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Design, Fabrication and Performance Evaluation of a Low-Cost Rod Twisting Machine.

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ABSTRACT

This study presents the design, fabrication, and performance evaluation of a low-cost rod twisting machine using locally available materials. The machine was developed to improve productivity, consistency, and efficiency compared to manual twisting methods. Mild steel rods of diameters 6 mm to 16 mm (500 mm length) were tested under identical operating conditions. The required torque was determined using torsion theory, and a 3 kW electric motor was selected based on power requirements. Experimental results showed that twisting time increased from 7.7 s to 26.0 s with increasing rod diameter, the number of twists decreased from 9.67 to 4.67. Efficiency analysis showed that the machine operates optimally at higher loads, with a maximum theoretical efficiency of 92.53%. However practical efficiency is expected to be lower due to transmission losses. The developed machine provides a cost-effective and reliable solution suitable for small-scale metal fabrication industries.

Keywords: Rod Twisting Machine, Torsional Deformation, Error Bar Analysis, Efficiency Evaluation, Torque Analysis, Power Transmission.

INTRODUCTION

Rod twisting is a widely used metal forming process in industries for producing decorative and structural elements such as gates, railings, and frames. Manual twisting methods are labor-intensive, inefficient and often produce non-uniform result (Hossain et al., 2022). Mechanized systems improve consistency, reduced labor, and enhance productivity (Dametew, 2017).

Machine design involves careful consideration of stress, power transmission, and material selection to ensure durability and safety (Farouki & Linke, 2016; Khurmi & Gupta, 2025)

Ngala et al. (2016) developed a combined bending, twisting, and cutting machine aimed at reducing manual labor and increasing production efficiency. Their study showed that integrating multiple operations into a single system improves productivity and reduces fabrication time. However, the design lacked optimization for different rod diameters, which is a key consideration in rod twisting machine design. Shaik et al. (2023) designed a multipurpose rod processing machine capable of bending, grinding and forming decorative patterns, including twisting. Their work emphasized low-cost fabrication and suitability for small-scale industries. The study demonstrated that simple mechanical systems can effectively produce torsional deformation in rods, although the accuracy of twist angle control remained limited. This highlights the need for improved control mechanisms in modern rod twisting machines.

Hanoofa (2014) focused on the design and fabrication of a pipe and rod bending machine, analyzing performance in terms of production rate and material deformation. While their working primarily addressed bending, the result indicated that mechanized systems significantly reduce material wastage and improve repeatability compared to manual processes. Similarly Wang et al (2026) developed an analytical model for twisting deformation in rod extrusion processes. Their study incorporated the effects of friction, material properties, and deformation mechanics to predict twisting behavior. The results showed that accurate modeling of torsional

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deformation enhances the predictability of machine performance and improves design reliability. This project aims to design and fabricate a low-cost rod twisting machine using locally available materials while maintaining structural integrity and operational efficiency.

MATERIALS AND METHOD

Rod to be Twist

Mild steel rods of 6 mm to 16 mm diameter with a length of 500 mm were used. Each test was carried out three times.

Design considerations

The design was carried out based on the following: torsion theory, material strength properties of mild steel and principles of power transmission.

Design Parameters

The following are the design parameters:

i. Rod diameters: 6 mm, 8 mm, 10 mm, 12 mm, 16 mm
ii. Length of rod: 500 mm
iii. Material: Mild steel
iv. Shear stress (τ) = 55 MPa
v. Modulus of rigidity (G) = 80 GPa
vi. Speed N = 60, rpm

Torque Requirement

The requirement torque to twist a solid rod is

$$T = \frac{\pi}{16}\tau d^3 \qquad \text{(Rogers \& Fleming, 2025)} \qquad (1)$$

Where:

T = Torque (Nm)

τ = Shear stress (Pa)

d = diameter (m)

For 6mm diameter rod

$$T = \frac{\pi}{16} \times 55 \times 10^6 \times 0.006^3$$

= 23.3 Nm

The calculated Torque for each Rod is tabulated in the table 1 below

Table 1

S/N	Diameter (mm)	Torque (Nm)
1	6	23.3
2	8	55.0
3	10	107.8

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4	12	186.6
5	16	442.0

Shaft Design

The shaft design was based on torsion equation from equation 1:

$T = \frac{\pi}{16}\tau d^3$

$d = \left(\frac{16T}{\pi\tau}\right)^{\frac{1}{3}}$ (2)

Using the maximum torque

$d = 30\ mm$

Shaft diameter of 35 mm selected

Power Requirement

$P = \frac{2\pi NT}{60}$ (Abbas et al 2021) (3)

Where N = Speed (rpm)

For the maximum load (442 Nm)

Therefore $P = \frac{2\pi \times 60 \times 442}{60}$

= 2.8 kW

3 kW electric motor was used.

Gear Design

The motor speed = 1440 rpm

The desired speed = 60 rpm

Gear Ratio = $\frac{1440}{60}$

= 24:1

Worm gear used

Velocity Ratio

$\frac{NI}{N2} = \frac{D2}{D1}$ (4)

$\frac{1440}{60} = 24$

This ratio is too large for a single belt stage, two stage belt drive was used.

Stage 1: 4:1

Stage 2: 6:1

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Error Analysis

$$SD = \sqrt{\sum \left(\frac{x-\bar{x}}{n-1}\right)^2} \quad (5)$$

Where SD = standard Deviation

$\bar{x}$ = mean value

n = number of trials

Efficiency Analysis

$$\text{Efficiency} = \frac{output\ power}{input\ power} \times 100 \quad (6)$$

$$\text{Power output} = \frac{2\pi NT}{60} \quad (7)$$

For maximum load (16 mm)

$P_{out} = 2\pi \times 442$

$= 2.8$ kW

Description of the machine

The isometric view of the constructed rod twisting machine is shown in Figure 1. The machine consists of the following components, namely; electric motor, hopper, mechanical gear, bearing, pulley, machine bed, structural base (iron), dies, transmission belt, cramp, shaft, switches, connection cables, and bolts and nuts.

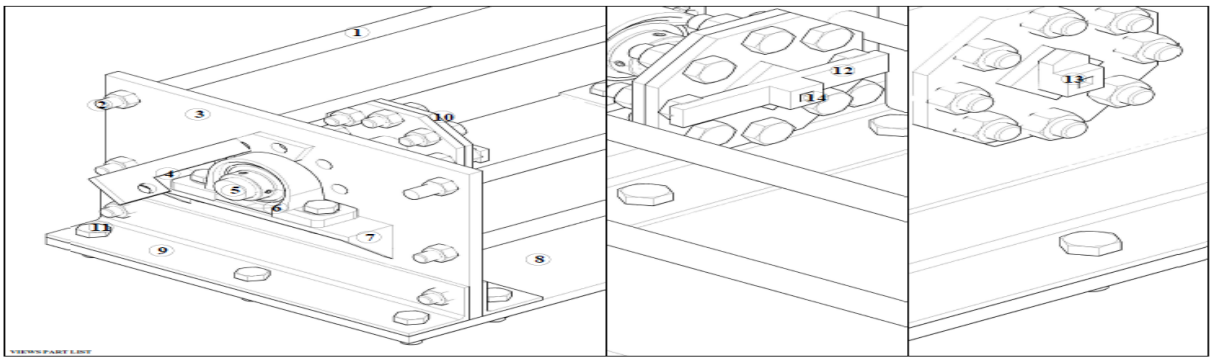


Figure 1: Rod Twisting Machine

Experimental procedure

The fabricated rod twisting machine was tested using mild steel rods of diameters 6 mm, 8 mm, 10 mm, 12 mm, and 16 mm. each rod was subjected to twisting under identical operation conditions. The rod was securely clamped between the fixed and rotating chuck, the machine was powered using a 3 Kw motor. Twisting was performed until a uniform spiral was achieved, each test was conducted three times to ensure accuracy and repeatability. All experiments were conducted under controlled environmental conditions to minimize external variability. The following parameters were recorded: twisting time, number of twists and observations (uniformity, deformation).

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RESULTS AND DISCUSSION

The experimental results clearly demonstrate the effect of rod diameter on twisting performance of the machine. Table 2

Table 2: Twisting Test Result

Diameter (mm)	Trial	Twisting time (s)	Number of Twists	Observation
6	1	7	9	Slight variation
	2	8	10	Uniform twist
	3	8	10	Uniform twist
8	1	11	9	Uniform twist
	2	10	8	Slight Variation
	3	10	9	Uniform twist
10	1	14	8	Uniform twist
	2	14	8	Uniform twist
	3	13	7	Slight Variation
12	1	17	6	Slight deformation
	2	18	7	Moderate resistance
	3	19	7	Uniform
16	1	25	5	High resistance
	2	27	5	Non-uniform
	3	26	4	Slight cracks observed

Table 3: Average Result

S/N	Diameter (mm)	Average time (s)	Average Twists
1	6	7.7	9.67
2	8	10.3	8.67
3	10	13.7	7.67
4	12	18.00	6.67
5	16	26.00	4.67

Table 4: Average twisting Time with Error Bar

S/N	Diameter (mm)	Average Time (s)	Error (SD)
1	6	7.7	0.58
2	8	10.3	0.58
3	10	13.7	0.58
4	12	18.0	1.00
5	16	26.0	1.00

Table 5: Average Number of Twists with Error Bar

S/N	Diameter (mm)	Average Number of Twists	Error (SD)
1	6	9.67	0.58
2	8	8.67	0.58
3	10	7.67	0.58
4	12	6.67	0.58
5	16	4.67	0.58

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Table 6: Efficiency of Rod Twisting Machine

Diameter (mm)	Torque (Nm)	Output Power (W)	Efficiency (%)
6	23.3	146.4	4.88
8	55.0	345.6	11.52
10	107.8	677.4	22.58
12	186.6	1172.6	39.09
16	442.0	2777.5	92.58

Effect of Rod Diameter on Twisting Time

The figure 2 below illustrated the graph of average twisting time against diameter of the rod. The result shows that twisting time increases with rod diameter, from 7.7 s (6 mm) to 26.0 s (16 mm). This may be due to the rapid rise in torsional resistance as torque requirement increases nonlinearly (approximately proportional to the cube of diameter under constant shear stress conditions). The observed increase in twisting time agrees with findings of Hossain et al. (2022), where increased diameter resulted in higher deformation resistance.

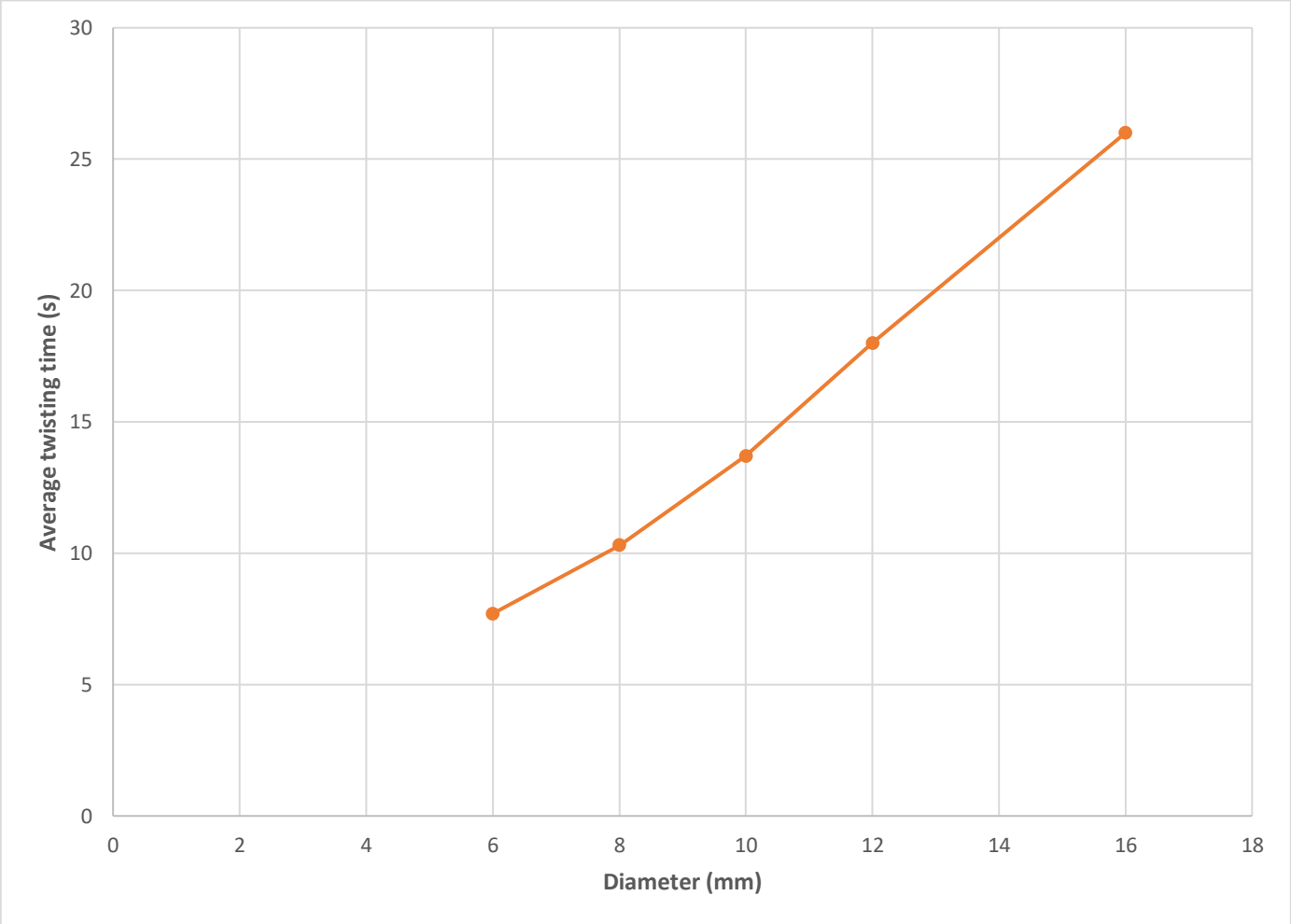


Figure 2: Average Twisting Time Variation with Diameter

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Effect of Rod Diameter on Number of Twists

There is decrease in number of twist as the rod diameter increased. This is because thicker rods exhibit higher stiffness and reduced angular deformation under the same applied torque.

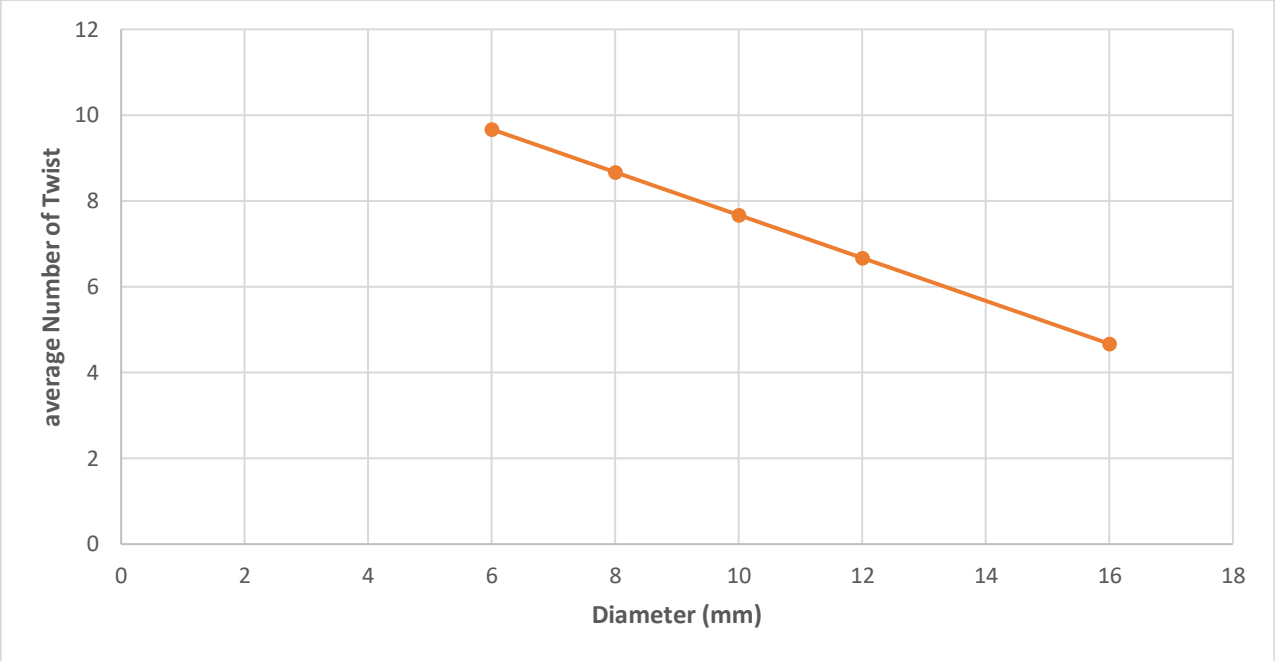


Figure 3: Average Number of Twist Variation with Diameter

Effect of Rod Diameter on the Torque

The figure 4 shows the relationship between rod diameter and the torque. The relationship follows a non-linear cubic trend, confirming theoretical expectations.

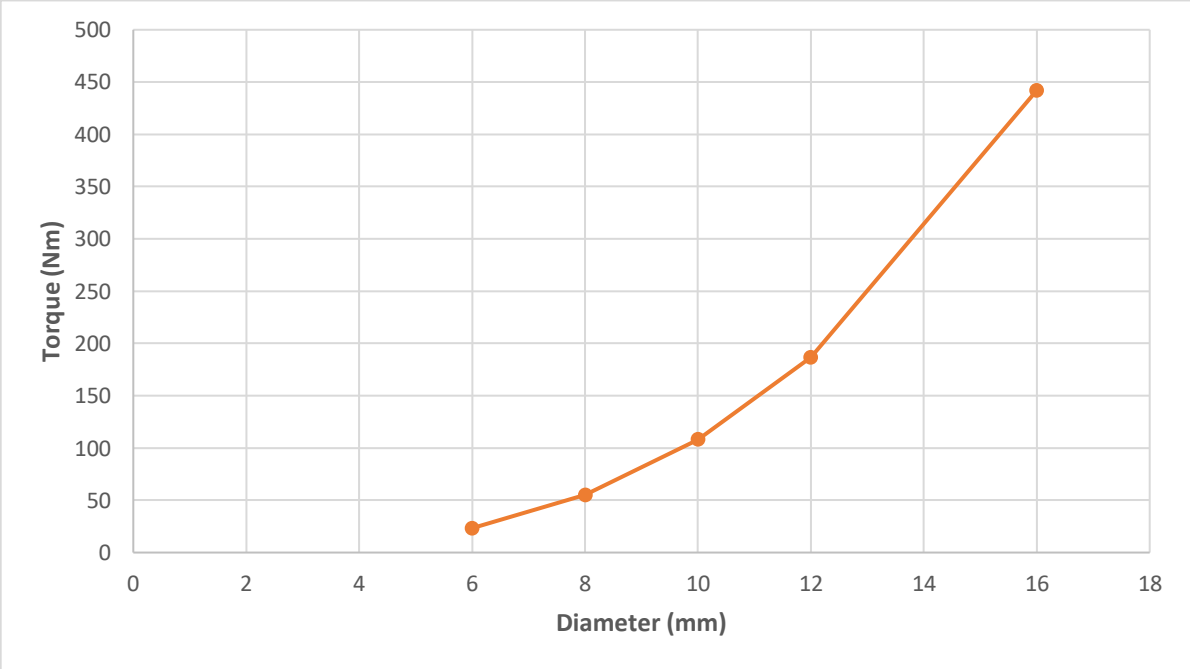


Figure 4: Torque Variation with Diameter

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Diameter vs Average Twisting Time (Error Bars)

Figure 5 illustrate the error bar graph for twisting time it shows a clear increasing trend with rod diameter, indicating that larger rods require more time to achieve uniform twisting. Small error bars across all the diameters indicate that the experimental results are consistent and reproducible. From 12 mm and 16 mm diameter there is a slight increase in error bar this indicates minor variability due to increased torsional resistance, machine vibration, and possible material inconsistencies.

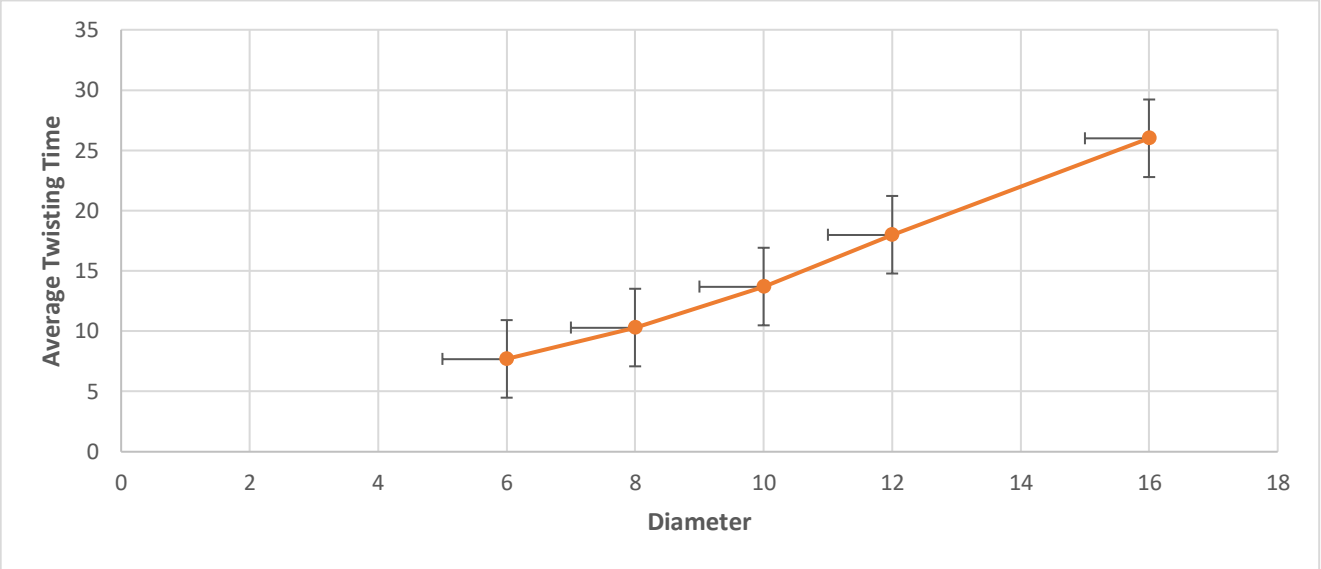


Figure 5: Diameter Variation with Average twisting Time (Error Bar)

Diameter vs Average Number of Twists (Error Bars)

The error bar graph for the number of twists indicate a decreasing trend with increasing rod diameter, which is consistent with the expected behavior of stiffer materials under torsional loading. The small and nearly uniform error bars shows minimal variation between repeated trials, demonstrating high repeatability of the machine. This suggests that the machine provides consistent twisting performance, particularly for smaller diameters where deformation is more uniform. Slight increases at higher diameters may be attributed to increased vibration, material heterogeneity, and higher torque fluctuations.

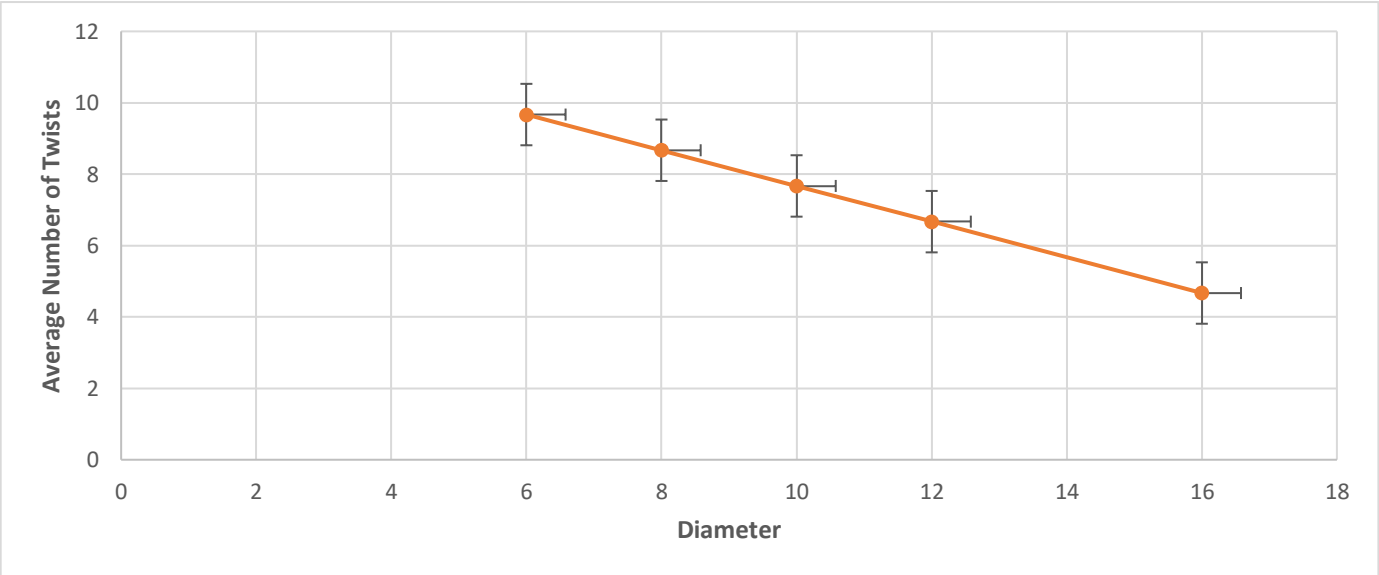


Figure 6: Diameter Variation with Average Number twists (Error Bar)

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Failure Analysis of the Machine

The experimental observations revealed that at larger diameters, mainly at 16 mm, slight cracks and non-uniform deformation occurred. This shows that the applied torque approached the torsional strength limit of the mild steel rods and possibly the mechanical capacity of the machine. The increased resistance at larger diameter leads to higher stress concentration, which may result in localized failure. Additionally, machine-related factors such as vibration, transmission losses, and possible slippage in the gripping mechanism may have contributed to uneven twisting. This suggests that while the machine performs effectively within lower and moderate diameter ranges, its performance at higher diameter is limited, this may require design improvements such as increased torque capacity, enhanced rigidity, or improved gripping mechanisms.

DISCUSSION OF EFFICIENCY

Efficiency increases with rod diameter because the motor operates closer to its rated capacity at higher loads. At low loads energy utilization is poor. The maximum efficiency was calculated theoretically to be 92.52%, at 16 mm. Although real efficiency is expected to be lower (60-70%) due to mechanical losses in the belt drive system, worm gear transmission, and frictional effects. At lower diameter, the efficiency is significantly reduced because the machine operates under partial load conditions, leading to inefficient energy use.

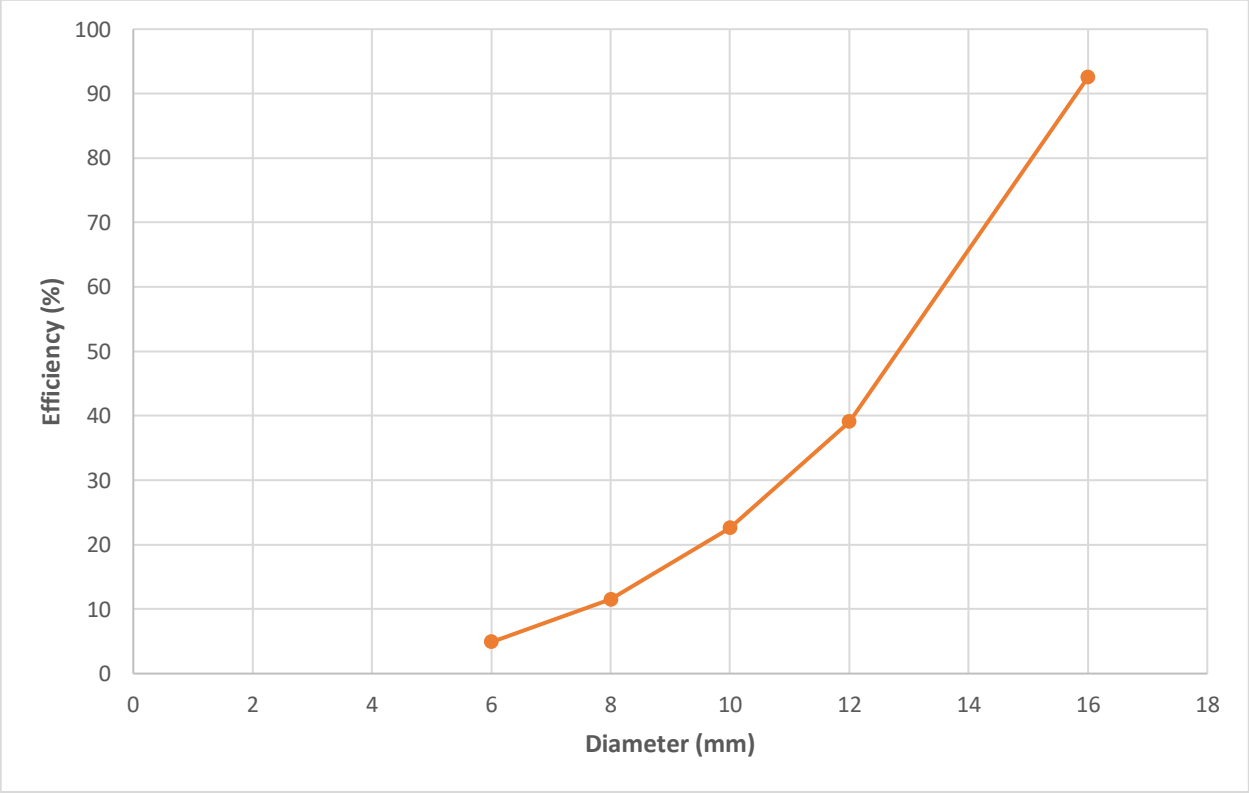


Figure 7: Machine Efficiency Variation with Diameter

CONCLUSION

The rod twisting machine was successfully designed, fabricated, and tested. The machine effectively twisted mild steel rods within the diameter range of 6 mm to 16 mm. The results showed that twisting time increases while the number of twists decreases with increasing in rod diameter due to higher torsional resistance and stiffness. The machine shows high repeatability with minimal variation across trials. Maximum theoretical efficiency of 92.52% was obtained, practical efficiency is expected to range between 60-70% due to mechanical and transmission losses. For higher diameter exhibited increased resistance and minor defects, suggesting the need for higher torque capacity or design improvements.

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The developed machine offer a cost-effective, efficient, and reliable alternative to manual rod twisting methods, making it suitable for small-scale industrial applications.

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