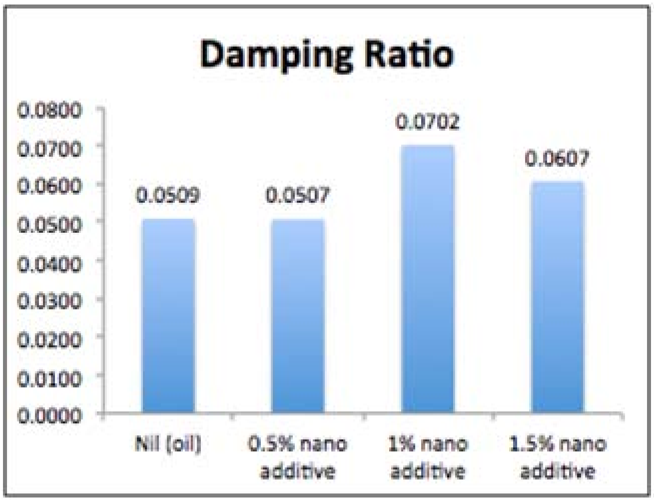

Figure 17: Damping Ratio with Y Tesla

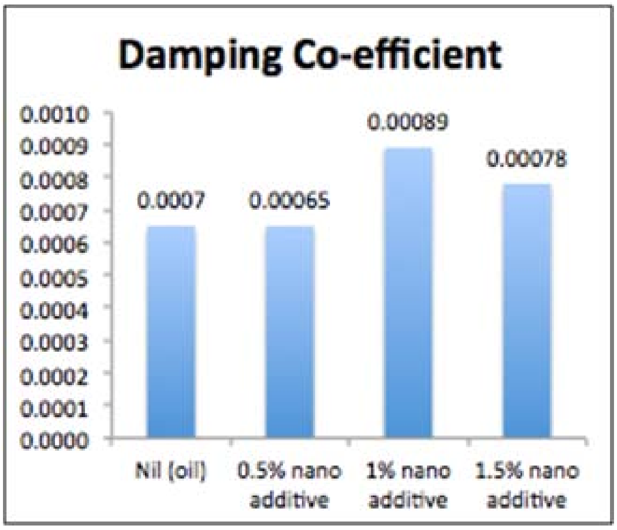

Figure 18: Damping Coefficient with Y Tesla

8. Results & Conclusion

The comparison of concentration of nano particles without magnetic flux, with magnetic flux of x and y tesla is studied and logarithmic decrement, damping ratio and damping co-efficient are as discussed as below.

Table 13: Logarithmic Decrement

Concentration	Nil (Oil)	0.5%	1%	1.5%
Logarithmic decrement	.3199	.3507	.3536	.4418
	.3199	.3277	.3573	.3485
	.3199	.3189	.4418	.3820

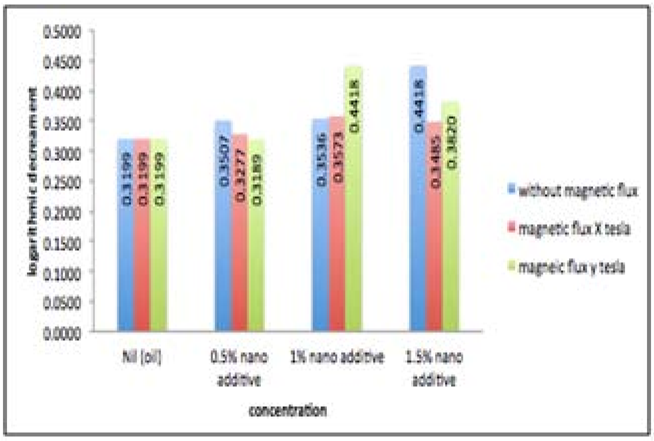

Figure 19: Logarithmic Decrement

Table 14: Damping Ratio

Concentration	Nil (Oil)	0.5%	1%	1.5%
Damping Ratio	.0509	.0558	.0562	.0702
	.0509	.0521	.0568	.0554
	.0509	.0507	.0702	.0607

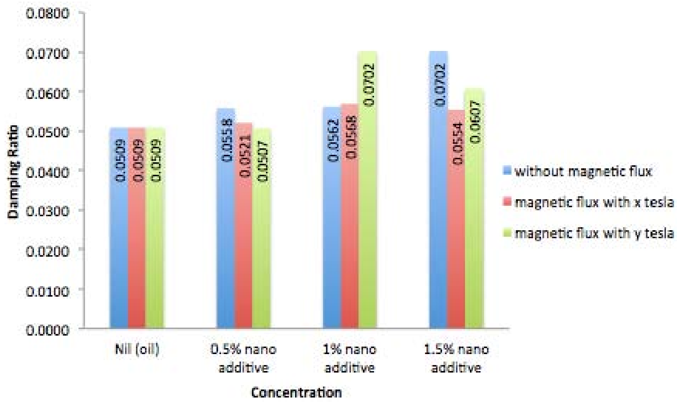

Figure 20: Damping Ratio

Table 15: Damping Coefficient

Concentration	Nil (Oil)	0.5%	1%	1.5%
Damping Coefficient	.0007	.0007	.0007	.0009
	.0007	.00067	.00073	.00071
	.0007	.00065	.00089	.00078

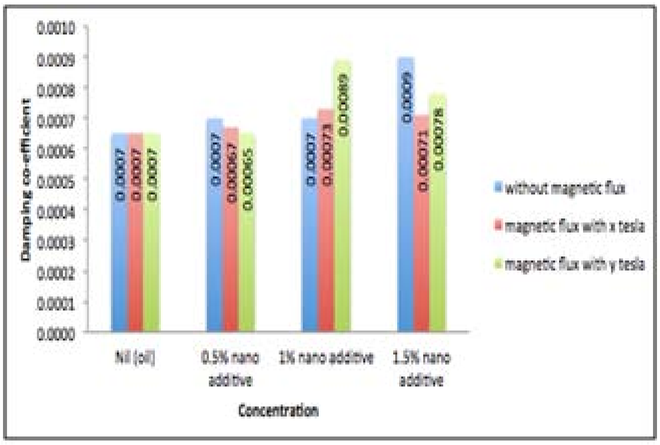

Figure 21: Damping Coefficient

Thus, it was found that at 1% concentration of nano additive, and with y tesla of magnetic field and at 1.5% concentration of nano additive, without any magnetic field applied, an improvement of 38.49% was seen in the logarithmic decrement.

An improvement of 37.91% was found in the damping ratio when the concentration of nano additives was 1.5% and no magnetic field was applied.

Also, an increment of 28.57% was found in the damping coefficient with an addition of 1.5% concentration of nano additive and no magnetic field.

9. Acknowledgment

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