

Analysis of Cutting System Failure in the CNC Vertical Machining Center of Hyundai Wia F500D Machine with the Root Cause Method at PT ABC

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Abstract

PT ABC as an automotive component manufacturing company faces the problem of high Downtime in CNC machines, especially the Hyundai Wia F500D Vertical Machining Center, which has an impact on decreased productivity and increased production costs. This study aims to identify the root cause of the failure of the cutting system in the machine and provide recommendations for appropriate repairs. The method used is Root Cause Analysis (RCA) with the Fishbone Diagram approach and 5 Why's analysis based on historical company data, field observations, interviews with related parties, and technical documentation. The results of the study show that the dominant root cause of cutting system failure is damage to the drawbar dispring which reduces the grip strength of the tool so that it triggers the condition of the tool oblique, spindle overload, and active system alarm. Other causative factors include production methods with aggressive cutting parameters, operator errors in tool installation and maintenance, machine age that has been more than 12 years with almost non-stop operation, and a less ergonomic working environment. These conditions have an impact on increasing the frequency of repairs, maintenance costs, decreased production output, and high potential product defects. The conclusion of this study is the need for corrective actions in the form of replacing drawbar disprings and repairing spindle components, as well as preventive measures through scheduled maintenance, optimization of production methods, improvement of operator competence, and improvement of the layout of the work area.

Keywords: *cnc machine, cutting system, root cause analysis, downtime, automotive manufacture*

Abstrak

PT ABC sebagai perusahaan manufaktur komponen otomotif menghadapi permasalahan tingginya Downtime pada mesin CNC khususnya Vertical Machining Center Hyundai Wia F500D yang berdampak pada penurunan produktivitas dan peningkatan biaya produksi. Penelitian ini bertujuan untuk mengidentifikasi akar penyebab kegagalan cutting system pada mesin tersebut serta memberikan rekomendasi perbaikan yang tepat. Metode yang digunakan adalah *Root Cause Analysis* (RCA) dengan pendekatan Fishbone Diagram dan analisis 5 Why's berdasarkan data historis perusahaan, observasi lapangan, wawancara dengan pihak terkait, serta dokumentasi teknis. Hasil penelitian menunjukkan bahwa akar penyebab dominan kegagalan cutting system adalah kerusakan drawbar dispring yang menurunkan kekuatan cengkaman tool sehingga memicu kondisi tool oblok, spindle overload, hingga alarm sistem aktif. Faktor penyebab lain meliputi metode produksi dengan parameter pemotongan agresif, kesalahan operator dalam pemasangan tool dan perawatan, usia mesin yang sudah lebih dari 12 tahun dengan operasional hampir nonstop, serta lingkungan kerja yang kurang ergonomis. Kondisi tersebut berdampak pada meningkatnya frekuensi perbaikan, biaya perawatan, penurunan output produksi, dan tingginya potensi cacat produk. Kesimpulan dari penelitian ini adalah perlunya tindakan korektif berupa penggantian drawbar dispring dan perbaikan komponen spindle, serta tindakan preventif melalui perawatan terjadwal, optimasi metode produksi, peningkatan kompetensi operator, dan perbaikan tata letak area kerja.

Kata Kunci: *mesin cnc, sistem pemotongan, root cause analysis, otomotif manufaktur*

1. Introduction

PT ABC is a manufacturing company engaged in the automotive component industry with a focus on the production of motor vehicle parts [1]. As part of the Bakrie Group, the company has a strategic role in supporting the needs of the domestic and international automotive industry through the application of modern manufacturing technology [2]. One of the main technologies used is a Computer Numerical Control (CNC) machine that is capable of cutting, drilling, turning, and milling processes with a high level of

precision [3]. However, operational data shows that the downtime rate of a number of CNC machines at PT ABC is still quite high and has a direct impact on production efficiency [4]. One of the machines with the largest downtime rate is the Hyundai WIA F500D Vertical Machining Center (VM 23), which plays an important role in the milling, drilling, and tapping process [5]. The high downtime on these machines is mostly due to failures in cutting systems, such as spindle alarms, ATC alarms, and tool drops, which not only reduce productivity, but also potentially increase product rejection and rework rates [6]. Therefore, it is necessary to conduct a comprehensive analysis to find the root cause of the problem so that the effectiveness of the machine and production quality can be improved [7].

Previous studies have highlighted the problem of machine effectiveness in the manufacturing industry using various analysis methods. Ambrawati (2024) on the debarker machine shows an OEE value of only 60%, far below the world-class standard of 85% [8]. Meanwhile, Pranata and Effendi (2024) found that the decrease in productivity in belt press machines was caused by mechanical failures such as damage to bearings, rollers, and conveyor belts, which reduced the OEE value by up to 67% [9]. Although previous studies have made important contributions to the analysis of machine effectiveness, most have focused more on performance evaluation using OEE and RCM without specifically examining cutting system failures in CNC machines. This creates a research gap that needs to be filled, especially related to an in-depth analysis of the root causes of cutting component failures in CNC machines using the Root Cause Analysis (RCA) method.

The novelty of this study lies in the application of the RCA method to identify the root cause of cutting system failure in the CNC Vertical Machining Center Hyundai WIA F500D machine, which until now has not been studied specifically in the context of the automotive component industry in Indonesia [10]. This analysis is expected not only to provide a comprehensive understanding of the dominant factors causing downtime, but also to produce strategic recommendations to reduce losses due to cutting system failures [11]. Thus, this study has the main objective of identifying and analyzing the root cause of high Downtime in CNC machines at PT ABC and provide applicable repair solutions [12]. The contribution of this research is expected to improve production efficiency, reduce process failure rates, and support the company's efforts in realizing sustainable competitiveness in the automotive manufacturing industry.

2. Material and Methods

This study uses a case study approach on PT ABC with a focus on the analysis of cutting system failures in the CNC Vertical Machining Center Hyundai WIA F500D machine which has the highest downtime rate [13]. The research design is descriptive-analytical with the aim of identifying the root cause of the problem through the Root Cause Analysis (RCA) method. The research object was chosen because of its strategic role in the production process as well as its significant impact on the company's efficiency [14].

The research data consists of primary and secondary data [15]. Primary data were obtained through unstructured interviews with MC shop department managers and staff, direct observation in the machine work area using non-participant observation techniques, as well as documentation in the form of notes and photographs [16]. Secondary data includes historical data of the company, such as organizational profile, production flow, machine specifications, production capacity, Downtime data, cause of damage, and machine maintenance history. The division of data into general and special categories is carried out to facilitate the analysis process.

Data analysis was carried out using the RCA approach using two main tools, namely the Fishbone Diagram and the 5 Why's method. Fishbone Diagram is used to map various factors causing problems from human, machine, method, material, and environmental aspects. Next, the 5 Why's method is applied to dig into the root of the most fundamental problem by asking the "why" question repeatedly. Through this stage, the research aims to find the dominant cause of high Downtime in CNC machines and provide effective recommendations to improve machine performance and production efficiency at PT ABC. The following is an overview of the series of research flows that can be seen in **Figure 1**.

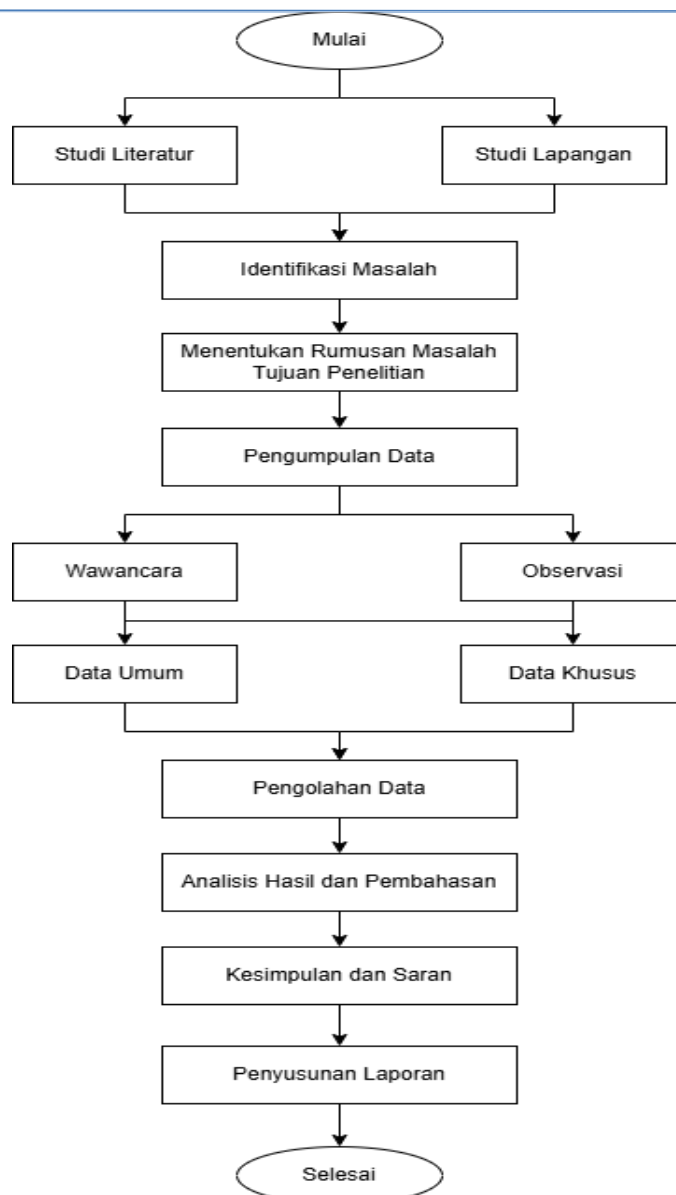


Fig. 1: Research Flow Flowchart
Source: Author's Processing Results, 2025

3. Results and Discussion

Problem Data

The object of this research is the Hyundai Wia F500D CNC Vertical Machining Center machine which is located in line 3 of PT ABC. This machine functions in the drilling, milling, and tapping process to produce 20-22 pcs per day Bracket S/A Cabin FR Monting Type L and Type R. Based on company data (Table 1.), PT ABC has 61 units of fabrication machines, of which the highest number is Vertical Machining (23 units), followed by Vertical Turning (16 units), and several other types of machines in smaller quantities.

The January Downtime data (Table 2.) shows that the total available time of the 10 largest machines is 35,906.8 minutes with a Downtime of 13,285 minutes. The VM 23 engine (Hyundai Wia F500D) is ranked third with an available time of 5,239.5 minutes and a Downtime of 1,823 minutes. In more detail, the data that caused the Downtime of VM 23 (Table 3.) shows that there are 10 types of problems, of which five are related to the cutting system (spindle alarm, ATC alarm, fall tool, shake tool, and setting tool) with a total Downtime of 1,710 minutes. Further analysis (Table 4.) revealed that these problems often originate from the condition of the tool, but the real root of the problem lies in the spindle system, such as the drawbar disspring breaking, the Q lock wearing, and the draw bar being damaged.

The results of interviews with management and operators reinforce these findings. The VM 23 machine is known to operate 21-24 hours per day with a capacity of 20-22 pcs of product, using FC (Ferro

Casting) and FCD (Ferro Casting Ductile) workpiece materials, as well as carbide cutting tools. In the last three months, this machine has produced Bracket S/A Cabin FR Monting Type R (1835) and Type L (1836). This data makes it clear that cutting system failure is the dominant factor that contributes to high Downtime, so it needs to be further analyzed with the Root Cause Analysis method.

Table 1. PT ABC Engine Data

No.	Machine Name	Qty	Unit
1	MC VT (VERTICAL TURNING)	16	UNIT
2	MC VM (VERTICAL MACHINING)	23	UNIT
3	MC HM (HORIZONTAL MACHINING)	4	UNIT
4	MC HT (HORIZONTAL TURNING)	6	UNIT
5	MC HN (HONING)	2	UNIT
6	MC BRC (BROCHING)	1	UNIT
7	MC MM (MILLING MANUAL)	2	UNIT
8	MC BL (BALANCING)	1	UNIT
9	MC PRESS	2	UNIT
10	MC DM (DRILLING MANUAL)	4	UNIT
TOTAL		61	UNIT

Source: Author's Processing Results, 2025

Table 2. Machine Downtime Data in January

No.	Machine Name	Code	Avb Time	Downtime
1	HM - 04 (DOOSAN)	HM 04	8352	4058
2	World Championship - 23 (HYUNDAI)	VM 23	5239,5	1823
3	VT - 02 (LATHE BD K3)	VT 02	3838,6	1088
4	VM - 15 (TONGTAI)	VM 15	2680	1064
5	VT - 13 (VT-550)	VT 13	3649,1	1043
6	VM - 10 (TONGTAI)	VM 10	2645	1005
7	VT - 04 (LATHE HUB K3)	VT 04	2959,6	964
8	VT - 03 (LATHE HUB K3)	VT 03	2564	766
9	HM - 01	HM 01	2344	759
10	VM - 16 (TONGTAI)	VM 16	1635	735
Total			35906,8	13285

Source: Author's Processing Results, 2025

Table 3. VM Engine Downtime Data 23 in January

Date	Problem Name	Total Downtime
2,6,8,10,11,13	Spindle Alarm	900
10,13,17,21,25	Alarm Atc	420
8,24	Tool Fall	190
14	Tool Shake	120
21	Setting Tool	80
7	Wind Drop	30
19	Coolant clog	28
31	Conveyor Alarm	20
2	Wind Hose	20
22	Parameter Alarm	15

Source: Author's Processing Results, 2025

Table 4. VM 23 Machine Problem Analysis Data in January

Date	Main Problem	Analysis/Status Part
6	Further repairs and <i>oblak tools</i>	<i>Tool oblak due to spindle problem</i>
8	<i>Tool falls when ATC</i>	<i>Tool oblak due to drawbar disspring broken</i>
10	<i>Tool oblak</i>	<i>Tool oblak due to drawbar disspring broken</i>
13	<i>Spindle tool oblak</i>	<i>Q lock off</i>
17	<i>clamp unclamp</i>	<i>Broken Draw Bar</i>
14	<i>Alarm ATC</i>	<i>There is a tool that carries</i>
25	<i>Continued repair (Tool drops during ATC)</i>	<i>Lock arm stuck</i>
21	<i>Tool drop during ATC, coolant charging production support</i>	<i>Zero arm position is not suitable after repair</i>
24	<i>Setting tool</i>	<i>Tool position is not up to standard</i>

Source: Author's Processing Results, 2025

Data Processing Using the 5 Why's Method

Based on the 5 Why's analysis in **Figure 2**, the root cause of the alarm spindle on CNC machines is the damage to the drawbar disspring which functions as a tool lock on the spindle. This damage lowers the grip strength of the tool from the standard 1000–1500 psi to only 200 psi, causing the tool to become oblique, the spindle is overloaded, and finally the alarm is activated. The impact of these conditions is quite significant, namely the instability of the cutting tool which has the potential to produce defective products, an increased risk of damage to the spindle due to overload, and the emergence of production downtime which can reduce the overall work efficiency of the machine.

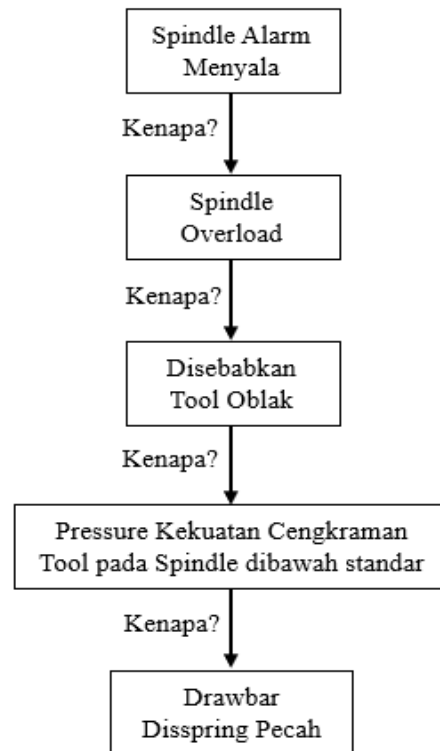


Fig. 2: Flow 5 Why's

Source: Author's Processing Results, 2025

Based on Fishbone's analysis (**Figure 3**), the failure of the cutting system on the Hyundai Wia F500D CNC machine is caused by a combination of Method, Man, Machine, and Environment factors. In terms of method, the application of aggressive cutting parameters (depth of cutting and high feed rate) increases the load on the spindle and drawbar disspring, plus the installation of tools that are often rushed increases the risk of vibration. The man factor also plays a role, such as tool installation errors, lack of thorough cleaning of chips, and delays in detecting drawbar wear marks.

From the machine factor, the age of the machine that is more than 12 years old and operates 21–24 hours per day causes component wear, heat accumulation, and a decrease in the strength of the drawbar material disspring. Meanwhile, environmental factors worsen the condition because the narrow workspace makes it difficult for operators to install tools and clean the machine area, so that metal chips are often left behind and interfere with the production process. The combination of all these factors accelerates the breakdown of the drawbar disspring and triggers the failure of the cutting system.

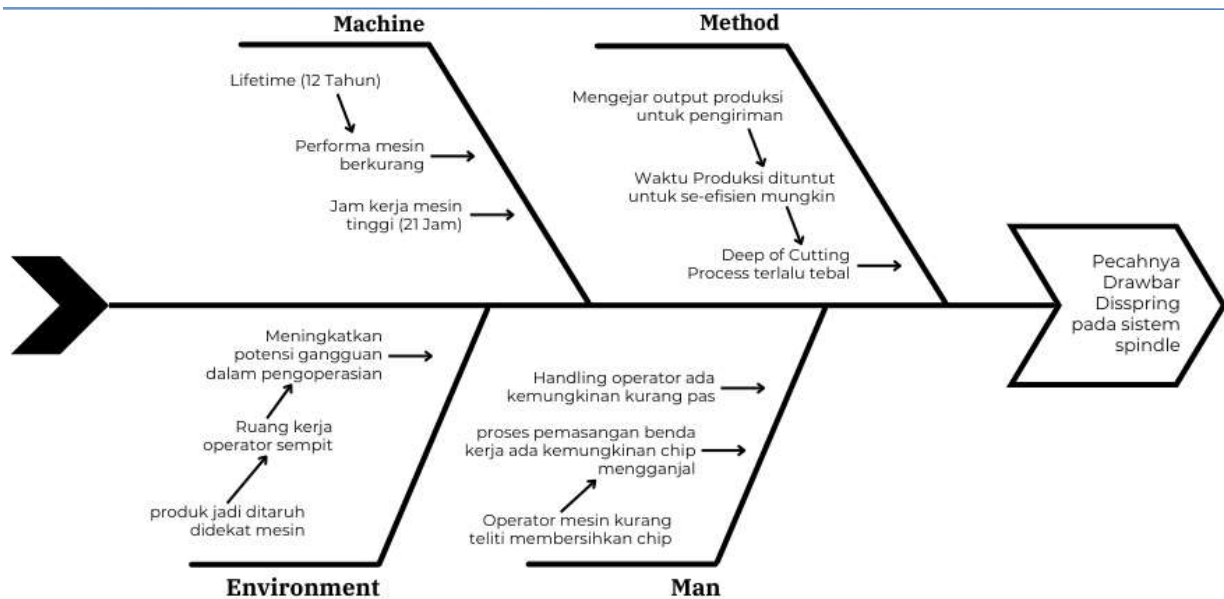


Fig. 3: Fishbone Diagram

Source: Author's Processing Results, 2025

To make it easier to map the Fishbone Diagram explanation above, here is the explanation using the 5W + 1 H method.

Table 5. Fishbone Diagram Explanation using 5W+1H

What	Why	When	Where	Who	How
Reduced Engine Performance	Due to the age of the machine that is already 12 years old	As the machine becomes more and more operational,	On the whole machine system	Div. <i>maintenance</i> to anticipate performance degradation	Degraded performance means that the machine is operating outside of its optimal conditions, which can accelerate the wear of components such as <i>drawbar disspring</i> .
Depth of cutting that is too thick	To achieve fast and time-efficient output, in response to production pressures	During the machining process	On VM machines	Operator or programmer who sets the cutting parameters	The thick cutting depth increases the load on the spindle and the tool clamping system, including the drawbar disspring, accelerates its wear.
Possible operators not handling the tool correctly	It may be due to lack of training, haste (due to time pressure), or lack of awareness	When making a tool change or setting preparation	In the working area of the machine	Machine Operator	Improper handling may lead to imperfect tool installation , causing vibration or excessive

What	Why	When	Where	Who	How
					pressure on the drawbar disspring
Tight operator workspace conditions	Due to improper placement of finished products and/or suboptimal factory layout	During machine operation	The area around the VM 23 machine	Production Manager	Narrow workspaces increase the potential for operator errors in tool handling or cleaning, due to limited movement and visibility, which indirectly contributes to disspring issues

Source: Author's Processing Results, 2025

The Root Causes of Cutting System Failure and Its Contribution to the High Rate of Downtime

5 Why's analysis shows that the root of the cutting system failure on the Hyundai Wia F500D CNC machine is the drawbar disspring damage, which lowers the grip strength of the tool to trigger tool overload, spindle overload, and system alarms. The results of the fishbone diagram reinforce these findings by outlining four causative factors: Method, in the form of aggressive production methods with overcutting parameters and hasty tool installation; man, namely operator error in tool installation, chip cleaning, and delay in detecting damage symptoms; Machine, which is the age of the machine for more than 12 years with non-stop operation that accelerates wear and heat accumulation on the spindle; and Environment, in the form of a narrow workspace that reduces ergonomics and the effectiveness of cleaning machine areas. The combination of these factors increases the mechanical stress on the drawbar disspring, accelerating wear, and causing its failure. This condition contributes greatly to the high rate of Downtime because every time the spindle alarm goes off, the production process is halted and requires time for diagnosis, repair, and component replacement.

The Impact of Cutting System Failure on Production Efficiency and Product Quality

The failure of the cutting system due to damage to the drawbar disspring has a major impact on production efficiency and product quality at PT ABC. In terms of efficiency, this condition triggers an increase in engine downtime due to frequent active spindle alarms, lowers output so that production targets are difficult to achieve, and increases production costs due to repairs, replacement parts, and potential overtime labor. In terms of quality, the instability of the cutting tool causes inaccurate products, rough surfaces, and geometric defects. This increases the rejection rate, the need for rework, and the risk of damage to the cutting tool and workpiece. The repeated impact of these failures not only slows down production but also reduces quality, increases costs, and potentially lowers customer satisfaction and company reputation.

Repair Strategies and Preventive Recommendations to Reduce Downtime and Improve CNC Machine Reliability

To overcome the failure of the cutting system on the Hyundai Wia F500D CNC Vertical Machining Center Machine at PT ABC, corrective actions that can be taken include: replacing the drawbar disspring with quality parts, checking and repairing related components such as spindle bearings and tool clamping mechanisms, and recalibration of the tool clamping system so that the grip strength is in line with the standard (1000–1500 psi). In addition, the recommended preventive actions include the implementation of routine maintenance schedules, optimization of production methods, improving operator skills, improving the work environment, and using a condition monitoring system to detect potential problems early. The preventive treatment schedule summarized in Table 6. Includes daily to quarterly inspections, such as cleaning of spindle areas, lubrication of components, disspring drawbar inspections, and quantitative measurement of tool grip strength.

Table 6. Recommended Preventive Schedule

Time Range	Activity Name	Description	Person in Charge	Note
Daily	Routine Cleaning of the Spindle Area	Clean <i>the chips</i> and other contaminants around the <i>spindle area</i> and the tool's <i>clamping mechanism</i> . Make sure there are no <i>chips</i> jammed.	Machine Operator	The importance of cleanliness should be emphasized to the operator
Daily	Initial Visual Inspection of the Clamping System Tool	Perform a quick visual inspection of the <i>tool</i> when it is installed to ensure that no <i>oblak tool</i> is clearly visible. Watch for unusual noises or vibrations when the machine starts operating	Machine Operator	
Weekly	Lubrication of Spindle Components	Ensure proper lubrication of the <i>spindle bearing</i> and tool clamping mechanism according to the manufacturer's recommended schedule and type of lubricant	Staff Maintenance	Make a list of lubricant types and lubrication points
Weekly	Routine Inspection of Grip Strength Tool	The operator can subjectively check the grip strength of the <i>tool</i> after installation. If in doubt, do further checks	Machine Operator	
Monthly	Visual Inspection of Detail Drawbar Disspring and Clamping Mechanism Tool	Perform a more in-depth visual inspection of the <i>drawbar disspring</i> (if accessible) and the entire clamping mechanism of the <i>tool</i> for signs of wear, cracks, or deformation.	Maintenance Technician	
Monthly	Thorough Cleaning of Spindle and Tool Changer Areas	More comprehensive cleaning, including tool <i>changer</i> and magazine areas, to ensure no accumulation of debris that could interfere with the system	Maintenance Technician	
Quarter	Measurement of Grip Strength Tool (Quantitatively)	Use an appropriate measuring tool to quantitatively measure <i>the grip strength of the tool</i> . Make sure the grip strength is within the standard range (1000-1500 psi)	Maintenance Technician	If the results are below standard, take corrective action immediately
Quarter	Spindle Bearing Inspection	Check the <i>condition of the spindle bearing</i> , including abnormal sound and vibration	Maintenance Technician	

Source: Author's Processing Results, 2025

With the implementation of this comprehensive repair and prevention strategy, the company can reduce downtime, improve machine reliability, and maintain product quality and production efficiency.

4. Conclusion

This study revealed that the root cause of the high rate of Downtime in the Hyundai Wia F500D CNC Vertical Machining Center machine at PT ABC is the damage to the drawbar disspring which reduces the grip strength of the tool from the standard 1000–1500 psi to only 200 psi, thus causing tool overload, spindle

overload, and the appearance of system alarms. Fishbone's analysis shows that the failure of the cutting system is influenced by a combination of aggressive production methods, operator error, machine age that is more than 12 years old, and less supportive working environment conditions. The impact of this failure is quite significant, namely increased Downtime, decreased production output, increased maintenance and component replacement costs, and increased risk of product defects that can reduce quality and customer satisfaction.

As a follow-up, companies are advised to implement corrective action strategies in the form of replacing drawbar dissprings and repairing spindle components, as well as preventive actions through periodic maintenance, optimization of cutting parameters, improvement of operator skills, and improvement of the layout of the work environment. The implementation of these measures is expected to reduce the level of downtime, improve engine reliability, maintain product quality, and support the company's efficiency and competitiveness in a sustainable manner.

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