AN INVESTIGATION OF THE EFFECT OF PROCESS PARAMETERS ON MRR IN TURNING OF PURE TITANIUM (GRADE-2)

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Abstract:
This paper investigates the effect of process parameters in turning of Titanium grade 2 on conventional lathe. Three parameters namely spindle speed, depth of cut and feed rate are varied to study their effect on material removal rate and tool failure. The experiments are conducted using one factor at a time approach. Moreover, a few random experiments are also carried to study the phenomenon of tool failure. The study reveals that material removal rate is directly influenced by all the three process parameters. However the effect of spindle speed and feed rate is more as compared to depth of cut. An optimum range of input parameters has been bracketed as the final outcome for carrying out further research.

Keywords: Material removal rate; Tool failure; Conventional turning; Process parameters.

1. Introduction

The scientists and technologies in the field of manufacturing are facing more and more challenges owing to use of high strength temperature materials especially in the aerospace and automobiles industries. These materials have high strength to weight ratio, high strength, toughness and other improved properties. The high strength, low weight ratio and outstanding corrosion resistance inherent to titanium and its alloys has led to a wide and diversified range of successful applications which demand high levels of reliable performance in surgery, medicine, aerospace, automotive, chemical plant, power generation, oil and gas extraction, sports, and other major industries [1]. In the majority of these engineering applications titanium has replaced heavier, less serviceable or less cost effective materials. Designing with titanium taking all factors into account has resulted in reliable, economic and more durable systems and components, which in many situations have substantially exceeded performance and service life expectations. Conventional machining of titanium requires forces only slighter higher than those needed to machine steel, but the alloys have metallurgical characteristics that make them somewhat more difficult to machine than steels of equivalent hardness on conventional machine tools [2]. Many of titanium's material characteristics make it expensive and hard to machine. These characteristics are:

- Titanium is a poor conductor of heat. Heat, generated by the cutting action, does not dissipate quickly. Therefore, most of the heat is concentrated on the cutting edge and the tool face [3].

- Titanium has a strong alloying tendency or chemical reactivity with materials in the cutting tools at tool operating temperatures. This causes galling, welding, and smearing along with rapid destruction of the cutting tool [3].

- Titanium has a relatively low modulus of elasticity, thereby having more "springiness" than steel. Work has a tendency to move away from the cutting tool unless heavy cuts are maintained or proper backup is employed. Slender parts tend to deflect under tool pressures, causing chatter, tool rubbing, and tolerance problems. Rigidity of the entire system is consequently very important, as is the use of sharp, properly shaped cutting tools [3].

- Titanium's fatigue properties are strongly influenced by a tendency to surface damage if certain machining techniques are used. Care must be exercised to avoid the loss of surface integrity, especially during grinding [3].

- In machining of Titanium alloys, a large shearing angel is formed. This cause a thin chip to contact a relatively small area on tool face and results in high loads per unit area. These high forces coupled with the friction developed by the chips as it passes over the cutting area; result in greater increase in the heat over a much localized portion of cutting tool. All this heat and pressure means tool life is short, so, when cutting titanium, as cutting speed increase, tool life dramatically decrease [4].

Because of these problems with machining of titanium, the effects of various process parameters like cutting speed, feed rate and depth of cut on the machining of titanium have to be studied. Titanium grade 2 is widely used because it combines excellent formability and moderate strength with superior corrosion resistance. These combinations of properties makes grade 2 titanium a candidate for a large variety of chemical and marine as well as aerospace and medical applications. Other uses have included items such as jigs, baskets, cathodes and starter sheet blanks for the electroplating industry [5]. The present work tends to explore the machining characteristics of the same material for turning on conventional lathe machine.

2. Literature Review

Several researchers have used this process for machining of wide variety of materials considering different process parameters. Suhail et al. [6] optimizes the cutting parameters such as cutting speed, feed rate and depth of cut based on surface roughness and assistance of work piece surface temperature in turning process. In machining operation the quality of surface finish is an important requirement for many turned work pieces. The work piece surface temperature can be sensed and used effectively as an indicator to control the cutting performance and improves the optimization process. So it is possible to increase machine utilization and decrease production cost in an automated manufacturing environment. Kirby [7] optimizes the turning process toward an ideal surface roughness target. This study seeks an actual target surface roughness value, which may allow for a higher feed rate depending upon that specified target. In using the variation of the nominal the-best signal to noise formula, variation about a specified (ideal) value is explored and sought to be minimized. Singh [8] optimizes tool life of Carbide Inserts for turned parts. The experiments were carried to obtain an optimal setting of turning process parameters- cutting speed, feed and depth of cut, which may result in optimizing tool life. The relative power of feed in controlling variation and mean tool life is significantly smaller than that of the cutting speed and depth of cut. Mahto et al. [9] optimizes the process parameters in vertical CNC mill machines. The study was conducted in machining operation in hardened steel DIN GX40CRMOV5-1. The processing of the job was done by Tin coated carbide inserted end-mill tool under semi-finishing and finishing conditions of high-speed cutting. The milling parameters evaluated was cutting speed, feed rate and depth of cut. Thamizhmanii et.al [10] analyses the surface roughness by turning process. The optimum cutting conditions were predicted to get lowest surface roughness in turning SCM 440 alloy steel. The study revealed that the depth of cut has significant role to play in producing lower surface roughness followed by feed. Also the cutting speed has lesser effect on the surface roughness. Petropoulos et al. [11] developed a predictive model of cutting force in longitudinal turning of St37 steel with a Tin coated carbide tool using Taguchi and Response surface techniques. The model is formulated in terms of the cutting conditions namely feed, cutting speed and depth of cut.

3. Experimental Methodology

The experiments are performed on conventional lathe machine CDL6241*1500 from Dalian Machine Tool Group Corporation, China. A single point high speed steel (MIRANDA S-400) tool is used as the cutting tool. The round bar of Titanium grade 2, 40mm diameter and 50 mm length is used as the work piece. The input parameters viz. spindle speed, depth of cut and feed rate were varied to study their effect on material removal rate (MRR) and the tool failure. Their respective ranges are given in Table 1.

Table-1 Input parameters and their range

Sr. No.	Name of Parameter	Symbol	Range
1	Spindle Speed	N	270-1000 rpm
2	Depth of Cut	d_{cut}	0.5-2.0 mm
3	Feed rate	F	0.13-0.29 mm/rev.

The experiments are conducted using One-factor-at-a-Time-Approach in which, one input parameter is varied and all other parameters are kept constant. Some random experiments are also carried out to study the phenomenon of tool failure. A Total of 30 experiments were performed. The MRR was calculated by measuring the weight of the specimen before and after machining on the digital balance meter with a least count of 10 mg of Sansui (Vibra), model no. AJ3200E.

4. Results and Analysis

The effect of individual process parameter on the MRR and tool failure is discussed as follows:

4.1 Effect of Spindle Speed (N)

Spindle speed refers to the rotating speed of the work piece. It was increased from 270 rpm to 1000 rpm keeping all other parameters constant. The depth of cut was kept at 0.9 mm and feed rate at 0.13 mm/rev. The MRR was increased from 0.30 g/s at 270 rpm to 0.78 g/s at 720 rpm (fig.1). This is attributed to the fact that the time required for the removal of material decreases. It was not possible to perform the cutting beyond N > 720 rpm because beyond that spindle speed the tool failure took place.

4.2 Effect of Depth of Cut (d_{cut})

Depth of cut is defined as the thickness of the layer being removed in a single pass from the work piece or the distance from the uncut surface of the work to the cut surface. With increase in depth of cut from 0.5mm to 2 mm by keeping spindle speed at 720 rpm and feed rate at 0.13 mm/rev., the MRR was increased from 0.44 g/s at 0.5mm depth of cut to 1.61 g/s at 1.9 mm depth of cut (fig.2). The MRR goes on increasing because the increase in depth of cut removes the more amount of material from the specimen. Very high depth of cut i.e. 2 mm causes the tool failure.

4.3 Effect of Feed Rate (f)

Feed rate is the rate at which the tool advances along its cutting path. The feed of the tool also affects to the processing speed and the roughness of surface. When the feed is high, the processing speed becomes high. When the feed is low, the surface roughness is less. With increase in feed rate from 0.13 mm/rev. to 0.29 mm/rev. by keeping the N at 720 rpm and d_{cut} at 0.9 mm, the MRR was increased from 0.78 g/s at 0.13 mm/rev. to 1.57 g/s at 0.26 mm/rev (fig.3). The increasing feed rate reduces the processing time thereby increasing the MRR. Beyond f=0.26 mm/rev. it was not possible to continue machining as the tool failure occurs.

5 Conclusions

This study reveals that during machining of Titanium grade 2 on conventional lathe machine, MRR is affected by all the process parameters viz. spindle speed, depth of cut and feed rate. The MRR is increased by increasing any of the process parameters. The effect of variation in spindle speed and feed rate is more as compared to depth of cut. The tool failure takes place at higher values of depth of cut, feed rate and spindle speed. So in order to avoid the tool failure a compromise in the MRR must be made. This study is carried out for bracketing the optimum range of three input parameters for carrying out further research.

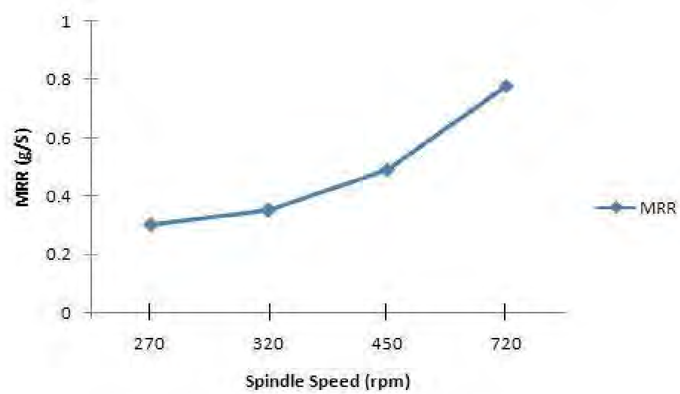

Figure 1: Effect of Spindle Speed on MRR

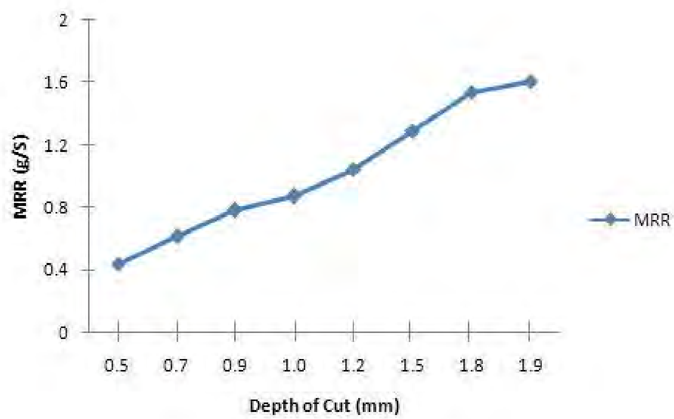

Figure 2: Effect of Depth of Cut on MRR

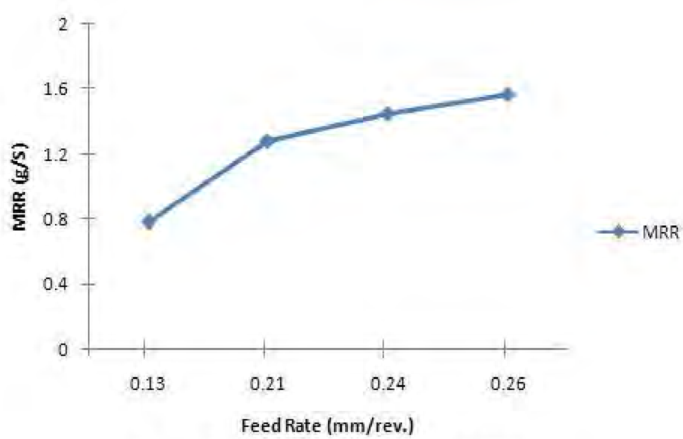

Figure 3: Effect of Feed Rate on MRR

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