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Machinability investigation on nickel based super alloys using textured inserts

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Abstract

Machinability investigation on nickel-based super alloy under the influence of textured tungsten carbide inserts is performed in this current study. Machinability indicators such as surface roughness and tool wear have been investigated. Similarly, texture patterns such as dots, circle chain and zig zag shaped textures have been fabricated on CNMG120408 WC inserts using Laser source. The primary objective of the present investigation is to compare the performance of different types of tools when they are used with different parameters such as cutting speed, feed rate, and depth of cut. It has been observed that the surface roughness and tool wear of the dot shaped textured tool were lower when compared to the other types of tools. Dot shaped textured inserts and circle chain shaped textured tool was able to perform better than the other tool inserts.

Introduction

Due to their exceptional mechanical and chemical properties, nickel-based super alloys are commonly used in various industrial sectors such as aerospace, chemical, and marine. With the increasing number of machining processes being used in the industry, the performance of these materials is expected to improve. Some of these include thermal-assisted and cryo-assisted machining. These are beneficial for improving the cutting tool life and reducing the overall machining conditions [1], [2]. During the manufacturing process of Inconel 718, various failure modes were identified. These include crater wear, notching, and flank wear. The main reason for these conditions is due to the presence of an abrasive wear mechanism and diffusion [3]. Due to their high strength and thermal conductivity, nickel-based superalloys are commonly used in areas where high heat is required. These materials are considered to be difficult-to-machine materials. They can also harden during the removal of material, which results in shorter tool life [4]. In 2005, a study conducted by Xu revealed that the design of tool materials should reflect the strength and fracture characteristics of their microstructural properties. He also noted that the smaller size of the secondary particles could help strengthen them. On the other hand, the larger secondary particles with a higher particle size ratio could cause them to resist fracture [5]. With the use of cryogenic assistance machining, hard to machine materials can be made to endure the temperature changes at the machining zone. This process improves their chemical stability and increases their productivity [6], [7]. In addition, studies have shown that certain types of ceramic tools, such as Al2O3 ceramics, are commonly used in the production of nickel-based super alloys. The effects of different tool materials on the performance of the machine are discussed in detail. Besides the machining parameters, the other factors such as the

cutting and surface textures of the tool are also taken into account to improve the overall performance of the machine [8]. The adhesion mechanism is a crucial factor that can cause tool failure or wear during the machining process. At high temperatures and stress levels, the surface of the tool can get damaged, which can lead to the accumulation of edge and eventually cause the tool to fail. The other factors that can affect the performance of the machine are the continuous exposure to the debris and the chip-making process [9]. Experimentation with coated WC-Co inserts in machining Aluminium metal matrix composite were done with different coated tools namely microcrystalline diamond, CVD coated nanocrystalline diamond and boron-doped diamond coating and the results were compared with that of polycrystalline diamond tool. Experimental results proved that polycrystalline diamond coated tool inserts performed better than the other coated tool inserts [10].

The performance analysis of Al-MMC machining process was carried out to study the effects of micro hole and pitch in between the holes on the overall performance of the machine. The various parameters such as pitch in between the holes, tool wear, surface roughness, and power consumption were analyzed. It was found that the micro hole and pitch in between the holes had an influence on the machining performance while using solid lubricants [11]. A study was performed on the mechanical properties of Al-Cu/TiB2 tool inserts with surface textures. The different types of textures were analyzed to determine their impact on the cutting force and tool wear. The results of the analysis revealed that the varying cutting energy and the tool wear caused by the surface textures were significant. The results of the experiment revealed that the tool insert with a linear texture in the direction of the chip flow performed better in improving the mechanical properties of the surface [12], [13], [14].

Experiments were conducted to analyze the machinability during machining of Al 6063 alloy with different parameters and carbon nitride inserts. It was stated that the feed rate and cutting speed are the most influencing parameters that affects the machinability [15], [16], [17]. A 3D Finite Element Model(FEM) was developed to envisage the tool wear of ceramic inserts and PVD-TiAlN coated carbide in machining of hard to machine material Inconel 625. It was perceived that among the parameters considered, the increase of depth of cut were found to the most influencing factor on the stresses and generation of temperature on the face of the tool [18], [19].Comparison between LN_2 and CO_2 cryogenic fluids were done to analyze their effects on tool life during machining Inconel 718. The results showed that the tool life is the shortest in the case of LN2 condition while CO2 condition shows lower value when compared with that of the traditional lubrication [20]. From the previous literatures, it is observed that various techniques has been adapted in machining hard to machine materials. Less or few work has been reported to study the influence of uncoated tungsten carbide inserts with textures on the rake face of the inserts. In this present work an attempt has been made to measure the surface roughness and tool wear during machining Inconel 718 with different textured uncoated tungsten carbide inserts under different machining conditions.

Section snippets

Materials and methods

The work piece material used in this present investigation is commercially available Inconel 718. The dimensions of work specimen used are of 550X30 mm length and diameter for this present analysis. Turning experiments were performed in Hi-Tech CNC turning Centre with different parameter conditions and is shown in Fig. 1. The machining conditions selected for this present study is of cutting velocities (Vc = 40 m/min and 80 m/min) and feed rate of [f = 0.05 mm/rev] and a constant depth of cut…

Effect of process parameters on surface roughness

The graph of surface roughness against cutting speed reveals that the values of surface roughness are high at low cutting speeds 40 m/min and reduced as the speed increased to 80 m/min is shown in Fig. 2. This is due to the fact that at higher cutting speeds there may be possibility of thermal softening effect and that the flaws at the surface of the machined areas gets wiped out during turning of high strength materials. From the present investigation it is observed that when machining speed…

Conclusions

Nickel based super alloys find wide range of applications in many engineering industries due to the superior mechanical and chemical properties, and hence the machinability of these alloys are always a challenge that are to be determined.

- Extended cutting tool life is another decision process of improving the machinability of nickel-based super alloys and to confirm the stability at higher production rates, many improved techniques such as textures on the rake face of the tool inserts are…

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CRediT authorship contribution statement

D. Palanisamy: Conceptualization, Data curation, Investigation, Methodology. **B. Vishnu Vardhana Naidu:** Writing – original draft, Validation. **K. Lenin:** Conceptualization, Supervision, Writing – review & editing, Visualization, Writing – review & editing, Visualization. **A. Parthiban:** . **A. Gnanarathinam:** Conceptualization, Supervision, Writing – review & editing, Visualization, Writing – review & editing, Visualization.…

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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