Simulation Methods for Improving Manufacturing System Performance Based on Optimum Downtime in Billet Steel Plant, Krakatau Steel Industry

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Abstrack, *Global economic crisis is affecting steel industry. Savings in the production line is one way for reducing the impact. This paper is discussing how to examine the balance of the production line that consists of 3 different types of machines in a Billet Steel Plant, Krakatau Steel Indonesia using Promodel. Simulation is very helpful in determining alternative solutions because of the uncertain processing time in the third machine. Results of the simulation model will be processed and optimized using SimRunner. The result of this research indicates that the balance of the production line in Billet Steel Plant depends on the downtime machine in Electric Arc Furnace (EAF). After experimenting some alternatives, the recommended delay-time for each EAF Machine as follow: 51 minutes for EAF-1; 56 minutes for EAF-2; and 87 minutes for EAF 3. The saving of this recommendation as the result of simulation process is about Rp. 14.104.531/hour.*

Keyword: *Electric Arc Furnace (EAF) Machine, Steel Industry, Simulation*

1. INTRODUCTION

Production line is one of the most important departments in steel industry. It is not easy to create an efficient and effective production line. This paper will examine the evaluation of production line in steel industry. The main problem that will be solved in this research is determining the scheduling in Electric Arc Furnace, adapted to the demand of the next machine for increasing the performance in production line.
The current condition indicates that the workers are experiencing difficulties in determining the schedule manually because of the uncertainty of processing time in each machine. The uncertainty variables belongs to the system create a complex system that is relatively difficult to analyze using common mathematical model. If this situation occurs, it is recommended to use simulation in order to analyze and solve the problem. According to Bank et. al. (1996) Simulation is a very good tool to use in analyzing complex problems. Because simulation is able to describe the complex system and accommodate the uncertainty variable, so in this research, simulation is used to model the entire system.

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Simulation has been implemented in various areas; services or manufacturing. One of the simulation methods implemented in services is presented by Robbin & Harrison (2008). Many researches discussed about simulation in Manufacturing Industry; analyzing the performance measurements, such as workers utility and workflow excess which cannot be predicted early (Bazargan, 2003). A similar paper discussing about utility in manufacturing industry also presented by Ertay & Beyhan (2008) also by Akyuz & Oncan (Akyuz & Oncan, 2008) and Armanery (2008). An similar simulation research report with this paper presented by Rouhonen et.al. (2008).

In some cases, simulation also be able to helps in deciding which parts of the plant that needs to be evaluated. Then, the evaluation will be performed by design of experiment generate by SimRunner. SimRunner is a facility provided by ProModel that help us find accurate solution by doing some experiments. In this case, SimRunner is used to find some alternative downtime for EAF machine thereby reducing Ladle's bottleneck between EAF and Laddle Furnace (LF).

2. MANUFACTURING SYSTEM OVERVIEW

2.1 Foreword

Billet Steel Plant (BSP) is one division at Krakatau Steel Indonesia companies that produces steel bars with the main raw material is scrap, sponge iron and limestone. All raw materials are included in the Electric Arc Furnace for processing and then molded into steel bars. The capacity of BSP is 500.000 ton/year and used to fulfill demand in Indonesia. The dimension of the billet is like follow: Length: 6m,10m, &12m. Section : 110x110m, 120x120m, and 130x130.

Electric Arc Furnace works to dissolve raw materials. There are 4 units EAF machine on the BSP, but only 3 units are used. EAF use electrical energy to dissolve raw material. There are also Laddle Furnace and Continous Casting Machine in Billet Steel Plant. First process is melting process in EAF, after that the molten steel will be transferred to LF to be processed according to the desired quality then transferred to CCM for the cast.

2.2 Process flow

The raw materials; scrab, sponges and limestone arrived in the raw materials storage. Each raw material will be scales before melting. In this plant, Krakatau Steel Indonesia has three EAF 3 machines. Molten steel from the EAF machine will be transferred to Ladle that prepared by the crane. This process called pouring process. After pouring is done, molten steel will be transferred to Laddle Furnace. In Laddle Furnace, molten steel is processed to obtain the specifications of the desired steel. There is only 1 LF machine.

When the steel is considered to has an appropriate quality according to particular category, it will be transferred to the CCM machine. Then, the molten steel is casted become steel bar known as Billet. Billet will be stored temporarily in a warehouse or directly transferred to the trailer.

Figure 1 presents the process flow of billet steel production process. BSP have 8 cranes which have a different capacities and functions. 2 units of crane are located in the raw material warehouse, 2 units are located before EAF machine in order to serve the EAF charging and transfer. 2 units are located between EAF and LF to serve Pouring, skimming and transfer. And the last 2 units are located in the warehouse to serve the billet transfer from buffer to storage or transport to the trailer.

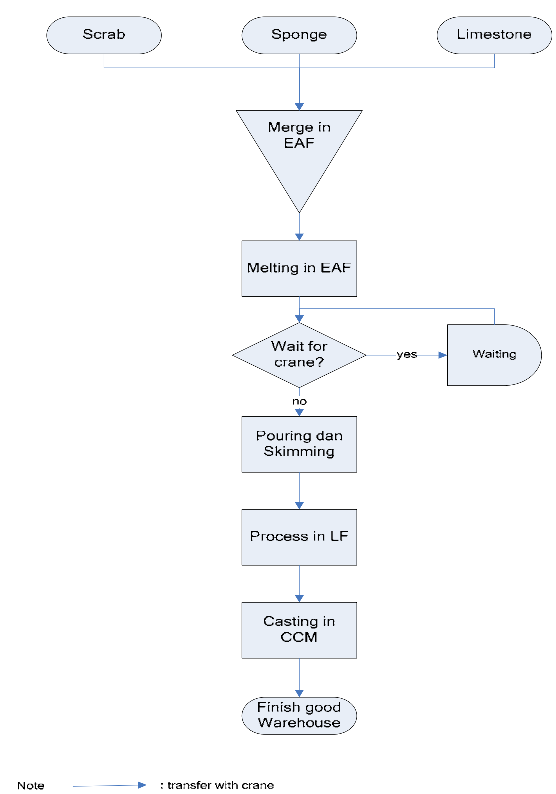

Figure 1. Process Flow

2.3 Challenges

Challenge or problem faced in this research is determining the balance of the use (balance of utility) of three main EAF machines, LF and CCM. The purpose of balancing process of these machines is to save the electric power. There are 3 EAF machines, 1 LF machine and 2 CCM machines that need to be scheduled properly to gain the main objective; the electrical power saving. EAF and LF machine have different capacity and processing speed. Proper machine scheduling is important in order for reduce the production cost caused by electrical power consumed from unnecessary idle time. The data shows that the company must compensate approximately Rp. 2.130.079/hour for idle time caused by bottleneck problem in EAF. The amount is paid for the wasted electricity, natural gas used for ladle and tundish heating and the cost of idle employees.

3. METHODOLOGY

In order to effectively respond to the challenges described in Section 2.3, we used 2 methods. First is simulation, used to help us to find a bottleneck problem, machine utilization, flow process of making billet, etc. And the second method is Optimization using SimRunner. SimRunner will help us to find accurate solutions for the model.

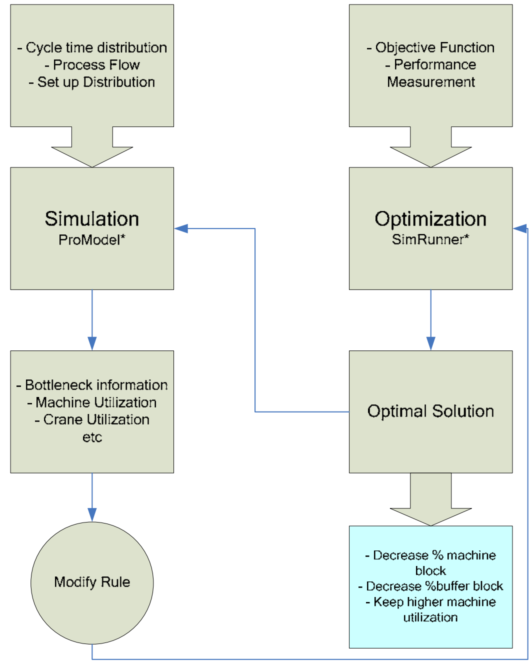

Figure 2. Methodology block diagram

Simulation model built using ProModel 7.0 while the optimal solution will be determined using SimRunner by generate some experiments.

4. DATA COLLECTION AND ANALYSIS

4.1 Input-Data Collection

In collecting data, we use several ways, such as interview, obtain the data directly in the field or in the company database. The data that was taken at the interview is used to strengthen the understanding of the concept of billets production process. The Data taken directly in the field such as : crane transfer time and flow process of making billet. While data from company databases is processing time of each machine (EAF, LF and CCM).

4.2 Input Data Analysis

Data are taken from companies such as transfer time or processing time will be process in the distribution test using Stat:: Fit. Distribution obtained for each machine presented in Table 1.

Table 1. Processing Time Distribution

Machine	Distribution
EAF 1	Log Logistic (127, 2.37, 18.8)
EAF 2	Pearson 6(127, 3.3, 0.734)
EAF 3	Inverse Weibull(107, 0.994, 6.26e-002)
LF	Weibull(22., 1.48, 39.7)
CCM 1	Gamma(43., 1.86, 35.5)
CCM 2	Gamma(38., 1.1, 41.6)

5. MODELLING, VALIDATION AND OPTIMIZATION

This section deals with the steps and techniques involved in building of the models simulation built as a part of this project.

5.1 Simulation Model

The process flow was converted into modeling logic in Promodel and presented in Figure 3.

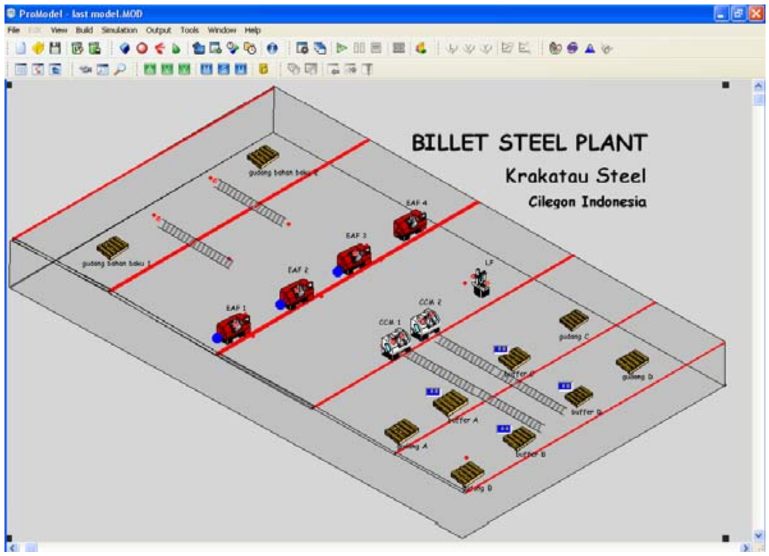

Figure 3. Layout Model

Modeling process adjusts to original state. This process is started by determining the number of machines, cranes, conveyor or plant layout. The model was built to represent the system from material warehouse until finished-goods warehouse. This is intended to ease the other modeler in continuing or developing the model for other purpose research in the same factory. In order to make sure that the model is fit to the system, it is needed to perform the validation process. For the quantitative validation process, process time is proposed to be the measured variable. According to Bank, et al. (1996), for validating the model we can use statistical methods such as: t-test and chi-square test. No difference of mean and variance test also implemented in this validation process.

5.2 Optimization

Once the model is completed, valid and the simulation model was run, then the report was obtained.From the report simulations we can see that EAF and buffer LF have a very big number of percent blocked. This shows that the LF machine is not fast enough in the processing entity compared with the 3 EAF machine. There are a bottleneck between EAF and LF. The long waiting time can reduce the temperature of liquid steel. To maintain the temperature of liquid steel, along the waiting time, the liquid steel is heated up to the ideal temperature (approximately 1650^{0}C). The heating process for maintaining the temperature can be categorized as waste of energy because the company must spend more electical enegy for unproductive process.
In order to reducing this loss, we try to develop some alternative of solutions. We make a downtime to EAF machine to reduce a %blocked of EAF but still concern to high machine utility. Here is the alternative made and will be inputed to SimRunner.

Table 2. Alternative Solution in SimRunner

Perfomance Measure	Respon and Weight	Input Factors
EAF 1 blocked	Min and 2	Downtime EAF Lower 0 mnt Upper 120 mnt
EAF 2 blocked	Min and 2	
EAF 3 blocked	Min and 2	
Buffer LF blocked	Min and 1	
LF operation	Max and 3	

With 24 hours length of simulation and 30 length of replication, obtained experimental results as much as 955 times and get maximum results in experiment 851.

Optimization Converged

Experiment	Objective Function	EAF_1: % Blocked	EAF_2: % Blocked	EAF_3: % Blocked	buffer_LF: % Blocked	LF: % Operation	dts_EAF_1	dts_EAF_2	dts_EAF_3	Low CI	Hi CI
851	108.148	0.449	0.858	0.661	20.996	67.525	51.000	56.000	87.000	103.382	112.91
648	106.942	1.208	1.009	0.865	26.934	71.561	50.000	60.000	86.000	101.139	112.74
300	106.835	1.197	1.147	0.702	24.510	70.241	46.000	57.000	88.000	101.883	111.78
200	106.689	1.048	1.156	0.833	24.489	70.144	54.000	55.000	88.000	102.037	111.34
828	106.377	0.591	1.684	0.607	25.565	70.293	62.000	52.000	82.000	101.097	111.65
945	106.294	1.037	1.282	0.725	29.664	72.546	49.000	59.000	83.000	100.487	112.10
884	105.739	0.951	0.998	0.854	24.777	69.462	50.000	57.000	85.000	99.570	111.90
707	105.658	1.185	1.131	0.965	26.900	71.201	51.000	46.000	76.000	100.067	111.24
910	105.629	1.256	1.295	0.852	27.903	71.871	49.000	59.000	82.000	98.531	112.72
820	105.582	0.701	1.265	0.880	25.150	69.635	50.000	59.000	82.000	100.174	110.98
952	105.498	1.011	1.501	0.700	26.100	70.618	48.000	59.000	90.000	100.194	110.80
183	105.348	1.003	1.518	0.420	24.723	69.448	49.000	66.000	87.000	99.854	110.84
594	105.347	1.105	1.173	0.806	25.632	70.116	48.000	62.000	89.000	100.100	110.59
175	105.335	0.352	0.729	0.652	21.867	66.201	83.000	73.000	77.000	100.106	110.56
596	105.296	1.053	0.816	0.716	24.691	68.870	45.000	62.000	73.000	98.895	111.69
922	104.964	0.849	1.161	0.458	23.275	67.822	53.000	51.000	88.000	97.808	112.12
735	104.963	1.428	0.984	1.266	27.115	71.556	50.000	59.000	84.000	97.813	112.11

Figure 4. Optimization result

6. RESULT AND RECOMMENDATION

The result of simulation report analysis concluded that the original system has a less good performance, especially in the utility of the machines. So, some experiment was created in order to improve the original system performance. The experiment was created by recommending different downtime for each EAF machine at each experiment.

Here is a comparison report on the simulation results before and after optimization process :

Table 3. Comparation Result

Machine	Before downtime built		After downtime built	
	%blocked	%opt.	%blocked	%opt.
EAF 1	7.39		0.71	
EAF 2	9.11		0.00	
EAF 3	13.36		1.56	
LF		85.24		80.94

From SimRunner, it recommends that downtime for EAF 1 : 51 minutes, EAF 2 : 56 minutes, EAF 3 : 87 minutes. Technically, each downtime of EAF can be applied after 1 time EAF melting process, then paused/down as the suggested time on each machine.

7. CONCLUSION

After performing simulation and optimization, the result shows that using recommended downtime (idle time) in each EAF machine can be able to reduce waiting time. The shorter waiting time can reduce the production cost.

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