ME351: Lab Report

Experiment 3: Universal Joint

Group 6 | Week 7

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Under the Guidance of
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1. Objective

The objective of this experiment is to design and fabricate a universal joint that can effectively transmit motion between two inclined shafts. The universal joint will be able to handle the misalignment between the two shafts and provide a flexible connection that can transmit motion at variable angles.

The experiment aims to achieve the following specific objectives:

- To design and fabricate a physical model of a universal joint that can effectively connect two inclined shafts.
- To measure the input and output angular speeds of the universal joint while the input shaft is driven by a motor.
- To analyze the data collected during the experiment to determine the efficiency of the universal joint in transmitting motion between two inclined shafts.
- To make observations and draw conclusions on the performance of the universal joint, its advantages, limitations, and potential areas of improvement.

2. Experimental design and Fabrication details

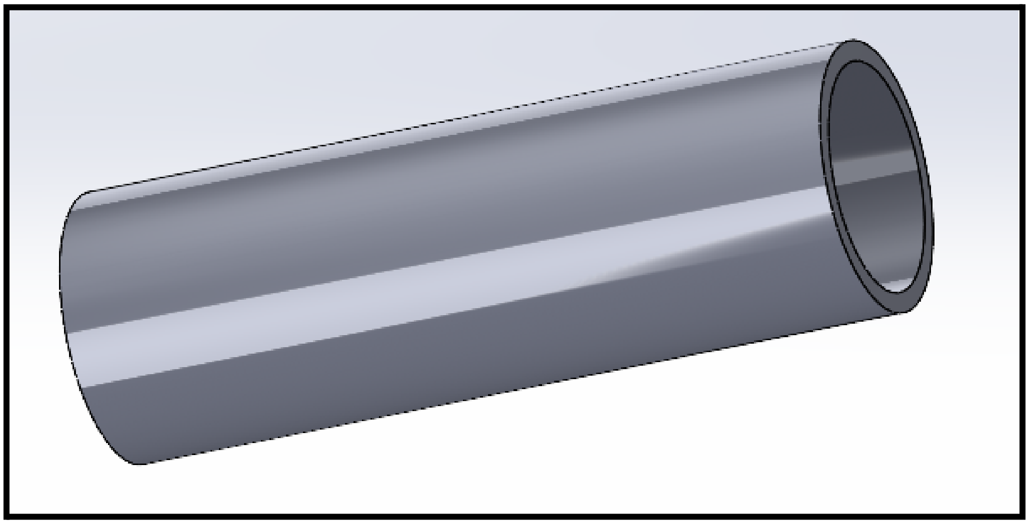
The experimental design and fabrication process for the universal joint to transmit motion between two inclined shafts is as follows:

1. Designing the Universal Joint: The first step is to design the universal joint that can connect the two inclined shafts. The design should take into account the angle of inclination between the shafts and the torque load that the joint is expected to handle.
2. Fabrication of the Universal Joint: The fabrication process involves 3d printing, cutting, shaping, and assembling the various components of the universal joint. The joint should be able to handle the misalignment between the two shafts and provide a flexible connection that can transmit motion at variable angles.
3. Mounting the Motor: The input shaft should be driven by a motor that can provide the necessary torque to test the universal joint. The motor should be mounted securely and aligned properly with the input shaft.
4. Measuring the Output Angular Speed: The output angular speed of the universal joint should be measured using an appropriate instrument such as a tachometer or a speedometer. The speed should be measured at different angles of inclination and torque loads to study the behavior of the joint under different operating conditions.
5. Analysis of Results: The data collected during the experiment should be analyzed to determine the efficiency of the universal joint in transmitting motion between two inclined shafts. The results should be used to make observations and draw

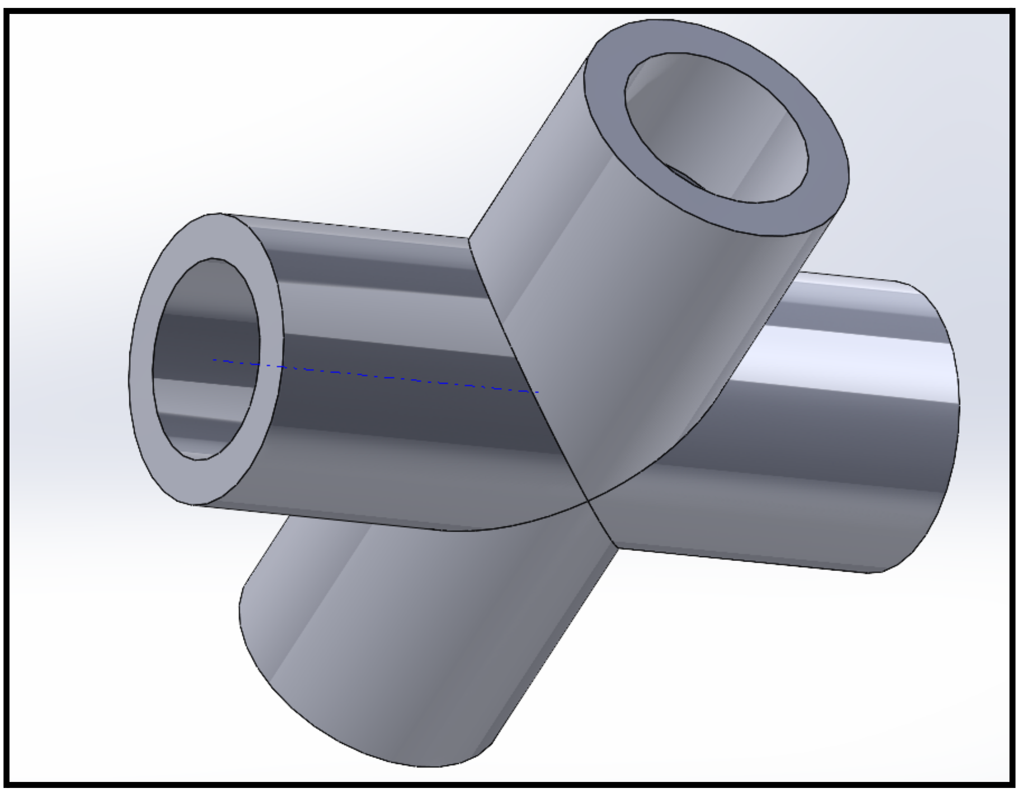
conclusions on the performance of the universal joint, its advantages, limitations, and potential areas of improvement.

CAD of various parts:

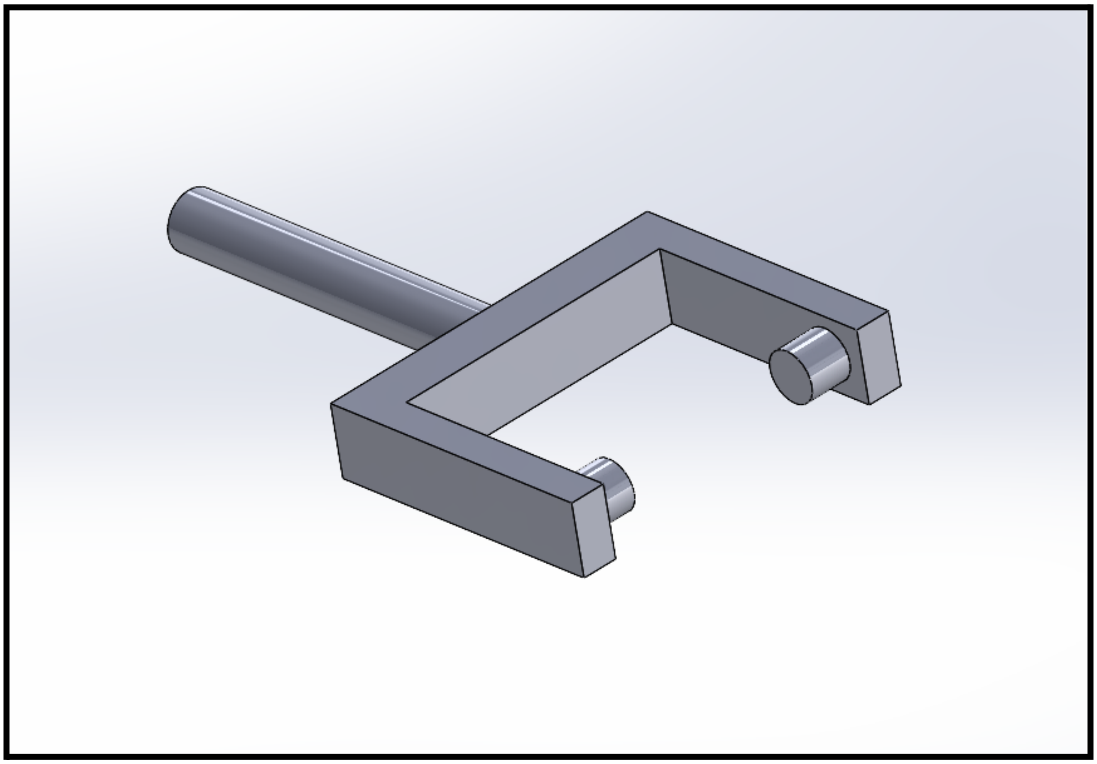
1. **Connector**



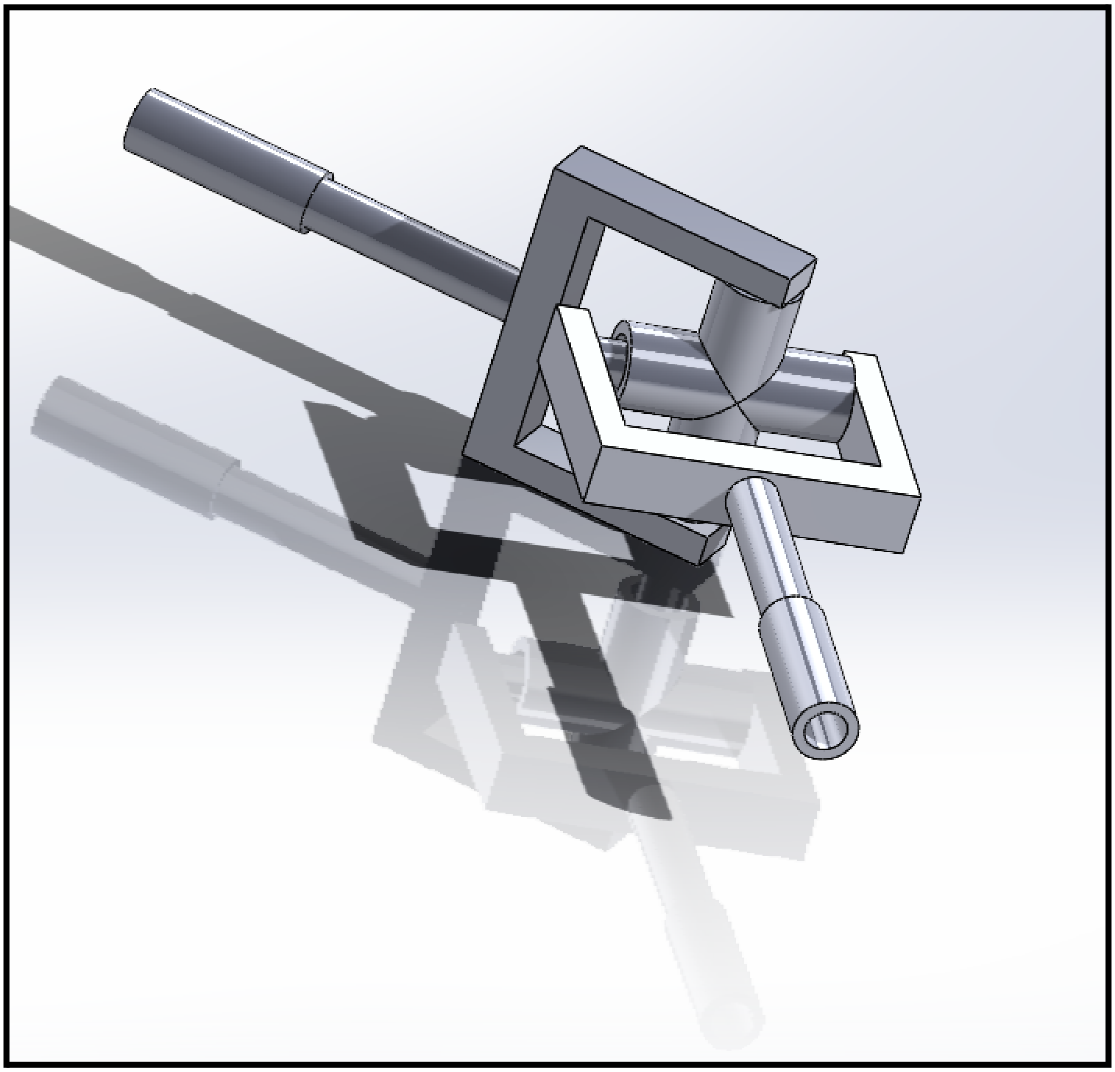
2. **Cross**



3. Fork

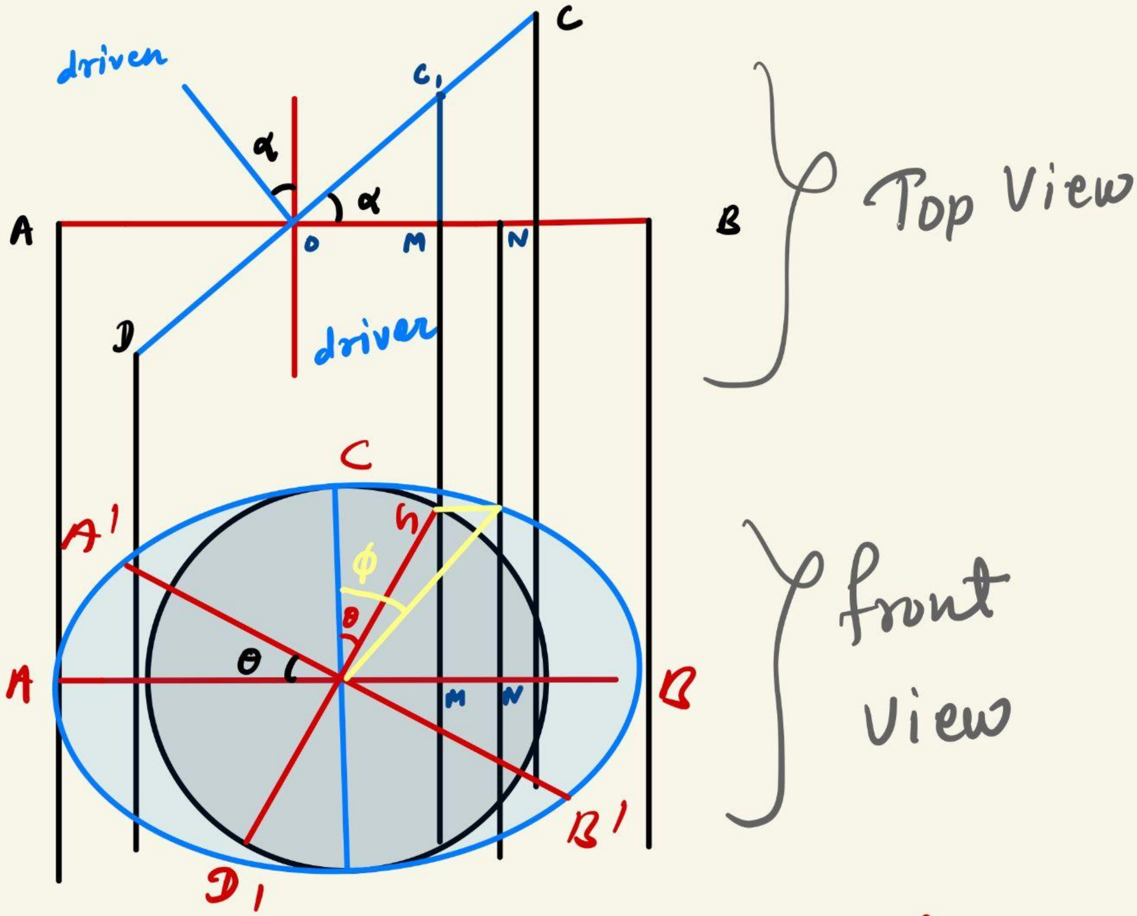


Assembly:



3. Mathematical and Theoretical Analysis:

Imagine a circle with a line in the middle (called the driver yoke), and another line connected to it (called the driven yoke). If the driver yoke is rotating at a steady speed, the driven yoke will move in a circular path around it. But if you look at it from a certain angle, it will look like the driven yoke is moving in an oval-shaped path instead of a circle. When the driver yoke moves a certain angle, the driven yoke will also move that same angle in the oval-shaped path, but it's actually rotating a different angle (shown in a picture).



here, θ = Angle turned by driver shaft

$\omega = \frac{d\theta}{dt}$ → Angular velo^ of driver shaft

ϕ = Angle turned by driven shaft

$\omega_1 = \frac{d\phi}{dt}$ = Angular velocity of driven shaft

α = Angle between driver and driven shaft from ΔOC_1M, we have

$$\tan\theta = \frac{OM}{C_1M} \quad \text{——— (1)}$$

$$OM = ON\cos\alpha \quad \text{——— (2)}$$

from ΔOC_2M, we get

$$\tan\phi = \frac{ON}{C_1N} = \frac{ON}{C_1M} \quad \text{——— (3)}$$

Now, by using eq^n (1), (2) & (3)

$$\frac{\tan\theta}{\tan\phi} = \frac{OM}{ON} = \cos\alpha$$

$$\Rightarrow \tan\theta = \tan\phi\cos\alpha \quad \text{——— (4)}$$

By differentiating the eq^n (4)

$$\sec^2\theta\frac{d\theta}{dt} = \cos\alpha\sec^2\phi\frac{d\phi}{dt}$$

$$\frac{\omega}{\omega_1} = \frac{\sec^2\theta}{\cos\alpha \sec^2\phi} \quad \text{—— (5)}$$

Now, using eq^n (4) & (5)

$$\sec^2\phi = 1 + \tan^2\phi$$

$$\Rightarrow \sec^2\phi = 1 + \frac{\tan^2\theta}{\cos^2\alpha} = \frac{\cos^2\theta\cos^2\alpha + \sin^2\theta}{\cos^2\theta\cos^2\alpha}$$

$$= \frac{\cos^2\theta(1-\sin^2\alpha)+\sin^2\theta}{\cos^2\theta\cos^2\alpha}$$

$$\Rightarrow \sec^2\phi = \frac{1-\cos^2\theta\sin^2\alpha}{\cos^2\theta\cos^2\alpha} \quad \text{—— (6)}$$

Now by using eq^n (5) & (6)

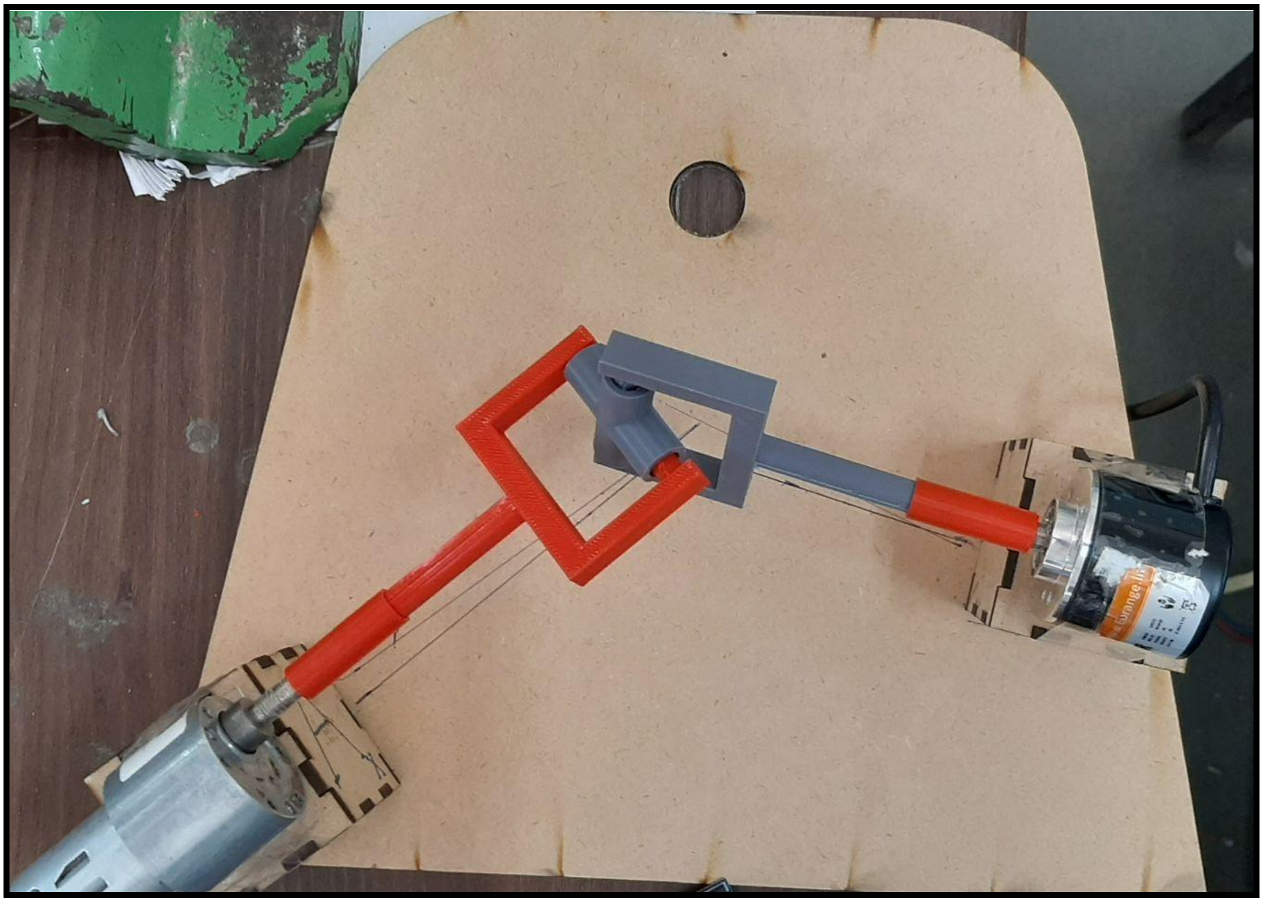
$$\frac{\omega_1}{\omega} = \frac{1}{\cos^2\theta\cos\alpha} \times \frac{\cos^2\theta\cos^2\alpha}{1-\cos^2\theta\sin^2\alpha}$$

$$\boxed{\frac{\omega_1}{\omega} = \frac{\cos\alpha}{1-\cos^2\theta\sin^2\alpha}} \quad \text{— (7)}$$

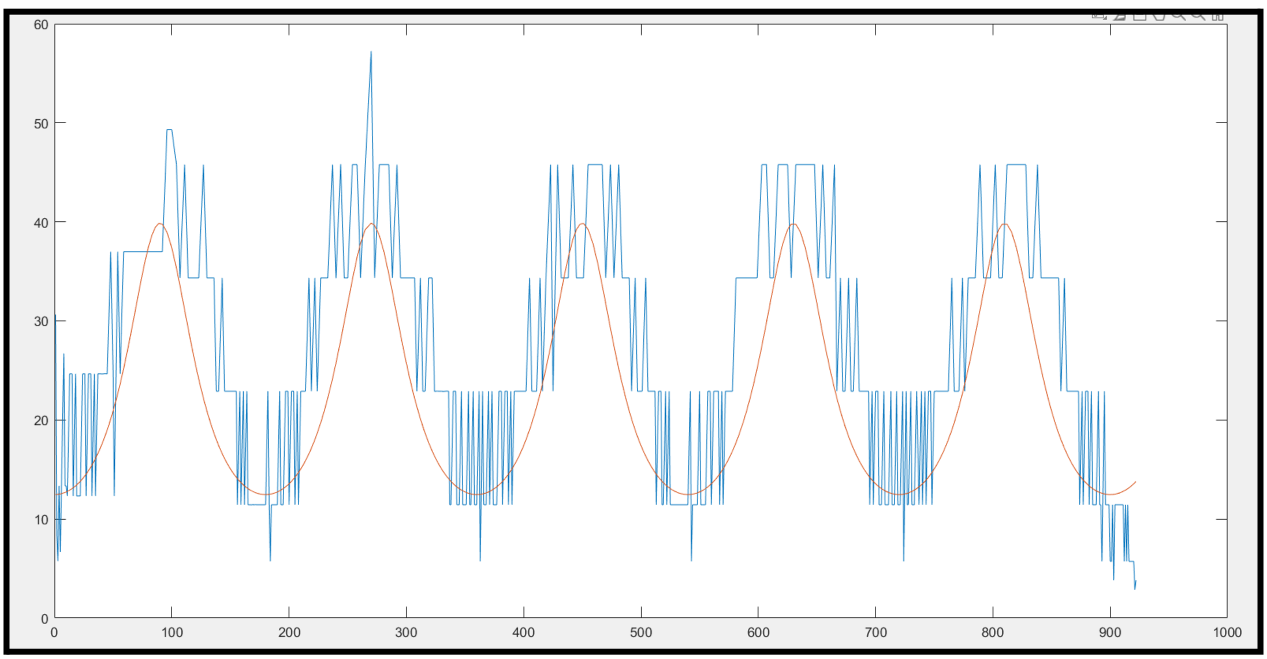
for the same angular speed of driver and driven shaft

$$\frac{\omega_1}{\omega} = \frac{\cos\alpha}{1-\cos^2\theta\sin\alpha}$$

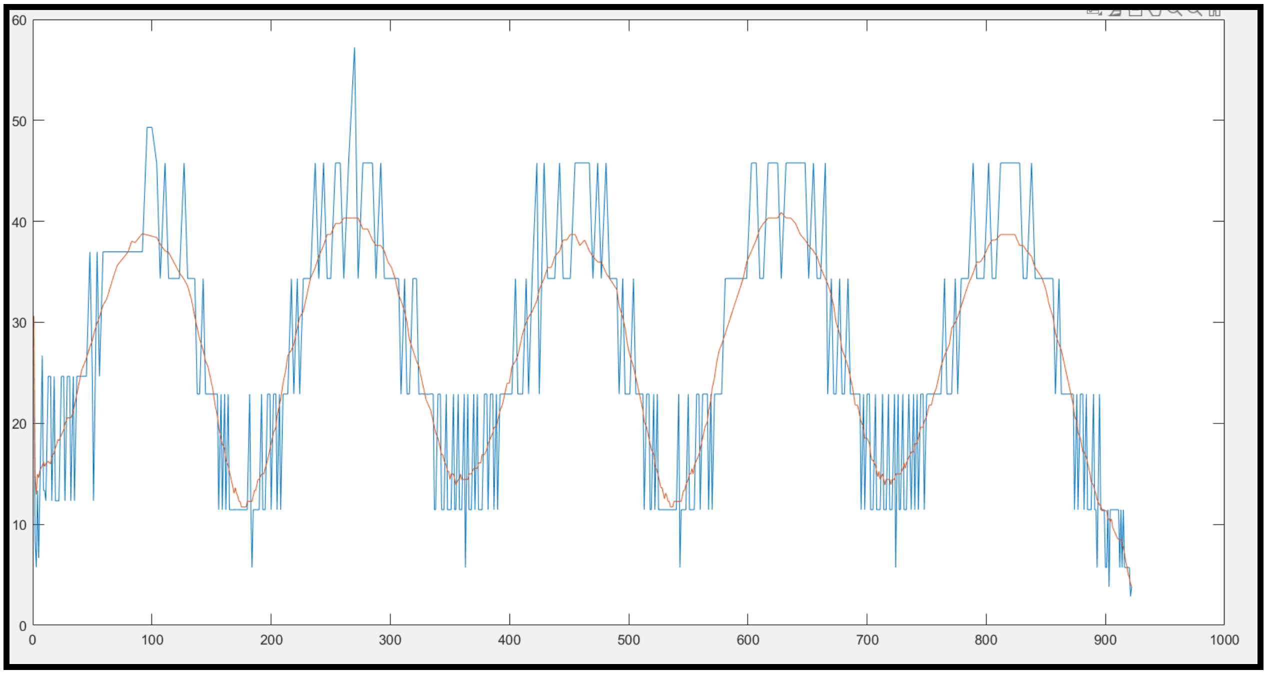
4. Results and discussions



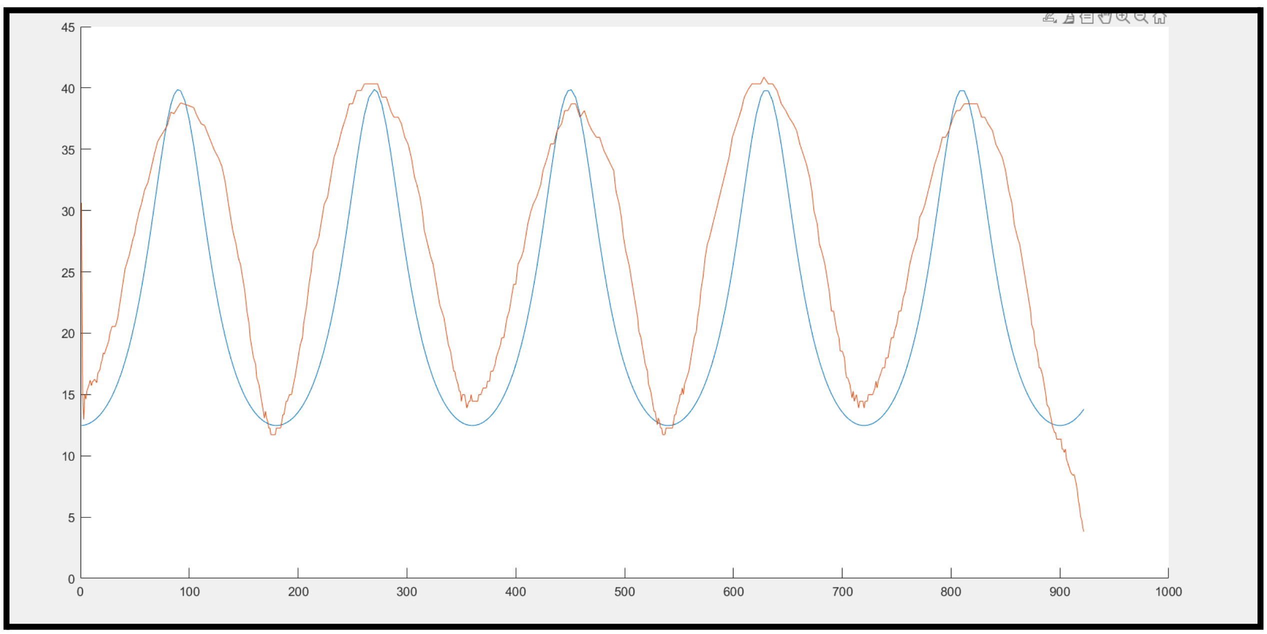
At an angle of 54° with an input angular velocity of 22.3 rpm(avg) the output angular velocity profile was obtained as follows.



Raw output angular velocity and expected result



Raw output angular velocity and smoothened angular velocity plot



Smoothened output angular velocity and expected result

5. Source of discrepancy/mismatch, if any

Mechanical friction: The universal joint and the shafts may have some mechanical friction that can cause energy losses and affect the accuracy of the output angular speed measurement. This friction can be reduced by using high-quality bearings and lubricants.

Misalignment: If the two inclined shafts are not properly aligned, it can cause stress on the universal joint and lead to misalignment, which can affect the accuracy of the output angular speed measurement. It is important to ensure proper alignment of the shafts and the universal joint.

Motor speed variation: The motor speed may vary due to fluctuations in the power supply or due to other factors, which can affect the accuracy of the output angular speed measurement. This can be reduced by using a stable power supply and by measuring the motor speed accurately.

Measurement errors: There may be errors in the measurement of the output angular speed due to factors such as human error, instrument error, or environmental factors such as vibrations or temperature fluctuations. To reduce measurement errors, it is important to use accurate instruments and to take measurements in a stable environment.

Structural rigidity: The universal joint and the shafts may not be structurally rigid, which can lead to flexing and deformation under load. This can affect the accuracy of the output angular speed measurement. It is important to ensure that the universal joint and the shafts are structurally rigid and can withstand the loads they will be subjected to.

6. Scope for improvement

Using a more precise motor: A more precise motor with lower torque ripple and better speed control can improve the accuracy of the output angular speed measurement.

Using higher quality components: Using higher quality universal joints, bearings, and shafts can reduce mechanical friction and improve the accuracy of the output angular speed measurement.

Using a more stable power supply: Using a more stable power supply with lower noise and voltage fluctuations can reduce motor speed variations and improve the accuracy of the output angular speed measurement.

Using more precise measurement instruments: Using more precise measurement instruments such as digital tachometers or optical encoders can improve the accuracy of the output angular speed measurement.

Minimizing sources of error: Minimizing sources of error such as measurement errors, misalignment, and structural rigidity issues can improve the accuracy of the output angular speed measurement.

Conducting multiple trials: Conducting multiple trials and taking an average of the measurements can help reduce the impact of any errors or fluctuations, and improve the accuracy of the results.

7. Acknowledgements

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8. References

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