ANALYSIS OF FORGING MACHINE EFFECTIVENESS USING OVERALL EQUIPMENT EFFECTIVENESS (OEE) AND SIX BIG LOSSES METHODS (CASE STUDY : PT X)

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ABSTRACT :
PT X is a company in the manufacturing industry, with automotive spare parts being its main product. The current issue at PT X is a production shortage. One of the causes of decreased productivity, according to observations, is that there is still waste in the form of waiting time produced by a variety of factors such as workers, machines, and materials. The forging machine factor is the problem that contributes the most to PT X. The problem is that waiting is often inefficient because the product is of poor quality. The purpose of this research was to determine the value of Overall Equipment Effectiveness (OEE) on fitting forging machines and to identify issues in the production line using Six Big Losses. The Overall Equipment Effectiveness (OEE) method is a comprehensive performance measurement related to the availability of quality and productivity processes, whereas the Six Big Losses are equipment failure, set up and adjustment losses, idling and minor stoppages, reduced speed losses, quality defects and rework, and reduced yield or scrap losses. According to the findings of this survey, the average OEE value is 83.84%. As a result, it falls under the category of not meeting the standards. While calculating the Six Big Losses, the most common type of waste is the lower yield or scrap loss of 4.25%. Improvement efforts are focused mostly on the quality line, with the 4M+1E (Man, Machine, Material, Method, and Environment) factor influencing the low OEE value. The machine factor is the most important contributor to the appearance of shape change or product reject deformation in the 4M+1E analysis. Thus, PT X must enhance the temperature parameter settings and the length of the pressing process to reduce shape rejects.
Keywords: Overall Equipment Effectiveness, Six Big Losses, Pareto Chart, 4M + 1E

ABSTRAK :
PT X merupakan perusahaan yang bergerak di bidang industri manufaktur, dengan suku cadang otomotif sebagai produk utamanya. Masalah saat ini di PT X adalah kekurangan produksi. Salah satu penyebab turunnya produktivitas menurut pengamatan adalah masih adanya pemborosan berupa waktu tunggu yang dihasilkan oleh berbagai faktor seperti pekerja, mesin, dan material. Faktor mesin tempa merupakan permasalahan yang paling banyak memberikan kontribusi bagi PT X. Permasalahannya adalah menunggu seringkali tidak efisien karena kualitas produk yang kurang baik. Tujuan dari penelitian ini adalah untuk mengetahui nilai Overall Equipment Effectiveness (OEE) pada mesin fitting forging dan

untuk mengidentifikasi permasalahan pada lini produksi menggunakan Six Big Losses. Metode Overall Equipment Effectiveness (OEE) adalah pengukuran kinerja yang komprehensif terkait dengan ketersediaan kualitas dan produktivitas proses, sedangkan Six Big Losses adalah kegagalan peralatan, kerugian pengaturan dan penyesuaian, pemalasan dan penghentian kecil, pengurangan kehilangan kecepatan, cacat kualitas dan pengerjaan ulang, dan mengurangi kehilangan hasil atau skrap. Berdasarkan hasil survei ini, rata-rata nilai OEE adalah 83,84%. Akibatnya, masuk dalam kategori tidak memenuhi standar. Saat menghitung Six Big Loss, jenis waste yang paling umum adalah yield atau scrap loss yang lebih rendah sebesar 4,25%. Upaya peningkatan sebagian besar difokuskan pada lini kualitas, dengan faktor 4M+1E (Man, Machine, Material, Method, and Environment) mempengaruhi rendahnya nilai OEE. Faktor mesin merupakan kontributor paling penting terhadap munculnya perubahan bentuk atau deformasi penolakan produk dalam analisis 4M+1E. Oleh karena itu, PT X harus meningkatkan pengaturan parameter suhu dan lamanya proses pengepresan untuk mengurangi shape reject.
Kata kunci: Efektivitas Peralatan Keseluruhan, Six Big Loss, Pareto Chart, 4M + 1E

1. INTRODUCTION

1.1 Background of the Problem

Competition between industrial competitors in the 4.0 revolution is currently a boost so that companies can continue to improve, one of which is by increasing their productivity. Increasing productivity is an important thing that is always noticed by various companies, especially manufacturing industry companies. Generally, problems in production facilities are divided into three factors, namely human, machine and environmental factors. These three factors are interconnected so that all elements of the company from the management level to the employee level must always work together well so that the targets and goals of the company can be achieved.

According to Hermanto (2018), one way to solve production facility problems and to support increased productivity is to evaluate and increase the effectiveness of production equipment or machines, so that they can be used as optimally as possible. According to Hadi Ariyah (2021) Overall Equipment Effectiveness (OEE) is the value of the effectiveness of an equipment or machine. OEE can be calculated by measuring the availability of the machine/equipment, the efficiency of the process, the performance of the process and the rate of the quality of a product. . This measurement is needed to determine the line that needs improvement in increasing productivity in the production process. Six big losses are six losses that must be avoided by every company that can reduce the effectiveness of a machine. Six big losses are categorized into 3 main categories based on the aspect of losses, namely downtime losses, speed losses dan defects losses (Fauzi, 2015). The use of six big losses can find out what losses are caused by the OEE value being below the standard. .

PT. X is a Japanese company that has branches in various countries, one of which is in Karawang, Indonesia. It focuses on manufacturing automotive parts, machine tools and mold design. The resulting product output is sent to various well-known companies, such as Honda, Suzuki and Daihatsu, and others. PT X's production processes include steal bar cutting, heating, forging, heat treatment and machining processes. The process on the hot forging machine is the object of the Overall Equipment Effectiveness (OEE) research because it has the biggest contribution to the problem at PT X. The problem is that waiting is often wasted because the quality of the product is not up to standard. So that the ineffectiveness factor can be known based on the OEE calculation on the machine and problems will be identified in the production line based on Six Big Losses, the results of which can be used as recommendations for improvement as consideration.

2. THEORETICAL BASE

2.1 *Overall Equipment Effectiveness* (OEE)

According to Abd Rahman (2020), OEE is the main metric of TPM which explains that OEE is the best execution to unify and improve the real of a tool relative to its performance capability under ideal manufacturing conditions. According to Nakajima (1998) there are three objectives of OEE:

a. OEE can be used as a “benchmark” to measure the initial performance of a manufacturing company. The initial OEE value can be compared with the OEE value at a later time, so that a measure of the level of improvement can be targeted.

b. A certain OEE value is calculated for one part (division) of manufacturing that is proportional to the company's performance.

c. If the machining process works individually, the OEE measure can identify which machine is performing poorly so as to identify where the goal will be focused. (Nakajima, 1988).

OEE decomposition can use the causal decomposition method, the purpose of making a cause-and-effect diagram is to find the root of the problem that is related (Annamalai, S., & Suresh, D, 2019). A structured approach that allows for detailed analysis to find the causes of problems, non-conformities and gaps. Overall Equipment Effectiveness (OEE) can also be said as the value of the effectiveness of an equipment or machine. OEE can be calculated by measuring the availability of the machine/equipment, the efficiency of the process performance of the process and the rate of the quality of a product (Arif Rahman, D. Siregar and S. Perdana, 2019). The calculations are as follows (Nakajima, 1988). a. Availability

Availability is a ratio between the useful life of the company's machine and the desired useful life in the time available.

Availability is a measure of how far the machine can continue to operate, formulated by

$$Availability = \frac{Loading\ Time - Down\ Time}{Loading\ Time}\ x\ 100\%\ (1)$$

b. Performance Efficiency

Performance efficiency is a relationship between what should actually be in a certain time period or can be described as a comparison between the actual and expected production levels.

$$Performance = \frac{Process\ Amount\ x\ Cycle\ Time}{Operating\ Time}\ x\ 100\%\ (2)$$

c. Quality Rate

Rate of Quality Product is a ratio between the number of good products and the total number of products processed. The level of product quality is able to show a product that can be accepted by all products produced.

$$Quality\ Rate = \frac{Processed\ Ammount - Deffect\ Amount}{Processed\ Ammount}\ x100\%\ (3)$$

d. Calculate *Overall Equipment Effectiveness*

$$OEE = Availability\ x\ Performance\ x\ Quality\ Rate\ x100\%\ (4)$$

According to Nakajima (1998) the results of OEE can be said to meet world-class standards of 85% with a standard availability value of 90%, a performance efficiency value of 95% and a quality rate value of 99.9%

2.2 Six Big Losses

The OEE value, which is commonly represented as a percentage, can be defined as the ratio of a machine's effective time to the total time available. Optimal and comprehensive time capability is claimed to be unachievable because the machine can always generate OK or good products as long as the complete available time is employed for production. There are usually production machine losses in the manufacturing process. The manufacturing machine losses are then classified into six major production losses or Six Big Losses (Pahmi Hamda, 2018). The primary goal of the six big losses is to eliminate or reduce all production system losses to increase OEE. The focus on eliminating the six big losses includes:

1. Equipment failure
   Equipment failure can also be referred to as unplanned downtime, caused by machines pausing due to machine failure activities or machine damage that occurs abruptly and unexpectedly.

$$Equipment\ Failure = \frac{Equipment\ Failure}{Loading\ Time} x100\% \quad (5)$$

2. Set up and adjustment losses
   Set up an adjustment losses can also be referred to as planned downtime, which is when the engine stops as a result of a previous plan. This setup also involves the machine configuration procedure, which is required to produce items that fulfill requirements.

$$Setup\ and\ adjusment\ loss = \frac{Setup\ and\ adjusment}{Loading\ Time} x100\% \quad (6)$$

3. Idling and minor stoppages
   Idling and minor stoppages are also transient issues or minor issues that cause the engine to stop briefly. Idling stops are often just 3-5 minutes long.

$$Idling\ and\ minor\ stoppages = \frac{Idling\ and\ minor\ stoppages}{Loading\ Time} x100\% \quad (7)$$

4. Reduced speed losses
   Reduced speed losses are losses due to differences in the planned speed of time with the real speed that occurs.

$$Reduce\ Seed\ Losses = \frac{Reduce\ Speed}{Loading\ Time} x100\% \quad (8)$$

5. Quality Deffects and Rework
   Quality Defect Rework is a loss caused by a product that needs to be redone. The product is being reworked because it does not satisfy product output criteria, but it can still be enhanced by reprocessing.

$$Rework = \frac{Ideal\ cycle\ Time\ x\ Rework}{Loading\ Time} x100\% \quad (9)$$

6. Reduced yield or Scrap Losses

Reduced yield or scrap losses are losses due to defects arising from products or not meeting product output standards so that the product is declared unable to be reworked.

$$Yield\ or\ Scrap\ losses = \frac{Ideal\ Cycle\ Time\ x\ Scrap}{Loading\ Time} x100\% \quad (10)$$

The correlation between OEE and the six big losses is summarized in table 1 below.

Table 1 Correlation of OEE with Six Big Losses

Six Big Losses	OEE Parameter
Equipment Failure	Avaliablity
Set Up and Adjustment Loss	
Idling and Minor Stoppages	Performance Efficiency
Reduced Speed Losses	
Quality Deffects and Rework	Quality Rate
Reduced Yield or Scrap Losses	

3. RESEARCH METHODOLOGY

The research used machine production data from the first quarter (January - June 2022) to determine the value of OEE in predicting six bid losses to overcome the ineffective factor of machine productivity in production operations on forging machines. The data utilized was for 6 months of production activities, where one complete month at PT X comprises 20 working days with 1 shift of production activities. As the object of data processing, the machine employed for the study was the serial number 1 forging machine. The study's data sources were gathered by paying attention to the productivity of forging machine production based on the category of six big losses. OEE requirements are divided into three categories: availability, performance efficiency, and quality rate. The percentages of the three categories acquired indicate how great the proportion of OEE was created. Six big losses data sets were discussed in to determine which line is the largest contributor to the potential losses that occur. The data obtained based on the percentage calculation of OEE and six big losses can be used to create a Pareto chart and establish the ideal solution from the highest to the lowest percentage, followed by the 4M + 1E description as the main recommendation for improvement. The conclusion in this case would respond to the statement on the research objectives.

The idea is to offer the researcher's perspective to ease the research that will follow.

4. FINDINGS AND DISCUSSION

Productivity data for the serial number 1 forging machine in the first quarter became the primary focus of the research.

4.1 Step 1 Define Data Components

The first stage is to define the data component, which is the hot forging machine manufacturing activity for one quarter, which is 6 months of work, with each working day lasting 7 hours. Table 2 has the data.

Table 2 Data Components

		Product Spesification Hot Forging							
	Part Name:	*Time Final Driven Standard:*		*Cycle*	0,29	'	(17,5 second)		
	Part Number:	*FD-01-AS*		*Cavity Standarc*	1	pcs			
No	Item - Sub Item	*Report Production Activity*						*Total*	*Average*
		January	February	March	April	May	June		
1	*Operating Time (Day Work)*	21	18	22	20	15	20		
	a. Full Time Production (min')	8820	7560	9240	8400	6300	8400	48720	8120
	b. Actual Time Production (min'): a-c	8446	7138	8675	7964	5885	7907	46015	7669,17
	c. Down Time (min'): I+II+III+IV	374	422	565	436	415	493	2705	450,833
	- I. Idling	40	120	110	98	86	143	597	99,5
	- II. Problem Machine	125	110	210	123	165	118	851	141,833
	- III. Set Up Machine	189	162	198	180	135	180	1044	174
	- IV. Reduce Speed	20	30	47	35	29	52	213	35,5
2	*Productivity*								
	a. Output Standard (pcs)	30414	26069	31862	28966	21724	28966	168000	28000
	b. Output Actual	28325	23253	28705	26342	19065	26010	151699	25283

(pcs)								
c. Reject Product (pcs)	799	1361	1209	1120	1228	1256	6973	1162
d. Rework	576	566	678	455	784	234	3293	549

Source: Company Data Quarter 1

4.2 Step 2 Perform Daily and Average OEE Data Processing

The OEE calculation can be done using the usual formula based on the data components in table 2. Calculations are divided into two categories: monthly data calculation and first-quarter average calculation. Table 3 shows the outcomes of the data processing.

Table 3 OEE Processing

No	Item - Sub Item	*Report Production Activity*						*Total*	*Average*
		January	February	March	April	May	June		
1	*Operating Time (Day Work)*	21	18	22	20	15	20		
	a. Full Time Production (min')	8820	7560	9240	8400	6300	8400	48720	8120
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	c. Reject Product (pcs)	799	1361	1209	1120	1228	1256	6973	1162
	d. Rework	576	566	678	455	784	234	3293	549
3	OEE Calculation								
	a. Availability	95,76%	94,42%	93,89%	94,81%	93,41%	94,13%		**94,40%**

	b. Performance Efficiency	97,26%	94,47%	95,96%	95,92%	93,95%	95,39%		**95,49%**
	c. Quality Rate	95,15%	91,71%	93,43%	94,02%	89,45%	94,27%		**93,00%**
	OEE	**88,61%**	**81,81%**	**84,17%**	**85,51%**	**78,50%**	**84,65%**		**83,84%**

Source: Quarter 1 Data Processing

Table 3 shows the results of processing OEE data with the following calculation examples. a. Availability January2022

$$Availability = \frac{Loading\ Time - Down\ Time}{Loading\ Time}\ x\ 100\%$$

$$Availability = \frac{8820 - 374}{8820}\ x\ 100\%$$

$$Availability = 95{,}76\%$$

b. Performance Efficiency January 2022

$$Performance = \frac{Process\ Amount\ x\ Cycle\ Time}{Operating\ Time}\ x\ 100\%$$

$$Performance = \frac{28325\ x\ 0{,}29}{8446}\ x\ 100\%$$

$$Performance = 95{,}15\%$$

c. Quality Rate January 2022

$$Quality\ Rate = \frac{Processed\ Ammount - Deffect\ Amount}{Processed\ Ammount}\ x100\%$$

$$Quality\ Rate = \frac{28325 - (799 + 576)}{28325}\ x100\%$$

$$Quality\ Rate = 88{,}61\%$$

d. OEE January 2022

$$OEE = Availability\ x\ Performance\ x\ Quality\ Rate$$

$$OEE = 95{,}76\%\ x$$

$$97{,}26\%\ x\ 88{,}61\%$$

$$OEE = 88{,}61\%$$

According to the monthly OEE calculation, there is a fluctuation in the data changes in the forging machine production continuity. The final data for availability during the first quarter of 2022 is 94.40%, for performance efficiency is 95.49%, and for quality, the rate is 93.00%, while the OEE results for June 2022 are 83.84%.

4.3 Step 3 Determine the Six Big Losses in Data Processing

The results of the calculation of the six big losses are presented in table 4 below.

Table 4 Processing of Six Big Losses

No	Item - Sub	*Report Production Activity*	*Total*	*Average*

	Item	January	February	March	April	May	June		
1	*Operating Time (Day Work)*	21	18	22	20	15	20		
	a. Full Time Production (min')	8820	7560	9240	8400	6300	8400	48720	8120
	b. Actual Time Production (min'): a-c	8446	7138	8675	7964	5885	7907	46015	7669,17
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2	*Productivity*								
	a. Output Standard (pcs)	30414	26069	31862	28966	21724	28966	168000	28000
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	d. Rework	576	566	678	455	784	234	3293	549
3	OEE Calculation								
	a. Availability	95,76%	94,42%	93,89%	94,81%	93,41%	94,13%		**94,40%**
	b. Performance Efficiency	97,26%	94,47%	95,96%	95,92%	93,95%	95,39%		**95,49%**
	c. Quality Rate	95,15%	91,71%	93,43%	94,02%	89,45%	94,27%		**93,00%**
	OEE	**88,61%**	**81,81%**	**84,17%**	**85,51%**	**78,50%**	**84,65%**		**83,84%**
4	*Six Big Losses*								
	1. Equipment	1,42%	1,46%	2,27%	1,46%	2,62%	1,40%		**1,77%**

	Failure								
	2. Set Up and Adjusment Losses	2,14%	2,14%	2,14%	2,14%	2,14%	2,14%		**2,14%**
	3. Idling and Minor Stoppages	0,45%	1,59%	1,19%	1,17%	1,37%	1,70%		**1,24%**
	4. Reduced Speed Losses	0,23%	0,40%	0,51%	0,42%	0,46%	0,62%		**0,44%**
	5. Quality Deffect and Rework	1,89%	2,17%	2,13%	1,57%	3,61%	0,81%		**2,03%**
	6. Redued Yield or Scrap Losses	2,63%	5,22%	3,79%	3,87%	5,65%	4,34%		**4,25%**

Source: Quarter 1 Data Processing

Table 4 shows the results of the Six Big Losses processing calculation using the standard formula. Calculations are divided into two categories: monthly calculations and first-quarter calculations, with examples of both below.

1. *Equipment failure* January 2022

$$Equipment\ Failure = \frac{Equipment\ Failure}{Loading\ Time} x100\%$$

$$Equipment\ Failure = \frac{125}{8820} x100\%$$

$$Equipment\ Failure = 1{,}42\%$$

2. Set up and adjustment loss January 2022

$$Setup\ and\ adjusment\ loss = \frac{Setup\ and\ adjusment}{Loading\ Time} x100\%$$

$$Setup\ and\ adjusment\ loss = \frac{189}{8820} x100\%$$

$$Setup\ and\ adjusment\ loss = 2{,}14\%$$

3. Idling and minor stoppages January 2022

$$Idling\ and\ minor\ stoppages = \frac{Idling\ and\ minor\ stoppages}{Loading\ Time} x100\%$$

$$Idling\ and\ minor\ stoppages = \frac{40}{8820} x100\%$$

$$Idling\ and\ minor\ stoppages = 0{,}45\%$$

4. Reduced speed losses January 2022

$$Reduce\ Seed\ Losses = \frac{Reduce\ Speed}{Loading\ Time}\ x100\%$$

$$Reduce\ Seed\ Losses = \frac{20}{8820}\ x100\%$$

$$Reduce\ Speed\ losses = 0{,}23\%$$

5. Quality Deffects and Rework January 2022

$$Rework = \frac{Ideal\ cycle\ Time\ x\ Rework}{Loading\ Time}\ x100\%$$

$$Rework = \frac{0{,}29\ x\ 576}{8820}\ x100\%$$

$$Rework = 1{,}89\%$$

6. Reduced yield or Scrap Losses January 2022

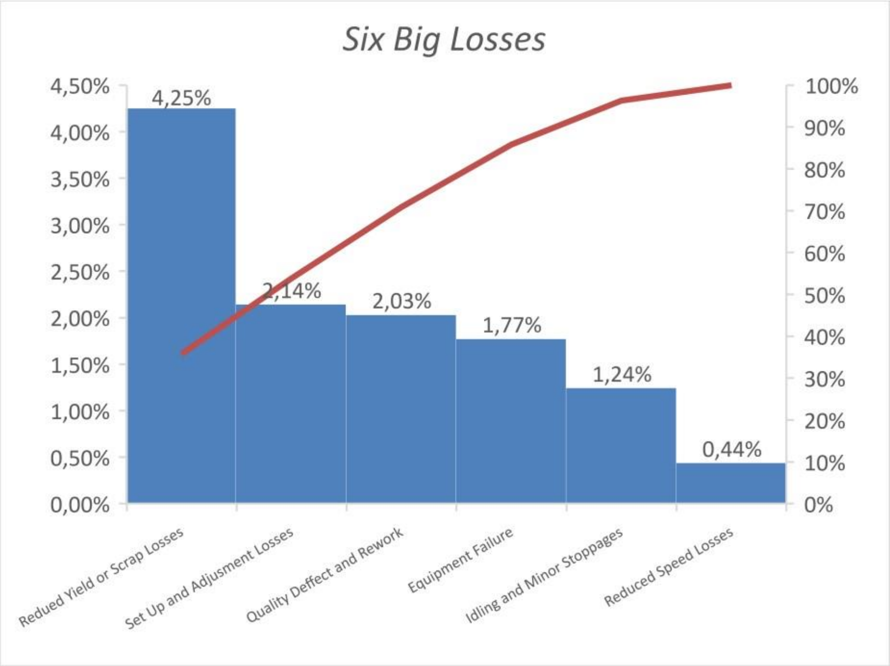
$$Yield\ or\ Scrap\ losses = \frac{Ideal\ Cycle\ Time\ x\ Scrap}{Loading\ Time}\ x100\%$$

$$Yield\ or\ Scrap\ losses = \frac{0{,}29\ x\ 799}{8820}\ x100\%$$

$$Yield\ or\ Scrap\ losses = 2{,}63\%$$

The overall results of the six big losses calculated above reveal varied outcomes every month, therefore the data in the first quarter can be shown in a Pareto chart from highest to lowest. The first is decreased or scrap losses of 4.25%, set up and adjustment losses of 2.14%, quality defect and rework of 2.03%, equipment failure of 1.77%, idling and small stoppages of 1.24%, and reduced speed losses of 0.44%. The data is contained in the Pareto diagram, and the idea behind using it is to deal with problems that have the highest level of reduced or scrap losses. The Pareto diagram of the problems that occur based on the highest order level is displayed in Figure 1 below.

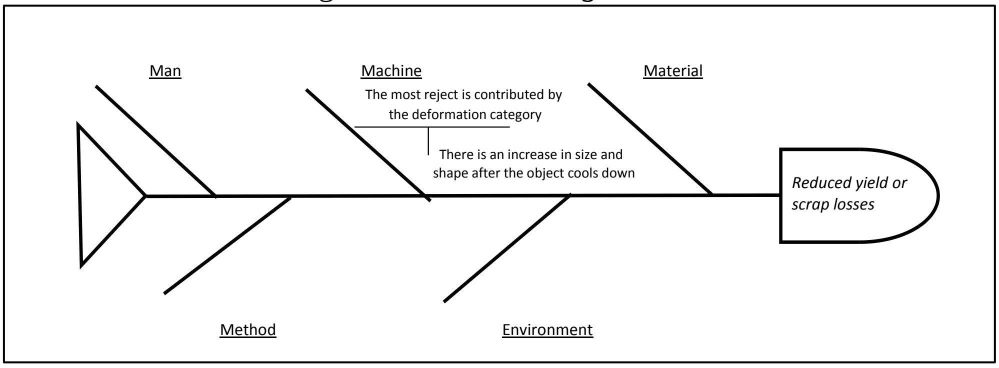
Figure 1 Pareto Six Big Loss Diagram



Source: Quarter 1 Data Processing

The generated Pareto chart can be defined by performing data dissection while considering the 4M + 1E factors, namely man, machine, material, method, and environment. The 4M + 1E factor is shown as a fishbone diagram in Figure 2.

Figure 2 *Fishbone Diagram*



Source: Quarter 1 Data Processing

The machine factor is the reason for the high reject ratio and affects the value of lower yield or scrap losses that have an impact on the quality rate, with the root cause coming from the addition of size and form after the item has been cooled for 5-10 minutes. The size variation is impacted by temperature instability during the manufacturing process as well as the differential in compressive strength of the object being manufactured. The forging temperature should be between 1100°C and 1200°C, with a press capacity of 2 - 2.5 tons.

4. Step 4 Determining the Optimal Solution

Based on the calculation of Overall Equipment Effectiveness (OEE) as a parameter of the effective level of machine used during the first quarter, the OEE value of the hot forging machine at PT X is 83.84%. The OEE number is calculated by multiplying three categories: availability (94.90%), performance efficiency (95.49%), and quality rate (93.00%). The standard OEE value set by the Japan Institute of Plant Maintenance is 85% with each category being 90% availability, 95% performance efficiency, and 99% quality rate.

The availability and performance efficiency categories of PT X's OEE are stated to have met the criteria of 94.90% and 95.49%, respectively, however, the quality rate category is said to have a very high deficiency t of 83.8%. Six Big Losses can be a grouping of categories that cause ineffectiveness on the machine; when examined from the calculation, the quality rate with the correlation of the six big losses, namely reduced yield or scrap losses, is the most important factor that influences the low OEE value. Several factors contribute to high scrap rates, according to the fishbone diagram. PT X must be able to pay attention to the temperature stability factor and compressive strength stability to suppress scrap so that it can increase the quality rate.

5. CONCLUSION

The following conclusions can be taken from research on Overall Equipment Effectiveness (OEE) in minimizing Six Big Losses on hot forging machines:

a. The findings of the OEE value of 83.84% indicate that the value does not meet the OEE standard of 85%, and the supporting factor for the low OEE is the quality rate of 93.00%, which is lower than the level that should be 99.9%.
b. The largest six big losses are in the reduced yield or scrap losses category, which has the highest proportion of 4.24% in the six big losses factor.
c. Reduced yield or scrap losses must be a primary concern in the process of increasing manufacturing productivity, particularly in terms of preserving temperature and compressive strength stability.

SUGGESTION

From this study, the following suggestions can be made:

a. Provides a more diverse grouping of possible types of rejects.

b. The OEE method can be utilized to minimize the six big losses in repairs and attention points with the highest potential loss.
c. PT X is expected to carry out additional improvements for the reduced yield or scrap losses category, particularly further analysis utilizing the 4M + 1E technique as a tool for quality seven tools to further study the causes of potential rejects.

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