POLBAN

Design and Implementation of Fan Chips as Cooling for Milling Process on Aluminum Alloy 5086 to Increase Tool Life

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ABSTRACT

In the metal machining process, especially in the milling process, the parameters that affect the quality milling process results are cooling media because it affects the tool life used. This paper aims to determine the performance of using fan chips as the coolant in the dry milling process area. The method used is the computational fluid dynamic (CFD) method and the experimental milling process on a workpiece made from aluminum alloy 5086. In experimental testing using a variation of the milling machine spindle rotation. The simulation test results on the fluid flow character on fan chips with a protector producing a central character with a small area. In contrast, fan chips without a protector make a central character with a broader area. The wind speed data in simulation testing and experimental testing produced the same trend graph. The results of the performance of fan chips after experimented with variations in spindle rotation, cooling process on area occurs when the motor spindle rotates above 1120 Rpm on the fan chips with a protector, and the engine spindle rotates above 770 Rpm on the fan chips without a protector. The effect of fan chips on tool life affects increasing tool life by 8 minutes on installing fan chips with a protector and increasing tool life by 12 minutes on installing fan chips without a protector.

INTRODUCTION

Technology development in the manufacturing industry continues to be carried out to maximize product productivity and reduce production costs (Berenji et al., 2019). There is a machining process in the manufacturing industry, and one of the machining processes carried out in the manufacturing industry uses a conventional milling machine. In the milling process, several parameters affect product yield. The parameters that influence are the geometry of the cutting tools used (Yufrizal etl al., 2019), the thickness of the feed, cutting speed (Luo et al., 2017), and cooling (Debnath et al., 2016).

The cutting fluid in the machining process plays a role in cooling the area where there is friction between the cutting tool and the workpiece. Cutting fluid can also be used to clean chips from the cutting process (Sharma et al., 2016). The process area needs to be cooled down, considering that the area that experiences friction between the tool and the workpiece area

impacts increasing the workpiece temperature. This will result in losses in reduced tool life, and the cooling liquid is also used as a cleaning medium to clean the chips during the cutting process.

In the machining process, it can be done by adding the lubricant or without using the addition of lubricant during the machining process or the dry cutting process (Nouari et al., 2003). The dry milling process is carried out without the use of coolant or lubrication during the machining process. The dry milling process can reduce the fluid coolant or lubricant used during the process. Dry milling can reduce cooling fluid waste after use and have an impact on minimizing environmental pollution. Besides reducing the risk to the environment, the dry milling method can also reduce the costs incurred for procuring coolants in the production process using the machining process (Weinert et al., 2004).

Tool Life (T) is a period with a unit of time in minutes, during which the tool or tool angle can maintain its cutting quality before re-indexing it to sharpen the cutting angle of the chisel or chisel (Tschätsch & Reichelt, 2009). Permanent damage to tools is due to plastic deformation that occurs, where plastic deformation occurs due to heat generated by tool friction (Grzesik, 2017).

A fan Chip is a fan installed at the end of a vertical milling machine that functions to clean the remnants of the milling process without having to clean the chip using a tool (Lang Technik, 2019).

The purpose aims to design and implement fan chips products using a protector and fan chips without a protector on the dry milling process and to know. The performance effect of fan chips can affect tool life—the fan chips product use for a cooling medium on the dry milling process. Where the fan chips mounted on the motor spindle and the fan chips can break the ambient air, which produces cold air, cold air generated by air velocity, and pressure air (Pang, Kalam et al., 2012), cold air can be used as convection cooling to transfer heat in the cutting area (Gupta & Nayak, 2018), and as a cleaning medium for the rest of the cutting process. The air generated by the fan chip rotating on the motor spindle is used to lower the temperature and also blow the chip from cutting.

MATERIALS AND METHODS

Design Fan Chips

Installation and design of fan chips in the milling process, both in the roughing process and in the finishing process, the fan chips installation on the milling machine is placed on the spindle, as shown in Figure 1.
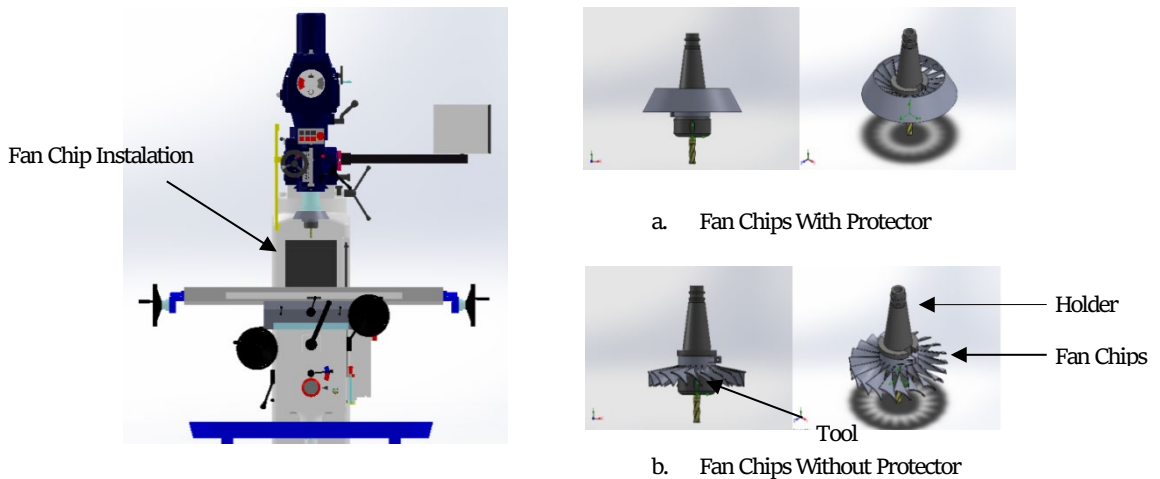
a. Fan Chips With Protector

b. Fan Chips Without Protector

Figure 1. Design and fan Chip Installation on conventional machine milling, (a) Fan Chips with Protector, (b) Fan Chips Without Protector

Materials

Making fan chips prototype using 3D printing techniques. The fan chips prototype was make using Polylactic Acid (PLA) material. PLA material can be used in the 3D printing process as a filler. The Mechanical Properties of PLA are shown in Table 1 (Chacón et al., 2017).

Table 1. Mechanical Properties Polylactic Acid (PLA)

Mechanical Properties	*Polylactic Acid*
Tensile Strength (MPa)	15.5 – 72.2
Tensile Modulus (GPa)	2.020 – 3.550
Elongation at Break (%)	0.5 – 9.2
Flextural Strength (MPa)	52 – 115.1
Flextural Modulus (GPa)	2.392 – 4.930

High-Speed Steel (HSS) is a conventional tooling material. All types of HSS contain large amounts of carbon, which reacts with refractory metals to form hard carbides, which increase wear resistance and heat hardness (Grzesik, 2017). The mechanical properties of the HSS material are shown in Table 2 (Azom, 2012), and the mechanical properties of the workpieces are shown in Table 3. (Anonymous, 2020).

Table 2. Mechanical Properties HSS Material

Mechanical properties	Metric
Hardness, Rockwell C (tempered at 1150°F, quenched at 2200°F)	62
Hardness, Rockwell C (as hardened, quenched at 2200°F)	65
Compressive yield strength (when tempered at 300°F)	3250 MPa
Izod impact unnotched (when tempered at 300°F)	67 J
Abrasion (loss in mm^3, as hardened; ASTM G65)	25.8
Abrasion (loss in mm^3, tempered at 1275°F; ASTM G65)	77.7

Poisson's ratio	0.27-0.30
Elastic modulus	190-210 GPa

Table 3. Mechanical properties Aluminium Alloy 5086

Properties	Proof Stress	Tensile Strength	Hardness Brinell	Elongation
Metric	125 Min MPa	275 - 350 MPa	75 HB	12 Min %

Methods

The method used to collect the test data is the simulation test method carried out using software engineering. The experimental testing method, which carried out by testing the application of Fan chips directly. The experimental test method used is to install fan chips on the holder of the milling machine. The fan chips rotate when the motor spindle rotates and produces air to blow the chips remaining from the milling process and reduce the milling process area's temperature. Installation of fan chips on the machine is shown in Figure 2.
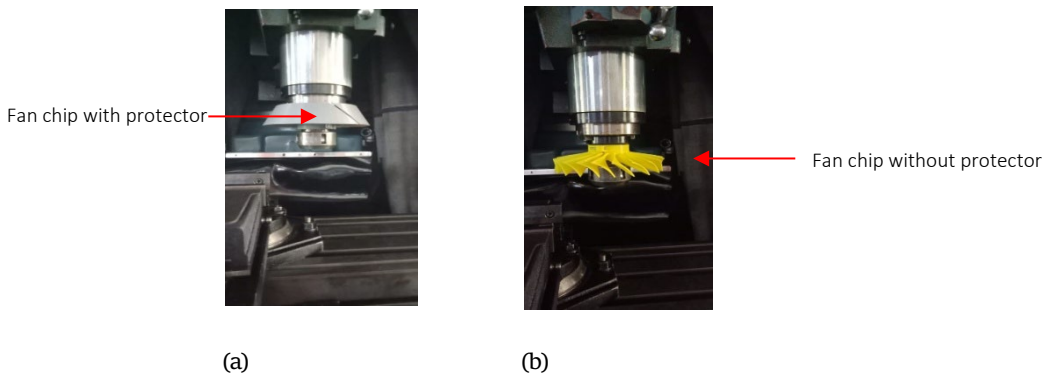
Fan chip with protector →

Fan chip without protector ←

(a)   (b)

Figure 2. Fan Chip Installation; (a) Fan Chips with Protector, (b) Fan Chips without Protector

Simulation Testing

The simulation test carried out is the Computational Fluid Dynamics (CFD) was carried out to determine the phenomenon of fluid flow when the fan chip was operated (Hu, 2012). The simulation parameters specified in the CFD simulation are shown in Table 4.

Table 4. CFD Simulation Testing Parameters

Description	Parameter
Analysis Type	External Rotation
Fluid Type	Air
Flow Type	Laminar and Turbulent
Initial temperature conditions	30°C
Spindle Rotation Speed	480 Rpm, 770 Rpm, 1120 Rpm and 1800 Rpm

The initial temperature condition is at 30ºC because of the average value obtained when taking ambient temperature data before testing. Variations in the machine's spindle rotation speed adjust to the milling machine's conditions at testing.

Experimental Testing

Experimental testing is carried out to collect wind speed data generated by fan chips and changes in temperature in the milling process area. Tests were carried out using a vertical milling machine with the specifications shown in Table 5.

Table 5. Machine Specification

Brand	PaoFong
Manufactured	PaoFongIndustry., LTD
Model	PF-5S
Serial Number	165004
Date Production	2016
Voltage	380 Volt

Figure 3. Fan Chips Weight, (a) Fan Chips with protector, (b) Fan Chips without protector

Figure 3 shows the difference in weight between fan chips with protectors and fan chips without a protector, where fan chips with protectors weigh 67, 435 grams, and fan chips' weight without a protector 55, 347 grams.

RESULTS AND DISCUSSION

Computing Fluid Dynamic

From the simulation test that has been carried out, the results of the wind fluid flow are shown in Figure 4.

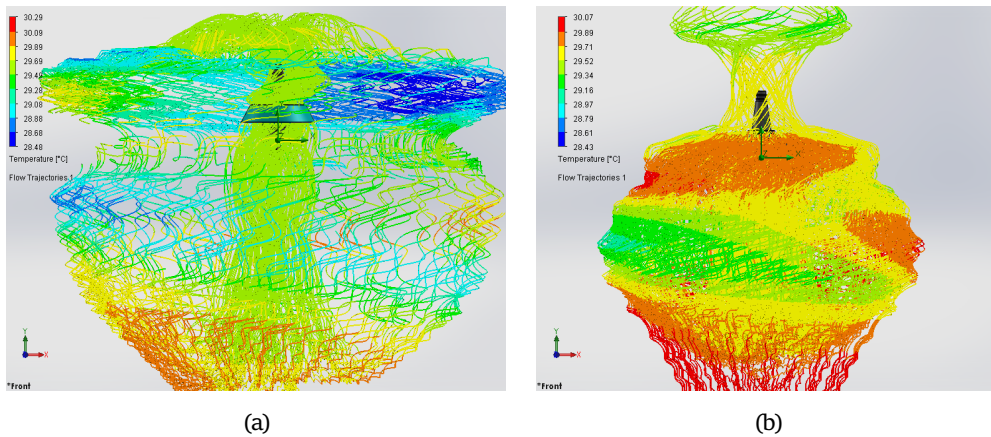(a)   (b)

Figure 4. Fluid Flow of Fan Chips; (a) Fluid Flow of Fan Chips with Protector, (b) Fluid Flow of Fan Chips without Protector (b)

The fluid flow that occurs in each fan chip has different characteristics. On fan chips with protector, the fan-produced is concentrated in the center but with a small area. The fan chips without a protector made airflow is centered on and has a larger size than fan chips with a protector. The fan chip without a protector affects the fan chip's performance to reduce the process area's temperature and blow off the milling process's scraps. Simulation testing uses flow simulation, the simulation design made according to fan chips installation conditions on the Milling machine. Fan Chips are mounting on the motor tool holder, and it can be velocity data generated by the fan chip is shown in Table 6 and Table 7.

Table 6. Wind speed Fan Chips with protector

Rpm	Velocity (m/s)
480	1.3
770	1.8
1120	3.1
1800	4.4

Table 7. Wind speed Fan Chips without protector

Rpm	Velocity (m/s)
480	1.3
770	1.9
1120	4.2
1800	6.6

Experiments

The experimental test is to measure changes in the temperature of the milling process area and the wind speed produced by fan chips. The measuring instruments used are an anemometer and infrared thermometer.

Testing fan chips with a protector to determine the effect on process temperature changes and clean the scrap from the milling process. Data on temperature changes in the milling process area by applying a fan chip with a protector, shown in Figure 5.
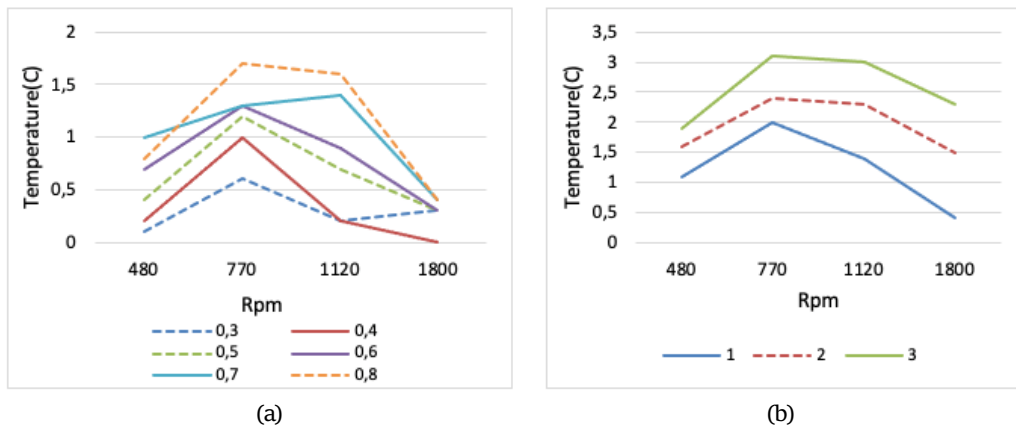
Figure 5. Temperature of Fan Chip without protector; (a) Finishing and (b) Roughing

The temperature changes that occur in the installation of fan chips with the protector, the temperature increase still occurs at each variation of cutting depth. However, when the spindle rotates above 1120 rpm, the milling process area's temperature decreases in cutting depth variations. So, it can be said that the effect of fan chips with the protector works to reduce the temperature of the process area when the motor spindle rotates above 1120 rpm.

Installation of fan chips without protectors is also carried out in the same way as testing fan chips with a protector. The experimental aims to determine the comparison of the two fan chips made. Data on temperature changes in the process area occur when applying fan chips without a protector, shown in Figure 6.
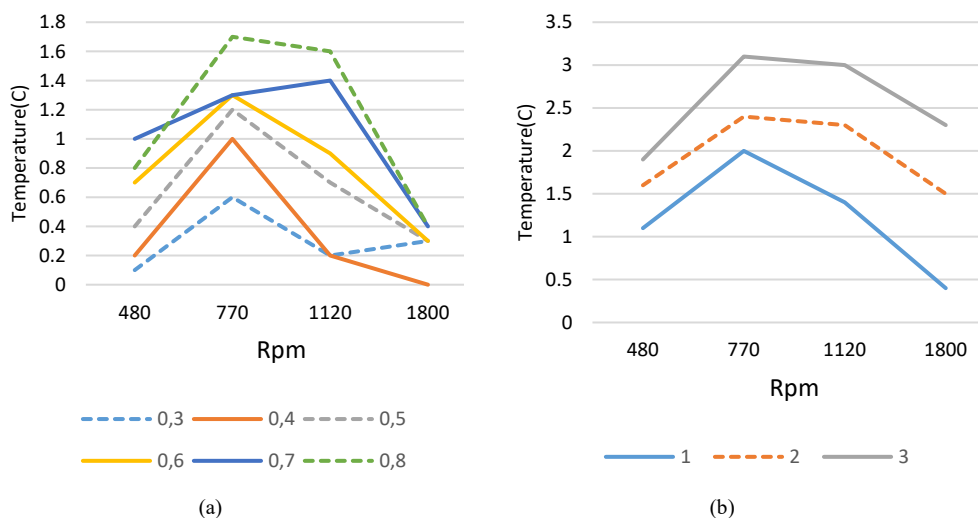

Figure 6. The temperature of fan chip without protector; (a) Finishing process and (b)Roughing process

In Figure 6, the test results obtained by the temperature difference between the temperature results in the tool edge and the environment. The temperature changes that occur when installing fan chips without a protector affected the temperature increase at every cutting depth variation. However, when the spindle rotates above 1120 rpm, the milling process decreases the

temperature in all cutting depth variations. So, that fan chips' effect with the protector works to reduce the temperature of the process area when the motor spindle rotates above 1120 rpm, as shown in Figure 6(a).

Installation of fan chips without a protector is doing the same as testing fan chips with a protector. The implementation of a fan chip to determine the comparison of the two fan chips made. Data on temperature changes in the process area that occur in fan chips' application without a protector, shown in Figure 6(b).

The temperature changes in installing fan chips without a protector show a decrease in the processing temperature when the spindle rotates above 770 rpm. The process temperature can drop when the motor spindle rotation is above 770 Rpm due to the wind generated by the fan chips. The comparison of the velocity produced by each fan chip, shown in Figure 6.
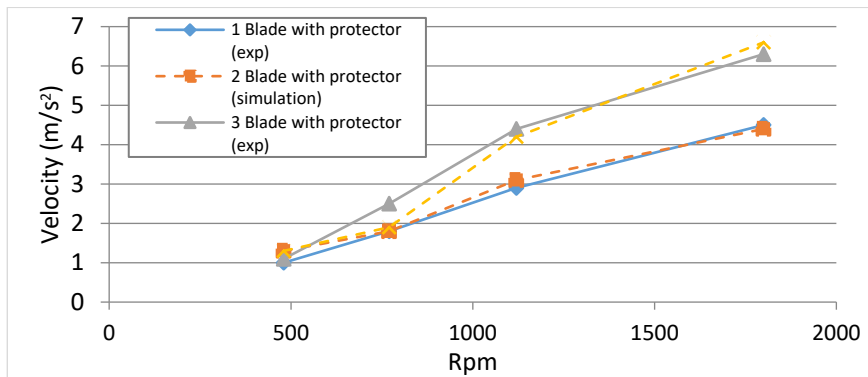

Figure 7. Fan Chips Wind Speed

Figure 7 is the velocity data generated by the fan chip in simulation testing and experimental testing. The test data on wind speed generated by simulation and experimental testing have the same trend line. The resulting line graph shows the same trending from the wind speed comparison data obtained in simulation testing and experimental testing. The velocity generated from fan chips affects the power to blow scraps for the milling machining process's remainder.

Power and Wind Force of Fan Chips

Fan Chips installed on the Milling machine produce air that blows the scrap/chips leftover from the cutting. From the wind, it can be seen that the power is generated using the following equation 1 (Rhett Allain, 2012).

$$P_{Wind} = \frac{\rho . A . v^3}{4} \qquad (1)$$

Where: P = Power Wind (Watt), ρ = Density of air (kg/m3), A = Fan Chips area (m2), v = Wind velocity (m/s), From the above equation in determining wind power, the area of the Fan Chips area and the speed generated by Fan Chips are variables that affect the value of the

wind power generated. The wind force can be calculated using the following equation(Rhett Allain, 2012).

$$F_{air} = \frac{\rho.A.v^2}{2} \qquad (2)$$

Where: ρ = Density of air (kg/m3), A = Fan Chips area(m2), v = Wind velocity (m/s), F = Wind force (Kg), wind power data of each fan chips is shown in Figure 8.
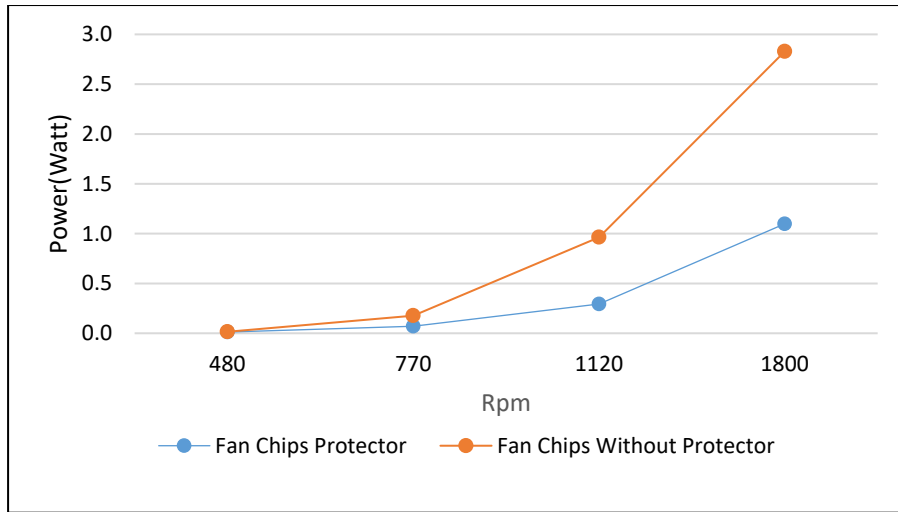

Figure 8. Wind Power Fan Chips

The wind-blowing force of fan chips blew chips leftover from the cut. The wind gust, which the wind blowing force calculated use equation 2, shown in Figure 9.
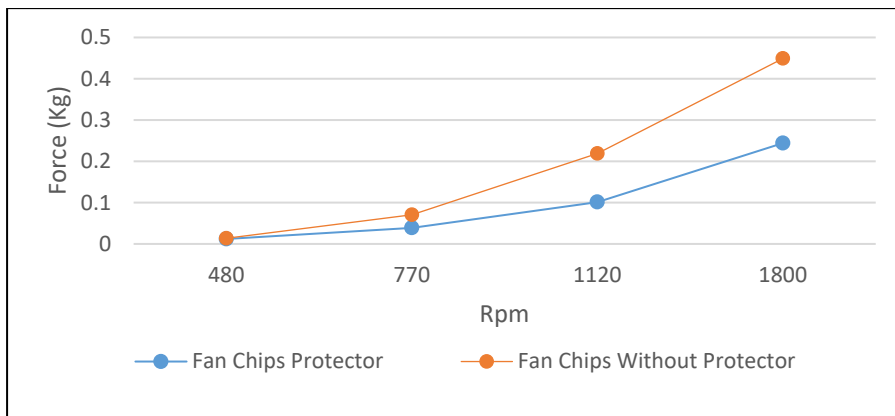

Figure 9. Wind Blowing Force

In experimental testing by cutting the workpiece, Fan Chip is not fully working optimally. Fan Chips with Protector can blow the remaining chips when the motor spindle rotates above 1120 rpm. Meanwhile, Fan Chips Without Protector works to blow chips, performs to blow the

remaining chips when the motor spindle rotates above 770 rpm, that the minimum force to blow the remaining chips is with a wind blowing force above 0.07 Kg. If it is less than this value, Fan Chips are not maximal in blowing the remaining chips. So that fan chips without protector have better performance than fan chips with protector.

Tool Life Prediction

Cutting tool life can be predicted using the Taylor equation. The general Taylor equation is written as follows (Johansson et al., 2017):

$$v. T^n = C \qquad (3)$$

Where: v is cutting speed, T is Tool Life, n is exponential tool life, and C is Constant. However, the Taylor equation, in general, has not been influenced by temperature in predicting tool life, so the Taylor equation is expanded by adding a temperature variable in predicting Tool Life which is written as follows (Kovac et al., 2019):

$$T = C_v. \left(\frac{C_\theta}{\theta_m} \right)^{\frac{Z}{P}} \qquad (4)$$

$$\theta_m = C_\theta. v^P \qquad (5)$$

Where: T is Tool life, θ_m is temperature, C_v, C_θ is constant, dan Z, P is exponential. From the temperature data obtained experimentally, the tool life predictions are shown in Figures 10(a) and Figure 10(b).

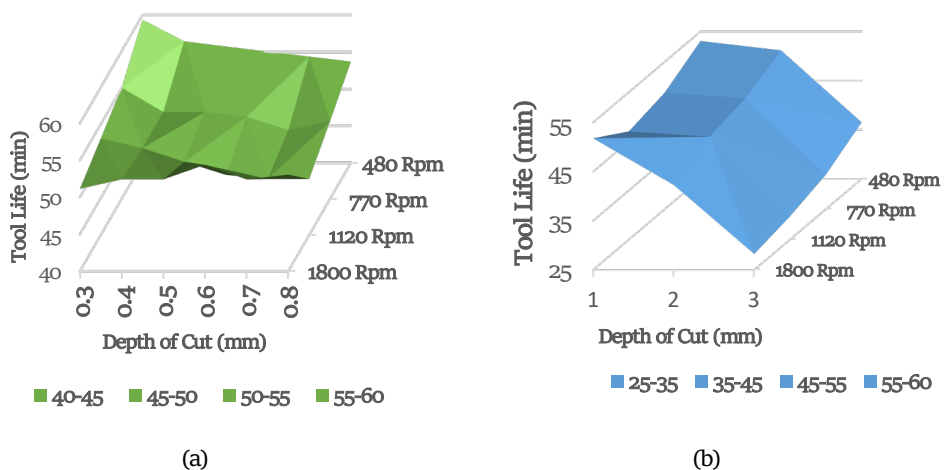(a)   (b)

Figure 10. Predict Tool Life Without Installing Fan Chips; (a) Finishing process and (b) Roughing process

In figure 10, Tool Life without Fan Chips installed has decreased lifetime, and the tool has increased temperature due to friction with the workpiece, which reduces the tool life used (Parida

& Maity, 2018). The Maximum value of Tool Life HSS does not reach 100 minutes (Debapriya M, 2020).

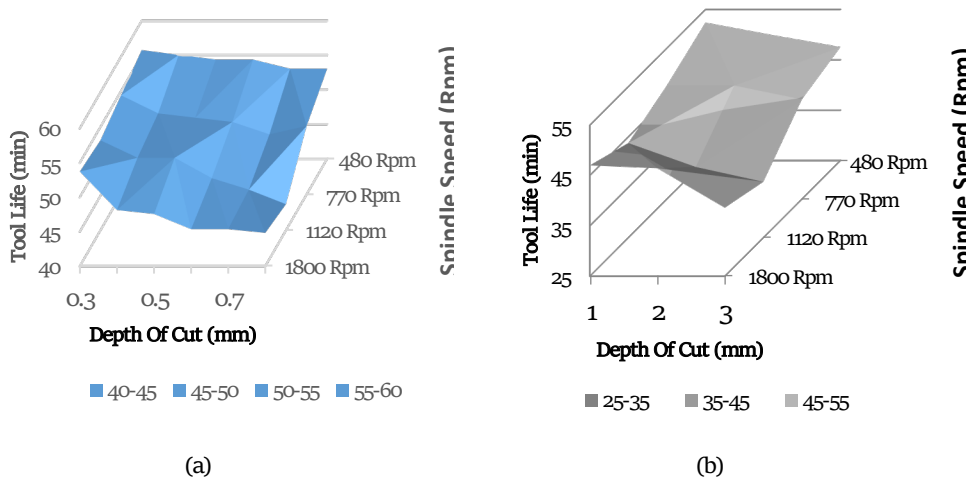(a)   (b)

Figure 11. Tool Life Prediction used Fan Chips with Protector; (a) Finishing process and (b) Roughing process

From Figure 11, tool life has decreased when installing fan chips with protector because the increasing rotation and cutting speed will decrease the value of tool life (Akbar et al., 2018). However, when the motor spindle rotates above 1120 rpm, the value of tool life increases because fan chips work to lower the process area's temperature. So that with the installation of fan chips with a protector, it can extend the life of the tool used. The increase in the value of tool life on fan chips with protector installation is ± 38 minutes at 1800 Rpm motor spindle rotation with an infeed depth of 3 mm. Before installing fan chips, the tool life value is ± 28 minutes with the same parameters.
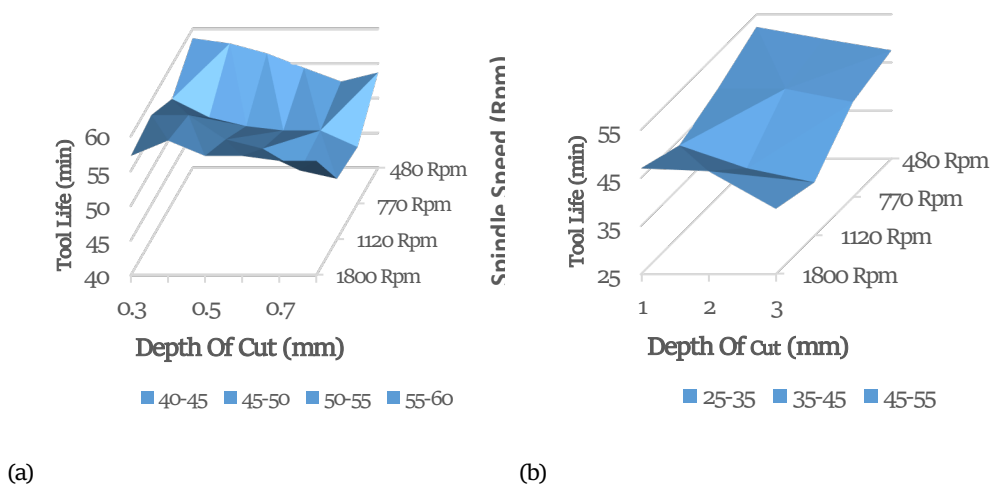

(a)   (b)

Figure 12. Tool Life Prediction used Fan Chips Without Protector; (a) Finishing process and (b) Roughing process

From Figure 11, tool life has decreased when installing fan chips with protector because the increasing rotation and cutting speed will decrease the value of tool life (Akbar et al., 2018). However, when the motor spindle rotates above 1120 rpm, the value of tool life increases because fan chips work to lower the process area's temperature. So that with the installation of fan chips with a protector, it can extend the life of the tool used. The increase in the value of tool life on fan chips with protector installation is ± 38 minutes at 1800 Rpm motor spindle rotation with an infeed depth of 3 mm. Before installing fan chips, the tool life value is ± 28 minutes with the same parameters.

(a)   (b)
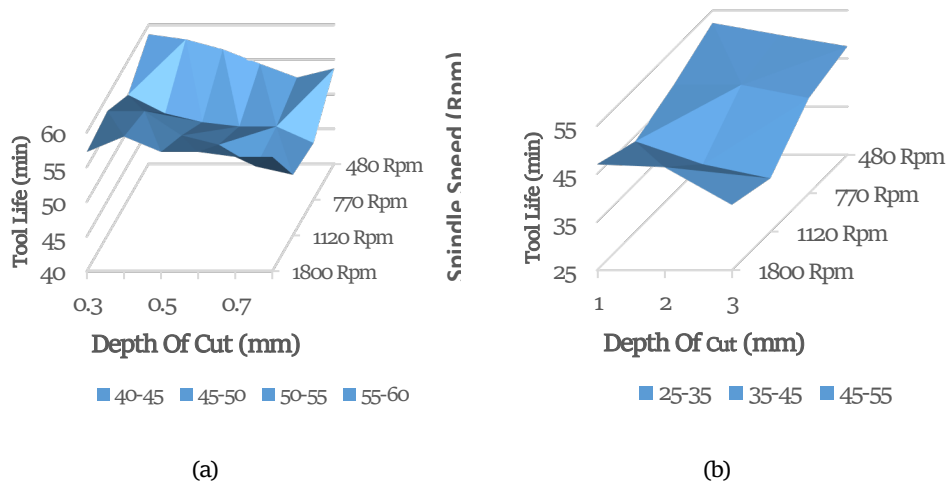
Figure 12. Tool Life Prediction used Fan Chips Without Protector; (a) Finishing process and (b) Roughing

From Figure 12, tool life has decreased when the motor spindle rotates below the rotation speed of 770 rpm, but when the motor speed is above 770 rpm, tool life has increased. This is because at this speed fan chips without a protector works to reduce the temperature of the process area, which affects the re-increase of tool life. The increase in tool life value that occurs is ± 44 minutes on the motor spindle rotation of 1800 rpm with an ingestion depth of 3 mm, while before installing fan chips, the tool life value is ± 28 minutes with the same parameters.

CONCLUSION

From the simulation tests carried out, the fluid flow generated by the fan chips with the protector produces a concentrated wind character but with a small area. Meanwhile, the fan chips without protection have a centralized wind character with a broader scope.

The experiment results show the fan chips affected by the temperature tool. The effect changed the temperature in the cutting process area. The fan chips with a protector can reduce the temperature when the motor spindle rotates above 1120 rpm. Fan chips without a protector can reduce the cutting process area's temperature when the motor spindle rotates above 770 rpm.

Tool life prediction has to determine the effect of installing a fan chip on tool Life. The impact of fan chips with the protector on tool life was found to extend tool life by 8 minutes. The effect of fan chips without a protector on tool life was seen to extend tool life by 12 minutes.

ACKNOWLEDGEMENTS

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