

**Production improvement by reducing Cycle-time for Electric Arc Furnace in
a Steel Melting Shop – a Case Study**

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Abstract

Cycle time is the total time from the beginning to the end of any process. Cycle time includes process time, during which a unit is acted upon to bring it closer to an output, and delay time, during which a unit of work is spent waiting to take the next action. In other words, Cycle Time is total elapsed time to move a unit of work from the beginning to the end of a physical process. Thus, cycle time of Electric arc furnace in steel melting is a very critical parameter and plays a significant role in improvement of productivity of the process. This paper basically involves critical path analysis of various activities of electric arc furnace in steel melting process in typical steel melting shop in India and subsequent identification of various parallel activities during a Tap to tap cycle and rearranging the activities that will reduce the cycle time of furnace. The study was carried out in three steps, in first out we made a simulation model for identifying bottleneck in production. In second step, after identifying that bottleneck is due to electric arc furnace, we identified various activities of electric arc furnace in between tap to tap cycle time and find out the critical activities that can lead to delay in the production process. Further in third step we rearranged the Critical activities with the help of Gantt chart and proposed list and sequence of activities in form of Gantt chart such that the cycle time for Electric arc furnace can be reduced. Data were collected on various parameters like, the produced heats and field observation with the help of Time study for different activities in tap to tap cycle. The outcome of this research will help the management of the company for initiating necessary planning and corrective actions to increase the production without any capital investment.

Keywords: Simulation, Cycle time, Critical Path, Gantt chart, Steel melting shop, case study.

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1. Introduction

Cycle time is the total time from the beginning to the end of your process. Cycle time includes process time, during which a unit is acted upon to bring it closer to an output, and delay time, during which a unit of work is spent waiting to take the next action. In other words, Cycle Time is the total elapsed time to move a unit of work from the beginning to the end of a physical process. Calculation of Cycle time helps in calculation of output in physical scenario and it can be taken as a small unit of output which is directly proportional to total production. The steps in calculation of cycle time primarily include analyzing and recording occurrence time of elemental activities whose combination makes a full cycle time. This paper basically involves finding bottlenecks in steel melting shop production with the help of ARENA software, then we have found that bottleneck exist in Electric Arc Furnace (EAF), so for improving service time of EAF, we have done critical path analysis of various activities of electric arc furnace in steel melting process in a typical steel melting shop in India and subsequent identification of various parallel activities during a Tap to tap cycle. Finally we have analyzed those critical activities and reduce the tap to tap cycle time and by this final production have increased.

Defined capacity of the Steel Melting Shop is 30 Heats per day whereas the average production was 14.1 Heats per day for the FY'10-11. However, the average production during April'11, May'11 & June'11 was 20.2 Heats per day, 21.1 Heats per day & 16.7 Heats per day respectively, which is far behind the defined capacity. Hence, the study was carried out in order to define cycle time of Tap end to another tap end to identify the critical path so that proper corrective actions can be taken to reduce the cycle time by proper handling of critical activities. Therefore, management was concern to calculate tap to tap cycle time and identify the existing critical activities so that delays can be avoided and production can be improved. Critical path and tap to tap cycle time calculated with the help of critical path method (CPM) and represented by Gantt chart.

2. About the Department

ABC Ltd., where the study was carried out, is one of the leading steel producers in India. The company produces economical and efficient steel and power through backward integration from its captive coal and iron-ore mines. In steel melting shop, hot Metal from the Blast Furnace is converted into steel by blowing 99.5% pure Oxygen through it. Suitable alloying elements are added to produce different grades of steel. At Steel Melting Shop of the concerned ABC Ltd., there is 1 Electric Arc Furnace (EAF), of 100T capacity. Transformer rating of that EAF is 100MVA. The EAF is equipped with 4 VLBs (Virtual Lance Burners) of 3.5MW capacity. These VLBs are used for oxygen lancing during melting process of DRI in EAF.

To produce 100T Steel, 102T liquid hot metal (from Blast Furnace) is required along with Alloys, Scrap Steel & Oxygen. The output of SMS (Steel) is represented in terms of Heat. (1 Heat \equiv 100T of Steel)

The block diagram representation of steel making process at steel melting shop is shown in Figure-1.

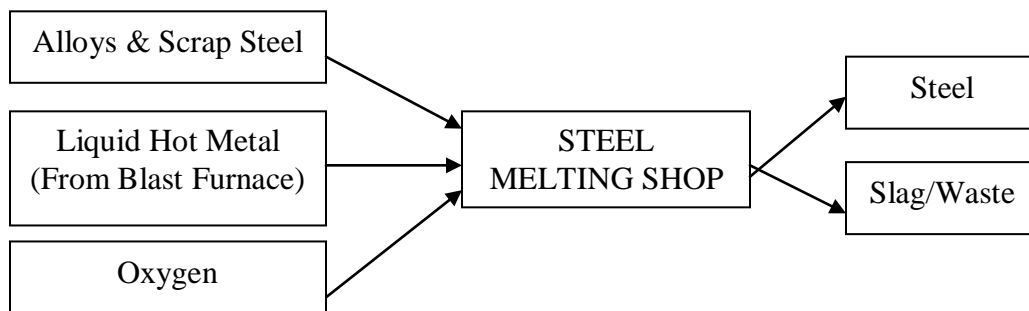


Figure – 1: Block Diagram Representation of Steel Making Process at Steel Melting Shop

3. Methodology

After obtaining approval of the head of the Steel Melting Shop and the HR-Manager of the steel manufacturing company, collection of the relevant information regarding the functioning and process detail of electric arc furnace at the steel melting shop was carried out. Study of existing practices in each section was carried out with the help of the head and the HR-Manager.

The study was carried out in few steps. Firstly, We have noted down the processing time of each process unit and made a simulation model in ARENA 12, then we have seen that a queue has been occurred at EAF, this signifies that bottleneck exist in EAF service time. In second step, we have understood all activities between tap ends to another tap end cycle at EAF and defining them for calculation of cycle time. Random cycle time data were collected from the shop floor for a period of about 10 days. Next, the Critical path for tap to tap cycle time were identified and categorized. Finally tap to tap cycle time has been calculated with help of critical path method and Gantt chart. In third and final step, we have analyzed all critical activities and proposed activities chart represented in Gantt chart by focusing some particular activities which can be reduce and causing delay in tap to tap cycle time.

4. Data Collection & Analysis

Our objective behind this study was to improve the production of Steel melting shop. For accomplish our objective, we have made a model of steel melting shop and taken the process and service time of each intermediate process which is shown in Figure. 2.

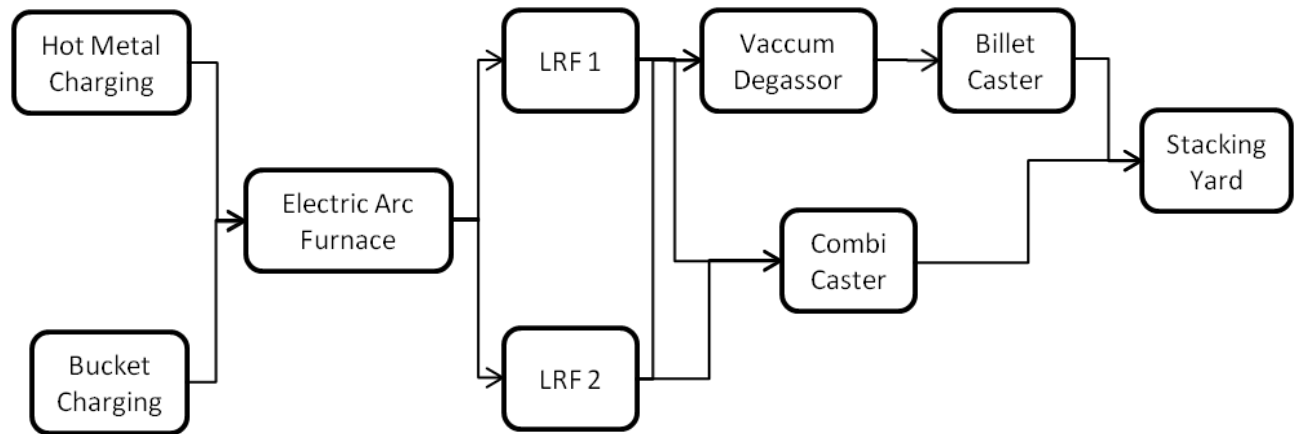


Figure. 2- Model for Steel Melting shop

4.1 Simulation Model

For analyzing the all process, we have made a simulation model with the help of ARENA 12. Process timing and service time of intermediate process were Inputs for simulation model. Result of simulation model has been shown below:

Time per Entity

VA Time Per Entity	Average	Half Width	Minimum	Maximum
Billet Caster	0.3972	(Insufficient)	0.3081	0.4799
Combi Caster	0.3796	(Insufficient)	0.3129	0.4468
EAF	0.6496	(Insufficient)	0.5162	0.7783
LRF 1	0.4961	(Insufficient)	0.3522	0.6379
LRF 2	0.2736	(Insufficient)	0.2063	0.3268
Vaccum Degassifier	0.4994	(Insufficient)	0.4622	0.5395
Wait Time Per Entity	Average	Half Width	Minimum	Maximum
Billet Caster	0.3262	(Insufficient)	0	1.5980
Combi Caster	1.0046	(Insufficient)	0	2.2115
EAF	11.4002	(Insufficient)	0	21.2218
LRF 1	0.00224713	(Insufficient)	0	0.05138951
LRF 2	0.1410	(Insufficient)	0	0.3354

Table 1- Simulation Model Result for Time per Entity

From simulation result, the Wait time per entity is highest for EAF (Electric Arc Furnace), therefore we can conclude that bottleneck exists in EAF service time and for improve the production we have to reduce the cycle time or service time of EAF.

4.2 Calculation of Cycle time for EAF

In first step we have defined the elemental activities between tap to tap cycles. These are following:

- EBT filling
- Scrap and DRI charging from bucket
- Roof opening and Closing
- Launder Placement
- Power On (Arcing and Oxygen blowing)
- Hot metal charging
- Launder Removal

- Sample Report
- Tapping
- Slag pot changing

There are some activities; those are not regular in every cycle. These activities occurred as per need listed as follows:

- Terminator Gunning (After 6 to 8 heats)
- Electrode Changing (3 electrode per 26 heats)
- Slinging (After 6 to 8 heats)

According to critical path method total span of any project or activity is equal to summation of time duration of critical activities. In our study, we have excluded the extreme case for elemental activities so as cycle time should not be affected by that extreme value or abnormality of data. After that we have taken average value of different elemental activities and drawn the Gantt chart. With the help of Gantt chart, we have defined the critical activities. Those are:

- EBT filling
- Roof opening and Closing
- Power On (Arcing and Oxygen blowing)
- Tapping

Cycle time was calculated by summing up the above activities duration that was 56 min. 28 sec. If we consider extra activities which were not regular then cycle time will be increased to 59 min. 28 sec.

The calculation table has been shown below in Table 2 and Gantt chart has been shown in Figure. 3

Activity	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6	Cycle 7	Cycle 8	Cycle 9	Cycle 10	AVG. TIME
Observation Date	26.05.11	26.05.11	27.05.11	27.05.11	27.05.11	27.05.11	27.05.11	30.05.11	31.05.11	31.05.11	[Excl. Extreme values (shaded)]
Observation Shift	B	B	A	A	B	B	B	A	B	B	
EBT filling	1:40	1:32	1:25	1:25	1:25	1:15	1:20		1:40	1:35	1:28
Scrap & DRI Charging from bucket	2:15	3:15	2:05	2:40	2:00	6:00	2:00		2:35	3:42	2:53
ROOF Opening to Closing	7:52	11:58	4:47	4:40	4:46	16:00			19:40	4:25	4:39
Launder Placement	1:52	4:32	2:25	0:00	2:00	2:00			2:20	2:05	2:27
Power On (Arching/ Oxygen Blowing)	49:17	49:00	49:00	55:00	43:00	40:00			52:00	49:00	46:32
Hot metal charging	10:36	6:59	7:00	10:00	7:00	6:00			7:00	6:00	7:34
Launder Removal	1:49	1:56	NA	NA	2:00	2:00			2:00	2:00	1:57
Sample Report	6:00	5:00	4:00	NA	4:00	3:00			4:12	4:34	4:23
Tapping	2:06	1:59	5:00	5:00	4:00	4:00			4:31	3:46	3:47
Slag Pot Changing	8:01	7:38	11:00	32:00	24:00	8:21			12:00	8:07	9:21
A) Tap End To Tap End Cycle Time (in Min:Sec)											56:28

Additional Activities performed as per need

											Avg. Time	Avg. time consider per Heat
B) Terminator Gunning (after 6-8 Heats)	5:05						9:00		7:08		7:04	1:00
C) Electrode Change (3 electrode per 26 Heats)		8:30				9:00					8:45	1:00
D) Slinging (after 6-8 Heats)								5:22	8:21		6:51	0:58
Overall time per heat (A+B+C+D) (in Min:Sec)											59:28	
Based on Above Cycle Time, Potential number of heats per day (considering 24 hours working time) (=24*60/59:28)											24	

Table 2 - Calculation sheet of Tap to Tap cycle time

TAP TO TAP CYCLE TIME OF EAF AT SMS

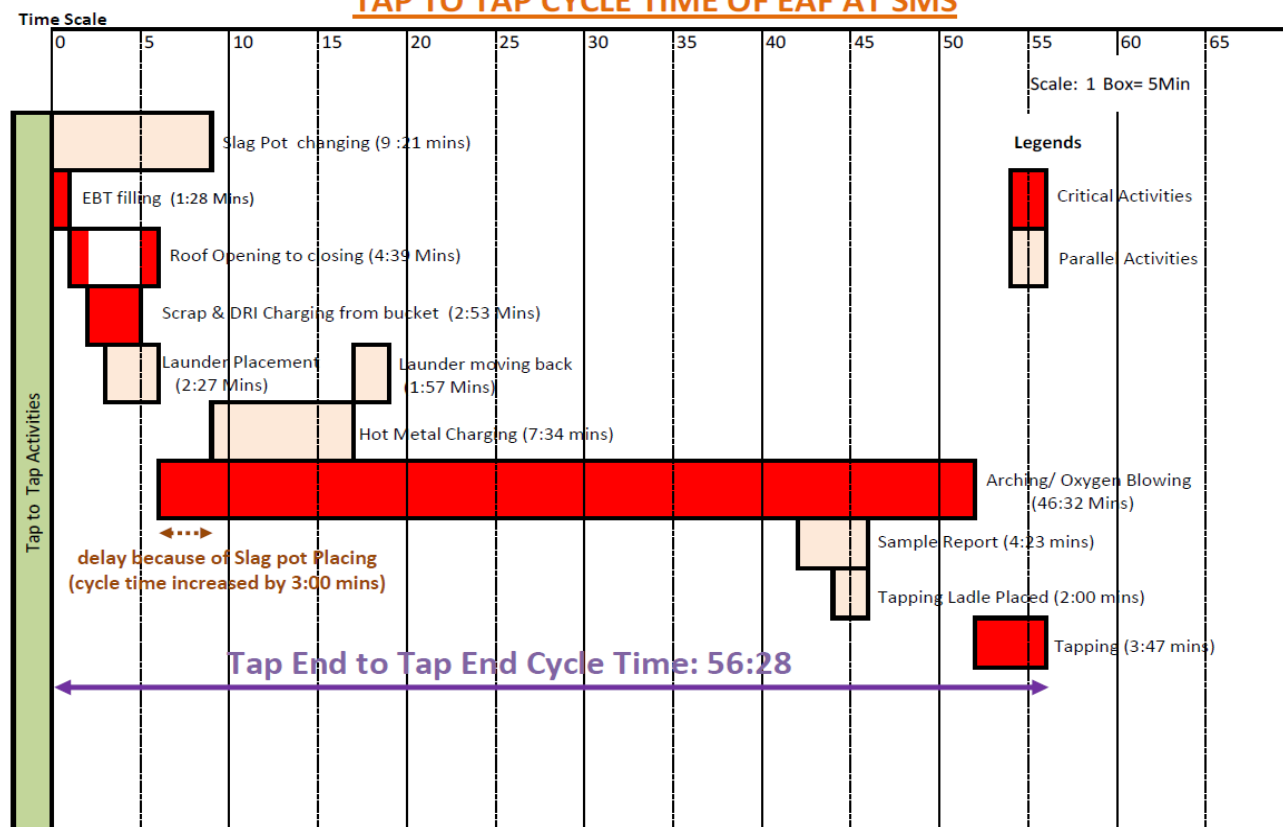


Figure. 3. Gantt Chart for existing regular activities in Tap to Tap Cycle

4.3 Reduction in Cycle Time of EAF

For reduction in cycle time of EAF, we have to reduce the time of critical activities and try to find out the possibilities of convert critical activities to parallel activities. Critical activities are EBT filling, Roof opening and closing for scrap & DRI charging from bucket, Arching/ Oxygen Blowing and Tapping.

4.3.1 EBT filling

For EBT filling, we can make this activity parallel to Roof opening for Scrap & DRI charging from bucket. Because EBT filling and roof opening both take approx 90 sec, when the roof of EAF will start to open by control room operator, the parallel gang will do the EBT filling.

4.3.2 Arching/ Oxygen Blowing

We can reduce this critical activity time by reducing delay happening in this activity due to delay in slag pot changing and fluctuation in power supply. For eliminating delay for this activity we have following suggestion:

For delay in Slag pot changing – we can eliminate delay in slag pot changing by providing one extra slag pot carrier which is in present only one. We have done detailed study for slag pot changing.

Existing activities in slag pot changing (One Slag pot Carrier):

- Travel without load for bringing full Slag pot (30 Sec)
- Pick up full slag pot (60 Sec)
- Travel with load to slag dumping Area (181 Sec)
- Travel without load for bringing empty slag pot (60 Sec)
- Pickup empty Slag pot (60 Sec)
- Travel with empty slag pot to slag pit below EAF (120 Sec)
- Place slag pot to slag pit (60 Sec)

Total Time taken: 571 Sec or **9 min. 31 Sec**

When we provide one extra slag pot carrier then during slag pot changing one extra slag pot carrier will be already with empty slag pot, when existing slag pot carrier will remove full slag

pot then immediately extra slag pot carrier will place the empty slag pot to slag pit below EAF. Other activities can be done during arching/ oxygen blowing period.

Proposed activities in slag pot changing (Two Slag pot Carrier)

- Existing Slag pot Carrier - Travel without load for bringing full Slag pot (30 Sec)
- Existing Slag pot Carrier -Pick up full slag pot (60 Sec)
- Extra Slag pot Carrier - Travel with empty slag pot to slag pit below EAF (45 Sec)
- Extra Slag pot Carrier - Place slag pot to slag pit (60 Sec)

Total Time taken: 180 Sec or **3 min. 15 Sec – Approx 4 min.**

Delay due to fluctuation in Power supply – In Table 2, minimum time for Arching/ Oxygen blowing was 40 min. During this heat, we have observed that fluctuation in power supply was negligible, so we can conclude, if we can eliminate these power fluctuations then we will be able reduce minimum 3 min. from existing time for this critical activity which will also reduce the total cycle time by minimum 3 min.

It can be reduced by following suggestions:

- Improve the stability of power distribution system.
- Improve the power factor of power system.
- Find the alternate source for power supply which has negligible fluctuation.

After considering all corrective measures, tap to tap cycle time for regular activities is 49 min. 58 Sec. which has shown in Proposed Gantt chart in Figure. 4.

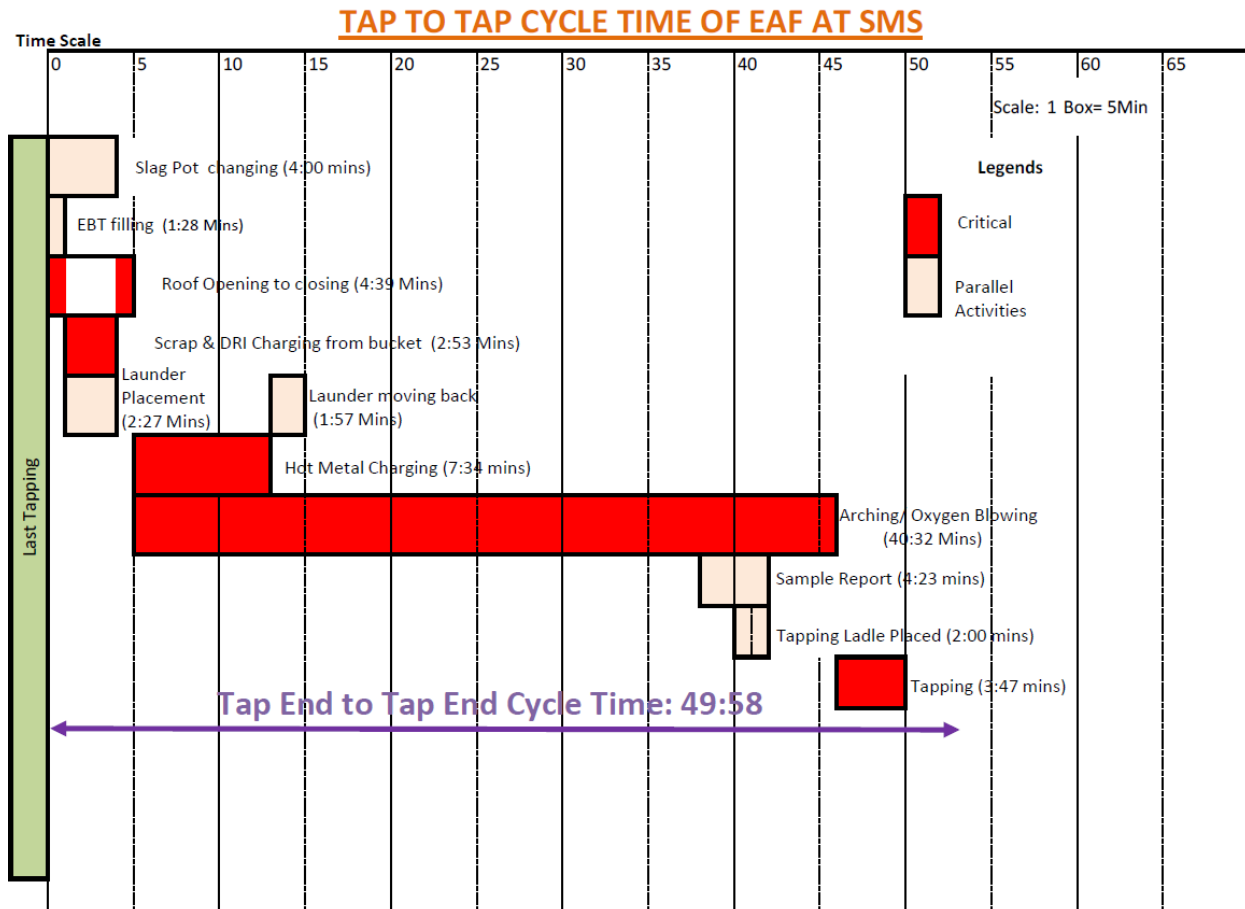


Figure 4: Gantt Chart for proposed sequence of regular activities in Tap to Tap cycle

If we will consider all addition activities which is shown Table 2 then we have to add 2 min. 58 Sec in cycle time of regular activities as per same calculation shown in Table 2 Therefore, proposed tap to tap cycle time will be 51 min. 56 Sec.

Based on above cycle time, Potential no. of heat per day (considering 24 working hours) will be **approx 27 heat/ day** (24*60/ Cycle time).

4.4 Profit Calculation

Profit / Ton = Rs 2300

Increase production by our suggestion = 3 heat/ day = 300 ton / day

Increase in daily profit = 300*2300 = Rs. 690000

Increase in Annual Profit = 690000*365 = Rs. 251850000 = **Rs 25.185 Crore**

5. Conclusion

Management always concern about profit and full utilization of existing resource. Therefore, as per our study, EAF was the bottleneck in exist system and by improving its utilization, we can improve the production of shop. As we have given the suggestion of one extra slag pot carrier and eliminate the fluctuation in power supply which will cause reduction in Tap to Tap cycle time and increase the production from 24 heats/ day to 27 heats / day that means Rs. 25.185 Crore extra annual profit.

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