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Identification of tool wear intensity during miniature machining of austenitic steels and titanium

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Abstract

Implementation and contribution of miniature machining is currently rapidly increasing in biomedical industry, machining of austenitic steels and titanium particularly. Machinability of materials with increased level of toughness depends on factors that are important in the final state of surface integrity. There are requirements for high precision in miniature machining with measures varying in microns. If we want to guarantee machining precision, it is necessarry to identify tool wear intensity in interaction with given materials. During long-term cutting process, different cutting wedge deformations occur, leading in most cases to a rapid wear and destruction of the cutting wedge. The article deald with experimental monitoring of tool wear intensity during miniature machining.

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Keywords: miniature machining ; titanium alloys ; tool wear

1. Introduction

Due to rapid changes in the age structure of the world's population, an increasing number of people need their failed tissues to be replaced by artificial implantable devices. Metallic materials (primarily titanium and cobalt chrome alloys) are widely used for surgical prostheses, such as joint replacements, mechanical heart valves and

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dental implants. Although conventional materials technology has resulted in clear improvements in implant performance and longevity, rejection or implant failures still happen. The increase in average life expectancy, as well as rapid advances in modern surgery require new generations of clinically relevant biomaterials, with enhanced biological and mechanical performance. Advances in titanium manufacturing technologies are expected to play an important role in the development of the next generation of medical implants.

For many decades, metallic biomaterials have been used extensively for surgical implants due to the good formability and high strength and resistance to fracture that this class of materials can provide.[16] The important disadvantage of metals, however, is their tendency to corrode in physiological conditions, and a large number of metals and alloys were found unsuitable for implantation as being too reactive in the body. Therefore, the list of metals currently used in implantable devices is limited to three main systems: iron-chromium-nickel alloys (austenitic stainless steels), cobalt- chromium-based alloys, and titanium and its alloys [14,15]. The advantages and drawbacks of metals used for implant fabrication, titan is superior to other surgical metals, due to the formation of a very stable passive layer of TiGr5 on its surface. Titan is intrinsically biocompatible and often exhibits direct bone apposition. Another favorable property of titan is the low elastic modulus (twofold lower compared to stainless steel and Co–Cr), which results in less stress shielding and associated bone resorption around titan orthopedic and dental implants. Furthermore, titanium is more light-weight than other surgical metals and produces fewer artifacts on computer tomography (CT) and magnetic resonance imaging [10-13].

Table 1 Chemical properties TiGr5 (ASTM F67)

Quality	C [%]	Fe [%]	H [%]	N [%]	O [%]	Ti[%]
Grade 5	max 10	max 40	max 1.5	max 5	max 20	up to 100
Grade 5 measuring	9	38	1.4	4.7	18	up to 100

The workpiece material used in the machining trials was a titanium alloy alpha-beta TiGr5 Extra Low Interstitial (TiGr5), which is lamella α phase and surrounded by β in the grain boundary. The chemical composition and physical properties of workpiece material are given in Table 1 and 2, respectively. At least 3 mm of material at the top surface of workpiece was removed in order to eliminate any surface defects and residual stress that can adversely affect the machining result [9].

Table 2. Factors and levels used in the experiment

Factors	Levels		
	0	1	2
A- Cutting speed (m.min-1)	50	70	90
B- Feed rate (mm.rev-1)	0.06	0.08	0.1
C- Depth of cut (mm)	1	1.25	1.5

The machining trials and high cutting speed were carried out using the SWISS TYPE CNC lathe machine. Tools and tool holders were selected based on the recommendation of the tool supplier. Chemical Vapor Deposition (CVD) inserts with designation AC610M (DCMT11T304N-SU, ISO designation) were used to turn the titanium alloy TiGr5 under dry cutting condition.

Tool Wear. The progress of flank wear land against tool life for turning TiGr5 using CVD carbide tools at cutting speed of 50, 70 and 90 $m.min^{-1}$, at various feed rate and depth of cut are shown in Fig. 1. It is clearly seen that a typical three-stages pattern of tool wear was obtained, while was similar with the pattern reported by Jawaid et al. [5] when machining titanium alloy with coated carbide tools. The wear occurred rapidly at the initial stage, gradually increased at the second stage and extremely increased at the final stage. Rapidly increased at the initial stage was due to small contact area between the cutting tool and the workpiece, which caused temperature increased at the cutting edge, and some material easily removed from the cutting tool [3,6] found that the burn mark appeared