International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 9 Sep. 2022, pp: 438-448 www.ijaem.net ISSN: 2395-5252

Impact of Bearing Pressure on Shaft Displacement

Engr. Ibrahim Rasaq, Engr. D.C Ugwuegbu, Ogunkunle Dele Kehinde, Mr. Ewurum Tennison. I

DEPARTMENT OF MECHANICAL ENGINEERING, FEDERAL POLYTECHNIC, OFFA.
DEPARTMENT OF MECHANICAL ENGINEERING, FEDERAL POLYTECHNIC NEKEDE, OWERRI.
DEPARTMENT OF MECHANICAL ENGINEERING, FEDERAL POLYTECHNIC NEKEDE, OWERRI.
DEPARTMENT OF MECHANICAL ENGINEERING, FEDERAL POLYTECHNIC NEKEDE, OWERRI.

Date of Submission: 05-09-2022 Date of Acceptance: 13-09-2022

ABSTRACT
The study, impact of bearing pressure on shaft displacement, was successfully carried out. Shaft element material was Alloy Austenitic Stainless Steel. Inventor software was used to create the shaft element design, with a variable cross sectional diameters of 50 mm and 30mm with length of 50mm each. Furthermore, Finite Element Analysis was conducted on shaft element to predict displacement under the same turning moment of 400 N mm and variable axial bearing pressure of 1200N, 4000N, 6000N, 8000N and 10000N respectively. Displacement at each bearing pressure was evaluated and analyzed using MATLAB. The analysis revealed that the shaft element had maximum displacement of 6.124 mm and minimum displacement of 0.001 mm. According to the findings, displacements corresponding to the chosen bearing pressures were: 1.225mm, 2.450mm, 3.675mm, 4.899mm and 6.124mm respectively. The bearing pressure and shaft displacement data were trained using levenberg marquardt algorithm at 70% training data, 15% test data and 15% validation data. Results revealed that the best performance level was at 0 and at epoch 0 and this suggested lowest value of the bearing pressure to avoid excessive shaft displacement. The correlation coefficient of -0.3174 at P-value of 0.4436 revealed that there is a negative relationship between the bearing pressure value and shaft displacement value. However, the hypothesis test indicated that no relationship exist between the two variables under consideration. The researchers made the following recommendations: Machine shaft should not be subjected to bearing pressure exceeding 10,000N to maintain shaft displacement within permissible limit, Shaft material with lighter weight should be used to reduce contact force/bearing pressure magnitude, etc.

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

I. INTRODUCTION

Background of the Study

Sara and Engel (as cited in Ugwuegbu and Ewurum, 2022) stated that fluctuated loads condition or combined torsion and bending loads condition are the usual work conditions of shafts, which usually cause shaft displacement. Displacement analysis relies on the overall shaft geometry, bearing pressure and the work condition.

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.

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.

Mechanical machines make use of shafts to transmit needed rotary motion and power. All machine shaft designers should ensure that the shaft bearing pressure can cover the requirements of the material strength and shaft-supported components (Khurmi and Gupta, 2012).

There are no doubts that bearing pressure affects 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 studying the impact of bearing pressure on shaft displacement.

Statement of Problem

Undoubtedly, excessive bearing pressure can lead to bearing failure (penning or deformation) or excessive shaft displacement. Mechanical machines make use of shafts to transmit needed rotary motion and power. 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 impact of bearing pressure on shaft displacement.

Purpose of the study

The general purpose of this study is to determine the impact of bearing pressure on 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 increase machine productivity and service life by choosing allowable bearing pressure that permits minimum 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 relationship between bearing pressure and shaft displacement?

Hypothesis

Null hypothesis, H_0 = there is a significant relationship between bearing pressure and shaft displacement versus **Alternative hypothesis,** H_i = there is no significant relationship between bearing pressure and shaft displacement.

Scope of the Study

This research focused on studying the impact of bearing pressure on shaft displacement. So, all efforts were directed towards the general objective. The researchers are members of Federal Polytechnic Nekede and Federal Polytechnic Offa in Nigeria. Results may be subject to variations within other parts of the World.

Review of Related Literature

Ugwuegbu and Ewurum (2022) studied impact of machine shaft geometry on shaft displacement, in Federal Polytechnic Nekede, Owerri and they concluded that 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.

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.

II. METHODOLOGY

The study considered a cylindrical step turned shaft geometry, made from the same

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 9 Sep. 2022, pp: 438-448 www.ijaem.net ISSN: 2395-5252

material, Alloyed Austenitic stainless steel for strength. The shaft is a variable cross sectional diameter of 30mm and 50mm with length of 50mm each. Shaft was subjected to turning moment of 400 N mm with variable normal bearing pressure of 1200N, 4000N, 6000N, 8000N and 10000N respectively. Displacement at each bearing pressure was evaluated using Finite Element Analysis approach and the data was analyzed using MATLAB.

III. RESULTS AND PRESENTATIONS

⊟ **Physical**

Material	Stainless Steel, Austenitic
Density	8 g/cm^3
Mass	1.06814 kg
Area	16493.4 mm^2
Volume	133518 mm^3
Center of Gravity	x=0.0000000046748 mm y=0 mm z=-11.7647 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

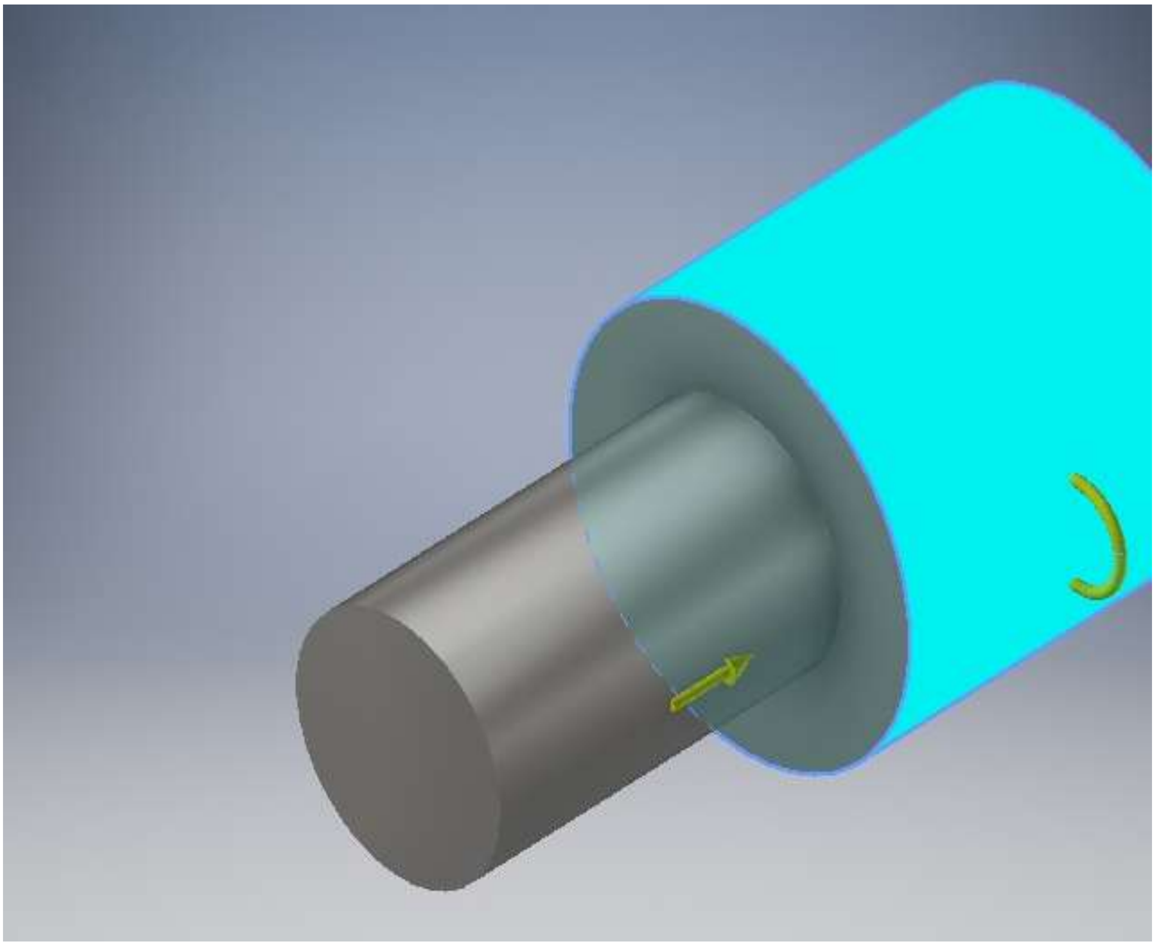
⊟ **Material(s)**

Name	Stainless Steel, Austenitic	
General	Mass Density	8 g/cm^3
	Yield Strength	228 MPa
	Ultimate Tensile Strength	540 MPa
Stress	Young's Modulus	190.3 GPa
	Poisson's Ratio	0.305 ul
	Shear Modulus	72.9119 GPa
Part Name(s)	Part12 Shaft Design	

⊟ **Operating conditions**

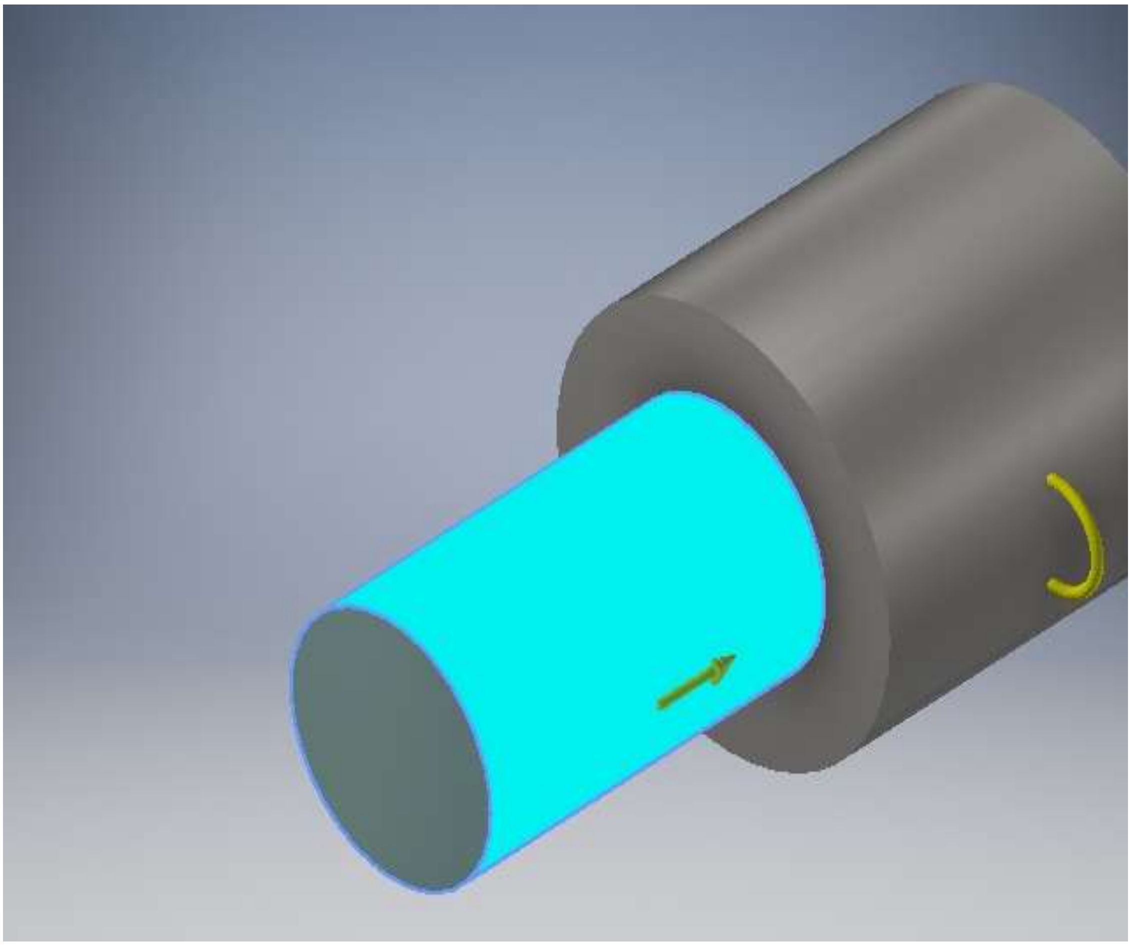
⊟ **Moment:1**

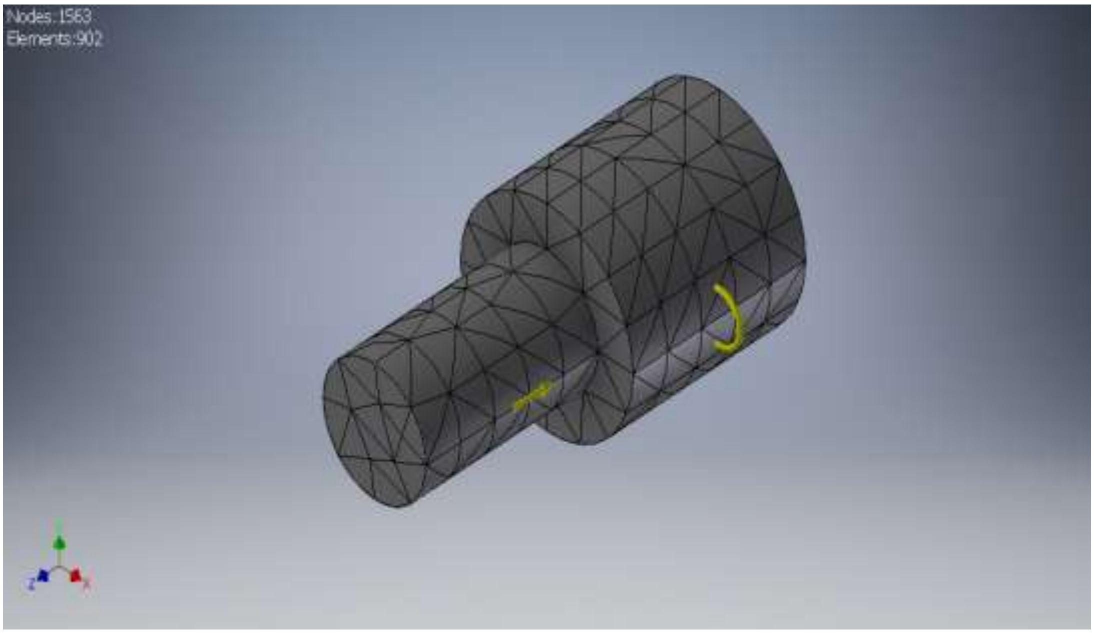
Load Type	Moment
Magnitude	400.000 N mm
Vector X	0.000 N mm
Vector Y	0.000 N mm
Vector Z	400.000 N mm



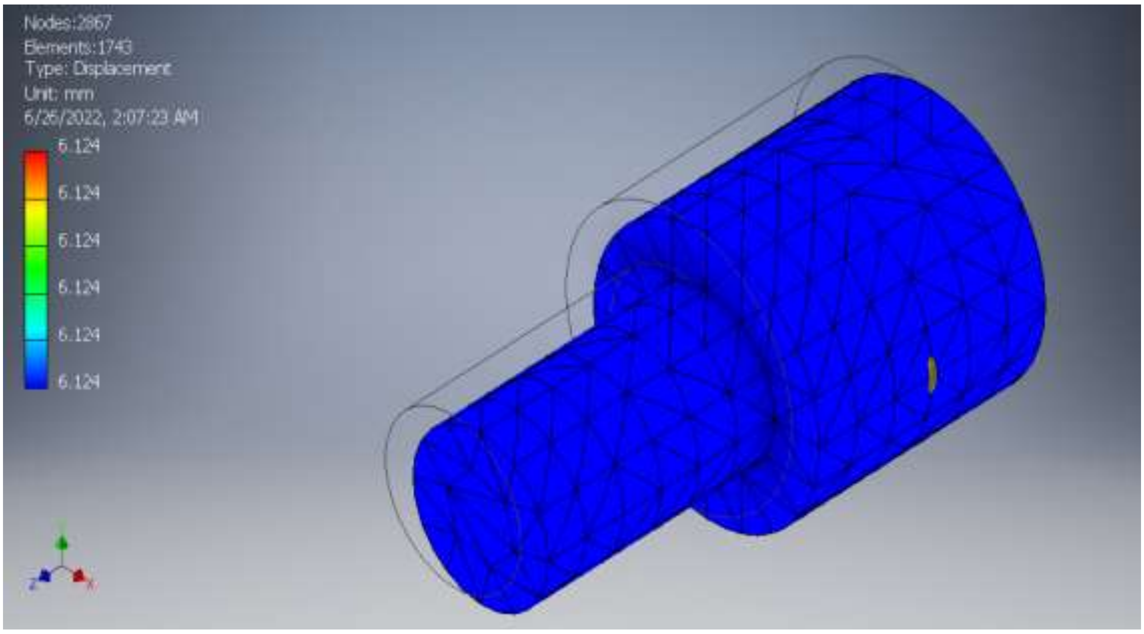
Bearing Load:1

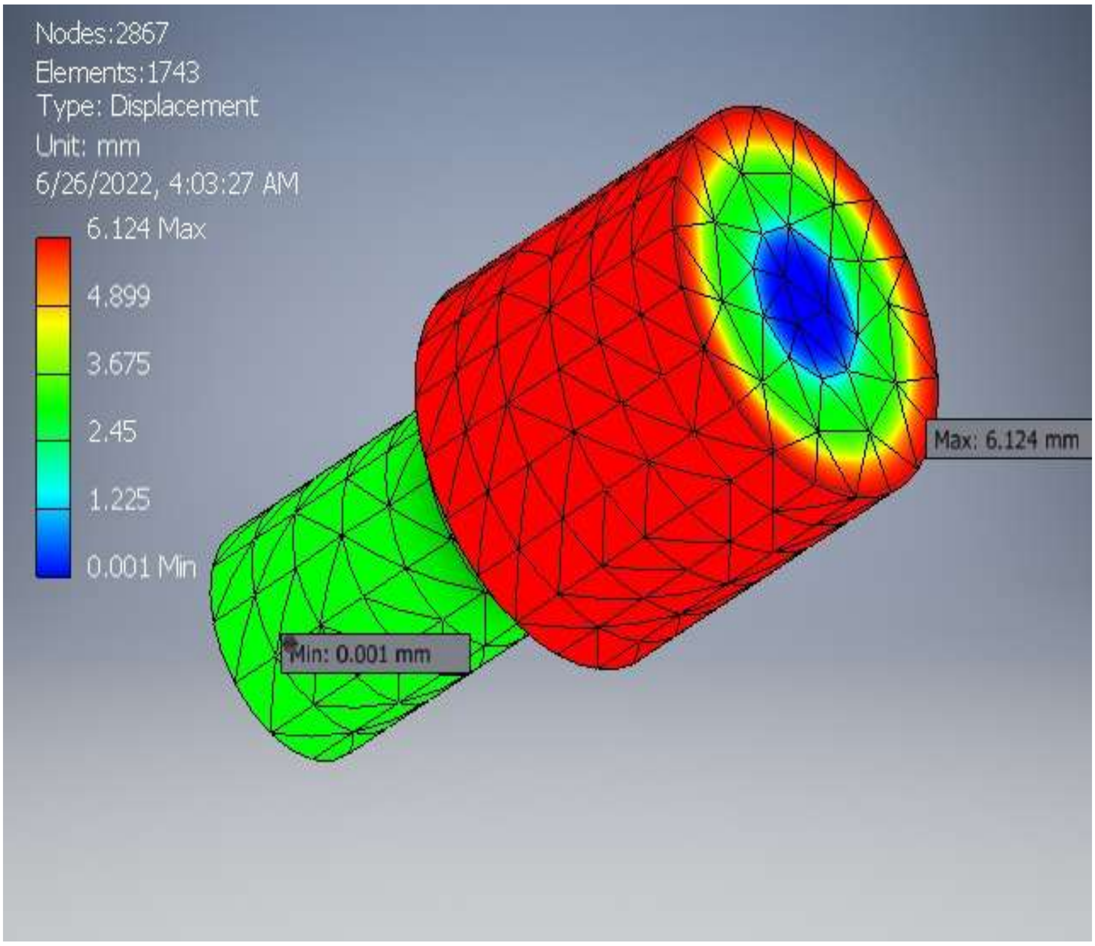
Load Type	Bearing Load
Magnitude	1200.000 N
Vector X	0.000 N
Vector Y	0.000 N
Vector Z	-1200.000 N

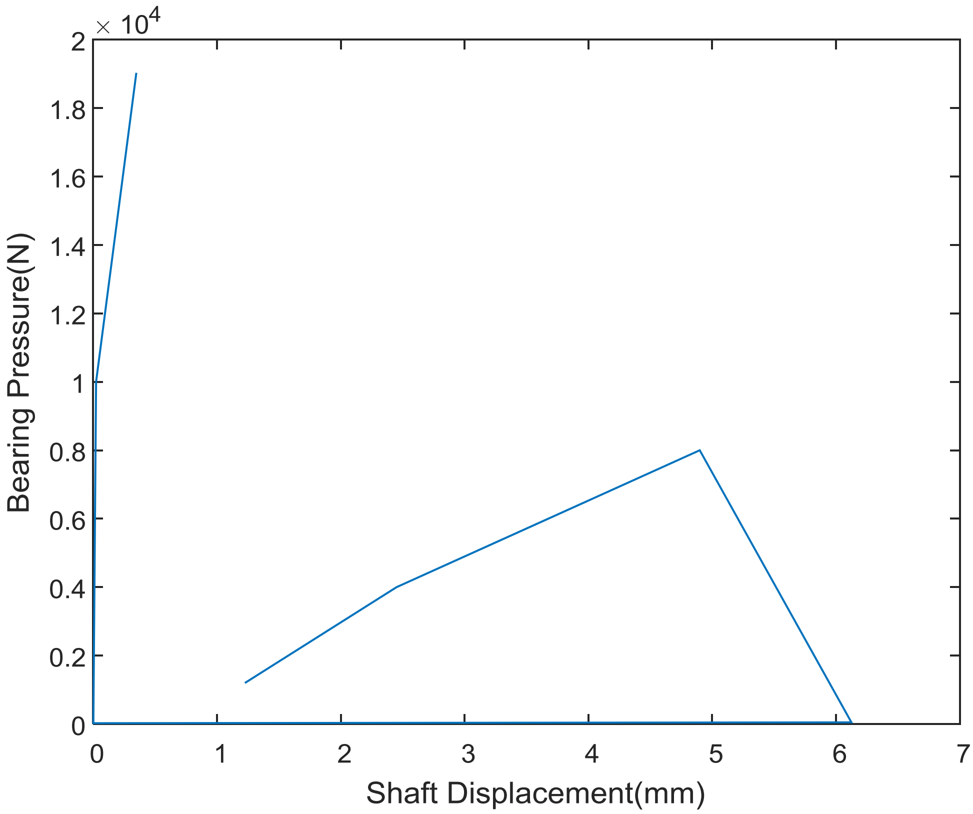



Nodes:1563
Elements:902

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 9 Sep. 2022, pp: 438-448 www.ijaem.net ISSN: 2395-5252







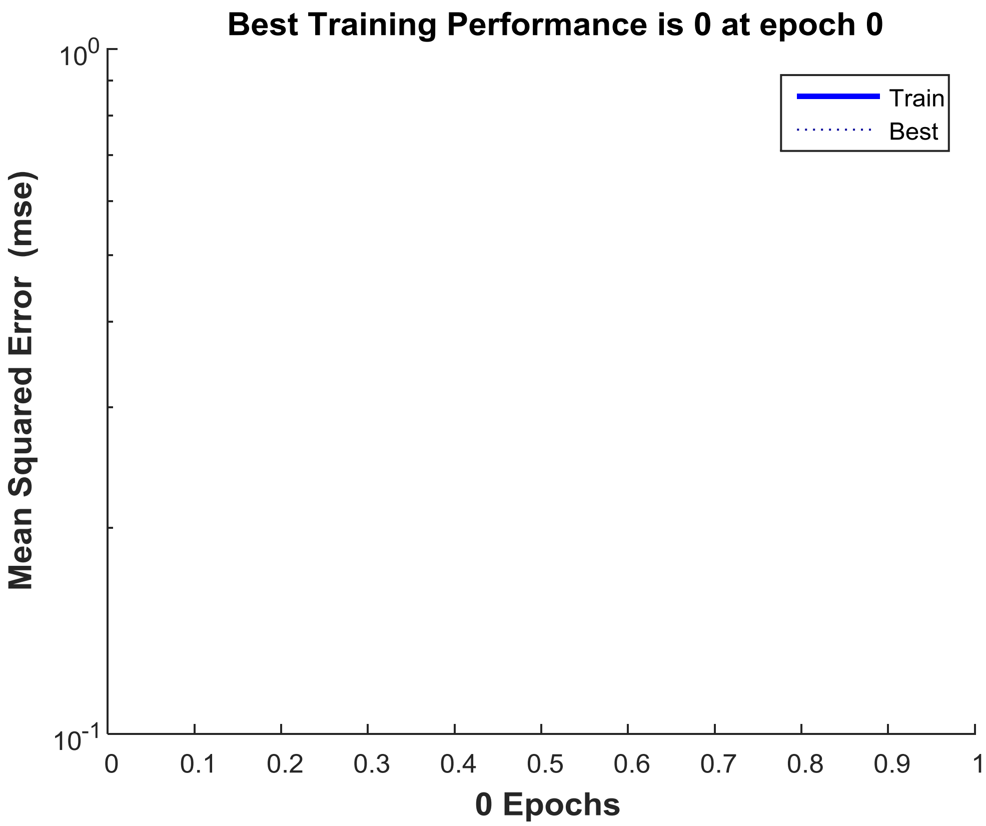
MATLAB FUNCTION FOR THE GRAPHS ABOVE

```
function createfigure1(X1, Y1)
%CREATEFIGURE1(X1, Y1)
%  X1:  vector of x data
%  Y1:  vector of y data

% MATLAB on 10-Sep-2022 01:42:46

% Create figure
figure1 = figure;

% Create axes
axes1 = axes('Parent',figure1);
box(axes1,'on');
hold(axes1,'on');

% Create plot
plot(X1,Y1);

% Create xlabel
xlabel({'Shaft Displacement(mm)'});

% Create ylabel
ylabel({'Bearing Pressure(N)'});
end
```

Matlab Computation Of Hypothesis And Correlation Coefficient.

```
>> [h,sig,ci] = ttest(B,D)
h =
     1
sig =
    0.0323
ci =
   1.0e+04 *
    0.0677    1.1387
>>[r,p] = corrcoef(B,D)
r =
    1.0000   -0.3174
   -0.3174    1.0000
p =
    1.0000    0.4436
    0.4436    1.0000
```

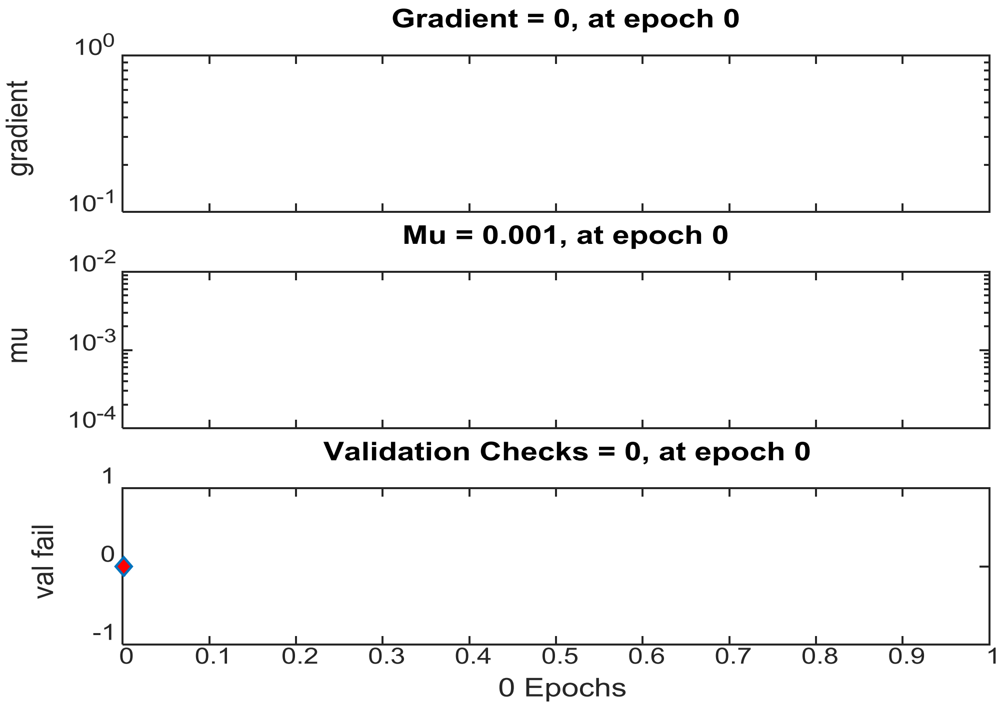
International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 9 Sep. 2022, pp: 438-448 www.ijaem.net ISSN: 2395-5252



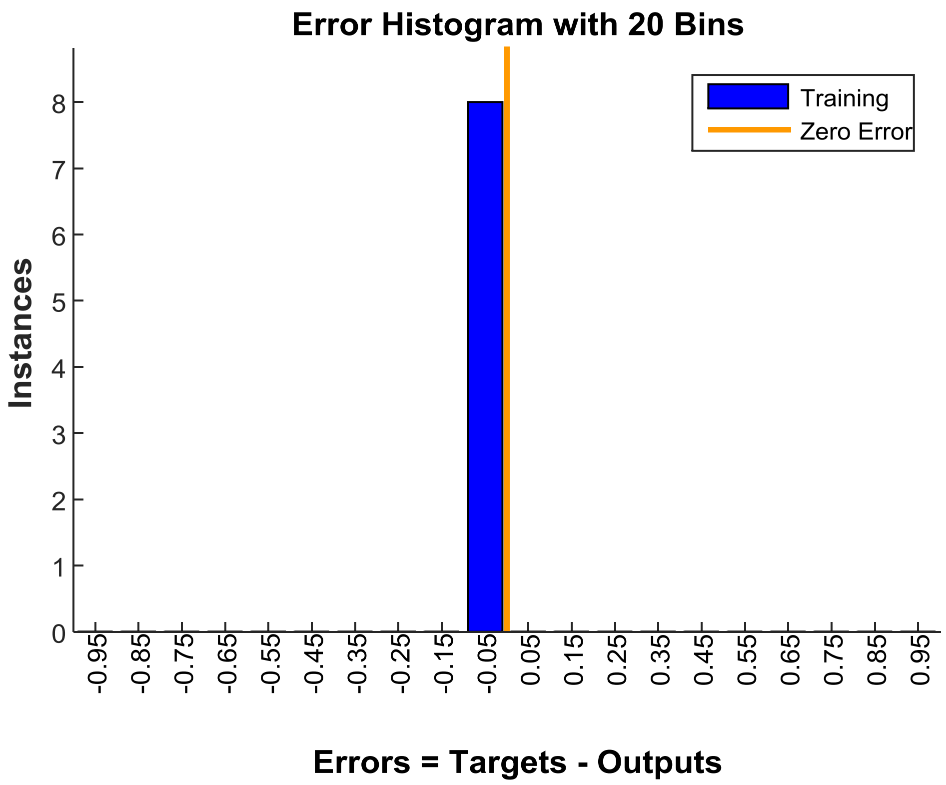
MATLAB FUNCTION FOR THE GRAPHS ABOVE

```
function createfigure1(X1, YMatrix1, X2, Y1, X3, Y2)
%CREATEFIGURE1(X1, YMATRIX1, X2, Y1, X3, Y2)
%  X1:  vector of x data
%  YMATRIX1:  matrix of y data
%  X2:  vector of x data
%  Y1:  vector of y data
%  X3:  vector of x data
%  Y2:  vector of y data

%  MATLAB on 10-Sep-2022 02:20:35

% Create figure
figure1 = figure('Tag','TRAINING_PLOTPERFORM','NumberTitle','off',...
    'Name','Neural Network Training Performance (plotperform), Epoch 0, Performance goal met.');

% Create axes
axes1 = axes('Parent',figure1,'YScale','log');
%% Uncomment the following line to preserve the X-limits of the axes
% xlim(axes1,[0 1]);
%% Uncomment the following line to preserve the Y-limits of the axes
% ylim(axes1,[0 1]);
hold(axes1,'on');

% Create multiple lines using matrix input to semilogy
semilogy1 = semilogy(X1,YMatrix1,'LineWidth',2,'Parent',axes1);
set(semilogy1(1),'DisplayName','Train','Color',[0 0 1]);
set(semilogy1(2),'Color',[0 0.8 0]);
set(semilogy1(3),'Color',[1 0 0]);
set(semilogy1(4),'MarkerSize',16,'Marker','o','LineWidth',1.5,...
    'LineStyle','none',...
    'Color',[0 0 0.6]);

% Create semilogy
semilogy(X2,Y1,'DisplayName','Best','LineStyle',':','Color',[0 0 0.6]);

% Create semilogy
semilogy(X3,Y2,'LineStyle',':','Color',[0 0 0]);

% Create xlabel
xlabel('0 Epochs','FontWeight','bold','FontSize',12);
```

```
% Create ylabel
ylabel('Mean Squared Error (mse)','FontWeight','bold','FontSize',12);

% Create title
title('Best Training Performance is 0 at epoch 0','FontWeight','bold',...
   'FontSize',12);

% Create legend
legend(axes1,'show');

% uicontrol currently does not support code generation, enter 'doc uicontrol' for correct input syntax
% In order to generate code for uicontrol, you may use GUIDE. Enter 'doc guide' for more information

% uicontrol(...);
end
```



International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 9 Sep. 2022, pp: 438-448 www.ijaem.net ISSN: 2395-5252



MATLAB CODES FOR THE GRAPHS ABOVE

```
% Solve an Input-Output Fitting problem with a Neural Network
% Created 10-Sep-2022 02:24:06
%
% This script assumes these variables are defined:
%
%   data - input data (Bearing Pressure).
%   data - target data (Displacement of Shaft).

x = data;
t = data;

% Choose a Training Function
% For a list of all training functions type: help nntrain
% 'trainlm' is usually fastest.
% 'trainbr' takes longer but may be better for challenging problems.
% 'trainscg' uses less memory. Suitable in low memory situations.
trainFcn = 'trainlm';  % Levenberg-Marquardt backpropagation.

% Create a Fitting Network
hiddenLayerSize = 10;
net = fitnet(hiddenLayerSize,trainFcn);

% Setup Division of Data for Training, Validation, Testing
net.divideParam.trainRatio = 70/100;
net.divideParam.valRatio = 15/100;
net.divideParam.testRatio = 15/100;

% Train the Network
[net,tr] = train(net,x,t);

% Test the Network
y = net(x);
e = gsubtract(t,y);
performance = perform(net,t,y)

% View the Network
view(net)

% Plots
% Uncomment these lines to enable various plots.
%figure, plotperform(tr)
%figure, plottrainstate(tr)
%figure, ploterrhist(e)
%figure, plotregression(t,y)
%figure, plotfit(net,x,t)
end
```

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 9 Sep. 2022, pp: 438-448 www.ijaem.net ISSN: 2395-5252

IV. DISCUSSION

The outcome of the study, impact of bearing pressure on shaft displacement was discussed here. Shaft element was made with Alloy Austenitic Stainless Steel material. Inventor software was used to create the shaft element design, with a variable cross sectional diameters of 50 mm and 30mm with length of 50mm each. Furthermore, Finite Element Analysis was conducted on shaft element to predict displacement under the same turning moment of 400 N mm and variable axial bearing pressure of 1200N, 4000N, 6000N, 8000N and 10000N respectively. Displacement at each bearing pressure was evaluated using Finite Element Analysis approach.

The analysis revealed that the shaft element has maximum displacement of 6.124 mm and minimum displacement of 0.001 mm. According to the findings, displacements corresponding to the chosen bearing pressures were: 1.225mm, 2.450mm, 3.675mm, 4.899mm and 6.124mm respectively.

Training of bearing pressure and shaft displacement data using levenberg marquardt algorithm at 70% training data, 15% test data and 15% validation data respectively revealed that the best performance level was at 0 and at epoch 0 and this suggested lowest value of the bearing pressure. The correlation coefficient of -0.3174 at P-value of 0.4436 revealed that there is a negative relationship between the bearing pressure value and shaft displacement value. However, the hypothesis test indicated that no relationship exist between the two variables under consideration.

CONCLUSION

The impact of bearing pressure on shaft displacement was investigated.

Obviously, results from the study revealed that there is a negative relationship between the bearing pressure value and shaft displacement value. Furthermore, the best performance test from graph showed that the lowest value of the bearing pressure is required to avoid excessive machine shaft displacement.

V. RECOMMENDATIONS

The following recommendations are suggested based on the study:

1) Machine shaft should not be subjected to bearing pressure exceeding 10,000N to maintain shaft displacement within permissible limit.
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 relationship between bearing pressure and shaft displacement?

Hypothesis

Null hypothesis, H_0 = there is a significant relationship between bearing pressure and shaft displacement versus **Alternative hypothesis,** H_i = there is no significant relationship between bearing pressure and shaft displacement.

```
>> [h,sig,ci] = ttest(B,D)
h =
    1
sig =
   0.0323
ci =
  1.0e+04 *
   0.0677    1.1387
```

At hypothesis of **1**, we accept **alternative hypothesis** H_i = there is no significant relationship between bearing pressure and shaft displacement.

REFERENCES

[1]. Christopher, D. W. & Michael, W. R. (2013). Shaft deflection: A very very long example. American Society for Engineering Education.

[2]. Khurmi, R.S & Gupta, J.K. (2014). Theory of machines. New Dehi: Khanna Publishers.

[3]. Rajput, R.K. (2012). Strength of materials. New Dehi: Khanna Publishers.

[4]. Sara,S.H. & Engel, B. (2017). Failure analysis and fatigue life estimation of a shaft of a rotary draw bending machine. International Journal of Mechanical and Mechatronics Engineering 11(11).

[5]. Ugwuegbu, D.C & Ewurum, T.I. (2022). Impact of Machine Shaft Geometry on Shaft Displacement. International Journal of Advances in Engineering and Management 4(5), pp. 1387-1398.

[6]. Ugwuegbu, D.C & Ewurum, T.I. (2022). Computer Aided Design and Computer Aided Manufacturing(CAD/CAM). Owerri: Ingenious Publishers.