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"Cutting Tool Wear Analysis"

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Abstract

The present work concerned an experimental study of turning on Austenitic Stainless steel of grade AISI 202 by a TiAlN coated carbide insert tool. The primary objective of the ensuing study was to use the Response Surface Methodology in order to determine the effect of machining parameters viz. cutting speed, feed, and depth of cut, on the surface roughness of the machined material and the wear of the tool. The objective was to find the optimum machining parameters so as to minimize the surface roughness and tool wear for the selected tool and work materials in the chosen domain of the experiment. The experiment was conducted in an experiment matrix of 20 runs designed using a full-factorial Central Composite Design (CCD). Surface Roughness was measured using a Talysurf and tool wear with the help of a Toolmaker"s microscope. The data was compiled into MINITAB ® 17 for analysis. The relationship between the machining parameters and the response variables (surface roughness and tool wear) were modelled and analysed using the Response Surface Methodology (RSM). Analysis of Variance (ANOVA) was used to investigate the significance of these parameters on the response variables, and to determine a regression equation for the response variables with the machining parameters as the independent variables, with the help of a quadratic model. Main effects and interaction plots from the ANOVA were obtained and studied along with contour and 3-D surface plots. The quadratic models were found to be significant with a p-value of 0.033 and 0.049. Results showed that feed is the most significant factor affecting the surface roughness, closely followed by cutting speed and depth of cut, while the only significant factor affecting the tool wear was found to be the depth of cut. The top three optimum settings for carrying out the machining were obtained from Response Surface Optimizer and are shown in the results section.

Introduction

1.1 Problem Statement

Tool life is a concern for many companies in the manufacturing industry. Since cutting tool inserts are used to cut away material of parts as they pass through machines, the inserts will naturally wear. It is common practice for the operators of the machines to change out the inserts at regular intervals as not to produce defective parts. The type of part being cut, the type of insert, and the amount of material being removed all determine how quickly the insert will wear. It is imperative that operators make frequent checks of the inserts by taking measurements of the part produced by the lathe to determine if the insert needs to be changed. It is also important to note that each machine may have a different maximum allotted life for its inserts.

1.2 Definition of Terms

The terms that follow will be used in greater depth in chapter 3 along with photos.

Shank: The smooth area on the piston end of the shock shaft. The diameter of the shank is measured to determine if it is within tolerance.

Inserts: Small metallic tools of varying shapes that cut the rods to form shock shafts

Rod: A cylindrical piece of metal that is sent through a lathe to be processed into a shock shaft

Shock Shaft: The part that is created when a rod is processed through a lathe

Lathe: A machine through which rods are processed to create parts such as shock shafts

1.3 Background

There are five stages in the rod process flow. Rods are metallic cylinders, which when first received to the plant are about 18 meters in length. They are then cut to 395 millimeters, or approximately 1.5 feet. Next, they are sent through a pre-grinder machine. This ensures that the diameter of the rod is consistent throughout the entire length of the rod. Then they are processed through the induction heating machine which uses electric current to quickly harden the rod.

This causes the rods to take on a distinctly bluish hue around the area that has been hardened. After the rods are hardened, they are then sent through a straightener which relieves internal stress and makes the rod less prone to cracking. Finally, the rods are sent through a lathe which creates the top end and piston end of the shock shaft. This is performed through a roughing insert which removes much of the material to create the shank After the roughing insert has removed all necessary material, a finishing insert then removes a small amount of material and gives the shock shaft a finished look If the lathe does not also perform threading, the rod will then be sent through a separate machine that specifically performs that function. The cycle time for this whole process varies depending on what part is being made.

The inserts within the tool holders are metallic and cut the rods as the rod passes over the tooL Insert life differs from machine to machine and from part replaced.to part. Inserts are generally triangular in shape and are rotated as each comer wears. After each comer is used, the insert is then flipped to the other side and the other three comers are used until the entire insert needs to The more material that is removed, the greater the rate at which the insert will wear when compared to other inserts that remove less material. This is because some parts have greater diameters, and therefore, the inserts that cut these rods remove more material.

1.4 Objectives

The main objectives of this study are listed below:

• To implement proper quality control procedures for the Shock Shaft Machining process that will result in cutting tool cost savings for the company.

• To establish appropriate control charts for continuous monitoring of the tool wear.

• To perform process capability studies.

1.5 Assumptions

There are many variables that can affect data collection. They include operator error, lathe shutdown, mechanical problems with the lathe that need to be fixed, and environmental concerns such as heat or cold. Such uncontrollable variables are not considered in this study as they are classified as standard error.

1.6 Organization of Thesis

This thesis is organized into five chapters: the introduction, literature review, methodology, data and analysis, and discussion and future research. The introduction considered the background of the thesis, assumptions, problem statement, and definitions of terms, and objectives. The literature review will consist of explanations of other studies that have been performed regarding inserts, different materials used to manufacture inserts, and an overview of statistical quality control methods used in various industries. The methodology explains the procedure, rod process flow, and inserts in more detail. The data and analysis chapter will include the data collected, the control charts, the trends, and the process capability study. Finally, the discussion and future research will summarize the study and provide recommendations for further research.

Literature Review

2.1 Overview of Cutting Tools

The literature is replete with articles regarding insert wear, what their causes are, and how to correct, prevent, and reduce them. Elmagrabi, Shuaeib, and Haron (2007) found that Gradual wear occurs at two principal locations on a cutting tool: the top rake face and the flank. Accordingly, two main types of tool wear can be distinguished: The crater wear and flank wear. For determining tool life, response surface methodology, and a factorial design experiment worked best. Insert wear will be discussed later in this study.

One study examined ceramic round (RNGN) and ceramic square (SNGN) inserts. Similar to the previous study, it was found that flank wear and crater wear were predominant at high cutting speeds for the square insert. Minimum flank wear is seen with SNGN tools at low cutting speeds while it is seen with RNGN tools at high cutting speeds" (Altin, Nalbant, and Taskesen, 2007).

Rosa, Diniz, Andrade, and Guesser (2010) observed a carbide insert in a turning machine which they coated with three different coatings including titanium nitride (TiN), aluminum oxide (Ab03) and titanium carbonitride (TiCN). After the coating process, the TiN layer was removed from the rake face using a micro-sandblasting process, which caused the increase of compressive residual stresses of the insert and, consequently, the increase of its toughness (Rosa,et aL, 2010).

Another study examined tool wear index (TWI) of the surface roughness finish in finishing operations. This study focused on four main topics: Developing a tool wear index, developing a control model for the surface roughness based on the TWI, creating a tool life model in order to prolong the life of a tool, and creating an ideal control strategy. Often a tool will be used for more than one machine and is not appropriately analyzed...

"With relation to surface roughness, the TWI measures the wear conditions more accurately and comprehensively, and the tool life model enables maximum use of a worn tool and minimum risk for in-process tool failure. The TWI and a surface roughness control model are integrated into an optimal control strategy that shows potential for productivity improvement and reduction of manufacturing cost." (Kwon and Fischer, 2003)

When a tool is used to cut different parts, the primary issue is whether to change the tool when starting a new batch of parts or to keep the tool but "change the machining parameters to adapt to the tool condition and the characteristics of the new operation" (Kwon and Fischer, 2003). The downside of changing a tool often is the incurring of extra cost associated with frequent change. If the tool is still usable, it should not be changed until just before it begins to make defective parts. The limitation of keeping a tool is the possibility that it could begin to create defective parts. Also, it is a difficult task to determine exactly when a tool will create defective parts because neither the machine nor the tool behaves exactly the same each time a new part is created. There will always

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be some amount of variability despite the best maintenance and monitoring.

2.2 Cutting Tool Materials

There are many types of materials that are used to create the inserts that perform the cutting. The following are the most common types of materials used: carbon steel, high speed steel, cast cobalt alloys, carbides, coatings, cermets, alumina, silicon nitride, cubic Boron nitride, and diamond. Carbon steel is best used for machines that cut wood, such as routers. It acts as a poor metal cutting material because carbon begins to soften around 180 degrees Celsius. High speed steel is used for higher speed cutting. These tools were first used with 12- 18% tungsten but were later formed with molybdenum to replace tungsten for economic reasons and higher abrasion resistance. Cast cobalt alloys comprise of about 40 - 55% cobalt, 30% chromium, and 10-20% tungsten. While they have good wear resistance, they can only be used at a moderate high rate of speed, but not as high as the high-speed steel tools. Carbides have a high hardness.

SUMMARY

This study is narrowly focused, and as such, there are many elements that are beyond its scope. Some improvements that could be made include performing a separate study of the roughing insert, related cost savings, determining the main type of insert wear for the roughing insert, and a comparative study of different brands of inserts. The roughing insert removes the majority of the material which forms the shank. What makes the roughing insert particularly difficult to assess is that the lathe must be stopped each time a measurement is taken since the part is still inside the machine after the roughing insert has completed its cutting. Stopping the machine, however, would cut into cycle time, and could only be performed when the machine is not in use. However, if one were to study this insert it would prove to be a great benefit because the roughing insert is changed more often than the finishing insert. Extending the life of this roughing insert would lead to savings for the company over time.

CONCLUSION

A cost analysis would be helpful since any cost savings can add to the bottom line of the company. The cost of each insert, the number of inserts used per day, and the total annual consumption on inserts across different product lines would all contribute to the savings. Also, determining the types of insert wear could potentially lead to extending the insert life. Once the type of insert wear is discovered, the appropriate measures can be taken to decrease the potential for that type of wear. These measures may include varying the cutting speed, using a different the angle for the insert, or using a special coating to reduce heat. Finally, performing a comparative study of the different brands of insert could benefit the company.

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