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Short communication

The effect of coating material and geometry of cutting tool and cutting speed on machinability properties of Inconel 718 super alloys

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Abstract

In this study, the effects of cutting tool coating material and cutting speed on cutting forces and surface roughness are investigated. For this purpose, nickel based super alloy Inconel 718 is machined at dry cutting conditions with three different cemented carbide tools in CNC lathe. Metal removing process is carried out for five different cutting speeds (15, 30, 45, 60, 75 m/min.) while 2 mm depth of cut and 0.20 mm/rev feed rate are to be constant. Main cutting force, F_c is considered to be cutting force as a criterion. In the experiments, depending on the tool coating material, lowest main cutting force is found to be 506 N at 75 m/min with multicoated cemented carbide insert whose top layer is coated by Al_2O_3. Lowest average surface roughness (0.806 μm) is obtained at the cutting speed of 15 m/min with single coated (TiN) cemented carbide inserts.

Keywords: Machining; CVD Coated cemented carbide inserts; Cutting force; Surface roughness; Inconel 718

1. Introduction

Advanced materials, such as nickel-base and titanium alloys as well as composites are generally used at 650 °C or higher temperatures at which high stresses occur and surface balancing is necessary. These materials are widely used in the areas of industrial gas turbines, space vehicles, rocket engines, nuclear reactors, submarines, stream production places, petrochemical devices, hot tools and glass industries [1,2].

These advanced materials, called "Super Alloys", are designed for high temperature applications and at the same time maintain very high strength to weight ratios. Generally known that nickel-base super alloys are one of the most difficult materials to machine [3,4].

Surface processes carried out by using different manufacturing methods are directly or indirectly affected by machining parameters. Poor selection of machining parameters causes cutting tools to wear and break quickly as well as economical losses such as damaged work-piece and poor surface quality [5]. Cutting speed and tool geometry are the most important parameters from the point of view of the effect of machinability properties [6,7]. Inconel 718 is machined by using cemented carbide inserts at lower speeds while it is machined by using ceramic cutting tools at higher speeds [1,8]. Cutting tool geometry and chip formation have an important effect on cutting forces. Greater negative rake angle increases tool–chip contact area causing friction force between tool–chip interface and cutting forces to increase [9,10].

In this paper, Inconel 718 is machined using quadruple (top layer is TiN), triple (top layer is Al_2O_3) and single (TiN) coated cemented carbide inserts by means of chemical vapor deposition (CVD) at five different cutting speeds and at constant feed rate and depth of cut. The effects of coating (layer) number and cutting speed on cutting forces and on arithmetic average surface roughness

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(R_a) are investigated for the cutting tools having same layer.

2. Materials and method

2.1. Experiment specimens

For the experimental study, Ø50 × 500 mm test specimens of Inconel 718 having special usage in industry (0.040% C, 0.08% Mn, 0.08% Si, 0.98% Ti, 0.50% Al, 0.23% Co, 3.04% Mo, 5.43% Nb + Ta, 17.80% Fe 19.00% Cr ve 52.82% Ni) are used. Mechanical properties of Inconel 718 are given in Table 1.

2.2. Cutting parameters, cutting tools and tool holder

Five different cutting speeds are chosen as 15, 30, 45, 60 and 75 m/min according to ISO 3685 and as recommended by manufacturing companies for cutting tool qualities. Feed rate of 0.20 mm/rev and cutting depth of 2 mm are used as recommended by ISO 3685.

In this study, whose purpose is to investigate the effects of coating material on main cutting force and on surface roughness taking into account the cutting speed; TiN and Al_2O_3 coated cemented carbide inserts having two different geometries are used. Technical specifications of cutting tools are given in Table 2.

SRDC N 2525 M 12 and CSRN R 2525 M12-MX7 type tool holders are used for RCMT 120400 and SCMT 120412 type cutting tools, respectively. CSRN R 2525 M12-MX7 type tool holder 75° approaching angle and SRDC N 2525 M 12 type tool holder 90° approaching angle. SCMT 120412 and RCMT 120400 cutting tools have 0° rake angle and 7° clearance angle. Full factorial design was applied in the experimental study.

Table 1
Selected mechanical properties of test specimens

Hardness (HB)	Tensile strength (MPa)	Yield strength (MPa)	Breaking extension% (5do)	Thermal conductivity (W/mK)
388	1370	1170	23.3	11.4

2.3. Machine tool and measurement of cutting forces and surface roughness

JOHNFORD T35 industrial type CNC lathe max. power of which is 10 kW and has revolution number between 50 and 3500 rev/min is used. During dry cutting process, Kistler brand 9257 B-type three-component piezoelectric dynamometer under tool holder with the appropriate load amplifier is used for measuring three orthogonal cutting forces (F_c, F_f, F_p). And data acquisition software was used. This allows direct and continuous recording and simultaneous graphical visualization of the three orthogonal cutting forces. Technical properties of the dynamometer and schematically figure of experimental setup are given in Table 3 and Fig. 1, respectively.

Surtrasonic 3-P measuring equipment is used for the measurement of surface roughness. Measurement processes are carried out with three replications. For measuring surface roughness on work-piece during machining, cut-off and sampling length are considered as 0.8 and 2.5 mm, respectively. Ambient temperature is 20 ± 1 °C.

Table 3
Technical properties of dynamometer [11]

Force interval (F_x, F_y, F_z)	−5...10 kN
Reaction	<0.01 N
Accuracy F_x, F_y	~7.5 pC/N
F_z	~3.5 pC/N
Natural frequency $f_0(x, y, z)$	3.5 kHz
Working temperature	0...70 °C
Capacitance	220 pF
Insulation resistance at 20°	>1013 Ω
Grounding insulation	>108 Ω
Weight	7.3 kg

Table 2
Properties of cutting tools

Coating material (top layer)	Coating method and layers	ISO grade of material (grade)	Geometric form	Manufacturer and code
TiN	CVD (TiN, Al_2O_3, TiCN, TiN, Wc)	P25-40, M20-30	SCMT 120412	Kennemetal KC 9225
Al_2O_3	CVD (Al_2O_3, TiC, TiCN, Wc)	P20-40, M20-35	SCMT 120412 MF	Kennemetal KC 935
TiN	CVD (TiN, Wc)	K05-20, M 10-25	RCMT 120400	SECO 560 45 F1

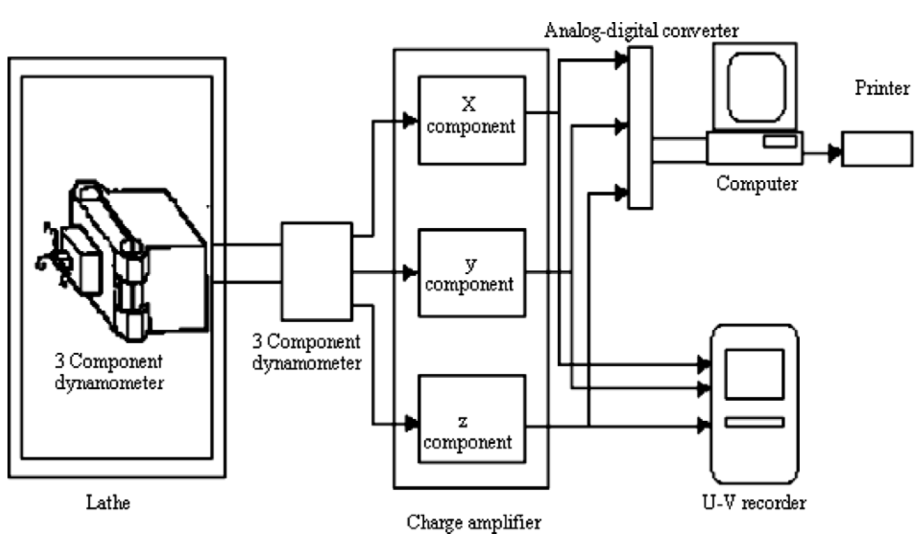

Fig. 1. Measurement of cutting forces and schematically figure of dynamometer unit.