A Systematic Approach to Reducing Compressor Downtime by 95.3% Within Six Months Toward Industry 4.0 Implementation

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***Abstract*— Workshop is one of the sections in the company that is tasked with supporting the productivity process, from Welding fabrication work, motor rewinding, machine tool work, to punch procurement (Mold). Supported by various machines used to support the production process, both for punch repair and fabrication. For this reason, the workshop always tries to provide the best, namely by creating improvements to speed up the process of procuring punches, both lower and upper, as well as master motifs and plain, while the improvements made are making improvements in the Compressor area. Thus, this compressor machine is a vital supporter of the machine's running process and product water usage services to achieve the target results of punch repair in the workshop, the purpose of the research is to add an automatic remote control at the nearest location & can be operated with Wi-Fi, create an auto evaporator cleaning program, install a compressor alarm notification, create an auto drain program for the compressor tube, create a safe compressor room. By implementing several improvements, the results were achieved by reducing downtime by 95.3% to 96.7%. Downtime decreased from 2784 minutes per 3 months to 92 minutes per 3 months. The potential profit was Rp 159.962.422 per year (Rp 13.330.202). Therefore, the research results can be applied to all workshop and production machines.**

Keywords: compressor; downtime; production machine; punch; workshop.

I. INTRODUCTION

The development of Industry 4.0 technology, which is based on increasing production efficiency, includes efficiency in the fields of production, materials, and human resources [1]-[3]. The use of industrial automation and the use and modification of more efficient production equipment is a necessity. The compressor is one of the compressed air-producing equipment used in all manufacturing industries, so more efficient use is very necessary [4]-[6]. In relation to technological developments and global market competition, workshops are required to always be ready to serve production needs [7]. With the development of ceramic dimensions and ceramic motifs that vary greatly due to increasing consumer demand, innovation is needed in terms of serving the needs of making punches through process stages supported by machines with various functions and ways of working. For this reason, the workshop classifies the type of work by dividing it into several sections to make it easier to carry out the stages of the process of completing notifications from production plant users [8]. The following is the division of the MKIR central engineering workshop machine area sections:

1. Punch repair section: yellow area
2. Mold repair section: turquoise area
3. Fabrication section: green area
4. Motor rewinding section: gray area
5. Design section: blue area

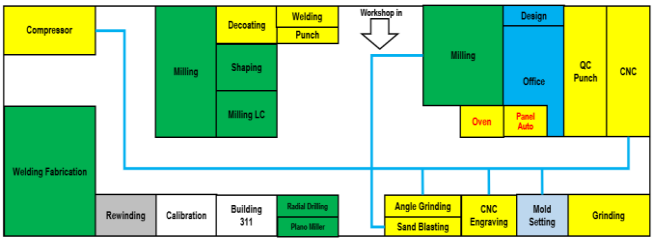


Fig. 1. Workshop Layout

A compressor machine is a machine or mechanical device that functions to increase pressure or compress gas or air fluids [9]-[11]. The compressor uses an engine as its driving force. The compressor is one of the company's pieces of equipment in the smooth running of the company for the purposes of starting the main engine and also functions to increase gas pressure, distribute air to other parts so that the process runs smoothly [12]. The working principle of the compressor is based on Boyle's law, which states that at a constant temperature, gas pressure will increase when its volume is reduced [13],[14]. In industry, compressors have an important role in various applications, one of the uses of compressors in industry is to change air from low pressure to high pressure [15],[16]. Over time, compressor performance will experience a decline due to wear and tear on the components of the compressor unit.

Previous studies have demonstrated the effectiveness of TPM in improving machine reliability and reducing downtime. However, research specifically addressing compressor applications in ceramic manufacturing environments is limited. Most studies focus on general

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machinery or the automotive industry, so the current research aims to address this gap by applying TPM principles to compressors in ceramic manufacturing [17].

Compressors come in various types and models depending on their volume and pressure. Compressors can be divided into two main types: positive-pressure compressors, where gas is drawn into a cylinder and compressed; and non-positive-pressure compressors, where the drawn-in gas is accelerated by an impeller, which then converts kinetic energy to increase pressure [18].

1. Piston Compressor. Reciprocating compressors operate on the principle of a forward/reverse piston movement. When the piston moves backward, the piston chamber volume is large, and the pressure is low, allowing air from outside to enter. When the piston moves forward, the piston chamber volume decreases, increasing pressure and forcing air into the reservoir. A valve is located in the reservoir to prevent air from returning to the piston chamber [19].
2. Rotary Compressor. Rotary compressors have a rotor in one housing with the piston and provide continuous, pulsation-free output.
3. Dynamic Compressor. Dynamic compressors supply energy to accelerate the flow of air or gas continuously using an impeller that rotates at very high speeds. Dynamic compressors are used for large-scale fluid compression.

The several machines that use compressors; some are users of compressor product water facilities, which are the heart of the wind supply whose existence and function are very important to support the productivity of punch repairs [20]. Thus, this compressor machine is a vital supporter of the machine's running process and product water usage services to achieve the target results of punch repairs in the workshop, as well as improving the idea [21]. The compressed air system has a supply and demand section. Good supply side regulation will produce clean, dry and stable compressed air for distribution to users (demand) [22],[3]. Likewise, good demand-side regulation will minimize losses due to waste, leaks, and improper use [23].

The compressor engine is one of the five engines with the highest energy consumption [24]. Over time, compressor performance will decrease due to wear and tear on the components of the compressor unit, which will affect the heat absorption process from the material to be cooled [25], [26]. Evaluation of compressor performance is necessary to select an efficient compressor [27]. Compressor performance can be seen from the compressor map curve, which shows variations in head and power with the volumetric flow rate of the feed at a certain compressor rotation speed [28]. Decreased compression in an air compressor results in slow filling of compressed air in the air bottle [29]. Compressor efficiency can be increased by using automatic controls to regulate compressor operation according to needs and maintain the air system pressure as low as possible to reduce leaks [30].

Compressor downtime is a condition where the operation of a compressor unit stops, resulting in a disruption in the supply of compressed air to the production process. This event will have a direct impact on reduced operational performance because several machines and equipment that require compressed air must stop working or operate below the desired standard. Compressor downtime can be caused by various factors, such as mechanical failure, lubrication failure, pressure drop due to leaks, operating temperatures exceeding limits, and electrical system disruptions. In some cases, unscheduled maintenance can also cause the compressor to be temporarily shut down for inspection or replacement of worn components due to the effects of continuous use.

During downtime, the maintenance team must immediately conduct a root cause analysis to determine the root cause and the necessary corrective actions. These actions can include filter inspections, oil level checks, leak repairs, and critical spare part replacements. Furthermore, detailed recording of downtime, causes, actions, and impacts is crucial as a basis for evaluation and future equipment reliability improvement.

Preventive measures are also crucial. Implementing preventive maintenance practices such as a routine maintenance schedule, periodic checks of operating parameters, vibration monitoring, and the use of sensor-based monitoring systems can reduce the likelihood of sudden downtime [31]. With good maintenance management, compressor downtime can be minimized, thus maintaining the continuity of the production process and increasing overall operational efficiency [32]. One of the main tasks of a speculator and temporary worker in the arrangement and implementation of construction work is to measure the progress of implementation in relation to the agreed due date and costs [33]. The initial goal can be calculated using the following equation:

$$Initial\ Goal = \frac{Highest\ Downtime - Lowest\ Downtime}{Highest\ Downtime} \times 100\% \quad (1)$$

II. Research Method

This compressor downtime optimization study uses a qualitative research method, which examines the condition of compressor objects based on facts obtained in the field. The method includes targeted data sampling from existing company data sources. The survey method utilizes triangulation (combination), data analysis is inductive or qualitative, and qualitative findings are not generalizations. The results of this study are presented in narrative form, providing detailed descriptive explanations of the findings.

A. Data Collection Techniques

The purpose of data collection is to find solutions to existing issues, in accordance with the descriptive qualitative research method. Therefore, the data obtained will be analyzed qualitatively, which means conducting an in-depth analysis of each piece of information carefully obtained from field sources. The hope is that the results of this analysis will yield adequate conclusions. Data collection methods include observation, interviews, and documentation.

B. Data Analysis Techniques

The method used to process the data in this final assignment is a fishbone diagram. A fishbone diagram serves as a visual tool for identifying, investigating, and clearly describing each component that contributes to a problem.

III. Results and Discussion

This research was conducted during the production process, so the data obtained accurately reflects actual field conditions. During the fieldwork, the researcher was assisted by several employees from the engineering and maintenance

departments. Data collection took place from October to December 2024, from the final processing stage to the punching process. The data collected can be seen in Table I and Table II.

TABLE I. MONITORING CHECKLIST DATA

No	Machine	Month (min)			Total
		Oct	Nov	Dec	
1	Decoating	40	30	60	130
2	Welding punch	40	40	50	130
3	Grinding surface	60	120	240	420
4	CNC	1200	60	120	1380
5	Sand blasting	550	220	0	770
6	Angle grinding	60	75	60	195
7	Press	120	60	180	360
8	Engraving	25	25	120	170
9	Compresor	692	692	1400	2784
Total		**2787**	**1322**	**2230**	**6339**

TABLE II. MONITORING CHECKLIST DATA (CONTINUED)

No	Machine	Total (min)	%	% Acc
1	Compresor	2784	44	44
2	CNC	1380	22	66
3	Sand blasting	770	12	78
4	Grinding surface	420	7	84
5	Press	360	6	90
6	Angle grinding	195	3	93
7	Engraving	170	3	96
8	Decoating	130	2	98
9	Welding punch	130	2	100
Total		**6339**	**100**	

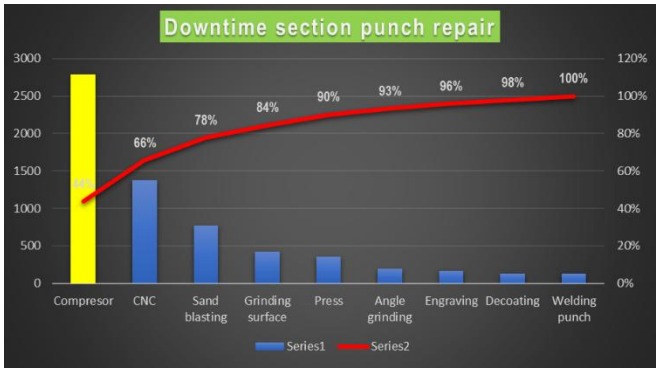


Fig. 2. Pareto Chart Diagram

So the initial goal can be calculated using Eq. 1 as follows:

$$Initial\ Goal = \frac{Highest\ Downtime - Lowest\ Downtime}{Highest\ Downtime} \times 100\% \quad (2)$$

$$Initial\ Goal = \frac{2.784 - 130}{2.784} \times 100\% \quad (3)$$

$$Initial\ Goal = 95.3\% \quad (4)$$

From the data table or Pareto graph above, it can be seen that the compressor machine has the highest downtime, namely 2784 minutes, so the researcher chose this compressor area as an improvement to reduce downtime.

A. Observation Results

Based on field observations, several dominant causes of reduced compressor downtime were identified, namely:

1. Dirty Evaporator



Fig. 3. Dirty Evaporator

2. No Alarm



Fig. 4. No Alarm

3. No Compressor Protection



Fig. 5. No Compressor Protection

4. Manual Drain Valve



Fig. 6. Manual Drain Valve

B. Interview Results

The researcher conducted interviews with several employees on-site, and the results were as follows:

1. What causes the decrease in compression in the air compressor? The employee explained that the

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decrease in compression in the air compressor is due to several factors, such as the low-pressure suction valve being no longer airtight or having passed its useful life and needing to be replaced. It can also be caused by a dirty evaporator in the air compressor, as well as a lack of maintenance.

2. What are the impacts of a decrease in compression in the air compressor? The employee explained that a decrease in compression in the air compressor would hamper the operation of the ongoing production process.
3. How is air compressor damage handled? The employee explained that, based on previous experience, proper handling involves replacing spare parts immediately and cleaning the air compressor evaporator.

The results of observation, documentation, and interview data were obtained using the fishbone analysis method. This method was used to find the results for the problem formulation described in the previous chapter. As shown in the fishbone diagram, researchers will discuss several important factors that contribute to the impact of reduced compression on compressed air. Using the fishbone analysis method, the causes of decreased performance in air compressors used in the production process can be identified. The results of the fishbone diagram analysis can be seen in Fig. 7.

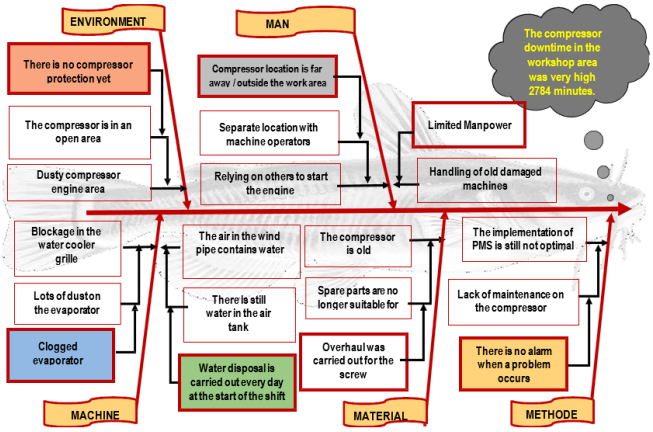


Fig. 7. Fishbone Diagram

Using a fishbone diagram to identify the causes of decreased compression in an air compressor at PT. XYZ, efforts can be made to address the decreased compression using a fishbone diagram analysis. Fishbone analysis is used to prevent recurring damage and maintain compressor performance. Several improvements were made by the team and researchers:

1. Evaporator Cleaning.
   Periodically clean the evaporator components to prevent clogging and restore normal operation. A PVC circuit is added for evaporator cleaning in auto-cleaning mode, with a PLC program cleaning system that runs every 10 seconds every hour to prevent compressor engine overheating. This can reduce downtime by 45 minutes per week.



Fig. 8. The Evaporator is Clean

2. Adding an Alarm Panel
   Adding a new panel with an alarm in the form of a light and siren to provide a signal if the compressor experiences problems such as overheating, electrical circuit problems, or pressure drops.



Fig. 9. New Alarm Panel

3. Making Auto Drain Faucet
   The addition of an automatic system with a valve component that is programmed automatically with a duration of 5 seconds every 1 hour so that there is no water content to supply to the machine, the air becomes dry, the sandblasting results are maximized, and there are no water spots.



Fig. 10. Auto Valve Installation

4. Construction of a Compressor Room
   The compressor room is constructed to protect the compressor from dust and other work objects, reducing cleaning time by 2x15 minutes per month.



Fig. 11. Compressor Room Construction

Future improvements should focus on enhancing machine performance, particularly by addressing the causes of speed losses, improving preventive maintenance, and optimizing the compressor's cooling efficiency. By addressing these key areas, management can significantly improve its operational efficiency and align more closely with industry standards

IV. Conclusion

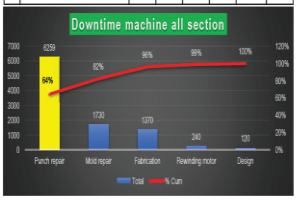
After making improvements to all line sections in the company, several data sets were collected for research analysis. The following is a comparison of the data before and after the improvements made by the researchers in all sections, reflecting the effects of the improvements made by the research team. See Table III.

Table III. Data Before and After Repairs To All Line Sections

Before Repair

Month (Minutes)

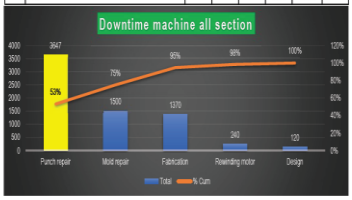
No	Section	Oct	Nov	Dec	Total	%	% Cum
1	Punch repair	2645	1332	2282	6259	64%	64%
2	Mold repair	250	280	1200	1730	18%	82%
3	Fabrication	120	250	1000	1370	14%	96%
4	Rewinding motor	120	60	60	240	2%	99%
5	Design	120	0	0	120	1%	100%
	Total				9719	100%	



After Repair

Month (Minutes)

No	Section	Apr	May	Jun	Total	%	% Cum
1	Punch repair	1215	1215	1215	3647	53%	53%
2	Mold repair	240	420	840	1500	22%	75%
3	Fabrication	120	250	1000	1370	20%	95%
4	Rewinding motor	120	60	60	240	3%	98%
5	Design	120	0	0	120	2%	100%
	Total				6877	100%	



From Table III, it can be concluded that downtime has decreased from 9719 minutes to 6877 minutes due to machine repairs across all line sections. Meanwhile, if we look at the reduction in downtime for compressors alone, it can be seen in Table IV.

Table IV. Data Before and After Repair of the Compressor

Before Repair

Data

No	Problem	Freq/month Oct '24	Nov '24	Dec '24	Total Freq	Duration (min)	Total
1	Start/Stop control is still manual	27	26	25	78	10	780
2	Water disposal is still manual	27	26	25	78	8	624
3	Evaporator cleaning is still manual	2	2	2	6	90	540
4	There is no overheat notification yet	1	1	2	4	120	480
5	Dirty and dusty compressor	4	4	4	12	30	360
TOTAL							2784

Before Repair

Data

No	Problem	Freq/month May '25	Jun '25	Jul '25	Total Freq	Duration (min)	Total
1	Addition of control panels at nearby locations & Wi-Fi	24	27	24	75	0,43	32
2	Auto drain fabrication	0	0	0	0	0	0
3	Auto cleaning fabrication	0	0	0	0	0	0
4	Alarm system installation	0	0	0	0	0	0
5	Compressor room construction	2	2	6	10	10	60
TOTAL							92

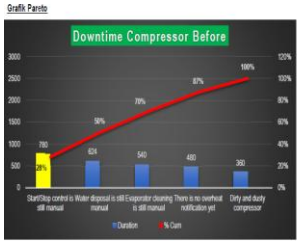
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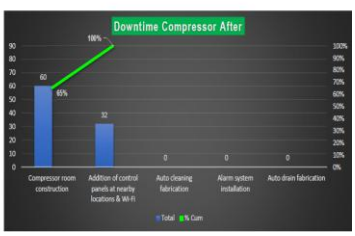
No	Problem	Duration	%	% Cum
1	Start/Stop control is still manual	780	28%	28%
2	Water disposal is still manual	624	22%	50%
3	Evaporator cleaning is still manual	540	19%	70%
4	There is no overheat notification yet	480	17%	87%
5	Dirty and dusty compressor	360	13%	100%
TOTAL		2784	100%	

Data

No	Problem	Duration	%	% Cum
1	Compressor room construction	60	65%	65%
2	Addition of control panels at nearby locations & Wi-Fi	32	35%	100%
3	Auto cleaning fabrication	0	0%	
4	Alarm system installation	0	0%	
5	Auto drain fabrication	0	0%	
TOTAL		92	100%	

Grafik Pareto





From the data in Table IV, after repairs, the researcher and team have succeeded in reducing the downtime volume by 2654 minutes for the compressor machine in the punch repair section.

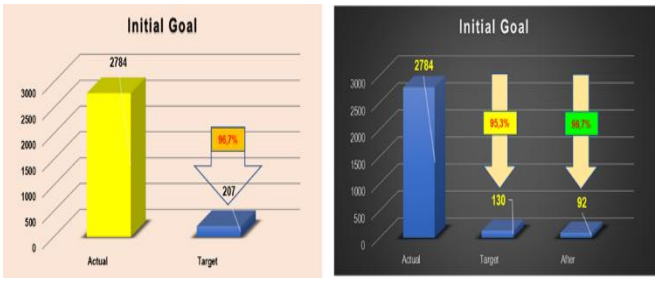


Fig. 12. Initial Goal Target Vs Actual

Meanwhile, if we look at the bar graph (Fig. 12), it can be seen that this research has succeeded in reducing downtime by 2692 minutes, exceeding the initial target from 95.3% = 130 minutes to 96.7% = 92 minutes within 6 months.

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