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Machining of Inconel 825 Using Distilled Water Based MQL Technique

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Abstract

Because of its high hot strength and corrosion resistance, Inconel 825 superalloy has various industrial uses in the aerospace, nuclear, automotive, and defense industries. However, characteristics like as work hardening, poor heat conductivity, and chemical reactivity with tool material make it "difficult-to-machine." Its machining via the traditional approach is difficult for industries. The machining behavior of Inconel 825 under distilled water-based minimum quantity lubrication (MQL) is examined in this work using a PVD-TiN/TiCN/TiN coated cermet insert. The tool's tip temperature, cutting force, and flank wear are all investigated.

Keywords: Inconel; corrosion resistance; MQL; cermet.

Introduction

Because of its excessive hot hardness and outstanding corrosion/oxidation resistance, Inconel 825 has various engineering applications in petroleum refineries, chemical plants, and acid production industries. However, some qualities of this alloy, such as low heat conduction, strain-hardening capabilities, and affinity for tool material, among others, cause major problems during conventional machining. When machining this superalloy, low tool life and poor surface finish are serious issues. Milling difficulties can be overcome by employing adequate cooling/lubrication techniques to lessen the excessive heat created during milling. Flood cooling has been the primary cooling method for decades. Flood cooling, on the other hand, can regulate heat evolved at lower cutting speeds. This approach is ineffective when cutting parameters like cutting speed, feed rate, and depth-of-cut are high. Flood cooling frequently endangers the health of operator and has a negative influence on the environment. The use of a large amount of cutting fluid creates disposal issues and raises the overall cost.

Minimum Quantity Lubrication (MQL), which is also known as Near-Dry Machining (NDM), outperforms flood cooling technique for machining superalloys with increased tool life and improved surface finish (Boswell et al., 2017). MQL cools and lubricates tool-workpiece/tool-chip interfaces with an aerosol mixture of cutting fluid (oil) in carrier gas (usually air). The MQL process employs a small amount of cutting oil, that is generally biodegradable, environmentally safe and cost effective. Extensive research has been conducted in recent decades to improve the machinability features of difficult-to-cut superalloys via MQL machining. Attanasio et al. (2006) investigated the turning behavior of 100Cr steel in dry as well as MQL conditions using a CVD TiCN/Al_2O_3 /TiN coated carbide insert. MQL environment was made using synthetic ester oil (COUPEX EP46) as cutting fluid. It was accomplished that MQL condition provided extended tool life due to decrease in tool wear when compared to dry environment. Sadeghi et al. (2009) machined Ti-6Al-4V alloy using synthetic ester oil and vegetable oil in MQL condition. Synthetic ester oil outperformed vegetable oil in terms of machined workpiece surface finish. Thakur et al. (2010) investigated the influence of lubricant quantity, nozzle direction, nozzle pressure, cutting speed, pulse frequency, and feed rate on MQL machining of Inconel 718 using a WC-Co tool and a water-miscible oil lubricant. Significant reductions in cutting force, temperature, and flank wear were seen during MQL machining using a pulsed jet delivery system. Hadad et al. (2013) used an HSS tool to test the turning responses of AISI 4140 steel in dry, wet and MQL conditions. For MQL, the authors employed ester oil as the cutting fluid, while for wet turning, they used water soluble cutting fluid (10% oil in water). MQL outperformed both dry and wet machining in terms of cutting force, tool temperature, and machined surface roughness. Lohar and Nanavaty (2013) investigated the machining behavior of AISI 4340 steel using a CBN tool in dry, wet (flood), and MQL environments. MQL demonstrated lower cutting force and temperature with improved machined surface finish when compared with conventional dry and wet machining. Ji et al. (2014) investigated MQL performance during machining of AISI 4143 steel by examining the impacts of MQL parameters including flow rate and air-oil mixing ratio on cutting force, temperature, and residual stresses. In this work, a PVD coated carbide tool and vegetable oil were used as lubricant. MQL performed better than dry conditions and was comparable with flood cooling, according to experimental results.

According to a literature review, machining hard superalloys is difficult and expensive due to rapid tool wear. Coolant is required to prevent tool wear and, as a result, improve machined surface quality. Due to environmental concerns, the use of synthetic/mineral oil-based flood cooling is considerably limited. On the contrary, the MQL process is superior in both dry and wet machining circumstances. The MQL machining method has demonstrated its ability to reduce cutting force, cutting temperature, and tool wear. Previous study findings showing MQL machining performance of superalloys were documented. However, the literature on the machinability of Inconel 825 under MQL conditions utilizing distilled water as coolant is limited. In this paper, the machining behavior of Inconel 825 is investigated using distilled water-based MQL at varying cutting speeds. Cutting speed has an effect on cutting force, tool-tip temperature, and tool wear. MQL performance is also compared to dry machining.

Experimental Details

The investigation employs a round Inconel 825 bar with diameter and length of 60 mm and 450 mm, respectively. Table 1 shows the chemical composition of Inconel 825 (Ni-Fe-Cr superalloy). Table 2 lists the properties of Inconel 825.

Table 1. Composition of Inconel 825 superalloy

Elements	Ni	Fe	Cr	Mo	Cu	Ti	Mn	Al	Si	C	S
Composition (in %)	38-46	22	19.5-23.5	2.5-3.5	1.5-3.0	0.6-1.2	1.0	0.2	0.5	0.05	0.03

Table 2. Properties of Inconel 825

Properties	Values
Density (g/cc)	8.14
Melting point (°C)	1400
Coefficient of thermal expansion (m/m/°C)	1.4×10^{-5}
Thermal conductivity (W/mK)	12.3
Modulus of elasticity (kN/mm^2)	196
Modulus of rigidity (kN/mm^2)	75.9

Turning is done using a heavy duty NH-26 lathe (HMT, India) with a maximum spindle speed of 1020 rpm. PSBNR2020 K12 (WIDIA) is used as tool holder. Machining takes 20 seconds, and the insert's new cutting edge is used for individual trials. Figure 1 depicts the experimental setup.

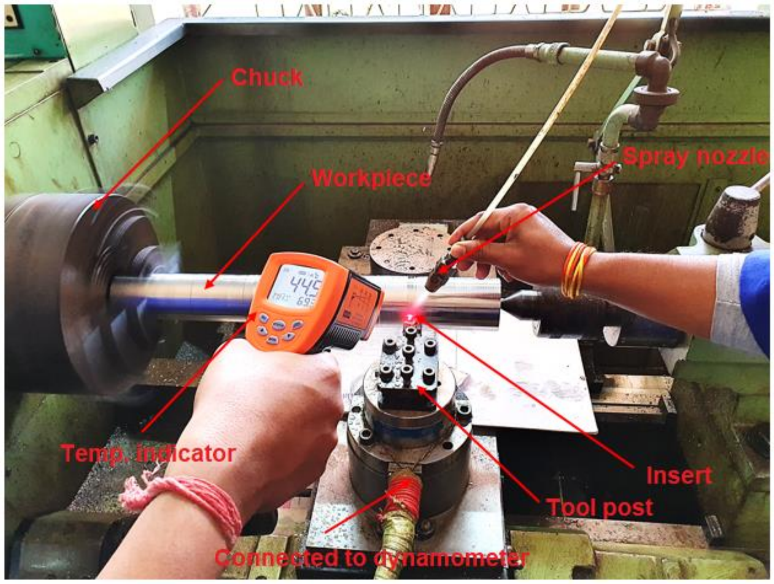

Fig. 1: Experimental Setup

The tangential component of cutting force (Fc) is measured using a KISTLER 9272 dynamometer, which is mounted on the tool post and linked to an amplifier (type-5070). AR882 non-contact type infrared thermometer is used to measure tooltip temperature. Wear study of the flank face of the insert is performed using an optical microscope.

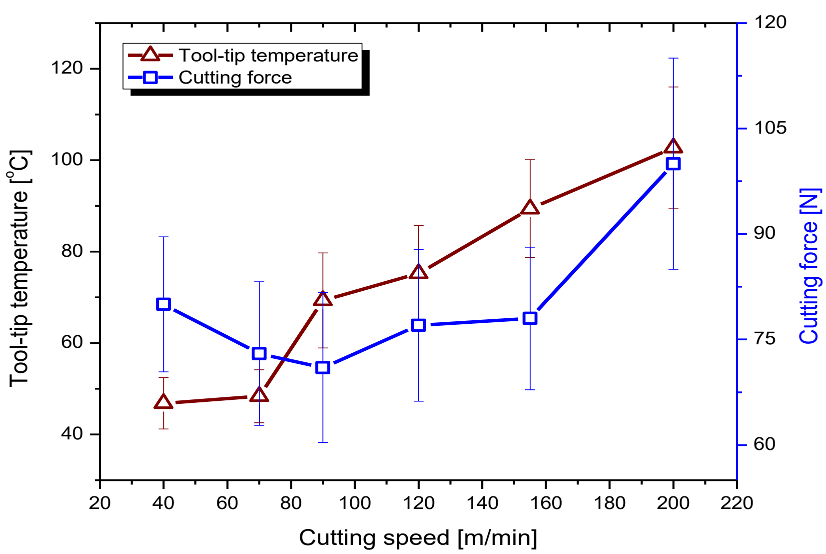

Fig. 2: Dependence of tool-tip temperature and tangential cutting force on cutting speed

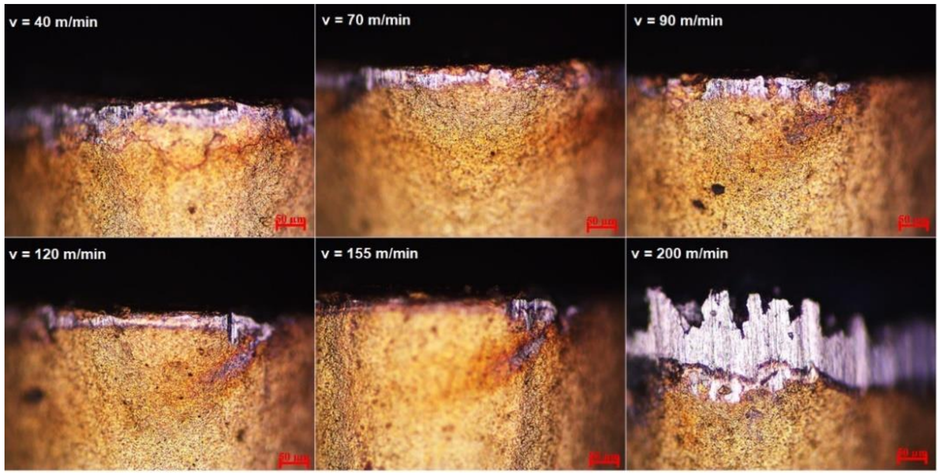

Fig. 3: Tool flank wear at varied cutting speeds under MQL

Results and Discussion

Figure 2 depicts the effect of cutting speed on cutting force and tool-tip temperature. At the beginning of the machining process, more cutting force is required to shear material from the workpiece. Cutting force decreases as speed increases up to 90 m/min, which could be attributed to good cooling and lubrication provided by distilled water at the tool-chip contact. When cutting speed is increased over 90 m/min, cutting force can reach 200 m/min. The increase in cutting force is attributable to the workpiece's work hardening characteristics. Furthermore, the use of distilled water alone is insufficient to provide appropriate lubrication, hence an increase in cutting power is observed as cutting speed exceeds 90 m/min.

As illustrated in Fig. 2, increasing cutting speed raises tool-tip temperature. During machining, friction between the worn-out tool face and the chip's rear surface generates heat, raising tool-tip temperature. Excessive rubbing at the tool flank face raises cutting speed, which raises tool flank wear. This raises the temperature of the tool's tip. Another aspect influencing heat generation is the tool's and workpiece's limited thermal conductivity. These factors are to blame for an increase in tool-tip temperature during machining Inconel 825 with the MQL method and DI water.

The optical micrograph of tool flank wear at different cutting speeds under MQL machining conditions is shown in Fig. 3. The rubbing of the final workpiece on the tool's flank face creates flank wear. The flank wear appears to be more noticeable at the fastest cutting speed, 200 m/min. The flank wear is lower in the cutting speed range of 90 m/min to 155 m/min than in lower and higher cutting speeds (40 m/min and 200 m/min). While machining Inconel 825 under MQL conditions with distilled water, this cutting speed range may be the most effective for minimizing flank wear. When machining Inconel 825 in dry conditions, the flank surface wear is more noticeable, and significant flank wear is observed at higher cutting speeds under dry conditions, which is related to the creation of tremendous heat in the tool-workpiece contact region.

Conclusions

- A higher cutting power is necessary at the first cutting speed to cause material shearing from the workpiece. Cutting force lowers as cutting speed (90 m/min) increases due to excellent cooling and lubrication provided by distilled water at the tool-chip contact. The cutting force was enhanced due to the work hardening capabilities of Inconel 825 as the cutting speed was increased beyond 90 m/min. Furthermore, the use of distilled water alone is shown to be insufficient in providing appropriate lubrication, resulting in an increase in cutting force as cutting speed exceeds 90 m/min.
- An increase in cutting speed resulted in an increase in tool-tip temperature, which was caused by friction between the worn-out tool face and the chip's rear surface. Furthermore, the increase in tool-tip temperature with cutting speed is caused by the tool's and workpiece's limited heat conductivity.
- An optical micrograph of the tool's flank surface revealed increased flank wear at a cutting speed of 200 m/min. The best cutting speed range for machining Inconel 825 using distilled water-based MQL is between 90 and 155 m/min.

References

B. Boswell, M.N. Islam, I.J. Davies, Y.R. Ginting and A.K. Ong, A review identifying the effectiveness of minimum quantity lubrication (MQL) during conventional machining. The International Journal of Advanced Manufacturing Technology, 92(1-4) (2017) 321-340.

A. Attanasio, M. Gelfi, C. Giardini and C. Remino, Minimal quantity lubrication in turning: Effect on tool wear. Wear, 260(3) (2006) 333-338.

M.H. Sadeghi, M.J. Haddad, T. Tawakoli and M. Emami, Minimal quantity lubrication-MQL in grinding of Ti–6Al–4V titanium alloy. The International Journal of Advanced Manufacturing Technology, 44(5) (2009) 487-500.

D.G. Thakur, B. Ramamoorthy and L. Vijayaraghavan, Investigation and optimization of lubrication parameters in high speed turning of superalloy Inconel 718. The International Journal of Advanced Manufacturing Technology, 50(5-8) (2010) 471-478.

M. Hadad and B. Sadeghi, Minimum quantity lubrication-MQL turning of AISI 4140 steel alloy. Journal of Cleaner Production, 54 (2013) 332-343.

D.V. Lohar and C.R. Nanavaty, Performance evaluation of minimum quantity lubrication (MQL) Using CBN tool during hard turning of AISI 4340 and its comparison with dry and wet turning. Bonfring International Journal of Industrial Engineering and Management Science, 3(3) (2013) 102-106.

X. Ji, B. Li, X. Zhang and S.Y. Liang, The effects of minimum quantity lubrication (MQL) on machining force, temperature, and residual stress. International Journal of Precision Engineering and Manufacturing, 15(11) (2014) 2443-2451.