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Analysis of BTA16 CNC Machine Performance Improvement with Total Productive Maintenance Approach

Welly Atikno[1*], Erik Odi Wijaya[2], Indra Setiawan[3], Rendy Susanto[2], Hibarkah Kurnia[4]
[1]Master of Industrial Engineering Program, Universitas Mercu Buana, Jakarta, Indonesia
[2]Department of Industrial Engineering, Universitas Serang Raya, Banten, Indonesia
[3]Department of Production and Manufactuing Engineering, ASTRA Polytechnic, Cikarang, Indonesia
[4]Department of Industrial Engineering, Universitas Pelita Bangsa, Cikarang, Indonesia

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A B S T R A C T

Machinery or production equipment was the most important part of a production system. Machines need effective and efficient maintenance to be able to guarantee and support the production process to operate properly. The gas filter industry is an industry that produces air and gas filters. The gas filter industry has many production machines, one of which is CNC BTA16. This machine often has problems such as downtime that interfere with smooth production. The purpose of this study was to determine the problems in the CNC BTA16 production machine and provide recommendations for improvements to improve machine performance. The approach used is Total Productive Maintenance. Problem analysis was carried out through Focus Group Discussions with experts. The results showed that the cause of the engine is not optimal comes from abnormal heat in the gearbox on the engine spindle component caused by operator error when inputting data. The results of the calculation of the OEE value on the BTA16 CNC machine during the January – December 2021 period, the average OEE value was 73%. Suggested improvements are to make a special schedule for maintenance, check all speeches, and conduct training for employees to improve knowledge and skills.

*Corresponding Author
Erik Odi Wijaya
E-mail: erikodiwijaya97@gmail.com

1. INTRODUCTION

The development of the industry presents the challenge of intense competition around the world. The manufacturing industry is under pressure to deliver high performance and customer commitment (Hernadewita et al., 2019). To deal with the ever-changing demands of customers, manufacturing companies choose to adopt strategic changes in management approaches, production processes, and technologies. Factors supporting the success of other manufacturing companies are determined by the ability of production equipment or machines to operate properly. Machines need effective and efficient maintenance to be able to guarantee and support the production process to operate properly. One approach to improve the performance of maintenance activities is to implement a Total Productive Maintenance strategy (Nurprihatin et al., 2019) (Prabowo et al., 2018). Total Productive Maintenance (TPM) is a typical Japanese maintenance method that has been developed. TPM was developed based on the concept and methodology of maintenance productivity (Thorat & Mahesha, 2020). The goal of TPM is to maximize the effectiveness of plant machinery and equipment in order to produce an optimal production machine life cycle (Purba et al., 2018).

The production process in the gas filter industry has several supporting machines in the fabrication process, namely CNC machines, welding machines, shearing machines, and polishing machines. During operation, downtime often occurs on some of these machines. The Brio Turner A16 (BTA16) CNC machine is a single-head CNC machine where the machine is only capable of turning one type of part with a certain program. The working concept of the BTA16 CNC machine is almost the same as a manual lathe where there must be unloading activities for each installation of the part that you want to process. BTA16 CNC machine is very suitable for companies engaged in fabrication. The turning process in this field is custom and does not mass produce for one type of product. Therefore the machine must have an intensive maintenance schedule to maintain the balance of production.

Companies must take appropriate policies in dealing with conditions that will occur (Nallusamy, 2016). To solve this problem, several methods are needed, such as the calculation of Overall Equipment Effectiveness (OEE) to calculate the effectiveness of the BTA16 CNC machine (Sukma et al., 2021) (Saleem et al., 2017) (Agung & Siahaan, 2020) and be combined with PDCA (Kurnia et al., 2022). Failure Mode and Effect Analysis (FMEA) to analyze errors/failures on the BTA16 CNC machine (Stamatis, 1995) (Zuniawan, 2020) and analysis of finishing defects (Sjarifudin et al., 2022). Fishbone diagram to determine the root of the problem that occurs on the CNC BTA16 machine and suggest improvements using 5W+1H in the hope of providing a solution to the existing problems, including finding out the factors for the low performance of the BTA16 CNC machine (Dewi et al., 2020) and Knitting machine for using 5W+1H (Kurnia et al., 2021). Previous research conducted by (Candra et al., 2017) (I. Setiawan, 2021) (Mkalaf, 2020) has used the TPM method to increase the effectiveness of machines in the manufacturing industry. In addition, sensors can also be applied to detect damage early. Research (Sukma et al., 2022) (S. Setiawan, 2021) applies TPM based on 3 pillars. Research by (Purba et al., 2018) (Sen et al., 2019) involves experts to make continuous improvements. The purpose of this study was to determine the problems in the CNC BTA16 production machine and provide recommendations for improvements to improve machine performance.

2. RESEARCH METHOD

This study will analyze the effectiveness and performance of the BTA16 CNC Machine. The research was conducted in one of the tool-making industries, namely the Gas Filter Industry. Primary data is needed through interviews and observations such as production process data. In addition, primary data was also obtained from the results of the Focus Group Discussion (FGD) (Hendra et al., 2021). Secondary data is needed through journal references and company reports such as downtime data for one year. This study uses a TPM approach with OEE as the engine effectiveness parameter. The research begins with determining the largest breakdown of the production machine. Then perform the calculation of the OEE value on the problematic machine. The following formula is used to calculate the OEE value:

$$\text{Availability} = \frac{\text{Loading Time} - \text{Downtime}}{\text{Loading Time}} \text{ X } 100\% \quad (1)$$

$$\text{Performance Efficiency} = \frac{\text{Process Amount x Ideal Cycle Time}}{\text{Operation Time}} \text{ x } 100\% \quad (2)$$

$$\text{Rate of Quality} = \frac{\text{Process Amount} - \text{Defect Amount}}{\text{Process Amount}} \text{ x } 100\% \quad (3)$$

$$\text{OEE} = \text{Availabilty x Performance RatexRate of Quality} \quad (4)$$

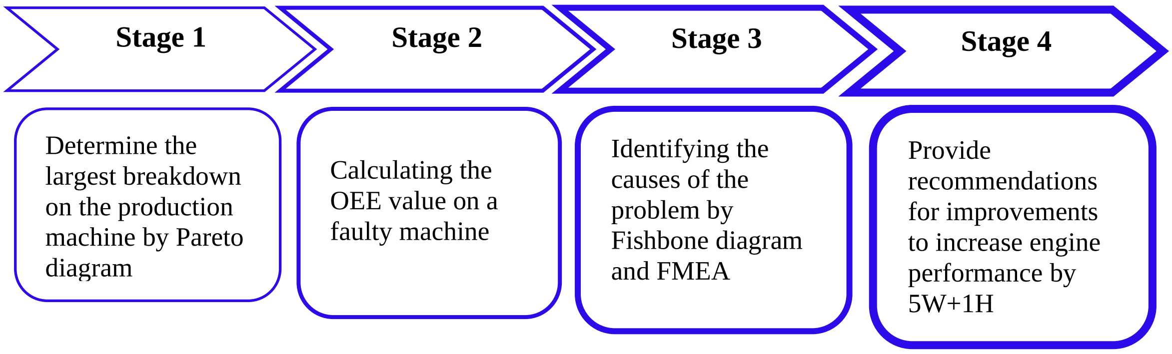

Fig. 1. Research framework

Analysis of the causes of the problem was carried out using a Fishbone diagram through an FGD with experts (Perdana & Santoso, 2019), and an FGD combination to determine 5W+1H (Sukma et al., 2022). The repair phase is carried out using 5W+1H. This study also uses a systematic flow chart which can be seen in Figure 1.

3. RESULT AND DISCUSSION

Stage 1

This section begins by analyzing the largest data breakdown that occurs in the production machine. Based on production data for the January – December 2021 period, it is known that the BTA16 CNC Machine is the machine with the largest downtime. Table 1 is a breakdown of production machines in the gas filter industry.

Table 1. Machine downtime data for 2021

Month (2021)	Machine Downtime (Minute)			
	CNC Machine	Welding Machine	Shearing Machine	Polish Machine
January	475	155	120	70
February	440	120	135	65
March	495	135	120	90
April	550	135	145	120
May	540	155	120	85
June	670	120	110	95
July	710	100	115	80
August	725	260	145	140
September	690	220	255	155
October	845	130	135	180
November	970	160	160	175
December	965	225	225	150
Total	8,075	1,915	1,785	1,405

Based on Table 1, it is known that the BTA16 CNC Machine is the machine with the largest breakdown with a total of 8,075 minutes for a year. Therefore, it is necessary to make improvements so that the machine works optimally and can produce products according to the target. More details can be seen in Fig. 2.

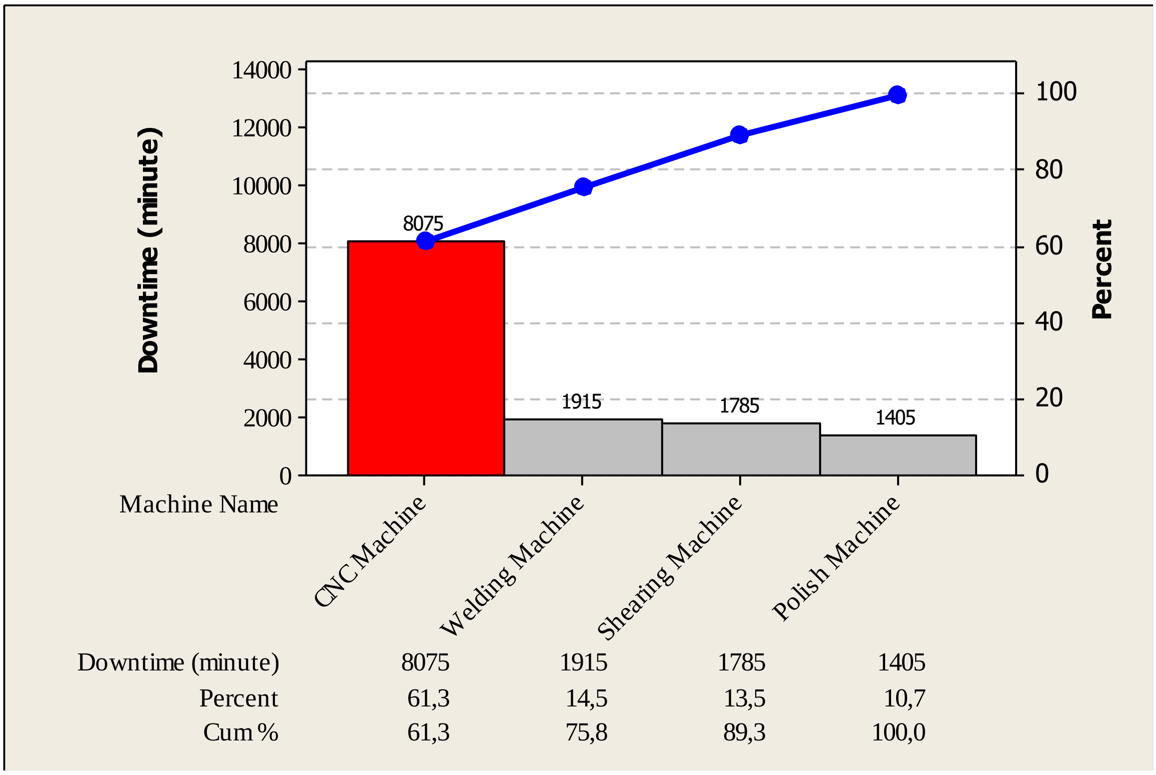

Fig. 2. Pareto diagram of downtime 2021

Stage 2

Before further analysis, the OEE value was calculated on the BTA16 CNC Machine. The calculation of the OEE value is carried out using the formulas (1), (2), (3), and (4) in the January 2021 sample, namely as follows:

$$\text{Availability} = \frac{416 - 8}{416} \text{ x } 100\% = 98\%$$

$$\text{Performance Efficiency} = \frac{1345 \text{ x } 0{,}25}{408} \text{ x } 100\% = 82\%$$

$$\text{Rate of Quality} = \frac{1345 - 55}{1345} \text{ x } 100\% = 96\%$$

$$\text{OEE} = 98\,\% \text{ x } 82\,\% \text{ x } 96\% = 77\%$$

Availability, Performance Efficiency, Rate of Quality, and OEE values in January – December 2021 can be seen in Table 2. Based on the calculations, it is known that the average OEE value during January – December 2021 is 73%. This value is still far from the OEE standard value of 85%.

Table 2. Recapitulation OEE value

Month	Loading Time (Hours)	Total Downtime (Hours)	Availability (%)	Processed Amount (Unit)	Ideal Cycle Time (Hours)	Operation Time (Hours)	Performance Efficiency (%)	Processed Amount (Pcs)	Defect Amount (Pcs)	Rate of Quality (%)	OEE (%)
January	416	8	98%	1345	0.25	408	82%	1345	55	96%	77%
February	384	7	98%	1353	0.23	377	82%	1353	47	97%	77%
March	416	8	98%	1325	0.25	408	82%	1325	75	94%	77%
April	416	9	98%	1335	0.25	407	82%	1335	65	95%	76%
May	416	9	98%	1343	0.25	407	82%	1343	57	96%	77%
June	416	11	97%	1330	0.25	405	82%	1330	70	95%	76%
July	416	12	97%	1255	0.27	404	82%	1255	145	88%	71%
August	416	12	97%	1230	0.27	404	82%	1230	170	86%	69%
September	416	12	98%	1280	0.26	405	82%	1280	120	91%	73%
October	416	14	97%	1275	0.26	402	83%	1275	125	90%	72%
November	416	16	96%	1245	0.27	400	83%	1245	155	88%	70%
December	416	16	96%	1210	0.28	400	83%	1210	190	84%	67%
Total	143	11	97%	1294	0.25	402	82%	1294	106	92%	73%

Improvements to the OEE value on the BTA16 CNC machine are still needed to improve overall performance capabilities. The average value of performance efficiency has the smallest value of 82% among the parameters that affect the OEE value. The performance efficiency value is the lower value in the OEE calculation. This value will cause a low effectiveness value in the production system. Based on observations, it was found that several things caused OEE to be not optimal, namely the existence of a failure mode in production results, and it was necessary to find the cause of the problem and propose improvements by increasing performance maintenance.

Stage 3

Analysis of the causes of the problem is carried out to find out the source of the problem. The fishbone diagram obtained is a causal analysis concept generated through FGD with experts. The FGDs that have been conducted consist of 5 experts who are experienced in their respective fields. For these experts, it can be seen in Table 3.
Fishbone diagram to describe a problem and its causes from the BTA16 CNC Machine. The results of the problem analysis are then interpreted in Fig. 2.

Table 3. Expert judgments member

Expert	Age (year)	Work Experience (year)	Position	Special Skill	Remark
Expert 1	45	20	Director	SCM, TQM	Internal
Expert 2	42	23	Factory Manager	TQM, TPM, Kaizen	External
Expert 3	47	17	Production Manager	Lean, TPM	External
Expert 4	52	18	Maintenance Manager	Kaizen, TPM	External
Expert 5	47	20	Spesialis	TPM, OEE	Consultant

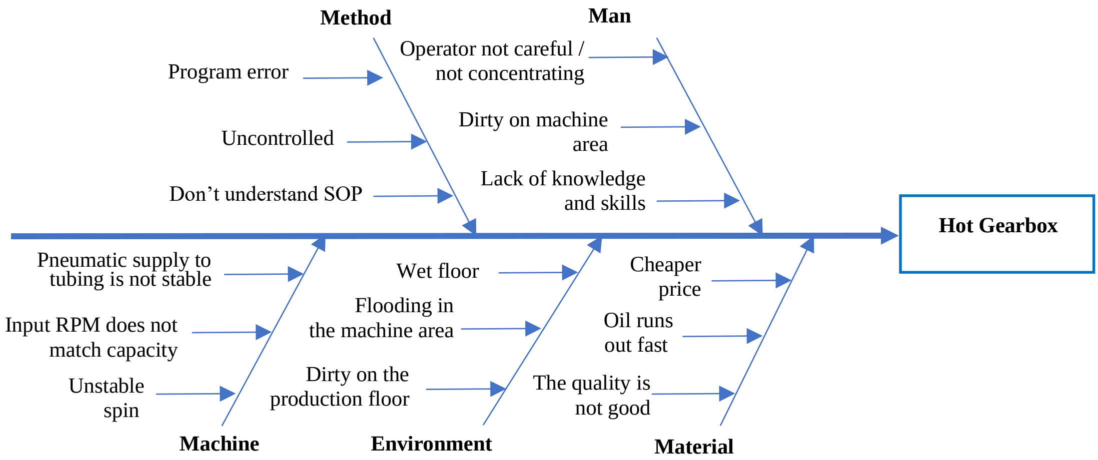

Fig. 3. Fishbone diagram of hot gearbox

After finding the various causes of the problem, it is then transformed into the FMEA method. This method is used to find out the causes of dominant problems and priorities that must be improved based on FMEA results (Manurung et al., 2021). The following analysis of determining the main problems with FMEA can be seen in Table 4.

Table 4. Analysis of FMEA

Component	Failure Mode	Failure Cause	Failure Effect	S	O	D	RPN
Control Panel	Hot CPU	The received power fan is unstable	Blank screen display	7	7	6	252
Machine Spindel	Hot gearbox	Input RPM does not match capacity	Oil runs out fast	7	7	8	448
Hose Collant	The pneumatic supply to the tubing is not stable	The pneumatic pressure of the compressor is very small	Coolant does not flow as needed	7	8	7	343
Panbelt	Broken fan belt	RPM gear set does not match capacity	Unstable engine rotation	8	6	5	240
Bearing Chuk	Head chuck shakes when turning	Grace on thirsty bearings	Unstable engine rotation	5	7	6	240
Existing Collect	The outlet hose is clogged scrub	The perforated plate hole is still too big	Flooding in the engine area	8	8	6	336
Insert Knife	Blunt blade	There are often collisions at the beginning of the process	Shorten the turn on the blade	7	6	6	294

Based on Table 3, the largest RPN value is found in the engine spindle component with a value of 448. Identification of damage comes from a hot gearbox which results in the lubricating oil running out quickly. This is caused by the RPM input process does not match the capacity. Thus this cause will be repaired with 5W+1H.

Stage 4

5W+1H is a method used to investigate and provide recommendations for improvements to problems that occur in the production process. After all the root problems are known, then improvements are made through the contribution of advice from experts. The following results of the improvement analysis with 5W+1H can be seen in Table 5.

Table 5. Analysis 5W+1H for improvement

Identification of the type of damage	What	Where	When	Why	Who	How
Wrong program input	Crash tool	Panel CNC	During the data input process	Not careful / Not concentrating	Operator CNC	Checking the program before running / trial part
Oil runs out fast	RPM decreased	Gearbox	During the data input process	Wrong program input	Operator CNC	Checking the program before running/doing a trial part
Program error	Machine stop	CNC Machine	When creating a program at the beginning	Lack of knowledge and skills	Engineering	Provide training to operators to increase the knowledge and special skills of CNC machine operators
Gearbox breaks fast	Unstable spine	Gearbox	During the production process	The quality of spare parts is not good	Maintenance	Give a clear speech to procurement related to spare parts procurement

Explanation and proposed fixes for malfunctions in the gearbox:

1. The root of the problem that causes the operator to enter the program incorrectly is because the operator does not concentrate on the work and the operator thinks too much outside of work so that the work loses focus and is less thorough which results in errors in the data input process. The suggested improvement is to focus on work and re-check the program before running, this is enough to minimize the occurrence of errors in the production process.
2. The root of the problem that makes the oil run out quickly is because the operator has set the RPM incorrectly for the material whose turning process takes a long time. Therefore, the gearbox rotation does not match the capacity. The suggested improvement is to re-check the program that has been inputted and master the datasheet for all material sizes
3. The root of the problem that makes the program error is due to lack of knowledge and skills so it is wrong to make the initial program which causes the CNC machine to not be able to run the program. The suggested improvement proposal is to conduct special training for operators to add insight and skills to the BTA16 CNC machine
4. The root of the problem that makes the gear fall out quickly is because the quality of the spare parts purchased is not very good in terms of price and quality. This causes the gear to have a short lifetime. The proposed improvement is to provide valid information to procurement regarding the quality of spare parts and recommend purchases according to the needs or specifications in the field.

4. CONCLUSION

Based on the analysis in the previous section, this research has identified and provided improvements to the BTA16 CNC machine. The results of the calculation of the OEE value on the BTA16 CNC machine during the period January - December 2021 obtained an average OEE value of 73%. This value is still far from the world-class OEE standard of 85%.

The low performance of the BTA16 CNC machine is caused by abnormal heat in the gearbox in the Machine Spindle component. This occurs due to operator error during the RPM input process at the beginning of the process so that the power output does not match the capacity. As a result, the rotational power of the gear becomes heavier and the oil in the storage gearbox runs out quickly.

Suggested improvements to maintain the performance of the BTA16 CNC machine to be more productive are to make a special schedule for maintenance, check all specifications related to the BTA16 CNC machine, and conduct training for employees to increase their knowledge and skills.

This research needs to be developed by applying the 8 pillars of TPM so that breeding is more specific to get complex and measurable results

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