ANALYSIS OF TOOL WEAR IN TURNING OPERATION OF ALUMINIUM

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Abstract - *The research focuses on analyzing tool wear during turning operations on aluminum using High-Speed Steel (HSS) tools. The primary objectives are to determine the specific speed, feed, and depth of cut that minimizes tool wear when working with aluminum parts and HSS tools. Additionally, the study aims to identify the maximum and minimum levels of wear on the HSS tool at different cutting speeds. The experiments involve varying cutting parameters to collect data on tool wear, and the results are analyzed to provide insights into optimizing machining conditions for extended tool life and enhanced efficiency in aluminum turning processes. The research has practical implications for industries seeking to improve tool performance in machining aluminum materials.*

Key Words: **Tool wear, Tool geometry, Aluminium machining, High-stress conditions, High-temperature conditions, Tool failure.**

1.INTRODUCTION

The turning operation is a fundamental machining process widely employed for shaping various components, with the primary use of a single-point cutting tool. In this context, a diverse range of cutting tools is available, each characterized by distinct geometries and materials tailored to machine different metals and alloys. Aluminium, extensively utilized in automotive, construction, and aerospace industries due to its lightweight and corrosion-resistant properties, is a common material of interest. Cutting tools undergo severe rubbing during metal-to-metal contact with the work piece and chip, operating under high-stress conditions and elevated temperatures. The situation is exacerbated by the presence of extreme stress and temperature gradients near the tool's surface. While cutting tools play a crucial role in removing material to achieve the desired shape, dimensions, and finish during cutting operations, wear inevitably occurs, leading to tool failure. Regular replacement of tools or edges becomes necessary when wear reaches a critical extent to ensure continued and effective cutting action. This research aims to explore the dynamics of tool wear during turning operations on aluminium, focusing on optimizing cutting parameters to mitigate wear and enhance the longevity of cutting tools.

1.1 Aim

The aim of the research is to analyze and understand tool wear during the turning operation of aluminum using High-Speed Steel (HSS) tools. The overarching goal is to gain insights into optimizing cutting conditions for enhanced efficiency and prolonged tool life

1.2 Objectives

1. **Specific Parameter Identification:** Determine specific combinations of cutting parameters, including specific speed, feed rate, and depth of cut, that result in the least tool wear when working with aluminum parts and HSS tools.
2. **Wear Analysis at Different Speeds:** Investigate and quantify the maximum and minimum levels of wear occurring on HSS tools at various cutting speeds during the turning operation of aluminum.

These objectives collectively aim to contribute valuable knowledge for improving the performance and durability of cutting tools in the machining of aluminum components, with potential applications in industries such as automotive, construction, and aerospace.

2. LITERATURE REVIEW

Thamizhmanii S. et al. [1] have recovered that the surface roughness from various tests shows a drop-off in value at higher cutting speed and the feed rate. The cutting tool has produced micro chipping and has not impressed the surface finish. Micro cracks were acquired from the border of micro chipping. The notch wear might have been caused due to difficult particles and other impurities existing in the material. There is no placement of built- up- edge that is normally occurring during machining cast iron at lower cutting speed. Advance work can be carried in the way of measuring the residual stresses by turning and placement of built- up edge under high speed machining.

Ozel Tugrul et al. [2] have deliberated that tool nose design affects the surface finish and productiveness in the finish hard turning processes. Surface finishing and the tool flank wear have been analyzed in finish turning of AISI D2 steels (60 HRC) using ceramic inserts. Twofold linear regression models and neural network models are formulated for predicting surface roughness and the tool flank wear. In neural network modeling, measured forces, power and specific forces are used in training algorithm. Experimental results point that the surface roughness values as degraded as 0.18–0.20μm is attainable with the wiper tools. Tool flank wear reaching to a tool life standard value of VBC = 0.15mm ahead or around 15 min of cutting time at higher cutting speeds due to elevated temperatures.

Omar B. Bin et al. [3] have observed that wear pattern depend on the CBN tools used, work piece material composition, and cutting conditions. They also concluded that generally, adhesion, abrasion and diffusion are reasoned to be main tool wear mechanisms in CBN hard turning: however, the individual effect of each mechanism depends on the combinations of the CBN tool and work materials, cutting conditions, tool geometry etc. A few elementary mechanisms rule cutting tool wear are: 1. Diffusion wear smitten by chemical loading on tool and cutting material 2. Oxidation wear - crusades gaps to occur in coated film and outcome in a loss of the coating at elevated temperature, 3. Fatigue wear - is a thermo-mechanical result and leads to the breakdown of the edges of cutting tool, 4. Adhesive wear happen at devalued machining temperatures on the chip face of tool and leads to shaping of a built up edge, and the perpetual break down of the built up edge and tool edge itself, 5. Abrasive wear affected by hardness of the work material and is restrained by content of the cutting material.

Lin H.M. et al. [4] have found that tool life emerges with the gain of cutting speed until a supreme is reached where it starts to drop-off. In a low-level speed cutting, abrasion is the firsthand form of wear. When cutting speed is augmented, a sticking layer is effected and stays on tool face which prevent tool face from wearing. At graduate cutting speed, the chip is exchanged from continuous type to saw-tooth type. Friction force is inflated consequently, and the layer on tool face is abrased bit by bit. Since scattering between work and the tool materials turn more than intense at higher cutting speed, the bond 'tween the hard particles is vitiated and wear on the rake face is exaggerated drastically.

Kamarudin K. et al. [5] have discovered that Flank wear in the ceramic cutting tools is mechanically stained wear ordinarily by the abrasive state of the hard work piece material with ceramic tools. The flank wear is characterized by the abrasive groove and elevation on the flank face. The flank wear of the cutting tool has a momentous result on the attribute of the machined surface. Flank wear has a prejudicial effect on the surface finish, residual stress and the micro structural changes, shape of tool, as well cutting conditions. The flooding temperature bring forth 'tween the cutting face and work piece justifies abrasive and or adhesive wear. These types of wear impact the tool materials attribute as well as work piece surface. The reasons for gain in flank wear were due to increase in temperature at the cutting edge due to more interaction time between tool and work piece. The temperature may causing to lose its hardness and wear. When the cutting speed was take down, the flank wear was taken down and as these parameters are accrued, the flank wear also exaggerated.

Vikas B. Magdum, Vinayak R. Naik. [6] in their paper used the cutting forces in a turning process of EN 8 steel to estimate the tool wear effect. Tool wear effect is obtained by monitoring the variation in the cutting forces. The intent of this study is to develop an on-line observation system. By distinguishing one or more than one criteria to efficiently specify and determine rapid tool wear, it can be ascertained when to change the tool. the correlation between the tool wear and cutting forces shows that, the cutting forces are increased as the tool wear increases.

Nithyanandhan.T T, Manickaraj.K and Kannakumar.R [7] in their study, an endeavor has been made to analyze the result of cutting parameters on the cutting forces and the tool wear in the hard turning of AISI 304 steel using the coated carbide tools. The results revealed that the feed and nose radius is the almost important process parameters on work piece surface roughness. Even so, the depth of cut and feed are the significant factors on MRR.

S. Thamizhmnaii, B. Bin Omar, S. Saparudin, S. Ha [8] have conducted research to exhibit tool wear with the help of hard turning of martensitic stainless steel and this material is articulated as difficult to machine material. The judgment was done utilizing CBN cutting tool on SS 440 C stainless steel with hardness between 45 to 55 HRC. The flank wear occurred at low cutting speed with high feed rate and more depth of cut i.e. at cutting speed of 125 m/min, feed rate of 0.125 mm/rev and DOC of 1.00 mm. The influence of tool flank wear was due to abrasive action between tool tip and cutting tool, hard carbides in the work piece material. At low cutting speed of 125 m/min. formation of built up edge was inevitable due to more contact time. The flank wear was also due to heat generated at low cutting speed.

Ning Fang, P Srinivasa Pai & Nathan Edwards [9] have analyzed tool-edge wear (i.e., the wear of a tool cutting edge before it is meagerly worn away) is among momentous concerns in high-speed machining because it can effect in early tool failure and decayed quality of machined parts. Founded on extensive experimental effect, this paper display how tool-edge wear is correlative with the cutting forces and vibrations in high-speed turning of Inconel 718. As tool-edge geometry show a important role in machining at small feed rates, tool-edge wear importantly contributes to primal tool failure and crumbled quality of machined components and parts.

Pramod Kumar N.et al. [10] in their present work which involve the study of thermal and wear behavior of tool and work interface. Experiments were conducted on a Turn master 35 automatic lathe. Different cutting forces, temperature of tool tip, thickness and the weight of the chips settled during machining along with tool wear information were canned. The causation of the cutting parameters was deliberated. Based on the research data plots are acquired. The mild steel turning procedure provided some helpful results in abstraction to machining parameters, which will be utile in developing turning process improvement with respect to power consumption and tool life.

3. Research Methodology

A HMT LT 20 make lathe was used for turning experiment. The dynamometer is mounted on tool post with the help of a holder specially designed for this experimental work. Then the actual experiments have been carried out with the different input cutting conditions for different experiments for constant volume of material removal in each case.

Fig. 1. Machine Setup

The experiments carried out are summarized as:

1. Carry out experiment on lathe machine using Aluminium as work piece and HSS turning Tool.
2. Machining is done with different sets of Cutting speed, depth of cut, & feed rates.
3. Measuring the cutting forces with dynamometer.
4. Measuring the flank wear of the HSS tool with microscope.
5. Observing the wear trends in SEM. The flank wear is measured and value of cutting forces is given by dynamometer. These values of flank wear and cutting forces are plotted against cutting speed to obtain the wear trends.

4. RESULTS AND DISCUSSION

The present problem that is Analysis of tool wear in turning operation of Aluminium have been developed in accordance with the previously developed models for tool wear [1], [3] and [5]. The number of experiments has been conducted to find out the cutting forces and flank wear of the tool, made of HSS tool, at varying machining parameters, which are cutting speed (v), cutting feed (f) and keeping depth of cut (d) constant. Using this data various graphs are plotted and analyzed. Also cutting tool wear behavior is observed using SEM after various cuts.

MACHINING PARAMETERS USED FOR EXPERIMENTATION:

Cutting speed v (rpm) (Range)	Feed f (mm/rev) (Range)	Depth of cut d (mm) (Range)
198,295,431,634	0.05,0.11,0.22,0.45	0.4(constant)

Table 1: Cutting parameters

The table 1 shows the numerical values of the various machining parameters (cutting speed, feed and the depth of cut), that have been selected for experimentation, for the measurement of cutting forces and flank wear. The Aluminium work-piece material has been used for experimentation. The cutting material used is High speed steel tool. The table 2 shows the experimental values of wear, and cutting forces for different speed, feed and depth of cuts for the different set of experiments conducted on the HSS cutting tool. Total 16 experiments were conducted and depth of cut is kept constant in all the experiments. To eliminate the effect of wear on the experiments, the tools have been replaced after every cut of constant volume of work-piece material. In total 16 HSS cutting tool have been used for all the different set of experiments to be conducted. Tool edge has been made straight or parallel to the chuck to have an orthogonal cut. The experiments were conducted for constant volume. Constant volume signifies that equal amount of material was removed in all the different sets of experiment conducted. This has been done so that all the measurements should be taken correctly at the same operating conditions to have a good accuracy in results with minimum possible error.

Sr. No.	Cutting Speed v (rpm)	Feed f (mm/rev)	Depth of cut d (mm)	Fx (N)	Fz (N)	Flank Wear (µm)
1	198	0.05	0.4	19.4	14.7	0
2	198	0.11	0.4	24.5	19.6	28
3	198	0.22	0.4	34.3	29.4	0
4	198	0.45	0.4	14.7	9.8	96
5	295	0.05	0.4	39.2	24.5	23.6
6	295	0.11	0.4	107.9	49	72.5
7	295	0.22	0.4	68.2	53.9	8.5
8	295	0.45	0.4	39.2	63.7	52.4
9	431	0.05	0.4	29.4	9.8	45.2
10	431	0.11	0.4	19.6	24.5	62.5
11	431	0.22	0.4	14.7	19.6	26.5
12	431	0.45	0.4	49	78.5	83
13	634	0.05	0.4	44.1	24.5	65
14	634	0.11	0.4	24.5	39.2	43
15	634	0.22	0.4	63.7	68.6	92
16	634	0.45	0.4	53.9	58.6	55.4

Table 2: Experimental Results of measured parameters against parameters V, f and d

Fig 2. Work- piece after machining

Fig 3. HSS tools after machining

VALIDATION:

In order to check the validity of the results various graphs are plotted between Cutting Speed and Force components (Fx and Fz) and between Cutting Speed and Flank Wear. These plots are compared with the results given by Thamizhmanii S. [1], for checking the validity of results. The results from the reference are well in accordance with the results of the present work.

VARIATION OF VARIOUS FORCES WITH CUTTING SPEED:

Fig. 4.1 to 4.4 shows the variation of forces with cutting speed

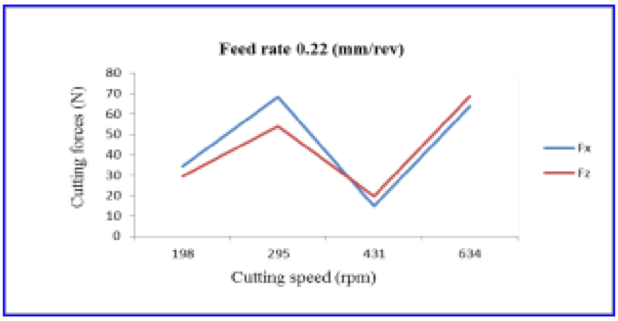

Fig. 4.1 Cutting Speed Vs Forces at 0.05Feed

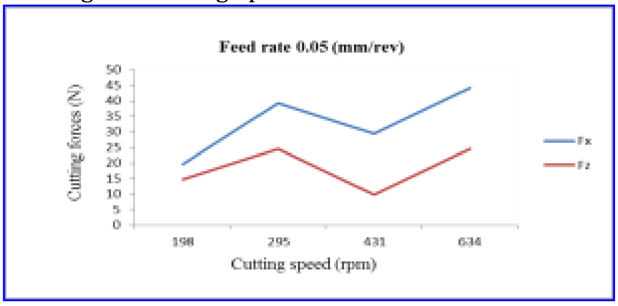

Fig. 4.2 Cutting Speed Vs Forces at 0.11 Feed

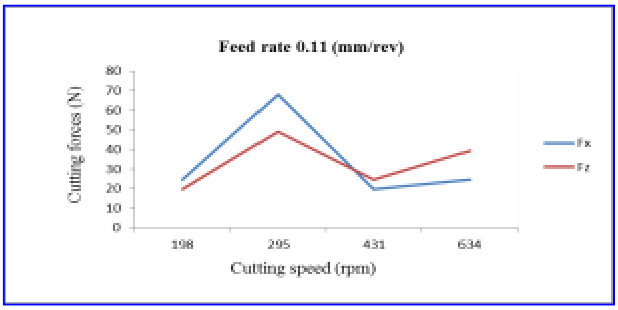

Fig. 4.3 Cutting Speed Vs Forces at 0.22 Feed

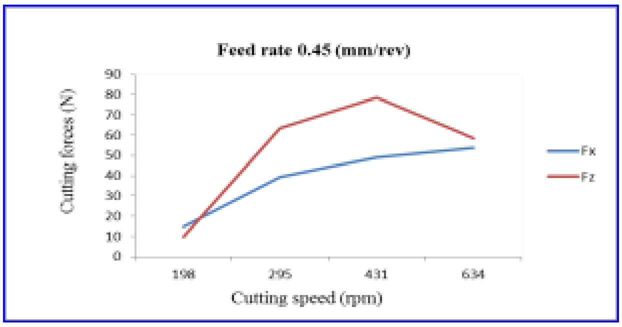

Fig. 4.4 Cutting Speed Vs Forces at 0.45 Feed

VARIATION OF FLANK WEAR WITH CUTTING SPEED:

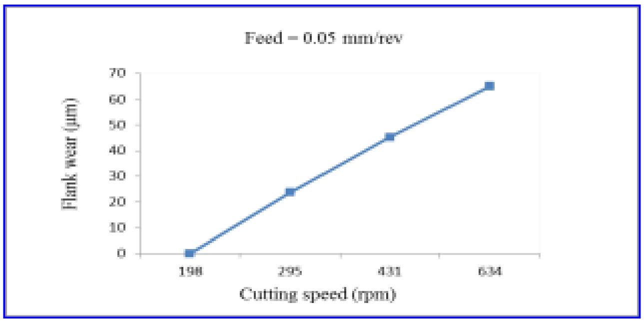

Fig. 4.5 Cutting Speed Vs Flank Wear at 0.05 Feed

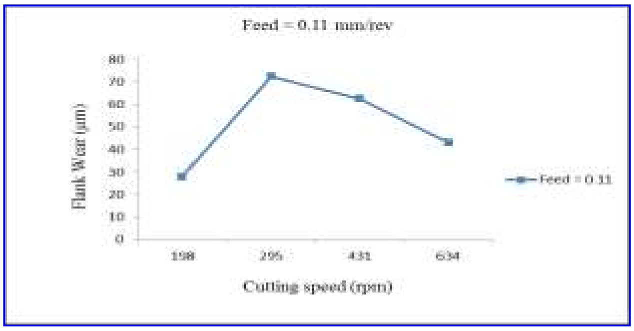

Fig. 4.6 Cutting Speed Vs Flank Wear at 0.11 Feed

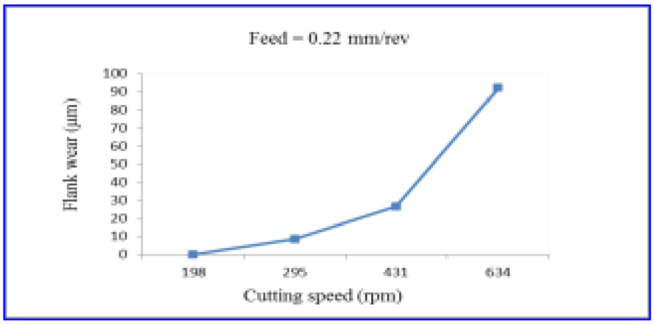

Fig. 4.7 Cutting Speed Vs Flank Wear at 0.22 Feed

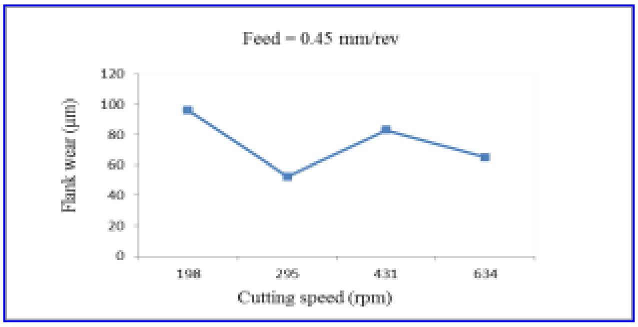

Fig. 4.8 Cutting Speed Vs Flank Wear at 0.45 Feed

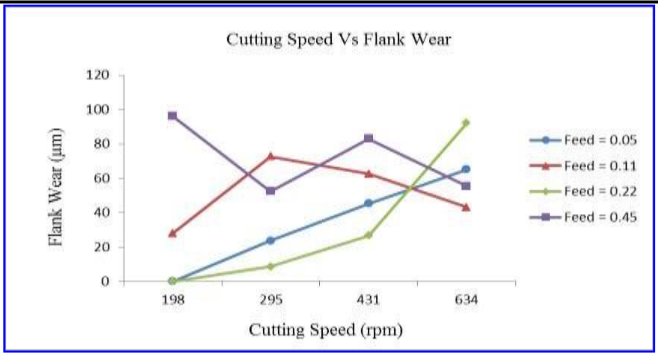

Fig. 4.9 Variation of Flank Wear with Cutting Speed

CUTTING FORCES

There are two cutting forces which are acting on a single point tool in orthogonal cutting (Fx and Fz). The Fx is the feed force which is acting on the X direction and Fz is the cutting force acting on the Z direction. The cutting forces were measured using 3 component dynamometer (Force measurement dynamometer). The figures above show the various cutting forces measured during turning. The cutting force Fz was low when cutting at feed of 0.05 and 0.11 and at cutting speed 198 and 431 rpm whereas the feed force Fx is low at the start and increased when the cutting speed increased. The feed force Fx and cutting force Fz is maximum at 295 and 431rpm cutting speed.

TOOL WEAR (FLANK WEAR)

The flank wear is a widely used criterion for evaluating tool life because of its importance in most applications. Flank wear is produced mainly due to abrasive wear of the cutting edge against the machined surface. The flank wear in this experiment was not present when machining at 198 rpm cutting speed and at 0.05 mm / rev feed, then increased to 65µm at 634 rpm speed having same feed rate. But flank wear 96 µm observed at speed 198 rpm having feed of 0.45 mm/rev. In other experiments, the flank wear was less than 150µm. Fig. 6.10 show flank wear at 634 rpm and 0.22 mm/rev feed and fig. 6.11 shows flank wear at 295 rpm and 0.45 mm/rev feed. The two main effects are responsible for tool wear are oxidation of the tool and inter diffusion of the constituting elements between tool and workpiece. Fig. 6.9 shows flank wear surface at 431 rpm and 0.05 mm/rev feed. Hard particles plough grooves into the cutting tool material. Excessive notch wear affects surface finish and weakens the cutting edge. Fig. 6.13 shows notch wear at 198 rpm and 0.45 mm/rev feed rate

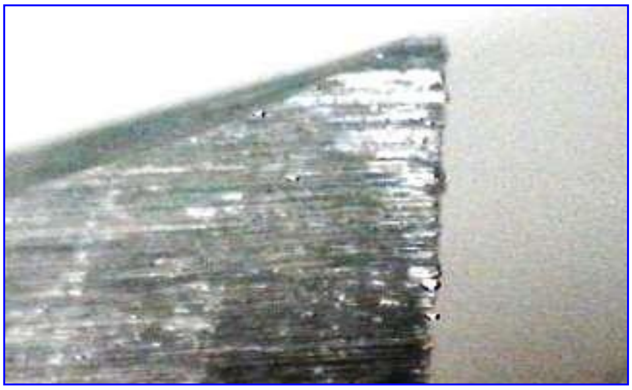

Fig. 4.10 Micrograph shows Flank Wear at 634 rpm and 0.22 mm/rev feed

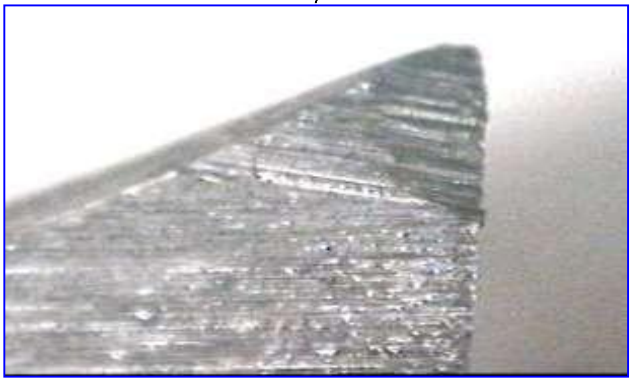

Fig. 4.11 Micrograph shows Flank Wear at 295 rpm and 0.45 mm/rev feed

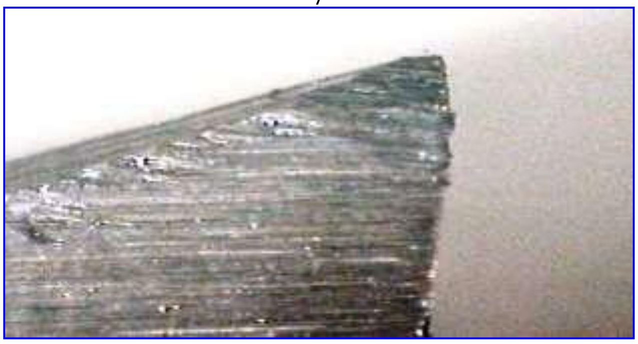

Fig. 4.12 Micrograph shows Flank Wear at 431 rpm and 0.05 mm/rev feed

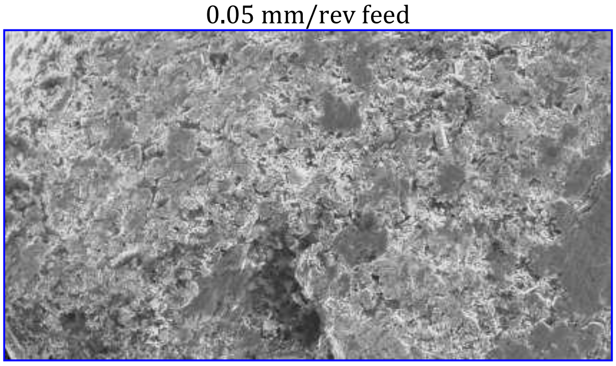

Fig. 4.13 Micrograph shows Notch Wear at 198 rpm and 0.45 mm/rev feed

5. CONCLUSION

The analysis of experimental results yields several noteworthy conclusions regarding the turning operation under varying cutting conditions. Firstly, it is observed that cutting forces exhibit significantly lower values at a cutting speed of 431 rpm for all feed rates, with the exception of a feed rate of 0.45 mm/rev. The tangential feed force (Fx) at this particular feed rate demonstrates a consistent increasing trend across different cutting speeds. Additionally, at lower cutting speeds, flank wear is found to be zero for feed rates of 0.05 mm/rev and 0.22 mm/rev. However, the maximum observed flank wear, reaching 96 µm, occurs at a speed of 198 rpm with a feed rate of 0.45 mm/rev. Notably, the flank wear at feed rates of 0.05 mm/rev and 0.22 mm/rev exhibits a consistent increasing trend, while the combination of a feed rate of 0.11 mm/rev and a cutting speed of 295 rpm results in maximum flank wear, showing a decreasing trend. These findings provide valuable insights into the intricate interplay between cutting speed, feed rate, and resulting forces and wear, facilitating informed decisions for optimizing machining parameters to enhance tool performance and overall efficiency in the turning process.

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BIOGRAPHIES

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