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Determination of Best Value of Bearing Pressure to Avoid Machine Shaft Displacement: Matlab Approach.

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ABSTRACT

Determination of best value of bearing pressure to avoid machine shaft displacement was successfully carried out. The study considered a machine shaft element made from Alloy Steel material for strength with the aid of inventor software. The shaft was element subjected to turning moment of 200 N mm with variable axial bearing pressure of 1200N, 1500N, 4500N, 7000N, 20000N respectively, had the following recorded corresponding displacements; 1.086mm, 2.173mm, 3.259mm, 4.345mm, 5.431mm respectively. In addition, the displacements and axial bearing pressure data gotten were used to formulate a linear regression function using MATLAB. Function was tested at displacement of 2.5 mm, which yielded a bearing pressure of 3,800.8293N. Also, the best performance graph shows that zero value of bearing pressure is required to avoid machine shaft displacement and the regression graph with coefficient of 1 indicated that there is closed and random relationship between bearing pressure and machine shaft displacement. The researchers made the following recommendations: Machine shaft and bearing contact surfaces must have effective hydrodynamic lubrication to achieve zero bearing pressure; Shaft material with lighter weight should be used to reduce contact force/bearing pressure magnitude, etc.

Keywords ---- MATLAB, inventor software, shaft displacement, turning moment, axial bearing pressure.

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1. INTRODUCTION

Background of the Study

Khurmi and Gupta (2014) opined that bearing pressure or contact pressure is a contact force which occurs when a shaft cylinder is in contact with a bearing bore surface. Excessive bearing pressure can lead to bearing failure (penning or deformation) or excessive shaft displacement.

Sara and Engel (as cited in Ugwuegbu and Ewurum, 2022) explained that 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.

Khurmi and Gupta (2012) defined machine shafts as integral part of machine itself. 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.

Best value here represents the value of bearing pressure to avoid machine shaft displacement.

There are obvious truth that bearing pressure influences machine shaft displacement 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 bearing pressure can ruin machine shaft operational performance and also lower service life of a mechanical machine. Hence, the paper aimed at determining the best value of bearing pressure to avoid machine shaft displacement through MATLAB approach.

Statement of Problem

In order to minimize failure and accelerated aging of mechanical machines, there is need to keep operational bearing pressure within the threshold level (best value) capable of causing zero machine shaft displacement.
There are no doubts that excessive bearing pressure can lead to bearing failure (penning or deformation) or excessive machine shaft displacement. All machine shaft designers must ensure that the shaft bearing pressure can cover the requirements of the material strength and shaft-supported components (Khurmi and Gupta, 2012).
Review of related literature done by the authors revealed that excessive bearing pressure can ruin machine shaft operational performance and also lower service life of a mechanical machine.
It is on this note that the researchers aimed at determining the best value of bearing pressure to avoid machine shaft displacement.

Objective of the study

The general objective of this study is to determine the best value of bearing pressure to avoid machine shaft displacement.

Significance of the Study

The result of this study will be beneficial to machine design/production engineers in the following ways:
1) Production engineers can reduce premature failure and accelerated aging of mechanical machines by adopting the best value of bearing pressure that permits zero machine shaft displacement.
2) It can improve the design life of bearing through the avoidance of contact force magnitude that causes bearing penning or deformation.

Research Question
Is there any best value of bearing pressure to avoid machine shaft displacement?
Hypothesis
Null hypothesis, H_0 = there is a best value of bearing pressure to avoid machine shaft displacement versus **Alternative hypothesis,** H_i = there is no best value of bearing pressure to avoid machine shaft displacement.

Scope of the Study

This research will focus on determining the best value of bearing pressure to avoid machine shaft displacement. So, all efforts will be directed towards the general objective. The study will not detail the finite element analysis approach for getting the displacements caused by axial bearing pressure. Data analysis will be done using MATLAB therefore; results may be subject to variations in other analysis models/softwares.

2. Review of Related Literature

Ugwuegbu and Ewurum (2022) studied impact of machine shaft geometry on shaft displacement. They evaluated that the maximum displacement of a machine shaft is dependent on shaft geometrical shape.
Khurmi and Gupta (2012) explained that 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) studied bearing pressure and concluded that excessive bearing pressure can lead to bearing failure (penning or deformation) or excessive shaft displacement.
Sara and Engel (2017) evaluated failure analysis and fatigue life estimate of rotary shaft and they concluded that 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.
Christopher and Michael (2013) studied shaft deflection and 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

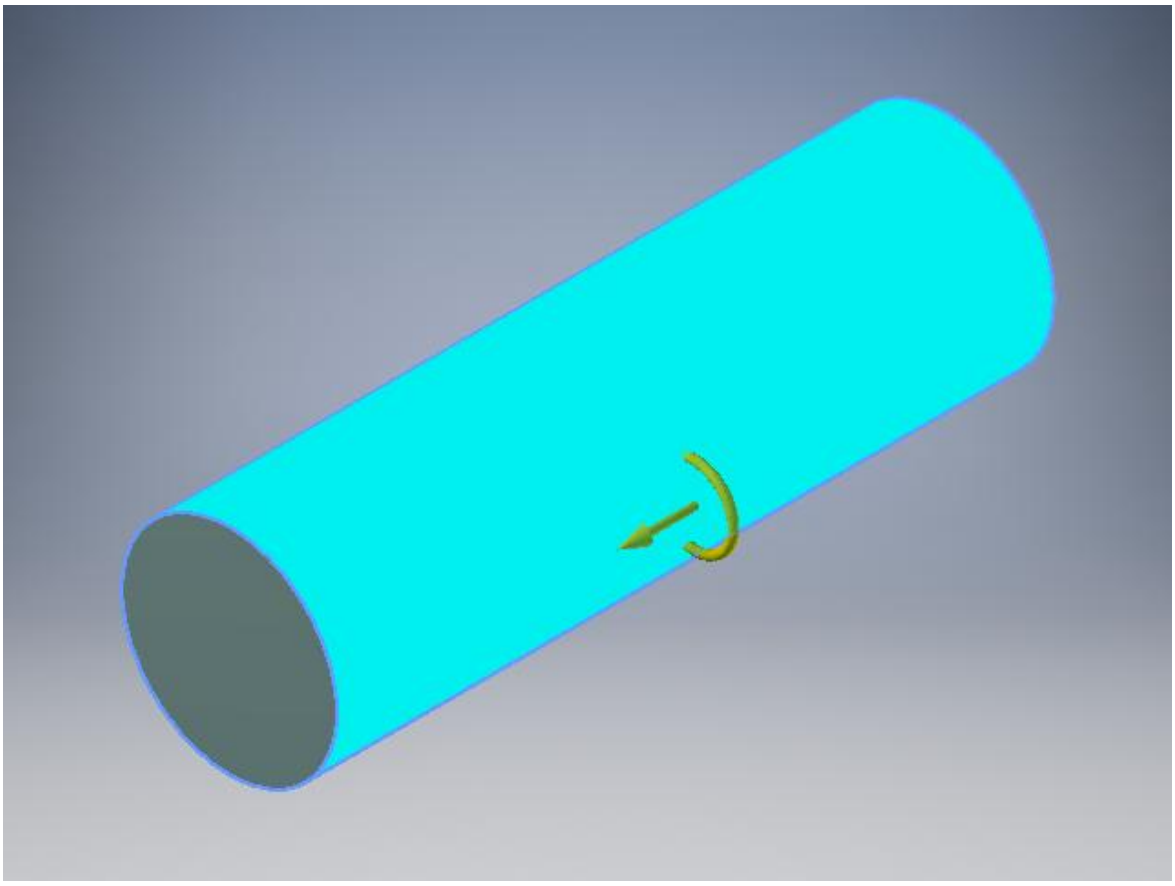
stepped shaft. They further added that 50 mm diameter shaft will experience smaller displacement/ deflection than the similar stepped shaft.

Gupta(2012) studied theory of machines and simple mechanisms and he concluded that shafts are the foundation of machine design and creation and capable of producing rotational, translational and oscillation motions through the movement of a prime mover.

3. METHODOLOGY

The study considered a machine shaft element made from Alloy steel material for strength with the aid of inventor software. The shaft is a solid cylindrical with a constant cross section diameter of 30mm and length of 100mm. Shaft element was subjected to turning moment of 200 N mm with variable axial bearing pressure of 1200N, 1500N, 4500N, 7000N, 20000N respectively. The displacements and axial bearing pressure data gotten were used to formulate a linear regression function. MATLAB was used to analyze the regression function to determine the best value of the bearing pressure that can give zero machine shaft displacement.

4. RESULTS AND PRESENTATIONS



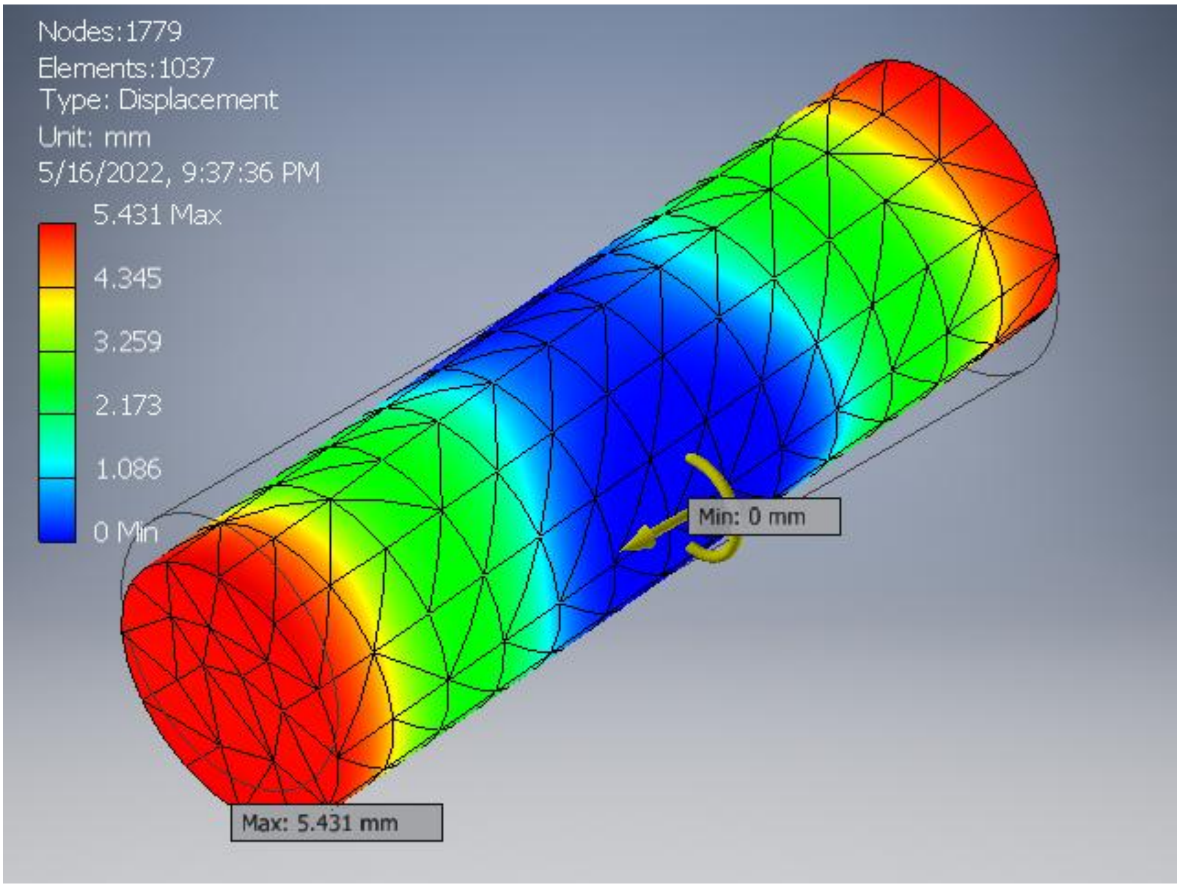


Table 1.0: Shows bearing pressure and corresponding machine shaft displacement.

S/N	BEARING PRESSURE (N)	SHAFT DISPLACEMENT(mm)
1	1200	1.086
2	1500	2.173
3	4500	3.259
4	7000	4.345
5	20000	5.431

```
>> %MATLAB PROGRAM FOR MACHINE SHAFT DISPLACEMENT AND BEARING PRESSURE.
>> X = [1.086 2.173 3.259 4.345 5.431];
>> Y = [1200 1500 4500 7000 20000];
>> mdl = fitlm(X,Y)

mdl =


Linear regression model:
    y ~ 1 + x1

Estimated Coefficients:
                   Estimate     SE      tStat      pValue
                   ________   ______   _______   ________


    (Intercept)     -6090       4420   -1.3778    0.26204
    x1             3967.7     1226.8    3.2341   0.048067


Number of observations: 5, Error degrees of freedom: 3
Root Mean Squared Error: 4.21e+03
R-squared: 0.777,  Adjusted R-Squared 0.703
F-statistic vs. constant model: 10.5, p-value = 0.0481
```

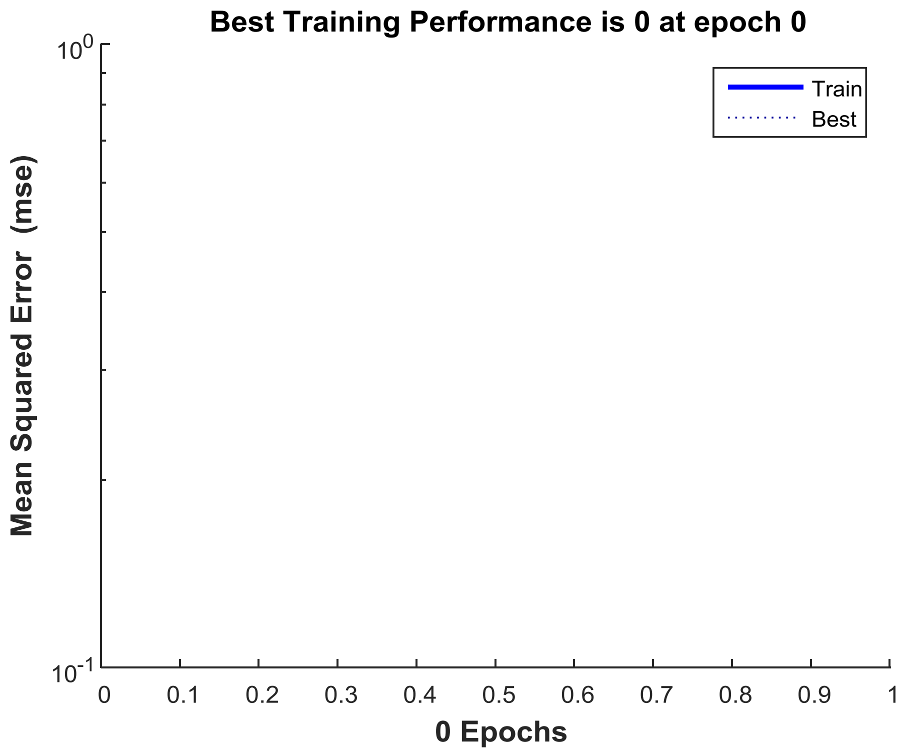
```
>> tbl = anova(mdl)

tbl =

          SumSq       DF     MeanSq        F       pValue
        __________    __   __________    ______   ________

x1      1.8574e+08    1    1.8574e+08    10.459   0.048067
Error   5.3275e+07    3    1.7758e+07
```

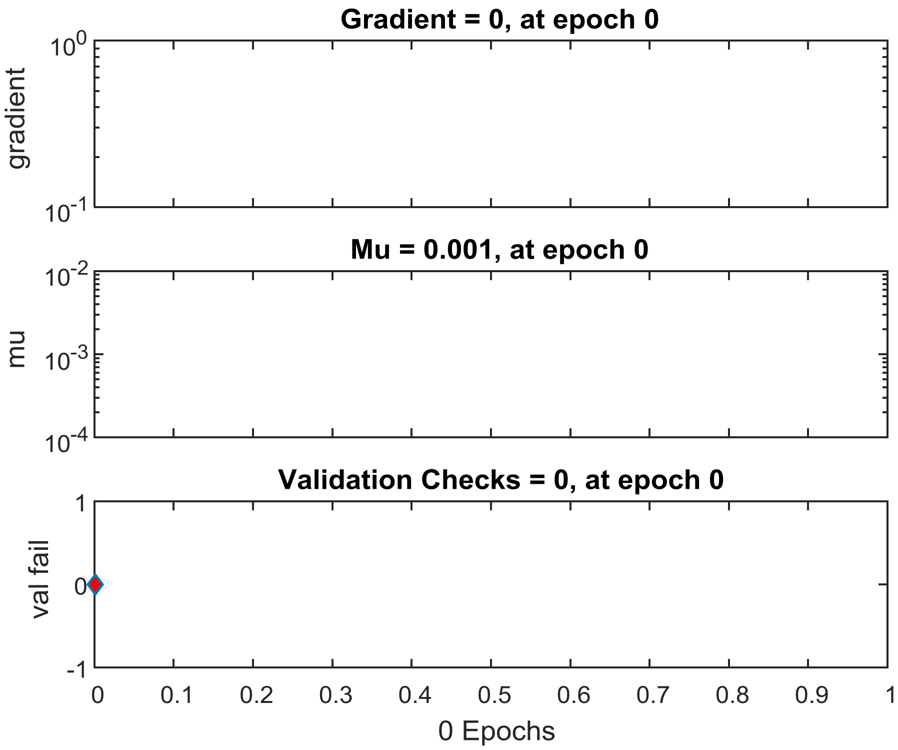
The computed linear regression model or the fitness function is shown below;

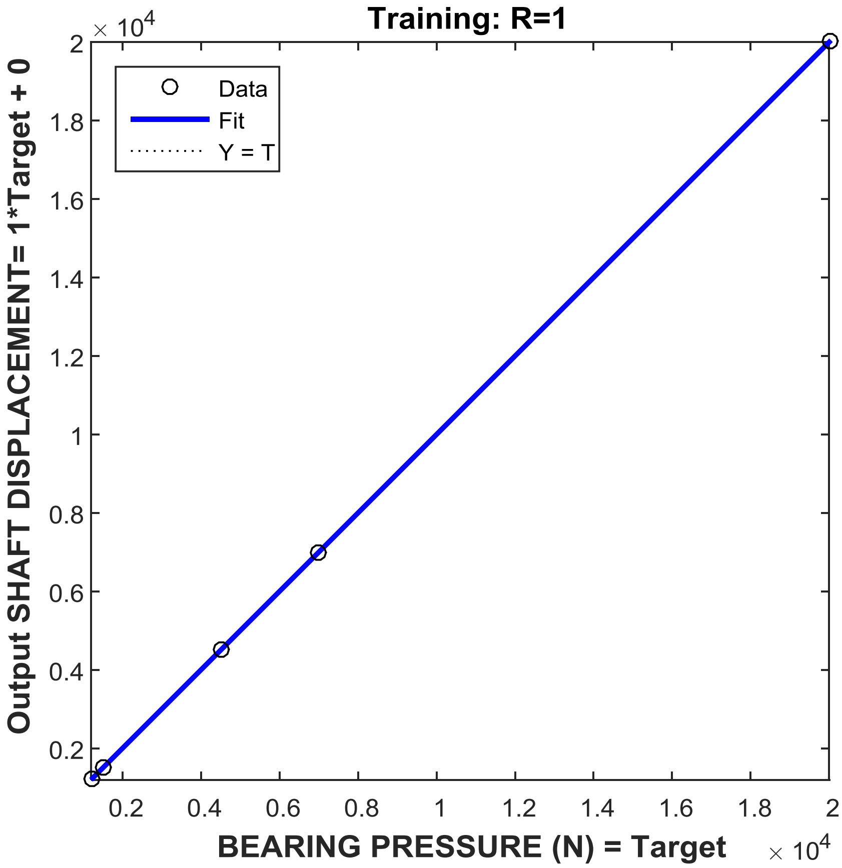
$$\boldsymbol{Y = 3967.7X - 6090}$$

Where Y = bearing pressure to be optimized and X = machine shaft displacement.

```
function  z = my_fun(x)
z = (3967.7* x)-6090;

my_fun(2.5)

ans,Z =

3.8293e+03
```




Gradient = 0, at epoch 0
gradient
10^0
10^{-1}
Mu = 0.001, at epoch 0
mu
10^{-2}
10^{-3}
10^{-4}
Validation Checks = 0, at epoch 0
val fail
1
0
-1
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
0 Epochs


Training: R=1
$\times 10^4$
2 1.8 1.6 1.4 1.2 1 0.8 0.6 0.4 0.2
Data
Fit
Y = T
Output SHAFT DISPLACEMENT= 1*Target + 0
0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
BEARING PRESSURE (N) = Target
$\times 10^4$

5. DISCUSSION

The results of the study, determination of best value of bearing pressure for minimum machine shaft displacement were discussed here. Shaft element was made with Alloy Steel material. Inventor software was used to create the shaft element design.

The shaft element subjected to turning moment of 200 N mm with variable axial bearing pressure of 1200N, 1500N, 4500N, 7000N, 20000N respectively, had the following corresponding displacement; 1.086mm, 2.173mm, 3.259mm, 4.345mm, 5.431mm respectively.

The displacements and axial bearing pressure data gotten were used to formulate a linear regression function. Testing the function at displacement of 2.5 mm yielded a bearing pressure of 3,800.8293N. Furthermore, the best performance graph shows that zero value of bearing pressure is required to avoid shaft displacement.

The regression graph with coefficient of 1 show that there is closed and random relationship between bearing pressure and machine shaft displacement.

CONCLUSION

The determination of best value of bearing pressure to avoid machine shaft displacement was investigated.
Undoubtedly, results revealed that the best value of bearing pressure to avoid machine shaft displacement is zero and this suggested effective hydrodynamic lubrication of contact surfaces.

RECOMMENDATIONS

The following recommendations are suggested based on the study:

1) Machine shaft and bearing contact surfaces must have effective hydrodynamic lubrication to achieve zero bearing pressure.

2) Shaft material with lighter weight should be used to reduce contact force/bearing pressure magnitude.

3) This research can also be done using other advanced software for generalization.

Research Question

Is there any best value of bearing pressure to avoid machine shaft displacement?

Hypothesis

Null hypothesis, H_0 = there is a best value of bearing pressure to avoid machine shaft displacement versus **Alternative hypothesis,** H_i = there is no best value of bearing pressure to avoid machine shaft displacement.

At this point, we accept **Null hypothesis,** H_0= there is a best value of bearing pressure to avoid machine shaft displacement.

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