ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 9, Issue 6, June 2022

Analysis of Cutting Parameters in CNC Turning of AISI 52100 Steel with Coated Cutting Tool

[1] Tanpure Sandesh Popat, [2] Prof. (Dr.) Netra Pal Singh

[1] Research Scholar, Mechanical Engineering Department, Oriental University, Indore, Madhya Pradesh, India.
[2] Professor, Mechanical Engineering Department, Oriental University, Indore, Madhya Pradesh, India.
Corresponding Author Email: [1] sani20048@gmail.com, [2] netrapalsingh@oriental.ac.in

---

Abstract— In the automotive industry, machining is an essential part of the production process. On mild steel, a turning process was utilised to create shafts of varied diameters. This work attempts to optimise multiple factors such as surface roughness, MRR, and tool wear during turning operations on various steel grades. The average surface roughness (Ra) is one of the most important measurements of surface quality during the machining process, and it is primarily influenced by a number of machining parameters such as true rake angle and side cutting edge angle, cutting speed, feed rate, depth of cut, nose radius, and machining time. The Taguchi technique was used to build a surface roughness model to study how machining factors such as feed rate, tool geometry, nose radius, and machining duration impact the roughness of the surface created during the dry turning phase. This study demonstrates how to determine surface roughness values for CNC turning of AISI 52100 steel with varying coated tool nose radius using tribiological parameters. The test was carried out on a commercial CNC machine with coated tool nose radiuses of 0.4, 0.8, and 1.2 mm. Further investigation revealed that the CNC machine's design had been completed in Solid Works. Static and modal analyses were carried out using ANSYS Workbench. A static structural analysis of a CNC machine was carried out using 1G lading, which met the minimum Yield Strength requirement.

Keywords – CNC machine; AISI – 52100 steel; surface roughness; coated cutting tool; machining;

I. INTRODUCTION

A high-quality item serves as a benchmark for determining whether or not a product is acceptable. The roughness and roundness of a turning item's surface are important features [1]. Surface roughness and roundness on machining boundaries are influenced by cutting apparatus determinations, workpiece, and cutting cycle boundary. A surface unpleasantness concentrate on machining measure was created with a number and a few cycle limitations [2]. This study looked at the impact of machining factors including cutting rate, feed rate, cut depth, equipment nose sweep, and ointment on surface pain when turning AISI 52100 steel [3,5]. This study investigates the machining boundaries influence of cutting velocities, feed, and cutting device nose sweep by using a constant depth of slice to quantify surface pain for Particulate Using a constant depth of slice to evaluate surface pain for Particulate, this study investigates the machining boundaries influence of cutting velocities, feed, and the nose sweep of the cutting equipment [4]. In light of the response surface approach, the model of surface discomfort improvement is to investigate the machining boundaries, such as feed rate, apparatus calculation, nose radius, and machining time in dry turning measurements [6].

A CNC machine

A computer manages the CNC system's many functions. Because the control is hard wired in the conventional configuration, any modifications or additions in the office will need adjustments to the regulator, which may or may not be possible owing to basic design constraints [7]. In a CNC system, on the other hand, electrical equipment is utilised sparingly, and programming is employed for the most fundamental operations [8]. That is why it is also known as programming control. This makes it possible to open more offices without any trouble or money. Because these PCs are devoted, they require considerably less capacity, and they are a smart investment at the current price and with outstanding dependability [9].

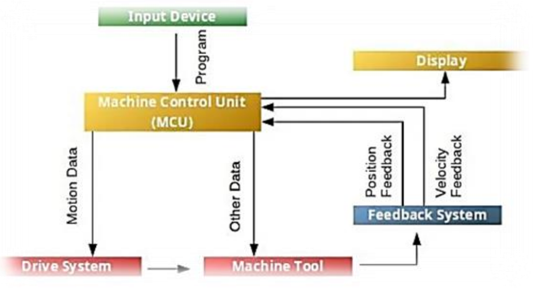

Figure 1: CNC machine block diagram

B CNC Turning

A CNC lathe manufactures components by "turning" pole material and incorporating a single point shaper into the material. Cutting activities are done using a cutting tool with one or more equal or right points in reference to the work piece's pivot. For machining tightens and points, the device can also be used close to the work piece's hub. The workpiece may have any cross-section at first, but the machined surface is typically straightened or tightened. CNC turning allows you to generate a wide range of shapes, including plain, tighten, form, fillet, and sweep profiles, as well as stringed surfaces. CNC turning may be used to create shafts, bars, centres, bushes, and pulleys, among other things [10].

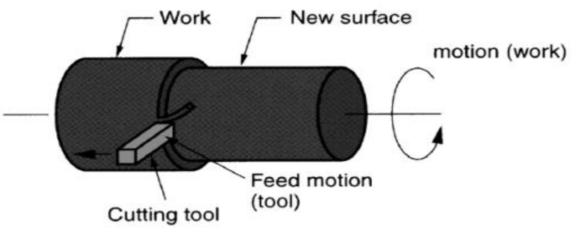

Figure 2: Turning operation

C AISI 52100 Steel

The AISI 52100 bearing steel alloy is good. It's a processed, solidified low-compound steel with a high carbon, chromium, and manganese content. Between 55 and 60 HRC is the hardness range. The microstructure after solidification shows mild tempered martensite, little held austenite, and significant carbides. As a consequence, mechanical properties such as rigidity, yield strength, high mass, and shear modulus are improved [11]. Valve bodies, syphons and fittings, transmission shafts, trains, machine instruments, agricultural haulers, and mining hardware components are all made from AISI 52100 steel. It is resistant to dynamic stacking and has a high wear resistance [12].

D Cutting tool

A cutting tool or cutter is any tool used to remove material from a work piece by shear deformation in the context of machining. Cutting can be done using single-point or multi-point tools. Single-point tools are used to remove material with a single cutting edge in turning, shaping, planning, and other related applications. Milling and drilling equipment with several points are common. A toothed body is a body that has teeth or cutting edges. There are additional multipoint grinding machines on the market [13].

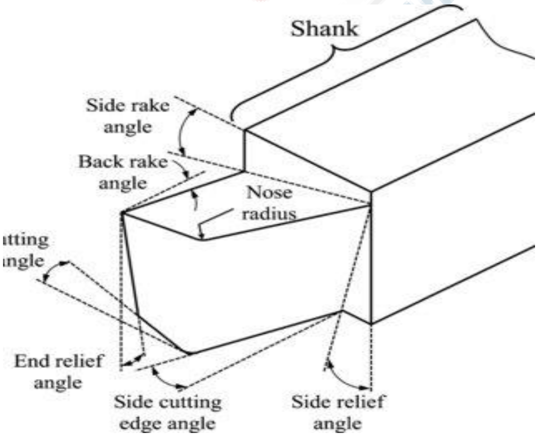

Figure 3: Geometry of Cutting tool [15]

Cutting tool materials must be tougher than the material being cut, and the tool must be able to withstand the heat and force generated during metal cutting. The tool must also have a certain shape, with clearance angles that allow the cutting edge to make contact with the workpiece without dragging on it. The cutting face angle, flute width, number of flutes or teeth, and margin size are all critical considerations. All of the foregoing, as well as the tool's speeds and feeds, must be adjusted in order for the tool to have a long operating life [19].

E Process parameters

1. Speed

When it comes to speed, the spindle and the work piece are frequently debated. The revolutions per minute (RPM) indicates how fast it turns (rpm). The surface speed, or the rate at which the work piece material goes past the cutting tool, is the most important part of the turning process.

2. Feed

The feed refers to the rate at which the cutting tool moves along its cutting path and is always referred to as the cutting tool. The feed rate on most power-fed lathes is related to spindle speed and is measured in millimeters (of tool advance) per spindle revolution, or mm/rev.

3. Depth of Cut

The term "depth of cut" is self-explanatory. It is the thickness of the layer being removed from the work piece (in a single pass) or the distance in millimetres between the work's uncut and cut surfaces. [14]

F Fatigue Basics

While many components may appear to work well at first, fatigue failure caused by cyclic stress causes them to fail in service. Fatigue analysis is used to assess a material's ability to resist the many cycles that a component may undergo over the course of its life. The three major approaches of Fatigue Analysis are Strain Life, Stress Life, and Fracture Mechanics, with the first two available inside the ANSYS Fatigue Module.

The Stain Life approach is now popular. Strain is a direct parameter that has been found to be a reliable predictor of low-cycle fatigue. Stress Life is concerned with overall life and does not discriminate between initiation and propagation. Strain Life is concerned with crack initiation, whereas Stress Life is concerned with fracture propagation [18].

II. MATERIALS AND METHODOLOGY

2.1 Material

Material Properties of Cutting Tool:
HSS Tool Characteristics: Mild Steel (EN19)
Modulus of Elasticity: 210 GPa.
Density: 7850 kg/m3

Melting Point = 460 °C
Poison’s Ratio = 0.3
Yield strength- 555-755MPa
Tensile strength- 775-1075MPa
Rockwell Hardness = 50 HRC or higher

2.2 Methodology

Because the current investigation includes streamlining of surface harshness of AISI 52100 steel in turning activity, the surface unpleasantness procedure was created for connecting the machining boundaries (cutting rate, feed rate, and depth of cut) with surface unpleasantness using various relapse methods. In fact, two development issues concerning the machining of coated and uncoated cutting apparatuses are identified inside the trial focus constraints by utilising surface harshness as the CNC machining boundary goals. After that, utilizing a Differential Evolution (DE) calculation, the machining boundaries are streamlined. Finally, to determine the DE's closeness, confirmatory tests were utilised. [16]

A. Tool Used:

Ansys 19.2 is used to explore natural frequencies and static deflection in this case. CATIA software is used for CAD modelling. The stp file was analyzed with ANSYs.

Ansys 19.2: Ansys Mechanical is a full-featured FE (finite element) structural analysis programme that can do linear, nonlinear, and dynamic studies. For a wide range of mechanical design challenges, the engineering simulation programme offers a comprehensive collection of element action, material models, and equation solvers. ANSYS Mechanical's heated examination and coupled-physical science capabilities also incorporate acoustic, piezoelectric, warm below, and thermo-electric research. ANSYS fundamental examination programming offers a strong basis in component and material design, as well as a variety of sophisticated visualisation approaches for various applications.

B. Static Analysis:

The displacements, stresses, strains, and forces induced by loads in structures or materials with no substantial inertia or damping effects are determined using static structural analysis.

The loads and the structure's reaction should stay steady throughout time. This approach may be used to calculate a static structural load. ANSYS Solver is a problem-solving software.

C. Dynamic Analysis (Modal Analysis):

Modal Analysis Basics:

The goal of fundamental mechanics modular study is to determine the common mode shapes and frequencies of a product or design during free vibration. It is not surprising that the finite element technique (FEM) was employed to perform this research since, as with prior FEM calculations, the item under consideration may have any shape and the estimation findings are relevant. The situations that arise as a result of modular research are comparable to those that arise in Eigen frameworks. When the framework is confronted, the actual knowledge of the eigenvalues and eigenvectors is that they deal with frequency and mode shape comparison. Because these are the most distinct modes in which the item would vibrate, the lowest frequencies are frequently the sole suitable modes [17].Here is the generalised motion equation:

$$[M][U] + [C]\,[\ddot{U}] + [K]\,[\dot{U}] = [F] \qquad (1)$$

Where,

[M] is the mass framework, and is the removal's second time subsidiary

[U] (i.e., the increase in speed), is the rise in speed,

[C] is a damping grid,

[K] is the solidness network, and

[F] is the power vector.

The entire problem is a quadratic eigenvalue problem with nonzero damping. Nonetheless, damping is frequently ignored in vibrational modular analysis, leaving just the first and third components on the left side:

$$[M][U] + [K]\,[U] = [O] \qquad (2)$$

This is the most common version of the Eigen system used in FEM structural engineering. To describe the structure's free-vibration solutions, [U] is considered to equal [U] λ, where is an eigenvalue (in units of reciprocal time squared, for example), s^{-2}, and the equation simplifies to

$$[M][U]\lambda + [K]\,[U] = [O] \qquad (3)$$

$$[K][U] = [F] \qquad (4)$$

In contrast, the equation for static difficulties is:

When all terms with a temporal derivative are set to zero, this is to be anticipated

In linear algebra, the standard form of an Eigen system, which is written as, is more often seen:

$$[A][x] = [x]\,\lambda \qquad (5)$$

The two situations are comparable in that the overall condition is improved by pushing the mass backwards, [M] ^ {-1}, It will appear in the same way as the last one. Because lower modes are desired, constructing the structure almost always requires ascending through the reverse of solidity, [K] ^ {-1}, converse emphasis is a cycle. When this is done, the eigenvalues that follow identify with the starting eigenvalue by:

$$\mu = \frac{1}{\lambda} \qquad (6)$$

The eigenvectors, however, are the same.

A modular investigation is carried out to establish the usual recurrence and manner created. This study pushes you to run the vehicle to the point when its excitation recurrence departs from the driving rod's normal recurrence. As a consequence, a modular research was conducted, with six modes divided in order to investigate the normal recurrence and its mode forms.

D. Force Acting against cutting tool:

The tool is acted upon by the two force components

1. Cutting force FC: This force is directed in the main motion's direction. The cutting force is used to calculate the power P necessary to complete the machining operation, which accounts for approximately 70% to 80% of the total force F,

P = VFC (7)

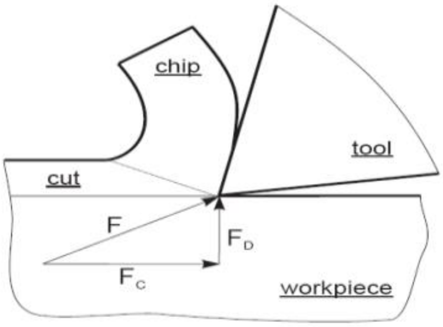

Figure 4: The total cutting force is split into two parts: a horizontal component FC and a vertical component FD

2. Thrust force FD: In orthogonal cutting, this force is in the feed motion direction. The power of feed motion is calculated using the thrust force. One additional force component appears along the third axis in three-dimensional oblique cutting. The thrust force FD is further subdivided into two parts: feed force F_f in the direction of feed motion and back force Fp in the direction of the cutting tool axis.

III. RESULTS

3.1 Results of CNC machine

A Motor System Analysis Results:

1. Results with Belt load:

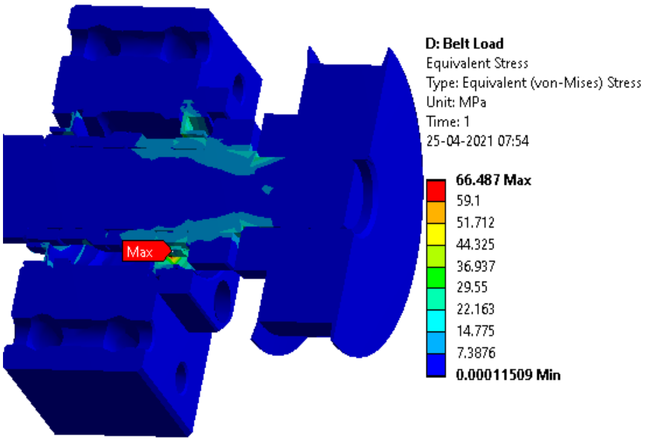

Figure 5: Von mises Stress plot wit Belt load

2. Results with Rotational velocity:

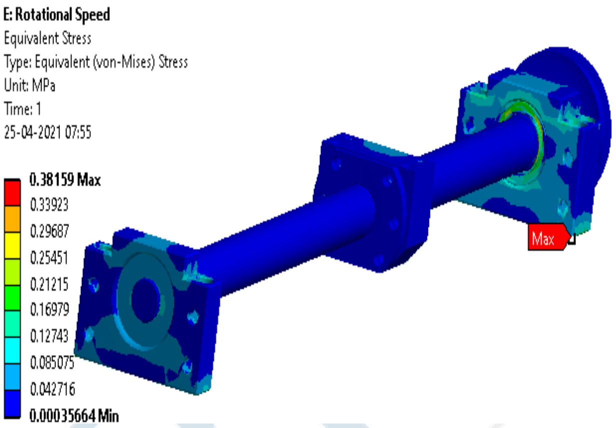

Figure 6: Von mises Stress with Rotational velocity

B Static Structural Results:

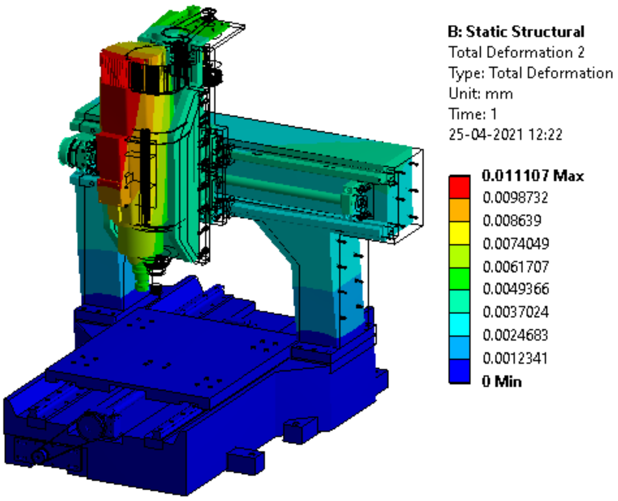

Figure 7: Total deformation of CNC machine

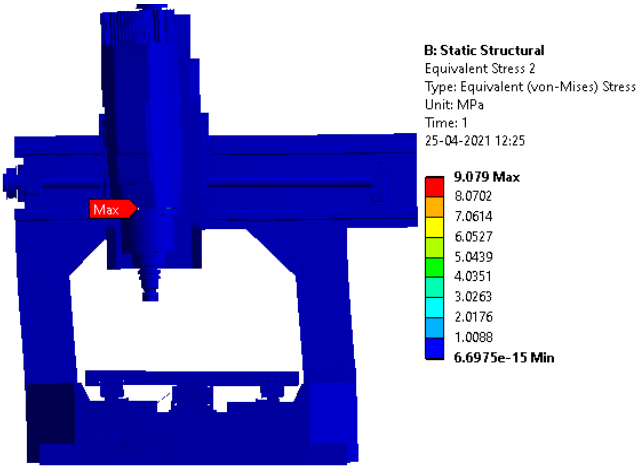

Figure 8: Von Mises Stress of CNC machine: Acc lading

C Modal Analysis Results:

The force frequency of the four cylinder engine running at max 4700RPM is

Force frequency: Critical order * RPM/60 * 1.2(20% higher for safer side)

Force frequency: 1*1000/60*1.2 = 20Hz

The initial natural frequency of the CNC machine should be more than 20Hz to minimize resonance. The CNC Machine assembly's first natural frequency (141Hz) is higher than 20Hz, suggesting that the design is vibration-free and that resonance conditions will never be obtained.

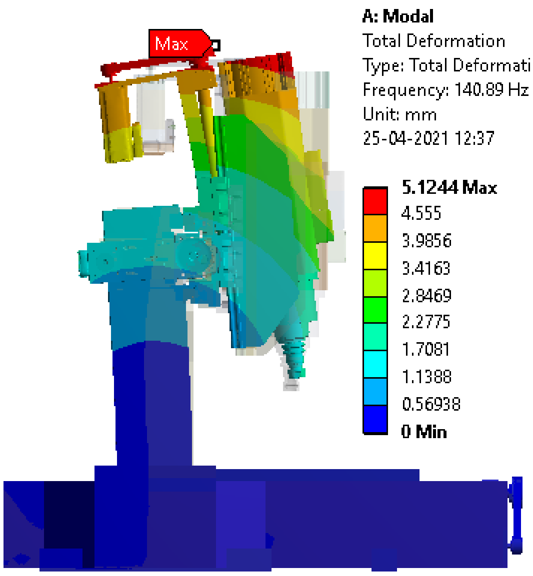

Figure 9: Model 1

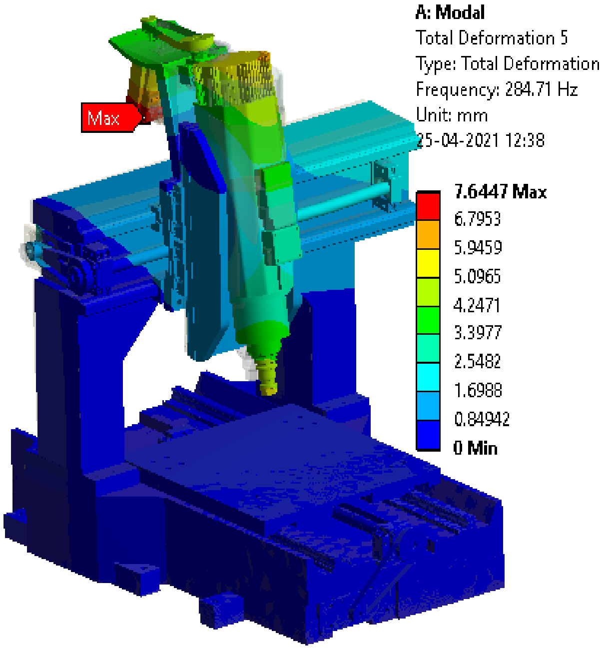

Figure 10: Model 1

3.2 Results of Cutting tool

A. Analytical Calculation of Forces on Cutting Tool:

Cutting and thrust forces are calculated analytically using different depths of cut (d) and feed rates (f), as shown below:

For d = 0.5 mm and f = 0.5 mm/rev

$Fc = 1593 \times f^{0.85} \times d^{0.98}$ N

$= 1593 \times 0.5^{0.85} \times 0.5^{0.98}$

Fc = 448.05 N

Where

d = Depth of Cut

f = Feed rate

Fc = Cutting Force

Calculation of Thrust Force:

Friction coefficient averaged throughout the tool face, μ = 0.7

Rake angle, α = 12

$$\mu = \frac{Fc \tan a + Ft}{Fc - Ft \tan a}$$

$$0.7 = \frac{448.05 \tan 12 + Ft}{448.05 - Ft \tan 12}$$

Thrust Force, Ft = 190.11

B. Deformation of Cutting Tool

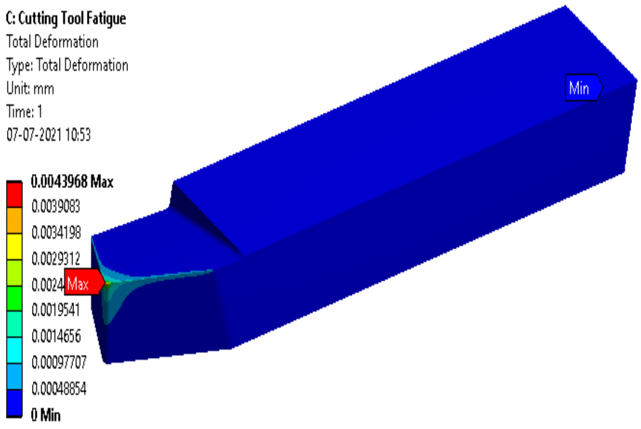

Figure 11: Deformation of cutting tool

C. Stress on the cutting tool caused by Von Mises

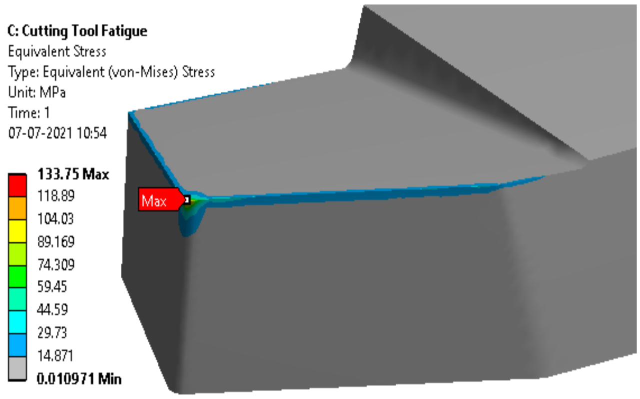

Figure 12: von mises stress of cutting tool

3.3 Results of Fatigue Calculation

A. S-N Curve

To compute the fatigue life of a leaf spring, stress life based on empirical S-N curves is used. The mean stress was calculated using Goodman theory with constant amplitude and totally reverse loading.

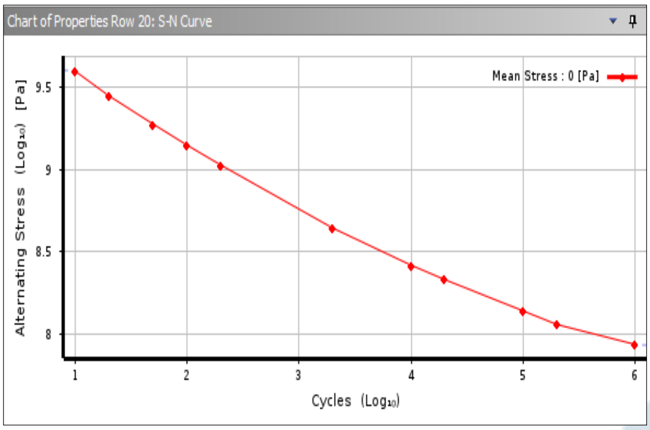

Figure 13: S-N Curve of Fatigue

B. Fatigue analysis plot

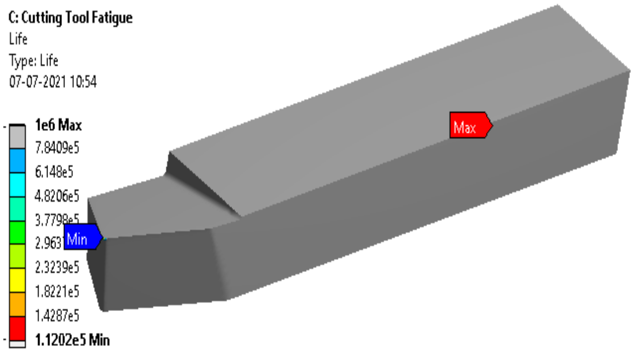

Figure 14: Life plot of Cutting Tool

IV. CONCLUSION

This work describes a method for developing mathematical models based on experimental measurements of surface roughness of stainless steel 52100 during dry machining with uncoated and coated carbide cutting tools. The possible benefits of surface discomfort are weighed against their projected exploratory tendencies. The feed rate has been proven to be an effective surface roughness barrier. In actuality, as the feed rate increases, the surface gets less abrasive, and as the cutting speed increases, the surface becomes more unpleasant. Surface roughness increased somewhat when speed increased due to gaps or vibrations, but the influence of cut depth was unusual. This research also yielded the following result:

1. The CNC machine was built using Soldworks. ANSYS Workbec was used to perform static and modal analysis.
2. A static structural analysis of a CNC machine employing 1G lading was completed and fulfilled the minimal Yield Stregth standards.
3. A modal investigation of a CNC machine was conducted to determine the system resonance, and the first frequency, 140Hz, was determined to be greater than the required frequency of 20Hz.
4. For belt load and rotation velocity, a sub-system level analysis of the motor system is conducted, and the findings are evaluated to ensure that the criteria are satisfied. Static analysis' limitations.
5. Tool coatings were developed to boost the wear resistance of cutting tools. This was evidenced by the reduced wear on the flank face of coated tools as compared to untreated tools.

REFERENCES

[1] Olugboji Oluwafemi Ayodeji et al., “In the lathe turning process, the effect of cutting speed and feed rate on tool wear rate and surface roughness”, International Journal of Engineering Trends and Technology (IJETT) – Volume22 Number 4- April 2015.

[2] Sachin Chauhan et al., “Study on Optimization of Turning Parameters on Various Steel Grades: A Review”, International Journal of Emerging Technologies in Engineering Research (IJETER), Volume 6, Issue 5, May (2018).

[3] Nexhat Qehaja, Kaltrine Jakupi et al., “Effect of Machining Parameters and Machining Time on Surface Roughness in Dry Turning Process”, 25th DAAAM International Symposium on Intelligent Manufacturing and Automation, DAAAM 2014.

[4] Sayyed Siraj et al., “Modeling of Roughness Value from Tribiological Parameters in Hard Turning of AISI 52100”, the 2nd International Conference on Materials Manufacturing and Design Engineering. 10.1016/j.promfg.2018.02.05.

[5] Abhang, L. B, and Hameedullah, M., 2014, “Parametric investigation of turning process on EN-31 steel”, Procedia Materials Science, (6), 1516-1523.

[6] Rao, C. R. P, Bhagyashekar, M. S, and Narendraviswanath, 2014, “Effect machining parameters on the surface roughness while turning particulate composites”, Procedia Engineering, (97), 421-431.

[7] Qehaja, N, Jakupi, K, Bunjaku, A, Bruçi, M, and Osmani, H., 2015, “Effect of machining parameters and machining time on surface roughness in dry turning process”, Procedia Engineering, (100), 135- 140.

[8] B sidda reddy, G.Padmanabhan and K.Vijay Kumar Reddy, “Surface roughness prediction technique for CNC technique”. Asian journal of scientific research 1 (3): 256-264, 2008 ISSN 1992-1454.

[9] Jitendra Thakkar et al., “A Review on Optimization of Process Parameters for Surface Roughness and Material Removal Rate for SS 410 Material During Turning Operation”, Int. Journal of Engineering Research and Applications ISSN : 2248-9622, Vol. 4, Issue 2(Version 1), February 2014, pp.235-242.

[10] Tian-Syung Lan, “Parametric Deduction Optimization for Surface Roughness”. American Journal of Applied Sciences 7 (9): 1248-1253, 2010 ISSN 1546-9239.

[11] C. M. Allen and B. Boardman, “ASM handbook, volume 1, properties and selection: irons, steels, and high performance alloys section: publication information and contributors publication information and contributors,” Fonderie, vol. 1, p. 1618, 2005.

[12] S. Chinchanikar and S. K. Choudhury, “Machining of hardened steel-experimental investigations, performance modeling and cooling techniques: a review,” International Journal of Machine Tools and Manufacture, vol. 89, pp. 95–109, 2015.

[13] Explain Cutting Tools Archived 2019-05-12 at the Wayback Machine, https://mechanicalsite.com , retrieved 2019-05-12

[14] Muammer Nalbant, Hasan Gokkaya, and ˙Ihsan Toktas, “Comparison of Regression and Artificial Neural Network Models for Surface Roughness Prediction with the Cutting Parameters in CNC Turning”, Hindawi Publishing Corporation Modelling and Simulation in Engineering, Volume 2007, Article ID 92717, 14 pages.

[15] https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.researchgate.net%2Ffigure%2FGeometry of-single-point-cutting tool_fig45_286842300&psig=AOvVaw0X4BfDR0GC2RQ03xGGZCQ1&ust=1633759138012000&sour e=images&cd=vfe&ved=0CAsQjRxqFwoTCPiDjpKEufMCFQAAAAAdAAAAABAD

[16] V Durga Prasada Rao et al., “Optimization of cutting parameters in CNC turning of stainless steel 304 with TiAlN nano coated carbide cutting tool”, IOP Conf. Series: Materials Science and Engineering 310 (2018) 012109 doi:10.1088/1757-899X/310/1/012109.

[17] Rajaguru et al., “Coated tool Performance in Dry Turning of Super Duplex Stainless Steel”, 45th SME North American Manufacturing Research Conference doi: 10.1016/j.promfg.2017.07.061.

[18] C.O. Izelu et al., “Effect of Depth of Cut, Cutting Speed and Work-piece Overhang on Induced Vibration and Surface Roughness in the Turning of 41Cr4 Alloy Steel”, International Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 4, Issue 1, January 2014).

[19] https://en.wikipedia.org/wiki/Cutting_tool_(machining)#cite_note-1