

# Effect of machining environment on surface topography of 6082 T6 aluminium

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## Abstract

Environmental and health issues associated with the use of conventional cutting fluids in machining operations is an ever growing concern among industries, workers, environment activists and governments. The aim of this paper is to explore the effects of alternative environmentally friendly approaches on the machinability of 6082 T6 aluminium alloy as compared to traditional flood machining. The experimental studies indicated that the best surface roughness (Ra) can be produced by dry machining followed by flood. However, microscopic analysis of the surfaces revealed that the surfaces produced in dry and flood conditions suffer from micro defects such as ductile deformation, smearing and chip redeposition, which have been eliminated through using cryogenic cooling techniques.

## 1. Introduction

Recent studies have shown a strong relation between exposure to cutting fluids and some occupational diseases such as respiratory disease, dermatitis and a range of cancers including skin, bladder and colon [1]. These, together with environmental issues with regard to maintenance and disposal of cutting fluids have accelerated the need to find alternative techniques for machining operations [1].

Using liquefied gases such as liquid nitrogen, also known as cryogenic machining, is an alternative technique compared to traditional flood cooling [2]. In machining 6061-T6 aluminium alloy, Dhananchezian *et al.* [3] reported that cryogenic temperatures reduce the stickiness of the workpiece material and results in improved machinability. In addition, they declared that cryogenic cooling helps reduce the cutting temperature, however it adversely increases the workpiece material's hardness resulting in higher cutting forces. Biermann and Heilmann [4] reported that using liquid carbon dioxide as cooling media has significantly reduced the burr formation in

CNC milling of 6068 aluminium alloy. This is attributed to the reduction in workpiece material ductility as a result of low temperatures.

This paper presents exploratory research on the effects of cryogenic cooling on surface topography of 6082 T6 aluminium alloy in end milling operations. A total of 9 machining experiments have been conducted at three different machining environments, namely dry, flood and cryogenic. The surface of the machined samples has been scanned and the surface roughness of the samples has been measured.

## 2. Methodology

The focus of this study is on end milling of 6082 T6 aluminium alloy using a 2-flute solid carbide cutter. For this study, three parameters of cutting speed, chip load and machining environment have been selected as input parameters. Axial and radial depth of cut have been kept constant at 1mm and 6mm respectively for all experiments. In order to compare the effect of machining environment on surface finish of aluminium, a hybrid design of experiment (DoE) was developed. In this DoE, each machining environment has been tested at three different combinations of cutting speed and feed rate. The developed DoE is shown in table 1.

Table 1: DoE indicating the input parameters used for the machining experiments

Experiment ID	Machining environment	Cutting speed (m/min)	Chip load (mm/tooth)	
D	1	Dry	300	0.04
	2	Dry	180	0.085
	3	Dry	60	0.13
F	1	Flood	300	0.04
	2	Flood	180	0.085
	3	Flood	60	0.13
C	1	Cryogenic	300	0.04
	2	Cryogenic	180	0.085
	3	Cryogenic	60	0.13

## 3. Results and discussion

Following the DoE, 9 machining experiments were conducted and the machined surfaces were scanned using a Proscan 2000 optical surface profiler. The measurement results for average surface roughness (Ra) and linear profiles of the surfaces are shown in figure 1. Analysis of mean and signal to noise ratio revealed that on average the lowest Ra is produced by dry machining whilst cryogenic cooling

has resulted in the highest Ra. The lowest Ra ( $0.930\mu\text{m}$ ) among all experiments was from experiment D2, followed closely by experiment C1 ( $0.984\mu\text{m}$ ).

Comparing the surface roughness profiles, it can be observed that the most repeatable profile is associated with the samples produced by cryogenic cooling. This is mainly due to the fact that aluminium becomes brittle at cryogenic temperatures and no ductile plastic deformation is produced. This can be particularly seen in experiments D1, F1 and C1 where significant plastic deformation is generated in dry and flood machining whilst the surface profile of experiment C1 is the most uniform. This has been reflected in the normalised peak count (ISO Nr) and peak count over the assessment length (ISO D) values of the surfaces. The average ISO Nr for cryogenic machining was 122.38 whilst it was 150.38 and 136.56 for dry and flood machining respectively. Similarly, the lowest ISO D has been measured to be 38 for cryogenic cooling which is significantly lower than that of dry (47) and flood (43) environments. In addition, microscopic images of the surfaces (figure 2) indicated that cryogenic cooling, particularly in experiments C1 and C2, has significantly reduced ductile deformation and smearing. From a micro topological point of view, the worst surfaces belongs to dry machining where the generated heat at the cutting zone has softened the workpiece material resulting in ductile deformation and chip redeposition on the machined surface.

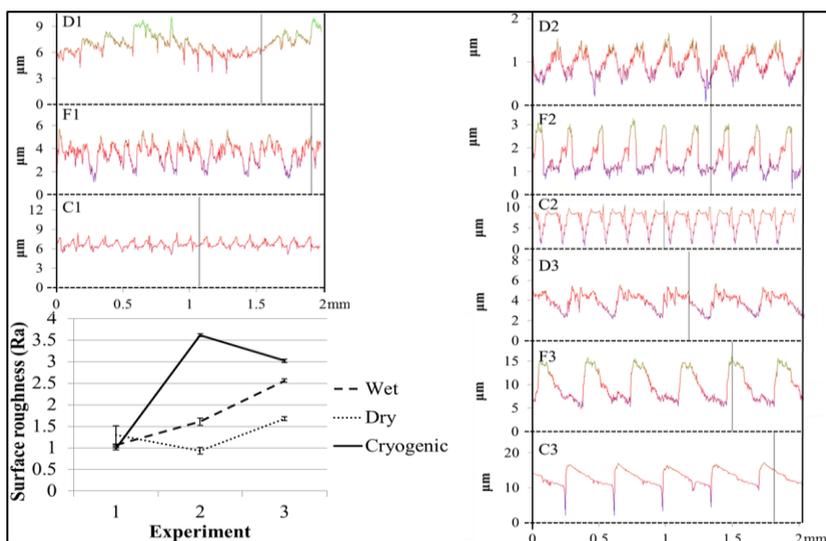


Figure 1: Surface roughness and linear profiles of machined surfaces

#### 4. Conclusions

Machining experiments under three different machining environments at different combinations of cutting parameters showed that the lowest Ra can be achieved by dry machining. However, where the micro topography of the surface is of interest, cryogenic cooling produces the most reliable surface as no or very limited surface defects pertaining to ductile deformation, smearing and chip redeposition have been observed. In addition, from surface roughness profiles and microscopic images, it can be inferred that as no or limited ductile deformation exist on the surfaces produced by cryogenic machining, modification of the cutting tool geometry can significantly improve the surface finish.

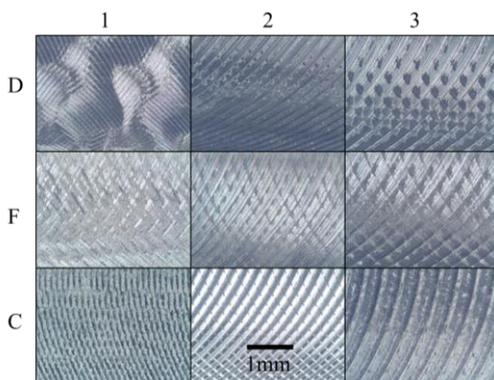


Figure 2: microscopic images of machined surfaces

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