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The Effect of Multipass Cutting in Grinding Operation

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***Abstract*—**Grinding requires high specific energy and the consequent development of high temperature at tool-workpiece contact zone impairs workpiece quality by inducing thermal damage to the surface. Finishing grinding process requires component to be cut more than one pass. This paper deals with an investigation on the effect of multipass cutting on grinding performance in term of surface roughness and surface defect. An experimental set-up has been developed for this and a detailed comparison has been done with a single pass and various numbers of cutting pass. Results showed that surface roughness increase with the increase in a number of cutting pass. Good surface finish of 0.26μm was obtained for single pass cutting and 0.73μm for twenty pass cutting. It was also observed that the thickness of the white layer increased with the increased in a number of cutting pass.

***Keywords*—**Cylindrical grinding, Multipass cutting, Surface roughness, Surface defect.

I. Introduction

MANY practical machining operations require components to be cut more than one pass in order to achieve final geometry with specific surface finish. Nowadays, the grinding operation is widely being used in industries for the surface finishing process. Grinding is often used, especially for works that require fine tolerances and smooth surfaces in the machining of metal components work.

Generally, there are two types of surface grinding which are cylindrical and horizontal that is used to produce a smooth finishing surface on flat and cylindrical workpiece. The typical precision operation of a surface grinder depends on the type and usage. It is a metal removing process by the application of abrasive wheel. The process will produce the desired surface for a functional purpose. The wheel removes material face to flat or smooth by rubbing action which produces heat.

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Factors to consider in grinding processes are the material of the grinding wheel and the sizes of material. The general types of work-piece materials used in grinding process are cast iron and mild steel. This is because the materials do not tend to clog the grinding wheel during the operation. The other materials used in grinding process are aluminum, stainless steel, brass and some plastics. These materials tend to become weakened and are more inclined to corrode at high temperatures [1].

The grinding process requires high energy expenditure per unit volume of material removed. Virtually all of this energy is dissipated as heat at the grinding zone where the wheel interacts with the work-piece. It has been shown that the percentage of heat that was carried away by the grinding swarf is small for most grinding operations [2]. Temperatures are generated during grinding as a consequence of the energy expended in the process. The generation of high temperatures can cause various types of thermal damage to the work-piece, such as burning, metallurgical phase transformations, and softening (tempering) of the surface layer. In addition the damages of the work-pieces can reduce fatigue strength, and thermal distortion and inaccuracies [3].

The grinding defects will affect the ground surface fatigue intensity, corrosion resistibility and contact rigidity [1]. According to [4], there is a high chance of thermal damage in grinding. It was found that when the surface temperature reached a value slightly in excess of 100^0C for water-based grinding fluid and 300^0C for oil-based fluid, the temperature increased rapidly, accompanied by thermal damage to the work-piece surface [5]. The maximum surface temperature which is being a major concern in grinding operations is determined by two factors which are the rate of energy dissipation and the rate of cooling.

According to [6], in creep-feed grinding, the principal mechanism of heat removal is by advection, less than 5% of the total heat is conducted into the workspace when water coolant is used. The energy partition to the work-piece depends on the operating parameters, thermal properties of the abrasive and work-piece, and cooling by the fluid at the grinding zone [7]. The surface temperature of the work-piece must be carefully controlled to ensure high product quality. In addition temperature control can decrease grit breakage and work-piece wear, to keep energy consumption down and to prevent rapid deterioration of the grinding fluid [8], [9].

The heat or high temperatures will affect the work material properties. The high grinding temperatures will also defects the surface of work-piece such as micro-crack, residual stresses and ground burn out [10]-[12]. The grinding process generates an extremely high energy and heat of removing material. The longer the contact time in grinding makes high temperatures penetrate deep into the workplace, resulting in a thick ground white layer. High grinding temperature and long time duration will promote a chemical reaction between the workpiece and the environment, and result in oxides in the ground white layer [13]. Barbacki et al. [14] in their study found that grinding parameters influence the white layer thickness which varies between 0 and 2mm. White layers are found in many material removal processes such as grinding, electrical discharge machining and drilling [15]-[17].

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II. Experimental Design

A. Work Material and Machine Setup

The work materials studied are AISI D2 cold work tool steel (45 HRC) provided by ASSAB steel, 200mm long and 32mm diameter. Tests were carried out using cylindrical grinder machine model SHARP 820H. The machine spindle is capable of running up to 20,000 RPM. The power of the spindle drive motor is 15 kW. In these tests, grinding parameters such as workpiece speed, grinding wheel depth of cut were kept constant. The wheel size is 200mm in diameter and feed rate was held constant at 100mm/min. The wheel was centered on the specimen width. The depth of cut used is 0.25mm. The numbers of cutting pass used are one pass to 20 pass. MITUTOYO Portable Surface Roughness Tester SJ-301 is used to measure the surface roughness of the specimens with 0.8 mm cut off length. The grinding process was done in dry condition.

B. Specimen Preparation and Microstructures Observations

Scanning Electron Microscope (SEM) images of the surface structure of the work material before grinding was taken to compare the microstructure changes at different magnifications. Sample size of 12 x 12 x 5mm was prepared by EDM wire cut. Specimens were cut under extremely mild conditions in order to avoid excessive modification of the workpiece microstructure. The sample is carefully protected from secondary abrasion and corrosion. Samples are oiled to prevent corrosion and packed to protect the surface during handling. The layer is removed by an electro polishing method that does not in itself induce any significant deformation induced transformation from mechanical grinding and polishing. The samples were etched using Nital (3% nitric acid in methanol). Changes in the microstructure were analyzed using a high power optical microscope and SEM for microstructural analysis. The samples were mounted on the specimen holder and transferred into the SEM chamber. High vacuum (pump) was created in the SEM chamber. An accelerating voltage of 20 KV was used in the SEM analysis.

C. Temperature Measurement

Laser thermometer is used as a temperature measurement device at cutting contact zone. Laser thermometer provides direct temperature readings in real-time at the work-piece contact zone. A disadvantage of this approach is that the temperatures in the plane of measurement may not be typical of temperatures central within the contact zone.

III. Result and Discussion

A. Surface Roughness

The surface roughness was measured by adjusting the profilometer to a cutoff length of 0.8mm. The Ra value was considered to be analyzed according to the objectives of the project stated to study the correlation between multipass cutting and surface finish. All measurements were made perpendicular to the grinding direction. Fig. 1 shows that the lowers value of surface roughness, *Ra*, 0.26µm was obtained with single pass cutting, while the highest value of *Ra,* 0.730µm was obtained from twenty pass cutting. From the results it was observed that the increased number of cutting pass makes the surface roughness increase consequently.

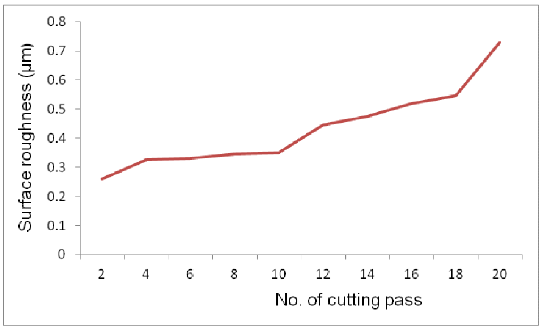

Fig. 1 Surface roughness test results for various cutting pass

There was a quite linear relationship between the number of cutting pass and surface roughness. As a number of cuttings are increased, resulting in more material removed and consequently high grinding force. The grinding forces are an important quantitative indicator to characterize the mode of material removal because the specific grinding energy and the surface damage are strongly dependent on the grinding forces. Higher grinding forces resulting increase in friction. The friction of grinding wheel increased the values of surface roughness. The friction coefficient varies with the grinding parameters such as wheel speed, metal removal rate and dressing lead, and highly depends on the heat input to the process [20]. Increased in the number of cutting pass will increase the temperature. Xu et al [21] indicated that the formation of a plastically deformed coating on the workpiece surface at high temperature increased the surface roughness. During the grinding process, mechanical, thermal and chemical loads are applied to the grinding wheel. One effect of these loads is wear which leads to a change of the micro topography.

B. Surface Morphology

Excessive grinding temperatures can cause thermal damage to the workpiece. Temperatures generated during grinding are a direct consequence of the energy input to the process. In order to study the subsurface, cross-sections of the workpiece samples were made. The cross-sections were made perpendicular to the grinding direction. SEM micrographs of the machined cross-sections surface are shown in Figs. 2 and 3.

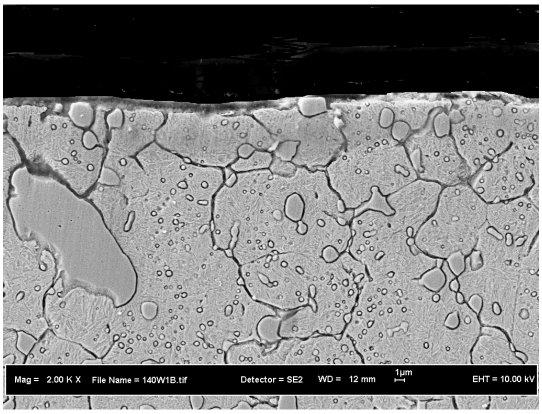

Fig. 2 Thin white layers (1μm) were observed in single pass cutting

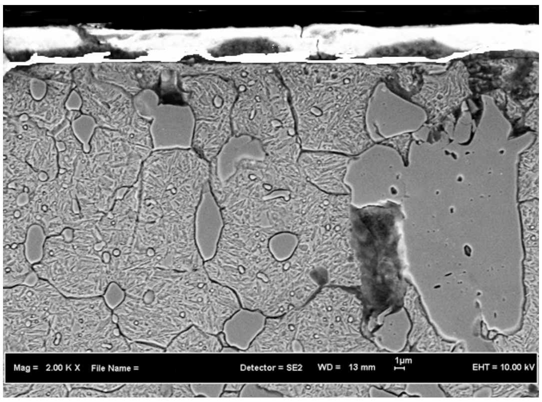

Fig. 3 Thicker white layers (3μm) can be observed in 20 pass cutting

The use of SEM to observe the microstructures can obtain the more details images because it can magnify up to 20000X. White layers have been observed and examined at each cutting pass. From the figure, as a general remark it can be said that white layer thickness grows with increasing of cutting pass. The significant effect of multi pass cutting on machined surface was observed. Multiple pass cutting is producing thicker white layer compared to single pass cutting. White layer is the most common types of thermal damage observed in grinding operations [14], [15]. The most significant increased in the thickness of the white layer has been observed as the number of cutting pass increased. Increasing the number of cutting pass will increase the heat produced at the same time.

White layer is etch resistant and shows a featureless structure. Based on previous research, white layer is much harder than the bulk material, and white layers have the highest hardness due to microstructure changes [13]. In this case, hardness of the white layer is difficult to determine due to the thickness which is smaller than the indenter (1μm to 3μm). The white layer formed in hard turning and grinding has received attention from the scientific community. Liao et al., [22] in their study considers that the heat sources during grinding are from the abrasive grain/workpiece interface and the shear plane between the workpiece and chip. White layers at the workpiece surface are considered detrimental to component performance, primarily in relation to either contact rolling fatigue or structural fatigue.

IV. Conclusion

From the experiment it was observed that the number of cutting pass influenced the morphology of surfaces generated. The surface roughness increase as the number of cutting pass increased. It has been found that there are significant differences in the thickness of the white layer compared between single pass with multi pass cutting. The contact time and time for heat conduction are much longer in multipass grinding, which makes high temperatures penetrate deep into the workpiece, resulting in a thick ground white layer.

Acknowledgment

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