International Conference on Mechanical, Industrial and Energy Engineering 2020
19-21 December, 2020, Khulna, BANGLADESH

ICMIEE20-146

Analysis of Overall Equipment Effectiveness in the Sewing Section of Garments Factory: A Case-Study

*Sourav Paul, Tanvir Mia, Syed Nafis Kamal, Shanta Saha**
Department of Industrial and Production Engineering, Shahjalal University of Science and Technology, Bangladesh

ABSTRACT
Bangladesh is a fast-growing economy powered by the readymade garments (RMG) industry that shares the major part of country's export earnings. However, competition is increasing day by day and this sector requires proper attention in performance improvement to strive with upcoming challenges. In this regard, continuous availability with reliable performance of resources and precise product production is indispensable. Considering this, present study aims to quantify the operational performance whereas overall equipment effectiveness (OEE) is taken as the metric of measurement. The sewing section of RMG factory is focused to conduct this study. Necessary data collection was carried out at five RMG factory based on the floor observation and the existing scenario of OEE was build up with its factors – availability, performance and quality. It was found that the average OEE along with its individual factors are far from the world standard. A regression model was developed to find the most influential factor for the resulted OEE. It has been found that, performance is the most dominating element for OEE, followed by availability and quality. Finally, root-cause analysis was carried out for performance loss to find the responsible causes that create hindrance in achieving the standard OEE. Accordingly, some recommendations were provided to improve the existing OEE condition.

Key Words: Garments factory, Sewing section, Overall equipment effectiveness

1. Introduction
Bangladesh has a flourishing economy, which is well backed by the ready-made garments (RMG) industry. The RMG industry is playing a key role in the growth of the economy, and has appeared as the largest export earning sector of the country [1]. Now-a-days this industry is continually facing economic challenges due to rising global competition in the perspective of production, management and technological processes, as well as consumers' expectations.

To meet the challenges, there is a need for operational performance improvement. In this regard, proper maintenance can play a very significant role. Proper maintenance leads to the higher productivity [2]. Equipment maintenance and reliability can raise operational performance and hence influence the organization's competitive advantage. One of the approaches to increase the efficiency of maintenance activities is to develop and implement Total Productive Maintenance (TPM) strategy. TPM is the method of managing the machines, equipment, employees and the supporting processes focusing on maintaining and improving the integrity of production and quality systems [3]. TPM progressively raises the operational performance of an organization [4]. Overall Equipment Effectiveness (OEE) measurement tool was developed from TPM concept with the objective of achieving zero breakdown and zero defects associated with equipment [5]. First described in 1982 as the central component of TPM methodology, OEE has become an established tool to measure and assess the floor productivity [6]. Hence, with the pace of market demand and growing challenges, productivity and operational improvement in the Bangladeshi RMG sector requires OEE measurement in its production lines.

* Corresponding author. Tel.: +88-01674806784
E-mail addresses: shanta-ipe@sust.edu

OEE is considered to be the gold standard for determining the manufacturing productivity [7]. Rouse (2017), defined OEE as "a measure of production operations performance and productivity, which is expressed as a percentage". They observed OEE measure as an indicator of manufacturing process whether it is productive or not [8]. The three parameters captured by OEE namely availability rate, performance rate and quality rate measure the degree of conformity to output requirements. Jon Bokrantz (2017) identifies the potentials of using OEE assessment for maintenance activity enhancement within the manufacturing industry [9]. This paper assessed OEE data of 98 Swedish companies and performed Monte-Carlo simulations with the intention of detecting how each OEE element influences the overall OEE. Fam et al., (2018) addressed the impact of TPM components on OEE in a semiconductor industry [10]. The implementation of measuring OEE strategy can indicate the scope of enhancing products' quality and reducing equipment breakdown, idle time, accidents, as well as scraps and defective products. Okpala et al. (2018), explained OEE as an effective way of analyzing equipment performance, by considering the major six big losses [11]. According to the Nakajima, S. (1989), six big losses are breakdown loss, set-up and adjustment loss, idling and minor stoppage loss, reduced speed loss, reduced yield loss and defect-rework loss [12]. The first two losses are recognized as down time loss and are used in the availability calculation of a machine. The following two are speed losses that set the performance, and the last two are the quality losses.

Therefore, OEE metrics can be a help of garments factory's efficiency and effectiveness indicator with categorizing the key productivity losses that occur within the production process. OEE empowers manufacturing industries to develop their processes and in turn ensure quality, consistency, and productivity [13]. The study is aimed at analyzing of OEE in the sewing section of a selected RMG factory. This study, therefore, aims to:

i. Analyze the extent of existing effects of OEE factors on OEE
ii. Find the root cause and their remedies of respective losses of the most influential OEE factor in existing condition

2. Methodology

The study was carried out in a renowned RMG industry, which has six factories situated at different locations of Gazipur, Bangladesh. The sewing section of each factory is focused to conduct this study. Each of the six factories was observed for five days for a single specific line. Table 1 presents the capacity of the whole and studied sewing section and the number of lines of each factory.

Table 1 Information regarding the sewing section of each factory

Factory	Line No.	Monthly Total Capacity (pieces)	Monthly capacity for studied line (pieces)
F1	42	1404000	36000
F2	48	1996800	43200
F3	24	960800	25500
F4	30	1092000	22000
F5	32	1289600	32500
F6	36	721095	18000

2.1 Data collection

Data was collected based on the floor observation. Each of the six factory was observed for five days for five specific line of garments and the following data were collected to calculate OEE: working hour, designed cycle time, target and output per day, planned and unplanned breakdown time, idle and minor stoppage, and defect per hundred units (DHU) etc.

2.2 Data processing and analysis

The collected data were inserted in excel sheet and processed in a usable format. The required calculations were carried out to get the existing scenario of OEE of the selected industry. According to Dal et al. (2000), OEE can be measured by multiplying the performance of the process, the availability of equipment, and rate of quality products [14]. Hence, the equations stand,

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

Where,
Availability (A) takes into account unplanned and planned stops. An availability score of 100% means the process is always running during planned production time and hence the equation stands,

* Corresponding author. Tel.: +88-01674806784
E-mail addresses: shanta-ipe@sust.edu

$$A = Run\ Time / Planned\ Production\ Time \quad (2)$$

$$Run\ Time = Planned\ Production\ Time - Stop\ Time \quad (3)$$

Performance (P) takes into account slow cycles and small stops. 100% performance score means the process is running as fast as possible.

$$P = (Ideal\ Cycle\ Time \times Total\ Count) / Run\ Time \quad (4)$$

$$Cycle\ time = Planned\ Run\ Time / Target\ Output \quad (5)$$

Quality (Q) takes into account defects. A quality score of 100% means there are no defects (only Good Parts are being produced).

$$Q = Good\ Count / Total\ Count \quad (6)$$

Utilizing the above equations; A, P, Q, and OEE were computed for six factories for each day. So that, total thirty data were produced for each of the variables. Pearson correlation was employed to reveal the existing degree of correlation among variables. The data were then used to develop multiple regression model for OEE, using the Design-Expert Software V7.0. The analysis of variance (ANOVA) was used to check the adequacy of the model. An investigation was carried out to explore the interaction of each factor to the OEE. Statistical validation was also performed to check the agreement level of the developed model with the input data. Root-cause analysis was then performed to identify potential reasons causing the losses which are responsible for controlling the OEE factor. This analysis was performed only for the most influential factor to OEE found from regression analysis.

3. Results and discussion

3.1 Status of OEE

OEE was calculated from field data by using the Equations (1), (2), (3), (4), (5) and (6) and reported in Table 2. The table represents availability (A), performance (P), quality (Q) and OEE scores for each factory for every five days. A comparison between the studied results and world standard (WS) [15] of OEE indicators is shown in Fig. 1. It reveals that none of the OEE factors meets the WS. Availability, performance and quality of the sewing section of the studied industry is 87.14%, 78.29% and 91.15% respectively, which are far from WS. The maximum value for OEE is 65.48% and the minimum one is 56.50%, while the average value is 62.09%, which is also far below from WS (85%). Availability depends on non-productive time (NPT) which includes breakdown time and change over time. These are the primary possible reasons of being less availability than WS [11]. More importantly, frequent style change was observed almost all of the lines, which results high change over time. In the case of performance, possible reasons for the deviation from WS could be idling and minor stoppage of sewing machines and reduced speed [12]. More defective products could lead less quality [11].

The Pearson correlation test has been conducted to observe the prevailing level of significance of the variables to each other. The results shown in Table 3 reveal that performance and quality are significant in predicting the OEE, while availability is not significant.

3.2 Effects of OEE factors

Response surface methodology was applied to the calculated data utilizing the Design-Expert Software V7.0. The OEE input variables are availability, performance and quality. The measured results of OEE for each day were inserted into the Design-Expert Software. Table 4 depicts the statistics of the variables A, P and Q in the system. It shows the low and high values in actual and coded terms for each of the variables and also displays the mean and standard deviation of these variables.

To select the best suitable model for the response factor OEE, the sequential model sum of squares (SS) were analyzed with a view to choose the highest order polynomial which is not aliased. Table 5 shows that two factor interaction (2FI) model is recommended for OEE as Prob. > F is less than 0.05 by maintaining the highest order (between linear and 2FI) polynomials.

Table 2 OEE matrix for each factory

Factory	Day	A (%)	P (%)	Q (%)	OEE (%)
F1	1	90.33	66.70	89.25	56.50
	2	85.79	81.55	91.03	64.12
	3	86.18	77.38	89.00	61.60
	4	89.76	78.06	93.11	64.76
	5	90.10	74.57	90.53	61.98
F2	1	91.72	78.02	89.75	62.74
	2	86.66	82.21	89.75	62.66
	3	89.47	77.88	89.87	63.74
	4	85.08	81.49	93.30	64.61
	5	88.08	79.08	91.50	63.27
F3	1	86.44	76.43	88.50	58.48
	2	84.50	74.90	89.75	56.93
	3	87.25	74.21	89.75	57.64
	4	89.29	76.07	89.75	60.99
	5	91.79	75.08	94.00	64.33
F4	1	85.82	81.13	94.25	65.48
	2	90.69	74.32	94.00	61.92
	3	84.13	82.32	88.50	59.88
	4	89.08	77.00	94.00	63.88
	5	84.83	81.13	92.50	63.54
F5	1	87.00	79.56	93.25	63.67
	2	82.38	83.81	89.00	61.67
	3	80.63	83.81	91.00	63.75
	4	86.46	79.84	91.75	63.97
	5	83.61	82.32	92.50	63.88
F6	1	79.75	92.91	88.00	64.18
	2	87.17	76.71	91.50	61.02
	3	88.83	76.59	92.50	62.88
	4	92.08	72.68	89.75	60.20
	5	89.38	70.81	93.25	58.52
Avg.		**87.14**	**78.29**	**91.15**	**62.09**

* Corresponding author. Tel.: +88-01674806784
E-mail addresses: shanta-ipe@sust.edu

Fig. 1 Studied result vs world standard (WS)

Table 3 Results of Pearson's correlations coefficient and significance for OEE and its variables

		A	**P**	**Q**	**OEE**
A	Pearson Corr.	1	-.756**	0.307	-0.126
	Sig. (2-tailed)		0.000	0.099	0.506
	N	30	30	30	30
P	Pearson Corr.		1	-0.135	0.608**
	Sig. (2-tailed)			0.477	0.000
	N		30	30	30
Q	Pearson Corr.			1	0.498**
	Sig. (2-tailed)				0.005
	N			30	30
OEE	Pearson Corr.				1
	Sig. (2-tailed)				
	N				30

**Correlation is significant at the 0.01 level (2-tailed)

Table 4 Descriptive statistic of the variables of OEE

Factor	**Actual (Coded)**		**Mean**	**Std. Dev.**
	Low	**High**		
Availability (A)	0.80 (-1.0)	0.92 (1.0)	0.871	0.031
Performance (P)	0.67 (-1.0)	0.93 (1.0)	0.783	0.047
Quality (Q)	0.88 (-1.0)	0.94 (1.0)	0.912	0.019

Table 5 Model type selection for OEE

Source	**SS**	**F val.**	**p-val. > F**	**Remark**
Mean vs Total	11.57			
Linear vs Mean	0.015	55.9	<.0001	
2FI vs Linear	7.9E-4	3.85	0.0228	Suggested
Quad. vs 2FI	2.8E-4	1.44	0.2619	
Cubic vs Quad.	5.0E-4	0.64	0.7544	
Residual	7.9E-4			
Total	11.58			

The ANOVA results of the OEE model is tabulated in Table 6. Model terms were assessed by the F value at 95% confidence level. Besides, significance of each coefficient were evaluated by the P values. Table 6 demonstrates that calculated F an P values, are, respectively, 39.10 and <0.0001 i.e.; the selected 2FI model is highly significant with a chance of only 0.01% that these F values could occur due to noise. Consequently, P value of less than 0.05 indicates the statistically significant model. The same table shows the other acceptability measures-R^2, adjusted R^2 and predicted R^2 values; that are in logical agreement. The R^2 value is 0.9107, close to 1, which is desirable for the model. Considering the determination coefficient, adj. R^2 is 88.74%, which demonstrate that the model is well fitted. Moreover, the adequate precision is 23.53 which is well above 4. This indicates adequate signals to use the model. Now, the main effects of variables, from Table 6 it is clear that, the influence of A, P, Q and only the interaction of P and Q are the significant terms for OEE. As the P value of interaction AP and AQ are greater than 0.05 these terms have been eliminated to obtain the final model. Following this, the resulted statistics terms of ANOVA remain quite good for the reduced model shown in Table 7. Therefore, it is apparent that the reduced 2FI model for OEE shown in Eq. 7 (in coded terms) is statistically fitted to the calculated values.

The contour plot shown in Fig. 2 represents the fact that combinations of upraised performance and quality results in increased OEE.

$$OEE=0.63+0.033A+0.09P+0.021Q+0.022PQ \qquad (7)$$

Table 6 ANOVA for OEE 2FI model

Source	SS	df	Mean Square	F Val.	p-val. > F
Model	0.016	6	2.67E-3	39.1	<.0001
A	2.74E-3	1	2.74E-3	40.0	<.0001
P	7.85E-3	1	7.85E-3	114.9	<.0001
Q	3.67E-3	1	3.67E-3	53.8	<.0001
AP	1.19E-4	1	1.19E-4	1.8	0.1994
AQ	1.22E-5	1	1.22E-5	0.2	0.6760
PQ	3.27E-4	1	3.27E-4	4.8	0.0390
Resid	1.57E-3	23	6.83E-5		
Cor. Total	0.018	29			

R^2 = 0.9107 Adjusted R^2= 0.8874 Predicted R^2=0.8524 Adequate Precision= 23.35

3.2.1 Statistical validation

In this study, the normality of residal data is verified by plotting the normal probability plot. This plot of residual values for OEE is depicted in Fig.3. It shows that the data points on the plot is quite close to the straight line specifies they are normally distributed. Fig.4 demonstrates studentized residuals against predicted values. The residuals are found dispersed arbitrarily about zero that is, the errors have a constant variance. The plot of studentized residuals versus predicted values shows the probable presence of outside data point. Fig.4 displays all the points are within ±3σ limits. The association between actual and predicted values of OEE is shown in Fig.5; indicates that the predicted values are in good agreement with the measured value as the points are adjacent to the oblique line.

Table 7 ANOVA for OEE 2FI (reduced) model

Source	SS	df	Mean Square	F Val.	p-val. > F
Model	0.016	4	3.4E-3	58.49	<.0001
A	2.9E-3	1	2.9E-3	43.27	<.0001
P	9.2E-3	1	9.2E-3	135.76	<.0001
Q	4.4E-3	1	4.4E-3	64.57	<.0001
PQ	6.6E-4	1	6.6E-4	9.73	.0045
Resid	1.7E-3	25	6.8E-5		
Cor. Total	0.018	29			

R^2 = 0.9035 Adjusted R^2= 0.8880 Predicted R^2=0.8654 Adequate Precision= 29.29

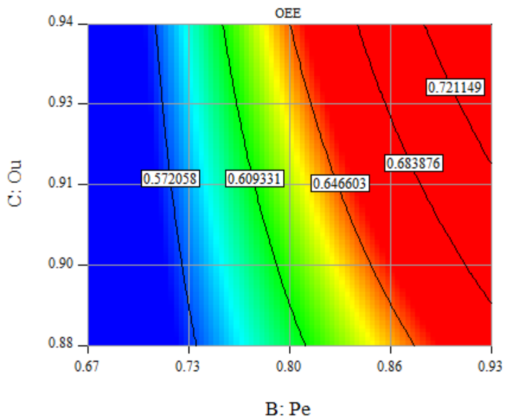

Fig. 2 Contour plot for OEE- performance and quality

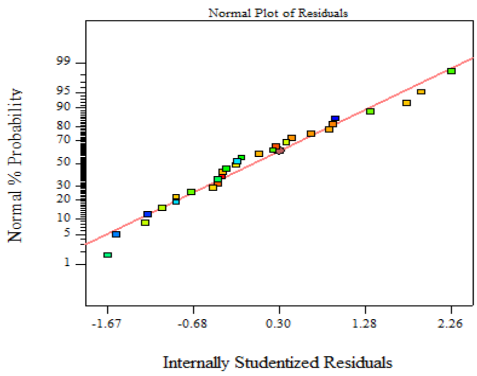

Fig. 3 Normal probability plot of OEE

* Corresponding author. Tel.: +88-01674806784
E-mail addresses: shanta-ipe@sust.edu

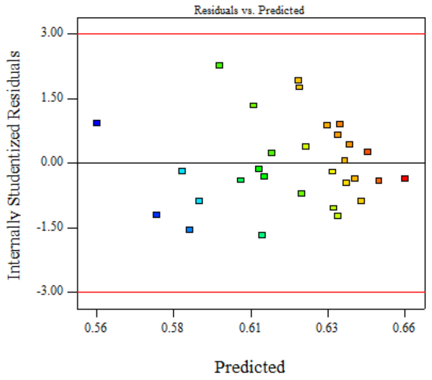

Fig. 4 Residual vs. predicted plot for OEE

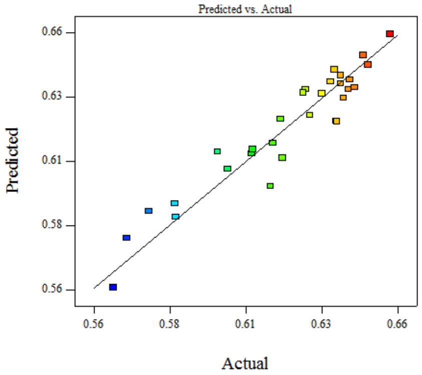

Fig. 5 Predicted vs. actual plot for OEE

3.3 Root-cause analysis

From the analysis of OEE it has been observed that, performance is the most influential factor, followed by

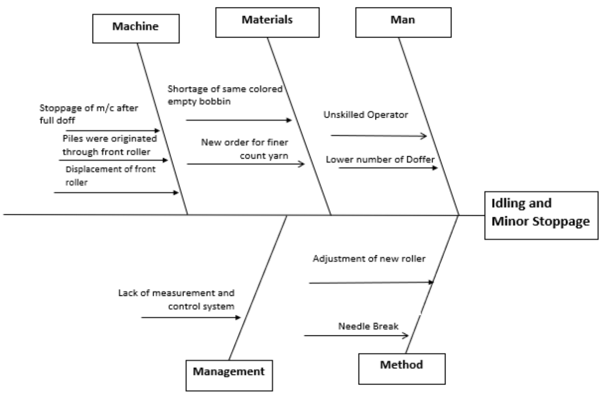

Fig. 6 Fishbone diagram for idling and minor stoppage

availability and finally quality. On the other hand, from the comparison between world standard and the calculated values of OEE factors; it has been observed that, performance has the highest deviation (16.71%) from the world standard. To improve OEE it will be a good initiative to improve performance by reducing performance related losses. The two big losses under performance are: a) idling time and minor stoppage and b) reduced speed. Root-cause analysis has been conducted on these two losses and recommendations are provided. The root cause analysis are performed through direct observation, discussion with experts and from some literature review [16,17]. The causes are classified into five categories: man, machine, material, method, and management system.

Fig. 6 represents the root cause analysis for idling and minor stoppage. Table 8 shows the corresponding recommendation for each cause of idling and minor stoppage under each of the five categories. If these causes are dealt properly and controlled, performance will improve. Similarly, Fig. 7 represents fish-bone diagram for reduced speed. Table 9 shows the recommendations for reduced speed loss against each causes of reduced speed under each category.

Table 8 Recommendations to reduce idling and minor stoppage

Category	Cause	Remedial actions
Machine	Needle break due to inconsistent machine spread	Use of guider [16]
	Piles were originated through front roller	Front roller setting has to be adjusted
Materials	Displacement of front roller	Front roller setting has to be adjusted [17]
	Shortage of supply	Use KANBAN
Man	Unskilled Operator	Training
	Deliberate slow work	Production Balancing
Management	Lack of measurement and control system of machines and equipment follow-up	Management initiative
Method	Unsettled new roller	Proper adjustment [16]
	Needle Break	• Needle plate should be positioned properly at the beginning of operation. [16] • Pressure guide should be tightened properly.

* Corresponding author. Tel.: +88-01674806784
E-mail addresses: shanta-ipe@sust.edu

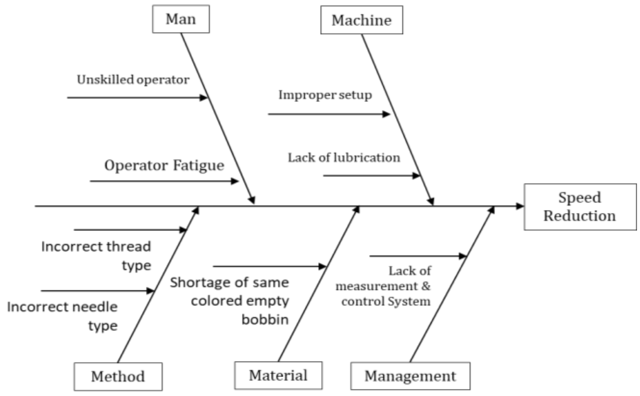

Fig. 7 Fishbone diagram for Reduced Speed

6. Conclusion

In the current global competitive environment, the demand for productivity enhancement requires precisely defined performance-measurement systems for manufacturing process. Analysis of overall equipment effectiveness (OEE) can help to track how effectively the resources are used and then it can help to reduce wastes.

Table 9 Recommendation to lessen the reduced speed loss

Category	Cause	Remedial actions
Machine	Improper Machine Set up	Follow instruction manual [16]
	Lack of Lubrication	Supervision
Materials	Shortage of input from cutting section	Accurate Planning
Man	Unskilled Operator	Training
	Operator Fatigue	Reducing excessive pressure on operators
Management	Lack of measurement and control system of Machines and Equipment Follow-up	Establish effective measurement and control system
Method	Incorrect needle Type	Procurement of correct type of needle [17]
	Incorrect thread Type	Procurement of correct type of thread

In this research it has been found that, the existing scenario of OEE is not satisfactory with the average OEE of 62% for the studied sewing lines of the selected RMG industry. The average scores of OEE factors – availability (87.14%), performance (78.29%) and quality (91.15%) are below from world standard. Performance is the most influential factor for OEE enhancement and followed by availability and quality. As the combined effect, only the performance-quality relation shows the significant interaction with OEE. Root-cause analysis reflects the responsible reasons for the performance loss associated with man, machine, material, method, and management system. Along with, the suggested corresponding remedial actions can be applicable in avoiding the performance loss.

* Corresponding author. Tel.: +88-01674806784
E-mail addresses: shanta-ipe@sust.edu

References

1. Islam, M. S., Rakib, M. A., & Adnan, A. (2016). Ready-made garments sector of Bangladesh: Its contribution and challenges towards development. *Stud*, *5*(2).
2. Maletic, D., Maletic, M., Al-Najjar, B., & Gomišcek, B. (2014). The role of maintenance in improving company's competitiveness and profitability: a case study in a textile company. *J. of Manufacturing Technology Management*, *25*(4), 441-456.
3. Oliveira, J., Sá, J.C., & Fernandes, A. (2017). Continuous improvement through" Lean Tools": An application in a mechanical company. *Procedia Manufacturing*, 13, 1082-1089.
4. McCarthy, D., & Rich, N. (2004). Lean TPM. *Book of Elsvier Publication*.
5. Pintelon, L.M-y.A, & Muchiri, P.N., (2008) Performance measurement using overall equipment effectiveness (OEE): Literature review and practical application discussion. *Int. J. of Production Research*, 46 (13), 3517-3535.
6. History of OEE and TPM. Accessed: 15 August 2019, https://www.oeefoundation.org/origin-of-oee
7. Otley, D.T. (1999). Performance management: a framework for management control systems research. *Qualitative Research in Accounting and Management*, 10 (4), 363-382.
8. Rouse, M., (2017). Definition of overall equipment effectiveness [Online]. Accessed 29 September 2019.https://searcherp.techtarget.com/definition/overall-equipment-effectiveness-OEE.
9. Ylipää, T., Skoogh, A., Bokrantz, J., & Gopalakrishnan, M. (2017). Identification of maintenance improvement potential using OEE assessment. *Int. J. of Productivity and Performance Management.* 66 (1), 126-143
10. Fam, S., Loh, S.L., Haslinda, M., Yanto, H., Khoo, L.M.S., & Yong, D.H.Y., (2018) Overall equipment efficiency (OEE) enhancement in manufacture of electronic components & boards industry through total productive maintenance practices. *MATEC Web of Conferences* 150, 05037
11. Okpala, C., & Anozie, S., (2018). Overall equipment effectiveness and the six big losses in total productive maintenance. *J. Sci. Eng. Res.* 5 (4).

12. Nakajima, S. (1989) Introduction to TPM: total productive maintenance, *Productivity Press, Cambridge, MA.*
13. Manojkumar, V., Kesavan, R., & Kalyanakumar, S. (2014). Analysis and improvement of overall equipment effectiveness in automatic fettling machine. *National Journal on Advances in Building Sciences & Mechanics*, 5(2), 10-14.
14. Dal, B., Tugwell, P., & Greatbanks, R., (2000). Overall equipment effectiveness as a measure for operational improvement: a practical analysis. *Int. J. Oper. Prod. Manag.* 20 (12).
15. World-Class OEE. Accessed: 15 August 2019, https://www.oee.com/world-class-oee
16. Mahmud, M., & Anisuzzaman, M. (2018). Study on different types of sewing faults and their remedies (Doctoral dissertation, Daffodil International University).
17. A., & Hasan, M. (2019). Study on Different Types of Sewing Faults and Their Remedies in Knit Garment Production.

* Corresponding author. Tel.: +88-01674806784
E-mail addresses: shanta-ipe@sust.edu