Overview On The Influence Of Parameters On The Surface Hardness Of Workpiece In Grinding Process

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***Abstract*—This paper presents a overview on the influence of parameters on the surface hardness of parts in the grinding process. Analyzing a number of published studies on the survey of the influence of machining process parameters on the surface hardness of parts in the grinding process, which has been carried out in recent years. From that, we can identify the parameters that are often selected by the researchers as input parameters when conducting experimental studies on surface hardness. Based on that, the orientation for selecting the input parameters of the experimental process when surveying the surface hardness of parts in the grinding process is given.**

Keywords—comprehensive study, the surface hardness of parts in the grinding process, parameters influencing surface hardness.

I. INTRODUCTION

In mechanical processing, grinding is a commonly used method for processing parts that require high accuracy [1]. There are many different criteria to evaluate the efficiency of the grinding process. Technically, the parameters commonly selected as the criteria to evaluate the efficiency of the grinding process are surface roughness, surface hardness, residual stress of surface, etc. In particular, the surface hardness of machine parts has a great influence on the abrasion resistance, chemical corrosion resistance, thereby influencing the product's durability. Therefore this parameter is often chosen as one of the criteria to evaluate the grinding process [2]. The surface hardness of parts in the grinding process is influenced by many parameters, those parameters influence the surface hardness through the influence of cutting heat and cutting force. The surface of parts after grinding may have increased hardness, decreased hardness or be cracked or burnt, and so on [1, 2]. To survey the influence of technological parameters on the surface hardness in the grinding process, it is necessary to conduct experimental studies in each specific case. However, in each published study, the parameters selected as input parameters were not the same. This paper will conduct a comprehensive study on a number of published works to determine the parameters commonly used by the authors as input parameters when conducting experimental studies of surface hardness in the grinding process.

II. LITERATURE REVIEW

Zhao Tao et al. [3] conducted an experiment to survey the influence of parameters of machining process on surface hardness in the process of grinding Titanium alloy *(TI–6AL–4V)* with S_iC wheel. The parameters of machining process they mentioned in this study include the grain size of grinding wheel, the cutting speed, the feed rate and the depth of cut. The results of their study have shown that:

- All four parameters surveyed influence surface hardness with quite complex laws, when increasing the value of these parameters, the surface hardness tends to increase. However, if the value of these parameters continues to increase, the surface hardness decreases.

- The depth of cut has a greater influence on the surface hardness than the on the grain size of grinding wheel, the cutting speed and the feed rate. This problem has been explained by Zhao Tao et al. [3] that the change of the depth of cut will have a great influence on the cutting force, thereby influencing surface hardness.

Marcelo Oliveira Gomes et al. [4] conducted an experiment to survey the influence of cutting speed, feed rate and depth of cut on the surface hardness of parts during machining 52100 steel. The grinding wheel they used in this study was silicon carbide. From the study results, they came to the following conclusions:

- When the value of cutting speed increases, the surface hardness decreases. However, the degree of influence of cutting speed on the surface hardness is not much. When the cutting speed increases from 12 m/s to 16 m/s (about 33%), the surface hardness only changes by about 8%.

- When the value of the feed rate increases, the surface hardness increases. If the feed rate increase by 100% (from 0.54 m/min to 1.08 m/min), the surface hardness will increase by 162%.

- The depth of cut also has a significant influence on surface hardness. Surface hardness will increase 624% if the depth of cut increases 10 times (from 10 µm to 100µm).

Kamlesh Pa et al. [5] conducted an experiment to survey the influence of cutting speed, feed rate and depth of cut on the surface hardness of parts in the process of grinding steel with medium carbon steel EN-18. From the study results, they have identified:

- The cutting speed and depth of cut have a greater influence on the surface hardness than on the feed rate.

- When increasing the value of all three parameters, including the cutting speed, the feed rate and the depth of cut, the surface hardness increases.

Azhar Thanedar et al. [6] conducted an experiment to survey the influence of workpiece velocity, cutting speed, feed rate, balance of grinding wheel, flow of coolant solution and the feed rate when dressing wheel and grinding time until non-sparking on the surface hardness in process of grinding 38MnVS6 steel with CBN grinding wheel. They reached the following conclusions:

- Cutting speed is the parameter that has the most influence on the surface hardness, followed by the extent of the influence of the workpiece velocity and grinding time until non-sparking. Meanwhile, the feed rate, the balance of the wheel and the feed rate when dressing wheel have a negligible influence on the surface hardness.

- When increasing the value of cutting speed and workpiece velocity, the value of surface hardness will increase. Meanwhile, if the value of grinding time until non-sparking increases, the surface hardness will decrease.

Balwinder Singh et al. [7] conducted an experiment to survey the influence of cutting speed, feed rate, the pressure of coolant solution and tilt angle of the coolant injection nozzle on surface hardness in process of grinding medium carbon steel. From the results of the study, they came to the following conclusion: all four parameters surveyed, including cutting speed, feed rate, the pressure of coolant solution and tilt angle of the coolant injection nozzle has the influence on the surface hardness of parts. When the value of these parameters increases, value of surface hardness will increase.

Brockhoft [8] conducted a surface hardness survey when using 10A90QU3B grinding wheel to grind two types of materials, SAE4140 and SAE52100. In particular, SAE52100 steel has been used in three states: tempered, annealed and normalized, and SAE4140 steel is used only in tempered state. During the experiment, they used dry grinding. The results of his study have shown that:

- Surface hardness always tends to decrease from the machining surface to the depth of parts. However, the degree of hardness reduction in different materials is relatively different. Even for a material but in different states (tempered, annealed and normalized), the degree of hardness reduction from the outside to the inside of parts is different.

- When the two materials are used in tempered state, the hardness of SAE4140 steel is always smaller than that of SAE52100 steel.

- For SAE52100 steel, when considering the hardness of the metal part close to the machining surface, all three states of steel have equal hardness. When considering the hardness deep in the metal, the hardness of tempered steel is the highest, followed by the hardness of normalized steel, and finally the hardness of annealed steel. This is because the metal layer deep in parts is not influenced by cutting heat but only depends on its hardness during heat treatment.

Feng et al. [9] surveyed the influence of cutting speed, part speed and depth of cut on surface hardness when deep grinding W6Mo5Cr4V2 steel with CBN grinding wheel using by both calculation and experimental methods. Their study results identified:

- When increasing the cutting speed and the workpiece velocity, the surface hardness will increase. However, the influence of these two parameters on surface hardness is not much.

- If the cutting speed is 40 m/s, when increasing the depth of cut, the surface hardness tends to decrease. If the cutting speed is 60 m/s, the increase of the depth of cut will increase surface hardness. However, the degree of influence of depth of cut on surface hardness is negligible.

Guoqiang Yin et al. [10] conducted an experimental study of the influence of cutting speed and depth of cut on surface hardness in the process of grinding QT700 material with CBN grinding wheel. Their study results confirmed:

- When increasing cutting speed, the hardness of machining surface decreases, but the influence of cutting speed on hardness is not much.

- In all three cases of the value of cutting speed, the hardness at the outermost will always have the greatest value, the deeper the parts are grinded, the more the hardness decreases.

- When increasing the depth of cut, the surface hardness will increase. The influence of depth of cut on surface hardness is greater than that of cutting speed.

- When the depth of cut are 0.05 mm and 0.08 mm, the hardness will gradually decrease from the outside to the inside of the part. However, when the depth of cut is equal to 0.03 mm, the hardness of the parts machined along the depth of the material is quite complex, from the machining surface to the inner player of the part, the hardness will increase or decrease irregularly.

Wen-jian Wang et al. [11] surveyed the influence of the grain size of the grinding wheel on surface hardness in process of grinding U71Mn materials. The three types of grain sizes used in this study were

12 #, 16 # and 24 #. Their study results showed that: When using a grinding wheel with a grain size of 24 #, the hardness of the workpiece surface will have the greatest value. Next is the surface hardness when using a grain size of 16#, when using a 12 # grain, the surface hardness will have the smallest value.

Hamid Reza et al. [12] conducted an experiment to survey the influence of five parameters of the machining process on surface hardness in process of grinding AISI1045 steel with A60L5V10 grinding wheel. The five parameters they surveyed include the cutting speed, the feed rate, the depth of cut, the cross feed and the methods of dressing wheel (Fine, Medium and Coarse). The value of the parameters at the coding levels is presented in Table 1. From the research results, they came to the following conclusion:

Table 1. Values at levels of parameters [12]

Parameter	Unit	Coding level		
		1	2	3
Depth of cut	mm	0.01	0.02	0.03
Cutting speed	m/s	20	25	32
Workpiece velocity	m/min	5	10	15
Cross feed	mm/rev	1	5	10
Method of dressing	-	Fine	Medium	Course

- The depth of cut is the parameter influencing the surface hardness to the greatest extent, followed by the extent of the influence of the cutting speed and methods of dressing. The workpiece velocity and the cross feed have a negligible influence on hardness.

- When the depth of cut and the cutting speed increases, the surface hardness increases. And for methods of dressing, when dressing fine grinding wheel, surface hardness will be greatest, followed by the case of dressing medium grinding wheel. If course grinding wheel is dressed, the surface of the part machined will have the smallest hardness.

Xiaoliang Shi et al. [13] surveyed the influence of the depth of cut, feed rate and flow of coolant solution on surface hardness in the process of grinding 1045 steel. Their study results reached the following conclusions: When the workpiece velocity and the depth of cut increase, the surface hardness increases. Meanwhile, the increase in the flow of coolant solution will decrease surface hardness.

Kipkurui et al. [14] surveyed the influence of coolant solution, cooling method and depth of cut on surface hardness in process of grinding Ti-6Al-4V alloy with WA80M5V grinding wheel. The three types of coolant solutions used in this study include sunflower oil (SO), sunflower oil-based emulsion (SOBE) and soluble cutting oil (SCO). In addition, the three cooling methods used are wet grinding with a flow of 72 liters/hour, grinding with minimum quantity lubrication (MQL1), corresponding to a flow of 0.57 liters/hour and grinding with minimum quantity lubrication (MQL2), corresponding to a flow of 0.65 liters/hour. Their study results are as follows:

- All three parameters of type of coolant oil, cooling method and depth of cut have a great influence on surface hardness.

- When using SO, surface hardness will have the highest value, while using SCO, surface hardness will have the lowest value.

- When using a coolant solution with a flow of 72 liters/ hour (Wet), the surface hardness will have the smallest value. When using a coolant solution with a flow of 0.65 liters/ hour (MQL2), the surface hardness is greater when using a coolant solution with a flow of 0.57 liters/hour (MQL1).

- When increasing the depth of cut, the surface hardness will decrease.

Heinzel et al. [15] in an experimental study determined the influence of specific material removal and depth of cut on surface hardness in process of grinding 42CrMo4 steel with A801L5B grinding wheel. From the study results, they made the following comments:

- If processing with specific material removal with the value of 0.3 mm^3/(mm.s) and 1 mm^3/(mm.s), the surface hardness has very close values. Hardness will increase if the value of specific material removal is increased. However, the influence of specific material removal on surface hardness is quite complex, comparing the two cases on the value of specific material removal (3 mm^3/(mm.s) and 8 mm^3/(mm.s)) at different depth values, the surface hardness will increase and decrease irregularly.

- When specific material removal has a value of 0.3 mm^3/(mm.s) and 1 mm^3/(mm.s), the depth of cut has a negligible influence on surface hardness.

- When specific material removal has a value of 3 mm^3/(mm.s) and 8 mm^3/(mm.s), the surface hardness will increase when the depth of cut increases from 0.02mm to 0.2mm. When the depth of cut is between 0.2mm to 1mm, the surface hardness is almost unchanged. If the depth of cut continues to increase, the surface hardness will decrease.

III. CONCLUSION

A comprehensive study of a number of published works on surface hardness survey of parts in the grinding process shows that there are many factors influencing surface hardness, such as parameters of cutting parameters, grinding wheel, cooling and lubrication mode and machined materials and so on. Published studies are usually conducted according to the experimental method. However, with a large number of parameters that influence surface hardness with different degrees and rules, it is difficult to consider all of these parameters within a study. The above comprehensive studies also show that the parameters of cutting parameters and grinding wheel are often chosen by scientists as the input parameters of the experimental process. The number of studies referring to these two groups of parameters accounts for a large proportion of the published studies. However, in each published study, the influence of parameters of cutting parameters and grinding wheel on surface hardness is different in each specific condition. Therefore, in order to have a basis for controlling the surface hardness of parts in grinding process in each specific case, it is advisable to survey the influence of parameters of cutting parameters and grinding wheel on surface hardness.

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