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Effect of Material on Lathe Rotation at HSS (High-Speed Steel) M42 Tool Cutting Tool Wear Level

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ABSTRACT

This research analyzes HSS tool wear in turning AFNOR 07-05-04-04-02 steel with variations in machine speed (RPM) and feed depth. Steel, as an iron-based alloy, is known for its superior strength and corrosion resistance, while HSS chisels are used in the machining industry for their wear resistance and ability to maintain sharpness at high temperatures. The results showed that increasing RPM caused greater tool wear, with the highest difference in tool weight at RPM 900 and 1200, reaching 1.0 grams, compared to 0.752 grams at RPM 700. Surface roughness also increased with higher RPM; at 1200 RPM the average value of Ra reaches 4.390565 µm, while at 700 RPM it is only 2.944778 µm. These findings indicate that greater tool wear contributes to increased surface roughness of the workpiece. Variations in Ra, Rz, Rq, and Rt values indicate that different cutting parameters significantly influence the surface quality. This research is expected to provide valuable information for the machinery industry and support the development of materials science and increased productivity in manufacturing.

Introduction

In the era of connected globalization, developments in science and technology make the role of humans as the main driving force of modern industry increasingly important (Industry, 2024). The ability to utilize knowledge and skills in implementing technological innovation is the main pillar. Like a harmonious symphony, the magnificent construction and precision machining process require science and technology integration expertise. Steel, with its superior strength and corrosion resistance, is a key material in a variety of industrial applications (Halim, 2022). HSS (High-Speed Steel) chisels, known for their high hardness and wear resistance, are often used in machining to maintain sharpness at high temperatures. In the turning process, the interaction between the tool and the workpiece is very crucial. Tool wear management is key to ensuring optimal results and production efficiency (Demmanggasa et al., 2023). This research aims to analyze HSS tool wear in turning AFNOR 07-05-04-04-02 steel with variations in rotation and feed depth, to provide valuable information for the machining industry and support the development of materials science as a whole (Rahmananda et al., 2024). The research results are expected to increase productivity and quality in the manufacturing industry.

Previous research has been conducted to further understand the factors influencing machining quality using HSS. For example, the study titled Investigation of Dimensional Deviation in Wire EDM of M42 HSS Using Cryogenically Treated Brass Wire identified that pulse-off-time, pulse-on-time, and spark gap voltage were the most significant variables in the wire EDM process for M42 HSS. (Singh et al., 2019). This research demonstrated that optimized parameter settings resulted in dimensional deviation variations of around 3.15% from the predicted values. Additionally, another study titled Optimization of Process Parameters for CNC Turning of High-Speed Steel (M42) found that the nose radius of the insert and feed rate were the most critical factors affecting surface roughness and material removal rate (MRR) during HSS turning at a constant spindle speed of 3000 rpm. (Singla & Singh, 2016).

The urgency of studying HSS tool wear in turning processes is highly relevant to the current developments in the manufacturing industry. In a competitive industrial world, improving production efficiency and product quality are primary objectives, making this research valuable for understanding how process variables influence tool wear. (Wiprayana & Sujana, 2024). The novelty of this study lies in the in-depth analysis of HSS tool wear during the turning of AFNOR 07-05-04-04-02 steel, with variations in rotation speed and feed depth, a topic that has not been extensively explored. The objective of this study is to analyze HSS tool wear during the turning of AFNOR 07-05-04-04-02 steel and to provide valuable information for the machining industry to improve productivity and the quality of manufacturing processes. The results of this research are expected to support the overall development of materials science and contribute to innovations in machining technology. (NURYANTO, 2024).

Method

This research method was obtained from street vendors at PT Gresik, a collection of relevant references obtained from the Nusantara PGRI Kediri University library, online sources, and books on composite materials. This research was carried out at PT Gresik. This stage is important as a theoretical basis, helping to classify, organize, and use literature that supports the development of initial foundations and assumptions.

Tool

Lathe machine, Vernier caliper, digital scale, HSS M42 chisel, surface roughness tester.

Research Materials

AFNOR Steel 05-07-04-04-02.

Testing

HSS (high-speed steel) tool wear testing and HSS M42 tool roughness testing.

Results and Discussion

This wear test uses 2 test methods, namely by using the method of weighing the initial weight and final weight of the HSS (high-speed steel) chisel and measuring the initial length and final length of the HSS (high-speed steel) chisel using a projector profile tool. (HARTANTO, 2019).

Chisel Weighing Results Before and After Turning

Table 1
Chisel Weighing Results Before and After Turning

Tool	Rpm	Initial Weight (Gr)	Final Weight (Gr)	Different
1		68,9875	68,9795	0,008
2	700	69,6875	69,6491	0,0384
3		67,9865	67,9695	0,017
4		66,9998	66,9631	0,0367
5	900	68,5571	68,5493	0,0078
6		66,8512	66,8482	0,003
7		69,8731	69,8531	0,02
8	1200	68,9241	68,9112	0,0129
9		66,8211	66,7141	0,107

Table 1 shows the results of weighing the HSS chisel before and after the turning process at various RPMs. At 700 RPM, the weight difference ranges from 0.0384 gr to 0.008 gr, while at 900 and 1200 RPM, the difference increases to 0.107 gr to 0.003 gr. This indicates that the higher the RPM, the greater the tool wear. Additionally, factors such as feed rate, depth of cut, and workpiece material characteristics also influence tool wear. (Fitriyadi, 2013). Comparisons with previous studies show a similar pattern, where increased rotational speed significantly contributes to tool wear, impacting machining quality and tool lifespan. These findings are essential for determining optimal cutting parameters in industrial applications.

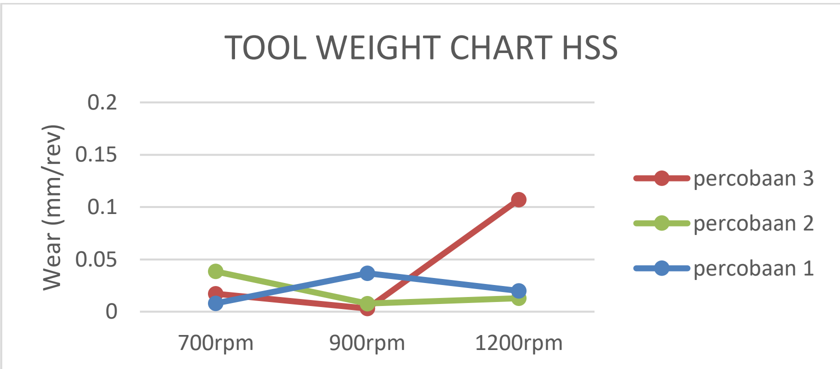

Figure 1
Results of weighing the chisel before and after turning

Figure 1 illustrates HSS tool wear across three experiments conducted at 700, 900, and 1200 RPM. As the RPM increases, tool wear also escalates, with experiments 1 and

3 displaying the most significant wear at 1200 RPM. This highlights the critical impact of rotational speed on tool wear, where higher speeds tend to accelerate the degradation of the cutting tool. Besides RPM, factors like feed rate and depth of cut also contribute to wear progression. Understanding these relationships is vital for optimizing cutting parameters, as excessive tool wear can lead to poor surface quality and increased operational costs. Therefore, finding the ideal balance between speed, feed rate, and depth of cut can extend tool life and improve the overall efficiency and quality of the turning process. This optimization ensures better surface finish, reduced tool replacement frequency, and greater cost-effectiveness in machining operations, particularly in high-precision manufacturing environments where maintaining tool sharpness is crucial.

Table 2

Results of measuring the initial length and final length of the chisel

Tool	Rpm	Initial Length (mm)	Final Length (mm)	Different
1	700	7,224	6,564	0,66
2		4,975	3,979	0,996
3		5,164	4,712	0,452
4	900	5,756	4,956	0,8
5		5,661	4,581	1,08
6		5,952	4,542	1,41
7	1200	4,955	3,923	1,032
8		4,464	3,864	0,6
9		4,821	3,486	1,335

In Table 2, the difference in the initial and final length of the HSS tool after turning demonstrates the effects of varying RPM, feed rate, tool material, depth of cut, and the workpiece on tool wear. The greater the difference in length, the more significant the tool wear, indicating the importance of carefully selecting cutting parameters to minimize tool degradation. These variations in tool length are crucial in the machining industry as they directly impact the precision of the cutting process, surface finish quality, and overall tool lifespan.

The results also underscore how each variable contributes differently to tool wear. For example, higher RPMs tend to accelerate tool wear, while the depth of cut and feed rate also play significant roles in determining the rate at which the tool deteriorates. By analyzing these factors, manufacturers can optimize their machining processes, improving tool performance and extending its life, ultimately reducing downtime and costs related to frequent tool replacement. This kind of analysis helps in refining operational parameters to achieve better accuracy and higher productivity in precision machining operations.

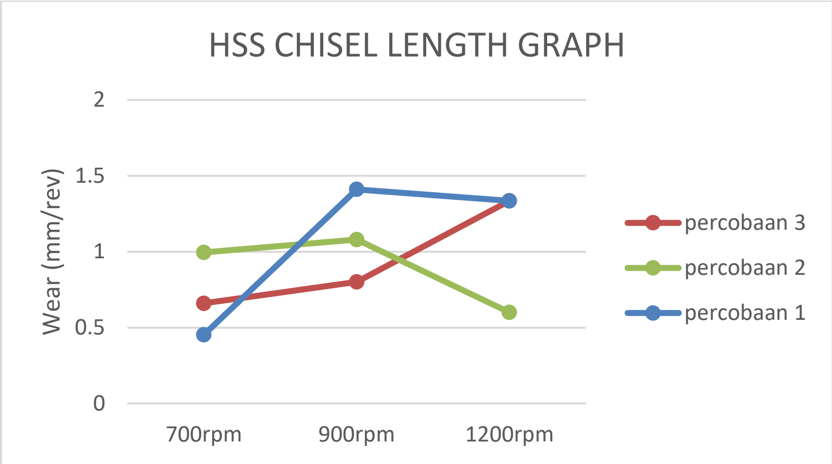

Figure 2
Results of measuring the initial length and final length of the chisel

Figure 2 illustrates the HSS tool wear across RPMs of 700, 900, and 1200 in three distinct experiments. Experiment 1 exhibited a notable increase in wear, escalating from 0.6 mm/rev at 700 RPM to 1.4 mm/rev at 900 RPM. In contrast, Experiment 2 recorded the highest wear rate of 1.0 mm/rev at 700 RPM, followed by a decrease at 900 RPM, and a slight increase again at 1200 RPM. Experiment 3 presented a steady increase in wear, starting at 0.8 mm/rev at 700 RPM and reaching 1.2 mm/rev at 1200 RPM.

These variations highlight the complex relationship between RPM and tool wear, indicating that while higher speeds generally lead to increased wear, other factors such as feed rate and tool geometry also influence the outcomes. Understanding these dynamics is crucial for optimizing cutting parameters in the machining industry, as effective management of tool wear can significantly enhance product quality and production efficiency.

Following this, the results of the AFNOR 07-05-04-04-02 steel roughness testing provide additional insights into the surface quality achieved during the turning process at the tested RPMs of 700, 900, and 1200. These roughness measurements are essential for evaluating the effectiveness of the machining parameters used, and they serve as an indicator of the overall performance of the cutting tools employed during the process. The correlation between tool wear and surface roughness will be discussed further, shedding light on the implications for quality control in manufacturing practices.

Table 3
Average roughness at 700 pm

TOOL	RPM	AFNOR STEEL ROUGHNESS 07-05-04-04-02			
		ra	rz	Rq	rt
1		5,430134	9,882669	2,693687	10,98367
2	700	3,155	8,520657	2,831647	8,500333
3		2,626	6,957	3,309	6,961313
Average		3,737045	8,453442	2,944778	8,815105

The surface roughness test presented in Table 3 reveals significant insights into the machining performance at 700 RPM, utilizing a 1 mm depth of cut and a 0.09 mm feed rate. The average values of Ra at 3.737045 µm, Rz at 8.453442 µm, Rq at 2.944778 µm, and Rt at 8.815105 µm indicate a relatively smooth surface finish, which is crucial for components requiring high precision and low friction. These metrics are essential for assessing the effectiveness of the machining parameters and ensuring that the final product meets the desired specifications. Additionally, maintaining optimal surface roughness levels can enhance the durability and performance of the machined components, reducing wear during subsequent operations and improving overall reliability in various industrial applications. This data underscores the importance of continuous monitoring and adjustment of cutting parameters to achieve the best possible outcomes in precision machining.

Table 4
Average Roughness at 900 pm

TOOL	RPM	AFNOR STEEL ROUGHNESS 07-05-04-04-02			
		ra	rz	rq	rt
4		2,139	3,987323	2,816	3,780466
5	900	2,535467	5,898	2,804	4,986
6		2,458667	4,778667	2,361867	4,69
Average		2,377711	4,887996667	2,660622333	4,485488667

The surface roughness test results in Table 4 demonstrate the impact of machining parameters at 900 RPM, with a 1 mm depth of cut and a 0.09 mm feed rate. The average roughness values of Ra at 2.377711 µm, Rz at 4.887997 µm, Rq at 2.660622 µm, and Rt at 4.485489 µm indicate an improvement in surface quality compared to the results at 700 RPM. This suggests that the optimized parameters used at this RPM effectively reduce tool wear while enhancing surface finish. The lower roughness values highlight the potential for achieving finer surface characteristics, which are crucial for applications requiring high precision and excellent aesthetic quality. Moreover, these findings emphasize the significance of adjusting spindle speed, as it directly influences machining efficiency and the final surface integrity. Thus, manufacturers can benefit from understanding these relationships to optimize their processes, ensuring that products meet stringent quality standards and performance requirements.

Table 5
Average Roughness at 1200 pm

TOOL	RPM	AFNOR STEEL ROUGHNESS 07-05-04-04-02			
		ra	rz	rq	rt
7		3,312363	8,698067	3,812	6,861637
8	1200	6,923	19,80113	6,832313	21,41333
9		2,936333	6,915233	3,519	7,764

Average	4,390565	11,80481	4,721104	12,012989

The surface roughness test results presented in Table 5 illustrate the challenges associated with higher machining speeds, specifically at 1200 RPM. The measured values of Ra at 4.390565 µm, Rz at 11.80481 µm, Rq at 4.721104 µm, and Rt at 12.012989 µm indicate a decline in surface quality compared to the lower RPMs. This increase in roughness highlights the adverse effects of elevated speeds, which tend to exacerbate tool wear and impact the finish of the machined surface. As spindle speed increases, the heat generated can lead to thermal softening of the material, further contributing to poor surface integrity. (Wibowo et al., 2021).

Moreover, these findings emphasize the critical importance of selecting appropriate cutting parameters. Manufacturers must find a balance between speed and surface quality to ensure optimal machining performance. This data not only assists in understanding the wear mechanisms at play but also guides the optimization of machining strategies to achieve desired surface characteristics while maintaining tool longevity. Therefore, continuous monitoring and adjustment of RPM, feed rate, and depth of cut are essential for enhancing overall machining efficiency and product quality in industrial applications.

Conclusion

In conclusion, this research underscores the critical relationship between spindle speed (RPM), tool wear, and surface roughness in the machining of HSS materials. The findings indicate that as RPM increases, not only does tool wear become more pronounced, but surface finish quality also deteriorates, with significant implications for manufacturing processes. Specifically, at higher RPMs, the tool wear observed was substantial, with measurements indicating a weight loss of up to 1.0 grams at 900 RPM, highlighting the need for careful management of cutting conditions to minimize wear and maintain tool effectiveness. Furthermore, the results emphasize that surface roughness is directly correlated with tool wear, illustrating that as tool integrity decreases, the quality of the machined surface suffers. The average Ra value of 4.390565 µm at 1200 RPM starkly contrasts with the smoother finish of 2.944778 µm at 700 RPM, demonstrating the importance of selecting appropriate rotational speeds.

The variations in surface roughness metrics, including Ra, Rz, Rq, and Rt, reveal that optimizing cutting parameters is essential for achieving desired surface quality and operational efficiency. This research serves as a valuable reference for industries engaged in precision machining, offering insights that can lead to improved production outcomes and enhanced product performance. Future studies may further explore the interplay of additional factors, such as feed rate and material characteristics, to develop a comprehensive understanding of their impacts on machining processes.

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