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Experimental Investigations on the Effects of Cutting Variables on the Material removal rate and Tool wear for AISI SI steel

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ABSTRACT

Machining is the most important of the manufacturing processes which involves the process of removing material from a workpiece in the form of chips. Machining is necessary where tight tolerances on dimensions and finishes are required. Being such an important process in manufacturing industry, a machining process is considered for investigation in the present work. This paper presents the experimental investigations on the effects of cutting variables like Spindle speed, Feed and Depth of cut on the Material removal rate and tool wear. The experiments were conducted on AISI SI steel grade on a CNC turning machine using ceramic insert. The experiments were conducted as per the design of experiments. Initial trial experiments were conducted to fix the ranges for the control parameters. After conducting the experiments the MRR and Tool wear were measured and recorded. The effects were studied after plotting the graphs between the Input process parameters versus the responses using Design expert software. The results obtained in this study can by further used for optimizing the process parameters there by the optimized results help the operator to enhance the quality as well as machining rate

Introduction

Machining involves the shaping of a part through removal of material. A tool, constructed of a material harder than the part being formed, is forced against the part, causing material to be cut from it. Machining, also referred to as cutting, metal cutting, or material removal, is the dominant manufacturing shaping process. It is both a primary as well as a secondary shaping process. Machining is the term generally used, rather than material removed or cutting. The device that does the cutting or material removal is known as the machine tool. Nearly all castings and products formed by deformation processing [bulk or sheet metal] require some machining to obtain the desired final shape or surface characteristics. Turning operation is the basic machining operation on lathe machine. With the advent of CNC technology, the machining processes are automated through which high quality of the machined components; high material removal rates can be achieved. In general, CNC lathe machine is operated with several controllable factors such as spindle speed, feed rate, depth of cut etc. In this work, metal removal rate and tool wear are considered as the performance measures as they affect cost and quality of the finished components. The optimization of CNC turning process is often achieved by trial-and-error method based on the shop floor experiences by determining the certain parameters of the process. But this does neither guarantee the quality nor the machining economics. Therefore a general optimization plan is required to avoid cumbersome trial runs on machine and wastages. Optimization of CNC Turning has been carried out in the literature by many researchers. A few works are based on simulations [1-4] and other works are based on many experimental runs [5-6], collecting huge amount of data and processing it to achieve the result. Taguchi method is widely adopted in the literature for the improvement of quality and machining economics. Taguchi method uses the orthogonal array concept with small number of experimental runs to investigate the effects of parameters on performance measures reduces the sensitivity due to inherent variations present in the system. Moreover, Taguchi method does not consider the interactive effects of control factors. Machining is the only primary forming process that is also used for secondary operations. This unique characteristic has led to the dominance of this process. Due to the high cost of machining and problems caused by the chips produced, casting and deformation processing try to produce "near-net shape" products, which can be completed with little or no machining. So In the present work, CNC Turning process is investigated by considering the performance measures, metal removal rate (MRR) and tool wear (TW) in terms of spindle speed, feed rate and depth of cut as control factors.

Experimental Work

The experiments were conducted on a high precision CNC-Turning centre. AISI SI is taken as the work piece material for investigation. It is a It is a shock resistant steel with excellent toughness and fine wear resistance and finds various applications in cutting tools for heavy plate, shear blades, cold punching and upsetting and used in various cutting tools. The specimen is prepared with the dimensions of 150mm length and 50mm diameter for turning and ceramic insert is used for experimentation. The control factors considered for experiments are spindle speed, feed and depth of cut while Metal removal rate and Tool wear are considered as the output responses. The ranges of the process control variables are given in table 1.

After conducting the experiments as per the design of experiments, the output responses were measured and recorded. Three continuous passes are taken in order to visualize the tool wear better. Tool wear (Tw) is measured with a precision tool

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maker's microscope. Another response, MRR is calculated as the ratio of volume of material removed from work piece to the machining time. In order to determine the volume of material removed after machining, the weights of work piece before machining and after machining are measured. Machining time taken for each cut is automatically displayed by the machine. The output responses recorded for each set of process control variables are listed Table 2.

Effect Of Process Parameters On Output Responses, Mrr And Tool Wear

The main effects of the process variables on MRR and Tool wear are studied after plotting the graphs by using Design Expert software. The cutting variables Speed, feed and depth of cut have a major effect upon the material removal rate, which has a major role in determining the power requirements. The effect of cutting parameters on MRR is as shown in Fig. 1 to 3. As the spindle speed increases, the removal of material per unit time also increases as shown in Figure 1.

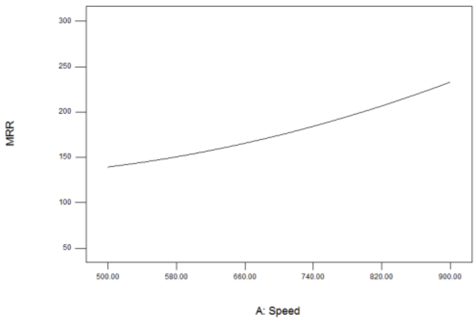

Figure 1. Effect of spindle speed on MRR

As the feed rate is increased, the material removal per unit time also becomes more as shown in Figure 2. As the tool movement per unit time increases, the greater amount of material is removed.

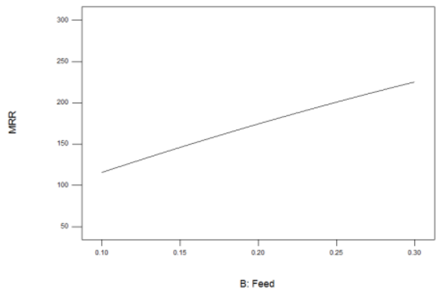

Figure 2. Effect of feed rate on MRR

The more the depth of cut, the more the material removal rate as shown in Figure 3. The chips removed per unit time will be more and thereby quantity of material removed is also high. As the depth of cut increases, the cutting force increases thereby increase in removal of material.

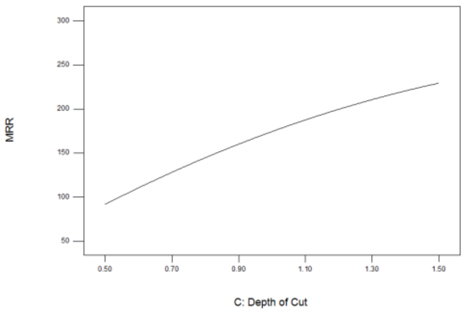

Figure 3. Effect of depth of cut on MRR

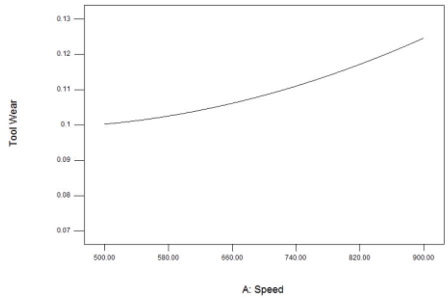

Figure 4. Effect of spindle speed on Tool wear

The effects of speed on the tool wear as shown in Figure 4. As the cutting speed is increased up to a certain limit, a brittle fracture occurs at the cutting edge rather than a gradual flank wear and the depth of the cracks on the cutting edge increases rapidly resulting in a catastrophic failure of the tool. When the cutting speed is comparatively low, the size and depth of the crack on the flank is very small. Crack grows rapidly at higher cutting speeds. The cutting force on the tool edge increases as the cutting speed is increased. Higher cutting speed increases tool temperature and softens material. It thereby aids abrasive, adhesive and diffusion wear. The cumulative effect is an exponential decrease in tool life as given by Taylor's life equation.

The effect of feed rate on tool wear is displayed in Figure 5. The larger the feed, the greater is the cutting force per unit area of chip-tool contact on the rake face and work –tool contact on the flank face. Cutting temperatures and therefore the different types of wear are increased. An increase in cutting force as a result of larger feed also increases the likelihood of chipping of the cutting edge through mechanical shock. It has, however been observed that the effect of changes in feed on tool life is relatively smaller than that of proportionate changes in cutting speed.

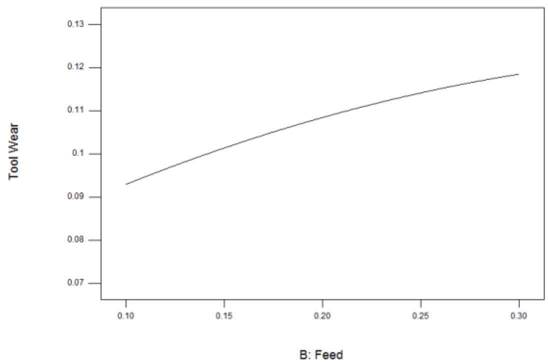

Figure 5. Effect of feed rate on Tool wear

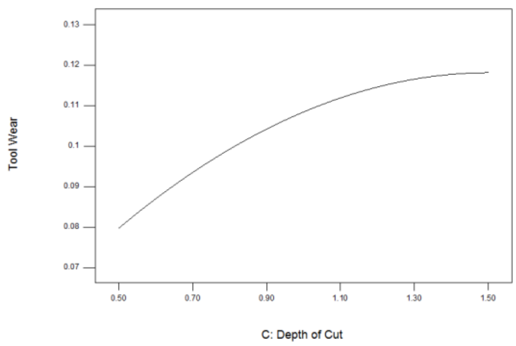

Figure 6. Effect of depth of cut on Tool wear

Figure 6. exhibits the effect of depth of cut on tool wear. If the depth of cut is increased, the area of the chip-tool contact increases roughly in equal proportion to the change in depth of cut. Consequently the rise in tool temperature is relatively small. That is not the case when feed is changed. In that case, the proportionate change in temperature is larger. This is on account of the fact that the area of chip-tool changes by a smaller proportion than the change in feed rate. Thus, an increase in depth of cut shortens tool life to some extent by accelerating the abrasive adhesive and diffusion types of tool wear.

Conclusion

In this work, the important performance measures namely the metal removal rate and the tool wear of CNC Turning on AISI SI material are analyzed. For conducting the experiments first trial experiments were conducted to fix the ranges of the process control factors and then the experiments were conducted as per the design of experiments. The results presented in the work can be used for further analysis. That is using the experimental data empirical models can be developed and then these models can be used for finding the optimal process parameters to get the best output. Then the problem can be formulated as the multi-objective optimization problem and get it solved using an efficient evolutionary approach to find out the optimal combinations of machining parameters, thereby the manufacturing engineer can choose the right combination depending upon his requirement.

Table 1. Control factors and their levels

S.No	Control Factor	Symbol	Levels			Units
			-1	0	+1	
1	Speed	A	500	700	900	rpm
2	Feed	B	0.10	0.20	0.30	mm/min
3	Depth of cut	C	0.5	1.0	1.5	mm

Table 2. Experimental observations

S.NO	Control Factors			MRR[gm/min]	Tool wear [mm]
	A	B	C		
1	900	0.1	1.5	218.72	0.115
2	500	0.1	0.5	47.845	0.0689
3	700	0.3	1.5	326.034	0.14
4	900	0.2	1	222.125	0.115
5	700	0.1	1	130.45	0.107
6	900	0.1	0.5	93.987	0.0798
7	500	0.1	1.5	126.789	0.089
8	500	0.3	1	167.89	0.1089
9	500	0.2	0.5	70.145	0.0712
10	700	0.2	1	172.456	0.113
11	700	0.2	0.5	99.034	0.084
12	500	0.1	1	95.678	0.083
13	500	0.2	1	128.789	0.098
14	900	0.2	1.5	312.789	0.135
15	900	0.3	1.5	389.435	0.168
16	900	0.2	0.5	119.145	0.085
17	500	0.2	1.5	184.567	0.113
18	900	0.3	0.5	165.456	0.106
19	700	0.1	0.5	73.425	0.074
20	700	0.1	1.5	72.275	0.073
21	700	0.3	1.5	310.456	0.124
22	500	0.3	1.5	233.567	0.122
23	700	0.3	1	231.347	0.114
24	700	0.2	1.5	248.09	0.129
25	900	0.3	1	299.09	0.131
26	500	0.3	0.5	92.56	0.075
27	900	0.1	1	169.05	0.114

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