INFLUENCE OF PREHEATING ON CHATTER AND MACHINABILITY OF TITANIUM ALLOY – Ti6Al4V

BY

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN MANUFACTURING ENGINEERING

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ABSTRACT

Numerous studies on machinability of titanium and its alloys have been conducted in the past few decades with the main objective of reducing cost of machining especially of aerospace alloys. Though classified as "difficult-to-cut" materials, titanium and its alloys are attractive materials due to their unique high strength-weight ratio, which is maintained up to elevated temperatures and their exceptional corrosion resistance. In this work, an experimental investigation of the influence of workpiece preheating using induction heating has been conducted for improvements of machinability of titanium alloy Ti-6Al-4V ASTM B348. The inserts used were uncoated cemented carbide filled into a 16 mm diameter end mill tool. The cutting speeds used in these experiments were 40, 80, 120 and 160 m/min; the depths of cut were 1 and 1.5 mm and the feed rates were 0.1 and 0.15 mm/rev. Thermo-couples were used in measuring the surface temperature of work material during machining. The experiments of end milling operation conducted on Vertical Machining Center (VMC) were designed to look into the effect of preheating on chip serration and chatter, cutting force and torque, tool wear and surface finish. A comparison of the above criteria for room temperature and preheated machining was made. The results show that preheating machining improves the machinability of titanium alloy. Increased plasticity of the work material during preheating reduces the frictional forces on the tool face and the fluctuation of cutting force and also contributes to improved damping capacity of the system. As a result preheated machining results in reduction in vibration amplitudes at resonance frequencies up to 67%. An increase in cutting force and torque mean value leads to the formation of relatively thicker chips, which in turn leads to an increase in chip-tool contact length. The hottest spot on the tool is thus shifted away from the cutting edge leading to a more favourable temperature distribution in the tool. More stable cutting, longer chip-tool contact length and favourable temperature distribution in the tool helps in reducing the dynamic stresses acting on the tool. This in turn reduces the enhances of micro and macro chipping of the tool. This leads to uniform and much lower tool wear up to three times reduction in flank wear has been achieved. Lower tools wear, helps in maintaining a sharp cutting edge at the nose section and the flank areas of the tool resulting in smoother surface roughness values during preheated machining.

ملخص البحث

في السنوات الماضية تمت كثير من الدراسات على قابلية التيتانيوم وسبائكه للتشغيل بهدف أساسي هو تخفيض تكلفة التشغيل لسبائك التيتانيوم المستخدمة في صناعة الفضاء. بالرغم من تصنيفها كمواد صعبة القطع , الا أن التيتانيوم وسبائكه كانت مواد جذابة لما لها من نسبة صلابة \ وزن عالية , وهى ميزة مستمرة حتي في درجات الحرارة العالية, وأيضاَ مقاومتها المتميزة للصدأ. في هذا البحث تم اختبار تجريبي على تأثير التسخين المبدئي علي الشغلة . تم التسخين باستخدام مسخَن حثّي لتحسين قابلية التيتانيوم Ti-6A1-4V ASTM B348 للتشغيل . أداة القطع المستخدمة كانت من الكاربايد السمنتي غير المطلى مركبة علي قاطع تفريز حدَي قطره 16 ملم . سرعات القطع المستخدمة في هذه التجارب تراوحت بين 40, 80, 120 و160 متر\الدقيقة . عمق القطع كان 0.1 و 0.15 ملم\الدورة. بينما كان مقدار التغزية 0.1 و 0.15 ملم\الدورة. تم استخدام مذدوجات حرارية لقياس درجة حرارة سطح الشغلة . التجارب على التفريز الحدَي تمت باستخدام مركز تشغيل رأسي (VMC) تم تصميمه ليمكن من النظر لأثر التسخين المبدئي على تدرَج الرائش و الأهتزاز, قوة القطع والعزم, تآكل القاطع ونعومة السطح. تمت مقارنة المعطيات السابقة في حالتي درجة حرارة الغرفة العادية و التسخين المبدئي. دلت النتائج علي أن التسخين المبدئي يحسن قابلية سبائك التيتانيوم على التشغيل. كما انه يزيد من لدونة المادة المشغولة مما يؤدى لنقص قوى الاحتكاك فى وجه اداة القطع والتذبذب فى قوة القطع كما يساهم ايضاَ فى تعزيز سعة الخمود للمنظومة. ونتيجة للتسخين المبدئي فقد انخفضت سعة الاهتزازات عند الرنين بحوالي 67%. الزيادة فى قوة القطع ومتوسط العزم ادتا لتكون رائش سميك نسبياَ, مما يؤدي بدوره لزيادة طول الاتصال بين الرائش واداة القطع. نتيجة للتسخين المبدئي تمت ازاحة اسخن نقطة باداة القطع بعيداَ عن حافة القطع مما نتج عنه توزيع جيد للحرارة فى اداة القطع. عملية قطع اكثر استقراراَ, اتصال بين الرائش والقاكع اطول, وتوزيع درجة الحرارة

بطريقة افضل على سطح اداة القطع ساعد فى تقليل الاجهادات الديناميكية المؤثرة على اداة القطع.هذا ادى بدوره لقلة محفزات تهتك اداة القطع علي المستويين الدقيق والكبير. هذا ادي لخفض وانتظام بري اداة القطع ونقص بري اداة القطع الجانبي بمعدل ثلاث مرات. قلة بري اداة القطع تساعد فى الحصول على حافة قطع حادة فى مقطع الانف والمقطع الجانبي من اداة القطع مما يؤدى لنعومة افضل للسطح عند استخدام التسخين المبدئي للشغلة.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Manufacturing Engineering.

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This dissertation was submitted to the Department of Manufacturing and Material Engineering and is accepted as partial fulfilment of the requirements for the degree of Master of Science in Manufacturing Engineering.

for Shahjahan Mridha
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DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by giving explicit references and a bibliography is appended.

Name: Kamaruddin bin Kamdani

Signature.. Date 10/5/05..

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DECLARATION OF COPYRIGHT AND AFFIRMATION OF FAIR USE OF UNPUBLISHED RESEARCH

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Affirmed by Kamaruddin Kamdani

Signature

10/5/05

Date

I dedicate this work to my beloved parent, wife and children, Maisarah and 'Aqil.

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N	Spindle speed [revolutions per minute] or [rpm]
f	feed rate [tooth/mm]
t_c	deformed chip thickness [mm]
t_u	undeformed chip thickness [mm]
t	depth of cut [mm]
v	cutting speed [m/min]
V_{chip}	Chip velocity in orthogonal cutting [m/min]
V_c	Cutting speed [m/min]
F_c	Tool cutting force (per unit width) in orthogonal cutting [N/mm]
F_t	Tool thrust force (per unit width) in orthogonal cutting [N/mm]
F_R	Resultant tool force (per unit width) in orthogonal cutting [N/mm]
F_s	Shear force on the shear plane in orthogonal cutting [N/mm]
F_{ns}	Normal force applying to the shear plane in orthogonal cutting [N/mm]
F_f	Friction force on the tool rake face in orthogonal cutting [N/mm]
F_n	Normal force on the tool rake face in orthogonal cutting [N/mm]
α	Rake angle [deg]
ϕ	Tool rotation angle[deg]
β	Friction angle in orthogonal cutting [deg]
τ_s	Shear stress on the shear plane [Mpa]
Ks	Shear stress [Mpa]
As	Area of cross section of the shear plane [mm^2]
Δh	Average amplitude of the serrated teeth (distance from top of saw teeth peak to bottom of serration)

h	Average maximum thickness of the chip (distance from the top saw tooth to flat area of the chip)
VMC	Vertical machining center
DAQ	Data acquisition card
DOC	Depth of cut [mm]
FFT	Fast Fourier Transform
VB	Flank wear
KT	Crater wear
VN	Notch at the depth of cut
cph	Closed-packed hexagonal
bcc	Body-centered cubic
PCD	Polycrystalline diamond
HSS	High speed steels
Ra	Average surface roughness

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