Industria: Jurnal Teknologi dan Manajemen Agroindustri
Volume 10 No 3: 216-226 (2021)

Industria: Jurnal Teknologi dan Manajemen Agroindustri
http://www.industria.ub.ac.id
ISSN 2252-7877 (Print) ISSN 2549-3892 (Online)
https://doi.org/10.21776/ub.industria.2021.010.03.3

Improvement of Ribbed Smoked Sheet (RSS) Production Effectiveness and Efficiency Using Total Productive Maintenance (TPM) Concept on Sheeter Machine

Peningkatan Efektivitas dan Efisiensi Produksi Ribbed Smoke Sheet (RSS) *Menggunakan Konsep* Total Productive Maintenance (TPM) *Pada Mesin* Sheeter

Usman Effendi*, Niken Yulia Anjas Juwita
[1]Department of Agro-Industrial Technology Faculty of Agricultural Technology, Universitas Brawijaya,
Jl Veteran, Malang 65145, Indonesia
*usman_eff@ub.ac.id
Received: 17th March, 2021; 1st Revision: 11th July, 2021; 2nd Revision: 21th August, 2021; Accepted: 3rd December, 2021

Abstract

This study aims to measure the sheeter machine's effectiveness, efficiency, and decline factors. Also, recommendations for improvement are made to counteract the decrease in RSS production efficiency. Overall Equipment Effectiveness (OEE) and Total Equipment Efficiency (TEE) were used to measure the effectiveness and efficiency of the machine. The Failure Method Effect Analyze (FMEA) is used to investigate machine failure, while TPM provides recommendations for improvement. The results showed that the sheeter machine effectiveness value in one year was almost entirely above the international standard at 85%, except for April and May at 72.27% and 80.33%. Furthermore, the highest and lowest TEE value was in February and April with 86.29% and 58.11%, respectively. According to the Six Big Losses calculations, the causes of a decrease in the effectiveness and efficiency of the sheeter machine were breakdown, setup, and adjustment losses, and idling, and minor stoppages. The failures with the highest Risk Priority Number (RPN) based on the FMEA were rusty bearings and halted machines resulting from tucked sheets under the roller. Minimizing Six Big Losses and adopting an autonomous maintenance system were two recommendations based on the TPM concept for increasing the efficacy and efficiency of RSS manufacturing.
Keywords: machine efficiency, maintenance, sheet rubber

Abstrak

Tujuan Penelitian ini adalah untuk mengukur nilai efektivitas, efisiensi dan mengidentifikasi faktor-faktor penyebab dasar penurunan efisiensi produksi pada mesin sheeter. *Rekomendasi perbaikan diberikan untuk mengatasi penurunan efisiensi produksi RSS.* Overall Equipment Effectiveness *(OEE) dan* Total Equipment Efficiency *(TEE) digunakan untuk mengukur efektivitas dan efisiensi mesin. Analisis penyebab kegagalan mesin dilakukan menggunakan* Failure Method Effect Analyze *(FMEA), sedangkan rekomendasi perbaikan diberikan berdasarkan konsep TPM. Hasil penelitian menunjukkan bahwa nilai efektivitas mesin* sheeter *dalam satu tahun hampir keseluruhan berada di atas nilai standar internasional (85%) kecuali pada bulan April (72,27%) dan bulan Mei (80,33%). Nilai TEE pada mesin* sheeter *tertinggi terjadi pada bulan Februari (86,29%) dan terendah pada bulan April (58,11%). Hasil perhitungan* Six Big Losses *menunjukkan bahwa penyebab penurunan efektivitas dan efisiensi mesin* sheeter *adalah* breakdown losses, setup and adjusment losses, *dan* idling and minor stoppages. *Kegagalan yang memiliki nilai* Risk Priority Number *(RPN) tertinggi berdasarkan FMEA adalah* bearing *yang berkarat dan mesin yang berhenti karena* sheet *yang terselip di bawah roller. Rekomendasi perbaikan untuk meningkatkan efektivitas dan efisiensi produksi RSS berdasarkan konsep TPM adalah meminimalkan* Six Big Losses *dan menerapkan sistem pemeliharaan mandiri (*autonomous maintenance*).*
Kata kunci : *efisiensi mesin, karet lembaran, perawatan*

INTRODUCTION

In Indonesia, plantation crops are the most important supporting factors for the agricultural sector, creating foreign cash for the country. Rubber is one of the plantation commodities with an essential role in economic activities. It is also an export commodity, which is quite large as a foreign exchange earner besides oil and gas. Indonesia has even been regarded as the world's best natural rubber producer. The rubber industry processes all rubber commodities produced as industrial raw materials, and one of the results is a Ribbed Smoked Sheet (RSS). This product is used as a material for the tire industry, increasing the demand for motorized vehicles (Wita & Asri, 2021).

RSS is created through a series of processes, and latex containing about 15%-16% rubber is dissolved and agglomerated in special tanks using formic acid or acetic acid. Clots will form 3-4 hours after administration of formic acid, and after washing and grinding, rubber is formed into sheets. The sheet thickness is between 2.5 to 3.5 mm, 24 cm wide, and 90 or 135 cm long. Furthermore, fumigation is then carried out to dry the rubber sheet (Siahaan, 2011). Milling is a critical point in the production process, and the discrepancy in the thickness of the coagulum produced affects the quality of the RSS. The thickness of the coagulum depends on the effectiveness and efficiency of the sheeter machine.

The demand for RSS increases with the need for machines, and when the engine experiences fatigue, the performance is decreased. This condition can be prevented by performing corrective or preventive machine maintenance to maintain the effectiveness and efficiency of RSS production.

The application of TPM increases the efficiency of RSS production. Furthermore, the level of input efficiency in the sheeter machine can be known based on the Overall Input Efficiency (OIE) to obtain the Total Equipment Efficiency (TEE). Overall Equipment Effectiveness (OEE) measures the effectiveness performance of machines before measuring OIE (Patil & Prasad, 2019).

Several studies have been conducted to measure OEE in the food and agricultural industries (Tsarouhas, 2019a; Tsarouhas, 2019b; Siregar et al., 2018; Maknunah et al., 2016; Maknunah et al., 2014); however, these studies did not consider TEE. OEE and TEE measure the effectiveness and efficiency of the output and inputs used (Yuniawan et al., 2014). Therefore, this study aims to measure the sheeter machine effectiveness and efficiency. Subsequently, it measures the fundamental factors that cause the decline in sheeter machine production efficiency. Recommendations should be made to improve RSS manufacturing efficiency by applying TPM.

METHODS

The study was conducted at PT Kaliduren Estates, located in Tugusari Village, Bangsalsari District, Jember, East Java, Indonesia. Measurement of machine effectiveness and input efficiency was based on 1-year production data starting in April. The measurement of input efficiency on the sheeter machine includes utilities (water and electricity), raw materials (coagulum), labor (operators and technicians).

OEE, OIE, and TEE Measurements

The OEE value determined the machine operational effectiveness, and the calculation is formulated as follows (Gupta & Garg, 2012):

$$\text{OEE} = \text{availability} \times \text{performance efficiency} \times \text{rate of quality product} \quad (1).$$

Availability calculation is based on the sheeter machine's operating and loading time data. The calculation is used to determine the availability of operating machines or the level of utilization of production equipment. The equation for calculating availability rate is (Mohammadi et al., 2017):

$$\text{Availability} = \frac{\text{operating time (minute)}}{\text{loading time (minute)}} \times 100\% \quad (2).$$

Loading time is working time minus planned downtime, which is the total scheduled downtime and scheduled maintenance. Operating time is the length of time the equipment is in use, and it is the loading time minus downtime.

The calculation of performance efficiency is based on the process amount, ideal cycle time, and sheeter machine operating time. This calculation determines the efficiency level of machines and equipment during production activities. The equation for calculating performance efficiency is as follows (Hedman et al., 2016):

$$\text{Performance efficiency} = \frac{\text{processed amount (kg)} \times \text{ideal cycle time (minute/kg)}}{\text{operating time (minute)}} \times 100 \quad (3).$$

Process amount is the number of products produced, while the ideal cycle time is the theoretical cycle.

The rate of quality product calculation determines the effectiveness of production based on the quality produced. The equation for calculating the rate of quality product is as follows (Tsarouhas, 2019a) :

$$\text{Rate of quality product} = \frac{\text{processed amount (kg) - defect amount (kg)}}{\text{processed amount (kg)}} \times 100\% \quad (4)$$

Defect amount is the number of defective products in one production.

The efficiency level of the input to the sheeter machine can be determined based on OIE and the equation is as follows (Sheu, 2006):

$$\text{OIE} = \sum_{i=1}^{I} \text{wi Ei} \quad i = 1,.....I \quad (5)$$

where,
Ei: input efficiency item i
w_i = level of importance of input i

The input efficiency calculation obtains the value of each input item derived from the division between the minimum and the actual amount. The equation for calculating input efficiency is (Neelakandan & Muralidhara, 2018):

$$E_i = D_i / A_i \quad (6)$$

where,
Di: Minimum number of input items i
Ai: Actual number of input items i

A Sheeter machine is used in milling coagulum frozen to remove water and residual latex that does not solidify, rinse the coagulum, form a thin sheet, and give a pattern to the sheet. The inputs to this milling are all components that support the process's running. These include water to rinse the coagulum, electricity to run the sheeter machine, coagulum as the material being processed, the operator handling the material, and the technician as the workforce controlling the sheeter machine operation process. The input importance level is determined by interviewing operators, and technicians and the total number of levels of importance is as follows (Sheu, 2006):

$$\sum_{i=1,2,3,\ldots i}^{I} wi = 1 \quad (7)$$

The TEE value can then be calculated by the following equation (Sheu, 2006) :

$$\text{TEE} = \text{OEE} \times \text{OIE} \quad (8)$$

Six Big Losses

Six Big Losses are considered the cause of production equipment not operating in OEE. The measurement of six big losses determines the losses that cause the effectiveness and efficiency of the sheeter machine to be low. Six Big Losses are grouped into 3, namely downtime, speed, and quality losses.

Downtime losses

Due to engine damage, downtime losses are caused by wasted time because the production process does not run. It consists of breakdown, setup, and adjustment losses that are sudden damage to machinery. This breakdown can result in losses because the machine does not produce the desired output and can be calculated using the equation (Rajput & Jayaswal, 2012):

$$\text{Breakdown losses} = \frac{\text{downtime (minute)}}{\text{loading time (minute)}} \times 100\,\% \quad (9)$$

Setup and adjustment losses are time lost due to long setup time and are calculated by the equation (Chikwendu et al., 2020):

$$\text{Setup and adjustment losses} = \frac{\text{setup time (minute)}}{\text{loading time (minute)}} \times 100\,\% \quad (10)$$

Speed Losses

Speed loss is a state of production that does not reach the expected level because the speed of the production process is disrupted. Speed losses consist of 2 types of losses: idling and minor stoppage losses and reduced speed losses. Idling and minor stoppage losses are due to machine jamming or machine stopping for a moment. Losses like this cannot be detected directly without a tracer. Minor stoppage losses can be considered a breakdown when the operator cannot repair the stop. Idling and minor stoppage losses can be calculated using equation (Ahmad et al., 2018):

$$\text{Idling and minor stoppage losses} = \frac{\text{non productive time (minute)}}{\text{loading time (minute)}} \times 100\,\% \quad (11)$$

Nonproductive time is when the machine cannot produce a product due to stalling or pausing.

Reduced speed losses are caused by machines experiencing a speed decrease and can be calculated by the equation (Firmansyah et al., 2015):

$$\text{Reduced speed losses} = \frac{\text{operating time (minute)-(ideal cycle time (minute/kg) x processed amount (kg))}}{\text{loading time (minute)}} \times 100\% \quad (12)$$

Quality losses

Quality losses consist of defects in the process and reduced yield losses (Fitriadi & Kuncoro, 2013). A deficiency is a loss caused by a defective product whose spelling process is repeated. This results in material losses and reduces the amount of production. In addition, losses due to rework will affect the time required to process or repair defective products calculated by the equation (Ahmad et al., 2018) :

$$\text{Defect in process} = \frac{\text{(ideal cycle time (minute/kg) x defect amount (kg))}}{\text{loading time(minute)}} \times 100\% \quad (13)$$

Reduced yield losses are caused by unused material or raw material waste and product damage. Due to design errors, decreased manufacturing performance, and equipment failure, raw material waste can be generated. Product damage can be caused by precision adjusting and unstable working conditions, hence, many rejects occur. Reduced yield losses can be calculated using equation below (Alvira et al., 2015):

$$\text{Reduced yield losses} = \frac{\text{(ideal cycle time (minute/kg) x reject (kg))}}{\text{loading time (minute)}} \times 100\% \quad (14)$$

Failure Mode and Effect Analysis (FMEA)

Failure Mode and Effect Analysis (FMEA) is a structured procedure used to identify and prevent as several failure modes as possible. The priority of action on the factors that cause a decrease in the effectiveness and efficiency of the sheeter machine is determined based on the value of the risk priority number (RPN). Meanwhile, the RPN value is calculated using equation (Yumaida, 2011):

$$\text{RPN} = \text{severity x occurance x detection} \quad (15)$$

Severity is the impact caused by the failure, while occurrence is the degree of probability that a loss will occur. Furthermore, detection is the probability that a failure can be detected before it happens. Sheeter machine operators and technicians conduct the severity, occurrence, and detection assessments. Severity is rated with a 1-10 rating, which indicates that the failure has no impact until a hazardous result. Occurrence is rated with a 1-10 rating, indicating that failure rarely occurs until it almost occurs. Detection rates are ranging from 1-10, denoting that a failure is almost certain to be detected until it is not detected.

Failure/risk is categorized as critical when it has an RPN value higher than the critical RPN limit calculated using equation (Yumaida, 2011):

$$\text{Critical RPN Value} = \frac{\text{RPN total}}{\text{number of failures}} \quad (16)$$

Total Productive Maintenance (TPM)

TPM uses machines, equipment, employees, and supporting processes to maintain and improve production integrity and system quality. It is a holistic approach to equipment maintenance to achieve flawless production. Therefore, this study's recommendations for improving the performance of sheeter machines are based on the TPM concept (Zlatić, 2019). The successful implementation of TPM is based on the following these principles (Pačaiová & Ižaríková, 2019):

1. Eliminate Six Big Losses to increase machine/equipment effectiveness and efficiency
2. Implementing an autonomous maintenance program
3. Make a maintenance schedule for the maintenance department
4. Designing machine/equipment management activities involving all management
5. Involve the participation of all operators and technicians

RESULTS AND DISCUSSION

OEE Sheeter Machine

OEE measurements of sheeter machines at PT Kaliduren Estate were conducted monthly in 1 year with April as the beginning of the implementation of this study. The sheeter machine can be measured by calculating the availability, performance efficiency, and rate of quality of the machine. Availability describes the utilization of available time for machine or equipment operation activities. Table 1 shows the sheeter machines availability value calculation result at PT Kaliduren Estate for a year.

Table 1 shows that the availability of sheeter machines in April was the lowest due to high total downtime, which was 22.96 hours in a month. The most significant cause was that the machine is often stopped due to slipping sheets on the rollers and replacing damaged or rusted bearings. According to Rahmad et al. (2012), the machine availability value of ≥90% indicates a balance between the operating time, affected by machine downtime and loading time.

Performance efficiency indicates the equipment's ability to produce output (operation time) (Jiwantoro et al., 2013). The efficiency value calculation results of the sheeter engine performance at PT Kaliduren Estate for one year had exceeded the standard value as shown in Table 2. Meanwhile, the ideal condition of the performance efficiency value is equal to or greater than 95%. Machines with a performance efficiency value in ideal conditions indicate an efficient use because it follows the engine capacity (Rahmad et al., 2012).

Table 1. Sheeter machine availability

Month	Operating Time (minute)	Loading Time (minute)	Availability (%)
April	3,782.58	5,160	73.31
May	4,492.62	5,394	83.29
June	5,100.60	5,220	97.71
July	3,708.48	4,176	88.80
August	4,912.62	5,394	91.08
September	4,928.58	5,046	97.67
October	5,100.60	5,220	97.71
November	5,100.60	5,220	97.71
December	2,852.52	2,964	96.24
January	3,774.54	3,888	97.08
February	2,740.50	2,850	96.16
March	3,076.56	3,192	96.38

Table 2. Performance efficiency of sheeter machine

Month	Process Amount (kg)	Ideal Cycle Time (minute)	Operating Time (minute)	PE (%)
April	71,436.00	0.0523	3,782.58	98.85
May	83,974.82	0.0517	4,492.62	96.67
June	78,530.48	0.0628	5,100.60	96.67
July	67,146.86	0.0534	3,708.48	96.67
August	78,530.48	0.0605	4,912.62	96.67
September	101,627.68	0.0469	4,928.58	96.67
October	78,695.46	0.0627	5,100.60	96.67
November	77,705.58	0.0635	5,100.60	96.67
December	33,160.98	0.0817	2,852.52	95.00
January	47,844.20	0.0757	3,774.54	96.00
February	42,729.82	0.0609	2,740.50	95.00
March	32,171.10	0.0908	3,076.56	95.00

Table 3. Sheeter machine rate of quality

Month	Total Product Processed (kg)	Total Defect (kg)	RQ (%)
April	71,436.00	193	99.73
May	83,974.82	186	99.78
June	78,530.48	172	99.78
July	67,146.86	151	99.78
August	78,530.48	168	99.79
September	101,627.68	201	99.80
October	78,695.46	173	99.78
November	77,705.58	170	99.78
December	33,160.98	159	99.52
January	47,844.20	159	99.67
February	42,729.82	104	99.76
March	32,171.10	147	99.54

Industria: Jurnal Teknologi dan Manajemen Agroindustri
Volume 10 No 3: 216-226 (2021)

The rate of the quality product describes the ability of equipment to produce products that comply with standards without any defects. This is calculated based on the ratio of the standard products and the amount processed (Jiwantoro et al., 2013). The results of the rate of quality calculation for sheeter machines at PT Kaliduren Estate for one year can be seen in Table 3.

Table 3 shows that the product quality rate for sheeter machines in 1 year was close to 100% per month. This was because the number of defects produced by the sheeter machine was not too high, and the highest rate of quality product value occurred in September (99.80%). The rate of quality products between 99% and 100% indicates that the machines measured are ideal in producing standard-compliant products (Fakhri et al., 2019).

OEE was then measured to determine the total effectiveness of the sheeter machine performance in grinding latex coagulum as planned. Table 4 shows the results of the sheeter machine OEE measurement at PT Kaliduren Estate for one year. OEE sheeter machine for one year was higher than 85%, except in April and May with values of 72.27% and 80.33%, respectively. This achievement had met the world-class OEE standard, requiring an OEE of 85%, and the low OEE was due to the availability of sheeter machines in that month which was also the lowest in one year. Therefore, PT Kaliduren Estate can increase OEE by increasing the availability of sheeter machines. Furthermore, this condition can be achieved by reducing sheeter machine downtime.

TEE Sheeter Machine

TEE is used to evaluate the efficiency level of machines in a certain period. It considers OEE, which measures the effectiveness in terms of the output produced, and OIE, which measures the efficiency of inputs that go into the machine (Sheu, 2006). The inputs for the milling process using a sheeter machine are water to rinse the coagulum, electricity to run the sheeter machine, coagulum as the material being processed, the operator as a worker who handles the material during processing, and a technician as a worker who controls the sheeter operation. Table 5 shows the calculation results of the TEE value for one year.

Table 4. OEE sheeter machine

Month	Availability (%)	Performance Efficiency (%)	Rate of Quality Product (%)	OEE (%)
April	73.31	98.85	99.73	72.27
May	83.29	96.67	99.78	80.33
June	97.71	96.67	99.78	94.25
July	88.80	96.67	99.78	85.65
August	91.08	96.67	99.79	87.85
September	97.67	96.67	99.80	94.23
October	97.71	96.67	99.78	94.25
November	97.71	96.67	99.78	94.25
December	96.24	95.00	99.52	90.99
January	97.08	96.00	99.67	92.89
February	96.16	95.00	99.76	91.13
March	96.38	95.00	99.54	91.15

Table 5. TEE sheeter machine

Month	OEE (%)	OIE (%)	TEE (%)
April	72.27	80.42	58.11
May	80.33	74.98	60.24
June	94.25	77.6	73.14
July	85.65	96.6	82.73
August	87.85	75.1	65.97
September	94.23	79.57	74.98
October	94.25	77.56	73.11
November	94.25	77.9	73.43
December	90.99	92.58	84.24
January	92.89	87.08	80.88
February	91.13	94.69	86.29
March	91.15	85.32	77.76

Table 5 shows that the highest TEE occurred in February because the water used as input in the milling process did not exceed the standard used. Conversely, the lowest TEE occurred in April because it was influenced by the low OEE value so that TEE improvements in April must still consider the availability of sheeter machines.

Six Big Losses Analysis

Every company needs to avoid six Big Losses because they can reduce the effectiveness and efficiency of machines or equipment. The PT Kalideres Estate measurement focuses on preventing machine damage and minimizing downtime. Furthermore, it considers the losses due to low productivity on machines and equipment that cause losses for the company. Table 6 shows the Six Big Losses of sheeter machine measurements at PT Kalideres Estate.

Pareto diagrams are then made to determine the dominant losses as the cause of the decrease in sheeter effectiveness. Pareto diagram of Six Big Losses of sheeter machine is shown in Figure 1. Prevention is performed using the 80/20 principle, which is carried out on losses that contribute 80% (Sunadi et al., 2021). Figure 1 shows that the types of breakdown losses, setup and adjustment, and idling and minor stoppage are the leading causes of decreasing the effectiveness and efficiency of sheeter machines.

FMEA Results

FMEA was used to identify sheeter machine failures and their impact, and the results are shown in Table 7. The FMEA results show that 11 failure modes caused a decrease in the effectiveness and efficiency of the sheeter machine. The critical RPN value on the sheeter machine FMEA calculated using equation (16) was 71.63. Therefore, the priority of preventive measures was carried out on failures with RPN values> 71.63, i.e. the rust on the bearing and sheeter machine stops suddenly.

Bearing is a sheeter machine element that functions as a support shaft with a load, allowing rotation or back and forth movement to occur smoothly, safely, and for an extended period. Rust on bearings causes a loss of time because the repair process took approximately six hours and the frequency of this failure was ten times in 1 year. This failure can be detected when the machine is stopped due to faulty bearings and can be detected while grinding is performed.

Table 6. Percentage of Six Big Losses

Six Big Looses	Losses (Minute)	Percentage (%)
Breakdown Losses	4,153.20	42.63
Setup and Adjusment Losses	2,040.00	19.77
Idling and Minor stoppage	1,835.00	18.47
Reduced Speed Losses	1,818.22	17.85
Scrap/Yield Losses	124.00	1.24
Defect Losses	0	0
Total	9,970.42	100.00

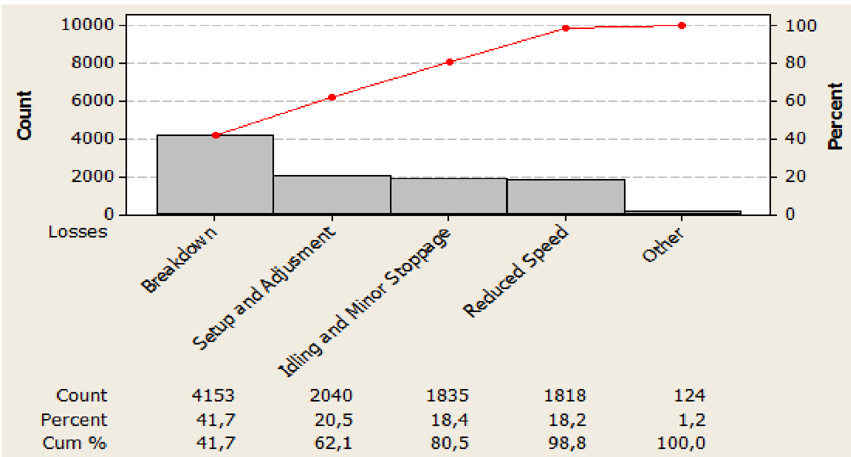

Figure 1. Pareto Chart

Table 7. FMEA of Sheeter Machine

Failure	Failure Mode	Failure Effect	RPN
The production target is not reached on time	The power goes out, or there is a short circuit in the engine components	Machine not operating	70
The machine stops suddenly	The operator is not careful in inserting the coagulum through the roller	Sheet tucked under the roller	90
Rust on bearings/lagers	Less lubrication	The bearing is damaged, so the machine stops operating	200
Van Belt is worn/slack	Roller rotation is too heavy because the coagulum that enters is too hard, and the oil often hits the van belt	The bearing is damaged, so the machine stops operating	56
Blockage of sheeter machine water pipe	The water that flows into the sheeter contains dirt so that it clumps in the pipes	The transfer of the rubber sheet from roller to the roller is prolonged	42
Roller shift/tilt	Bolts are not tight, and bolt checking is less intensive	Uneven sheet thickness	42
The position between the upper and lower rollers does not match the distance criteria	Checking per block setting is not thorough	Sheet thickness does not match the expected criteria	42
Rust on Roller	Obsolete machine	Sheet contaminated with rust	56
The sprocket chain is getting longer or loose	Incorrect engine chain adjustment	The engine chain noise is noisy, and the engine is stuck	28
Gear stuck	Sprocket chain problem and lack of lubricant	Machine stop operating	56
Pulley bent/damaged	Loose van belt and sticky flying waste	The pulley is heavy, and the engine slows down	56

According to NTN Corporation (2017), corrosion/rust on rings and roller bearings is caused by direct contact with acidic water, humid air, poor packaging and storage conditions, and hand-held bearings. Therefore, a mineral grease lubrication system should be applied regularly, and preventive maintenance should be performed when a bearing is not used for an extended period. Furthermore, predictive and corrective maintenance should also be conducted on sheeter machines.

The machine frequently stops because the operator does not carefully insert the coagulum; therefore, it clings, folds, and accumulates on the roller. The folded/tucked coagulum causes the next to stop and clog the proceeding coagulum. As a result, the machine should be stopped, and the coagulum pulled from the roller clamp manually. This failure can occur up to 150 times a year, and the prevention can be conducted by checking the level of softness before inserting the roller. This will train the user to operate the sheeter machine, process the coagulum, and encourage the operator to focus more on this process for safety.

Application of the TPM Concept

The application of TPM is the basis for recommendations to increase the effectiveness and efficiency of sheeter machines, and one of the principles is to perform autonomous maintenance. Therefore, sheeter machine operators should be trained to carry out machine maintenance independently and be responsible for damage from the use of sheeter machines by the operator.

Increasing the effectiveness and efficiency of sheeter machines can be conducted by increasing the availability, reducing breakdowns, setup adjustments, and idling and minor stoppages. This can be achieved by thorough inspection using a checklist before and after using the machine, making standard operational procedures (SOP) for lubrication and cleaning of machines, providing spare parts for machine component replacement in the event of a sudden stop, and replacing the sheeter machine after ten years. Improvements can also be made by paying attention to the use of materials in the formation of coagulum to prevent the formation of hard coagulum. For example, latex coagulant influences the coagulum hardness level (Valentina et al., 2020).

The repairs carried out should involve all operators and technicians by providing training on how to process latex, use and repair machines, and maintain sheeter machines following SOPs. Also, all top to operational management should also support this improvement process.

CONCLUSIONS

The results on the sheeter machine used for RSS production at PT Kalideres Estate showed that the OEE was already above the international standard value at 85%, except for April and May with a value of 72.27% and 80.33%. Furthermore, the lowest TEE occurred in April, while the highest occurred in February with 86.29% and 58.11%. However, the effectiveness and efficiency of the machine are low due to breakdown losses, setup and adjustment losses with idling, and minor stoppage. Two machine failures that cause a decrease in the effectiveness and efficiency of RSS production are rusty bearings and machine stalling due to slip sheets. Therefore, the application of TPM in overcoming the problem is carried out by increasing the availability of sheeter machines, reducing breakdowns, setup adjustments with idling and minor stoppages, and applying the principle of autonomous maintenance.

References

Ahmad, N., Hossen, J., & Ali, S. M. (2018). Improvement of overall equipment efficiency of ring frame through total productive maintenance: a textile case. *The International Journal of Advanced Manufacturing Technology*, *94*(1–4), 239–256. https://doi.org/10.1007/s00170-017-0783-2

Alvira, D., Helianty, Y., & Prassetiyo, H. (2015). Usulan peningkatan overall equipment effectiveness (OEE) pada mesin tapping manual dengan meminimumkan six big losses. *Reka Integra: Jurnal Teknik Industri*, *3*(3), 240–251.

Chikwendu, O. C., Chima, A. S., & Edith, M. C. (2020). The optimization of overall equipment effectiveness factors in a pharmaceutical company. *Heliyon*, *6*(4), e03796. https://doi.org/10.1016/j.heliyon.2020.e03796

Fakhri, N., Supenti, L., & Prabawo, G. (2019). Overall equipment effectiveness (OEE) analysis to improve the effectiveness of vannamei (Litopenaeus vannamei) shrimp freezing machine performance at PT. XY, Situbondo-East Java. *IOP Conference Series: Earth and Environmental Science*, *278*(1), 012022. https://doi.org/10.1088/1755-1315/278/1/012022

Firmansyah, M. M., Susanty, A., & Puspitasari, D. (2015). Analisis overall equipment effectivenessdan six big losses pada mesin pencelupan benang (Studi kasus PT. Pismatex Textile Industry). *Industrial Engineering*, *4*(4).

Fitriadi, R., & Kuncoro, G. B. (2013). Analisa perbaikan mesin CNC MA-1 dengan menggunakan indikator kinerja overall equipment effectiveness (OEE). *Prosiding Seminar Nasional Sains Dan Teknologi 4*, *1*(1), 26–31. Semarang: Fakultas Teknik. Universitas Wahid Hasyim.

Gupta, A. K., & Garg, R. K. (2012). OEE improvement by TPM implementation: A case study. *International Journal of IT, Engineering and Applied Sciences Research*, *1*(1), 115–124.

Hedman, R., Subramaniyan, M., & Almström, P. (2016). Analysis of Critical Factors for Automatic Measurement of OEE. *Procedia CIRP*, *57*, 128–133. https://doi.org/10.1016/j.procir.2016.11.023

Jiwantoro, A., Argo, B. D., & Nugroho, W. A. (2013). Analisis efektivitas mesin penggiling tebu dengan penerapan total productive. *Jurnal Keteknikan Pertanian Tropis Dan Biosistem*, *1*(2), 18–28.

Maknunah, L. U., Achmadi, F., & Astuti, R. (2016). Penerapan overall equipment effectiveness (OEE) untuk mengevaluasi kinerja mesin-mesin di stasiun giling Pabrik Gula Krebet II Malang. *Jurnal Teknologi Industri Pertanian*, *26*(2), 189–198.

Maknunah, L. U., Astuti, R., & Effendi, M. (2014). Perancangan aplikasi pengukuran overall equipment effectiveness (OEE): Studi kasus di PG Krebet Baru II. *Jurnal Teknologi Pertanian*, *5*(1), 7–14.

Mohammadi, M., Rai, P., & Gupta, S. (2017). Performance evaluation of bucket based excavating, loading and transport (BELT) equipment – an OEE approach. *Archives of Mining Sciences*, *62*(1), 105–120. https://doi.org/10.1515/amsc-2017-0008

Neelakandan, B., & Muralidhara, C. (2018). A review of literature on overall equipment effectiveness

(OEE). *Journal of Applied Science and Computations*, *5*(11), 188–200.

NTN Corporation. (2017). *Care and Maintenance of Bearings (Revised)*. Osaka: NTN Corporation.

Pačaiová, H., & Ižaríková, G. (2019). Base principles and practices for implementation of total productive maintenance in automotive industry. *Quality Innovation Prosperity*, *23*(1), 45–59. https://doi.org/10.12776/qip.v23i1.1203

Patil, M. S., & Prasad, P. (2019). Improvement of overall equipment effectiveness of valve stem seal finishing machine. *International Research Journal of Engineering and Technology*, *6*(8), 678–685.

Rahmad, Pratikto, & Wahyudi, S. (2012). Penerapan overall equipment effectiveness (OEE) dalam implementasi total productive maintenance (TPM) (Studi kasus di Pabrik Gula PT. “Y”.). *Jurnal Rekayasa Mesin*, *3*(3), 431–437.

Rajput, H. S., & Jayaswal, P. (2012). A total productive maintenance (TPM) approach to improve overall equipment efficiency. *International Journal of Modern Engineering Research*, *2*(6), 4383–4386.

Sheu, D. D. (2006). Overall input efficiency and total equipment efficiency. *IEEE Transactions on Semiconductor Manufacturing*, *19*(4), 496–501. https://doi.org/10.1109/TSM.2006.884718

Siahaan, G. P. (2011). *Penerapan total productive maintenance (TPM) untuk peningkatan efisiensi produksi pada pabrik RSS PT. Perkebunan Nusantara II Kebun Batang Serangan*. Department of Industrial Engineering. Faculty of Engineering. Universitas Sumatera Utara. Medan.

Siregar, I., Muchtar, M. A., Rahmat, R. F., Andayani, U., Nasution, T. H., & Sari, R. M. (2018). Method of calculation overall equipment effectiveness in fertilizer factory. *IOP Conference Series: Materials Science and Engineering*, *308*, 012053. https://doi.org/10.1088/1757-899X/308/1/012053

Sunadi, Purba, H. H., & Paulina, E. (2021). Overall equipment effectiveness to increase productivity of injection molding machine: A case study in plastic manufacturing industry. *ComTech: Computer, Mathematics and Engineering Applications*, *12*(1), 53–64. https://doi.org/10.21512/comtech.v12i1.6706

Tsarouhas, P. H. (2019a). Improving operation of the croissant production line through overall equipment effectiveness (OEE). *International Journal of Productivity and Performance Management*, *68*(1), 88–108. https://doi.org/10.1108/IJPPM-02-2018-0060

Tsarouhas, P. H. (2019b). Overall equipment effectiveness (OEE) evaluation for an automated ice cream production line. *International Journal of Productivity and Performance Management*, *69*(5), 1009–1032. https://doi.org/10.1108/IJPPM-03-2019-0126

Valentina, A., Herawati, M. M., & Agus, Y. H. (2020). Pengaruh asam sulfat sebagai bahan koagulan lateks terhadap karakteristik karet dan mutu karet. *Jurnal Penelitian Karet*, *38*(1), 85–94. https://doi.org/10.22302/ppk.jpk.v38i1.639

Wita, P. A. R., & Asri, Z. (2021). Petani karet di Kabupaten Kampar pada tahun 2010-2019: Pasang surut ekonomi dan gaya hidup petani Desa Salo. *Kronologi*, *3*(1), 338–351.

Yumaida. (2011). *Analisis Resiko Kegagalan Pemeliharaan Pada Pabrik Pengolahan Pupuk NPK Granular (Studi Kasus: PT. Pupuk Kujang Cikampek).* Faculty of Engineering. Universitas Indonesia. Depok.

Yuniawan, D., Ito, T., & Mohamad, E. Bin. (2014). Overall equipment effectiveness estimation for priority improvement in the production line. *International Journal of Internet Manufacturing and Services*, *3*(4), 279–299. https://doi.org/10.1504/IJIMS.2014.070694

Zlatić, M. (2019). TPM - total productive maintenance. *Proceedings on Engineering Sciences*, *1*(2), 581–590. https://doi.org/10.24874/PES01.02.057