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RESEARCH ARTICLE

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EXPERIMENTAL ESTIMATION OF PROCESS PARAMETERS UNDER DRY TURNING OF AISI-4340 WITH CVD-CARBIDE INSERT

AKASH SAINI
Assistant Professor, Lovely Professional University, Jalandhar

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ABSTRACT

An experimental study has been performed on AISI 4340 steel in this paper. The influence of approach angle, feed rate, cutting speed and depth of cut has been on cutting force and tool tip temperature has been experimentally investigated. Before conducting experiments on the AISI 4340 steel work-piece, the chemical composition test, microstructure test were performed and hardness of the work-piece was improved by heat treatment. A total of 64 experiments by CVD-coated insert were conducted on AISI-4340 steel under dry environmental conditions. During the experiments, approach angle, cutting speed, feed rate are varied to four levels and the depth of cut is kept constant to investigate the effect of the same on the three cutting force component on the tool-tip. It is observed that the main cutting force was largest among the three cutting force components in case of AISI 4340 steel turning.

***Keywords*:** Dry machining; Approach angle; Feed rate; Cutting speed; Cutting force prediction, Cutting temperature.

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INTRODUCTION

Machining is the most important part of the the manufacturing process. The turning is one of the most commonly employed basic operations in the experimental work of metal cutting. The work material is held in the chuck of a lathe and is rotated. The tool is held rigidly in a tool post and moved at a constant rate along the axis of the feed bar, cutting away a layer of metal to form a desired profile. The components of cutting force acting on the tool are an important aspect of machining. Basic information oncutting force must be known in order to understand the relationship among various cutting force components. Many force measurement devices like dynamometers have been developed which are capable of measuring tool forces with increasing accuracy.

Avila and Abrao (2001) studied the effect of machining of hardened AISI 4340 steel. The work-piece material was heat treated to an average hardness of 49 HRC. Mixed alumina tools were used as cutting tool. The experimental tests were carried out with varying cutting speed ranging from 50 to 100m/min with a constant feed rate of 0.15 mm/rev. and a constant depth of cut of 2mm in rough turning. For finishing, the cutting speed values range from 200 to 400 m/min for a constant feed rate and depth
of cut of 0.05 mm/rev and 0.5 mm respectively. The different cutting fluids used were; emulsified without mineral oil, synthetic and emulsified containing mineral oil. The fluids were pumped at a rate of 75l/min. the experimentation concluded that the cutting fluid (emulsifiedwithout mineral oil) resulted in longer tool life compared to dry cutting. At high cutting speeds, the cutting fluid was responsible for reducing the scatter in the surface roughness values and also for the chip control.

Diniz and Oliveira (2004) optimized the use of dry cutting in rough turning steel operations. Several experiments were carried out varying parameters such as cutting speed, feed, depth of cut and tool material in rough turning of ABNT 1045 steel in dry and wet cutting. The material used had an average hardness of 97 HRB. The work-piece diameter varied from 60 to 100mm for the experimental work. The cutting fluid used was synthetic oil with 6% concentration the water having a flow rate of 4.3 l/min. Based on the work it could be said that dry turning could not be used for high values of depth of cut in order to obtain long tool life. The cause of wear on flank face was due to abrasion and adhesion, whereas the wear on the rake face was due to diffusion, abrasion and attrition.

Salgam et al. (2005) studied the effect of tool geometry and cutting speed on main cutting force and tool tip temperature. In this paper, the influence of rake angle and entering angle in tool geometry and cutting speed on cutting force components and the tool tip temperature generation during the turning process were evaluated. The data used for the investigation derived from experiments conducted on a CNC lathe according to the full factorial design to observe the effect of each factor level on the process performance. On their evaluation basis, they concluded that rake angle was effective at all the cutting force components, while cutting speed was effective at the tool tip temperature. The cutting force signals and temperature values provided extensive data to analyse the orthogonal cutting process.

EXPERIMENTAL METHODOLOGY

1. Heat treatment and Selection of experimental conditions

Experiments were carried out by a plain turning on the selected work-piece AISI-4340(C = 0.39, Si = 0.26, Mn = 0.54, P = 0.026, S = 0.026, Ni = 1.47, Cr = 1.21, Mo = 0.19). This medium carbon steel has a wide range of application in automobile and industries related to automation by the asset of its worthy hardenability facilitating its usage in many working sections. The selected work-piece having 55 mm diameter and 150 mm long rod was machined under dry machining and MQL machining at the selected experimental conditions. The chemical composition tests were performed by Spark Emission Spectrometer, Make: BAIRD USA, Model: DV6, Test Method:ASTM: E415-2008. The material selected for experimentation was having hardness of 23HRC at raw state and was then heat treated using quench hardening process (at 860℃) and tempering process (530± 5°C). Meta quench 39 (HPCL) oil was preferred for cooling and was quenched vertically.Micro-structure of the material was studied on an inverted type microscope (made by Nikon, Epiphat.200), before and after heat treatment at 500X. The microstructure of material in the raw state consisted of lower Bainite with patches of free ferrite (represented by the circle “A” and “B” respectively in Fig. 1a.) whereas the microstructure of heat treated material consisted of tempered martensite mixed with fine globular carbides mixed (represented by the circle “A” and “B” respectively in Fig. 1b.).

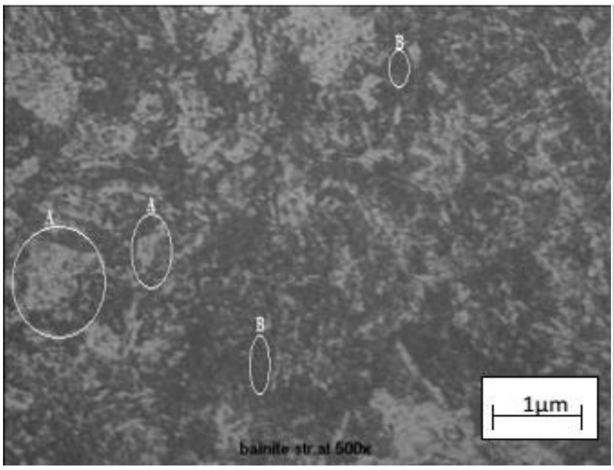

Fig. 1a. Microstructure of raw Material 500x magnification

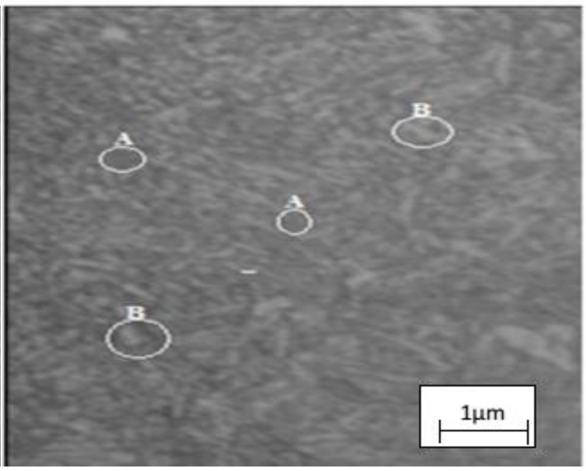

Fig. 1b. Microstructure of heat treated Material 500x.

Taegu-tec insert having a CVD coating was used for the cutting operation. Longitudinal turning was performed on all geared high precision DRO lathe (having specifications as cutting speed values, 39.75m/min, 55.91m/min, 88.74m/min, and 137.5m/min and feed rate values, 0.066 mm/rev, 0.080 mm/rev, 0.100 mm/rev and 0.120 mm/rev) and for each test the length of cut was kept to 18mm in axial direction. The experimental conditions selected are shown in Table 1. The experimental range of the cutting velocity and feed rate were selected based on the tool manufacturer's recommendation and industrial practices.

Table 1. Experimental conditions

Machine Tool	**Lathe machine, 2HP**
Work specimen material	AISI-4340 steel (C = 0.39, Si = 0.26, Mn = 0.54, P = 0.026, S = 0.026, Ni = 1.47, Cr = 1.21, Mo = 0.19)
Hardness	39HRC
Size	Ø55 × 150 mm
Cutting insert	"Taegu-Tec" CVD coated
Tool holder	Lathe tool dynamometer DKM 2000
Process parameters	
Cutting speed, Vc (m/min)	39.75, 55.91, 88.74, 137.5
Feed rate, So (mm/rev.)	0.066, 0.080, 0.100, 0.133
Approach angle, °	45, 60, 75, 90
Depth of cut, t (mm)	0.6
Environment	Dry

2. Measurement of chip–tool interface temperature and cutting force

MQL machining is expected to provide some favourable effects mainly through reduction in cutting temperature and cutting force. Lathe tool dynamometer (make TeLC Germany) DKM 2000, a 5-components tool dynamometer with XKM 2000, software is used. It measures forces on the cutting tool up to 2000N with a resolution of 0.1%. Schematic diagram of sensing elements installed that measures five components of forces are given below in Fig. 3. It can measure temperature on the tool tip between 300°C to 800°C with an InGaAS radiation sensor (Impact Electronic Series 300, 24 VDC, and 4-20mA). Dynamometer is equipped with adjustable inserts-holder to change the approach angle into 45 , 60 , 75 , 90° with a turn of the excenter bolt. A key is used to clamp tight. If the arrow on the excenter points nearly to back then clamping is tight. For use in left direction the left holder is to be used. The sensor was mounted in such a manner that it focused the tool tip at the back relief face right aside the tip. It was positioned at approximately 90mm from the tool tip and light spot was of approximately 2mm diameter. Temperature Sensor was inclined at 30o with the axis of the work piece. The dynamometer was rigidly held on tool post. Cutting force and cutting tool-tip temperature signals obtained from the dynamometer were transferred to desktop by means of the data acquisition card and were evaluated by using XKM software.

RESULTS AND DISCUSSION

Effect of Dry Machining on cutting force

Experiments were conducted at four different approach angles by varying cutting speeds with a tool having a constant rake angle of 6 , it was observed that with the increase of the cutting speed, all cutting force exhibited reducing trend. The reason associated with this is that at higher cutting speeds, the cutting energy and the stresses generated during the process were significantly higher and lead to increase in heat generation. The heat generated in the shear zone helps to soften the work-piece material. The inter-molecular forces between the molecules in the work-piece reduced due to the increase in temperature at the chip-tool interface. The inter-atomic attraction between the molecules was more in case of cutting tool so they did not dislodge too much as in the case with the work-piece material. Therefore, weakening of inter-atomic forces between the molecules of work-piece at higher cutting speeds results in reducing the forces required to cut the material. The tool chip contact length also played an important role in reducing the cutting force at higher speeds. Due to the decrease in tool–chip contact length, the shear stress reduces and also the reduction in frictional forces occur which helps in decreasing the main cutting force and passive force as well. With the increase in the value of feed rate, it is observed that the value of all the cutting force components increases. As the feed rate increases, the section of sheared chip increases because the metal resists the rupture more and requires larger efforts for chip removal which results in the production of higher cutting force values.

Effect of MQL on cutting temperature

In orthogonal cutting, the cutting is assumed to be uniform along the cutting edge; therefore, it is a two dimensional plane strain deformation without side spreading of the material. At higher cutting speeds, the cutting energy and the stresses generated during the process were significantly higher and lead to increase in heat generation. The main cutting force was maximum at an approach angle of 45°approach angle. Evaluating the results of machining conditions in respect to low cutting force and temperature in all the experiments, the optimum cutting speed was obtained at 60°-75°. The machining temperature at the cutting zone is an important index of machinability and needs to be controlled as far as possible. During machining any ductile materials, heat is generated at the primary deformation zone due to shear and plastic deformation, whereas secondary deformation and sliding cause heat generation at chip–tool interface. Furthermore, rubbing produces heat at work–tool interfaces. The average chip–tool interface approach angles, and different environments undertaken.

CONCLUSION

In the course of this study, the cutting force and the tool tip temperature were measured in turning and from the experimentation the results obtained from CVD insert using dry conditions. On the other hand, the effects of cutting speeds, approach angles and feed rates on cutting force and tool-tip temperature were evaluated. The following conclusions were made from the investigations that cutting force (Fc) shows an increasing trend with the increase in approaching angle, feed where as it showed a decreasing trend with speed, passive force (Fp) increases with the increase in cutting speed and feed, whereas for approaching angle showed decreasing trend with the increase in approaching angle, feed force (Ff)showed an increasing trend with all variables.

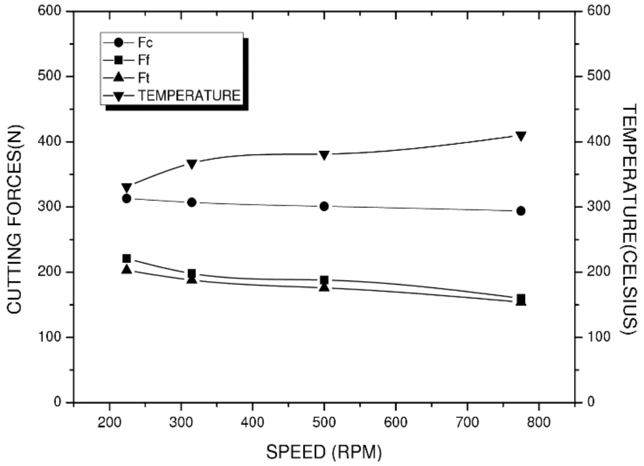

Fig. 2a. Effect of Cutting force on Cutting Speed at 45° Approach Angle

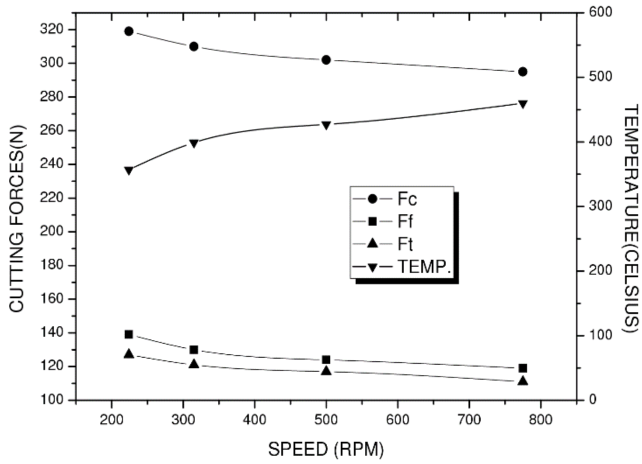

Fig. 2b Effect of Cutting force on Cutting Speed at 60°Approach Angle

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