



Vol. XI &amp; Issue No. 3 March - 2018

INDUSTRIAL ENGINEERING JOURNAL

## ENHANCEMENT OF PRODUCTIVITY IN AN IRON AND STEEL RE-ROLLING MILL USING TPM APPROACH

Kushal Sharma  
Dr. Girish D Thakar,  
Dr. B E Narkhede

### Abstract

India is the third largest producer of crude steel in the world. Steel is a vital element for the socioeconomic development of a developing nation like India. This study aims at evaluating the performance of a steel re-rolling mill by calculating the OEE and measures like implementation of Total Productive Maintenance (TPM), Proper Production Planning and Control (PPC) etc to improve the performance were also suggested. Implementation of the solutions and suggestions showed a growth of approx. 17% in the Overall Equipment Effectiveness.

**Keywords:** - OEE, TPM, PPC, Steel Re-rolling

### INTRODUCTION

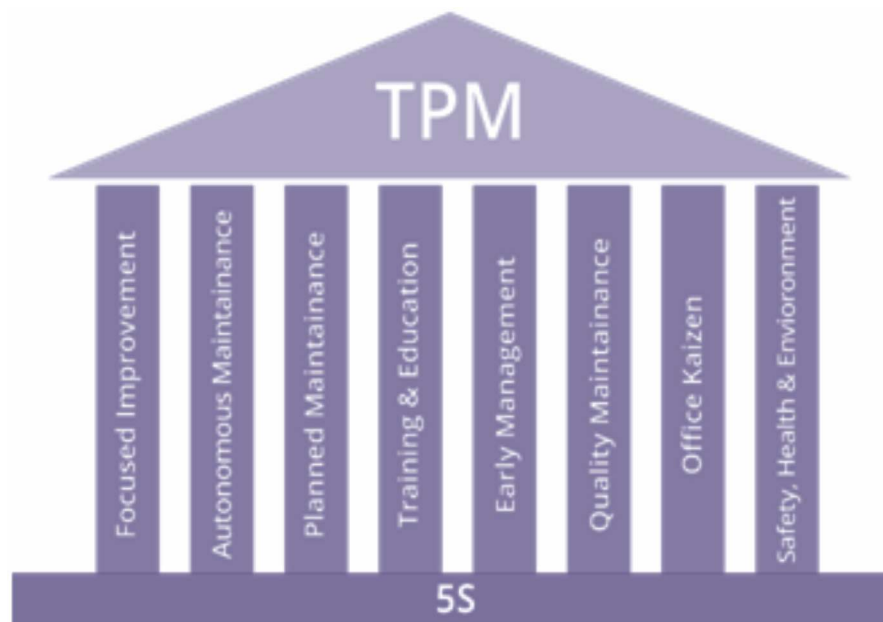
Steel is one of the world's most essential materials, fundamental to every aspect of our life. Steel is of strategic importance to a rapidly industrializing nation like India. In 2015, India overtook the United States to become the 3rd largest steel producer in the world and is poised to become the second largest steel producer shortly. In Stainless Steel, in the year 2016, India has already become the second largest producer. Today, the Indian steel industry contributes about 2% to the country's GDP and employs about 5 lakh people directly and about 20 lakh people indirectly. Capacity for domestic crude steel production expanded from 90.87 million tonnes per annum (mtpa) in 2011-12 to 121.97 mtpa in 2015-16, a compound annual growth rate (CAGR) growth of 9% during this five-year period. Crude steel production grew at 5% annually (CAGR) from 74.29 mtpa in 2011-12 to 89.79 mtpa in 2015-16.

In the previous works of the authors OEE was calculated and improvements were done in OEE by reducing the cobbles and misrolls. The main aim of this study is to further enhance the

productivity by improving the maintenance practices by implementing Total Productive Maintenance (TPM). Total Productive maintenance is basically an expansion of lean manufacturing system with major goals of zero breakdown, zero accident, and zero loss. With the help of implementing the TPM and proper training to employees, companies have been able to increase OEE and reduce the downtimes very effectively.

### LITERATURE REVIEW

Earlier works reported by the authors includes the calculation of OEE of a steel re-rolling mill. And then finding the root causes of the low OEE. Lots of issues were identified and listed. But the major ones include Cobble, misroll and improper maintenance practices. Issues and root causes related to cobbles and misrolls were discussed in the previous works done by the author. And after that the OEE has been calculated to be increased by nearly 10%. The issue of improper maintenance practices was yet to be resolved and has been taken care by implementing TPM in the industry.



12 Steps of TPM	
Stage	Step
Preparation	1. Announce Top Management's Decision to Introduce TPM
	2. Launch Educational Campaign
	3. Create Organizations to Promote TPM
	4. Establish Basic TPM Policies and Goals
	5. Formulate a Master Plan for TPM Development
Implementation	6. Hold TPM "Kick-off"
	7. Improve Equipment Effectiveness
	8. Establish an Autonomous Maintenance Program for Operators
	9. Set-up a Scheduled Maintenance Program for the Maintenance Department
	10. Conduct Training to Improve Operation and Maintenance Skills
Stabilisation	11. Develop Initial Equipment Management Program
	12. Implement TPM Fully and Aim for Higher Goals

**TOTAL PREVENTIVE MAINTENANCE**

Total Productive Maintenance (TPM) is a maintenance program, which involves a newly defined concept for maintaining plants and equipment. The goal of the TPM program is to markedly increase production while, at the same time, increasing employee morale and job satisfaction. Nakajima, a major contributor of Total Productive Maintenance (TPM) defined TPM as an innovative approach to maintenance that optimizes equipment effectiveness, eliminates breakdown, and promotes autonomous operator maintenance through day-to-day activities involving the total workforce. TPM's cooperative effort dramatically increases productivity and quality, optimizes equipment life cycle cost, and broadens the base of every employee's knowledge and skills, by increasing their motivation and competency.

The most important features of TPM are 1) activities to maximize equipment effectiveness; 2) autonomous maintenance by operators, and 3) company-led small group activities. Maximizing equipment effectiveness requires the complete elimination of failures, defects and other negative phenomena — in other words, the wastes and losses incurred in equipment operation. This goal is consistent with Philip Crosby's philosophy of zero defects (ZD), Autonomous maintenance by operators maybe difficult to introduce where operation and maintenance were clearly separated. Company-led small group activity is consistent with Likert's participative management model, with Ouichi's Theory Z management, and with Peters and Waterman's definition of the excellent company in In Search of Excellence. Nakajima 1988 has also given 8 Pillars of TPM which are supported on a strong foundation of 5S. He has also given 3 Phases and 12 Steps of implementation of TPM.

**Overall Equipment Effectiveness Calculations: -**

Overall equipment effectiveness is a productivity and performance metric that is widely used in manufacturing industries. When associated with the reasons for performance loss, OEE provides the means to compare and prioritise improvement efforts.

$$"OEE = Availability (A) \times Performance (P) \times Quality (Q)"$$

**Availability (A)**

$$Availability = \frac{Hourly\ production\ rate\ in\ planned\ time}{Hourly\ production\ rate\ in\ real\ time}$$

$$Availability = \frac{Days\ Actual\ run}{Days\ planned}$$

$$Days\ actual\ run = Days\ planned - downtime\ (in\ days)$$

$$Days\ planned = Days\ available - Planned\ downtime\ (in\ days)$$

$$Days\ available = Calendar\ Days - Weekly\ offs - Holidays - No.\ of\ days\ of\ material\ shortage$$

**Performance (P)**

$$Performance = \frac{Expected\ hourly\ production\ rate}{Hourly\ production\ rate\ in\ real\ time}$$

$$Hourly\ production\ rate\ in\ real\ time = \frac{Total\ Production}{Days\ Actual\ Run \times 24\ hours}$$

**Quality (Q)**

$$Quality = \frac{Total\ production - Total\ Rejection}{Total\ production}$$

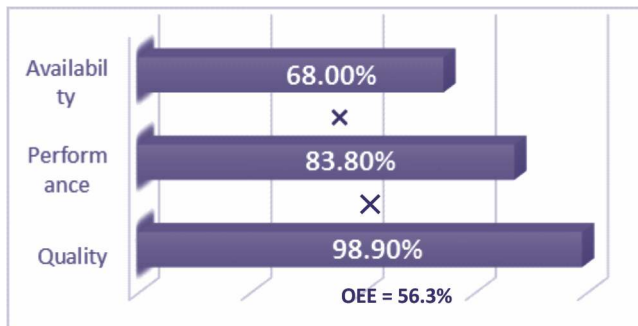
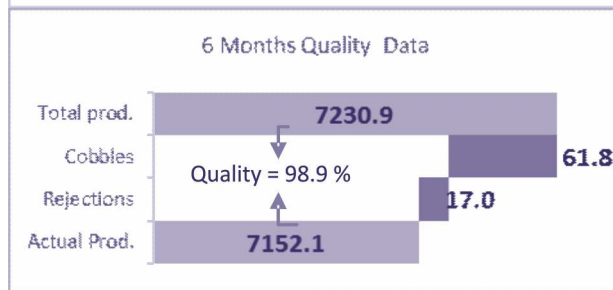
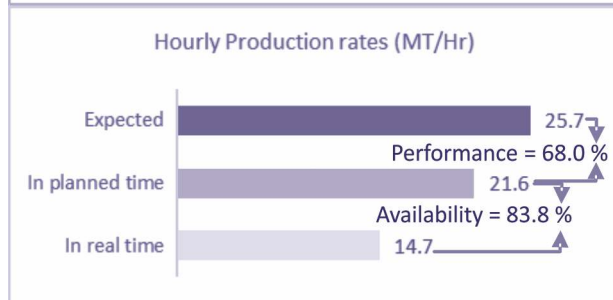
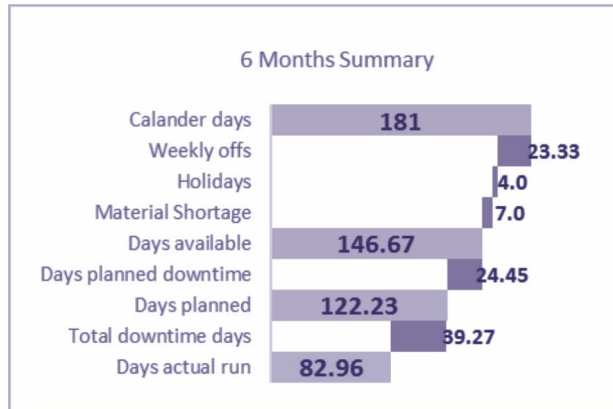
$$Total\ Rejection = Quality\ Rejections + Cobbles$$

[\*Where Cobble is a defect in a rolled piece resulting from loss of control over its movement. It is totally a waste in any hot rolling industry]

**Efficiency (η)**

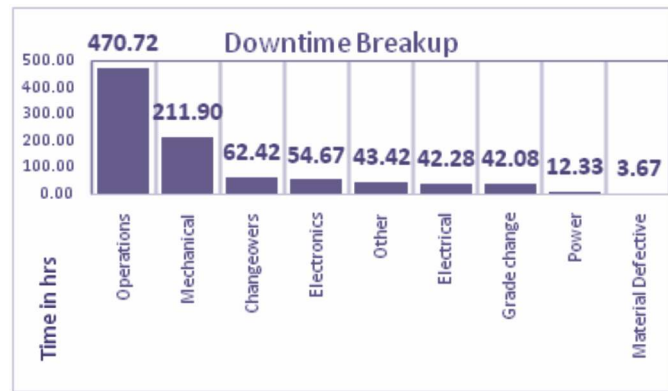
$$Efficiency = \frac{Expected\ hourly\ production\ rate}{Hourly\ production\ rate\ in\ real\ time}$$

Data Analysis



The OEE calculated above using the formulas given is found to be 56.3% which is very low. In the previous work by the authors many problems were identified for this low OEE but only issues related to cobble and misrolls were taken ahead. Now in this study we will be further analysing the problem of improper maintenance practices and frequent changeovers which were the next major elements leading to low OEE.

The company under analysis has a planned shutdown of plant daily for 4 hours from 6:00 PM to 10:00 PM intended for maintenance and changeovers purpose. But apart from that the company is having a lot of breakdown and downtime because of maintenance and changeovers. The following data gives the breakup of 6 months downtime data.



breakup of 6 months downtime data.

As it can be seen from the above data, the major downtime elements are Operational downtime, Maintenance (including mechanical, electrical and electronics) and Changeovers. The operational issue is due to the cobbles and misrolls whose frequent occurrence causes the repeated stoppages and breakdowns and restoring then takes time and adds to the operational downtime. The root causes and issues causing cobble and misrolls have been identified and solutions were given in the previous works done by the authors. The next major issue includes maintenance and changeovers which have to be resolved by implementing TPM and proper production planning which basically includes the utilization of 4 hours daily planned shutdown i.e. about 720 hours or 30 days in a time frame of only six months. Apart from having a month of planned downtime in six month the plant has 943.48 hr i.e. nearly 40 days of additional downtime. On this basis, in 180 days the plant is actually functioning only about 110 days which makes the availability very low also making the OEE and Efficiency loss.

Proper implementation of TPM and having a well defined and implemented preventive maintenance schedule will help reducing the maintenance downtime to a great extent. The reduction of cobble and misroll has already reduced the damage to machines which ultimately reduced the maintenance. Along with this, as the second phase the implementation of TPM and Proper production planning the problem of maintenance and changeovers can be further reduced increasing the net production of the plant and also improving the OEE.

ROOT CAUSES AND ISSUES

Using a group approach to solve the problems, various brainstorming sessions were conducted in the plant, which includes interdepartmental groups, Departmental groups, maintenance department groups and lots more. This groups also includes all levels of managers along with the workers and helpers. So that thoughts and experiences of all the experienced persons and experts can be captured. The Fishbone diagram below describes the major issues and their root causes. And summarising the data from all the brainstorming sessions, the following major problems and their solutions were identified: -

- ➔ Corrective Maintenance Over Preventive Maintenance (Equipment reliability)
- ➔ Quick fix solutions Over permanent solutions
- ➔ Unplanned maintenance Over planned maintenance

- ➔ Cost cutting measures Over high level maintenance effectiveness
- ➔ Ad-hoc Spares Policy Over Planned spares inventory
- ➔ Symptoms cure Over root cause analysis
- ➔ Improper production planning Over Proper production scheduling
- ➔ Using random working practices Over Standard Operating Procedure (SOP).

**SOLUTIONS AND SUGGESTIONS**

In the brainstorming sessions, it has been concluded that the implementation of the following suggestions and solutions will help to reduce the downtime by a great extent.

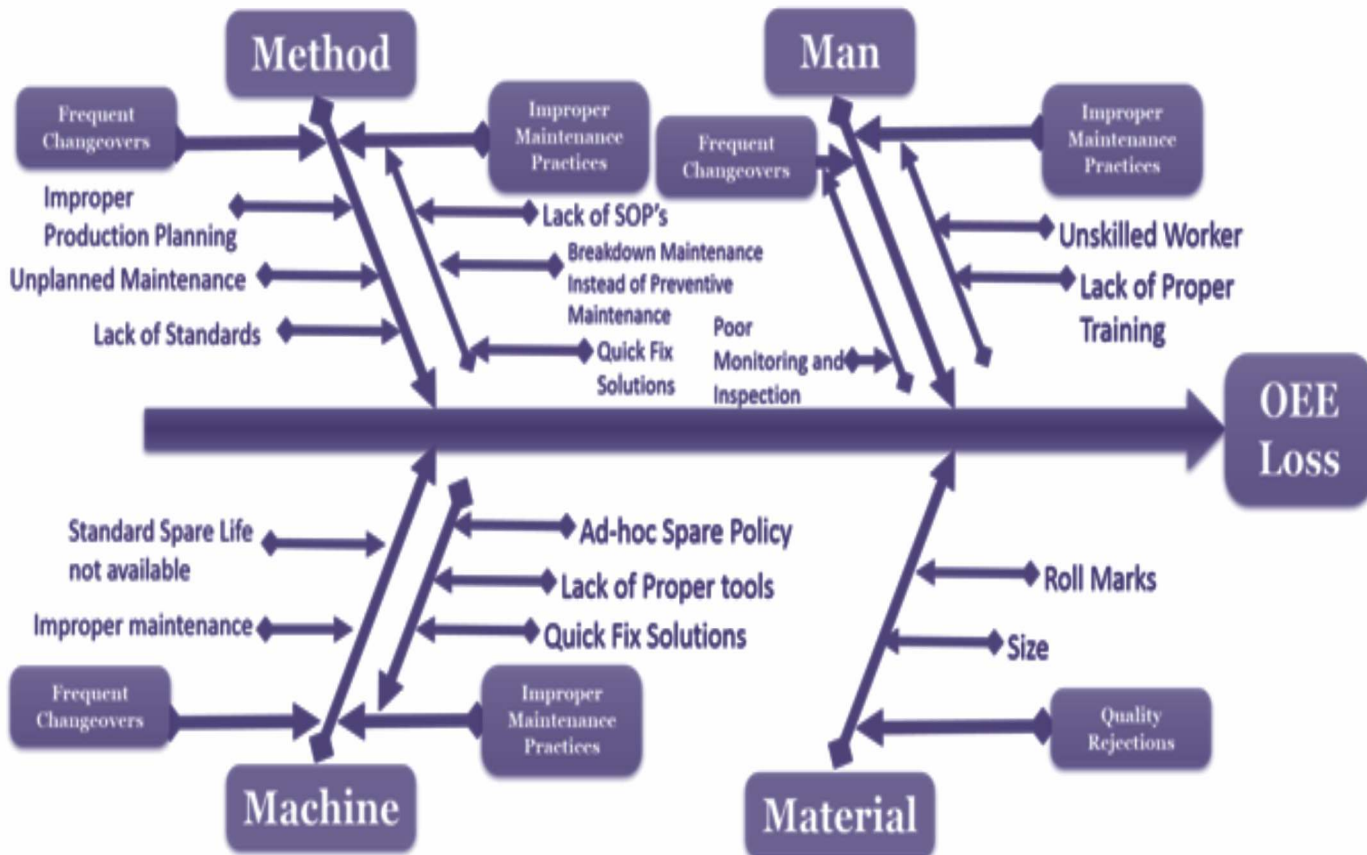
- ✓ Implementation of TPM

**RESULT AND DISCUSSION**

The initial calculations of OEE (56.3%) clearly suggests that there exists a vast possibility of improvement. World class OEE data suggests that if the OEE is less than 85% then there always exist chances of improvement.

The root causes and issues that were causing the loss in OEE has been identified and also the solutions of each root cause and issue has been discussed in the brainstorming sessions. The issues due to cobbles and misrolls has been already resolved in the previous works done by the authors and the remaining issue that are mainly changeovers and maintenance activities has been resolved by the suggestions and solutions arrived in the brainstorming sessions.

After the implementation of the solutions and suggestions above



- ✓ Proper Preventive Maintenance Schedule
- ✓ Elimination of Quick fix solutions and cost cutting maintenance practices
- ✓ Better spaces management
- ✓ Frequent Brainstorming sessions for root cause analysis of problems
- ✓ Proper production planning and scheduling the different sizes accordingly to reduce the changeover timing
- ✓ Use of Standard Operating Procedures
- ✓ And all this solutions and suggestions backed by thorough monitoring.

improvement in various sections of downtimes were observed. When we take the improvements by reduction of cobbles along with better maintenance practices and proper production planning following observations in the major five sections of the downtimes has been observed.

- Operational Downtime accounts for the maximum downtime which is nearly 50% of the total downtime. When the cobbles are reduced and proper maintenance and care of the machines and equipments is done, the no. of breakdowns due to cobbles and misroll gets reduced and well-maintained machines took lesser time to restart reducing the operational downtime to about 60%.

• Mechanical downtime is the second most frequent downtime which was our major concern in this study and has been taken care by implementation of TPM and a properly planned and implemented preventive maintenance schedule. Even after the 4 hour daily planned downtime for these activities it accounts for the second major element of the downtime. Proper maintenance practices made the machine conditions better and time in mechanical maintenance, apart from 4 hours daily maintenance reduced by about 75%.

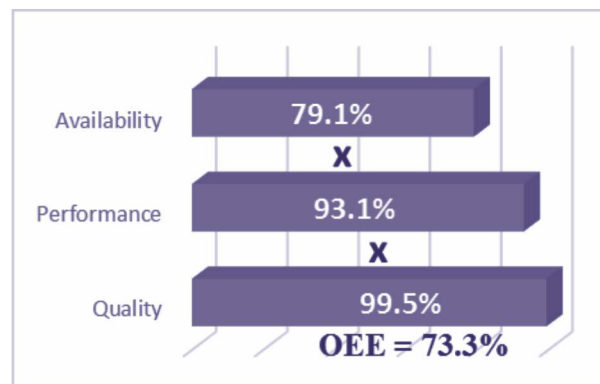
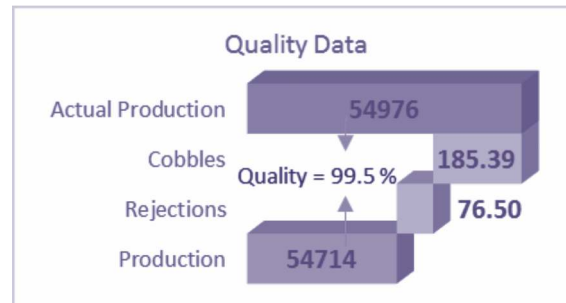
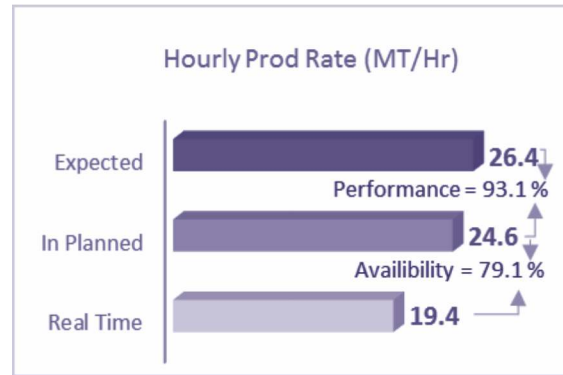
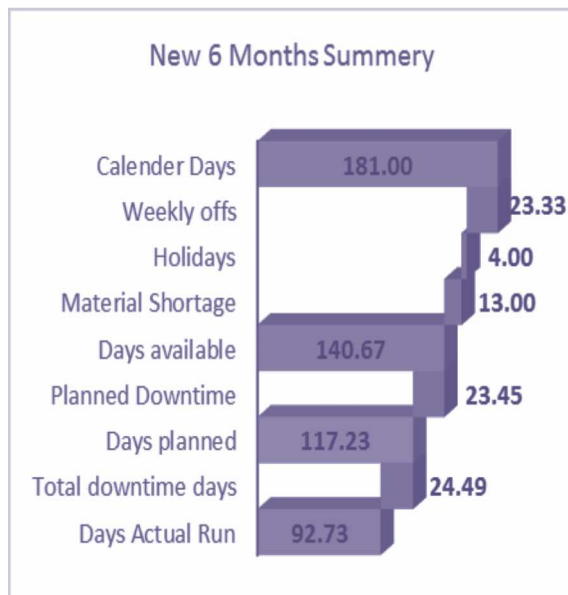
• Changeover ideally should take place in the 4 hour daily planned downtime. But due to improper production planning it accounts for the third highest downtime. Also, Changeover is not carried out as per SOP and done randomly which consumes more time than it should ideally take. So, by improving the production planning and using SOP's to make any changeover this downtime is reduced by 75%.

• Electrical and electronics downtime also accounts for a considerable downtime when taken individually. Electronic downtime can be reduced to a great extent only by implementing 5S practices because many of the electronic failures occurs only due to sensor faults. Same applies to an extent with the electrical downtime also. Therefore, by implementing the TPM and preventive maintenance practices and applying 5S this downtime is reduced by 60%.

Applying these reductions, the new productions has been calculated and on the basis of the new downtimes and new productions, New OEE has been calculated and compared with the old OEE.

Category	Value
Previous Delay (in Mins)	56544.00
Reduced Delay (in Mins)	32780.25
hourly production (in MT/Hr)	21.6
Increase in production (in MT)	11800.89
Previous production (in MT)	42912.81
New monthly production (in MT)	54713.7

After the implementation of the solutions and



suggestions the overall equipment effectiveness has increased from 56.3 % to 73.3% and seems to be a substantial improvement in the performance and availability. The above graphs summarise the results.

**CONCLUSION**

In the present context, India overtook USA to be the third largest producer of crude steel in the world for year 2015. Also, India contributes to be the largest producer of the sponge iron in the world. The effective implementation of TPM, use of effective preventive maintenance schedule, proper production planning and scheduling, efficient utilization of 4 hours daily planned downtime the following improvements were observed:

- ✓ Production: Greater than 11000 MT
- ✓ OEE: approx. 17%.

As the study has been done on a continues running mill, the analysis has been done on the whole line and not on individual equipments, which can be carried out in future studies. Also till now the major issues of cobble and misroll, improper maintenance practices, and irregular production planning has been resolved but still the company has some minor issues which can be taken care to improve the OEE further

## REFERENCES

1. Sharma k, Thakar GD, (2017), *Productivity enhancement at an Indian Iron and steel re-rolling mill, Performance Improvement, Vol-56, Issue 7.*
2. Zandieh, S., Tabatabaei, S., & Ghandehary, M. (2012). *Evaluation of overall equipment effectiveness in a continuous process production system of condensate stabilization plant in Assalooeyeh. Interdisciplinary Journal of Contemporary Research in Business, 3(10), 590-598.*
3. Nakajima, S. (1988) *Introduction to TPM: Total Productive Maintenance, Cambridge, MA, Productivity Press.*
4. Nakajima, S. (1989), *TPM Development Program: Implementing Total Productive Maintenance, Productivity Press, Portland, OR.*
5. Ministry of Steel, Government of India. (2015). *An overview of the steel sector. Retrieved from www.steel.gov.in/overview.htm.*
6. Raghuram, R. (2014). *Implementation of overall equipment effectiveness (OEE). Middle-East Journal of Scientific Research, 20(5), 567-576.*
7. Steel Re-Rolling Mills Association of India. (SRMA). (2017, January). *SRMA Steel Newsletter.*
8. F. Chan, (2005) *Implementation of total productive maintenance: a case study, International Journal of Production Economics, vol. 95, pp. 71-94. s*
9. Vorne Inc. (2015). *World-class OEE. Retrieved from www.oee.com/world-class-oee.html*
10. Ministry of Steel, Government of India. (2011). *Annual Report-2010-11. Retrieved from http://steel.gov.in/Annual%20Report%20(2010-11)/English/Annual%20Report%20(2010-11).pdf*
11. World Steel Association, *World Steel in Figures (2017), Retrieved from worldsteel.org*

## AUTHORS

**Kushal Sharma**, Asst. Professor, Dr. APJ Abdul Kalam UIT, Jhabua 457661 MP.  
E mail: kushal.sharma005@gmail.com.

**Dr. Girish D Thakar**, Professor and Head, Department of Ind. and Prod. Engg., SGSITS, Indore 452003 MP.  
E mail: thakargirish@yahoo.com

**Dr. B E Narkhede**, Associate Professor, Ind. Engg. and Mfg. Systems, NITIE, Mumbai 400087.  
E mail: benarkhede1@gmail.com.