Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 13 (2017) 89–93

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

Manufacturing Engineering Society International Conference 2017, MESIC 2017, 28-30 June 2017, Vigo (Pontevedra), Spain

Internal cryolubrication approach for Inconel 718 milling

O.Pereira*, G. Urbikain, A. Rodríguez, A. Fernández-Valdivielso, A. Calleja, I. Ayesta, L.N. López de Lacalle

University of the Basque Country, Dpt. of Mechnical Engineering, Bilbao, Bizkaia, Spain

Abstract

Due to their extremely performant capabilities, super-alloys are gratefully acknowledged by mechanical designers to satisfy the requisites from the combustion chambers and other hot parts from the aircraft turbine. However, the high mechanical resistance and high chemical reactivity of heat resistant super-alloys (HRSA) lead to very aggressive machining operations where the tool life must be conveniently protected with cutting fluids. The novelty in this work lies in the idea of applying cryogenic cooling with MQL lubrication (CryoMQL) with CO2 as internal coolant to favor the integration of more environmental friendly machining systems. To prove the benefits from the novel technique, CryoMQL was compared with other lubri-coolant technologies. In this context, contour milling tests were carried out in Inconel 718.

Peer-review under responsibility of the scientific committee of the Manufacturing Engineering Society International Conference 2017.

Keywords: Cryogenic machining; Inconel 718; CryoMQL; CO_2 coolant.

1. Introduction

The use of heat-resistant alloys in aeronautical turbomachinery industry is growing worldwide. Improving machining processes in this type of alloys is a challenge which has to be faced due to both economic and environmental reasons. On one hand, cutting fluids in difficult-to-cut alloys supposes between 20-30% of manufacturing costs [1]. On the other hand, although some of fluids are recovered, 30% is lost due to system leaks, evaporation or dirty [2].

* Corresponding author. Tel.: +34-601-3932.
E-mail address: octaviomanuel.pereira@ehu.eus

2351-9789
Peer-review under responsibility of the scientific committee of the Manufacturing Engineering Society International Conference 2017.
10.1016/j.promfg.2017.09.013

Hence, it is needed to explore new lubri-cooling techniques and strategies. Within this context, minimum quantity lubrication (MQL) and cryogenic technologies are positioned as key alternatives for improving both technical and environmental pollution produced by machining processes. MQL lubrication consists in spraying biodegradable micro-oil particles in the cutting zone with an oil flow-rate between 10-100 ml/h. This reduces the environmental and economic impact associated to machining processes. On the other hand, in cryogenic machining, liquid nitrogen (LN2) or carbon dioxide (CO2) is used as cutting fluid. Among other advantages, it does not generate any waste being completely harmless to workers' health. Furthermore, in the case of CO2, it is obtained from a primary process, that is, it is used a second time instead of being directly exhausted to the atmosphere as waste. Thereby, environmental innocuousness associated to conventional cryogenic machining is maintained.

Inconel 718 is the most heat-resistant alloy used in turbomachinery critical components. Properties such as good tensile strength, fatigue or creep resistance combined with a high corrosion resistance at high temperature makes it the best choice. However, these properties during machining processes lead to high cutting forces, low material removal rates, adhesion, welding and other problems that cause premature tool breakage. Furthermore, surface integrity shall be damaged by both thermal and mechanical effects [3]. Therefore, during machining there is a dual need of lubricating and cooling the cutting zone. From the literature, predominant wear effects are produced by chipping, adhesive, abrasive or diffusion wear [4-8]. So, the combination of cryogenic technology with MQL lubrication could be an advantageous alternative. This combination, also known as CryoMQL, was explored and studied in several researches either for roughing operations or in finishing operations, to enhance surface integrity in comparison with other lubri-cooling technologies [9-11]. However, CryoMQL applied to contour milling using end mills with internal channels was not tested. This is a common operation in the manufacturing of turbine cases and so, tooling costs (end mills and fluids) could be significantly reduced. In this case, MQL is injected in the cutting zone externally and CO2 is injected through the tool. Thus, the tool works as a heat exchanger and the material is not hardened by CO2 resulting in relatively lower and stable shear stress during the machining.

Under this perspective, in order to prove the benefits from the novel technique, CryoMQL with internal CO2 setup was compared against conventional CryoMQL with external CO2 for milling Inconel 718 between other techniques as wet machining or MQL lubrication. The experimental procedure included the recording of cutting forces and wear measurements at different tool life stages to choose the best performance.

2. Experimental setup

Experimental tests were performed in a Kondia A6 three axis-machining center under wet machining, MQL lubrication and CryoMQL machining. The oil emulsion flow-rate was 7 l/min. The oil flow-rate used during MQL and CryoMQL machining was 100 ml/h. In the case of CryoMQL machining, CO2 was injected with 14 bars and -78ºC. Besides, when it was needed, CO2 was injected through the internal tool channels, as shown in Fig. 1.

Fig. 1. CO2 injected as external and internal coolant.