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Comprehensive Study of Surface Roughness of Workpiece When Surface Milling Using a Face Milling Cutter

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Abstract-This paper presents a comprehensive study of the surface roughness of workpiece when surface milling using a face milling cutter. Analyzing nearly forty studies on the survey of the influence of machining process parameters on surface roughness in the milling process, which have been conducted in recent years. From that, we can identify the parameters that are often selected by the studyers as input parameters when conducting experimental studies on surface roughness. Based on that, the orientation for selecting the input parameters of the experimental process when study on the surface roughness of workpiece in the milling process is given.

Keywords- *Comprehensive Study, Parameters Influencing Surface Roughness, Surface Roughness, Surface Milling Using a Face Milling Cutter*

I. INTRODUCTION

Surface milling with a face milling cutter is known to be one of the most efficient machining methods for plane machining [1]. Besides the ability to ensure high productivity during machining, this method can also machine surfaces with small roughness, ensuring the required surface roughness of workpieces in certain circumstances. However, the control of the technological system to machine the surface of surface workpiece with small roughness is highly dependent on the value of the parameters that greatly influence the surface roughness. To determine the parameters influencing surface roughness, studies are usually conducted through empirical study. However, in each of the studies, the parameters selected as the input parameters were not the same. In this paper, a comprehensive study of some published works will be carried out to identify the parameters commonly used by the authors as input parameters when conducting empirical studies on surface roughness when surface milling by a face milling cutter.

II. LITERATURE REVIEW

Hayajneh et al. [2] conducted an experiment to survey the influence of cutting parameters, including cutting velocity, feed rate and depth of cut on surface roughness. From the experimental results, they conclude: The feed rate has the greatest influence on surface roughness, followed by the degree of influence of the cutting velocity. The influence of depth of cut on surface roughness is smaller than the influence of feed rate and cutting velocity. Regarding the interaction between parameters: the interaction between the feed rate and the depth of cut has the strongest influence on surface roughness, followed by the degree of interaction between the cutting velocity and the feed rate. The interaction between the cutting velocity and the depth of cut does not significantly influence surface roughness.

Kadirgama et al. [3] when conducted an experiment to survey the influence of cutting velocity, feed rate and depth of cut on surface roughness when milling Hastelloy C-22HS corrosion resistance alloy with PVD TiN/ iCN/Al2O3-coated milling cutter show that the feed rate has the greatest influence on surface roughness, followed by the influence of the depth of cut, the cutting velocity has a negligible influence on surface roughness.

Ladislav et al. [4] studied the influence of milling cutter diameter, cutting velocity, feed rate and depth of cut on surface roughness when milling E295 steel. The results of their study show that the feed rate is the parameter having the greatest influence on surface roughness, followed by the influence of the depth of cut. Meanwhile, milling cutter diameter and cutting velocity have negligible influence on surface roughness.

Hasan Gökkaya [5] when experimenting with AA2014 (T4) alloy milling concluded: the feed rate has a significant influence on the surface roughness, while the cutting velocity has a negligible influence on surface roughness. When increasing the value of the feed rate, the surface roughness will increase. Meanwhile, the law of influence of cutting velocity on roughness is quite complicated. When increasing the value of cutting velocity, the value of surface roughness may increase or reduce.

Basim et al. [6] conducted an experiment to survey the influence of the nose radius on the surface roughness when milling nickel based hastelloy (276). The three types of nose radius used in this study are 0.4mm, 0.8mm and 1.2mm respectively. The results of their study indicate that the nose radius has a significant influence on the surface roughness of the surface workpiece. When increasing the value of the nose radius, the surface roughness will decrease.

Dražen Bajić et al. [7] conducted an experiment on 42CrMo4 steel milling with TiN-coated cutting tools. After analyzing the experimental results, they made the comments: the cutting velocity has not much influence on the surface roughness. As for the feed rate, when machining with a fixed depth of cut, the influence of the feed rate on surface roughness is greater when machining with a variable depth of cut.

Jignesh et al. [8] studied the influence of cutting velocity, feed rate and depth of cut on the surface roughness when milling MS material with a carbide-coated tool determine: the feed rate is a parameter that greatly affects the surface roughness, when the feed rate increase, the surface roughness also increase. Meanwhile, the cutting velocity and depth of cut have negligible influence on surface roughness.

Okokpujie Imhade et al. [9] conducted an experiment on 6061 aluminum alloy milling under the condition of Minimum Quantity Lubrication (MQL) with a high speed steel cutter and made the following comments: The interaction between the cutting velocity and the feed rate has a great influence on the surface roughness. The influence of cutting velocity on surface roughness is greater than the influence of the feed rate. In addition, Okokpujie Imhade et al. [11] also asserted that depth of cut has a negligible influence on surface roughness.

Pathak et al. [10] studied the two-alloy milling process Al-1Fe-1V-1Si and Al-2Fe-1V-1Si to determine the influence of cutting parameters on surface roughness. Their study results show that: All three parameters of the cutting including depth of cut, cutting velocity and feed rate have almost negligible influence on surface roughness when milling 1Fe-1V-1Si alloy. When milling Al-2Fe-1V-1Si alloy, the parameters of the cutting have a great influence on the Rz. But for Ra, the cutting parameters have a negligible influence.

Avinash [11] investigated the influence of coolant flow rate, cutting velocity, feed rate and depth of cut on surface roughness when milling AISI 1040 MS. Their study show that the flow of coolant is the parameter having the most influence on surface roughness, followed by the influence of the depth of cut, the cutting velocity and the feed rate have a negligible influence on surface roughness.

Roshani et al. [12] investigated the influence of cutting velocity, feed rate and reverse feed rate on surface roughness when using a milling cutter to machine (drill) holes in SAE D7003 cast iron material. The milling cutters coated with K20 cemented carbide were used in this study. The results of their study determine that the cutting velocity and the feed rate have a significant influence on the surface roughness, when increasing the cutting velocity, the surface roughness will decrease. Meanwhile, if the value of the feed rate increases, the surface roughness will increase. The reverse feed rate has a negligible influence on surface roughness.

Goutam Devaraya Revankar et al. [13] carried out an experiment on milling Titanium alloy with cutting tool material of Polycrystalline diamond. The five parameters selected as the input parameters of the testing process include: cooling method (Floor, MQL and Dry), cutting velocity, feed rate, nose radius and depth of cut. Their study shows that the cooling method has a great influence on the surface roughness. When machining by MQL method, the surface roughness will be smaller when machining by Floor and Dry method. Cutting velocity, feed rate and nose radius also have a great influence on surface roughness. Surface roughness will decrease if the values of cutting velocity and nose radius increase. Meanwhile, the increase of the value of the feed rate and the depth of cut will increase the value of surface roughness.

Nguyen Thanh Binh et al. [14] studied SKD11 steel milling, from the results of their experiments, they concluded: when the feed rate and the depth of cut increase, the surface roughness increase. However, the influence of depth of cut on surface roughness is smaller than that of feed rate and cutting velocity. This was explained by them as follows: when high speed milling, the cutting force is smaller than normal milling, the influence of depth of cut on surface roughness is mainly due to deformation. As the cutting velocity increases, the surface roughness decreases.

Changfeng Yao et al. [15] experimented to determine the influence of cutting velocity, feed rate and depth of cut on the surface roughness of workpiece in the process of high-speed milling of 7075 aluminum alloy concluded that: when increasing cutting velocity, the surface roughness tends to decrease, but the influence of cutting velocity on surface roughness is not much. The feed rate has a significant influence on the surface roughness, as the value of the feed rate increases, the surface roughness will increase rapidly. Depth of cut has a negligible influence on surface roughness.

Ugochukwu et al. [16] experimentally investigated the influence of spindle speed, feed rate and depth of cut on surface roughness when milling 6061 aluminum alloy in two cases, dry machining and machining by MQL method. The results of their experiment show that: when using the MQL machining method, the surface roughness is always about 20% smaller than that when dry machining. The cutting velocity and feed rate have a great influence on the surface roughness. When increasing the cutting velocity and reducing the value of the feed rate, the surface roughness will decrease. Meanwhile the influence of depth of cut on surface roughness is negligible. The interaction between the cutting velocity and the feed rate also has a significant influence on the surface roughness, the interaction between the depth of cut and the remaining two parameters has a negligible influence on the surface roughness.

Waseem Akhtar et al. [17] used the PVD-TiAlN-coated milling cutter to examine the influence of cutting velocity, feed rate and depth of cut on surface roughness when milling GH4169 material (equivalent of Inconel 718). The results of their study show that all three parameters of the cutting parameters had a significant influence on the surface roughness. For surface roughness to have a small value, it is recommended to choose the value of three cutting parameters at the average.

Murat Sarýkaya et al. [18] studied the influence of cutting velocity, feed rate and number of cutter (number of cutters from 1 to 6) on surface roughness when milling AISI D3. The type of cutters used in this study was SEMT13T3AGSN-JM. The results of their study show that the number of cutters of cutting tools is the parameter that has the greatest influence on surface roughness, the increase of the number of cutters will cause the rapid increase of surface roughness. The feed rate also has a significant influence on surface roughness, the increase of the value of the feed rate will increase the value of the surface roughness. Cutting velocity is a parameter that affects the surface roughness to a lesser degree than the influence of the number of cutters and the feed rate. As the value of the cutting velocity increases, the surface roughness will increase but at a slow rate.

Huu-That Nguyen et al. [19] studied on the influence of cutting parameters and hardness of machining materials on surface roughness when milling SKD61 steel with a milling cutter with TiAlN-coated cut pieces. The parameters of the cutting parameters surveyed in their study included the cutting velocity, the feed rate and the depth of cut. After analyzing the experimental results, they made the following remarks: all three parameters of the cutting parameters, including the cutting velocity, the feed rate, the depth of cut and the hardness of the machining material have a significant influence on surface roughness. The interaction between the cutting velocity and the depth of cut, the interaction between the feed rate and the depth of cut, the interaction between the feed rate and the hardness of the machined material have a significant influence on the surface roughness. The interaction between the cutting velocity and the feed rate, the interaction between the cutting velocity and the hardness of the machined material, the interaction between the depth of cut and the hardness of the machined material have a negligible influence on the roughness surface.

Muhammmad Yasir et al. [20] investigated the influence of cutting velocity and feed rate on surface roughness when milling AISI 316L SS steel. Their study concluded: both the feed rate and the cutting velocity have a significant influence on the surface roughness. In particular, the influence of the feed rate on the surface roughness is greater than the influence of the cutting velocity. The law of influence of the feed rate and the depth of cut on surface roughness is quite complicated. When increasing the value of these two parameters, the value of surface roughness may increase or decrease.

Pham Thi Hoa et al. [21] experimented the process of A6061 aluminum alloy milling with a milling cutter with hard APMT1604PDTR TC300 alloy cut pieces made the following comments: when changing the cutting velocity in the speed range from 356 m/min to 659 m/min in the constant cutting conditions, the surface roughness decreases. As the feed rate and depth of cut increases, the surface roughness increases.

Bapi Sarkar et al. [22] studied the influence of the cutting velocity, the feed rate and the depth of cut on the surface roughness when milling Inconel 718. The cutting tool they used in this study was a VC--8MH-coated milling cutter, and the two milling methods used were dry milling and wet milling. The results of their study show that: in both dry milling and wet milling cases, the surface roughness was equal. Also in both cases, the depth of cut has a great influence on the surface roughness. Meanwhile, the cutting velocity and the feed rate have a negligible effect on the surface roughness.

Muhammmad Yasir et al. [23] conducted an experiment to investigate the influence of the cutting velocity and the feed rate on surface roughness when milling AISI 316L (316L stainless steel). The 5mm-diameter milling cutters coated with WC material were used in this study. The results of their study determine that the feed rate has a great influence on the surface roughness, the surface roughness will increase if the value of the feed rate increases. Meanwhile, cutting velocity has very little influence on surface roughness.

Oosthuizen et al. [24] investigated the influence of cutting velocity, feed rate and depth of cut on the surface roughness when milling TI6AL4V alloy. The cutting tool used in this study was the VP15TF-coated milling cutter. The results of their study show that the increase of the value of cutting velocity will reduce the surface roughness. Meanwhile, the increase of the value of the feed rate will increase the surface roughness. Depth of cut has a negligible influence on surface roughness.

Jagannadha Raju et al. [25] investigated the influence of cutting velocity, feed rate and depth of cut on surface roughness when milling two types of 6063 and A380 aluminum alloys. Their study determines: for both types of aluminum alloys used, the depth of cut is the parameter that has the greatest influence on surface roughness, followed by the influence of the feed rate, cutting velocity is the parameter having the least influence on the surface roughness. Increasing the value of the cutting parameters, the value of the surface roughness will increase.

Sanya Kumjing [26] investigated the influence of the cutting velocity, the feed rate and the depth of cut on the surface roughness when milling two materials, AISI-P20 and AISI-1050. HSS-AL-coated cutting tools were used in this study. His study shows that, for both machining materials, the cutting velocity, feed rate and depth of cut have a significant influence on surface roughness.

Erol Kilickap et al. [27] studied milling Ti-6242S, they concluded that all three cutting parameters including feed rate, cutting velocity and depth of cut had a significant influence on surface roughness. If increasing the value of the feed rate and the depth of cut, the surface roughness will increase. Conversely, surface roughness will decrease if the value of the cutting velocity increases.

Emel Kuram [28] investigated the influence of the nose radius on the surface roughness when milling AISI 304 steel. The three values of the nose radius used in this study had a value of 0.4mm, 0.8mm and 1.2mm respectively. The results of his study show that the increase of the value of the nose radius would reduce the value of surface roughness. Explaining this problem, Emel Kuram said that when the nose radius is large, the contact length between the cutter and the machining surface increases causing the decrease of the depth of the cut, so the surface roughness decreases.

Tomadi et al. [29] studied the influence of cutting velocity, feed rate, depth of cut and type of cutting tool material (PVD

TiAlN-coated and -uncoated cutting tools) on surface roughness when milling AlSi/AlN alloys. Their study determines: when machining with PVD TiAlN-coated cutting tools, the surface roughness is much greater than that withPVD TiAlN-uncoated cutting tools. For both types of cutting tool materials: the depth of cut has a great influence on the surface roughness, followed by the influence of the feed rate. Cutting velocity has almost no influence on surface roughness.

Sathyamoorthy et al. [30] experimented to examine the influence of cutting velocity, feed rate and depth of cut on surface roughness when machining Magnesium AM60 Alloy. The TiN-coated milling cutter with a diameter of 10mm was used in this study. The results of their study indicate that the feed rate and depth of cut are two parameters that significantly affect surface roughness. In which the influence of the feed rate on the surface roughness is greater than the influence of the depth of cut. The increase of the value of the feed rate and the depth of cut increases the surface roughness. Cutting velocity has negligible influence on surface roughness.

Prasadraju et al. [31] when studying the influence of cutting velocity, feed rate and depth of cut on surface roughness when milling AISI 304 concluded that all three cutting mode parameters have a significant influence on the surface roughness. Of which, the depth of cut has the greatest influence on the surface roughness, followed by the influence of the feed rate, the cutting velocity is the parameter that has the least influence on surface roughness compared to the other two parameters of the cutting parameters.

Luis Wilfredo Hernández-González et al. [32] investigated the influence of cutting mode parameters on surface roughness when milling AISI 304 steel. Two cutting parameters mentioned in this study include cutting velocity and feed rate. From the empirical data, they came to the conclusion: both the cutting velocity and the feed rate greatly influence the surface roughness. In which the influence of the cutting velocity on the surface roughness is greater than the influence of the feed rate.

Maohua Xiao et al. [33] studied the influence of cutting velocity, depth of cut and feed rate on surface roughness when milling 1Cr18Ni9Ti stainless steel. The 41305A carbide-coated cutting tool was used in this study. The results of their study determine: all three parameters investigated have a significant influence on the surface roughness, in which the feed rate is the parameter that has the greatest influence on surface roughness, followed by the influence of the depth of cut and the cutting velocity.

Tien Dung Hoang et al. [34] when studying SKD61 steel milling concluded that the feed rate is the parameter that has the most influence on surface roughness. When reducing the feed rate, increasing the cutting velocity from 0 to 130 mm/min and increasing the depth of cut from 0 to 0.3mm, the surface roughness will decrease.

Ireneusz Zagórski et al. [35] investigated the influence of cutting velocity, feed rate and depth of cut on surface roughness when milling AZ91D Magnesium alloy with TiAlN-coated cutting tool. Their study shows that only the feed rate has a significant influence on the surface roughness, while the cutting velocity and depth of cut have a negligible influence on the surface roughness.

Om Prakash Singh et al. [36] experimented to investigate the influence of the feed rate, depth of cut and cutting velocity on surface roughness when milling AA6063 T6 aluminum alloy in two cases, dry and wet machining. The cutting tools used were 12mm in diameter and coated with carbide. Their study determine: the feed rate is the parameter that has the most influence on the surface roughness, followed by the influence of the depth of cut, the cutting velocity is the parameter having the third greatest influence on the surface roughness. Surface roughness is almost uninfluenced by the use of a coolant solution or not.

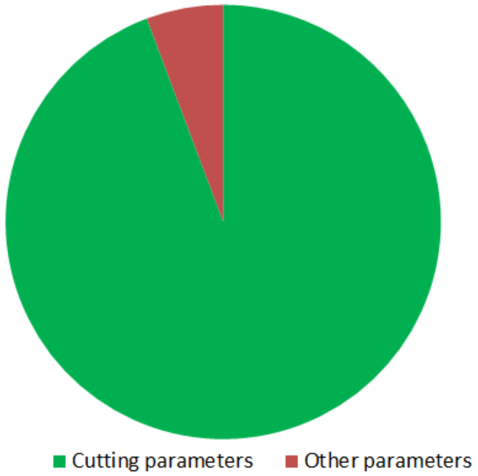

Figure 1. Rate of studies by input parameters

The comprehensive study of 35 recently published works (from study [2] to [36]) on surface roughness of workpiece when surface milling by a face milling cutter shows that: Up to 33 of these studies selected the cutting parameters as input parameters when doing experimental study. Only two studies did not select the cutting parameters as the input parameters (studies [6] and [28]). From that, it is shown that the rate of studies that selected the cutting parameters as input parameters accounted for about 94% (Figure 1).

III. CONCLUSION

Through the general analysis of the studies when investigating the surface roughness of the workpiece when surface milling by a face milling cutter, there are many parameters influencing the surface roughness such as cutting parameters, cutting tool parameters, cooling technology parameters, etc. In particular, the cutting parameters including cutting velocity, feed rate and depth of cut were used by many authors as the input parameters in their study. However, in each specific machining condition, the degree and law of influence of cutting parameters on surface roughness are different. Therefore, in order to determine the influence of cutting parameters on surface roughness, it is necessary to conduct study in each specific case. The results of each study are the basis for selecting cutting parameters to ensure the surface roughness of workpiece meets specific requirements.

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