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RESEARCH ARTICLE

INVESTIGATION OF CHIP MORPHOLOGY AND TOOL WEAR IN PRECISION TURNING PROCESS

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ABSTRACT

The objective of the work is to perform precision turning using conventional lathe on Ti6Al4V under dry working conditions. Various parameters that affect the machining process were identified and a consensus was reached regarding its values. The proposed project is to perform machining under these conditions and parameters and to compare the chip morphology and tool. This thesis work aims to optimize the machining performance in precision turning operations. In finishing operations, Tool wear and Chip Morphology are major concerns. Hence, to quantify the machining performance in precision turning operations, two criteria are used in this thesis; Chip breakability and Tool Wear. Chip breakability takes care of chip shape and size, and chip side flow. By finding optimal depth of cut and feed in each segment through the profile, the machining performance in precision turning can be improved

INTRODUCTION

Manufacturing industries all over the world are focusing more on achieving higher quality and reliability for existing products and introducing new products into the market. One of the major initiatives associated with this trend is the development of precision manufacturing systems. The issues associated with the scaling down of a macro scale manufacturing system to precision levels are assessed. A brief overview of the developments in precision machining, in terms of the manufacturing processes, equipment and the techniques used, is given in this report. The operational requirements and issues faced in the scaling down of conventional manufacturing systems into micro, meso and nano levels are discussed. [1]Some specific issues associated with non-orthogonal single point diamond facing of Ti-6AL-4V are addressed in detail. The machining parameters ranged from micro levels to meso and nano levels. The cutting energy associated with the process is analyzed to compare the cutting mechanism at different scales. At small depths of cut, the edge preparation of the tool significantly affected the cutting process. Non cutting plastic work on the material including plowing and flank face rubbing had more impact on the unit energy than the cutting process at lower depths of cut. Manufacturing systems have advanced to higher levels of precision to cater to the growing needs of the ‘soft manufacturing’ sectors dominated by the electronics, computer and biomedical industries. One of the main features of this development is the scaling down of the operational characteristics of manufacturing from macro levels to micro, meso and nano levels. The chapter looks at some of the developments that have occurred in the precision manufacturing sector.

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A deeper look into the characteristics of manufacturing at a scaled down level is attempted. Manufacturing dominates world trade. It is the main wealth creating activity of all industrialized nations and many developing nations. A manufacturing industry based on advanced technologies with the capability of competing in world markets can ensure a higher standard of living for an industrial nation [2].

Two current issues faced by manufacturing industry all over the world are increasing global competition and increasing demands from the soft manufacturing sectors. Lean manufacturing techniques and automation are used to deal with the former whereas precision manufacturing is the answer for the latter. These developments aim to improve the quality of existing products and introduce new products into markets, which will help the manufacturing industry to cater well to growing industries such as electronics, computer, biomedical and optical sectors. The soft manufacturing sectors aim to achieve greater miniaturization and packing densities for the components. For the electronics and computer industries smaller sizes implies less time for information transfer and higher input/output rates. [3]These urge manufacturers to focus on the scaling down of manufacturing processes to achieve the required miniaturization. The manufacturing processes thus scaled down fall under the general category of precision manufacturing. This takes a look at some of the issues in the manufacturing system from a macro level to micro, meso and nano levels. The relevance of precision machining in the current manufacturing scenario is explained. Some of the important aspects associated with precision machining are described in detail. The difference in characteristics and capabilities between the existing 2D fabrication processes and the 3D precision machining systems is explained. The history of precision machining is reviewed by detailing the development of machining processes and its equipment. They also explains the characteristics of the 3D precision machining systems by looking at the scaling down issues associated with the different operational characteristics of a machining system like machine tool, tooling/production engineering, material removal process, product design and assembly/material handling. The need for precision machining exists in areas other than electronics. The attempts to define precision machining can be traced back to the 1970s [4]. Some of the definitions that closely capture the nature of the machining processes covered by the precision regime are given below. Precision machining is "the process by which the highest possible dimensional accuracy is achieved at a given point in time" according to the definition given by Taniguchi (5). The machine accuracy capabilities Taniguchi predicted along with the processes or tools used to achieve it. The target material used for the experimentation is Ti-6Al-4V. The high toughness to mass ratio of titanium alloys and excellent resistance to corrosion has made this titanium alloy a very suitable component in the industry [6]. Gedee Weiler MLZ 250V variable speed adjusting capstan lathe is used for the experiment. PVD coated carbide tool with 98 HRC hardness, nose radius of 0.1 0.2 and 0.4 are used for the turning operation. Surface roughness was measured using mitutotyo surftest SJ-301 portable surface roughness tester with a sampling length of 4 mm. The cutting temperature is measured using a thermocouple. The cutting parameters were so selected after comparison with different literature surveyed. The design of experiments and analysis of variance was done using Minitab 15 software.

During conventional machining with a single point tool, the rake angle will be positive or close to 0o. With positive rake angle, the cutting force will generally be of a higher order of magnitude than the thrust force and therefore the deformation ahead of the tool will be in a concentrated shear plane. In precision machining of brittle materials at depths of cut smaller than the tool edge radius, the tool presents a large negative rake angle and the radius of the tool edge acts as an indenter. This is similar to a situation where the tool is rigidly supported and cuts the workpiece under a stress such that no median vents are generated, but the material below the tool is plastically deformed due to large hydrostatic pressure. Due to this, a large nose radius is theoretically desirable, but the waviness control of the large nose radius is very expensive Fang [7]. A negative degree rake angle tool with a large nose radius will have an effective negative rake angle that could be much higher, creating excessive pressure that could damage the surface.

In precision cutting of easily machinable materials such as copper and aluminum, continuous and stable chip, analogous to that in conventional cutting, can be observed. This occurs when material is removed under depths of cut at values of a few nanometers using a sharp diamond cutting edge. During micro cutting, narrow zones of shear originate at the location of the tool tip and evenly separate the chip into segments or lamella. The chip exhibits a lamellar shear structure in the shear zone. The thickness of these lamellae varies directly with the local chip thickness or depth of cut. The chips produced at low cutting speeds are similar in structure to those created at higher speeds. However, the lamella spacing will depend on crystallographic orientation.

Design of experiments and observations

Design of Experiments is a highly efficient and effective method of optimizing process parameters, where multiple parameters are involved. The design of experiments using Taguchi approach was adopted to reduce the number of trials. The time and cost for doing an experiment is very high, therefore it is necessary to select an orthogonal array with minimum number of trials. In this research work L27 orthogonal array is chosen which is a multilevel experiment Feed, depth of cut, cutting speed, nose radius are the. Feed four factors considered for the experiment.

Table 1. Chemical composition of titanium alloy

Alloy	Al	V	Fe	C	Ti
Ti-6Al-4V	6.40%	3.89%	0.16%	0.002%	Balance

These treatments Ti-6al-4v is an example of β alloys. Alpha + Beta alloys contain compositions which support a mixture of α and β phases. These alloys may contain from 10 to 50 % of β phase at room temperature.

Table 2. Mechanical Properties of Ti-6Al-4V

Hardness (HRA)	Hardness (HRA)	Hardness (HRA)	Hardness (HRA)	Hardness (HRA)	Hardness (HRA)	Hardness (HRA)
70	363	950Mpa	14%	0.342	113Gpa	4.43g/cm3

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Table 3. Typical physical properties for Ti6Al4V

Density g/cm3 (lb/ cu in)	4.42 (0.159)
Melting Range °C±15°C (°F)	1649 (3000)
Specific Heat J/kg.°C (BTU/lb/°F)	560 (0.134)
Volume Electrical Resistivity ohm.cm (ohm.in)	170 (67)
Thermal Conductivity W/m.K (BTU/ft.h.°F)	7.2 (67)
Mean Co Efficient of Thermal Expansion 0-100°C /°C (0-212°F /°F)	8.6x10-6 (4.8)
Mean Co-Efficient of Thermal Expansion 0-300°C /°C (0-572°F /°F)	9.2x10-6 (5.1)
Beta Transus °C±15°C (°F)	999 (1830)

Ti-6Al-4V is considered to be the most common α+β alloy. Heat treatment can be used to control the properties of these alloys; it is used to adjust the amounts and types of β phase present. Alpha+Beta alloys generally have good formability; except for Ti-6Al-4V in particular has poor formability (Table 3).

Table 4. Tool specifications of CCGT09T301F Coated carbide insert

Composition	80% Al2O3 and 20% TiC
Grain Size	3.0 µm
Transverse Rupture Strength	551-786 MPa
Average density	3.90-3.99 g/cm3
Youngs Modulus	641 GPa
Hardness	91-94 HRA
Coefficient of Thermal expansion	Good

The cost of machining a Ti6Al4V sample is very high and a highly time consuming process. For a 4 factor 3 level experiment more than 80 experiment have to be carried out leading to a very huge expenditure and waste of time. Taguchi [8] designed certain standard orthogonal arrays by which the simultaneous and independent evaluation of two or more parameters for their ability to affect the variability of a particular product or process characteristics can be done in a minimum number of tests. Taguchi's method of experimental design provides a simple, efficient, and systematic approach for the optimization of experimental designs for performance quality and cost. Table 1 shows the machining parameter and their levels. Table 6 shows the machining parameters and observation for each trail of experiment.

Table 5. Machining parameters and trail level

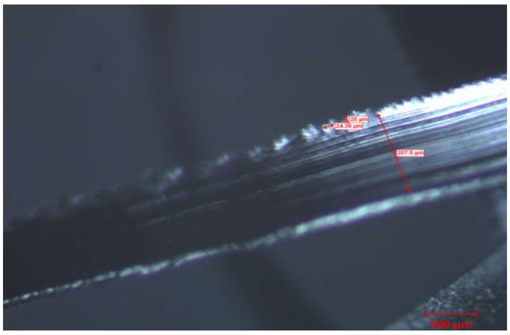
Cutting parameter	Level 1	Level 2	Level 3
Feed (mm/rev)	0.02	0.04	0.06
Depth of cut (mm)	0.05	0.10	0.15
Cutting speed (m/min)	30	60	90
Nose radius (mm)	0.1	0.2	0.4

Table 6. Experimental observations

S. No.	Feed	Depth Of Cut	Cutting Speed	Nose Radius	Saw Tooth		Chip Width
	mm/ rev	mm	mm/ min	mm	width mm	height mm	mm
1	0.02	0.05	30	0.1	0.012	0.013	0.149
2	0.02	0.05	60	0.2	0.031	0.023	0.170
3	0.02	0.05	90	0.4	0.021	0.035	0.201
4	0.02	0.1	30	0.2	0.032	0.025	0.203
5	0.02	0.1	60	0.4	0.015	0.021	0.272
6	0.02	0.1	90	0.1	0.023	0 .020	0.186
7	0.02	0.15	30	0.4	0.013	0.014	0.145
8	0.02	0.15	60	0.1	0.027	0.017	0.267
9	0.02	0.15	90	0.2	0.024	0.025	0.207
10	0.04	0.05	30	0.1	0.007	0.011	0.087
11	0.04	0.05	60	0.2	0.016	0.023	0.161
12	0.04	0.05	90	0.4	0.021	0.024	0.220
13	0.04	0.1	30	0.2	0.026	0.017	0.223
14	0.04	0.1	60	0.4	0.026	0.037	0.269
15	0.04	0.1	90	0.1	0.024	0.009	0.068
16	0.04	0.15	30	0.4	0.047	0.060	0.276
17	0.04	0.15	60	0.1	0.023	0.025	0.236
18	0.04	0.15	90	0.2	0.033	0.026	0.134
19	0.06	0.05	30	0.1	0.027	0.021	0.089
20	0.06	0.05	60	0.2	0.026	0.025	0.190
21	0.06	0.05	90	0.4	0.015	0.023	0.177
22	0.06	0.1	30	0.2	0.021	0.017	0.240
23	0.06	0.1	60	0.4	0.020	0.024	0.238
24	0.06	0.1	90	0.1	0.013	0.018	0.147
25	0.06	0.15	30	0.4	0.076	0.039	0.282
26	0.06	0.15	60	0.1	0.017	0.012	0.165
27	0.06	0.15	90	0.2	0.025	0.021	0.049

RESULTS AND DISCUSSION

In addition, the highly non linear thermo mechanical behaviors of a work material are heavily coupled during precision machining. Even if these two issues had been resolved, the exact wear mechanisms would not have been identified and described quantitatively. During machining, the cutting tool directly interacts with a work material. Chip is generated by shearing the work material while the generated heat from plastic deformation of the work material and the interfacial friction between work material and cutting tool transfers into a cutting tool. The temperature in both work material and cutting tool increases substantially as the cutting condition becomes more severe. This is the motivation for this paper so that the fundamental mechanisms of tool wear can be revealed to the researchers in this field. The readers should be cautioned that this paper will claim neither to be a complete review paper on this topic nor to represent a complete understanding of the tool wear. The purpose of this paper is to cite the literatures that have delineated the physics behind the tool wear to provide the fundamental tool wear mechanisms in machining.



F 0.02 DC 0.15 CS 90

F 0.04 DC 0.1 CS 30

F 0.04 DC 0.05 CS 60

F 0.04 DC 0.15 CS 90

Tool wear is of foremost importance in metal cutting. Owing to its direct impact on the surface quality and precision machining economics, tool wear is commonly used to evaluate the performance of a cutting tool. Many research studies to understand and predict tool wear have been carried out. However, most of these studies are considered to be an empirical approach to tool wear. Consequently, many fundamental issues have not been resolved mainly due to the complex physics behind tool wear. Fig 2

Fig 2 Experimentation setup

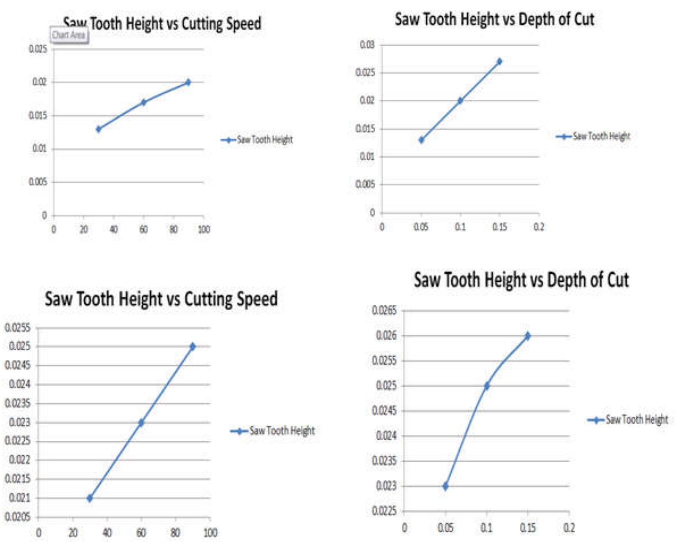


Fig 2. Saw tooth height and cutting speed Saw tooth height and Depth of cut

The complexity surrounding tool wear stems from many factors including work material, machine tool, cutting tool, coolants and cutting conditions. Because of the coupled effects of these factors, the tool chip and tool work interfaces have almost unidentifiable contact conditions with highly localized interfacial temperatures and tractions.

CONCLUSIONS

In this study effect of tool wear and chip morphology on the cutting conditions was examined in the machining of Titanium alloy. The work is of interest because of its relevance to increasing hard machining implementation as a quicker, cleaner and practical alternative to finish grinding. Cutting condition was quantified to measure the effect of Chip Morphology and Tool wear. The following conclusions can be drawn based on this study.

- Saw Tooth Height increases with an increase in Depth of Cut and Cutting Speed at constant Feed and Nose Radius.
- Tool Wear increases with an increase in Depth of Cut and Cutting Speed at constant Feed and Nose Radius.
- No monotonic relation can be established between the Machining Parameter and Chip Width.

REFERENCES

[1] Corbett, J., McKeown, P. A., Peggs, G.N., Whatmore, R., (2000) "Nanotechnology: International Developments and Emerging Products," Annals of the CIRP, Vol. 49, n 2, pp. 523-544

[2] Taniguchi, N. (1983) Current status in and future trends of precision machining and ultrafine Material processing, Ann CIRP, 32(2),1-8

[3] McKeown, P.A., 1986, High Precision Manufacturing and The British Economy, James Clayton Lecture, Inst. Mech. E. Roc., Vol. 200, No. 76.

[4] Thomas, T.R., Rough Surfaces, 2nd ed., Imperial College Press, London (1999).

[5] Thomas, T.R., "Trends in surface roughness", International Journal of Machine Tools and Manufacture, 38, Issues 5-6, pp 405-411 (1998).

[6] E. M. Trent, and P. K. Wright, Metal Cutting, third ed. Butterworth Heinemann, Boston, 2000, USA.

[7]. A. R. Machado, and J. Wall bank, 'Machining of titanium and its alloys: a review Proceedings' of the Institution of Mechanical Engineers Part B, Journal of engineering manufacture, 204:11, 2005, pp 53-60.

[8] S. Vajpayee, Analytical study of surface roughness in turning, Wear 70(1981) 165-175

[9] M.A. EI Baradie, surface roughness model for turning grey cast iron, J, Eng. Manuf. 207 (1993) 43-54.

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