Improvement of Overall Equipment Effectiveness for Manufacturing of Ductile Iron Casting

R. V. Tambad[1], Dr. Vishal R. Balwan[2], Dr. Bahubali B. Kabnure[3]

[1,2]Senior Scientist, FIE Research Institute, Ichalkaranji
[3]Assistant Professor, DKTE's TEI, Ichalkaranji

Abstract— The purpose of this work is to implement the various methods towards improving manufacturing performance and calculation of overall equipment efficiency in a Ductile Iron foundry. High equipment availability, which is impacted by equipment dependability and maintainability, is necessary to increase the intended production output. Data for a model machine over the previous six months is documented in a case study from a ductile iron sand casting foundry. An autonomous maintenance crew has been established for the next four months in order to raise the total equipment efficiency by a certain percentage, based on the observed data that revealed the losses. Based on the results, it was suggested that a pilot project be carried out in order to use techniques such as the TPM program for the ductile iron foundry and extend it to the other divisions of the business. The main advantages are decreased losses, teamwork, and operator knowledge of the equipment. Also, the rejection of the components studied was controlled by implementing casting simulation technique. This technique helps to identify and eliminate the defects occurred due to faulty process parameters. The outcome from all the work is improvement in overall equipment efficiency which in turn improves the production and productivity of the part analyzed.

Keywords— OEE; Availability; Performance; Quality; Ductile Iron Casting.

I. INTRODUCTION

One technique to track and enhance manufacturing process efficiency is through Overall Equipment Effectiveness (OEE). OEE is now a widely used management technique for assessing and measuring plant floor productivity [1]. Availability, performance, and quality are the three measuring criteria that make up OEE. The true "Hidden capacity" of an organization is highlighted by OEE. OEE is not the only metric used to assess the performance of the maintenance department. The OEE is impacted by the equipment's installation, design, operation, and maintenance. It evaluates the equipment's efficacy (performing the appropriate things) as well as efficiency (doing things correctly) [2]. OEE is computed by calculating the equipment availability, process performance efficiency, and rate of high-quality goods. [3].

Availability, Performance Rate, and Quality Rate are all components of Overall Equipment Effectiveness (OEE). To put it another way, OEE covers all losses resulting from equipment failures, set-up and adjustment losses, and reduced speed, idle, and minor stoppage losses that prevent the equipment from operating at its best, as well as defects, rework, and start-up losses that prevent the equipment from producing first-pass quality output [4]. Starting with Planned Production Time, OEE examines productivity and efficiency losses in order to minimize or eliminate them [5]. Less operator understanding of the machine (human), inconsistent glue temperature (machine), delayed vendor supply (material), and ineffective knife change time (method) are the four key reasons that might reduce the machine's productivity [6].

II. OVERALL EQUIPMENT EFFICIENCY

The primary indicator used to assess the effectiveness of the TPM implementation program is OEE. Increasing total equipment effectiveness is TPM's main objective. OEE is computed by calculating the product of equipment availability, process performance efficiency, and rate of high-quality goods.

The different losses in any organization are listed below. [7]-

a) Losses from downtime:
- Losses from equipment failure
- Losses from setup and adjustment

b) Decreases in speed:
- Minor stoppage losses and idle
- A decrease in speed losses

c) Damages brought on by subpar production:
- Process flaws
- Product flaws or losses from rework

When originally assessed, the OEE of most equipment is between 40% and 60%, whereas the benchmark is 85%. OEE has therefore emerged as the recognized metric for evaluating how businesses truly handle their most costly asset, the machinery, to generate marketable items with the fewest possible losses and wastes [8].

III. OEE CALCULATION

OEE is calculated by multiplying the three primary bases for losses:

1. Availability shows issues brought on by downtime losses.
2. Performance shows the losses brought on by speed reductions and
3. Quality shows the losses from scrap and rework.

Overall Equipment Effectiveness (OEE) = A x PR x Q

Where, A= Availability of the machine

= (Planned production time – unscheduled downtime)

Planned production time

PR- Performance Rate

Performance (Speed) = (Cycle time x Number of products processed)

Production time

Q=quality rate.

Quality (Yield) = (Number of products processed – Number of products rejected)

Number of products processed

The availability is calculated as the loading time (Planned production time) minus the unscheduled down time and then divided by the loading time [9]. Loading time is the total available time minus planned down time, where planned down time is total loss time i.e., machine breakdown time, set up and adjustment time etc. as shown in Figure 1. The performance rate/ efficiency can be defined as the theoretical cycle time to produce the item multiplied by the total production numbers or output of equipment and then divided by the net operating time. The quality rate can be expressed as the accepted parts divided by the total produced parts [10].
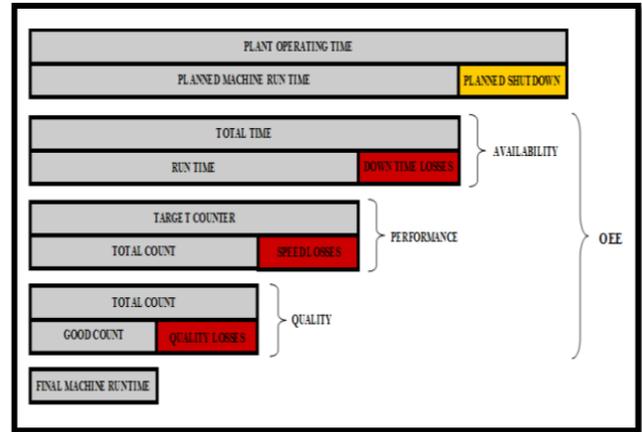

Figure 1: Overall Equipment Efficiency

IV. CASE STUDY

A ductile iron flange casting is taken for the study of OEE. The flange is manufacturing by sand casting process with required material properties. The flange is shown by Figure 2. It is used in pipe fittings for joining the ductile iron pipes.

Figure 2: Photo of Flange

Table 1 shows the data of model product foundry for October 2019. One-month data of foundry has been represented for example. The present OEE is calculated from the month September 2019 to February 2020.

Table 1:
Present OEE of Foundry Month: October

Dates	Target capacity	Melting in ton	Melting OEE 1	Target (Capacity) Box	Moulding Boxes	Poured Boxes	Production OEE 2	Casting OEE
1	15	9.45	63	1200	1134	1066	88.83333	75.916
2	15	9.87	65.8	1186	956	844	71.16358	68.48
3	15	10.1	67.33333	1186	993	942	79.42664	73.37
4	15	7.53	50.2	1087	903	808	74.33303	62.26
5	15	10.41	69.4	1074	995	923	85.94041	77.67
6	15	10.09	67.26667	1087	873	860	79.11684	73.19
9	15	7.95	53	1125	897	740	65.77778	59.38
10	15	9.59	63.93333	1049	911	755	71.97331	67.95
11	15	10.18	67.86667	1050	807	800	76.19048	72.02
12	15	8.82	58.8	1062	997	858	80.79096	69.79
13	15	10.9	72.66667	1168	1065	924	79.10959	75.88
14	15	9.22	61.46667	1200	1009	915	76.25	68.85
15	15	8.06	53.73333	1049	911	707	67.39752	60.56
16	15	9.85	65.66667	1050	807	745	70.95238	68.30
17	15	10.91	72.73333	1168	1065	889	76.11301	74.42
18	15	10.3	68.66667	1200	926	879	73.25	70.95
19	15	8.01	53.4	1200	1013	819	68.25	60.82
20	15	7.52	50.13333	1200	1062	1000	83.33333	66.73
22	15	10.49	69.93333	1050	807	777	74	71.96
23	15	7.38	49.2	1200	1062	1000	83.33333	66.26
24	15	10.47	69.8	1049	911	794	75.69113	72.74
25	15	10.63	70.86667	1200	1062	1000	83.33333	77.1
30	15	9.48	63.2	1200	956	931	77.58333	70.39
31	15	9.22	61.46667	1087	923	758	69.73321	65.59
Average OEE of the month October								69.61

The Table 2 shows the six months Casting OEE. The last six months average OEE of the casting department is 72.01%.

Table 2:
Six-month Foundry OEE (Sept-Feb)

Sr. No.	Month	Casting OEE (%)
1	19-Sep	72.35
2	19-Oct	69.61
3	19-Nov	73.09
4	19-Dec	73.59
5	20-Jan	72.63
6	20-Feb	70.81
Average value		72.01

The rejection analysis is done to identify the major defects in the casting. It was found that the rejection in the casting is major due to shrinkage defect. The main cause for shrinkage is faulty methoding. The Figure 3 shows the layout of present and modified casting method.

For present method the rejection is about 46 %. The modified method layout eliminated the rejection due to shrinkage.
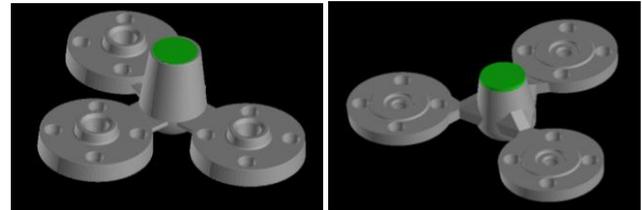

Figure 3: Present and modified casting layout

The suggestion for modification in layout is taken with the help of casting simulation tool. This was reduced the shop floor trial of actual pouring and reduced the cost of production.

To improve the OEE and reduce the rejection several methods like 5S, TPM, Autonomous maintenance and standardization were implemented in the Foundry. The OEE is calculated after implementing above methods. The implementation took around 5 months from March 2020 to July 2020. The OEE then obtained from August 2020 to November 2020 for four months. The OEE for month of August is mentioned in Table 3.

Table 3
Foundry OEE Month: August

DATES	1	2	4	5	6	7	8	9	11	12	13	14	16	18	19	20	21	22	23	25	26	27	28	29	30
TARGET CAPACITY	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
MELTING IN TONN	11.15	11.03	11.54	11.18	11.31	11.62	9.19	11.15	9.42	12.24	12.19	9.76	11.41	11.28	10.91	10.78	9.31	9.62	10.31	11.69	10.45	11.56	10.93	10.21	10.2
MELTING OEE 1	74.333	73.533	76.933	74.533	75.4	77.467	61.27	74.333	62.8	81.6	81.27	65.07	76.07	75.2	72.733	71.87	62.07	64.13	68.73	77.93	69.67	77.07	72.86667	68.06667	68
Target (Capacity) BOX	1200	1200	1186	1087	1062	1087	1137	1049	1050	1062	1168	1200	1049	1050	1168	1200	1200	1200	1200	1050	1200	1049	1200	1200	1087
Moulding Boxes	1145	957	1087	1026	989	943	992	1011	1000	1030	1112	1089	1033	907	1087	1151	1067	1108	1103	953	1123	998	1110	1105	955
Poured Boxes	1053	931	1017	943	926	897	799	981	828	960	1018	821	927	839	879	1043	995	990	1006	874	963	926	946	1009	868
PRODUCTION OEE 2	87.75	77.583	85.75	86.753	87.194	82.521	70.27	93.518	78.857	90.395	87.16	68.42	88.37	79.9	75.257	86.92	82.92	82.5	83.83	83.24	80.25	88.27	78.83333	84.08333	79.85281
CASTING OEE	81.042	75.558	81.342	80.643	81.297	79.994	65.77	83.925	70.829	85.998	84.21	66.74	82.22	77.55	73.995	79.39	72.49	73.32	76.28	80.59	74.96	82.67	75.85	76.075	73.9264
AVERAGE CASTING OEE -77.46%																									

In foundry areas it was found some improvement in availability and performance due to effective utilization of 5S mechanism. And casting quality also improved through modification of design of component and it is proved by its simulations. The Table 4 shows improved OEE of the foundry.

Table 4:
Month wise Foundry OEE (Aug-20 - Nov-20)

Sr. No	Month	Improved OEE
1	Aug-20	77.46
2	Sep-20	77.67
3	Oct-20	77.97
4	Nov-20	77.2
	Average Value	77.57

V. CONCLUSIONS

The OEE of Ductile Iron sand casting was obtained initially for six months. The product selected is critical as it has major rejection. The rejection was major due to shrinkage defect and improper process parameters. The rejection was minimized by using casting simulation method. The 5S and TPM are major contributors for improving the OEE of the product. This was led to standardization of the process for continuous improvement. The initial average OEE for six months was 72.01 %. The various techniques were implemented and the observation was done for 5 months. The OEE after implementing simulation, 5S and TPM was taken for next four months. The improved OEE was 77.57 %. The OEE for the process is improved by 5.56 %.

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