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An Analysis of Machine Effectiveness on the Production Line by Using Overall Equipment Effectiveness (OEE) Method Based on Total Productive Maintenance (TPM) Principle (A Study Case of Ball Tea Machine in PT Kabepe Chakra)

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ABSTRACT

Total Productive Maintenance (TPM) is an approach in Preventive Maintenance which can be used by a company to evaluate the effectiveness of the company's facility. This evaluation is conducted to improve the facility value of Overall Equipment Effectiveness (OEE) and to eliminate the main loss known as The Six Big Losses. TPM is a maintenance approach focusing on the equipment which is suitable to be implemented on the manufacture company and production industries. This research is conducted on the Ball Tea machine in PT Kabepe Chakra which is a production machine to dry tea. The calculation of OEE value is conducted based on the data in January-December 2014, the calculation results show that the OEE value is 59.30897433% and it is still under the World Class standard. The calculation of Six Big Losses shows that the percentage of the most dominant of machine losses is on the Set-Up and Adjustment Loss which is 42.6768183%. The research results can be used to show that the effectiveness of Tea Ball machine still has to be improved by focusing on the most dominant loss elimination.

ARTICLE INFO

Keywords:
Preventive Maintenance, Total Productive Maintenance, Overall Equipment Effectiveness, The Six Big Losses.

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1. INTRODUCTION

Along with the development of technology, today's production activity is more performed by using production machines. Moreover, there have been some businessmen who prefer machines for production (Rusadi, 2013). However, the performance of machine may not be always stable if it is used continuously in a long term. The industry machine is an important part to smoothen the production process; it is the reason why maintenance is so important (http://www.vibrasindo.com, 2015). One of the maintenance process methods which are developed to improve the productivity is Total Productive Maintenance (TPM). The indicator of the success of TPM implementation is determined by OEE (Overall Equipment Effectiveness) (http://shiftindonesia.com, 2012).

Overall Equipment Effectiveness (OEE) is the best practice metric which identifies the percentage of production time which is really productive in planning (Vorne Industries, 2013). The OEE value of

100% is a perfect production. The OEE value of 85% is considered as the World Class standard manufacture. The OEE value of 60% is a typical value for Manufacture Company. The OEE value of 40% is a low value but it is possessed by many manufacture companies. The OEE value can be easily improved through simple stages of specification (OEE Industry Standard, 2014).

The usage of machine and equipment itself increasingly improves. The very potential markets for domestic machine industry are food and beverage industry. Food and beverage industry in each year always purchases the capital goods around 15-20% from its budget to fix the machine (Dharmawan, 2008). The percentage amount of machine repair budget usage shows the low value of machine effectiveness so that there are still many spaces to repair the machine of food and beverage machine in Indonesia.

One of food and beverage Industry Company in Indonesia, especially in West Java, tea production company, PT. Kabepe Chakra. PT Kabepe Chakra uses the production machine technology in processing the tea. The tea processing consists of several stations; every station processes the average tea of 91.792,58 kg per month with the highest operational working hours which is in the drying station using Ball Tea in which it reaches 24 hours per day where it will influence the effectiveness of the machine (Kabepe Chakra, 2014). Thus, to maintain the performance and the effectiveness of the machine, the suitable maintenance activity is necessary to be conducted in order to minimize all forms of losses.

This research aims to find out the effectiveness level of Ball Tea machine used by the company and the losses of the machine so that the company can focus on the most dominant loss elimination to improve the OEE value.

2. THEORY AND HYPOTHESIS

2.1 Preventive Maintenance

Maintenance covers all activities related in maintaining the system equipment in order to keep working. The preventive maintenance covers the routine inspection and maintenance and maintains the facilities in a good condition. This activity is intended to build a system which will find the potential failure and to make a change or repair which will prevent the failure. The emphasis on the preventive maintenance is on the understanding of process and keeping it working without obstacles (Heizer and Render, 2005).

2.2 Total Productive Maintenance

Total Productive Maintenance (TPM) is a productive maintenance performed by all employees through a small group activity (Nakajima, 1988). The definition of TPM completely covers five those elements (Nakajima, 1988):

1. TPM aims to maximize the effectiveness of the equipment (Overall Equipment Effectiveness).

2. TPM makes a detailed system to expand the life of the equipment.
3. TPM is implemented by various departments (machine, operation, maintenance).
4. TPM involves each employee, from the highest management until the lowest level of employee.
5. TPM is based on the promotion from PM through the motivation management: autonomous small group activities.

2.3 Overall Equipment Effectiveness

TPM has a measuring tool to consider important points within it, namely Overall Equipment Effectiveness (OEE). OEE is a result from availability, performance, and quality (Borris, 2006). The formula of OEE calculation value is:

$$OEE = Availability \times Performance \times Quality \quad (1)$$

Availability Rate is a ration from the amount of time which can be used by the machine to produce a qualified product divided by the total of time in which the machine works. The mathematic formula of availability is:

$$Availability = \frac{Operation\ Time}{Loading\ Time} \times 100 = \frac{Loading\ Time - Down\ Time}{Down\ Time} \times 100 \quad (2)$$

Performance Efficiency or performance of equipment can be meant as the ratio from the amount of products divided by the amount of the products which should be produced (Borris, 2006). The formula of Performance Efficiency is:

$$Performance\ Efficiency = \frac{process\ amount \times theoretical\ cycle\ time}{operation\ time} \times 100 \quad (3)$$

Rate of Quality. The meaning of product quality is a ratio from the amount of the products which can be accepted divided by the overall amount of the products which are made (including the products that failed). The formula of Quality Product is:

$$Rate\ Of\ Quality = \frac{number\ of\ units\ produced - number\ of\ defects}{number\ of\ units\ produced} \times 100 \quad (4)$$

OEE Industry Standard is a recognized world class target where each factor of OEE has different values. It is shown in following table (Vorne Industries, 2008):

Table 1: OEE Industry Standard

OEE *Factor*	***World Class***
Availability	90.0%
Performance	95.0%

Quality	99.0%
OEE	85.0%

The world class OEE standard forms some hypothesis:

Hypothesis 1. The Availability level of Ball Tea machine used by Chakra Group Company in 2014 met the world class standard which is ≥ 90%.

Hypothesis 2. The Performance Efficiency of Ball Tea machine used by Chakra Group Company in 2014 met the world class standard which is ≥ 95%.

Hypothesis 3. The Rate of Quality Product of Ball Tea machine used by Chakra Group Company in 2014 met the world class standard which is ≥ 99%.

Hypothesis 4. The Overall Equipment Effectiveness of Ball Tea machine used by Chakra Group Company in 2014 met the world class standard which is ≥ 85%.

2.4 The Six Big Losses

Facilities suffer losses from things which prevent them to effectively operate and from problems caused by the errors and operational problems. TPM seeks to eliminate The Six Big Losses which become the main obstacles against the effectiveness of equipment to reach OEE (Nakajima, 1988). Steps of losses calculation refer to previous research (Hasriyono, 2009).

1. Equipment Failure: breakdown

$$Equipment\ Failure\ Loss = \frac{Total\ Breakdown\ Time}{loading\ time} \times 100 \quad (5)$$

2. Setup and adjustment: Retooling of the dead machine

$$Setup\ and\ Adjustment\ Loss = \frac{Total\ Set\ up\ and\ Adjustment\ Time}{loading\ time} \times 100 \quad (6)$$

3. Idling and minor stoppages: The abnormal operation from censor, the obstruction of the machine works, etc.

$$Idling\ and\ Minor\ Stoppage = \frac{Nonproductive\ Time}{loading\ time} \times 100 \quad (7)$$

4. Reduced speed The difference between the recoroded speed of equipment and the actual speed.

$$Reduced\ Speed = \frac{\text{Operation Time} - (\text{Theoritical Cycle Time} \times Processed\ Amount}{loading\ time} \times 100 \quad (8)$$

5. Defect in Process: The bad record and quality which have to be improved.

$$Defect\ In\ Process = \frac{Theoritical\ Cycle\ Time\ xRework}{Loading\ Time} \times 100 \quad (9)$$

6. Reduced Yield: The needed time from start-up the machine until the stable production process.

$$Reduced\ Yield = \frac{Theoritical\ Cycle\ TimexScrap}{Loading\ Time} \times 100 \quad (10)$$

3. METHODOLOGY

The type of the research is basic research. Basic research is general knowledge as a tool to solve the practical problem although it does not give the thorough answer for each problem, (Nazir, 2005).

This research is a research which uses a mixed method based on the type of the data and its processing. The mix method research is an approach of research which combines or associates the qualitative and quantitative forms (Creswell, 2010). The qualitative approach of this research is used when the primary data are being collected from the interview to find an idea from the problems that may occur on the machine that can cause a loss in the production process. The interview is conducted against three resources (source triangulation) in order that the obtained data are valid. The resources are selected based on the consideration of their knowledge of machine; production, machine technician and general affairs. The quantitative approach of this research is used when the secondary data are being processed to calculate the value of Overall Equipment Effectiveness and the identification of losses. The needed secondary data are Loading Time, Down Time, Planned Downtime, Number of Defect (reduced yield/reject and rework component, Output, Theoretical Cycle Time, and Actual Cycle Time. The used secondary data are the data of Ball Tea machine in 2014. This machine is selected based on the level of influence of the machine against the product quality, machine usage frequency, and the damage frequency.

The technique of data analysis which is firstly used is Fishbone Diagram. Fishbone Diagram of his research is used to process the interview results regarding the condition and the performance of the machine to dig and learn the cause of the problem which may cause losses against the machine. The Fishbone Diagram technique refers to the previous research (Hasriyono, 2009; Rinawati and Dewi,

2014). The causes are usually divided into the main cause from methods, material, measurement, people, equipment, and environment (Besterfield et al., 2003).

The further analysis is conducted by calculating the percentage of OEE by multiplying the three constituent factors of OEE namely availability, performance, and quality based on each formula.

The calculation results are then compared to the attainment with world class OEE standard. The calculation of OEE value has been conducted on some previous research (Afefy,2013; Almeanazel, 2010; Hasriyono, 2009; Rinawati and Dewi, 2014).

The further analysis is by calculating the six big losses with each formula based on the theory of The Six Big Losses. Sorting the percentage of the greatest or the most dominant losses is depicted through the Pareto diagram so that the causes can be analysed and the repair can be focused on the losses. The usage of Pareto diagram is for sorting the percentage of the losses, based on the research (Hasriyono, 2009; Rinawati and Dewi, 2014).

4. RESULTS

4.1 Descriptive Data

The early used data are the results from interviews with some related parties, they are the production department, the machine technician, and the general Affairs. The interview results data are then processed by using Fishbone diagram so that the link of the problem becomes clear.

The Fishbone diagram on the picture 1 shows that the root cause of the low value of OEE on the Ball Tea machine can be identified into four categories: Material/Spare part, Machine, People, and Method. The problems of Material/Spare part factor are that the spare part suffers the damage because of the worn-out, the spare part is not original, the spare part is sometimes not available in the company storage, and the hard tea raw materials can damage the machine.

The problems of machine factor are that the machine has the highest working hours so that it needs a special treatment, then, the machine has a high delay time so that the existing working hours becomes less, the technical problems often occurs on the machine where the machine often suffers the breakdown.

The problems of the people are that the machine operators are still lack of awareness about the importance of machine inspection, the operator does not check and report to the technician when there are peculiarities on the machine. The machine operators are also still lack of knowledge, when the machine suffers the congestion, they tamper the machine without a clear understanding and procedure.

The problems of the processing method are the screening of raw materials with Roll causes a very strong vibration so that the Roll will be loose sooner or later and its performance decreases, the machine is also set in a very high temperature to dry the tea leaves so if it is not treated well, the machine will be easily broken.

Those problem are then adapted with the theory of Total Productive Maintenance which focuses on the machine to calculate the OEE and the Six Big Losses in details.

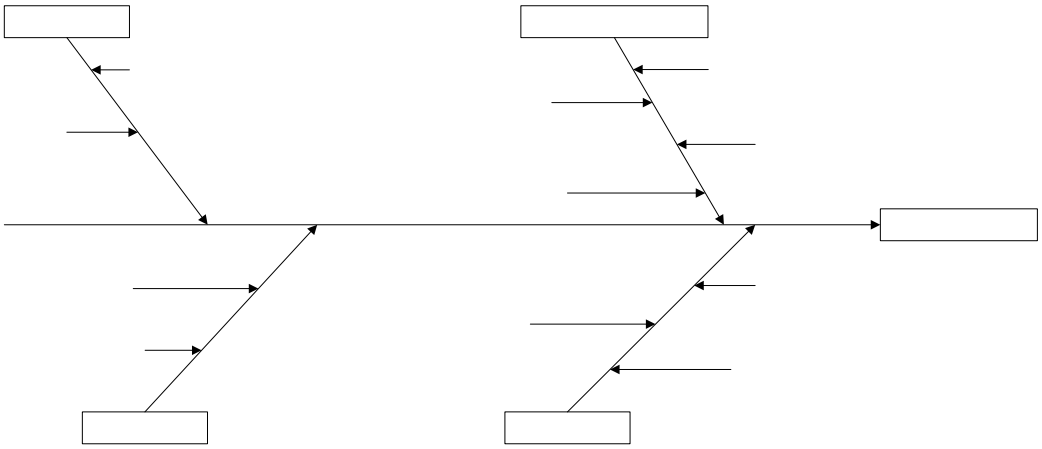

Figure 1: Fishbone Diagram of Problem Causes of the Machine

The needed secondary data are Loading Time, Down Time, Planned Downtime, Number of defect (reduced yield/reject and rework component), Output, Theoretical Cycle Time, and Actual Cycle Time. Those data are obtained based on the data of Ball Tea machine in 2014 in the company. Table 2 and table 3 are the outcome of the collected data recap:

Table 2: Delay Time of Machine

Month	Available Time (Hour)	Delay				Total Delay (Hour)
		Schedule Shut-down (Hour)	Warm-up Time (Hour)	Planned Downtime (Hour)	Machine Break (Hour)	
January	744	168	48	96	2.17	314.17
February	672	96	48	112	1.50	257.50
March	720	120	50	100	0.67	270.67
April	720	120	50	100	1.17	271.17
May	744	192	46	92	0.42	330.42
June	720	120	50	100	2.75	272.75
July	744	96	54	108	0.92	258.92
August	744	120	52	104	0.42	276.42
September	720	96	52	104	1.17	253.17
October	744	120	52	104	0.17	276.17
November	720	120	50	100	1.25	271.25
December	744	120	52	104	4.50	280.50

Table 3: Working Hours and Production Machine

Month	Item						
	Loading Time (Hour)	Down Time (Hour)	Total Production (kg)	Good Product (kg)	Number Of Defect (kg)	Theoritical Cycle Time (hour/kg)	Actual Cycle Time (hour/kg)
January	648	218.17	86,581	85,800	781	0.004323842	0.007484321
February	560	145.5	81,209	79,100	2,109	0.004253391	0.006895787
March	620	170.67	102,946	101,399	1,547	0.003758508	0.006022575
April	620	171.17	107,563	106,600	963	0.003593144	0.005764064
May	652	238.42	101,010	100,500	510	0.003588162	0.006454806
June	620	172.75	101,528	90,800	10,728	0.003793354	0.00610669
July	636	150.92	78,151	77,599	552	0.005305954	0.008138092
August	640	172.42	68,435	66,900	1,535	0.005877414	0.00935194
September	616	149.17	85,762	85,300	462	0.004657027	0.007182668
October	640	172.17	58,374	57,738	636	0.006894028	0.010963785
November	620	171.25	101,357	99,563	1,794	0.003812477	0.006116992
December	640	176.5	128,595	126,901	1,694	0.003100488	0.004976865

4.2 Calculation Results

The analysis of the machine effectiveness is conducted with a calculation by using OEE formula as well as the losses of the machine which cause the low value of OEE. The calculation of OEE and the losses of the machine are as elaborated as following:

1. The calculation of Availability, Performance, Quality, and OEE.

   Availability Ratio is calculated to find out how much the ratio of the amount of the time which can be used by the machine to produce products with the total of the time when the machine works. To calculate the Availability Ration, it needs the data of Loading Time which has been found out previously and the data of Operation Time.

   Performance Efficiency is the performance of the machine which is showed by the ratio of the products made by the amount of products which should be produced in a cycle. The calculation of Performance Efficiency uses the data of Good Product Ideal Cycle Time, and Operation Time of Ball Tea machine.

   Rate of Quality Product is calculated to find out the level of product quality which is produced by the machine. The calculation of Rate of Quality Product uses the data of Good Product and Total Broke which have been known.

   Overall Equipment Effectiveness shows the overall effectiveness value of machine based on the factors of Availability, Performance Efficiency, and Rate of Quality which have been obtained.

   The calculation results of OEE and the three factors are presented in table 4:

Table 4: The Calculation Results of Availability, Performance, Quality, and OEE

Month	Availability (%)	Performance Efficiency (%)	Rate Of Quality Product (%)	OEE (%)
January	66.3317901	86.3098526	99.08974359	56.72974056
February	74.0178571	81.1684437	97.33375474	58.47728541
March	72.4725807	84.81716947	98.47434393	60.5313831
April	72.3919355	85.33948307	99.09662289	61.22080705
May	63.4325153	87.19239741	99.49253731	55.02766172
June	72.1370968	77.01207446	88.18502203	48.99054936
July	76.2704403	84.88017506	99.28865063	64.27796641
August	73.059375	84.09234144	97.70553064	60.02767816
September	75.7840909	85.09401146	99.45838218	64.138446
October	73.0984375	85.08376934	98.89847241	61.5098119
November	72.3790323	84.58643272	98.19812581	60.11968285
December	72.421875	84.88780454	98.66510114	60.65667939
Average	71.98308554	84.20532961	97.82385727	59.30897433

2. The Calculation of The Six Big Losses

Based on the principle of TPM, the losses of the machine are classified into six types which are called The Six Big Losses. Those Losses are: Equipment Failure Loss, Set-up and Adjustment Loss, Idling and Minor Stoppage, Reduced Speed, Yield/Scrap Loss, and Rework (Davis,1995). On the Ball Tea machine which is used by PT Kabepe Chakra to dry the tea, the losses have been identified in accordance with the theory of The Six Big Losses.

Table 5: The Calculation Results of the Six Big Losses

No	Six Big Losses	Total *Time Loss* (Hour)	Percentage (%)	Cumulative Percentage (%)
1	Set up and Adjustment	2,092	42.67681828	42.6768183
2	Idling and Minor Stoppage	1,845.11	37.64026012	80.3170784
3	Reduced Speed Loss	853.013013	17.40147292	97.7185513
4	Scrap/Yield Loss	94.72567189	1.932404534	99.6509559
5	Equipment Failure Loss	17.11	0.349044149	100
6	Rework Loss	0	0	100
	Total	4,902		

5. DISCUSSION

5.1 Overall Equipment Effectiveness

The calculation results show that the value of Availability is only around 63.43251534% until 76.27044025%, the average of the level of available machine (availability) in 2014 is 71.98308554% which is still under the world class standard which is 90%. The Performance Efficiency value is around 77.01207446% until 87.19239741%, the average of the level of performance efficiency in 2014 is 84.20532961%, and this value is still under the world class standard which is 95%. The Quality value of the machine is around 88.18502203% until 99.49253731%, although in January, April, May, and September, the value of machine Quality has met the world class standard which is over 99%, however, when it is averaged in a year, the value of Quality becomes 97.82385727% that has not met the standard by 99%. The combination of those three factors produces an average value of OEE which is 59.30897433%. This value has not met the world class standard of 85% and it still needs to improve, however, according to Vorne Industries (2013), the OEE value has been good enough for the standard of industry since the average of industrial machine commonly still produces the OEE value of 35% until 45%.

The compliance of OEE value criteria on the Ball Tea machine in 2014 at PT Kabepe Chakra has been obtained based on the calculation is as following:

Table 6:The Comparison of OEE Value

OEE Factors	Results	World Class	Meet or does not meet the standard
Availability	71.98308554%	90%	Does not
Performance Efficiency	84.20532961%	95%	Does not
Rate Of Quality	97.82385727%	99%	Does not
OEE	59.30897433%	85%	Does not

The OEE value and those three factors are in table 5, thus, the conformity with the proposed hypothesis are:

Hypothesis 1 that is “the level of Availability of Ball Tea machine which is used by Chakra Group Company in 2014 met the world class standard which is ≥ 90%” is rejected.

Hypothesis 2 that is “the level of Performance Efficiency of Ball Tea machine which is used by Chakra Group Company in 2014 met the world class standard which is ≥ 95%” is rejected.

Hypothesis 3 that is “the level of Rate of Quality Product if Ball Tea machine which is used by Chakra Group Company in 2014 met the world class standard which is ≥ 99%” is rejected.

Hypothesis 4 that is “the level of Overall Equipment Effectiveness of Ball Tea machine which is used by Chakra Group Company in 2014 met the world class standard which is ≥ 85%” is rejected.

5.2 The Six Big Losses

The order of Six Big Losses percentage on the machine is depicted in the Pareto Diagram:

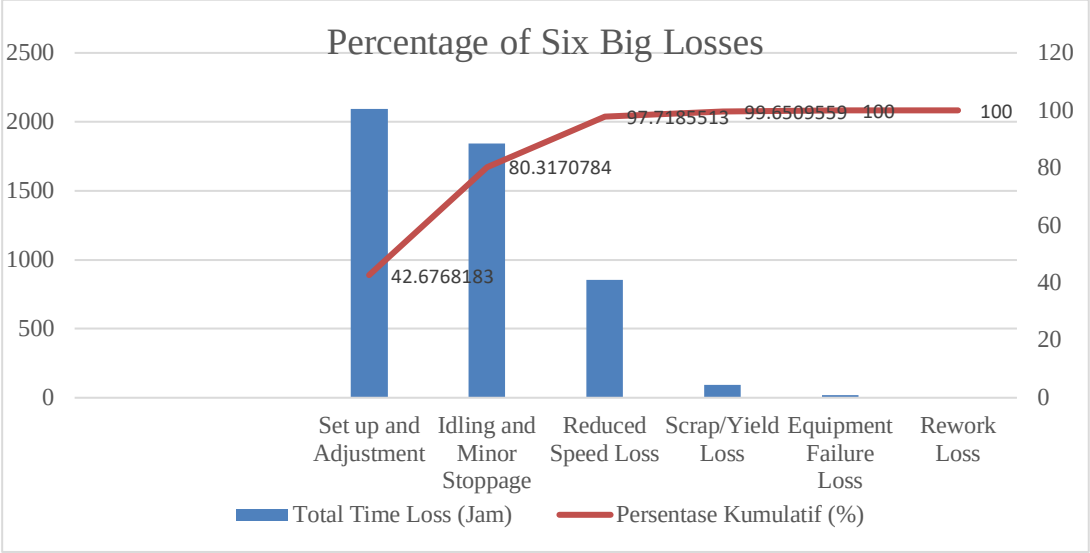

Figure 2: Pareto Diagram of Six Big Losses Percentage

The percentage of losses on the machine which causes the machine not working optimally is calculated based on the theory of The Six Big Losses and is sorted based on its percentage as following:

a. The most dominant loss is the set-up and adjustment loss. The Percentage of set-up and adjustment loss in 2014 is 42.6768183%, it is caused by the time length of the machine set-up during the heating and during the machine stoppage schedule so that it produces the high time total of set-up and adjustment.
b. The second loss is the loss which is caused by the idling and minor stoppage. The total of loss percentage in 2014 is 37.64026012%. This loss is caused by the existence of unproductive time where the machine cannot work.
c. The third loss is the reduced speed loss with the percentage total of 17.40147292%. This loss is caused by the machine which operates under the standard of the speed.
d. The fourth loss is the scrap/yield loss. The scrap produced by the machine is in forms of tea shoots which cannot be sent because it is scorched during the drying process in the Ball Tea. The calculation of the loss based on the production data in 2014 is 1.932404534%.
e. The percentage of the lowest loss is the equipment failure loss with the percentage total of 0.349044149% in 2014. The failure occurs only in form of small damage on some parts of the machine like chain, clutch, roll, etc in which the repair does not take long.

6. CONCLUSSION

The average of the effectiveness level of Ball Tea machine in January-December 2014 is 59.30897433%, this average of the effectiveness level of Ball Tea machine is still under the world class standard which is 85%. The effectiveness of Ball Tea machine which does not meet the standard is caused by those three factors, they are availability, performance, and quality by which each of them does not meet the world class standard. It shows that the Ball Tea machine has the total of loss which is 40.69102567% which means that there are still many things which have to be improved in order that the performance is getting better. It is in accordance with the aim of TPM that is to improve OEE by eliminating the loss suffered by the machine.

The identification of the loss on the Ball Tea machine in 2014 is Set-up and Adjustment (42.67681828%), Idling and Minor Stoppage (37.64026012%), Reduced Speed (17.40147292%), Scrap/Reduced Yield (1.932404534%), and Equipment Failure Loss (0.349044149%). Those losses are caused by the amount of delay time and defect product. The Six Big Losses which are not identified is re-work loss. The company can improve the OEE value by focusing on the most dominant loss elimination which is on the Set-Up and Adjustment. The management of maintenance which can be applied to reduce the loss in the machine based on the TPM principle is education and training, the autonomous maintenance principle, planned maintenance, and focused improvement.

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