Enhancing a System's Performance by utilizing its Hidden Capacity using Discrete Event Simulation: A Case Study of a Steel Melt Shop

Swarnendu Kirtania – Associate Consultant, Dastur Business and Technology Consulting, a division of M.N. Dastur & Co. Pvt. Ltd. E-mail swarnendu.k@dasturco.com

Prateek Raj – Associate Consultant, Dastur Business and Technology Consulting, a division of M.N. Dastur & Co. Pvt. Ltd. E-mail prateek.r@dasturco.com

Arnab Adak – Senior Consultant, Dastur Business and Technology Consulting, a division of M.N. Dastur & Co. Pvt. Ltd. E-mail arnab.a@dasturco.com

Atanu Mukherjee – President, Dastur Business and Technology Consulting, a division of M.N. Dastur & Co Pvt. Ltd. E-mail : atanu.mukherjee@dasturco.com

Abstract:

Utilizing hidden capacity of a system is crucial, especially when production expansion plans are constrained by financial and operational resources. Discrete event simulation helps in identifying and validating process improvement and resource augmentation plans thus allowing better informed decisions on enhancing the system performance.

A simulation model of a steel melt shop in a steel plant was developed the existing facilities and operational philosophy, to check whether the plant could produce a desired target. It was found that technical constraints are not met and the system cannot sustain the desired target. Hence new simulation models were built by augmenting the existing facilities and varying the operational delays in the system. What-if-analysis of these scenarios was done to check whether the required throughput could be achieved.

1. Background and Objectives

Due to rising domestic demand of rebars and increased requirement of cast steel billets, an integrated steel plant planned to increase production capacity of long products and explore options to increase liquid steel production from existing melt shops. The plant is based on direct reduction – electric arc furnace (EAF) route. Expansion plan for the steel melt shops is based on the already established route with existing & proposed equipment, its operating assemblies and related auxiliaries.

In order to make better informed decisions regarding the plant capacity and resource requirements, the following objectives were set:

- Develop a simulation model of the facility in order to identify bottlenecks
- To check, if up gradation of EAFs to 90 MVA will produce the required cast steel with the existing casters with the proposed cast heat sequences
- To check the adequacy of existing 2 EOT cranes in the ladle transfer aisle for ladle handling
- Utilization of current facilities
- Analysis of how minimization of current operational delays can result in improved production

2. The System

In a steel melt shop, the scraps are brought by the scrap transfer cars from the scrap yard cars and charged into the Electric Arc Furnaces by EOT cranes, the liquid steel from the Electric Arc furnace is tapped to ladles. From a unit optimization perspective, it is essential that the arc furnace does not have any wait time other than the preparation time. This means that the optimal number of ladles, the optimal number of cranes and the optimal movement algorithm of cranes needs to be determined such that the scrap feed to the Arc Furnace is synchronous and without wait.

The ladles are transferred to the ladle furnaces by the ladle transfer cars and then EOT cranes at the ladle transfer aisle. It is essential that the Ladle Furnaces are synchronized with the Continuous casting machines such that the heat sequences for different grades of steel are maintained while maximizing the utilization of the casters. It is also required that when a heat sequence has started in a caster, it should complete the cast sequence without interruption due to the unavailability of heat.. The simulation model of the steel-melting-shop unit included all these elements and constraints to reflect the behavior of the unit in operation.

The existing facilities included

- 2 scrap charging cranes
- 3 Electric arc furnaces

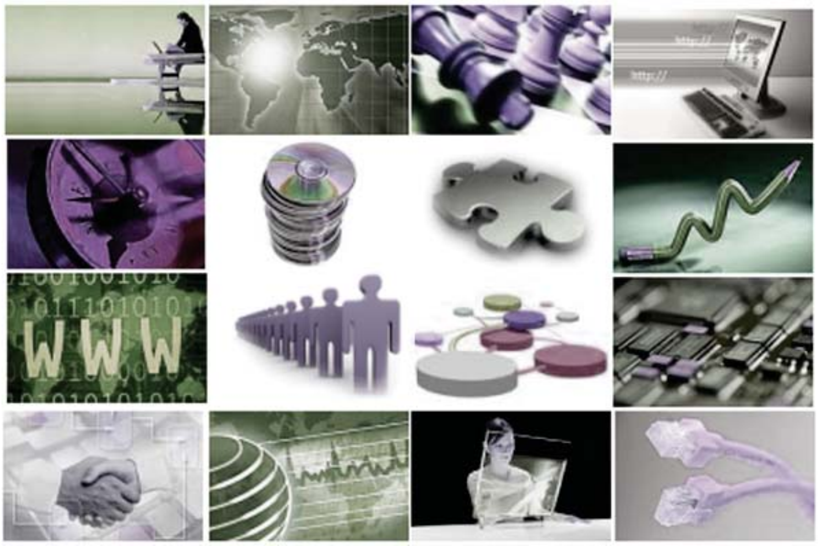
- 2 Ladle Furnaces
- 1 Ladle treatment furnace
- 2 EOT cranes in the ladle transfer aisle
- 3 Continuous casting machines

3. Analysis & Results

A base line model comprising of the above mentioned facilities could not produce the desired quantity of liquid steel and it was determined that the ladle transfer aisle was the bottleneck, as this was creating a blockage for the EAFs resulting in increased tap-to-tap time. This also resulted in frequent breaks in the casting heat sequences and henceforth additional cost incurred for caster preparation.

So a new model was made by introducing one more EOT crane in the ladle transfer aisle. This model showed, it could produce the desired quantity of steel and maintain a fair cast heat sequence with an acceptable utilization of the facilities.

The next point of concern was how delays could affect the production. What-if analysis was carried out on various internal and external delays. The model was run with combinations of internal and external delays currently happening in the existing system and analyses were made how this could affect the target production. This helped in identifying, how minimizing the delays incurred in the current system can lead to system's performance optimization and achieve the desired production target.



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Steel melt shop of a steel plant

Arc Furnace | **Ladle Furnace** | **Caster**

- **Arc Furnace:** Raw materials like direct reduced iron, scrap, etc. are charged into electric arc furnace to produce liquid steel
- **Ladle Furnace:** The liquid steel is taken to the ladle furnace for additional treatment
- **Caster:** The steel is then taken to the casters to produce blooms and billets

Maintain tap-to-tap time of furnaces

Optimal resource utilization

- Cranes
- Ladle cars

Maintain heat sequence of casts at the casters

The client system

Casting Aisle

Ladle Transfer Aisle

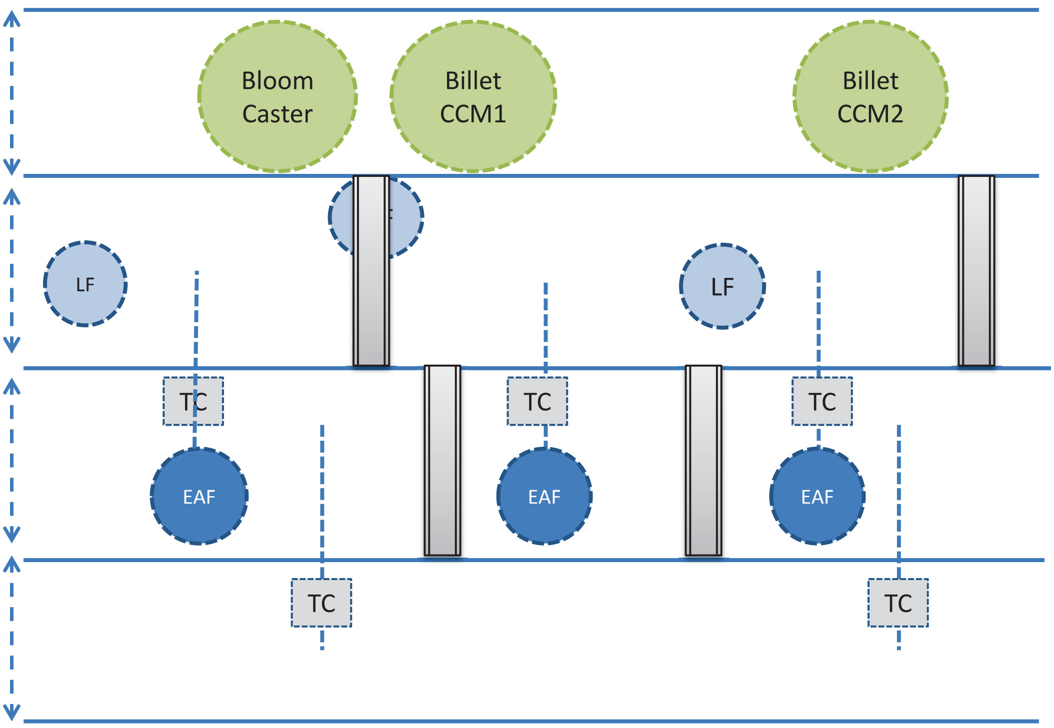
No. of EOT Cranes=2

Furnace Aisle

No. of EOT Cranes=2
No. of ladle Transfer Cars=3

Scrap Aisle

No. of Scrap Transfer Cars=2



Background

Rising domestic demand of re-bars and increased requirement of cast steel billets

Increase optimum possible production capacity from existing melt shops

Financial constraints

Hidden capacity exists?

Additional facilities required?

Delays need to be minimized by at least how much?

What gives rise to hidden capacity

When…

- The focus is on balancing the capacities and not on synchronize the flow
- The utilization of a non-bottleneck resource are being controlled by other constraints within the system
- Resource is simply activated but not utilized
- The movement of auxiliary/transfer equipments within the plant is not optimal and their availability at different point of time is uncertain

How Simulation could help…

- Complex systems and their flows could be studied by incorporating the variables which are stochastic in nature
- Machine downtimes can be taken into consideration and their variability in time could also be treated
- Observing the system over time and capture the system dynamics for further analysis
- System can be studied by building different scenarios with different governing and operating parameters and perform experiments before real life implementation

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Make better informed decision

- To check if up gradation of EAFs to 90 MVA will produce the required cast steel with existing caster and proposed cast heat sequences
- To check the adequacy of the existing 2 EOT cranes in the ladle transfer aisle for ladle handling
- Utilization of the current facilities
- Analysis of how minimization of current operational delay can result in improved production

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Model building

Data collection

- Past furnace heat log data
- Operation data
  - Arc furnace, ladle furnace, caster
  - Planned maintenance downtimes
  - Ladle handling time components etc.

Modeling delay patterns

- One year of historical heat log data collected
- The internal and external delay occurrence distribution was created and applied to the new production requirement
- The new delay occurrences were matched with the "best-fit" distribution

Model building

Baseline model was created with

- Existing facilities
- Proposed capacity augmentation of arc furnaces
- Same pattern of delay occurrences

- Unable to produce at desired capacity
- Heat sequences broken; Ladle transfer isle a bottleneck
- Blockages at furnaces; increasing the tap-to-tap time

Possible solution

- Can additional crane at ladle transfer aisle help?
- How much reduction in delays needed?

Result

Run the model with additional crane in the ladle transfer aisle

Experiment with various job assignments of the cranes to minimize hindrances

Perform what-if analysis by varying internal and external delays

- Capable of producing at desired capacity
- Able to maintain a fair cast heat sequence with an acceptable level of utilization of the facilities
- Reduction in delays at least by 20% needed