FEA RESULTS VALIDATION BASED ON ANALYTICAL CALULATIONS USING ANSYS SOFTWARE

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Abstract
Currently, industrial sectors depend heavily on CNC turning operations to carry out a number of essential tasks, and production represents a significant portion of a product's life cycle. CNC machining techniques for aluminum are used less frequently than those for metal. In this study, a cylindrical work piece made of the aluminum alloy AA6082-T6 is subjected to a finite element analysis during the CNC machining process. Carbide tip tool was the instrument utilized in this investigation. Spindle rotation speed, feed rate, and cut depth are the cutting parameters utilized in CNC machining. Ansys 19.2 is used for analysis, while CATIA V5 is used for modeling. On the basis of the analytical calculations, the FEA findings are validated.
Keywords: CNC Turning; FEA; Analysis; Catia; Ansys.

1. Introduction

In the industrial sector, modeling and analysis are crucial for determining the quality of services and goods. Since aluminum is one of the most machined materials currently available, we are using AA6082-T6 as a work piece in this study. Aluminum CNC machining methods came in second to steel in terms of consistency of application because of their exceptional mach inability. Every firm on earth seeks to fulfil two key objectives of any equipment or manufacturing business: quality and customer pleasure. The main routine metal processing task carried out in many industrial enterprises is machining. Numerous operational factors affect the quality of metal cutting obtained, and these input factors affect the output reaction and functional characteristics of the finished product. A cutting tool is being used in the turning process to process and removes surplus material from the workpiece in order to transform the workpiece into a desired component that may subsequently be employed in a range of activities. Manufacturing a strong end product at a cheap cost is an important component of a product's life cycle, and it may be accomplished by choosing the optimum tool material, cutting settings, machine equipment, and tool geometry. The environment and procedures in manufacturing and services sectors are evolving very quickly, therefore to keep up with the evolution in the contemporary world, theoptimization of metal cutting operations is handled on several levels to adapt to the new needs in the production system.

1.1 CNC Turning Process

Turning is a machining operation wherein a cutting tool, usually a non-rotary tool bit, moves somewhat linearly as the workpiece revolves. The term known as "turning" is designated for the change or the creation of exterior surfaces and can also be used for reducing the diameter by this cutting motion. Turning can be carried out manually, in a classic version of lathe machine that typically requires continual monitoring by the worker or operator, or can also be done automatically, in an automated lathe. The most popular kind of such automation nowadays is computer numerical control, abbreviated as CNC. In addition to turning, CNC is widely utilized in several other forms of machining like drilling, milling etc.

Figure 1: Turning Process

1.2 Software Used

There are two types of software used for the research work in this paper. The first one is a modelling software which is used to model the tool and the workpiece and the other one is a type of analysis software which is used for the analysis part of the research. The modelling software used is Catia V5 and the analysis software is Ansys R19.2. Catia V5 (computer-aided threedimensional interactive application) is a multi-platform software package developed in the year 1998 by the French company Dassault Systèmes, which is now widely utilized in the automotive, aerospace, and other sectors for computer-aided design (CAD), computer-aided manufacturing (CAM), computer-aided engineering (CAE), 3D modelling, and Productmanagement (PLM). V5 in Catia V5 indicates the fifth version of the software. The second software Ansys that is an analysis software is used to simulate computer models of structures, electronics, or machine components in order to analyze their strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other characteristics. Ansys is used to assess how a product will perform under diverse conditions without any need for conduct tests or crash testing. The version of the software used in this research paper is Version R19.2.

1.3 CNC Machine Used

The CNC machine used in this research paper is Siemens Sinumerik 828D. The machine is manufactured by the siemens company. The machine SINUMERIK 828D control, with its distinctive CNC capability, establishes production standards for conventional machining on conventional machines, and also functionality to simply manage grinding machines. The SINUMERIK 828D CNC's technology-specific system software allows for a wide range of application areas, including vertical and basic horizontal machining centers ideal for mould making surface and cylindrical grinding machines, and two-channel turning centers with counter spindle, driven tools, and Y axis. Robust hardware design, clever controller design, and quality drive and motor equipment offer the best dynamic responsiveness and accuracy during milling and turning.

2. Properties

A workpiece made of AA6082-T6 and a tungsten carbide-tipped tool were employed. Aluminum is among the most processed materials accessible nowadays, hence AA6082-T6 was chosen as a workpiece. Aluminum follows steel in terms of consistency of performance in conventional machining due to its great machinability. Tungsten carbide is used as a tool since it keeps a sharper cutting edge than steel tools and enables for quicker machining.

2.1 Tool Properties

The tool we are employing in this study is a single-point cutting tool made of Tungsten Carbide. Table 1 lists the mechanical qualities of the tool. Some of the parameters in the table are derived from others, such as shear modulus and bulk modulus, which are derived from young's modulus and poison's ratio, respectively.

Table 1. Mechanical Properties of the Tool

Property	Value (Unit)
Density	20 (kg/m^3)
Young's Modulus	$6e^{11}$(Pa)
Poisson's Ratio	0.2
Bulk Modulus	$3.33e^{11}$(Pa)
Shear Modulus	$2.5e^{11}$(Pa)
Specific Heat	$1.84e^{-7}$(J/gK)

2.2 Workpiece Properties

This paper's workpiece is a cylindrical AA6082-T6 bar with a length of 150mm. AA6082-T6 is an aluminium alloy with strong corrosion resistance that is mostly used for machining. It has more strength than other alloys and, as a result, is replacing other aluminum alloys in the industry. Table 2 shows the chemical formula for AA6082-T6. The Johnson-Cook failure model is utilized for the failure model, with a linear connection between the shock velocity and the particle velocity. Table 3 lists the mechanical properties of the workpiece.

Table 2. Chemical Composition (wt.%) of AA6082-T6

Aluminium	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Zinc	Titanium	Others
95.2-98.3	0.7-1.3	0.5	0.1	0.4-0.1	0.6-0.1	0.25	0.2	0.1	0.15

Table 3. Mechanical Properties of the Workpiece

Property	
Density	
	Value (Unit)
Specific Heat	2710 (kg/m^3)
Shear Modulus	0.9(J/gK)
Melting Temperature	$2.69e^{10}$(Pa)
Reference Strain Rate	555(°C)

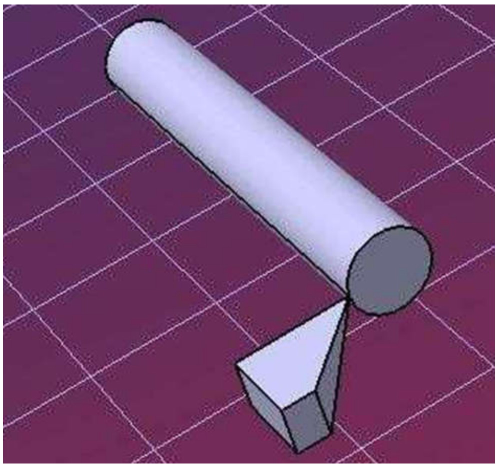
	Shock EOS Linear		1(/s)			
	Gruneisen Coefficient		2.1			
	Parameter C1		5380(m/s)			
	Parameter S1		1.337			
	Johnson Cook Failure					
	D1		0.0164			
	D2		2.245			
	D3		-2.798			
	D4		0.007			
	D5		3.65			

Modelling

A 3D model of the workpiece and the tool is first modeled in Catia V5 part design module under mechanical design. Both the model i.e., the workpiece and the tool is to be modelled in the same file but both have to be containing a different body so that the analysis can be carried out smoothly. If both the tool and the workpiece is made in the same body then, the analysis software will treat both the components as one whole body and then the penetration of the workpiece is impossible. The workpiece is made on the y-z plane whereas the tool is made on a user-specified plane.

The workpiece has a diameter of 25.5 mm with a length of 150mm. The tool is then made by using a different body in the same file. The tool is modelled by taking into account the back rake angle and side rake angle which is 0 and 5 respectively in this case. The part program for the model can also be created by selecting the machining processes in lathe machining under machining for the practical work of the same model. A simulation can also be made for the CNC work done on the workpiece. For the model to be imported we saved the file as a .stp extension or we can also save it as .iso file so that the model can easily be identified and processed in the Ansys module. The Tool and the workpiece which is modelled in Catia V5 is shown in Fig. 3.

Figure 3: The Tool and the Workpiece modelled in Catia V5



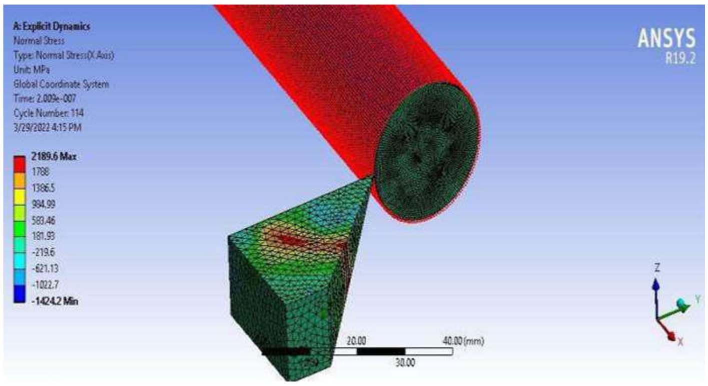
4. Results

There are three types of results obtained in this study. The first one is FEA result which is obtained in Ansys R19.2 software and the second one is the Experimental result which is obtained by a dynamometer and the third one is the Analytical result which is obtained by mathematical functions which is related to the cutting problems and values obtained in theexperimental results. All the results are shown in the next section with the pictures and the graph representation 0of the values.

FEA Results

After the analysis of the CNC turning operation of AA6082-T6 with the tool as Tungsten Carbide is completed, we got the result for Normal Stress, Shear Stress, and Shear Elastic Strain. The result shows us the final stage of the process of the CNC turning process with the desired results to be calculated in the explicit dynamics of the Ansys.

Figure 4: Normal Stress Analysis



In figure 4 the analysis results of normal stress are shown. The Maximum Normal Stress in the system is 2189.6 and the minimum Normal stress is -1424.2. The red part on the workpiece shows the part which will break and flow away from it as a chip. The graph between the Normal stress and the time is plotted and shown in figure 5. The graph is plotted by using 100 Normal stress points. The graph shows the trendline for the Normal stress concerning time.

Figure 5: Line Graph (Time vs Normal Stress)

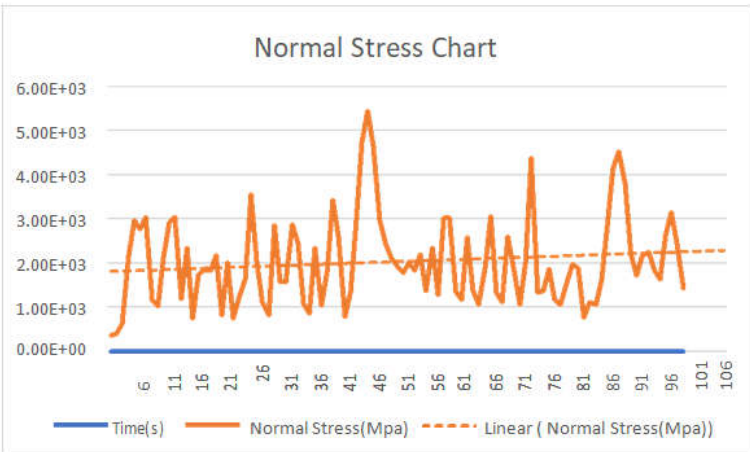
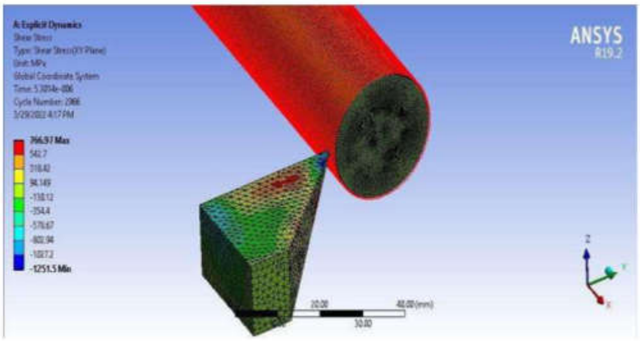


Figure 6: Shear Stress Analysis



In figure 5 the analysis results of shear stress are shown. The Maximum Shear Stress in the system is 766.97 and the Minimum Shear Stress is -1251.5. The red part on the workpiece shows the part which will break and flow away from it as a chip. The graph between the Shear Stressand the time is plotted and shown in figure 7. The graph is plotted by using 100 Shear Stress points. The graph shows the trendline for the Shear Stress concerning time.

Figure 7: Line Graph (Time vs Shear Stress)

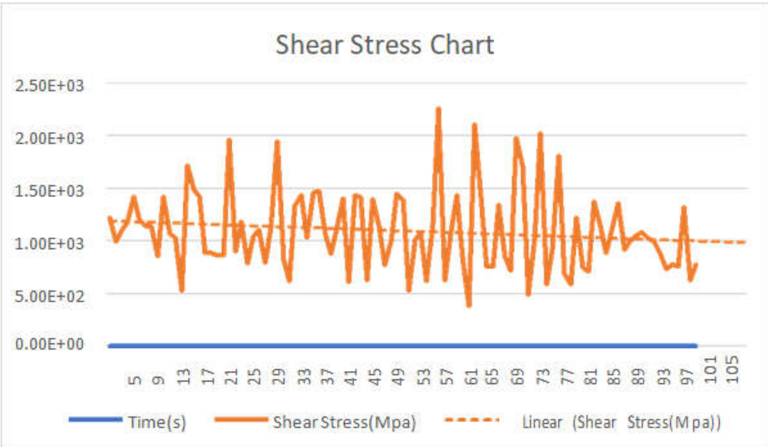
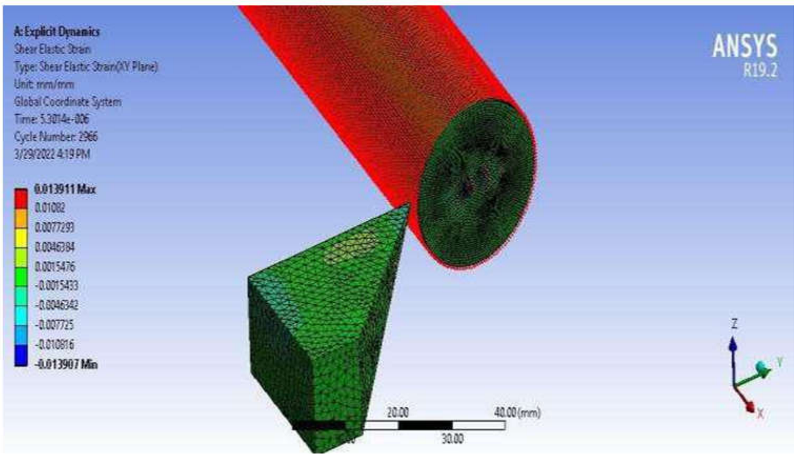


Figure 8: Shear Elastic Strain Analysis



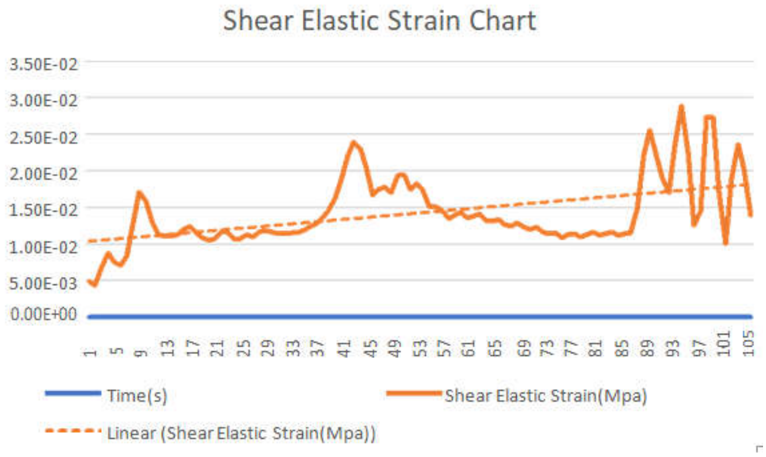


Figure 9: Line Graph (Time vs Shear Elastic Strain)

In figure 8 the analysis results of shear Elastic Strain are shown. The Maximum Shear Elastic strain in the system is 0.013911and the minimum elastic strain is -0.013907. The red part on the workpiece shows the part which will break and flow away from it as a chip. The graph between the Shear Stress and the time is plotted and shown in figure 9. The graph is plotted by using 100 Shear Stress points. The graph shows the trendline for the Shear Elastic Strain concerning time.

Experimental Results

The Experiment is carried out on a Siemens Sinumerik 828D CNC machine and the forces are calculated with the help of the Kistler dynamometer. The diameter of the workpiece was 25.5and the length of the workpiece was 150 mm. After the Turning process is carried out the diameter of the workpiece was minimized to 20mm. The cutting parameters used in CNC machining are Spindle rotational speed, feed rate, and depth of cut. In this experiment, the spindle speed taken chosen is 200 rev/min, Feed 0.1 mm/rev, and the depth of cut is 0.2 mm. The total time taken by the CNC machine to finish the turning process is 5:17 minutes.

Figure 10: Turning Process

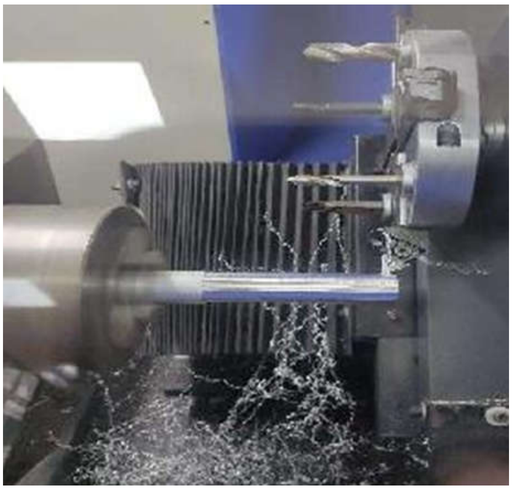
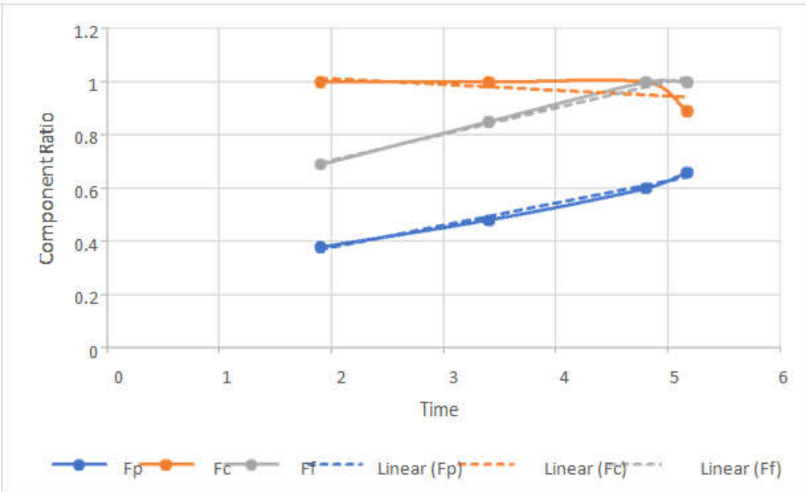


Figure 11: Chip formed in turning process

Figure 10 shows the turning process carried out in the Siemens Sinumerik CNC machine and the setup of the dynamometer is also done so that the components of the force can be measured for further results. Figure 11 shows the chip formed in the process of cutting AA6082-T6 and It can easily be seen that the type of chip formed is a continuous chip. For the further calculation of normal stress, shear stress, and shear strain the chip thickness and the chip width is measured by a digital vernier caliper. The dimensions of the chip are as follows: chip thickness of 0.2 mm and chip width of 0.75 mm.

Figure 12: Component ratio vs Time Graph of Results



The component ratio vs Time graph is shown in Figure 12 which shows the results graph of the result taken from the dynamometer. In the graph, Fp is the radial component of the cutting force, Fc is the Cutting component of the cutting force, and Ff is the feed component of the cutting force. Linear Fp, Linear Fc and Linear Ff show the linearity in the cutting component of the system.

4.3 Analytical Results

With the help of the experimental results, we can find the Normal Stress, Shear Stress, and Shear Strain. For that, we first find the cutting ratio which is the ratio of uncut chip thickness to cut chip thickness.

Cutting Ratio, = = 0.909

Conclusion

In this study, the values of three parameters—Normal Stress, Shear Stress, and Shear Strain—are determined. The estimated result for Normal Stress in Ansys R19.2 analysis is 716.14 MPa whereas the actual value is 2189.6 MPa. The Ansys computed value for shear stress is 766.97 MPa, whereas the calculated value is 803.81 MPa. The Ansys computed value for shear elastic strain is 0.013911, while the calculated value is 0.0184.
The percentage inaccuracy under normal stress is determined to be 67.3%.
The computed percentage error for shear stress is 4.80%.
The percentage inaccuracy in shear strain is determined to be 32.27%.

The Percentage error is maximum in Normal Stress and minimum in Shear Stress which concludes that in this analysis shear stress is the most common factor that is affecting the turning process or the cutting of the workpiece. Percentage error shows that the normal stress value is very far from the expected value.

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