International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 11 Issue 6 ǁ June 2023 ǁ PP. 239-244

Effects of the cutting parameters on flank wear during Slide Milling Process Using Nanofluid

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Abstract
Nanofluids made by mixing the nanoparticles with the cutting fluid can be applied in the maching process to reduce the tool wear. In this study, the influence of cutting parameters on the flank wear in the groove milling process using nanofluids is studied. Research results show that the amount of flank wear is significantly reduced when using a lubricating oil mixed with nanoparticles. A Taguchi experimental model is proposed and shows that the cutting speed and nanoparticle concentration are the factors that greatly affect the amount of flank wear. In this research, the flank wear reaches the minimum value with the technological parameter set: cutting speed V=25m/min, NC=0.2 %. The influence of the survey parameters on the S/N ratio of the flank wear value is also analyzied. The S/N ratio of the flank wear was greatest when using a cutting speed of 25 m/min and mixing the cooling lubricating oil with 0.2% Al_2O_3-80 nm nanopowder.

Keywords:*Milling, nanofluid, flank wear, Taguchi*

Date of Submission: 04-06-2023 Date of acceptance: 17-06-2023

I. INTRODUCTION

The slide milling process is one of the processes to machine the grooves in many parts. In the groove milling process, a slide tool is used to remove material of workpieces with three cutting edges. Thus, the machining processes cause high cutting forces and friction on the cutting tool and high temperature as well [1]. Those factors lead to the reduction of the surface quality, and tool life, so using an appropriate cooling lubricant is very important. In recent years, the nanofluid made by adding the nanoparticles (MoS2, WS2, Al2O3, …) into the normal cutting oil has been studied to apply on many machining processes [2]. Many researchers indicated that applying nanofluids on the machining process can reduce cutting force, temperature, improving surface finish, and decreasing tool wear in the machining process [2]. In recent studies, Ahmed reported that new nanofluids made by mixing SiO2 the normal oil exhibits the promising were applied on the machining process to reduce the friction and cutting force compared to the normal lubrication [3]. The research of Vasu showed that the Al2O3 nanoparticles have many properties consistent with adding to the industrial oils [4]. In 2009, Malkin studied the applying nanofluid (mixing the Al2O3 nanoparticles with water) on the grinding process to decrease the cutting forces, the cutting temperature and the surface roughness [5]. Khalil studied the effects of the parameters of cutting fluid added MoS2 nanoparticles on the force, temperature and surface roughness in CNC milling of aluminum alloy [6]. M. Amrita added nano graphite into water SO and studied their effects on cutting forces, temperature, tool wear and roughness of machined surface [7]. Roja Abraham studied the applying Multi-Walled Carbon Nano Tubes suspended in water and sodium dodecyl sulfate surfactant on the turning process to reduce the surface roughness, tool wear and cutting forces [8]. But, the effect of Al_2O_3 nanoparticle concentration that mixed with cutting fluids in slide milling proccess has not been published yet.

This research investigates applying the cutting fluids mixed nanoparticle Al_2O_3 to reduce the tool wear in the slide milling process. The effects of the cutting parameters and interactions between them to the flank wear in this process were analyzed by the Taguchi model.

II. EXPERIMENT AND METHOD

The machining process uses a slide milling tool with the three cutting edges made by HSS material having hardeness 65HRC in the horizontal milling machine, as figure 1. The workpieces were made by C45 steel. The cutting depth and feed rate are selected as the same conditions of the slide milling process used in the machining Company at Viet Nam. And the cutting speed was varied in the range from 25 m/min to 35 m/min.

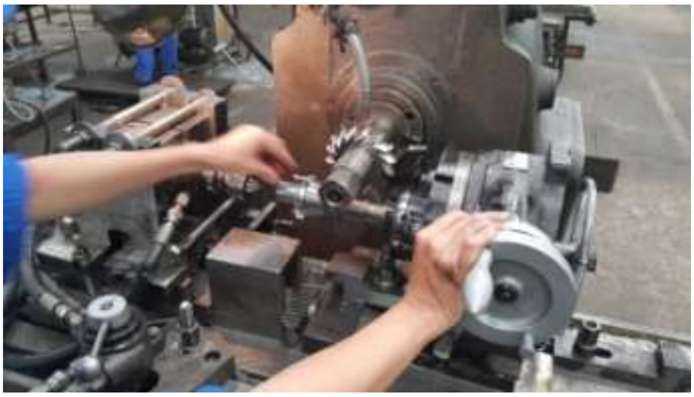

Figure 1. Experiment setup

Depending on the actual machining process, the ISO BW Cool EX-8500V cutting oil was widely used for the slide milling process due to its economical characteristics. In this research, the Al_2O_3 nanoparticles made by US Research Nanomaterials is added to the normal cutting oil. The Al_2O_3 nanoparticle with the size of 80nm was selected in order to determine the optimize cutting condition for the slide milling process using the nanofluid. The nanoparticle concentration is 0 %, 0.2% and 0.4%.

With the purpose of investigating the influence of technological parameters on the tool wearin slide milling processs using HSS tool made in Viet Nam, the experiment to select survey parameters including: nanoparticle concentration and cutting speed with survey values as shown in Table 1.

Table 1.Cutting parameters and level

No.	**Input parameters**	**Symbols**	**Level**		
			1	**2**	**3**
1	Cutting speed -V (m/min)	A	25	30	35
2	Nanoparticle concentration -NC (%)	B	0	0,2	0,4

Minitab 19 Software (Minitab Inc., USA) is applied to build experimental model for this research. A Taguchi model L9 was designed with 2 input parameters and three levels as table 2. The flank wear width is measured after cutting the 10 parts and shown in table 3.

Table 2. Experimental model L9

No.	**A**	**B**
1	1	1
2	1	2
3	1	3
4	2	1
5	2	2
6	2	3
7	3	1
8	3	2
9	3	3

Table 3. The experimental results and the S/N ratios for the flank wear

No.	**NC (%)**	**V (m/min)**	**VB (µm)**	**S/N-VB**
1	0.0	25	90.00000	-39.0849
2	0.0	30	95.00000	-39.5545
3	0.0	35	118.33333	-41.4621

4	0.2	25	41.66667	-32.3958
5	0.2	30	45.00000	-33.0643
6	0.2	35	46.66667	-33.3801
7	0.4	25	51.66667	-34.2642
8	0.4	30	61.66667	-35.8010
9	0.4	35	63.33333	-36.0326

III. RESULT AND DISCUSSION

Analysis of variance for the flank wear value with a 95.6% confidence interval was performed using Minitab software. The analysis results show that the average value of the flank wear amount corresponds to different levels with each survey parameter and the order of influence of the parameters on the flank wear amount is shown in table 4. The analysis results show that among the surveyed parameters, the nanoparticle concentration is the parameter that has the most decisive influence on the average value of the flank wear.

Table 4. Response Table for Means

Level	NC (%)	V (m/min)
1	101.11	61.11
2	44.44	67.22
3	58.89	76.11
Delta	56.67	15.00
Rank	1	2

The influence of the survey parameters and their interaction on the amount of flank wear is shown in Figures 2 and 3. Through the graph, the influence of the input parameters on the flank wear is analyzed and evaluated.When increasing the cutting speed from 25 m/min to 35 m/min, the average value of flank wear increased from 61.11 µm to 76.11 µm. Thus, with a low cutting speed range, when increasing the cutting speed, the cutting force tends to increase gradually increasing the amount of flank wear.

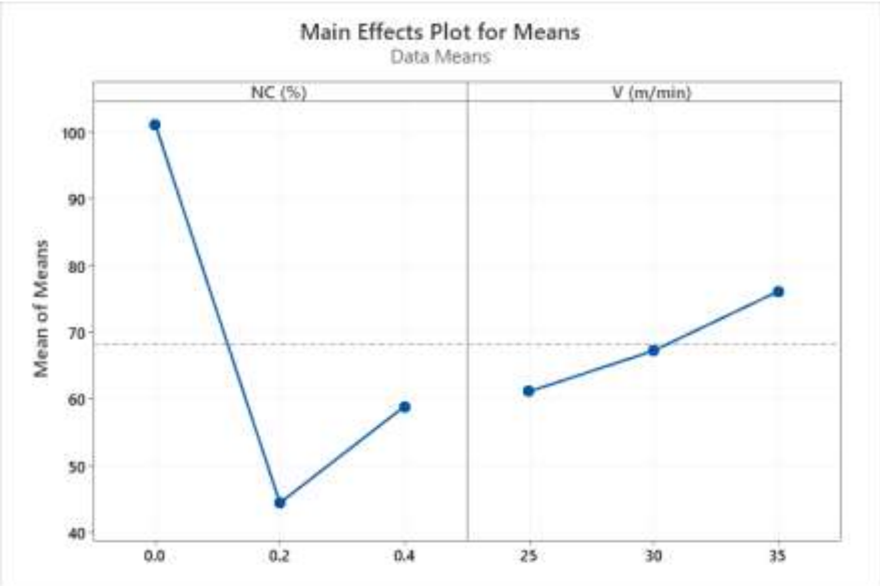

Figure 2. Effects of input parameters on the average value of flank wear

Observing the graph, it was found that, when increasing the percentage of Al2O3 nanopowder mixed into the oil, the average value of the flank wear decreased and reached the smallest value when the powder ratio was 0.4%. The reason is that when the powder ratio increases, the number of Al2O3 nanoparticles on the contact surface increases (contact between the chip and the front or the contact between the rear and part), reducing friction, increasing the ability to chip removal and, as a result, reduced cutting forces, reducing the flank wear of the cutting tool. Al2O3 nanoparticles have a spherical shape, capable of reducing friction while increasing heat transfer leading to a reduction in the energy required for chip removal, thus reducing cutting force and reducing tool wear. When the nanoparticle is mixed, an oil layer and thousands of spherical nanoparticles are formed in the friction contact area, allowing the chip to escape easily and thereby reducing the wear of the milling cutter. However, the value of flank wear after milling increased as the percentage of Al2O3 nanoparticles mixed into the cooling lubricating oil continued to increase to 0.4%. When the powder ratio is large, it can cause deposition, the nanoparticles will clump and cause scratching, leading to wear of the cutting tool.

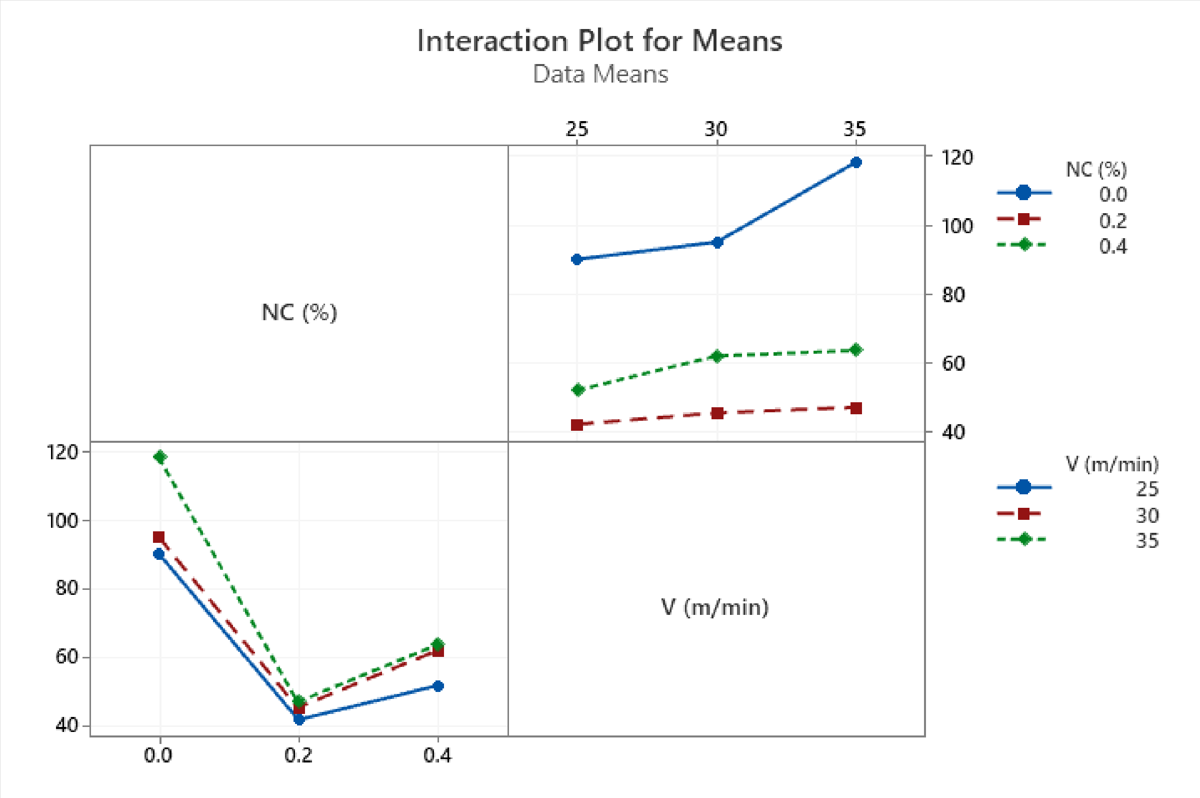

Figure 3. Interaction effect of cutting parameters on the amount of flank wear

Taguchi analysis also allows us to evaluate the influence of the interaction between the survey parameters on the average value of back wear, as shown in Figure 3. It can be seen that the interaction between cutting speed and powder ratio has little influence on the flank wear of the milling cutter. With a cutting speed of 35 m/min, the nanoparticle concentration has the greatest influence on the flank wear. without nanoparticles, the cutting speed has a strong influence on the flank wear amount, but when mixing the nanoparticles, the cutting speed has a small influence on the flank wear amount. The amount of flank wear was minimal when using a cutting speed of 25 m/min and mixing nanofluids with 0.2% Al2O3-80nm nanopowder.

Analysis of variance for signal-to-noise ratio S/N calculated for back wear with over 95% confidence intervals determined using Minitab software. The analysis results show that the signal-to-noise ratio calculated for the amount of flank wear with different levels for each survey parameter and the order of influence of the parameters on the value of the S/N ratio of the flank wear, shown in Figure 4. The analysis results show that among the survey parameters, the powder ratio is the parameter that has the strongest influence on the S/N ratio of the flank wear.

Table 5. Response Table for Signal to Noise Ratios

Smaller is better		
Level	NC (%)	V (m/min)
1	-40.03	-35.25
2	-32.95	-36.14

3	-35.37	-36.96
Delta	7.09	1.71
Rank	1	2

The influence of the survey parameters on the S/N ratio of the flank wear value is shown in Figure 4. The results show that the S/N ratio increases rapidly when increasing the nanoparticle ratio to 0.2 % and there was a slight decrease when it continued to increase to 0.4%. As the cutting speed decreases, the S/N ratio for the flank wear increases. Figure 5 depicts the interactive effect of the survey parameters on the S/N ratio of the flank wear. The results also show that the interaction between cutting speed and powder ratio has little influence on the S/N ratio. When not mixing the powder, the cutting speed has a strong influence on the S/N ratio of the flank wear, but when mixing the powder, the cutting speed has a small influence on the flank wear. The S/N ratio of the flank wear was greatest when using a cutting speed of 25 m/min and mixing the cooling lubricating oil with 0.2% Al2O3-80 nm nanopowder.

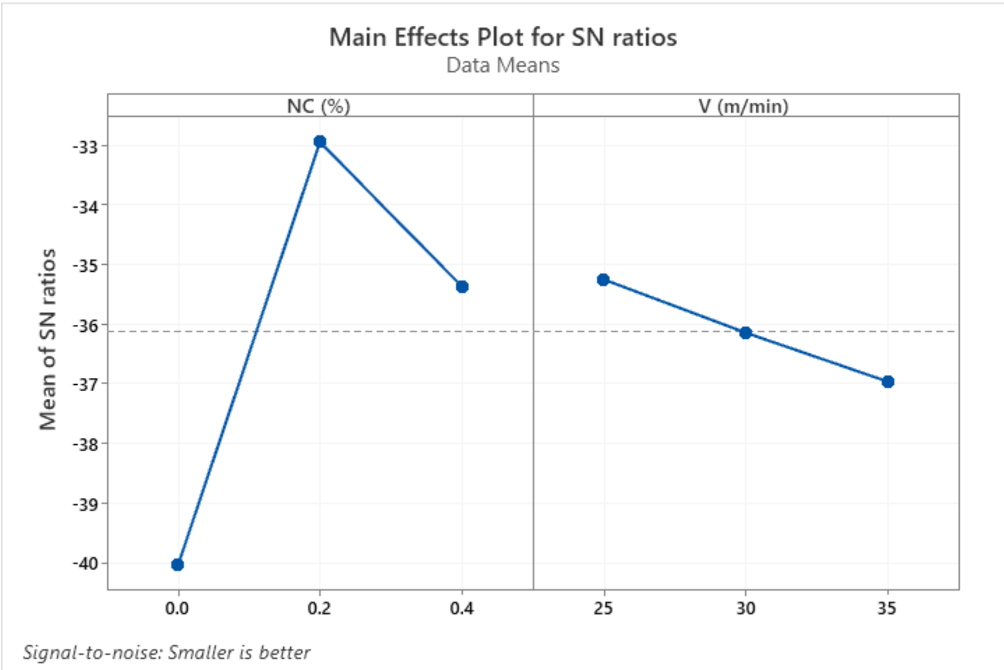

Figure 4. Influence of cutting parameters on the S/N ratio for the flank wear

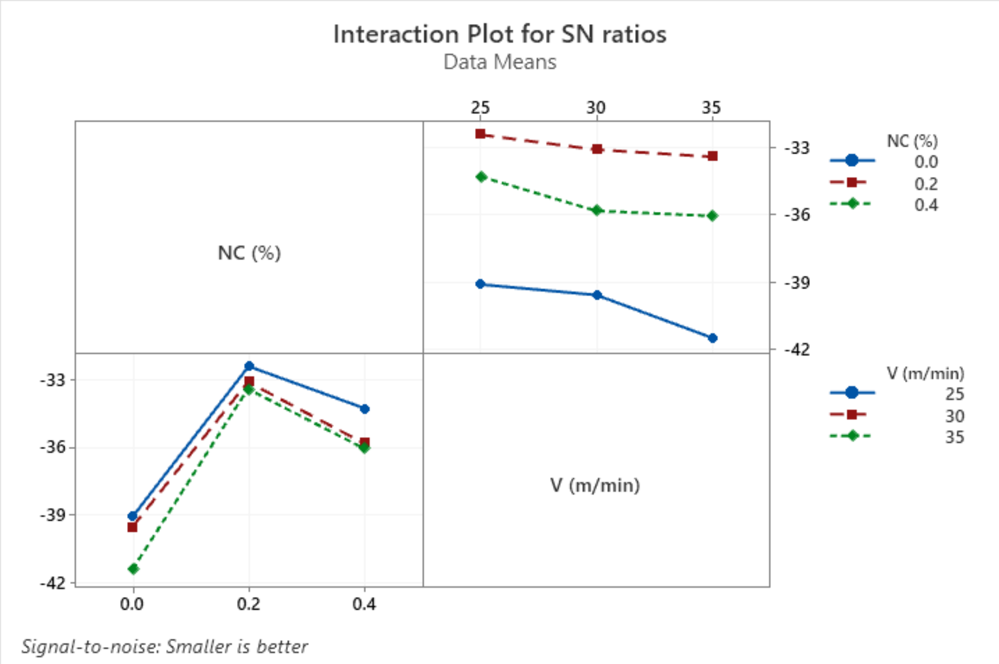

Figure 5. Interaction effect of cutting parameters on the flank wear

IV. CONCLUSION

An experimental Taguchi model was used to study the influence of cutting speed, and nanoparticle concentration on the flank wear in the slide milling process. The researched results indicated that the nanoparticle concentration is the strongest influence parameter on the flank. In this research, the flank wear reaches the minimum value with the technological parameter set: cutting speed V=25m/min, NC=0.2 %.The influence of the survey parameters on the S/N ratio of the flank wear value is also analyzied. The S/N ratio of the flank wear was greatest when using a cutting speed of 25 m/min and mixing the cooling lubricating oil with 0.2% Al_2O_3-80 nm nanopowder.

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