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Tool Life Study of HSS Tools Used in CK45 Steel Turning

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Abstract: ***Cutting tools can be used when they do not reach tool life criteria and can produce parts with desired surface finish and dimensional accuracy. When the cutting edge of the tool reaches one of the tool life criterion, the tool should be replaced by a new one or sending it for regrinding [1]. During cutting operations, the cutting tool experiences various stresses such as normal, shear and also thermal shocks. These stresses cause wear and breakage of cutting edge. Tool wear is defined as a gradual loss of tool material at contact zones of workpiece and tool material, resulting the cutting tool reaches its life limit [2]. This research is based on ISO3685 and***
Investigates the flank wear patterns of HSS tools during machining of CK45. It also determines the effects of cutting conditions on Taylor tool life equation.
Keywords: ***Flank Wear, Tool Life, Machining, Ck45.***

I. INTRODUCTION

In practical situation, the time at which a tool ceases to produce workpieces with desired size, surface quality and acceptable dimensional tolerances, usually determines the end of tool life. Several mechanisms of wear can contributes to the tool life period. The main objective of tool life testing and wear investigation is to determine experimentally how wear affect the useful life of cutting tool. In most cases the tool wears gradually and the work done by the tool becomes less satisfactory. For instance, the roughness of the machined surface becomes too high, cutting forces rise and cause intolerable deflections or vibrations. As the tool wear rate increases, the dimensional tolerances cannot be maintained. Various damage and wear of the cutting tool can be developed during cutting process [2]. The various features of turning tool wear, cracks and breakage indicated in Figure 1. There are several different causes and mechanisms of tool wear. Friction on the rake face and on the flank of the tool occurs under a close contact of freshly created surface of the workpiece material. The coolant penetrates into this contact zone only at very low cutting speed. The pressure in the contact zone is at least equal to the yield stress of the workpiece material [1] [2]. The temperatures in the contact zone are high and may reach the melting temperature of the one of the materials in this zone, most often that of the workpiece material.

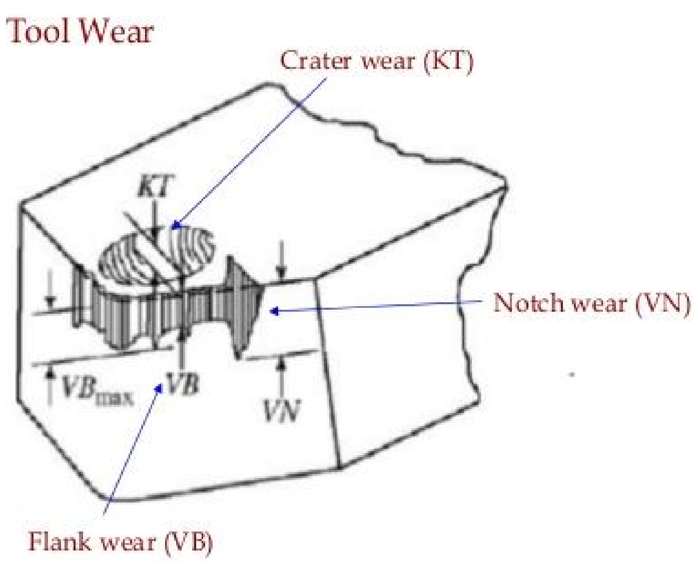

Fig. 1 schematic of friction stir welding process

Nowadays, in order to reach minimum production cost in machining operations, various optimization methods have been proposed. Since turning operation has different parameters affecting the workpiece quality, it was selected as a complicated manufacturing method in this paper. To reach sufficient quality, all influencing parameters such as cutting speed, federate, depth of cut and tool rake angle were selected as input parameters. Furthermore, both surface roughness and tool life were considered as the objectives. Also, CK45 steel and M1 high speed steel (HSS) were selected as workpiece material and tool, respectively. Subsequently, grey relational analysis was performed to elicit optimal values for the mentioned input data. To achieve this goal, first, degree of freedom was calculated for the system and the same experiments were performed based on the target values and number of considered levels, leading to calculating grey relational generating, grey relational coefficient and grey relational grade. As the next step, the grey relational graph was sketched for each level. Finally, optimum values of the parameters were obtained for better surface roughness and tool life. It was shown that the presented method in the turning operation of CK45 led to high surface quality and tool life.

II. REVIEW OF PAST STUIES

Material removal from rotating workpiece by applying forces is known as turning operation [1]. In turning operation, significant controllable parameters on the surface roughness and tool wear can be listed as follows: tool geometry, cooling system, depth of cut, spindle rotational speed, cutting speed, cutting tool geometry and federate [1]. There are also uncontrollable parameters such as ambient temperature, machine age and type of used material. Due to the constraints of full elimination of effects of uncontrollable parameters and their negligible effectiveness, optimization is taken into consideration for controllable parameters in order to obtain more efficient parameters [1]. Nowadays, various optimization methods have been proposed in order to obtain minimum production cost in manufacturing operations, especially machining operations.

Since turning operation has different parameters affecting the workpiece quality and tool wear, it was selected as a complicated manufacturing method in this paper. Optimization of turning parameters by Taguchi method was reported in 1998 [2]. Sori et al. utilized micro-genetic algorithm method for optimizing the turning operation. Surface roughness and tool wear were selected as output parameters [3]. Davim investigated optimization of turning parameters through the orthogonal arrays [4]. A plan of experiments based on Taguchi technique was performed on machining with the cutting conditions prefixed in workpieces. An orthogonal array and analysis of variance were employed to investigate cutting characteristics of MMC (A356/20/SiCp-T6) using PCD cutting tools [4]. The objective was to optimize tool wear, power consumption of machining operation and surface roughness in the workpiece. To have sufficient quality, all influencing parameters such as cutting velocity, federate and cutting time were selected as input parameters. Lin used a combination of Taguchi method and grey relational analysis for optimization of the turning operation [5]. Mana and Bhattacharyya studied machining conditions of Al/Sic alloy in order to reach minimum surface roughness [6]. The corresponding L27 orthogonal array was selected prior to investigating degree of freedom for the system and number of levels for the tests. Also, Analysis of Variance was utilized to optimize height of surface roughness Ra and Rt . Nalbat et al. utilized Taguchi method in order to minimize surface roughness values in turning operation [7]. Golkarpoor et al. studied cutting forces, cutting temperature and surface roughness as input parameters in turning operation of CK45 steel in order to determine tool life cycle [8]. Mahdavinezhad et al. considered effect of cutting speed on the tool wear ratio and material removal rate in the turning operation of CK45 steel. Turning operation was performed in two conditions of with and without lubricant [9]. Using grey analysis, the problem with multiple objectives was changed to the problem with one objective which led to easier data analyses and inferences. Due to different restrictions and amounts associated with optimization parameters, a rather challenging comparison is expected. Hence, normalization is necessary to accomplish a valid comparison between the parameters. After normalizing the data, which was done in the stage of generating grey relational to obtain grey relational coefficient and grey relational grade, the final decision from plotted grey graph can be made. In this work, due to high effect of the cutting tool angles on the turning operation, the tool rake angle was studied using grey method for the first time. Furthermore, in order to determine effect percentage of the parameters in the optimum condition as well as effect of input parameters on the output ones, some new equations were recommended. The ultimate goal of the current paper was to investigate simultaneous effects of different turning parameters on surface roughness of the manufactured CK45 steel workpieces as well as high steel speed (HSS) cutting tool wear. Here, the grey method was selected to extract optimal values of the cutting speed, depth of cut, federate and tool rake angle that led to the minimum surface roughness and tool wear. First, degrees of freedom of the system were calculated. Then, based on these data and the number of levels, the corresponding orthogonal arrays were obtained for the tests. After the grey relational coefficient and grade were calculated, grey relational graph was depicted.

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III.EXPERIMENT SETUP

The workpiece used in this study had effective length of 400 mm and diameter of 45 mm [3]. Chemical composition (weight percent) of CK45 steel is given in Table 1 [10]

TABLE I
CHEMICAL COMPOSITION OF THE MATERIAL

Material	Thickness or Diameter (mm)	Chemical Composition								
		C	Cr	Ni	Mn	Si	P	S	Mo	Fe
CK45	8	0.45	< 0.40	< 0.40	0.60	< 0.40	0.035	< 0.035	< 0.10	Bal.

Figure 2 shows the geometry of tool used in the experiment. Rake and clearance angles of the tool are grounded with acceptable surface finish and tolerances according to ISO 3685.

Fig. 2 Geometry of the HSS turning tools

Table 2 shows the cutting conditions used in the experiment. Each of the 12 cases started with a new tool until it reached its life limit which was then replaced by a new one. During cutting process and after each pass, the tool was unclamped and a CCD image of the flank face was taken using a CCD camera enhanced with a tele-centric lens, further details will be found in [5]. These images are calibrated and then used for measuring the flank wear of the worn tool.

TABLE II
CUTTING CONDITION

Cutting Condition	case	Depth of Cut (mm)	Feed (mm/rev)	Spindle Speed (rpm)	Cutting Velocity (m/min)
A	1	1	0.11	180	21.48
	2	1	0.11	355	40.13
	3	1	0.11	500	53.38
B	4	2.5	0.24	500	56.52
	5	2.5	0.24	355	35.67
	6	2.5	0.24	250	29.83
C	7	2.5	0.4	355	31.21
	8	2.5	0.4	250	29.83
	9	2.5	0.4	180	18.65
D	10	2.5	0.56	250	25.92
	11	2.5	0.56	180	21.49
	12	2.5	0.56	125	11

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IV. MEASURING THE CUTTING FORCES

In addition to the wear rate and tool life experiment, the cutting forces are measured for Case 2 in 1, 8 and 12 minutes after the beginning of the cut. The force measurement was performed by experimental setup, which contains load cell for measuring the cutting forces and date acquisition card to get the data, see [6]. The Figures 13-15 illustrates that there is an increasing trend for the average of cutting forces. The average cutting force for 1-minute operation is around 110 N and increased to 125 N for 8-minutes operation and then reached 150 N for 12-minutes operation.

V. CONCLUSIONS

Tool life of HSS turning tools is modelled using Taylor tool life equation. Taylor's coefficients are derived for the combination of HSS tool and Ck45 work piece material for recommended cutting conditions. The criterion used for tool life prediction is based on ISO 3685 and the average width of flank wear is chosen. Cutting forces are measured during cutting process at certain times. There is a good correlation between the average cutting force and the amount of flank wear. Due to simplicity of force measurement it is recommended to measure the average cutting force instead of measuring the amount of wear which is a time consuming and inefficient.

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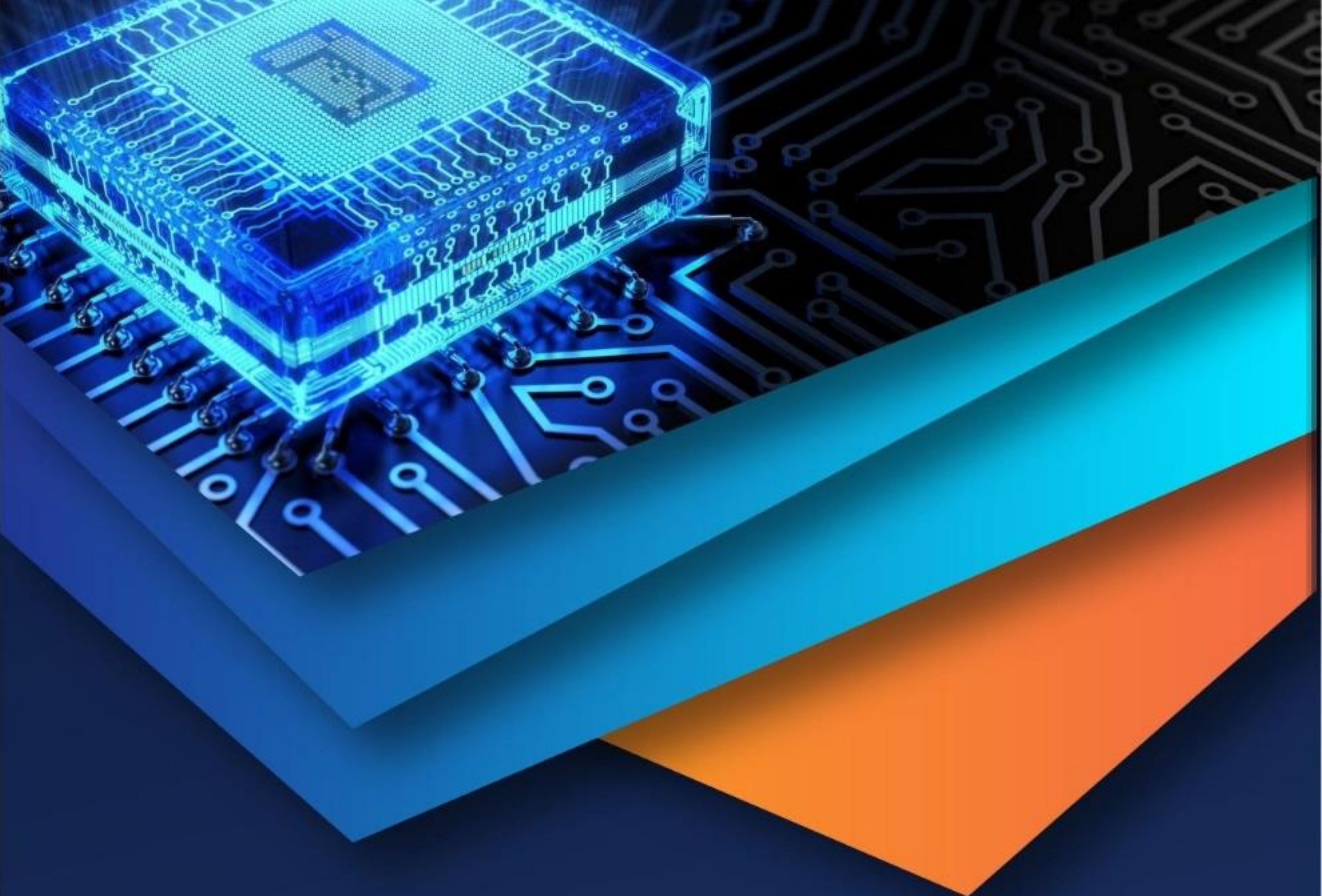

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