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Impact of Machine Shaft Geometry on Shaft Displacement

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ABSTRACT

The study, impact of machine shaft geometry on shaft displacement, was successfully carried out. Researchers considered two shafts element; one with constant cross sectional diameter, 30 mm and the other with two stepped diameters, 20mm and 30 mm respectively within a length of 100 mm. The shaft element models were prepared with the aid of inventor software. In addition, Finite Element Analysis was conducted on each shaft element to predict displacement under the same turning moment of 200 N mm and axial bearing pressure of 1,200N representing the weight of shaft supported elements such as gear, pulley, etc. The analysis revealed that the two shaft elements irrespective of their geometrical variation had the same maximum displacement of 5.431 mm but differed in their minimum displacement of 0.002 mm and 0.001 mm for stepped shaft and shaft with constant cross section respectively. According to the findings, it can be deduced that the maximum displacement of machine shaft is independent of the shaft geometrical shape. The researchers made the following recommendations: Machine shaft should not be step turned more than 10mm deep from the original diameter to ensure that the shaft displacement is within permissible limit, shaft geometry that can reduce weight of shaft and at the same time transmit the required power and retain the required strength should be adopted to improve mechanical machine efficiencies, etc.

Keywords ---- shaft geometry, inventor, displacement, finite element analysis, turning moment, axial bearing pressure.

I. INTRODUCTION

Shaft is a rotating machine element which either receives power, transmits rotary motion or both. Shafts are normally of circular cross section. Shaft may be solid or hollow depending upon the application. Machine shaft are integral part of machine itself (Khurmi and Gupta, 2012).

Mechanical machines make use of shafts to transmit needed rotary motion and power. All machine shaft designers should ensure that the shaft geometry can cover the requirements of the material strength and shaft-supported components. A fluctuated loads condition or combined torsion and bending loads condition are the usual work conditions of shafts, which usually cause shaft deflection/displacement. Deflection/displacement analysis relies on the overall shaft geometry and the work condition. In general, shafts deflect linearly as a beam and angularly as a torsion bar (Sara and Engel, 2017).

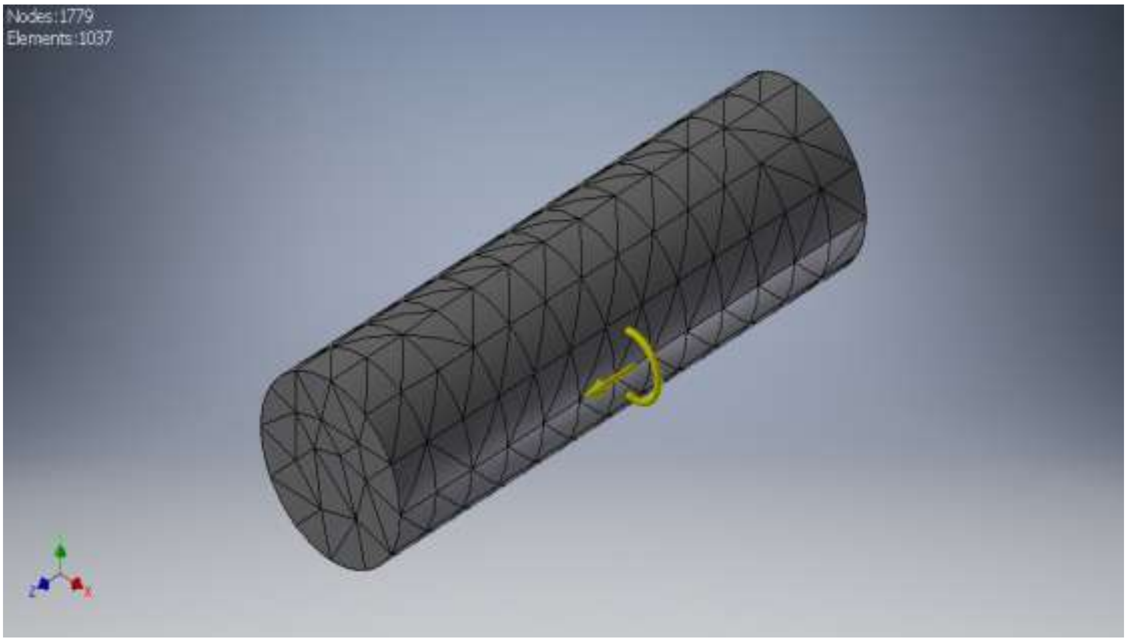
Christopher and Michael (2013) claimed that a machine shaft of 30 mm diameter constant cross section of the entire shaft will usually experience larger displacement/deflection than the similar stepped shaft. They further added that 50 mm diameter shaft will experience smaller displacement/ deflection than the similar stepped shaft.

There are no doubts that machine shaft geometry determines shaft displacement/deflection and also shaft ability to support other machine element components such as gears, pulleys, bearings, flanges, etc. Review of related literature done by the authors revealed that excessive shaft displacement can ruin machine operational performance and also lower service life of a mechanical machine. Hence, the paper aimed at studying the effect of machine shaft geometry on shaft displacement.

II. METHODOLGY

The study considered two shafts geometries, made from the same material, Alloy steel for strength. The first shaft is a solid cylindrical shaft with a constant cross section diameter of 30mm and length of 100mm. Similarly, the second shaft is a variable cross sectional diameter of 20mm and 30mm with length of 50mm each. Both shafts were subjected to the same turning moment of 200 N mm with axial bearing pressure of 1200N representing shaft supported weigth.

III. RESULTS AND PRESENTATIONS



Stress Analysis Report

⊟Physical

Material	Steel, Alloy
Density	7.73 g/cm^3
Mass	0.546402 kg
Area	10838.5 mm^2
Volume	70685.8 mm^3
Center of Gravity	x=0.00000000313704 mm y=0 mm z=-50 mm

Mesh settings:

Avg. Element Size (fraction of model diameter)	0.08
Min. Element Size (fraction of avg. size)	0.2
Grading Factor	1.5
Max. Turn Angle	60 deg
Create Curved Mesh Elements	Yes

⊟Material(s)

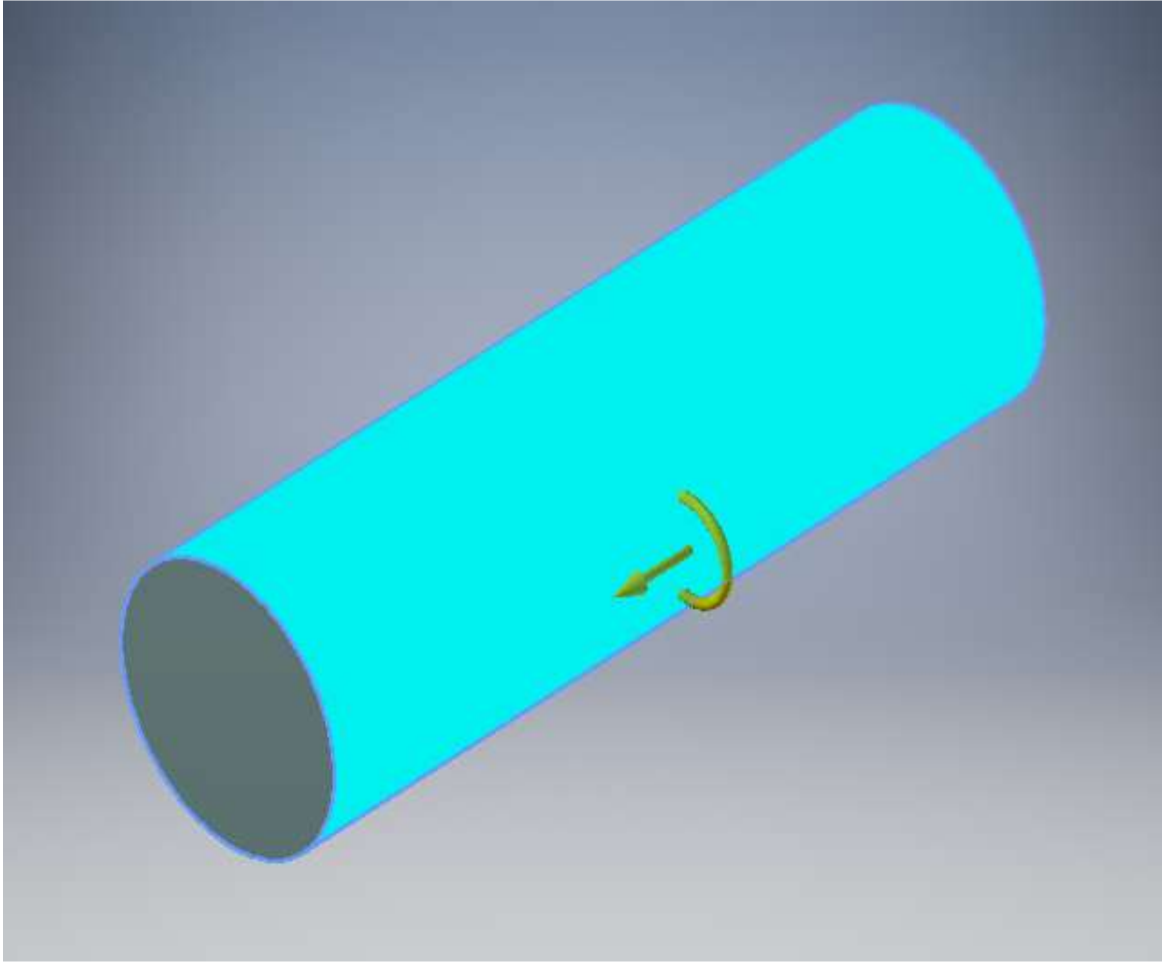
Name	Steel, Alloy	
General	Mass Density	7.73 g/cm^3
	Yield Strength	250 MPa
	Ultimate Tensile Strength	400 MPa
Stress	Young's Modulus	205 GPa
	Poisson's Ratio	0.3 ul
	Shear Modulus	78.8462 GPa
Part Name(s)	Part1	

⊟Operating conditions

⊟Moment:1

Load Type	Moment
Magnitude	200.000 N mm
Vector X	0.000 N mm
Vector Y	0.000 N mm
Vector Z	200.000 N mm

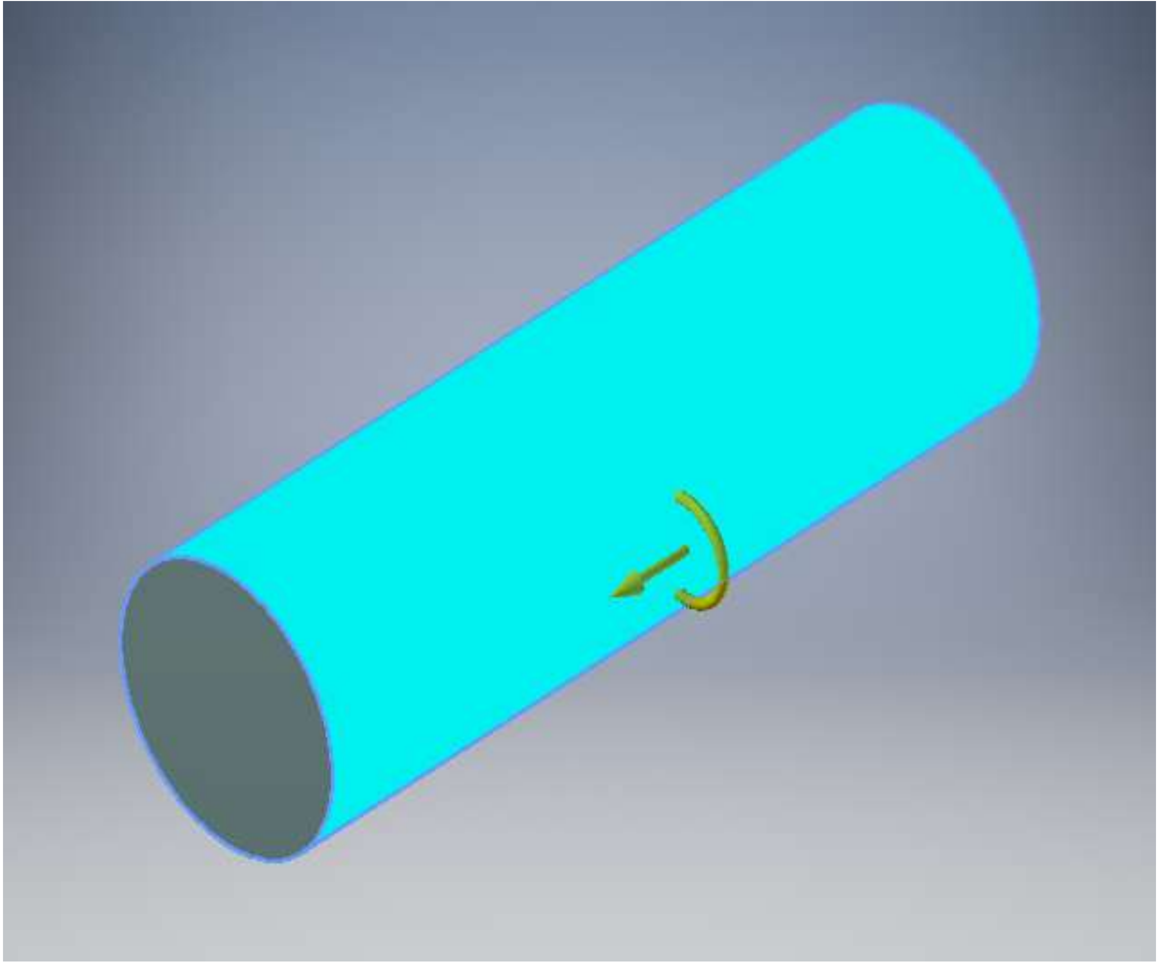
⊟Selected Face(s)



⊟ **Bearing Load:1**

Load Type	Bearing Load
Magnitude	1200.000 N
Vector X	0.000 N
Vector Y	0.000 N
Vector Z	1200.000 N

⊟ **Selected Face(s)**



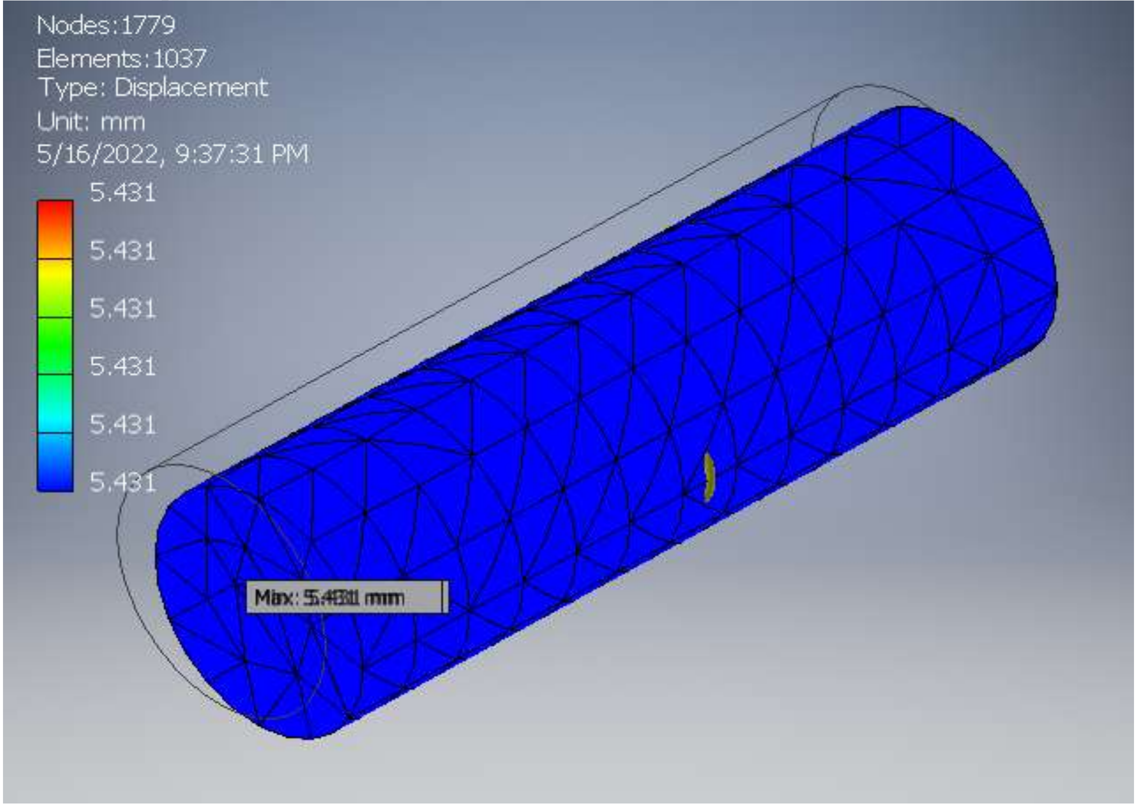
⊟ **Parametric Configuration:1**

⊟ **Frequency Value(s)**

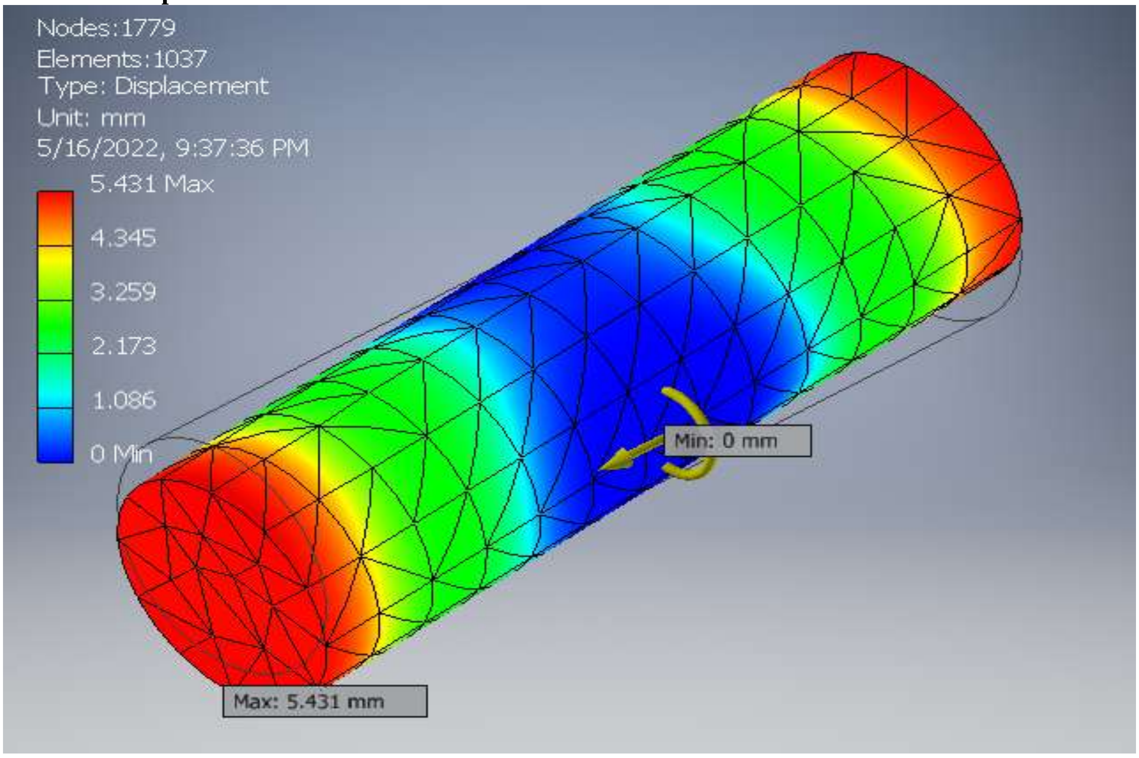
F1	0.00 Hz
F2	0.00 Hz
F3	0.00 Hz
F4	0.00 Hz
F5	0.00 Hz
F6	0.00 Hz
F7	11409.68 Hz
F8	11410.15 Hz

⊟ **Figures**

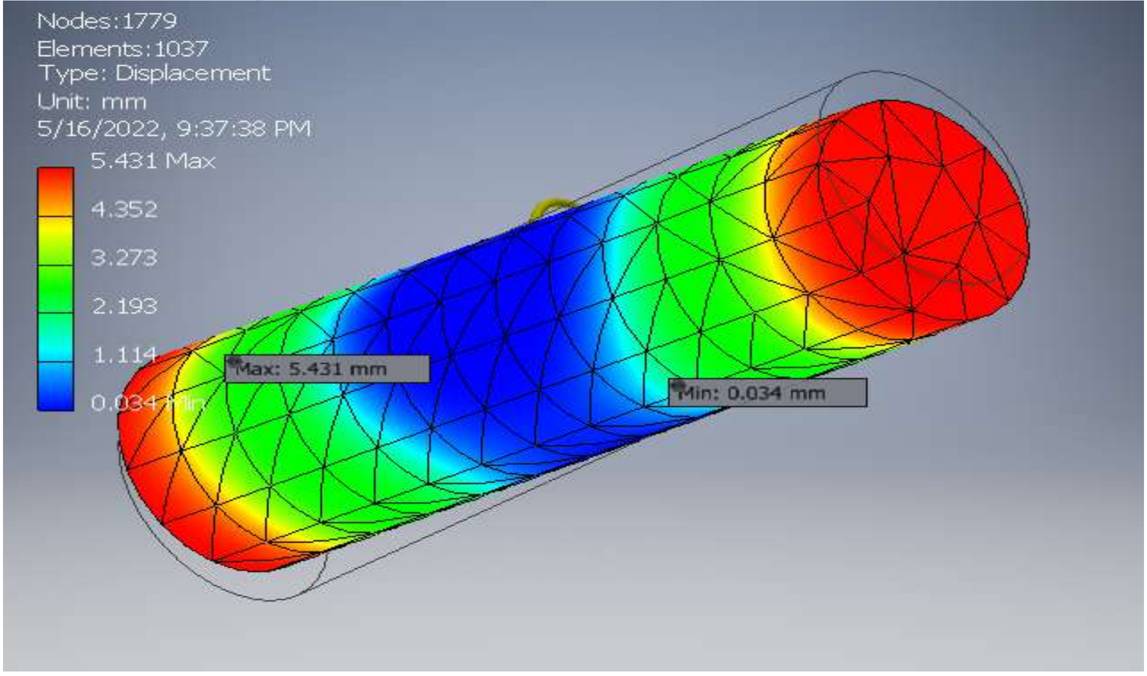
⊟ **F1 0.00 Hz Displacement**



⊟ **F4 0.00 Hz Displacement**



⊟ F4 0.00 Hz Z Displacement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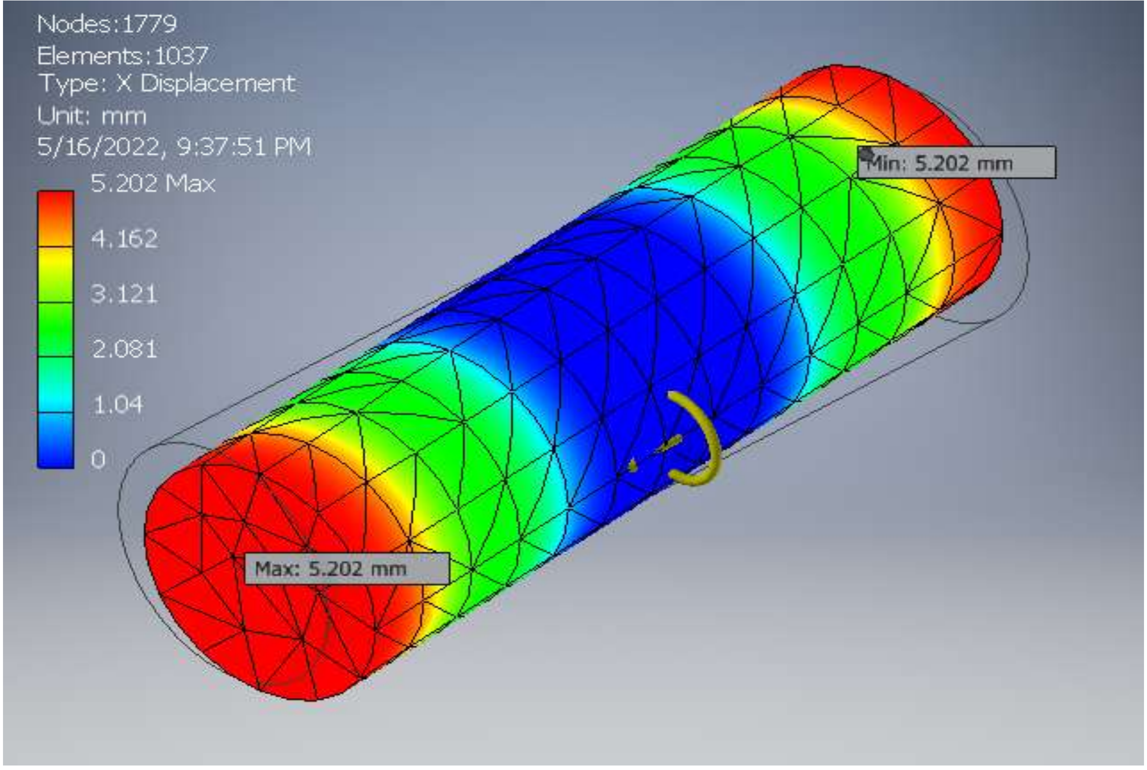
Elements:1037
Type: Displacement
Unit: mm
5/16/2022, 9:37:38 PM

⊟ F5 0.00 Hz X Displacement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Type: X Displacement
Unit: mm
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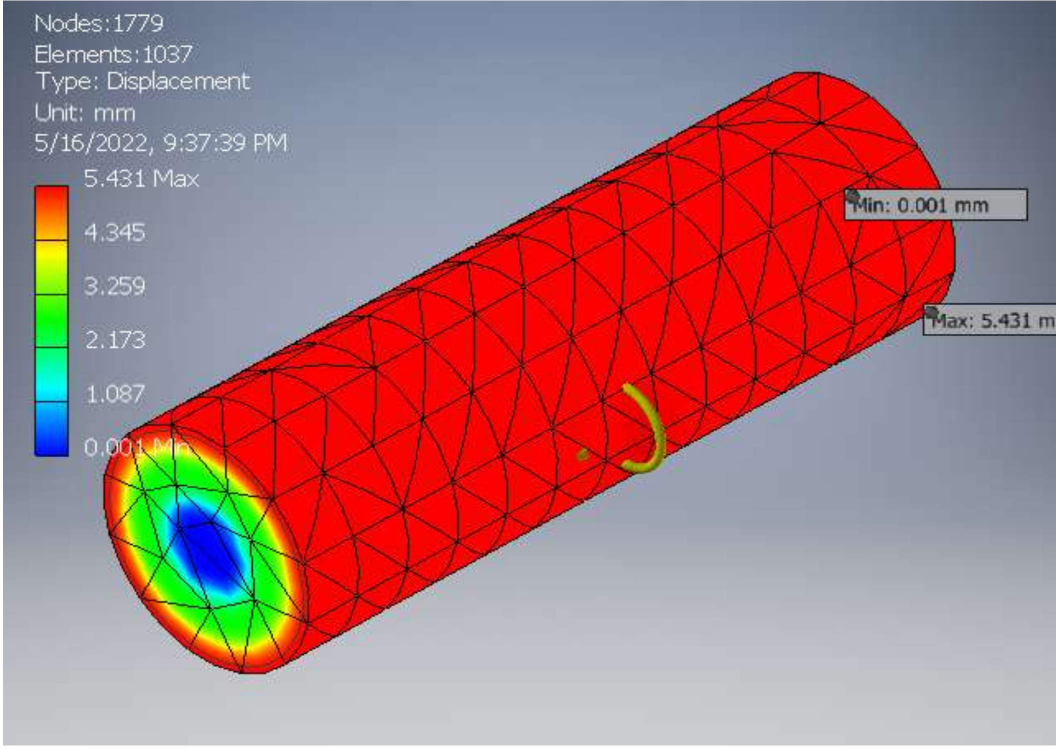
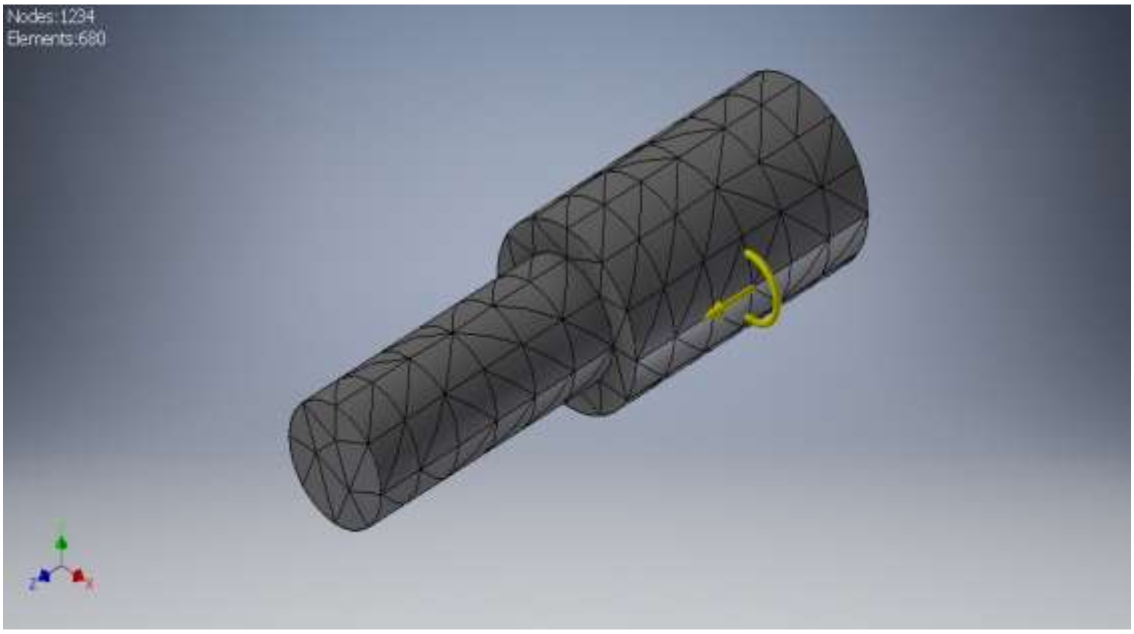
⊟ F6 0.00 Hz Displacement





⊟ Physical

Material	Steel, Alloy
Density	7.73 g/cm^3
Mass	0.394623 kg
Area	9267.7 mm^2

Volume	51050.9 mm^3
Center of Gravity	x=0.00000000281529 mm y=0 mm z=-9.61538 mm

⊟ Modal Analysis:1

General objective and settings:

Design Objective	Parametric Dimension
Study Type	Modal Analysis
Last Modification Date	5/16/2022, 10:21 PM
Number of Modes	8
Frequency Range	Undefined
Compute Preloaded Modes	No
Enhanced Accuracy	No

Mesh settings:

Avg. Element Size (fraction of model diameter)	0.08
Min. Element Size (fraction of avg. size)	0.2
Grading Factor	1.5
Max. Turn Angle	60 deg
Create Curved Mesh Elements	Yes

⊟ Material(s)

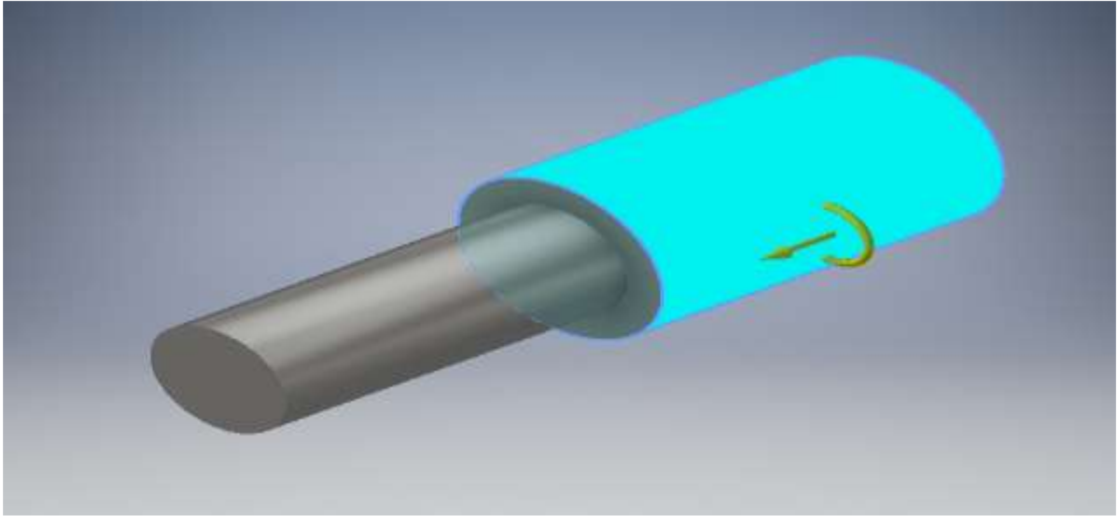
Name	Steel, Alloy	
General	Mass Density	7.73 g/cm^3
	Yield Strength	250 MPa
	Ultimate Tensile Strength	400 MPa
Stress	Young's Modulus	205 GPa
	Poisson's Ratio	0.3 ul
	Shear Modulus	78.8462 GPa
Part Name(s)	Part3	

⊟ Operating conditions

⊟ Moment:1

Load Type	Moment
Magnitude	200.000 N mm
Vector X	0.000 N mm
Vector Y	0.000 N mm
Vector Z	200.000 N mm

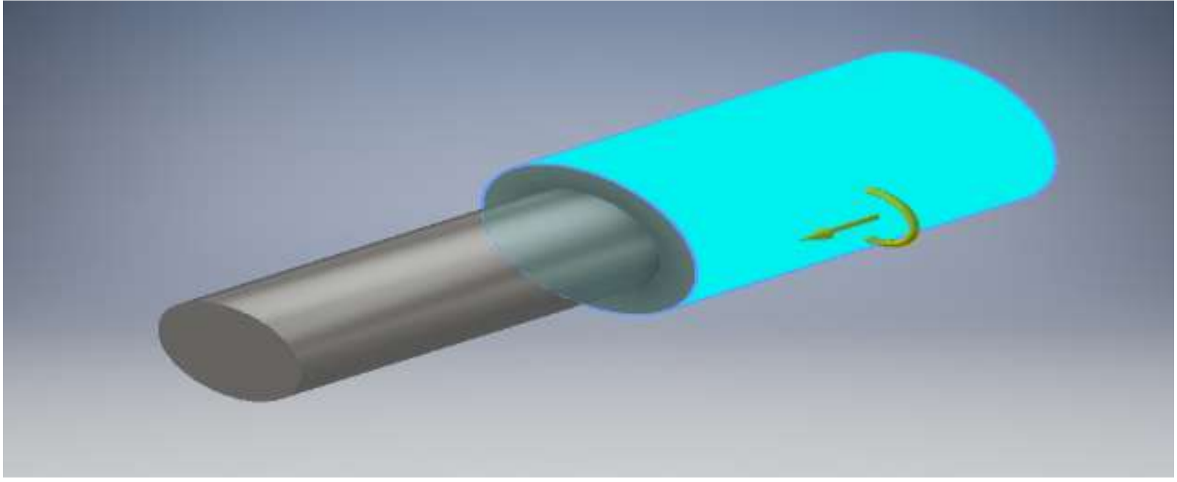
⊟ **Selected Face(s)**



⊟ **Bearing Load:1**

Load Type	Bearing Load
Magnitude	1200.000 N
Vector X	0.000 N
Vector Y	0.000 N
Vector Z	1200.000 N

⊟ **Selected Face(s)**



⊟ **Results**

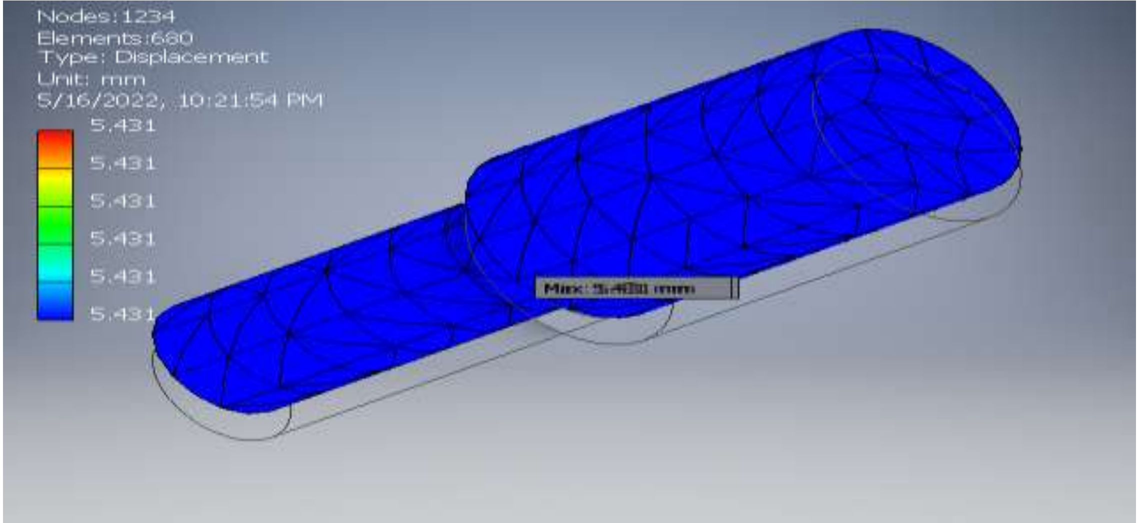
⊟ **Parametric Configuration:1**

⊟ **Frequency Value(s)**

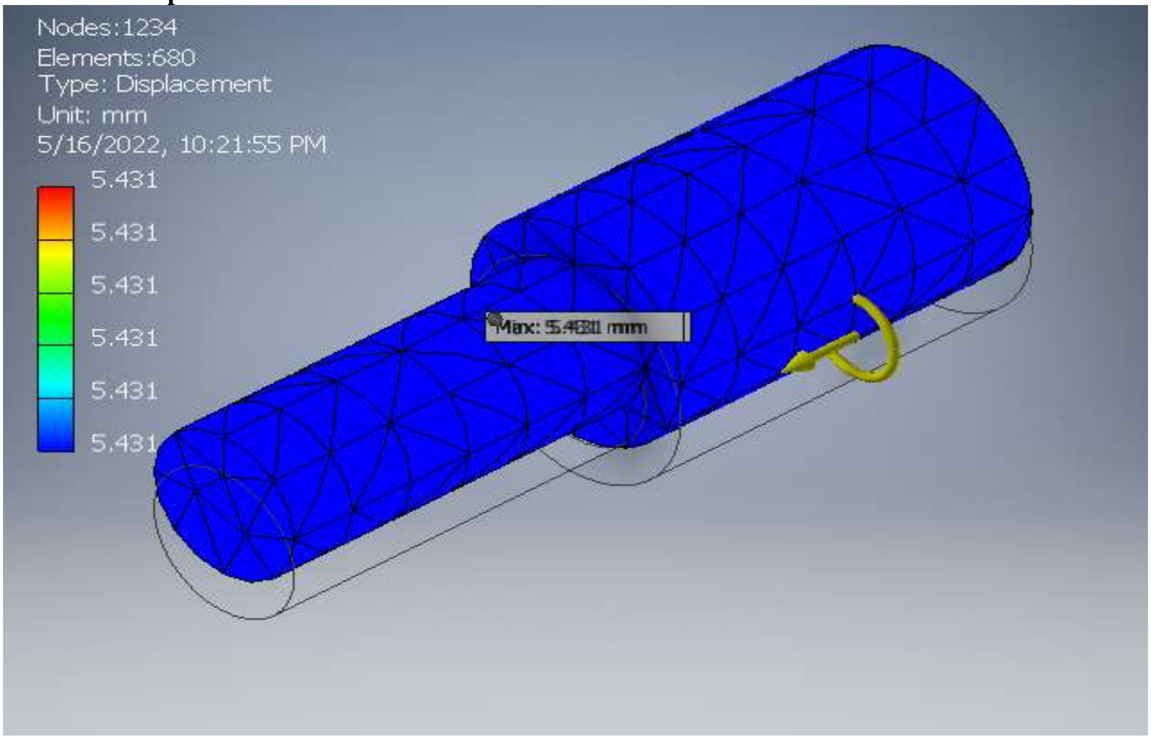
F1	0.00 Hz
F2	0.00 Hz
F3	0.00 Hz
F4	0.00 Hz
F5	0.00 Hz
F6	0.00 Hz

F7	8330.34 Hz
F8	8338.30 Hz

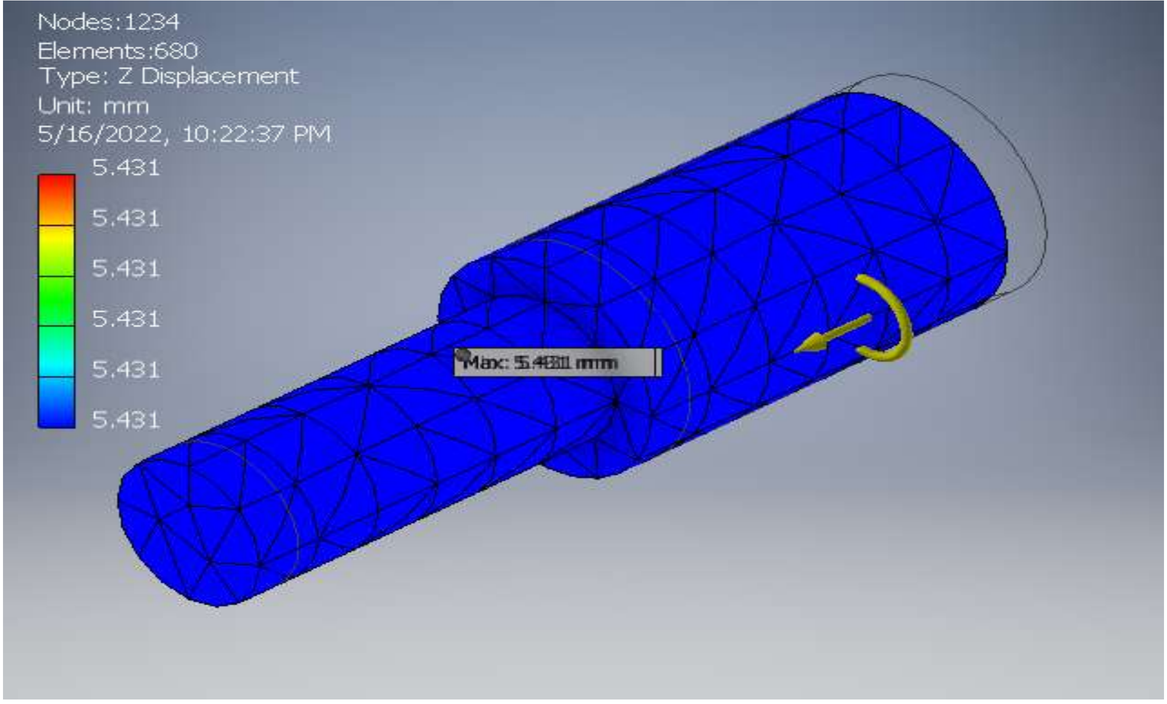
⊟ F1 0.00 Hz Displacement



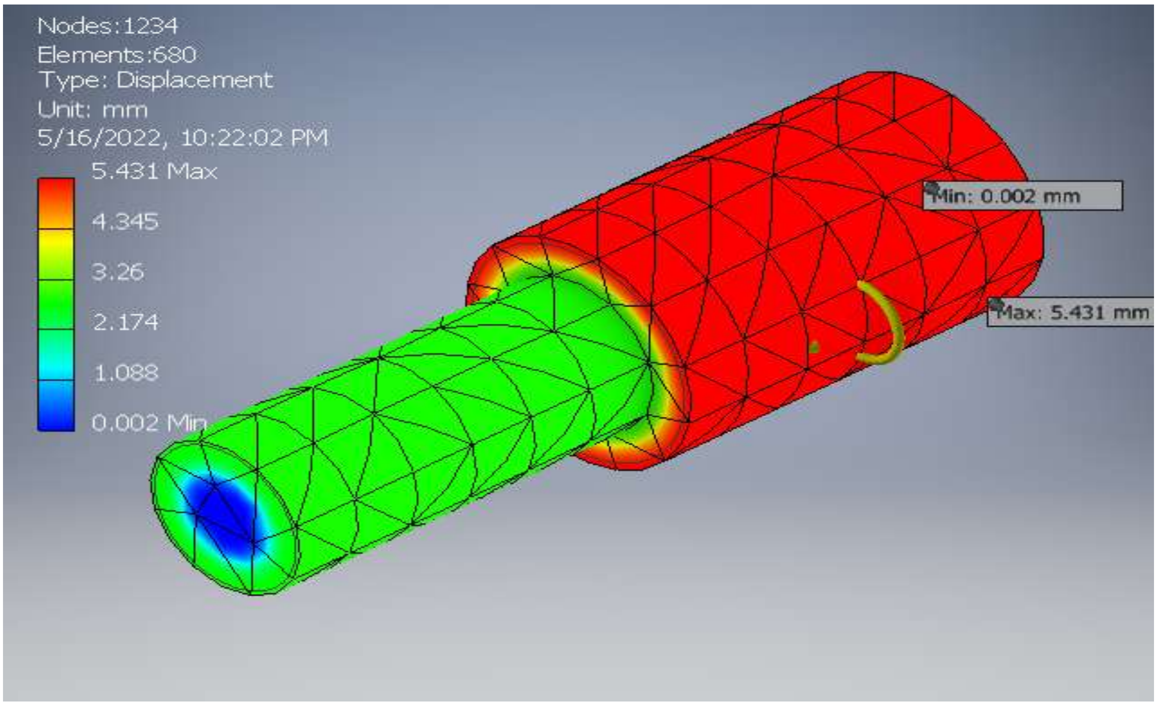
⊟ F2 0.00 Hz Displacement



⊟ **F3 0.00 Hz Z Displacement**



⊟ **F8 8338.30 Hz Z Displacement**



IV. CONCLUSION

The impact of machine shaft geometry on shaft displacement was investigated, with two shafts element; one with constant cross sectional diameter, 30 mm and the other with two stepped diameters, 20mm and 30 mm respectively within a length of 100 mm. Furthermore, finite element analysis was conducted on each shaft element to predict displacement under the same turning moment of 200 N mm and axial bearing pressure of

1200N. The analysis revealed that the two shaft elements irrespective of their geometrical variation have the same maximum displacement of 5.431 mm and minimum displacement of 0.002 mm and 0.001 mm for stepped shaft and shaft with constant cross section respectively. According to the findings, it can be deduced that the maximum displacement of machine shaft is independent of the shaft geometrical shape.

V. RECOMMENDATIONS

The following recommendations are suggested based on the study:

1) Machine shaft should not be step turned more than 10mm deep from the original diameter to ensure that the shaft displacement is within permissible limit.
2) Shaft geometry that can reduce weight of shaft and at the same time transmit the required power and retain the required strength should be adopted to improve mechanical machine efficiencies.
3) This research can also be done using multiple geometrical shapes such as square, polygon, variable shaft lengths and other advanced software for generalization.

REFERENCES

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