

Effect of Machining Parameters and Cutting Edge Geometry on Surface Integrity when Drilling and Hole Making in Inconel 718

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ABSTRACT

Superalloys such as Inconel 718 have high strength at elevated temperatures, which make them attractive towards various applications in aerospace industry. However, these materials are considered difficult to machine materials. The state of a workpiece surface after machining is definitely affected by cutting parameters, such as cutting speed, feed rates, drill types and drill geometries. Drilling tests, at different spindle-speed, feed rates, drills and point angles of drill, were conducted in order to investigate the effect of the above parameters on the quality of machined holes and surface integrity of Inconel 718. The quality of machined holes was evaluated in terms of the geometrical accuracy and burr formation. Surface integrity involved the aspect of surface roughness, metallurgical alterations and microhardness of the substrate of the hole surface. High hole quality was observed even at holes produced using worn tools, in relation to dimensions, surface roughness and burr height. However, microhardness measurements and microstructural analysis of work-piece showed significant microstructural changes related with a loss of mechanical properties. In general the cutting parameters have significant effects on the surface quality and surface integrity when drilling Inconel 718 using uncoated carbide drill.

INTRODUCTION

Nickel-based alloys account for 80% of the superalloy usage within the aerospace industry, with the remainder being iron and cobalt based. Approximately 45–50% of the total material requirements for a gas turbine engine are met using nickel alloys [1]. Other areas of application are within space exploration (main space shuttle engine, nickel–hydrogen batteries (international space station)), power generation (industrial gas turbines), chemical industry (cryogenic tanks), etc. [1–3]. The properties that make nickel-based superalloys attractive to industry are: high yield strength (retained to approximately 750° C), high ultimate tensile strength, high fatigue strength, retention of corrosion and oxidation resistance up to elevated temperatures and good creep resistance [1,4,5].

Numerous publications have shown that nickel based superalloys are difficult to machine regardless of the process being used [6-11]. The properties that make Inconel 718 an important engineering material are also responsible for its generally poor machinability. Low thermal conductivity (11.4 W/mK) leads to high cutting temperature being developed in the cutting zone. In turning, temperatures of around 900°C have been reported at the relatively low cutting speed of 30 m/min with over 1300°C found at 300 m/min [12]. In addition, temperature gradients in the tool are much steeper than for steels with the maximum temperature being generated in the tool nose region [13]. The materials ability to retain its mechanical properties at elevated temperature results in high cutting forces being

generated, around double that found when cutting medium carbon alloy steels. This in combination with the relatively short chip tool contact length means that stress is concentrated on the area of maximum tool temperature leading to chipping and/or plastic deformation of the cutting edge [10, 13]. Nickel based superalloys have a high chemical affinity for many tool materials and as such form an adhering layer leading to diffusion and attrition wear[14]. They are also highly sensitive to strain rate and rapidly work harden causing abrasive wear, particularly at the depth of cut and leading edge positions. The presence of hard phases in the microstructure, such as carbides, nitrides, oxides, etc, further exacerbates tool abrasion.

In contrast to other machining processes drilling has received relatively little attention and most literature available for nickel base superalloys are related only to tool wear and productivity [15]. Since, drilling is one of the most important processes in aerospace manufacture and being the last operation performed, particular emphasis on the reliability of the process due to the costs already entailed. In addition a hole amplifies the stress around it by a factor of two, placing considerable restraints on dimensional tolerance and hole quality. This work is focused on the evolution of the machined hole quality and surface integrity of Inconel 718 when drilling used carbide tool.

EXPERIMENTAL SETUP

The response variables include:

- Surface integrity which include surface roughness, microhardness changes and microstructure of drilled surface.
- geometrical accuracy
- burr height

Inconel 718 plate of 18 mm thick and uncoated of solid carbide (WC/Co) twist drill was used in the drilling experiments on a MAHO MH 700S CNC machining center. The machining parameters were selected on the basis of the information available in the literature. The value of independent variables runs are shown in Table.1.

Table.1. Experimental planning at all levels

Experiment No.	Cutting Speed (m/min)	Feed rate (mm/rev)	Point Angle (°)
1	13	0.12	125
2	8	0.1	130
3	8	0.1	120
4	18	0.05	130

Tool wear was measured with a toolmaker microscope fitted with a digital camera and image analysis software. When flank wear reached $VB = 0.25\text{mm}$ or $VB_{\max} = 0.5\text{mm}$ the drilling trials were stopped. Number of holes created in each run is shown in Table 2. In evaluating the roughness of the drilled hole a Handysurf model E-35A was used. Two surface roughness readings were taken at four positions spaced at 90 deg intervals around the hole circumference and approximately mid-way down the depth of the hole. The hole diameter was measured at 6 points located at different height and orientation using of CMM- KN810 Mitutoyo. The first and last hole of each run was separated from the main plate by electro-discharge wire cut, AQ537L Sodick. To measure the burr height separated sample was located under an optical microscope and the burr was focused and captured digitally. The height of burr was analyzed using an image analyser. In order to investigate the microstructure of machined surface and sub-surface sample specimens were prepared using standard metallography techniques. Subsurface microstructural analysis was conducted with 'Olympus toolmakers' light optical microscope which is connected to a Sony Digital hyper head color video camera. Microhardness (Vickers) was measured at five points (located at a certain distance from machined surface ranging from 40 to 480 μm) in four line positions spaced at 90 degree intervals around the hole perpendicular to the drill direction and 2mm away from the drill entrance. Measurement was conducted using SHIMADZU micro hardness tester under 4.903 N force with Vickers pyramid indenter.

Table.2. Number of holes drilled under different conditions

Experiment No.	1	2	3	4
Number of holes	10	29	24	27