Proceedings of the 2006 Winter Simulation Conference
L. F. Perrone, F. P. Wieland, J. Liu, B. G. Lawson, D. M. Nicol, and R. M. Fujimoto, eds.

A DECISION SUPPORT TOOL FOR DOFASCO'S PRIMARY STEELMAKING OPERATIONS

Darrell W. Starks
Robert S. Schwieters

Simulation Consultant
Rockwell Automation
Sewickley, PA 15143, U.S.A.

Daniel Creces

Process Manager
Dofasco Inc.
Hamilton, ON L8N3J5, Canada

ABSTRACT

Dofasco Inc. needed a dynamic decision support tool in order to evaluate its primary steelmaking operations. Before working with Rockwell Automation, Dofasco used spreadsheet models and smaller simulations to evaluate capital expenditures at its steel mill. It was determined that modeling all of Dofasco's primary steel operations using Rockwell Software's Arena® coupled with an Excel user interface would allow Dofasco to perform various scenarios in a timely fashion. Through the use of modeling and simulation Dofasco was able to identify bottlenecks in its system, improve throughput by more efficient use of system resources, and understand the impact of proposed system changes before investing additional capital.

1 INTRODUCTION

This paper illustrates the benefits for using simulation and modeling in the analysis of steel making operations. Dofasco approached Rockwell Automation with a request to build a modeling tool to identify bottlenecks within its primary steel making operations and help quantify the impact of changes to its system. Dofasco planned to use the model to validate the assumption that the current steel making system and process is capable of achieving its yearly production goal. The model would also be used in analyzing the impact of sub-system reliability and processing variability on steel slab production.

1.1 Steelmaking Operations

The primary process can be best described as a linear (series) process where the whole system is constrained by the slowest element in the process line. Figure 1 shows a graphical depiction of the 5 main process steps for steel slab production.

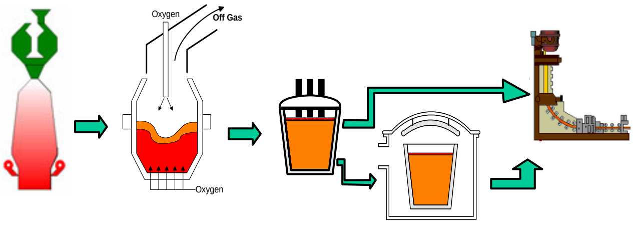


Figure 1: Primary Steelmaking Process

The main process steps are as follows:

1. Iron Making & Desulph – Raw materials, combustion elements combine in the blast furnace to produce molten iron. This iron must be transferred into torpedo cars, moved to the desulph station for desulphurization, and then transferred to the melt shop via rail cars. The iron from the torpedo car is then transferred to an iron teeming ladle so it can be charged into the steelmaking vessel. The iron must conform to specific chemical requirements as delivered.
2. Steelmaking (KOBM) – scrap metal (30% of charge) is combined with the liquid iron (70% of charge) in the KOBM vessel. Chemical energy in the form of oxygen is used to melt the scrap, decarburize the iron to the required level for further processing of the steel. The finished heat of steel is then tapped into a steel ladle and transferred via rail car to the next stage.
3. Ladle Metallurgy Facility (LMF) - The ladle of steel enters LMF where several operations (slag raking, synthetic slag addition, heating, stirring, alloying, etc.) may occur. The types and magnitude of the secondary operations are dependant to a large degree on the final product chemistry requirements. The processed ladle is delivered to the caster turret (via crane) at the correct temperature to enable casting.

1-4244-0501-7/06/$20.00

4. Vacuum Degassing (VD) – This process is used for steel products that are typically highly formable or have high quality requirements. Approximately half of all steel made in the KOBM is processed via the VD tank. The ladle is placed in an evacuated chamber and stirred with argon to encourage flotation of impurities and the removal of carbon and oxygen from the liquid. Once the degas cycle ends, the ladle is delivered to the caster turret at the correct temperature to enable casting.
5. Casting - Continuous casting is the process of transforming the molten liquid steel into solid steel slabs, at the correct size for further processing in the Hot Mill. The caster speed must match the ladle delivery time to ensure continuity of casting. Different grades (chemical compositions) of steel can be cast at different speeds (throughput rate), thus the constraint changes between ladle delivery to the turret and casting capability.

2 SIMULATION MODELING APPROACH

Rockwell Automation developed a simulation model of Dofasco's Primary Steel Making Operations using the Arena® simulation language. To facilitate Dofasco's engineers in their evaluation of simulation scenarios, Rockwell Automation designed and linked a Microsoft Excel® spreadsheet that incorporates all of the system inputs and key outputs to the simulation model.

2.1.1 Documenting the Process

The first step in Rockwell Automation's simulation model-ing development process was to document all of the processes in Dofasco's Primary Operations. Working with Dofasco, Rockwell Automation consultants defined all of the relevant system processes and the level of detail required in the model to allow for future system evaluations. Dofasco and Rockwell Automation identified 87 unique system processes/activities that required modeling. The end result of Rockwell's initial meetings with Dofasco was a complete functional specification for the simulation model and a set of process flows. Figure 2 shows an example of the process flows prepared for the functional specifications.

2.1.2 Simulation Model Development

Rockwell Automation consultants translated the documented process flows and the functional specification's requirements into an Arena® simulation model. The model logic was divided into four modular areas:

- Iron Making & Desulph
- Steelmaking (KOBM)

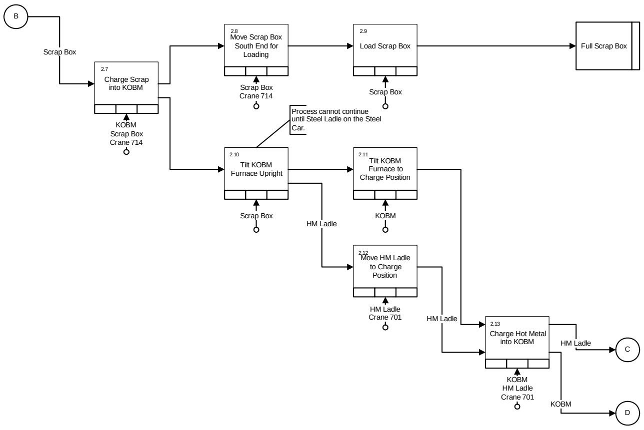


Figure 2: Process Flow Segment

- LMF & Vacuum Degassing
- Casting & Ladle Repair

Each of the members of the team of Rockwell Automation consultants was given responsibility of different modules to develop. In addition, Rockwell Automation consultants created an intuitive spreadsheet for system inputs and coded an interface between Microsoft Excel® and Arena® to transfer data from the spreadsheet to the model at run-time. After the simulation logic was programmed, Rockwell Automation added animation to the simulation model to show the movement of molten iron and steel through the system. Figure 3 shows the model's steelmaking and casting animation.

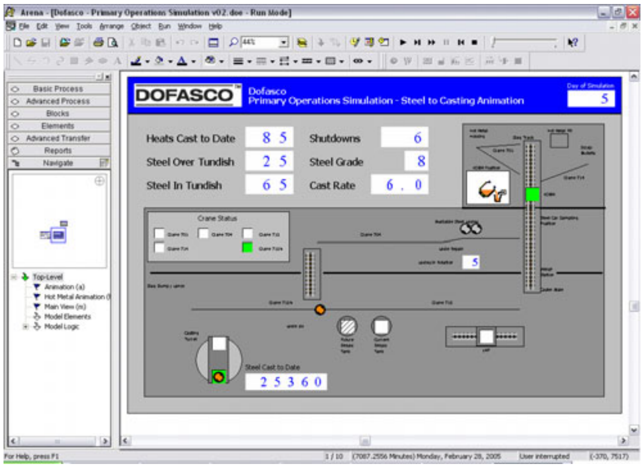


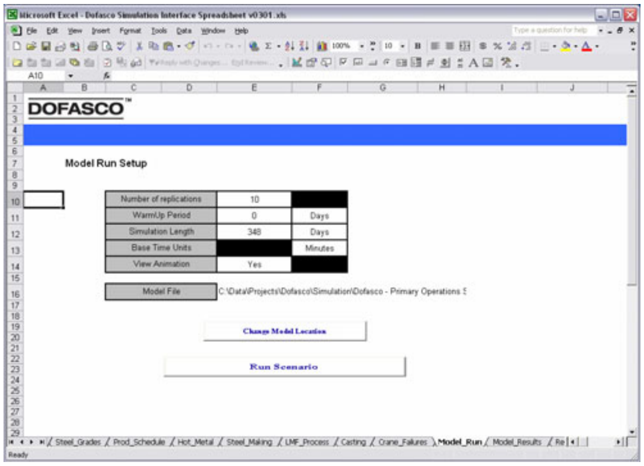
Figure 3: Steeling Making through Casting Animation

While Rockwell Automation consultants developed the simulation model, Dofasco engineers collected processing times, decision probabilities, and failure parameters for all of the documented processes and system resources. Rockwell and Dofasco analyzed the data and created distributions to stochastically describe each of the processing delays and resource failures.

2.1.3 Inputs

All of the system inputs to the model are entered through an Excel user interface (see Figure 4) and include the following categories:

- Steel grades
- Production schedule
- Hot metal parameters
- Steel making parameters
- LMF parameters
- Casting parameters
- Maintenance and failure parameters
- Model run setup



Model Run Setup

Number of replications	10	
WarmUp Period	0	Days
Simulation Length	348	Days
Base Time Units		Minutes
View Animation	Yes	

Model File C:\Data\Projects\Dofasco\Simulation\Dofasco - Primary Operations

Figure 4: Spreadsheet Interface

2.1.4 Outputs

Standard Arena reports and an Excel Output Spreadsheet are available to view model outputs such as:

- Total casting overall and by product
- Number of ladles cast overall and by day
- Casting cycle time
- Caster shutdowns
- Specific queue times to determine bottlenecks
- Hot metal production delivered to steel making and to coffining

Each of these performance measures has an average, minimum, and maximum with a confidence interval, where appropriate.

2.1.5 Simulation Model Validation

To validate the simulation model for Dofasco's Primary Steel Making Operations, Dofasco and Rockwell Automation ran the model with the Dofasco's Steel Making Operations data for 2005. Dofasco compared the results of the simulation model with the actual steel casting production, cycle times, and iron production. The simulation results were within 1% of the actual production for calendar year.

3 ANALYSIS & PRELIMINARY RESULTS

The two main reasons for developing a model were: a) validate whether incremental changes in sub-process averages had a significant impact on shop productivity; and, b) identify what was constraining the output potential of the operation.

With this in mind, two major groups of simulation scenarios were conducted. The first group was designed to model changes to various sub-processes against the outputs above and validate which were significant. Although there are well over 100 user input variables in the model, only about 20 or so are considered potential candidates for process improvement. A 20 factor design-of-experiments (DOE) was developed evaluating the key inputs against the outputs defined earlier. In general, the first round of the DOE looked for significant impacts only and thus the number of model runs was limited. Once identified, those changes that showed a significant impact will be remodeled to determine their effect on system interactions.

The second half of the modeling effort is to re-test the influence of the same sub-process changes in a newly configured shop i.e. with a shop after the addition of significant capital upgrades. The goal is to determine whether simple shop process changes can deliver the needed productivity increase or whether major capital equipment investments are required. Once this is determined, the model should be able to help Dofasco decide which of 4 proposed shop configurations provides the greatest benefit. Again, this is run as a DOE, same as above, with the static model inputs adjusted to reflect the new business rules of the new equipment configuration.

While both of these models are being run, the secondary outputs to be considered are the working queues. These queues are indicators of where the bottlenecks are in the system. For example, if during the DOE runs, one particular queue value indicates that it is unable to supply the next operation, the DOE may have to be re-run after making adjustments to the process feeding the queue to remove that constraint. The entire process of constraint removal is expected to be somewhat iterative and even intuitive from the point of view that the modeler must have a feel for what can and cannot be done.

4 CONCLUSION

At the time of this writing, the DOE trials are not yet complete. However, there are some things that can be said from the results so far.

The model confirms that when looking to make improvements to an already well matched, efficient process, spreadsheet models that deal strictly with averages and standard deviations are not accurate enough and often overstate the potential results. The ability to model random variability provides a much more realistic view of process improvement.

The model has also confirmed that so far, there is no single factor that provides a panacea to make productivity improvements easy. The greatest effect is provided by the most obvious changes, increase shop up-time and the productivity increases over all scenarios run so far. The up-time referred to is overall up-time, that is, all operations must have coincident improvement in up-time or an improvement in productivity cannot be realized.

The model provides some good insight into what was previously not well understood. The modeling effort has led to a much greater understanding of the process of steelmaking, the relationships between sub-processes and the dependence upon improvement in one area to realize an improvement in another. This leads to potential improvements in delay and opportunity tracking in the Steelmaking shop.

Finally, the results of the DOE trials will become inputs into the SIP (Steelmaking Improvement Program) capital improvement project designed to improve the output of the 20 year old shop.

AUTHOR BIOGRAPHIES

DARRELL W. STARKS is a Simulation Consultant with Rockwell Automation. Darrell has over 28 years of experience in applying simulation technology to a broad spectrum of real-world systems including metals, manufacturing, food processing, banking, logistics, quick service restaurants, health care, emergency response and criminal justice. Darrell also continues as an Adjunct Professor at the University of Louisville Speed School Department of Industrial Engineering teaching at the Louisville campus and in the off site Panama campus.

DANIEL CRECES is a Technology Coach in the Steelmaking Business Unit at Dofasco. He has had several roles over his 17 years at Dofasco, working in maintenance, operations and technology. He played a lead role in the 1996 Steelmaking expansion as project lead on the installation of the #2 Continuous Caster. Dan is currently on assignment to the SIP program as Process Manager of the CC Renewal project.

ROBERT S. SCHWIETERS is a Simulation Consultant with Rockwell Automation. Robb has over 5 years of experience designing, documenting, developing, and analyzing Business Process Simulation solutions. Previous to working for Rockwell Automation, Robb worked for Accenture's Federal Government Operating Group and its Simulation Practice in CRM.