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Finite Element Analysis on The AISI 4340 Steel Shaft

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ABSTRACT

Finite Element Software was applied to predict and determine stress distribution in the machined AISI steel shaft. The cutting forces which were measured from experimental observation were compared with predicted ones from the FEM. The result showed that the predicted value for maximum stress and minimum stress are 0.107Mpa and 0.053Mpa respectively. The total deformation of the AISI steel is 7.55e^{-10}m for a spindle speed of 1182.57m/s. The predicted values were found to be within the recommended range of AISI materials and were with good precision when machined. The determined values from the Finite elements software were used to conduct experiment in the machine workshop so as to validate the results obtained.

Keywords: *AISI steel, Finiet element method(FEM), maximum stress and total deformation.*

INTRODUCTION

The application of Finite Element Method (FEM) in the modeling and simulation of machining process is yielding adequate breakthrough in better understanding of optimized machined surfaces and generation of heat in cutting zones. Also, the prediction of optimal process parameters, temperature and stress distribution in machining components and technology by FEM has reduced the colossal money and time spent on machining tools and workshop manpower (Al-Ahmari, 2007). The application of FEM is pivotal in the development of tool edge geometry and accurate surface integrity of components.

Also, it was observed that there exist effects of different parameter like cutting speed, feed and rake angle on the surface roughness of metals (Bhattacharya & Faria, 2015). They compared the result of regression modeling and genetic algorithm. Three parameters namely cutting speed, feed rate and radial depth of cut for turning process and applied ANN resulted in good

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agreement between predicted and actual values (Saravanan & Vijayakumar, 2008). Puneet (2011) attempted optimization of Cutting Parameters in Hard Turning of AISI 4340 Steel. They investigated the effect on surface continuous turning of hardened steel. This report describes about the hard turning of AISI 4340 alloy steel by varying various parameters. The hard turning parameters are: Cutting speed, Feed and Depth of cut (Anthony-xavior, 2009).

This research will serve as a reference material for future researchers who may have similar research of this study. The findings of this study will redound to the benefit of industries and manufacturing companies who engage on manufacturing parts for specific purpose which involve the removal of excess materials by turning (Lin, 2008).This research will improve on the existing method for turning AISI steels and also system performance, and reduction in production cost (Oktem, 2008). The study will uncover critical areas in empirical modeling using Ansys finite element software that many researchers were not able to explore. Thus, new findings on turning AISI structural steels and knowing areas where stress and vibration occurs most will be revealed.

It was observed that analysis of AISI steel has been done by using conventional process like Turning, Optimization without knowing the best and accurate factor to use when turning AISI Structural Steel (Madhavan, Chandrasekar & Farris, 2000). Also some researchers haven't worked on optimization of AISI steel using Optimization Techniques, Genetic Algorithm and advanced software etc (Maheswara, 2006). To know stress distribution and fatigue occurrence, we selected this area to carry out analysis and to know the best optimum factor in turning AISI Structural Steel.

An optimization problem consists of optimizing one or more turning parameters objective functions while satisfying several constraints like size, turning and material removal rate (Ibrahim, 2010). These problems are often conflicting in design and they are carefully studied. This study is aimed at modelling and optimizing the operating parameters for turning AISI Structural steel using FEM.

Many works have not been reported on the determination of optimum mechanical properties of AISI 4340 steel shaft; but very few researchers have worked on optimization of AISI steel shaft stress and strain distribution using advanced optimization techniques and optimization of mechanical parameters for AISI steel shaft, so we selected this area to carry out analysis.

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MATERIALS AND METHOD

This study aimed at ascertaining the magnitude of the stress and strain distribution of AISI steel. In achieving this aim the following objectives were pursued:

i. Design of shaft in the ANSYS space claim

ii. Meshing of the AISI steel shaft into finite elements

iii. Application of Fixed supports and forces to the shaft in the ANSYS environment

iv. Determination of deformation, equivalent stress distribution and the rotational acceleration in the AISI steel shaft

In the machining operation we use the Colchester lathe machine to carry out this experiment we selected the cutting method in turning the AISI steel from the gears on the lathe (Ram,2006). A Carbide tool was used in turning due to the ability to machine at elevated temperature and higher speeds (Basil & Tina, 2014). When turning the AISI Structural steel the cutting fluid was applied to reduce excessive heat generated during turning. AISI Structural Steel is used as the workpiece material to know the Material Removal Rate (Ranganathan, 2018).

ANSYS software was used to create simulated computer model of the shaft structural component to ascertain its respective strength, toughness, elasticity and stress distribution. The procedures applied in generating the ANSYS simulation on the shaft design are given as follows (Yang & Liu, 2002).

1. Creation of Geometry

2. Meshing into elements and nodes.

3. Application of Fixed supports

4. Application of Rotational Acceleration.

5. Application of solutions such as deformation and equivalent stress

The diagram and chemical composition of AISI Structural Steel shaft is shown in Figure 1 and Table 1 respectively.

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Figure 1: AISI Steel 4340

Table 1: Chemical composition of AISI steel 4340

Element	C	Cr	Mn	Mb	Ni	Ph	Si	S	Fe
% composition	0.40	0.90	0.80	0.30	2.00	0.04	0.30	0.04	95.23

Source: (Ibrahim, 2010)

RESULTS AND DISCUSSION

Design Geometry Using Ansys

The shaft geometry as designed in the Finite Element software ANSYS spaceclaim with the interface tools as shown in Figure 2:

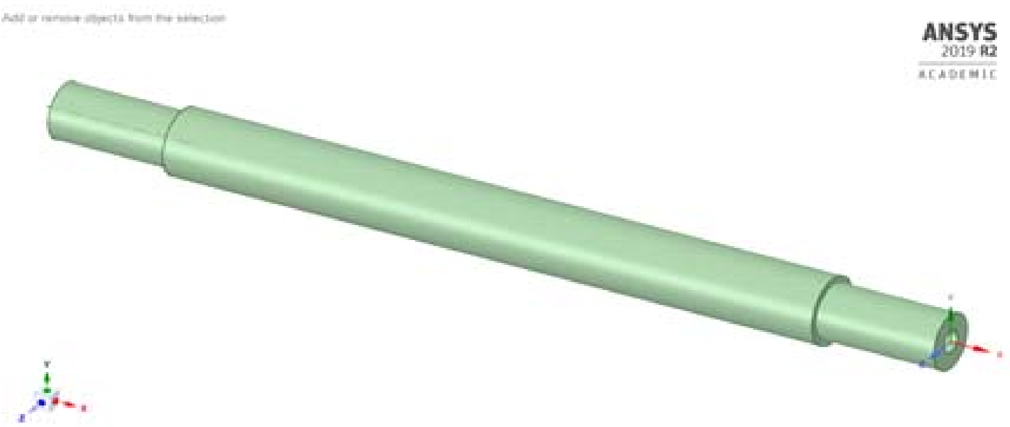

Figure 2: Shaft Geometry (Source: Researcher)

The Meshed shaft component is shown in Figure 3.

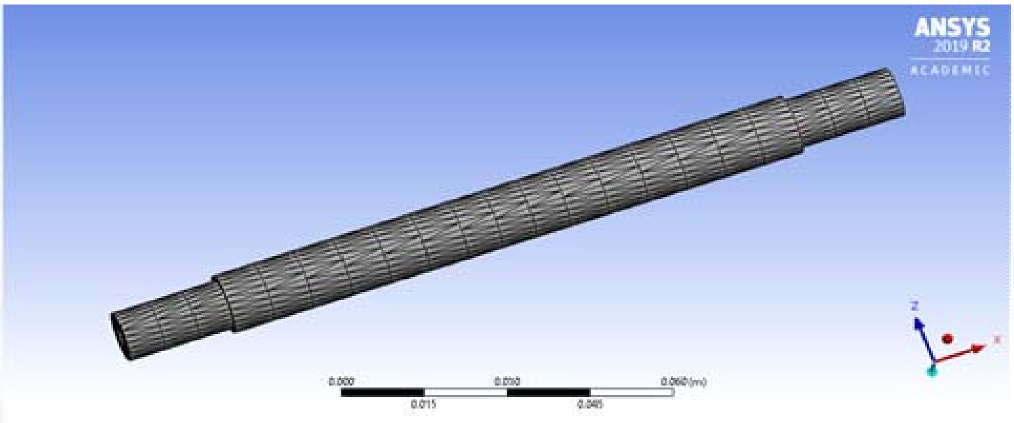

Figure 3: Meshing Of Shaft Geometry (Source: Researcher)

Fixed support was applied to the two ends of the meshed shaft to eliminate unnecessary movement during simulation. The supported shaft component is shown in Figure 4.

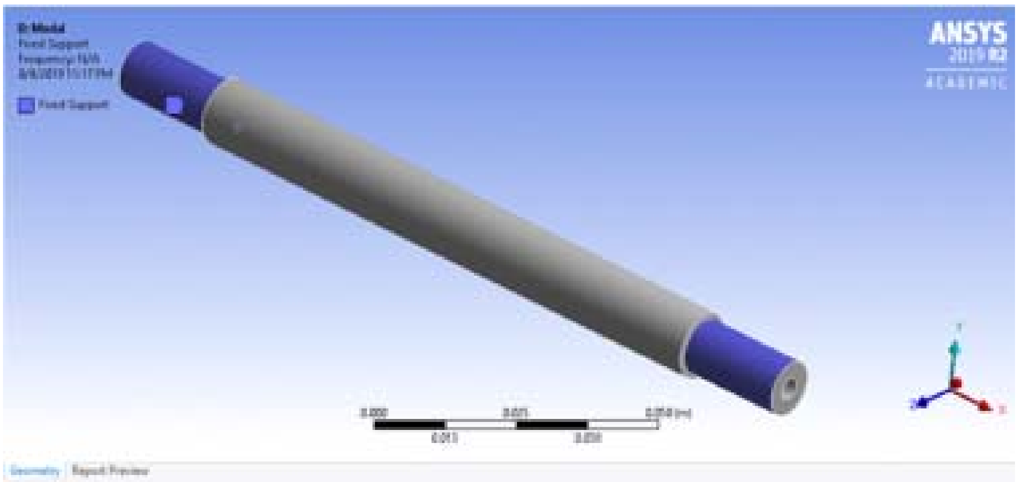

Figure 4: Application Of Fixed Supports (Source: Researcher)

An optimum spindle speed of 1182.57471m/s was applied in the determination of the rotational acceleration value with an assumption that the shaft will rotate at this steady speed. The diagrammatical representation of the rotational acceleration on the meshed shaft is shown in Figure 5.

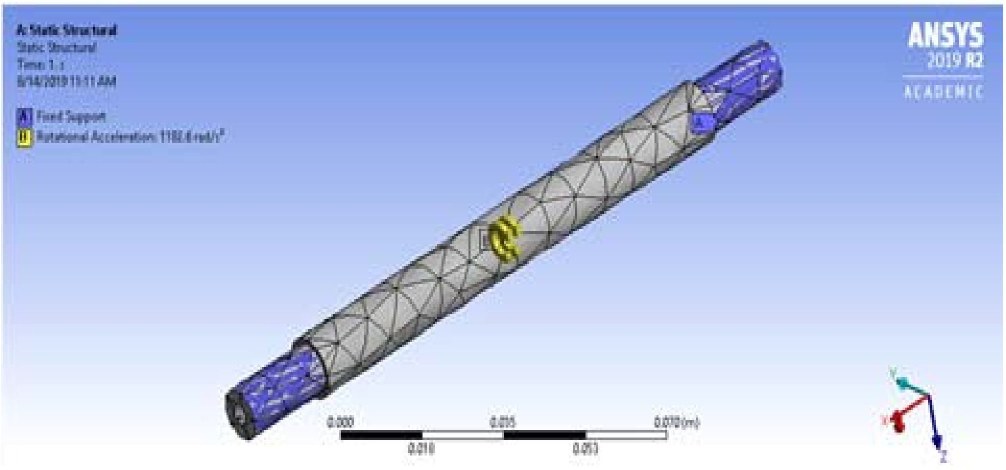

Figure 5: Application of Rotational Acceleration (Source: Researcher)

Determination of Total Deformation and Equivalent stress

The ANSYS solution shows that the maximum Total Deformation on structural steel shaft is $7.5508_{e}{}^{-9}{}_{m}$. The solution is shown in Figure 6.

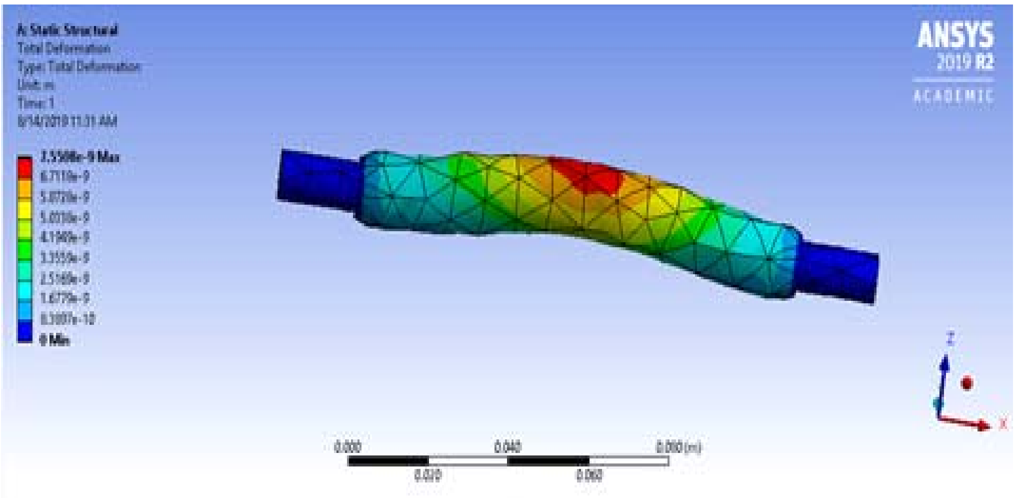

Figure 6: Total Deformation of the AISI 4340 (Source: Researcher)

Also, the maximum and minimum equivalent stress developed in the shaft component is 106560Pa and 5301Pa respectively. The static structural equivalent stress analysis is shown in Figure 7.

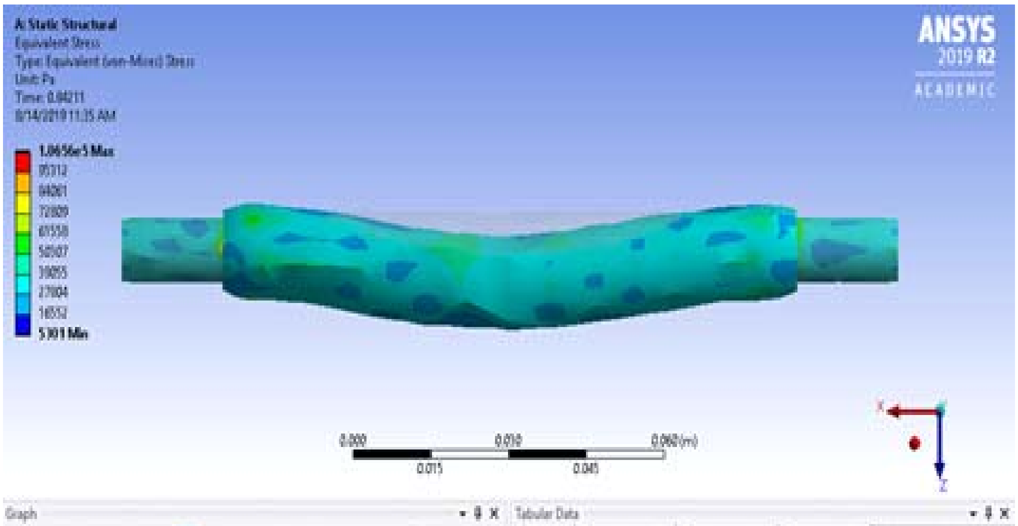

Figure 7: Equivalent Stress obtained in the AISI 4340 shaft (Source: Researcher)

CONCLUSION

ANSYS Finite Element Software was introduced to analyze and determine stress distribution in the machined shaft. The cutting forces which were measured from experimental observation were compared with predicted ones from the FEM. The result showed that the prediction was with good precision when machining with FEM model. The predicted values from the Finite elements software were applied in conducting experiment in the machine workshop so as to validate the results obtained.

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