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Effect of Turning Parameters and Coolant Usage on Tool Wear in Lathe Process-Review

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Abstract— Turning products must have high quality. The quality of turning results can be affected by tool wear. Turning parameters and the use of coolant are the main factors that can control the level of wear, because they can control the temperature and cutting force during turning. This study aims to analysing the gap regarding effect of turning parameters and coolant use on tool wear in the lathe process. The main parameters analysed include spindle rotation speed, depth of cut, and feed rate. In addition, the role of coolant as a coolant and lubricant is also studied in relation to controlling tool wear. The method used was a literature study. The results showed that all turning parameters have an influence on tool wear, with depth of cut as the most significant factor in increasing wear. High spindle speeds and large feeding motions also accelerate wear due to increased friction and temperature in the cutting zone. This means that the greater the parameter values used, the greater the tool wear. Where with a depth of cut of 0.05 mm causes tool wear of 0.094 mm, while with a depth of cut of 1.5 mm causes tool wear of 0.746 mm. With a spindle rotation speed of 185 rpm the tool wear is 2 mm, while with a spindle rotation speed of 2200 rpm the tool wear is 11.36 µm. With a feed motion of 0.05 mm/rev the tool wear was 0.094 mm, while with a feed motion of 1.5 mm/rev the tool wear was 0.746 mm. The use of coolant proved effective in lowering the cutting temperature, reducing friction, and extending tool life. The results of this study can be used as a practical reference in future research to analyse interactions between parameters comprehensively using statistical approaches or comprehensive predictive models, as well as to examine the use of coolants in terms of composition, concentration and application methods, reviewing environmental aspects and the efficiency of using alternative coolants such as vegetable oil or MQL (Minimum Quantity Lubrication) systems.

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1. INTRODUCTION

Along with the times, many technologies in the industry are also developing in order to achieve targets and efficiency in time [1]. In the industrial world, especially manufacturing, the machining process is an important stage, one of which is the turning process. The turning process is a process of cutting metal material which aims to change the geometry into goods / products using a lathe by rotating the workpiece using a machine then the workpiece is subjected to a translational moving tool that is parallel to the workpiece rotating axis [2] [3] [4]. This process relies on the rotation of the workpiece and the linear motion of the tool to remove material to achieve the desired shape and size. The feeding process occurs when the tool blade comes into contact with the workpiece which can cause high temperature changes in the area. This affects tool blade wear, surface quality and machining time [5]. To get the quality of surface roughness as expected and minimal tool wear during the turning process, it is necessary to pay attention to the turning parameters used [6] [7] [8]. In the turning process there are many parameters that affect the results of the turning process [9] [2]. The main parameters that affect the turning results are the spindle rotation speed (speed) [10], depth of cut (depth of clutch) [11] [12] and feed motion (feed) [13] [14] [5] [15] [16]. In addition to turning parameters, to obtain good cutting and feeding quality, several factors are needed, including machine conditions, workpiece material, operator, tool shape and material and coolant [17] [18] [19] [20].

The tool on the lathe is one of the tools/components that is indispensable for the feeding/turning process and affects the turning time [21][22]. During the turning process, of course, the interaction between the tool and the workpiece is very high. Almost all of the cutting energy is converted into heat through the friction process between the grit and the tool and between the tool and the workpiece [17]. So that in the turning process it is very necessary to choose the tool used. The tool materials commonly used in the machining process are High Speed Steel (HSS), carbide, ceramic, cermet, diamond and others [23]. The properties of lathe chisels are strong, hard, not wear fast and heat resistant. The hardness of the tool is very important in order to cut the workpiece that will be turned and must have a higher hardness level than the material [14].

Coolant is a mixture of ethylene or propylene glycol and water that usually has a 50/50 ratio. Cooling fluid based on its composition consists of: a) Synthetic fluids, b) Emulsion liquid, c) Semi-synthetic liquid, d) Oil (cutting oils). The types of coolants that can be used include water, oil, air spray, water and oil, ethanol and liquid ice [24] [25]. Cooling fluid has special uses in the lathe process. Coolant serves to protect workpieces and machine components from corrosion [26]. Another function of the coolant is as a cleaner or carrier of grime, lubricant [27] [28], lowering the cutting force, smoothing the workpiece and extending the tool life [29] [30] [31].

In turning practice, the tool can experience wear due to friction and high temperature during the cutting process [32]. Tool wear can occur at various areas such as cutting edges, surfaces, or corners of the cutting tool geometry. Factors that affect tool wear include the hardness of the material being cut, cutting speed, cutting feed, cooling, and the condition of the cutting tool itself [33] [34]. This tool wear can lead to reduced workpiece surface quality, increased cutting forces, and reduced tool life [17]. Excessive wear rates will ultimately have a negative impact on productivity and manufacturing costs. Many previous studies have been conducted on various combinations of parameters, tool and workpiece materials. Research results from Muhammad Lukman et al [19] show that increasing the depth of cut will cause greater tool wear because the friction area between the tool and the workpiece increases. Other research results by Angga Suhendi et al [35] are that the greater the spindle speed, the depth of cutting and the greater the coolant ratio, the greater the wear value produced. However, a more comprehensive understanding of the interaction and combined effect of the three main cutting parameters (cutting speed, feed rate, and depth of cut) and the use of coolant on tool wear characteristics specifically in the turning process is still needed.

In this journal, the author reviews several journals related to the influence of machining parameters (cutting speed, feed rate, and cutting depth) and the use of coolants on the wear rate of cutting tools in the machining process. The results of the review are expected to provide data and analysis that can be used as practical references in selecting cutting parameters and effective coolant use to minimise tool wear and identify gaps for further research.

2. METHODOLOGY

2.1 Research Methods

The method used in this research is a literature study, which is a systematic method, and can be used to identify, evaluate, and synthesise the results of research and thoughts that have been carried out by researchers and practitioners. The steps in conducting a literature study are as follows:

- Determine the scope of the topic to be studied
- Identifying relevant sources
- Reviewing the literature
- Writing the results of the study

In this study, the authors used secondary research data obtained from data sources in the form of related national and international journals or articles that had been conducted by previous researchers. In its implementation, the author looks for research journals published online. The data collection process is carried out by filtering based on the criteria set by the author of each journal taken, then the gaps in the research data were analysed. The journal collection criteria are as follows:

- The year of publication of the literature used is between 2020 and 2025, taking into account the suitability of keywords, the relevance of research results, and the suitability of the discussion.
- The strategy in collecting various literature journals was carried out through accredited journal sites such as ResearchGate, Google Scholar, and others.
- Applying the results of the literature review
- Effective writing methods for journal searches include using keywords that match the research title and searching using advanced search features.
- Assessing journals based on their suitability for the study.

2.2 Research Parameters

A. Turning Parameters
The turning parameters studied include spindle rotation speed (n), depth of cut (a), feed motion (f) and coolant usage.

B. Testing
The test carried out is tool wear testing.

3. RESULT AND DISCUSSION

Turning parameters are the main variables that influence the turning process. In this journal, the parameters studied consist of spindle rotation speed, depth of feed and feeding motion. The spindle rotation speed is a component that is determined by how much rotation is produced from the machine. The rotational speed affects the stability of the turning process, the temperature in the turning zone, and the interaction force between the tool and the workpiece [36]. The size of a rotation will affect the level of vibration during the lathe process when operating the machine. Vibrations caused during the turning process can be caused by the influence of the tool gripping method [37]. These vibrations can cause damage to the cutting tool or workpiece [38]. Before the machine is started, it is better to determine the number of revolutions per minute that will be used from the main spindle [39]. In the lathe process, the spindle rotation speed affects tool wear, cutting temperature, and surface roughness. The rotation speed mechanism of the lathe can produce cuts with units of revolutions/minute, or rpm. This level of incision affects the quality of the workpiece [40]. Depth of cut is the thickness of the workpiece that is removed or the distance between the cut surface and the surface that has not been cut. Feeding motion is the magnitude of the lathe tool shift in each rotation of the lathe [41]. In addition, the increase in cutting speed and the length of the machining process contributes to tool blade wear. Slowly the tool blade will experience wear caused by friction between the surface of the tool blade contact area with the workpiece [42]. The formula for determining turning parameters is as follows:

- Spindle rotation speed [43]

$$n = \frac{C_s x\ 1000}{\pi\ x\ D} \tag{1}$$

Where:
n : spindle rotation speed (rpm)
C_s : cutting speed (metres/ minute)
D : workpiece diameter (mm)

- Depth of cut [4]

$$a = \frac{d_0 - d_m}{2} \tag{2}$$

Dimana:
a : depth of cut (mm)
d_0 : initial diameter of the workpiece (mm)
d_m : final diameter of the workpiece (mm)

- Feeding motion [4]

$$f = \frac{V_f}{n} \tag{3}$$

Dimana:
f : feeding motion (mm/rev)
V_f : feeding speed (mm/minute)
n : spindle rotation speed (rpm)

Below, the author has summarised several studies conducted by previous researchers regarding the effect of Turning Parameters on Tool Wear in the Lathe Process. In a study conducted by Fahrizal et al [41], research was conducted to obtain the optimal cutting parameter combination to minimise tool wear in the low carbon steel turning process. The results showed that the minimum tool wear was obtained at a combination of the number of revolutions of 180 rpm, depth of cut of 1.5 mm, and feed motion of 0.8 mm/minute. Based on the results of the variation analysis, the contribution of each factor to tool wear is obtained, each feeding motion provides the largest contribution of 35%, followed by a depth of cut of 10%, and the cutting speed factor does not contribute. The results of research conducted by Effendi Zulnasri et al [44] show that with a spindle rotation of 112 rpm has a faster work rate with the consequence of rapid wear on the HSS type tool blade.

I Putu Gede Ferdyan Abdika Wiprayana et al [45] conducted research with the aim of analysing the wear on HSS chisels in turning ST 42 steel with variations in rotation and depth of feed. The results of HSS (high speed steel) tool wear testing showed that the MO rapid extra 1200 type HSS (high speed steel) tool experienced increased wear growth in the turning process of ST 42 steel. At 700 rpm, the lowest wear growth was recorded (1.05 mm/min), but increased at 900 rpm (1.35 mm/min) and again increased at 1200 rpm (1.8 mm/min). In addition, at 900 rpm, there was an unstable increase in wear, evident from the difference in tool weight and length before and after turning. In the test with a depth of cut of 1 mm and a feed rate of 0.09, the tool experienced rapid wear, indicating limitations in the cutting process.

In another study, Bayu Setiawan et al [46] conducted a study aimed at finding out about tool wear on ST42 steel influenced by the machining process. This research uses HSS tools. The steel used is ST42 steel with audio signal method and concentrate on tool wear, using spindle rotation of 790rpm, 940rpm, and 1300rpm. Feeding motion 0.06 mm/put, depth of cut 0.5 mm, 0.75 mm, and 1 mm. material diameter 25.4 mm. The results of this study were analysed with a two-way anova test, in the variation of spindle speed obtained F count > f table (224.521 > 4.26), in the variation of depth of cut obtained F count > f table (48.904> 4.26). This means that h1 is accepted that there is a difference in the results of spindle rotation variations and depth of cut variations on tool wear.

Meanwhile, in a study conducted by Ghani Resa Mahendra et al [21], research was conducted which aims to determine the effect of cutting thickness on wear and life of carbide tools in the 316 stainless steel turning process. In this study, 3 cutting variations of 0.5 mm, 1mm, and 1.5 mm were carried out with spindle rotations of 833 rpm, 869 rpm, and 909 rpm at (Vc) 68.2 m/min and feeding 0.12 mm/rev. The results showed that the cutting thickness of 0.5 mm experienced edge wear (Vb) = 0.014 mm, at a cutting thickness of 1 mm experienced edge wear (Vb) = 0.019 mm, and with a cutting thickness of 1.5 mm experienced edge wear of (Vb) = 0.034 mm in using a cutting speed of 62.8 m/min then the tool will be 10,000 minutes / 166.6 hours.

Research conducted by Joko Waluyo et al [6] aims to obtain optimum surface quality and minimal tool wear using CNMG and DNMG tool materials. The tool angle parameters used were 80º and 55º with a cutting thickness and cutting speed of 300 metres/minute with a feeding thickness of 1 mm, 0.5 mm and feeding 0.25 mm / rev. The results showed the value of tool wear with CNMG material geometry tool angle 800 the amount of wear for cutting with a thickness of 1mm and 0.5 mm is 0.016 mm and 0.024 mm for tool angle 550 with DNMG material cutting thickness of 1 mm and 0.5 mm the amount is 0.023 and 0.035 mm.

Research conducted by Nurlaila Rajabiah et al [17] with the aim to determine the effect of coolant viscosity with depth of cut variations on carbaide tool wear in the VCN 150 turning process. The results showed that the Depth of Cut (DOC) value during the feeding process was directly proportional to the tool wear value. The lowest wear value at DOC 1 mm with viscosity value (ƞ) 0.44 which is 0.1479 mm and the largest at DOC 3 mm which is 1.0524 mm, of course for the optimum viscosity value is at viscosity value (ƞ) 0.44 with water and oil mixing composition (50%:50%).

Another study was conducted by Sri Widiyawati et al [24] with the aim of knowing the effect of using coolant on HSS lathe tool wear. The results showed that the greatest tool wear of 1.392 mm was located in the 1: 40 coolant treatment due to the liquid slurry attached to the coolant which was able to cause melting due to the frictional force between the workpiece and the HSS tool so that the tool could not perform maximum feeding.

The results of research conducted by Benattia Bloul et al [47] show that the depth of cut affects the tool side wear. Using a cutting speed of 35 m/min, a depth of cut of 0.5 mm and a machining time of 10 minutes caused tool side wear of 0.123 mm as shown in Figure 1.

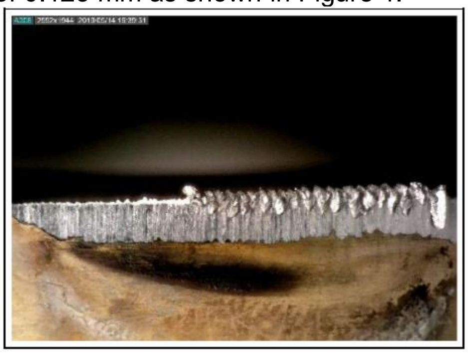

Figure 1. Carbide tool side wear

As for the results of research by Feri Hariyanto et al [20] that the greater the depth of cut and cutting speed, the greater the growth of edge wear. For more details can be seen in Figure 2.

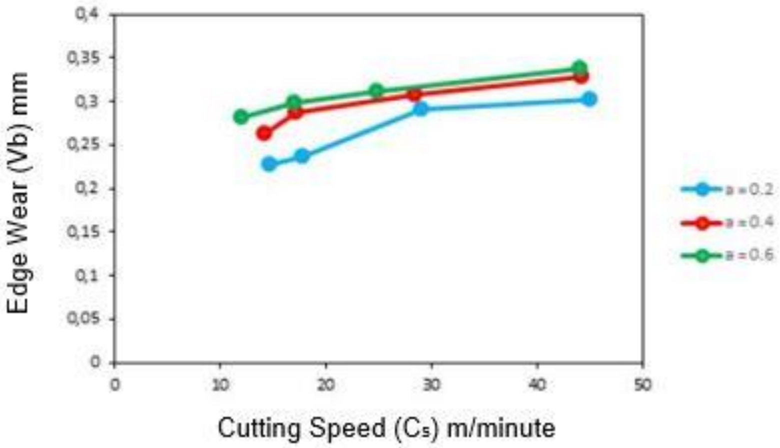

Figure 2. Graph of tool wear against cutting speed and depth of cut (a)

Furthermore, the results of research conducted by Rasyid Ridho Harahap [43] show that the composition of the mixture of coolant and water in the ratio of 1:10, 1:20, and 1:40, can be known to affect the wear of the HSS tool blade and the quality of Stainless Steel and ST37 steel materials. Where the value of the largest wear field is with a coolant composition of 1:40 in Stainless Steel machining of 0.174 mm². The results of the review relating to studies on the effect of turning parameters and coolant usage carried out by the previously mentioned researchers showed an influence on tool wear, as shown in Table 1 below.

Table 1. Effect of Turning Parameters and Coolant Use on Tool Wear

Researcher	Turning Parameters and Coolant Usage	Parameter Value	Tool Type	Steel Type	Tool Wear
Bambang Pratowo et al. [1]	Spindle rotation speed	n=185 rpm; L=8.9 mm	HSS	S45C	2 mm
Bambang Pratowo et al. [1]	Spindle rotation speed	n=185 rpm; L=22.2 mm	HSS	S45C	0.89 mm
Faisal Manta et al. [40]	Spindle rotation speed	n=190 rpm	Insert tipe VNMG 160408-MA	AISI 4340 Steel	0.002 gram
Faisal Manta et al. [40]	Spindle rotation speed	n=1255 rpm	Insert tipe VNMG 160408-MA	AISI 4340 Steel	0.053 gram
Ikhsan Ikhtiardi et al. (2023) [48]	Cutting speed, depth of cut and feeding motion	V_c=100 mm/minute; a=1 mm; f=0.2 mm/rev	Carbide	AISI 1045 Steel	0.069 mm
Ikhsan Ikhtiardi et al. [48]	Cutting speed, depth of cut and feeding motion	V_c=100 mm/minute; a=1 mm; f=0.2 mm/rev	Carbide	AISI 1045 Steel	0.124 mm
Nurlaila Rajabiah et al. [17]	Depth of cut and Coolant Viscosity	a=1 mm; η=0.44	Carbide	VCN 150	0.1479 mm
Nurlaila Rajabiah et al. [17]	Depth of cut and Coolant Viscosity	a=3 mm; η=0.44	Carbide	VCN 150	1.0524 mm
A.R. Nistelroy et al. [5]	Cutting speed	V_c =141.3 mm/minute	Ceramics	Cast Steel	0.3 mm

A.R. Nistelroy et al. [5]	Cutting speed	V_c =222.9 mm/minute	Ceramics	Cast Steel	0.35 mm
A.R. Nistelroy et al [5]	Cutting speed	V_c =351.6 mm/minute	Ceramics	Cast Steel	0.32 mm
Mazwana et al. [49]	Cutting speed, depth of cut, feeding motion, coolant	V_c =196 mm/minute; a=1.5 mm; f=0.15 mm/rev; C= Sunflower oil	Carbide	AISI 4140 Steel	0.746 mm
Mazwana et al. (2024) [49]	Cutting speed, depth of cut, feeding motion, coolant	V_c =144 mm/minute; a=0.5 mm; f=0.05 mm/rev; C= Sunflower oil	Carbide	AISI 4140 Steel	0.094 mm
Mazwana et al. [49]	Cutting speed, kedalaman potong, gerak makan, coolant	V_c =144 mm/minute; a=1.5 mm; f=0.1 mm/rev; C= Palm oil	Carbide	AISI 4140 Steel	0.746 mm
Mazwana et al. [49]	Cutting speed, depth of cut, feeding motion, coolant	V_c =196 mm/minute; a=0.5 mm; f=0.1 mm/rev; C= Palm oil	Carbide	AISI 4140 Steel	0.123 mm
Meilani Mandhalena Manurung et al. (2024) [50]	Depth of cut, Spindle rotation speed	a= 1.0 mm; n= 560 rpm	CNMG 150604r-k 4325	ST 37	0.05 gram
Meilani Mandhalena Manurung et al. [50]	Depth of cut, Spindle rotation speed	a= 1.0 mm; n= 560 rpm	CNMG432-MS3	ST 37	0.04 gram
Meilani Mandhalena Manurung et al. [50]	Depth of cut, Spindle rotation speed	a= 1.0 mm; n= 560 rpm	CNMG120408-NM4 WPP20	ST 37	0.02 gram
Roberth M. Ratlalan et al. [39]	Spindle rotation speed	n= 2200 rpm	Carbide	ST 37	11.36 µm

Description:
V_c : cutting speed (m/minute)
n : spindle rotation speed (rpm)
L : turning length (mm)
a : depth of cut (mm)
f : feeding motion (mm/rev)
C : coolant

4. CONCLUSION

Based on the results of the review of several studies above, it can be concluded as follows:

- Most studies only discuss the effect of one parameter separately, without analysing the interaction between parameters comprehensively using a statistical approach or comprehensive predictive model.

- The use of coolant has also not been studied in depth in terms of composition, concentration, and application methods, and there has been little research reviewing the environmental aspects and efficiency of using alternative coolants such as vegetable oil or MQL (Minimum Quantity Lubrication) systems.
- The review shows that the turning parameters consisting of spindle speed, depth of cut and feed motion affect tool wear. High spindle speed increases friction and temperature, thus accelerating wear. Likewise, the increase in depth of cut and feeding motion has a significant effect on tool wear.

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