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# Determination of Cutting Tool Performance Characteristics in Machining Nickel Based Super Alloys

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***Abstract* -** Cutting tool materials often undergo severe mechanical stresses and thermal changes when machining nickel-based superalloys. The stresses and temperatures that arise when machining nickel-based superalloys greatly increase the blunting and wear rate of the cutting tool. As a result, tool life is adversely affected. It is seen from important studies that adhesion and abrasion wear mechanisms are more dominant in the processing of Inconel 718. The work material adheres to the cutting edge, forming a BUE. Depending on the cutting conditions, stable BUE is not always formed and this layer is sometimes repeatedly removed with the chips. Notching in the depth of cut, wear on the tool nose and coating layer is caused by the presence of hard particles in Inconel 718 and causes severe flank wear. Flank wear and notch are the main factors limiting tool life, and oxidation and diffusion occur as a result of high temperatures.

*Keywords: Machining, Optimization, Wear, Surface Roughness, Cutting Force.*

## • Introduction

The most common form of tool deterioration in machining nickel-based superalloys is notching at the depth of cut. This is due to the combination of high temperature, high work hardness, high stresses of the workpiece and abrasive chips [1, 2, 3, 4, 5]. Side edge, snapping, severe damage are other causes of cutting tool deterioration in machining nickel-based superalloys. In many machinability studies, special physical conditions, overvoltages and heat gradients have been investigated, doubting the notch shape formed during machining and many theories on this subject. As a result, there is no consensus on the situation seen in notch wear in the machining of nickel-based superalloys. However, the general belief is that the notch shape is formed by a combination of many factors. It is not only caused by a point wear mechanism. It has been reported that large heat gradients in welds have little effect on notch formation in the depth of cut [6]. The cause of notch formation is the presence of a hard surface layer formed during machining [7, 4]. The notch formation is seen as a result of the particles breaking off from the tool material at the depth of cut as a result of boiling between the chip and the tool [1, 8]. The work hardness layer often appears in the form of a crust during machining. In addition, during machining in a crusted environment, fractures occur all over the edge of the cutting tool [9, 10].

Tool life is very limited at high cutting speeds. Excessive notching occurs as a result of boiling and pull-out processes occurring at the depth of cut. As Incoloy 901 is processed with mixed ceramics [4] at a cutting speed of 300 m/min, and Inconel 718 at high cutting speeds, but with mixed ceramics of another quality [Al+Zr+W], both cutters are due to their mechanical strength. a satisfactory tool life for the tool was obtained [11, 12].

## • Materials and Method

### *Literature Studies on Cutting Tool Performance Characteristics*

According to Shaw et al. [9], when waspalloy was processed from nickel-based superalloys, a red-colored heat was observed at the cutting edge, while a darker region was observed towards the center behind. As a result, it has been observed that the edge of the chip is not restricted, on the contrary, it receives a greater amount of special energy from the center and welds occur by tearing material from the edge of the tool. However, this extraordinary phenomenon was not observed in the recent study by Khamsehzadeh. In the study of Khamsehzadeh, notch formation was discussed in two stages [4]. According to the author's statement, side-edge plastic bleed of workpiece material at the edge of the cutting zone is the result of operations between the chip and the workpiece. As a result of this initial lateral flow, a crust forms. The lateral flow on the chip surface is shaped circularly.

According to Lee et al. [13], In many studies, the accepted principles are generally similar to each other, although the conclusions about the notch shape during processing are not conclusive. The recommended situation for minimizing the chipping or breaking of the tool edge in reducing the notch at the depth of cut is that the side edge of the cutting tool to be used is large and negative angled. A recent study has shown how the notch on the cutting tool can be eliminated or minimized by using stepped taper turning [ramping] techniques with continuously varying depth of cut along the cutting edge of the cutting edge [24, 14]. In this layer, the tungsten carbide grains are lower than the original material and are more rounded. A link between the location of the maximum temperature and the location of crater erosion supported these observations. In general, the crater location appears on the chip surface, away from the cutting edge when machining steel. It has been seen in turning operations with different tool materials on Inconel 718 that the crater starts just behind the cutting edge [16]. As the cutting speed increases, the crater profile also changes [2, 14]. Diffusion with cemented carbide tools has been observed to significantly limit tool performance [15]. This view is in Ezugwua et al. It is also supported by [17, 25].

Bhattacharyya and Jawaid [19] In their work, It is stated that crater and flank wear, which is one of the reasons that deteriorate the cutting tool, occurs partially as a result of the diffusion wear mechanism. In machining nickel-based superalloys, cracking or cutting edge breaks are the predominant conditions [Inconel 718 and Nimonic 75]. Crater and thermal cracks seen at high temperatures were seen as the cause of fractures in the tool [7, 17].

This type of wear, which occurs in the machining of nickel-based super alloys, in which a crater is formed by the work material by breaking off grains or metal grains from the tool material, and then leaves itself in a rough area, has been reported by many researchers in the sources [4, 18]. Crater wear has been attributed to uneven contact of the work material on the cutting edge of the tool. Fatigue is caused by saw-tooth chips, while cracks are the result of thermal or mechanical fatigue. Cutting tool breakage has been attributed to higher stresses or higher stresses just behind the cutting edge [19]. Because the normal stresses on the tool surface were found to be two times higher for nickel-based superalloys than for steel machining in the same environment where the cutting parameters are used [20]. Tool wear accelerates, cracks appear. This is especially noticeable in intermittent cuts. [21]. In the literature, attention is drawn to abrasion wear when machining nickel-based superalloys with ceramic tipped tools [4, 19].

- DISCUSSION

Although pure oxide [Al2O3 + ZrO2] ceramic tipped tools have good chemical stability, high thermal hardness and high wear resistance, they are not effective in machining nickel-based superalloys [22, 23]. The poor performance of pure oxide ceramics is due to poor mechanical and thermal shock resistance at high temperatures and low fracture hardness [24, 25]. These tools have also shown excellent performance in machining hardened steels and cast irons [26, 27]. The relatively high hardness of ceramic cutting tools allowed them to be machined at high cutting speeds and high feeds of superalloys, hardened steels and cast irons. [28, 29]. It is reported in the sources that the notch formed when Incoloy 901 is processed with silicon nitride-based ceramic tipped tools, decreases by 70%. This results in a 57% cost reduction when compared to plain carbide tools in Inconel 718's semi-finish turning operations [24]. Another suggestion is that waspalloy, one of the nickel-based superalloys, is better processed with sialon ceramic cutting tools in the coolant medium [30]..

Literature Studies Evaluating Tool Life and Tool Wear

In the study conducted by A. Chouldhury and M. A. El-Baradie in 1998 [1], tool wear tests were carried out after three series of studies with coated and uncoated cemented tungsten carbide tools Each experiment was started with a new cutting edge and the process was stopped and the wear values were measured from one minute to two minutes by measuring tool wear at different time intervals. In addition, in cases where the side edge wear value [average] exceeded 0.3 mm, the bench was stopped and the pencil tip was replaced. Three shear tests were performed for each shear condition. Average side edge wear values and tool wear values were decisive in determining the tool life.

- CONCLUSION

As a result of the literature research, the following results were obtained.

1- The notable factors in machining nickel-based tools are tool life, limited stock removal, cutting forces, power consumption, surface finish, integration of machined elements, chip shape/saw tooth chip formation, high strength and hardness of the work material. These are all important factors to consider in the structure of the machined surface and tool life [31].

2- The notch formed in the depth of cut region is the most noticeable form of tool wear [32]. In machining nickel-based superalloys with different cutting tools, work hardness, chip-tool boiling, material rupture from the cutting tool and crater wear are the dominant conditions for tool deterioration. Flank wear, snapping, and fatigue and wear are also factors that limit tool life. Other factors are thermal and mechanical fatigue loads acting alone or in combination on the cutting tool, crater wear, abrasion wear and adhesion wear [31].

3- The presence of different atmospheres in the machining of nickel-based superalloys had different effects on tool wear. The notch decreased in machining operations performed in the presence of oxygen. However, more severe indentation occurred in machining in an environment with argon and nitrogen [31].

4- It has been seen that the coolant plays a very important role in the machining of nickel-based super alloys. As a result of the irregular contact of the hot chip on the cutting tool, fatigue and wear occurred. Coolant was used to reduce the heat generated in the cutting zone. However, the use of high pressure coolant resulted in a shorter tool life despite a smoother chip. With the use of high-pressure coolant, the contact area between the tool and the chip was significantly reduced, resulting in a stress increase at the cutting edge [31].

5- When there is a reduction in the approach angle of the cutting tool, longer tool life is achieved as a result. When machining round and square shaped cutting tools and nickel-based alloys, better performance was obtained than round [rhombic] shaped tools [31].

6- The fracture hardness and excessive notch formation of unsuitable ceramic tipped tools could be overcome by using taper turning techniques with varying depth of cut [31].

7- In cases where the depth of cut exceeds 1 mm, coated tools are found suitable for use, while the effect of the depth of cut element on coated tools is seen more than the effect of uncoated tools in Taylor's tool life equation [30].

8- In a literature study, in 8 machining operations, the tool life of the carbides was found to be longer when the side edge wear value of 0.20 mm was reached, when similar experimental conditions were performed with coated and uncoated tools, while the tool life of the carbides was found to be shorter in four machining operations. The recommended machining parameters for machining Inconel 718 were a cutting speed of V=20-25 m/min. for carbide tools, a feed rate of 0.15-0.20 mm/rev., and a depth of cut greater than 1 mm [30].

9- Uncoated tools performed better at different cutting speeds and feed rates. No significant difference was observed in terms of tool life at cutting speeds of 26 to 48 m/min. At higher cutting speeds, there was no reduction in cutting forces due to higher shear stress. Cutting forces increased in machining with a cutting speed of 50 m/min and a feed of 0.30 mm/rev. [30]

10- The abrasion resistance of the carbide cutting tool associated with low cobalt content has increased, and the cutting geometry, especially the side edge cutting angle, has a serious effect on the tool life. Good performance was demonstrated for the K20 grade carbide insert with high thermal conductivity and low thermal growth coefficient, thanks to the reduction of thermal shocks.

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