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Vibration Control of Variable Speed Rotating Beams by Using Semi Fluids

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I. Introduction

1.1 Vibration control of rotating flexible beams.

Rotating flexible beams are found in many practical applications. It can be seen in robot arms, turbine blades ,and aircraft rotary wings. Generally, severe transverse vibration occurring in such systems may cause the degradation in performance and accuracy, and even the failure of such elements..

Many studies has been directed towards the development of various control approaches to damp out the vibration of rotating beams. These techniques mainly fall into two categories: passive control and active control. In the former, constrained viscoelastic damping layers are usually used to attenuate the vibration of rotating beams. This method is conventional and well developed. However, the passive approach suffers from the major drawback of being ineffective at low frequencies. In the active control systems, the piezoelectric composites are used extensively. In the present study, a new approach, embedding fluid into the sandwich structure, is considered to suppress the vibration of rotating beams. The viscous fluids can change its physical properties such as viscosity and shear modulus. In this experimental approach the results were obtained by embedding a semi fluid such as grease in between two aluminium surface plates.

The experiment was conducted by using different grades of grease such as NLGI 2,NLGI 3,EPL and RBC.These different grades of grease have different viscosities. The test was conducted with the help of an experimental setup which consists of a stepper motor, a microcontroller and a switch. The various results for displacement and acceleration were plotted with the help of LabVIEW software. The stepper motor can be rotated at various RPM ranging from 30 to 90 with the help of microcontroller. The results have shown that the beam with high viscous fluid has high vibration attenuation capacity. Similarly a viscous fluid with low viscosity also attenuates vibration. This occurs due to the occurrence of a coriolis component of force which absorbs energy from the solid material like aluminium and thereby induces damping.

II. Theory

In continuous system, it is not possible to identify discrete masses, dampers or springs. We are considering that the system is having continuous distribution of mass, damping and elasticity. In this system infinite number of points of the system can vibrate. That is why a continuous system is called a system with infinite number of degrees of freedom [1]. If the system is modelled as a continuous one the governing equation in the system is partial differential equations. We need to apply the boundary conditions to find the natural frequencies of a continuous system. The emphasis of this work is to experimentally present and discuss the feasibility of using viscous fluid in controlling the Suppressing the vibration of the arm tip in a very short time becomes more and more important in the field of semiconductor and electronic components manufacturing.

In this study, an viscous sandwich beam specimen, in which a grease layer is sandwiched between two aluminium surface layers, is constructed. An experiment setup is established to investigate the effect of the viscous fluid on vibration suppression of the rotating beams. Vibration control responses subjected to different angular speeds are plotted with the help of LabVIEW software.

III. Literature Review

The main idea for doing this project was obtained from a science direct journal named vibration control of variable speed/acceleration rotating beams by using smart materials. In that journal vibration control was achieved by using Electrorheological fluids in place of viscous semifluids.Several experiments were also conducted in getting the vibration responses of sandwich beams with the help of piezoelectric composites. The ER fluid or generally the smart materials can change its physical properties such as viscosity and shear modulus. These can be changed instantaneously and reversibly. Recent developments in smart materials and their potential structural applications have resulted in significant improvements in vibration control problems. Enhanced actuation and sensing capabilities of the smart materials have led to effective means of handling unwanted vibrations in automobile and aerospace industries. Varied physical phenomena such as the piezoelectric effect, magnetostriction, and electrostriction underpin the functioning of these materials.

IV. Experimental Layout

The beam specimen, as shown in Fig. 2, is treated with viscous fluid layer which confined by a 2mm rubber dam on the edges sandwiched between two aluminium face-plates. At one end of the beam, a glass/epoxy pad with a length 20mm and width 35mm is used as the mid-layer to provide the rigidity for the clamping force. The viscous fluid used in this study is Grease. The test beam was clamped at a rotating platform driven by a variable speed stepper motor in a cantilevered configuration. For adjusting the speed of stepper motor a pick was programmed to obtain rotation of the beam from 0 degree to 180 degree. The speed can be adjusted by means of a switch. The deflection at the tip end of the beam was found out with the help of an accelerometer. By the vibration theory, beam is a continuous system. The test is being carried out at different speeds of 30,60 and 90 RPM.Five beams were constructed one without grease and the other four with different grades of grease such as NLGI 2,NLGI 3,EPL and RBC. It is having a length of 15cm and a width of 35mm.The aluminium plates has a thickness of 0.4mm.

A stepper motor is the one which can give angular displacements in steps. It can give precise angular movements. Here the stepper motor used is having steps of range 120 steps/rev.

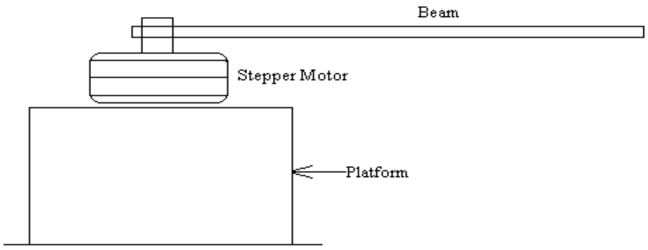


Figure 1. Schematic diagram of Experimental setup

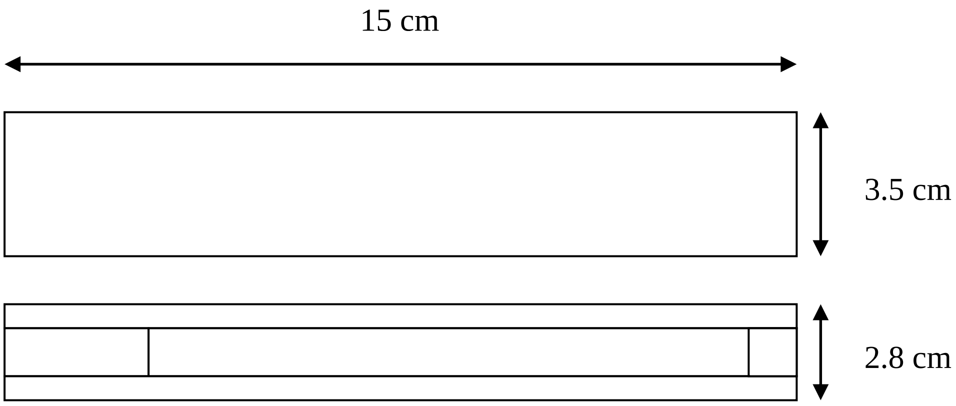


Figure 2. Dimensions of the beam

The schematic diagram of the experimental setup is shown below. It consists of a micro controller which is programmed to give angular rotations from zero to 180 degree and then in backtracking. Two switches are provided to adjust the speed of the motor. The motor speed can be changed from 30 RPM to 100 RPM.A transformer is used to step down the voltage.

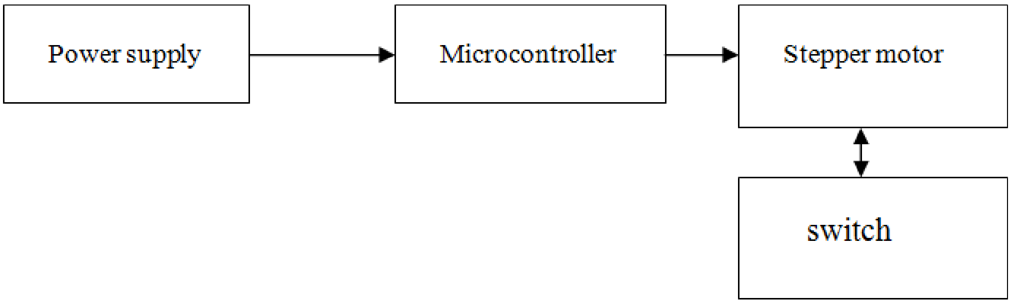


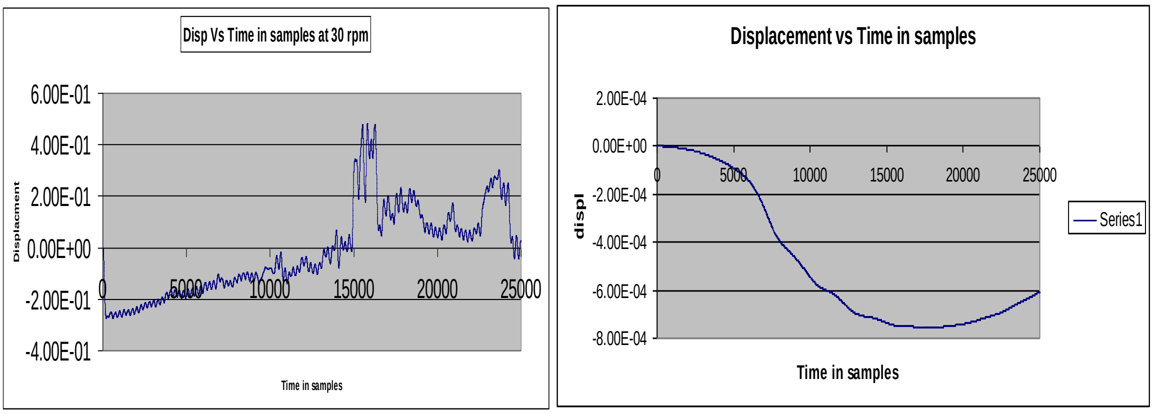
Figure 3.Schematic diagram of components in the experimental setup

Labview

LabVIEW is a virtual analysis tool. “LabVIEW” package is one of the important works of National Instruments. This package is specifically designed to permit us to quickly implement a Computer-controlled data gathering and analysis system which can be extensively customised to suit our needs. It is a very capable package, but is probably unlike anything we have met before. There is therefore going to be a steep learning curve ahead of us before we will be able to be proficient in such work.LabVIEW is an entirely graphical language which looks somewhat like an electronic schematic diagram on the one hand and a 1950's vintage style electronic instrument on the other, these are the concepts of the block diagram and the front panel. LabVIEW is hierarchical in that any virtual instrument that we design (any complete functional unit is called a virtual instrument and is almost always referred to as a “VI”) can be quickly converted into a module which can be a sub-unit of another VI. This is entirely analogous to the concept of a procedure in conventional Programming. LabVIEW is also designed to be extendible. We can add modules also.

V. Results And Discussions

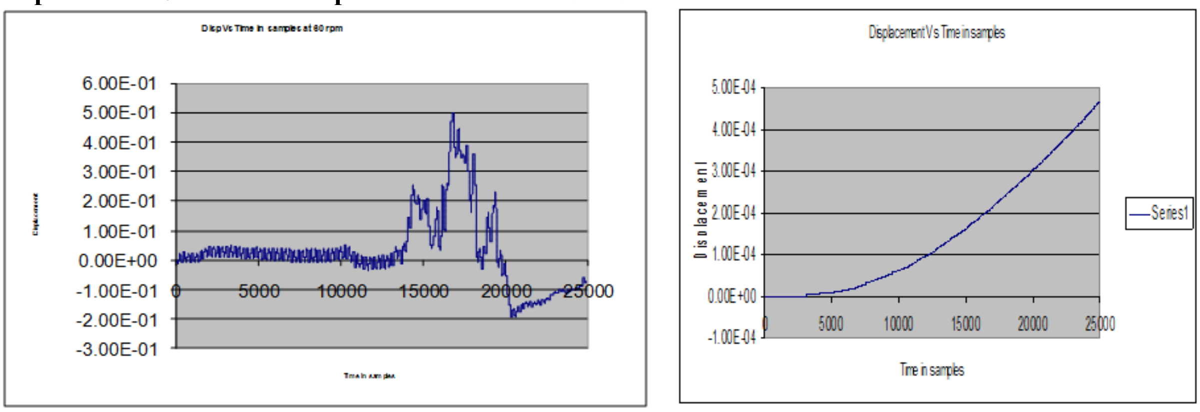
Results for vibration of beam in comparison with NLGI 2 At 30 RPM
Displacement Vs Time in samples for beams without fluid and NLGI 2



Graph 1 a) Graph without fluid b)Graph with NLGI2

At 30 rpm we can see from the results that the vibration is getting controlled, while the beam is filled with grease having grade NLGI 2. The two graphs at 30 rpm for the displacement clearly show that displacement is getting marginally reduced. The maximum amplitude at 30 rpm without grease was .05.But with grease it has reduced to a value of -.0007.The vibration responses of the beam without fluid clearly shows that the damping is very less. We obtain a clear vibration pattern at this rpm for the beam without fluid. But for the beam with NLGI 2 the vibration is getting attenuated. the displacement range is very less. The grease with this grade has a viscosity higher than NLGI 3 ,EPL, RBC etc. So more damping is obtained here. The highest peak is obtained in both the cases in the region were the beam backtracks. At the time of backtracking the beam suddenly stops and then returns. So at the time of stopping it vibrates more.

At 60 RPM
Displacement Vs Time in samples for beams without fluid and NLGI 2

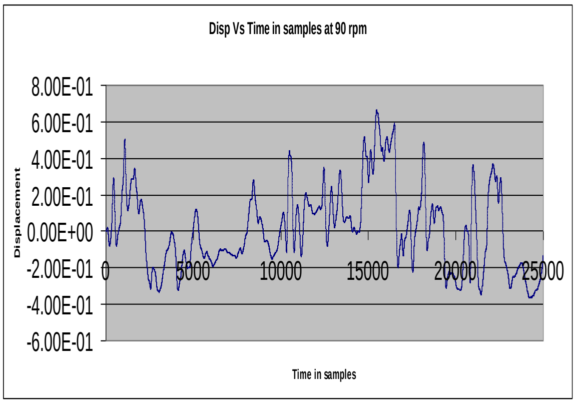


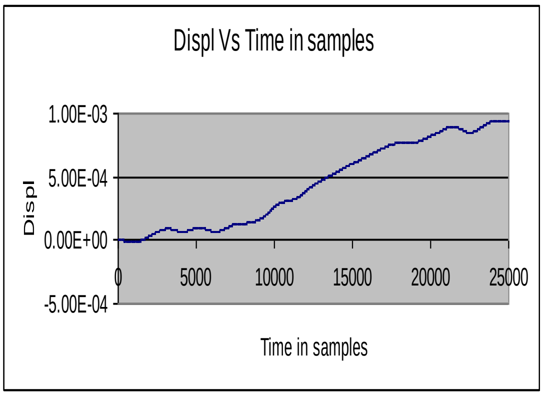
Graph 2 a) without fluid b) with NLGI 2

At 60 rpm we can see from the results that the vibration is getting controlled, while the beam is filled with grease having grade NLGI 2. The two graphs at 60 rpm for the displacement clearly show that displacement is getting marginally reduced. The maximum amplitude at 60 rpm without grease was .053.But with grease it has reduced to a value of -.00045.The value of deflection in both cases has increased while comparing with 30 RPM.This is due to the fact that at higher RPM the deflection will be more. The vibration responses of the beam without fluid clearly show that the damping is very less. We obtain a clear vibration pattern at this rpm for the beam without fluid. But for the beam with NLGI 2 the vibration is getting attenuated. the displacement range is very less. The grease with this grade has a viscosity higher than NLGI 3 ,EPL, RBC etc. So more damping is obtained here.

At 90 RPM

Displacement Vs Time in samples for beams without fluid and NLGI 2





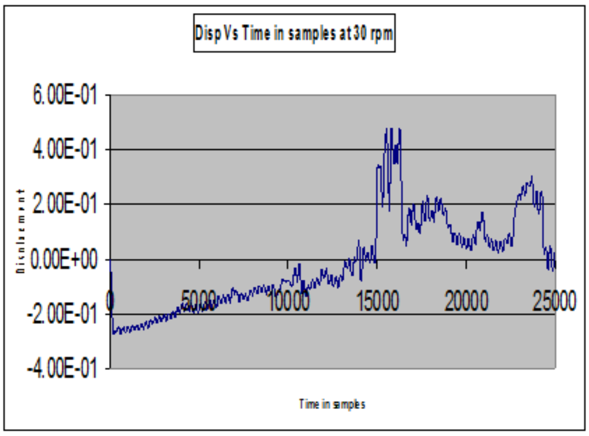
Graph 3 a) without fluid b) with NLGI 2

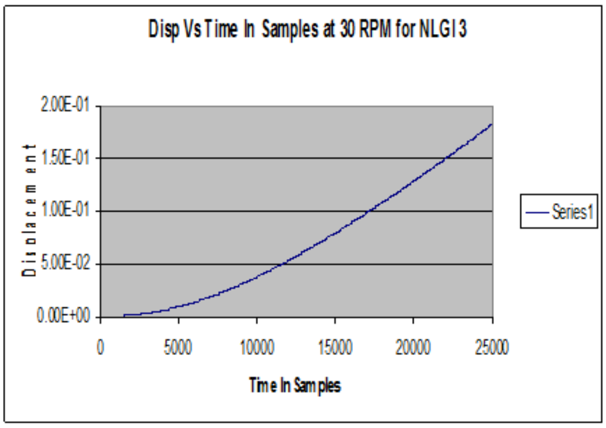
At 90 rpm we can see from the results that the vibration is getting controlled, while the beam is filled with grease having grade NLGI 3. The two graphs at 90 rpm for the displacement clearly show that displacement is getting reduced. The maximum amplitude at 90 rpm without grease was .07.But with grease it has reduced to a value of .001. The vibration responses of the beam without fluid clearly show that the damping is very less.

Results for vibration of beam in comparison with NLGI 3

At 30 RPM

Displacement Vs Time in samples for beams without fluid and NLGI 3

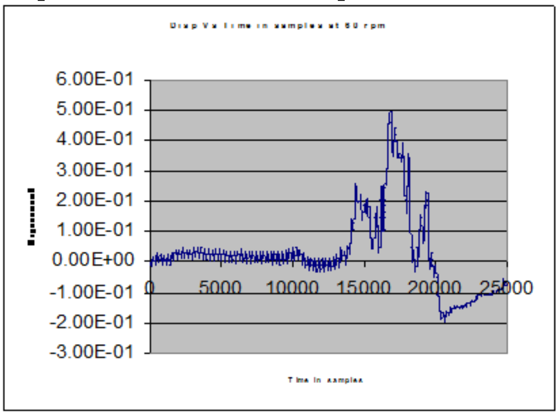


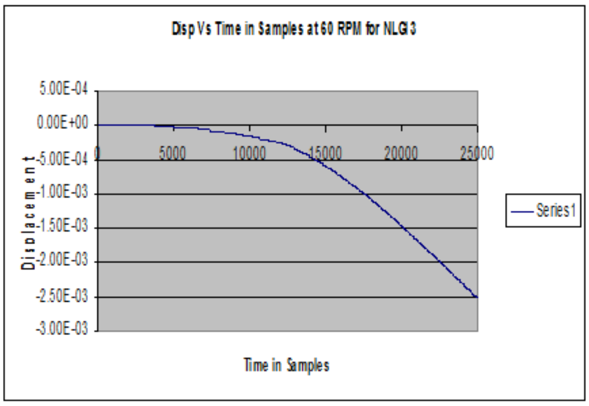


Graph 4 a) without fluid b) with NLGI 3

At 30 rpm we can see from the results that the vibration is getting controlled, while the beam is filled with grease having grade NLGI 3. The two graphs at 30 rpm for the displacement clearly show that displacement is getting reduced. The maximum amplitude at 30 rpm without grease was .05.But with grease it has reduced to a value of -.017. The vibration responses of the beam without fluid clearly show that the damping is very less. We obtain a clear vibration pattern at this rpm for the beam without fluid. But for the beam with NLGI 3 the vibration is getting attenuated. the displacement range is very less. The grease with this grade has a viscosity less than NLGI 2.So damping is less when comparing with the vibration response at 30 rpm of NLGI 2.

At 60 RPM
Displacement Vs Time in samples for beams without fluid and NLGI 3

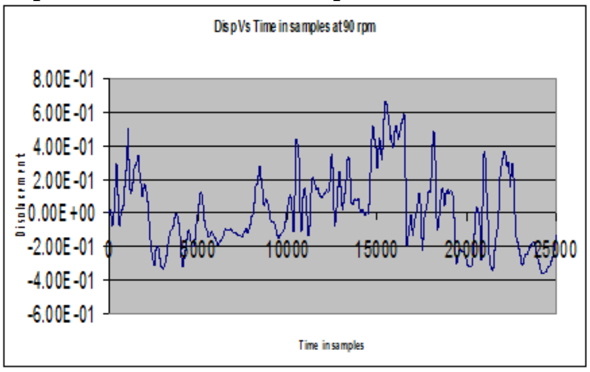


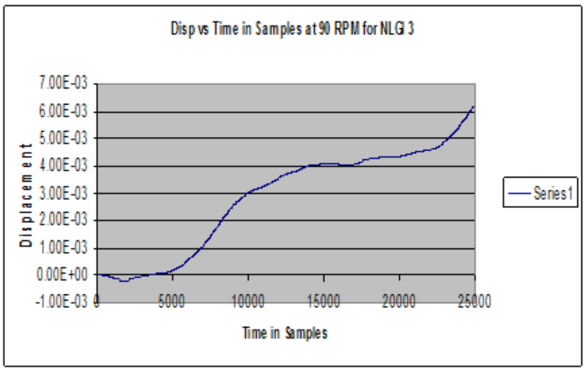


Graph 5 a) without fluid b) with NLGI 3

At 60 rpm we can see from the results that the vibration is getting controlled, while the beam is filled with grease having grade NLGI 3. The two graphs at 60 rpm for the displacement clearly show that displacement is getting marginally reduced. The maximum amplitude at 60 rpm without grease was .053.But with grease it has reduced to a value of -.00025. The vibration responses of the beam without fluid clearly show that the damping is very less. The value of displacement is less when comparing it with beam filled with NLGI 3.This is due to the fact that NLGI 3 is having less viscosity when comparing with other fluids.

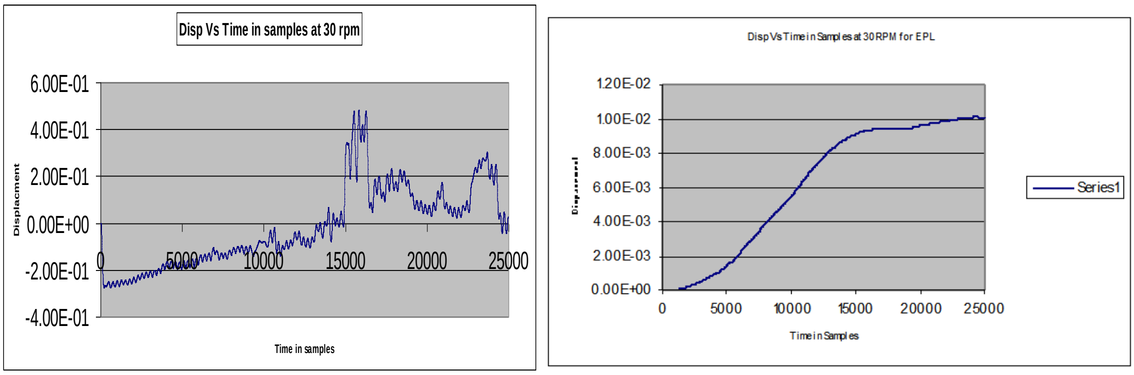
At 90 RPM
Displacement Vs Time in samples for beams without fluid and NLGI 3





At 90 rpm we can see from the results that the vibration is getting controlled, while the beam is filled with grease having grade NLGI 3. The two graphs at 90 rpm for the displacement clearly show that displacement is getting reduced. The maximum amplitude at 90 rpm without grease was .07.But with grease it has reduced to a value of .0006. The vibration responses of the beam without fluid clearly show that the damping is very less.

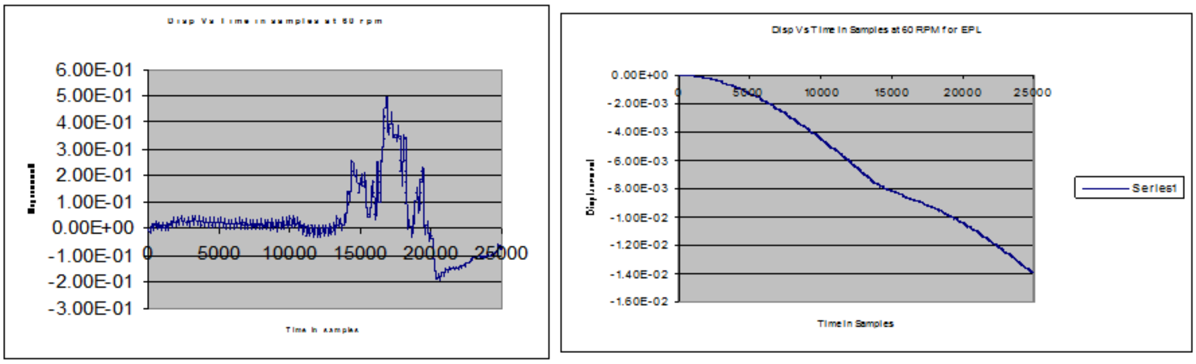
Results for vibration of beam in comparison with EPL
At 30 RPM
Displacement Vs Time in samples for beams without fluid and EPL



Graph 7 a) without fluid b) with EPL

At 30 rpm we can see from the results that the vibration is getting controlled, while the beam is filled with grease having grade EPL. The two graphs at 30 rpm for the displacement clearly show that displacement is getting reduced. The maximum amplitude at 30 rpm without grease was .05.But with grease it has reduced to a value of .01. The vibration responses of the beam without fluid clearly show that the damping is very less. We obtain a clear vibration pattern at this rpm for the beam without fluid. But for the beam with EPL the vibration is getting attenuated. The displacement range is very less. The grease with this grade has a viscosity less than NLGI 2 and NLGI 3.So damping is less when comparing with the vibration response at 30 rpm of NLGI 2 and NLGI 3.

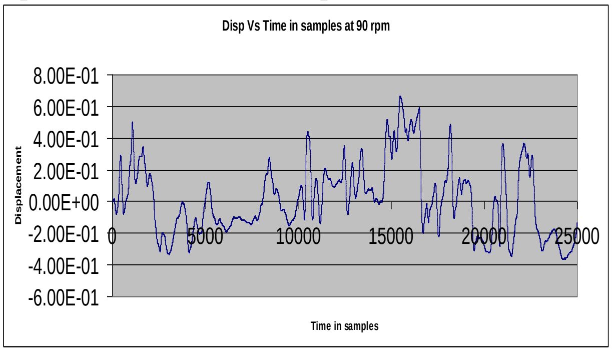
At 60 RPM
Displacement Vs Time in samples for beams without fluid and EPL

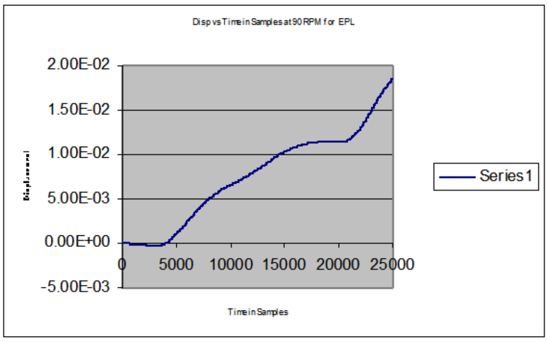


Graph 8 a) without fluid b) with EPL

At 60 rpm we can see from the results that the vibration is getting controlled, while the beam is filled with grease having grade NLGI 3. The two graphs at 60 rpm for the displacement clearly show that displacement is getting marginally reduced. The maximum amplitude at 60 rpm without grease was .053.But with grease it has reduced to a value of -.014. The vibration responses of the beam without fluid clearly show that the damping is very less. The value of displacement is less when comparing it with beam filled with NLGI 2 and NLGI 3.This is due to the fact that EPL is having less viscosity when comparing with NLGI 2 and NLGI 3.

At 90 RPM
Displacement Vs Time in samples for beams without fluid and EPL

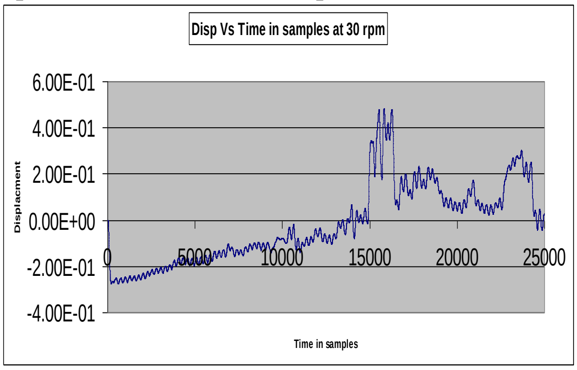


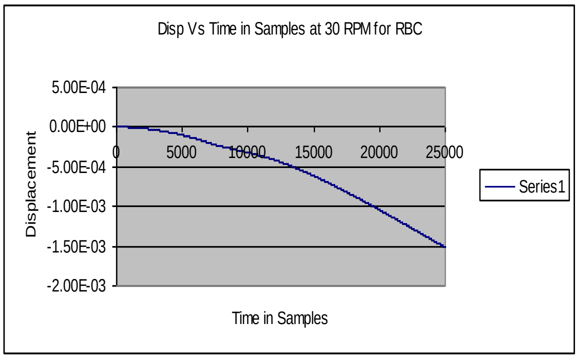


Graph 9 a) without fluid b) with EPL

At 90 rpm we can see from the results that the vibration is getting controlled, while the beam is filled with grease having grade NLGI 3. The two graphs at 90 rpm for the displacement clearly show that displacement is getting reduced. The maximum amplitude at 90 rpm without grease was .07.But with grease it has reduced to a value of .02. The vibration responses of the beam without fluid clearly show that the damping is very less.

Results for vibration of beam in comparison with RBC
At 30 RPM
Displacement Vs Time in samples for beams without fluid and RBC



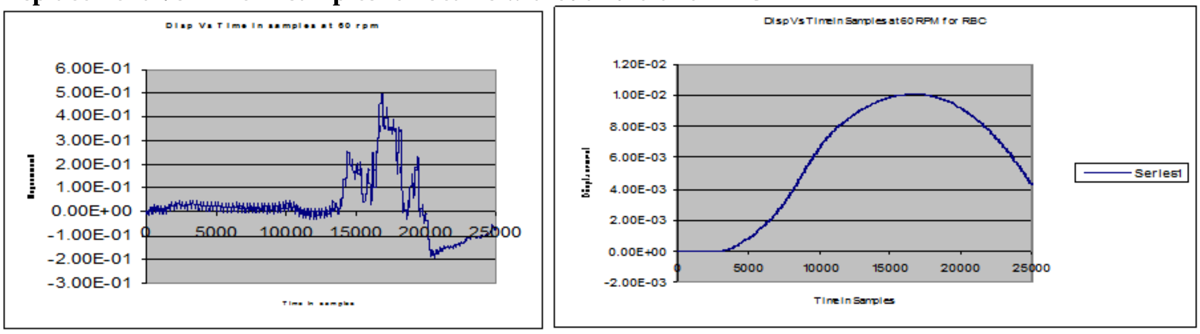


Graph 10 a) without fluid b) with RBC

At 30 rpm we can see from the results that the vibration is getting controlled, while the beam is filled with grease having grade RBC. The two graphs at 30 rpm for the displacement clearly show that displacement is getting reduced. The maximum amplitude at 30 rpm without grease was .05.But with grease it has reduced to a value of -.0015. The vibration responses of the beam without fluid clearly show that the damping is very less. We obtain a clear vibration pattern at this rpm for the beam without fluid. But for the beam with RBC the vibration is getting attenuated. The displacement range is very less.

At 60 RPM

Displacement Vs Time in samples for beams without fluid and RBC

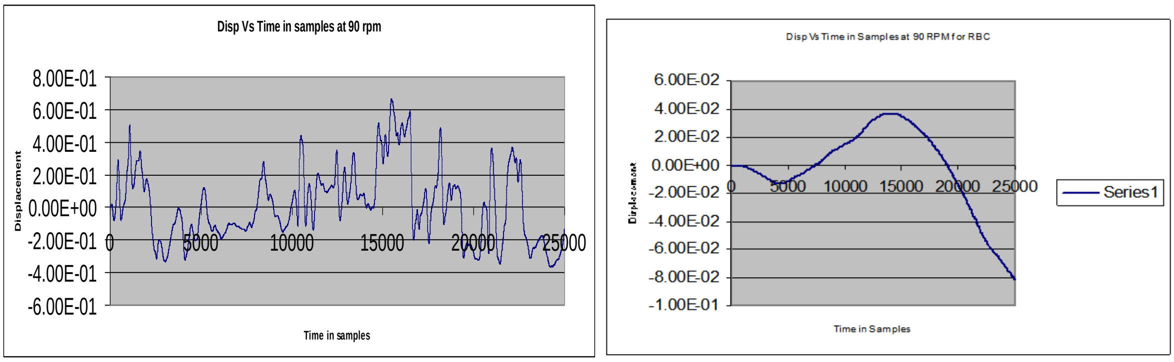


Graph 11 a) without fluid b) with RBC

At 60 rpm we can see from the results that the vibration is getting controlled, while the beam is filled with grease having grade RBC. The two graphs at 60 rpm for the displacement clearly show that displacement is getting marginally reduced. The maximum amplitude at 60 rpm without grease was .053.But with grease it has reduced to a value of .01. The vibration responses of the beam without fluid clearly show that the damping is very less.

At 90 RPM

Displacement Vs Time in samples for beams without fluid and RBC



Graph 12 a) without fluid b) with RBC

At 90 rpm we can see from the results that the vibration is getting controlled, while the beam is filled with grease having grade RBC. The two graphs at 90 rpm for the displacement clearly show that displacement is getting reduced. The maximum amplitude at 90 rpm without grease was .07.But with grease it has reduced to a value of .04. The vibration responses of the beam without fluid clearly show that the damping is very less than the beam filled with grease.

In all the cases where the experiment is being carried out with RBC grease vibration is getting attenuated marginally or it produces similar damping as that of NLGI 2 ,NLGI 3 and EPL.This is due to the fact that in low viscous fluids the particle will be in random motion with each other.This induces a coriolis component in the fluid particles. The instability of solid which is undergoing vibration induces coriolis force and centrifugal force in the fluid thereby absorbs energy from solid and attenuates vibration.

VI. Conclusion

From the various results we can see that the vibration is getting reduced upto a marginal extend. The fluid with high viscosity can attenuate vibration more. Similar is the case with low viscous fluid due to the development of a coriolis component of force. This is due to the fact that the fluid with the solid forms a compound structure. The instability of the solid structures induces the fluid vibration and produces the Coriolis force and centrifugal force in fluid .The fluid absorbs the energy from the solid structure and suppresses its vibration [7].

The same experiment can be done by using ER fluid or MR fluid in place of grease and that might give some better results, since the change in applied voltage or magnetic field in both the fluids respectively can actively control the vibration. This is the future scope of this project.

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