Measurement of effectiveness spinning fiber machines using total productive maintenance method at textile manufacturing

Edi Supriyadi[1*], Rully Nurdewanti[2]
[1,2] Department of Industrial Engineering, Tangerang City, Banten Province, Indonesia
* Corresponding author: dosen00905@unpam.ac.id

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ABSTRACT

PT XYZ is a textile industry manufacturing company whose main products are Polymer Chips, Pre-Oriented Yarn (POY), Draw Twister Yarn (DTY), Bi Shrankage Yarn (BSY), and Polyester Staple Fiber (PSF) which are marketed domestically and internationally. There are still high breakdown problems, which can hamper the production process and result in a decrease in production capacity. The purpose of this study was to measure the Performance Effectiveness of Fiber Spinning Machines using the Total Productive Maintenance (TPM) Method and to find the causes of the Six Big Losses that affect the Performance Effectiveness of Fiber Spinning Machines. The application of TPM in the manufacturing industry aims to extend machine life and maximize the effectiveness of machine performance. The results of measuring the Performance Effectiveness of Fiber Spinning Machines using the TPM Method obtained an Overall Equipment Effectiveness (OEE) value of 87.85% and the cause of Six Big Losses that affect the effectiveness of the performance of Fiber Spinning Machines is Equipment Failure Losses, the most dominant factor is the Human Factor, namely lack of control, lack of understanding of Standard Operational Procedure (SOP), lack of thoroughness when cleaning spinnerets.

1. Introduction

PT XYZ is a textile industry manufacturing company that has been established since 1979. The main products produced from the production of PT XYZ are Polymer Chips, Pre-Oriented Yarn (POY), Draw Twister Yarn (DTY), Bi Shrankage Yarn (BSY), and Polyester Staple Fiber (PSF) which is marketed to cover the whole world, both domestic and foreign markets. One of the mainstay products for PT XYZ to market is Polyester Staple Fiber (PSF) which is produced at the Staple Fiber Department. Polyester Staple Fiber (PSF) is the main raw material used by the textile industry to produce Polyester Spun Yarn, which is widely used for clothing and household appliances. The Fiber Spinning Machine is the most important part of the overall production in the Staple Fiber Department because this machine is a critical unit where if there is damage to this machine it will stop the production process (Syafwiratama et al., 2017). The Fiber Spinning Machine itself is always in operation for 24 hours without stopping with a production capacity of 67 tons/day, where every month of production there are a few product defects during the production process. In carrying out the production process in the Staple Fiber Department, there are still high breakdown problems. This can hamper the production process which results in a decrease in production capacity (Haviana & Hernadewita, 2019).

In overcoming this, a comprehensive solution is needed so that companies can improve their maintenance concepts and systems, where the new concepts and systems are not only able to ensure that the equipment owned can produce High-Quality Products but can also measure the overall efficiency of the equipment and facilities provided (Harahap et al., 2021) owns and can identify problems and provide

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ideas for production improvements and machine maintenance that must be done. Total Productive Maintenance (TPM) is a good method of maintaining production machines to be applied in the manufacturing industry (Hardono, 2020). The application of TPM in the manufacturing industry aims to extend machine life and maximize the effectiveness of machine performance. The effectiveness of machine performance can be measured using the Overall Equipment Effectiveness (OEE) method (Indriawanti & Bernik, 2020). OEE measurement is based on three categories, namely Availability Rate, Performance Rate, and Quality Rate (Muhaemin & Nugraha, 2022).

The gap with other research which is almost the same as the object of this research is that there are not so many textile products around textiles (Kurnia, Tumanggor, et al., 2021). Research at spinning factories confirms that spinning machine performance can also be improved, namely with TPM, especially periodic maintenance (Sihombing & Sumartini, 2017). Apart from that, in the Weaving section of tape making, there has been an increase in the OEE value and a reduction in tape defects with Six Sigma. In the Knitting section, many researchers have also produced scientific work analyzing OEE and Six Sigma DMAIC values (Kurnia, Jaqin, & Manurung, 2022). Identifying all production machines with OEE values that must be known both before repair and after repair can help companies increase company profits (Kurnia, Jaqin, & Purba, 2022).

The TPM is an approach to reduce and eliminate breakdowns that occur on machines innovatively in the maintenance process by optimizing the effectiveness of each piece of equipment and also carrying out maintenance carried out independently by the operator (Hairiyah et al., 2019)(Gianfranco et al., 2022). Based on the background and theoretical studies, the researcher tries to conduct research using the TPM Method to provide input on the problems encountered through the calculation of OEE and tries to uncover the root of the problem from the researcher's point of view.

2. Methods

The primary data in this study came from sources that were directly observed to obtain actual data. The process observed was the breakdown data of the Fiber Spinning machine. The stages of observation and interviews were carried out with informants who were related to the object of the research problem, namely the process in the Staple Fiber department and the problems experienced during the process. Company documentation is used for research needs, while secondary data comes from literature studies with literature and research methods (Kurnia & Hardi Purba, 2021).

Research data collection was carried out by direct observation to obtain actual data to find out the problems and their causal factors so that researchers can easily map out the corrective steps taken. The steps for the data analysis method are divided into 4 (four) outlines as follows (Hairiyah et al., 2019).

a. Overall Equipment Effectiveness (OEE)

Provides an overview of machine performance and accurate numbers to determine the level of effectiveness of the machine used (Wahid, 2020).

$$OEE\ (\%) = AxPxQx100\% \tag{1}$$

Information:
A = Availability (machine/equipment availability)
B = Performance Effectiveness
C = Quality

b. Availability

It is the ratio of operation time by eliminating equipment downtime to loading time (Atmaja et al., 2018).

$$\text{Loading Time} = \text{Running Time} - \text{Planned Downtime} \tag{2}$$
$$\text{Operating Time} = \text{Loading Time} - \text{Down Time} \tag{3}$$

c. Performance

Is a ratio that describes the ability of equipment to produce products (Firman et al., 2019).

$$Performance = \frac{Cycle\ Time}{Operating\ Time} \tag{4}$$

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d. Quality

Is a ratio that describes the ability of the machine to produce products according to the specifications set (Kartika & Bakti, 2019).

$$Quality = Processed\ Amount - \frac{Defect\ Amount}{Processed\ Amount} \quad (5)$$

The stages of the research starting from the formulation of the problem to the conclusion can be seen in Fig. 1.

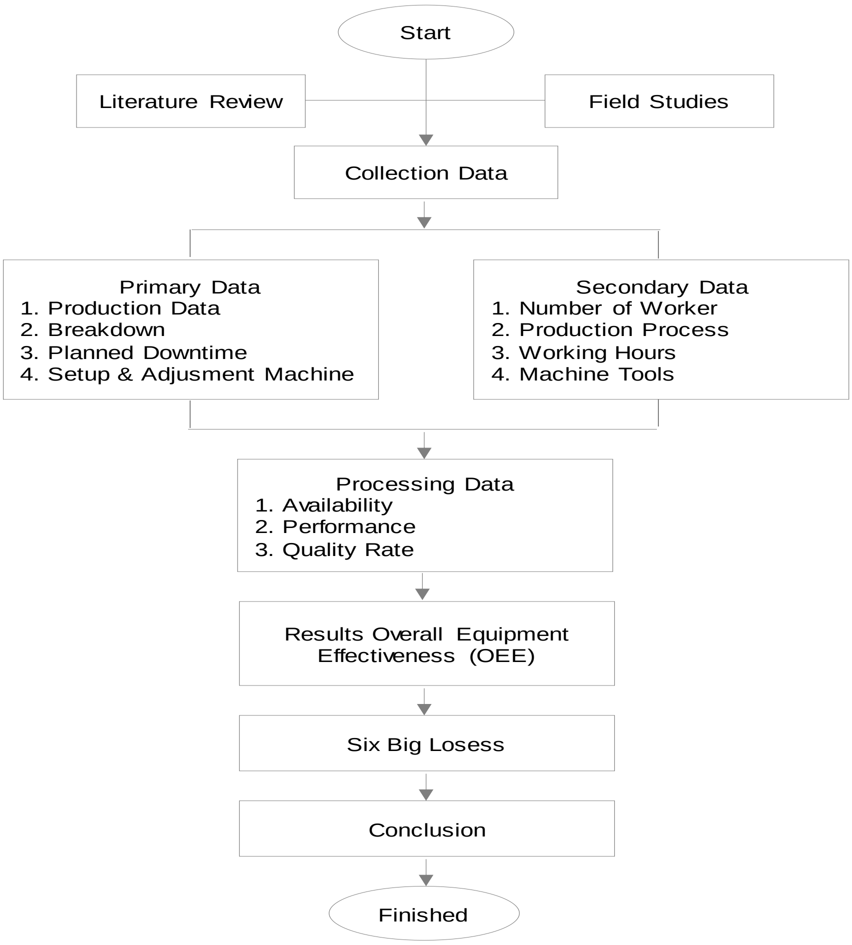

Fig. 1 Research flowchart

3. Results and Discussion

Data Output is a good output product from the production process that occurs in the Spinning Fiber department (finished products), Data defects are product data that fails from the production process that occurs in the Spinning Fiber department (product defects), while the total production data is the total of all processes production that occurs in the Spinning Fiber department in the form of finished products and defects. The following is data on the number of outputs, defects, and total production of Fiber Spinning machines for the period January to December 2022 which are listed in Table 1.

Table 1 Data on the number of outputs and production defects (2022)

Month	Output (Tons)	Defect (Tons)	Total Production (Tons)

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Month	Output (Tons)	Defect (Tons)	Total Production (Tons)
Jan	1.239,04	10,97	1.250,02
Feb	1.654,31	10,97	1.665,28
Mar	1.818,87	25,85	1.844,72
Apr	1.988,84	22,08	2.010,93
May	1.972,55	19,67	1.992,22
Jun	1.856,05	31,48	1.887,53
Jul	1.965,61	21,9	1.987,51
Aug	1.997,81	17,74	2.015,55
Sep	1.919,28	27,56	1.946,85
Oct	2.019,93	18,88	2.038,81
Nov	1.918,18	22,16	1.940,34
Dec	1.936,53	26,27	1.962,80
Amount	**22.287,01**	**255,54**	**22.542,55**

Availability Rate Data for Fiber Spinning Machines from January to December 2022, can be seen in Table 2. Next, the researchers carried out an analysis of the Six Big Losses, which is an analysis of the 6 biggest losses from spinning machines which often result in product defects or machine stops. Six Big Losses analysis is needed to analyze the types of defects that often occur over several periods (Sukma et al., 2022). The analysis can be seen in Table 2.

Table 2 Availability rate calculation data (2022)

Month	Machine Work Time (Hours)	Planned Downtime (Hours)	Loading Time (Hours)	Breakdown (Hours)	Setup (Hours)	Downtime (Hours)	Operating Time (Hours)	Availability Rate (%)
Jan	744	33,47	710,53	54,97	4,42	59,39	651,15	91,64%
Feb	720	31,15	688,85	47,50	0	47,50	641,35	93,10%
Mar	744	29,17	714,83	45,73	0	45,73	669,10	93,60%
Apr	720	30,10	689,90	46,27	0	46,27	643,63	93,29%
May	744	28,70	715,30	44,82	0	44,82	670,48	93,73%
Jun	744	24,82	719,18	43,05	0	43,05	676,13	94,01%
Jul	720	16,02	703,98	29,87	0	29,87	674,12	95,76%
Aug	744	23,13	720,87	36,05	0	36,05	684,82	95,00%
Sep	720	26,33	693,67	40,60	0	40,60	653,07	94,15%
Oct	744	28,08	715,92	42,78	0	42,78	673,13	94,02%
Nov	744	33,35	710,65	52,30	0	52,30	658,35	92,64%
Dec	696	37,82	658,18	56,18	0	56,18	602,00	91,46%
				Average				**93,54%**

Before calculating the percentage of Performance Rate, it is necessary to know the Ideal Cycle Time value which is presented in Table 3.

Table 3 Ideal cycle time calculation data (2022)

Month	Machine work time (Hours)	Total delay (Hours)	Loading Time (Hours)	Total Production (Tons)	Percentage Hours Worked (%)	Cycle Time (Hours)	Ideal Cycle Time (Hours)
Jan	744	97,27	710,53	1250,02	86,93%	0,57	0,49
Feb	720	78,65	688,85	1665,28	89,08%	0,41	0,37
Mar	744	74,90	714,83	1844,72	89,93%	0,39	0,35
Apr	720	76,37	689,90	2010,93	89,39%	0,34	0,31
May	744	73,52	715,30	1992,22	90,12%	0,36	0,32
Jun	744	67,87	719,18	1887,53	90,88%	0,38	0,35
Jul	720	45,88	703,98	1987,51	93,63%	0,35	0,33
Aug	744	59,18	720,87	2015,55	92,05%	0,36	0,33
Sep	720	66,93	693,67	1946,85	90,70%	0,36	0,32

Month	Machine work time (Hours)	Total delay (Hours)	Loading Time (Hours)	Total Production (Tons)	Percentage Hours Worked (%)	Cycle Time (Hours)	Ideal Cycle Time (Hours)
Oct	744	70,87	715,92	2038,81	90,47%	0,35	0,32
Nov	744	85,65	710,65	1940,34	88,49%	0,37	0,32
Dec	672	94,00	658,18	1962,80	86,01%	0,34	0,29

Data on the percentage value of the Performance Rate of Fiber Spinning machines for the period January to December 2022 can be seen in Table 4.

Table 4 Performance rate calculation data

Month	Ideal Cycle Time (Hours)	Total Production (Tons)	Operating Time (Hours)	Performance Rate (%)
Jan	0,49	1250,02	651,15	94,07%
Feb	0,37	1665,28	641,35	95,67%
Mar	0,35	1844,72	669,10	96,08%
Apr	0,31	2010,93	643,63	95,82%
May	0,32	1992,22	670,48	96,14%
Jun	0,35	1887,53	676,13	96,66%
Jul	0,33	1987,51	674,12	97,78%
Aug	0,33	2015,55	684,82	96,89%
Sep	0,32	1946,85	653,07	96,34%
Oct	0,32	2038,81	673,13	96,23%
Nov	0,32	1940,34	658,35	95,52%
Dec	0,29	1962,80	602,00	94,04%
Average				**95,94%**

The results of the Quality Rate calculation for the Spinning Fiber machine for the period January to December 2022 can be seen in Table 5.

Table 5 Quality rate calculation data (2022)

Month	Output (Tons)	Defect (Tons)	Total Production (Tons)	Quality Rate (%)
Jan	1239,04	10,97	1250,02	98,24%
Feb	1654,31	10,97	1665,28	98,68%
Mar	1818,87	25,85	1844,72	97,20%
Apr	1988,84	22,08	2010,93	97,80%
May	1972,55	19,67	1992,22	98,03%
Jun	1856,05	31,48	1887,53	96,66%
Jul	1965,61	21,90	1987,51	97,80%
Aug	1997,81	17,74	2015,55	98,24%
Sep	1919,28	27,56	1946,85	97,17%
Oct	2019,93	18,88	2038,81	98,15%
Nov	1918,18	22,16	1940,34	97,72%
Dec	1936,53	26,27	1962,80	97,32%
Average				**97,75%**

The following is the result of calculating the Overall Equipment Effectiveness (OEE) value of Fiber Spinning machines for the January to December 2022 production period.

Table 6 Calculation of Overall Equipment Effectiveness (OEE) in 2022

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Month	Availability Rate (%)	Performance Rate (%)	Quality Rate (%)	Overall Equipment Effectiveness (%)
Jan	91,64%	94,07%	98,24%	84,69%
Feb	93,10%	95,67%	98,68%	87,90%
Mar	93,60%	96,08%	97,20%	87,41%
Apr	93,29%	95,82%	97,80%	87,43%
May	93,73%	96,14%	98,03%	88,34%
Jun	94,01%	96,66%	96,66%	87,85%
Jul	95,76%	97,78%	97,80%	91,56%
Aug	95,00%	96,89%	98,24%	90,43%
Sep	94,15%	96,34%	97,17%	88,14%
Oct	94,02%	96,23%	98,15%	88,80%
Nov	92,64%	95,52%	97,72%	86,47%
Dec	91,46%	94,27%	97,32%	83,92%
Average				**87,74%**

Based on the results of calculating the percentage of Six Big Losses from the Fiber Spinning machine, it can be seen that the loss factors that most influence the effectiveness of the performance of the Fiber Spinning machine are shown in Table 7.

Table 7 Percentage of Six Big Losses Factors

Six Big Losses	Value	Percentage	Cumulative
Equipment Failure Losses	0,0641	56,67%	56,67%
Reduced Speed Losses	0,0379	33,50%	90,17%
Defects in Process Losses	0,0101	8,93%	99,10%
Setup and Adjustment Losses	0,0005	0,46%	99,56%
Idling and Minor Stoppage Losses	0,0005	0,44%	100,00%
Reduced Yield Losses	0	0,00%	100,00%

Next, carry out a Fishbone diagram analysis which functions to analyze the root causes of the main causes of the problem (Sjarifudin & Kurnia, 2022). The cause and effect diagram analysis of Six Big Losses on a Fiber Spinning machine can be seen in Figure 2.

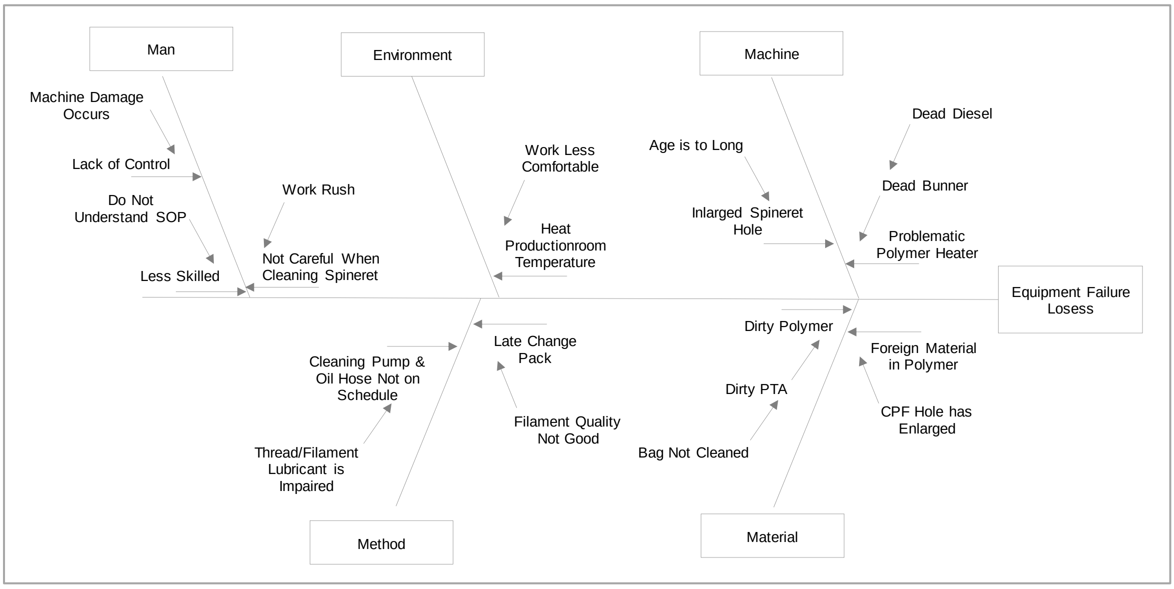

Fig. 2 Cause and effect diagrams

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After analyzing the main causes, the next step is to carry out a corrective action plan using the 5W+1H method (Kurnia, Jaqin, et al., 2021). The action plan for fixing the problem using 5W+1H can be seen in Table 8.

Table 8 5W+1H corrective action plan

Factor	Problem	What	Why	When
Man	Less skilled, less control, and less thorough	Improved way of working and communication	It is necessary to increase work productivity and product quality	Conduct new employee training and skill up every 6 months
Machine	The spinneret holes are enlarged and the polymer heater is problematic	Evaluating and determining spinneret service life and handling of machines is more towards predictive maintenance	Machine repair to support the production process	Weekly, monthly, and yearly evaluation of machine life
Material	The polymer is dirty and there is foreign material in the polymer	Frequent cleaning of the PTA tub should be carried out	Prevention of poor product quality	Checking raw materials and cleaning PTA storage tanks for quality improvement
Method	The cleaning pump and oil hoses are not on schedule and it's too late to replace the pack	Improvement of work methods, directed communication, regular replacement of parts, and increased supervision of pack installation	Increasing production capacity and quality according to standards	Perform pack changes, pump cleaning, and oil hoses when engine damage
Environment	Heat production room temperature	Air circulation in the spinning process	Provides comfort for employees at work	January 2022 and so on
Man	Less skilled, less control, and less thorough	HRD, Maint, and Production	Employees and Management	Perform work communication and supervision
Machine	The spinneret holes are enlarged and the polymer heater is problematic	Maint and Production	*Maintenance*	Provide direction according to maintenance and supervision procedures
Material	The polymer is dirty and there is foreign material in the polymer	Polymer	Logistics and Quality Control	Quality Control is more thorough in the inspection of raw materials
Method	Cleaning pump and oil hose were not on schedule, and it was too late to replace the pack	Maint and Production	Maint and Production Supervisor	Improve supervision in carrying out machine maintenance and perform timely replacement of parts according to schedule
Environment	Heat production room temperature	Production	Production Manager and Utilities	Adding a blower in the spinning process area

In principle, this research was carried out because, before 2022, machine productivity will decline drastically to 80% for the OEE value. Meanwhile, the company's target, namely increasing the OEE value to 85%, is a shared responsibility. Therefore, during 2022, the research team will carry out analysis, identify problems, and make improvements, to increase the OEE value to more than 85%. After carrying out the Six Big Losses analysis, there were equipment failure losses of 56.67% of the total problems. Therefore, the research team looked for the cause of the problem using the Fishbone diagram method. After finding the root of the problem, the next step is to take corrective action for the 5 main causal factors. After processing the data resulting from the improvements, the average OEE value during 2022 increased by 87.74%. So the company benefits in terms of increased productivity due to a significant increase in OEE value.

The comparison of results with other research related to the application of TPM to increase the OEE value in spinning factories that produce staples or filaments produced by spinning machines. Achieving OEE by identifying six major losses that occurred, resulted in an average OEE value for ring frame machines of 79.96%. This effectiveness value is quite low because the standard OEE value for world-class companies is ideally 85%. The biggest factor influencing the low OEE value is the level of performance with the percentage of six major loss factors reducing the speed of loss by 17.303% of all lost time. The proposed corrective action is the implementation of autonomous maintenance, providing training for operators and maintenance maintenance as well as operator supervision (Martomo & Laksono, 2018). TPM strategies can lead to improvements in availability, performance, and quality, the three main factors that contribute to OEE can be achieved by implementing the proposed strategies (Subha Shree et al., 2015). Increasing the OEE value can be done by analyzing large losses by looking for the main causes with the Ishikawa diagram. Corrective action is carried out using Root Cause Analysis of the main causes of production losses (Musyoki et al., 2019).

In theory, the implications of this research can be used as a reference for other researchers who wish to research the application of OEE in the textile industry, especially in spinning factories. The implications of this research can be practically applied in spinning factories in terms of increasing the OEE value of spinning machines by analyzing the Six Big Losses and corrective actions by implementing TPM on the machine. So the application of this OEE method can increase machine efficiency, reduce production waste caused by machines, and increase company profits.

4. Conclusion

Based on the research that has been carried out to determine the OEE value for Spinning Fiber machines at PT XYZ using the TPM method during the period January to December 2022, the following conclusions can be drawn, Measuring the Performance Effectiveness of Spinning Fiber machines with using the TPM method, the OEE value is 87.85%. This value indicates that the average OEE of Fiber Spinning machines is effective, with an OEE value above ≥ 85% which is an international standard. The cause of the Six Big Loss that affect the effectiveness of the performance of the Fiber Spinning machine is Equipment Failure Losses, the most dominant factor is the Human Factor, namely lack of control, lack of understanding of SOPs, lack of thoroughness when cleaning spinnerets.

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