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Aspect of Tool Wear in Machining of Inconel 718

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Abstract: Machinability of Nickel-based superalloy Inconel 718 used in aerospace applications is the point of focus since many years. Inconel 718 is one of the most difficult to cut alloys. The properties which make Inconel 718 suitable to work in challenging environments at aero engines themselves increase the difficulty in its machining. This paper reviews the machinability aspect of Inconel 718 under various environments keeping in view important response parameters in machining such as tool wear, cutting forces and other surface integrity issues. Some possible solutions to improve the machinability of Inconel 718 are also suggested at the end.

***Index Terms* -** Turning , Inconel 718, MQL, Tool Wear, Chip Formation, Surface Finish.

I. Introduction

The advanced technologies of the aerospace industry demands the use of materials with superior properties to fulfill the requirements such as weight, reliability and precision in complex environments. Aerospace parts must retain stability, resist corrosion and metal fatigue, and maintain their strength over a wide range of high temperatures; this can only be satisfied by the use of high-performance metal alloys. Nickel base superalloys being strong, lightweight and aesthetic in appearance, turns out to be an excellent choice for aerospace components construction[1].The recent developments in aerospace, petrochemical, marine, nuclear power generation, and process industries have driven the need for hard, high-strength and heat-resistant super alloys (HRSA). Both nickel-based and titanium-based alloys are suitable for aircraft engine components, particularly rotating parts of gas turbines such as blades and disks, because of their ability to maintain high strength even at elevated temperatures prevailing in the engine [2, 3]. Nickel-based superalloys are mainly used for static or rotating components of the hottest sections of aero engines. These rotating parts are the blades and the disks in the high-pressure compressor (HPC) and turbine (HPT) stages. As far as disks are concerned, nickel-based superalloys are selected for the last HPC (hot) stages, while titanium-based alloys are used for the first (colder) compressor stages due to their lower density [4].

Inconel 718 is one of the Heat Resistant Super Alloy (HRSA) from the nickel-chromium group suitable for aerospace applications. It is a precipitation-hardenable nickel-chromium alloy containing significant amounts of iron, niobium and molybdenum along with lesser amounts of aluminum and titanium. It combines physical properties like corrosion resistance with high strength and outstanding weldability. It has excellent creep–rupture strength and a high fatigue endurance limit up to 1300 °F (700 °C). Inconel 718 is used in hot sections of gas turbines, rocket engines (including the space shuttle main engine), spacecraft structural components, nuclear reactors, pumps, tooling, in the manufacture of components for aircraft turbine engines, cryogenic tankage and nuclear industries [5, 6] Inconel is considered as one the difficult to cut metal and to find out causes of why Inconel 718 is difficult to machine is a topic of research for many researchers since past many years. Most of the researcher has focused their study on the difficult machinability of Inconel 718 and issues regarding the surface integrity. Inconel 718 has poor machinability due to the same properties that make it suitable for application in aero-engine components. Some of the properties which make Inconel 718 difficult to machine are.[3,5,8-16]

- During machining Inconel 718, the cutting tool often supports extreme thermal and mechanical loads close to the cutting edge leading to rapid tool wear.

- Welding and adhesion of worked material onto the cutting tool frequently occur during machining, causing severe notching.
- Poor Thermal Conductivity.
- High-temperature strength, hardness.
- Presence of abrasive carbide particles in the microstructure.
- High shear strength.
- High chemical reactivity to most tool materials.
- Strain rate sensitivity and readily work hardening properties.
- Very high cutting forces due to the material strength which may result in vibration.

This paper provides an overview of machining of Inconel 718 under, Machining with Minimum Quantity Lubrication (MQL). The major emphasis is given to important response variables in machining like tool wear and surface finish. In the following sections, the machining of Inconel 718 has been discussed based on the above-mentioned response variables.

Tool Wear Literature

Tool wear leads to tool failure; the failure of a cutting tool occurs as premature tool failure, i.e. and progressive tool wear. Generally, the wear of cutting tools depends on tool material and geometry, workpiece materials, cutting parameters (cutting speed, feed rate and depth of cut), cutting fluids and machine-tool characteristics [17].

The high stress at the tool–chip interface, the work hardening, and the high temperature involved in the machining of Inconel 718 all contribute to tool wear; hence understanding and predicting tool wear and tool life is an important task in turning nickel-based alloy such as Inconel 718 [18]. Machining of Inconel 718, high-pressure cooling leads to more efficient chip breaking and usually extends the tool life; also, conventional cooling leads to a slightly higher wear rate and more welding of work as compared to high-pressure cooling[19]. Thakur et al.[20] reported that tool wear is very much dependent on cutting condition, tool geometry, material hardness, etc. It was observed during their investigation that flank wear increases gradually when cutting speed was increased for constant feed rate and depth of cut. They also reported that flank wear and microchipping were the predominant failure modes of cemented carbide tool insert affecting tool performance and tool life in machining Inconel 718. The main failure modes of ceramic cutting tools during machining of Inconel718 are notch wear and flank wear [21].

Altin et al.[22] while studying the effects of cutting speed on tool wear and tool life when machining Inconel 718 with ceramic tools reported that generally, flank wear, crater, notching and plastic deformation are the wear mechanisms observed with ceramic inserts. The dominant wear mechanisms seen at round type inserts are flank and notch wear while flank wear and crater are the major wear types of square type inserts. The major cause of tool rejection when machining Inconel 718 is high-temperature generation at the tool– chip and tool-workpiece interfaces which can be significantly reduced by administering coolant under high pressures directly to the cutting interface. This could, therefore, minimize thermally related wear mechanisms [23]. Tool wear is a result of extreme thermal and mechanical stresses close to the cutting-edge during machining due to the poor machinability of nickel-base alloys [24]. PVD-TiN coated tools give better performance as compared to uncoated tools due to the high wear-resistant and low thermal conductivity of the TiN coating layer that remained intact of the flank face [15]. Sharman et al. [13] used CrN and TiAlN coated tools while machining Inconel 718 and reported extensive BUE and peeling of coating with CrN tools because of the higher chemical affinity of CrN for Inconel 718 than that for TiAlN. They also mentioned about better performance of TiAlN tools in the machining of Inconel 718.

Conclusion and Future Scope:

A review on the machinability of Inconel 718, which is one of the most difficult to cut alloys of Nickel, has been discussed in this paper. Tool wear, cutting forces, residual stresses, and surface roughness microhardness variation are the major parameters which are the main focus of the paper. From the above discussion, it can be concluded that:

1. The properties of Inconel 718, which make it suitable for aerospace applications, pose major problems during its machining.
2. Aspect of chip morphology, high temperature and stresses generated during machining needs to be explored more.
3. There is a vast scope in the machining of Inconel 718 with techniques like the use of High-Pressure Coolant, Minimum Quantity Lubrication, and Hot machining.

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