Energy Optimization using a Virtual Foundry Model

(An NFTN project)

by

Adrian Paine, ***SimLogic*** *(adrian.paine@simlogic.co.za) & Fred Cooper*, ***PDC***

Main Collaborators: ***PDC & KWA Kenwalt Australia (SysCAD)***

Abstract

The paper describes the development of a dynamic plant simulation capability for applications in the foundry industry, specifically relating to energy usage and costs. Developing such a capability entails breaking down a complete foundry operation into discrete unit models. These unit models are then linked to form a mathematical flow diagram. Mass flow (batch or continuous) as well as energy consumption and cost for each specific step is simulated. Furthermore, the work involved validating the plant model's simulation behaviour as well as performing various comparative analyses using carefully selected process parameters.

The efficient usage of power in any process plant environment is fast becoming a major topic for research in many organisations. The realisation that the world's natural energy resources is depleting at an alarming rate at a time when the world is experiencing its fastest economic growth is placing more and more pressure on industries to reduce their energy consumption.

Foundries, although strategic to a country's economic development, by nature are high energy consumers making them an obvious target for improving energy efficiencies. The ability to simulate the whole foundry operation from beginning to end is essential for building an understanding of the energy usage and determining the potential areas for energy saving.

The objective of this study was to develop an energy model for a foundry operation which is to be used as a benchmark for future model developments. This is achieved by adapting a dynamic plant simulation software package, SysCAD, which is typically used for simulating mining, minerals processing and chemical operations, for modelling foundry processes.

Comments from the client, PDC

"Our energy costs, as a percentage of total costs, is increasing every year with Eskom's higher than inflation increases. Business is tight and we are finding it very hard to pass some of these large increases onto our customers so there is only one alternative – save energy to save costs.

One of our Engineers, Fred Cooper, did a manual Xcel spreadsheet simulating energy consumption in our business. All equipment was included which included furnaces, compressors, CNC etc. This data was used by SimLogic to build a "real time" simulation model with the SysCAD software. This allowed us to do various "what if scenarios" to see how and where energy can be saved. As a result of the simulation we implemented two small, low cost ideas which paid for the cost of simulation in 6 months!

a) we moved our tea times out of off peak power times to peak power times

b) we put furnace lids on our furnaces to reduce radiant heat

With the assistance of the NFTN, you cannot afford to miss this opportunity to save on energy costs."

Key Words

Process simulation, process optimisation, virtual processing, foundry energy modelling, dynamic time based event modelling.

1. Introduction.

This dynamic model simulates all the relevant aspects of the plant, including the physical process, equipment, the control system, the operational strategy and the interactions on these systems (e.g. production and plant scheduling, etc). One of the benefits of this approach is that the model can represent and behave as the real plant. Therefore, the complex interaction of the various plant units and their resultant effects can be captured. The dynamic behaviour of various surge units due to feed variability and plant and operator control strategies is also captured. The model, by design, provides a true mass and energy balance.

In this case, the main challenges were to capture all the relevant foundry related units and processing operations such as:

- Capturing and reformatting the necessary foundry specific thermo-physical data in order to fit the typical format of a chemical engineering simulation software;
- Developing foundry specific furnace models for melting and holding liquid metal. This involved modelling typical heat losses to the environment, energy input as well as furnace temperature;
- Capturing non-automated events and developing them into a mathematical programmable logic, such as furnace level control, temperature control, melting operations, etc. These are necessary to emulate operator control behaviour;
- Capturing and implementing time based events in order to simulation a complete production cycle;
- Develop a simple simulation interface in order to allow a foundry user to make basic process changes.
- Develop an energy and power, time based cost model which can be used for scenario testing.

2. Methodology.

At first it was necessary to incorporate all the necessary species data into the model, which, in this case, included all the thermo-physical energy data for copper base and aluminium based alloys. The next step was to develop and test a generic furnace unit model which was to be used for modelling a typical melting and holding furnace unit operation. The model incorporates the conversion of electrical energy to heat energy, taking into account any conversion losses which may occur. Heat transfer or losses to the environment through radiation, convection and conduction control were all captured in this model. The furnace temperature was controlled using a temperature control algorithm. Furthermore, the optional use of furnace lids were also introduced.

The complete foundry was then mapped out into a flow diagram, linking the inputs to the foundry to the various thermal operations and then to the outputs. The control logic was incorporated into various control units. Furthermore, the model was configured with all the relevant processing detail typically used in a foundry. The cost of electricity was incorporate into the model through the use of a time based costing schedule. The energy, power and cost were then validated by comparing them with actual foundry data. Finally, in order to search for conditions which would make a significant impact on energy saving, various comparative scenarios were set up and used to study the foundry's energy behaviour.

3. Virtual Foundry Model.

In this particular case, the model flow diagram of the foundry was divided up into Melting, Holding and Peripheral Equipment sections, as shown in **Figure 1**.

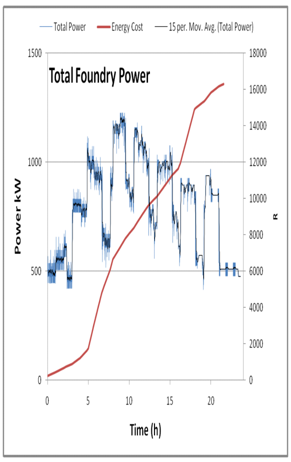
The model captures typical foundry operations such as metal storage, melting, liquid metal transfer with furnace level management as well as other processes such as metal conditioning, casting, recycling of gates, cast finishing etc. All these use energy and are accounted for in the model.

Furnace behaviour such as melting, heat lost to the environment, temperature control, insulation, use of lids, recycle streams etc have been successfully modelled using an adapted "Tank" unit model with integrated furnace subroutines. Different generic models where developed for melting and holding furnaces. Melting furnaces typically use batch processing to address loading and transfer operations while holding furnaces are used for conditioning the metal for subsequent processing.

Plant control logic has been used in a "global subroutine" to simulate the integration of all the foundry operations, such as alloy supply, melting, metal transfer, furnace level control etc. A second subroutine called, "EnergyStat", is used to total and present energy usage in different ways. Other cost based information are captured in a third subroutine called, "Cost Calculator".

Figure 1: *Flow diagram of Foundry operation including melting, holding, casting and all peripheral equipment.*

The cost calculator is responsible for calculating the power and energy costs for a month's operation. This is based on a time dependent usage of power and energy. The cost rates are entered into the "Cost Rates" control and include, "power access", "power demand", "basic, energy peak", "energy standard" and "energy off-peak" cost rates.



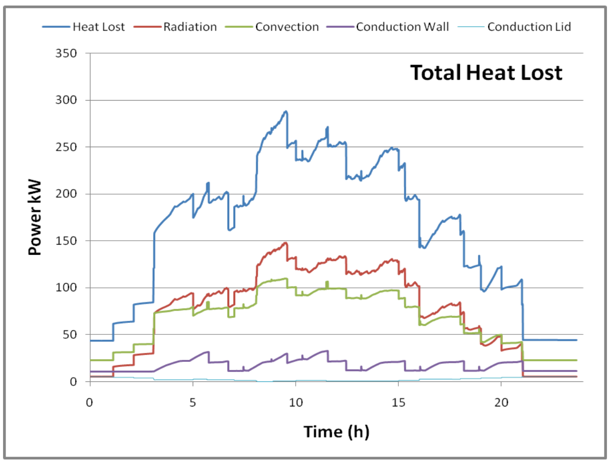


Figure 2: *Daily power and cost usage.*

Figure 3: *Heat losses to the environment.*

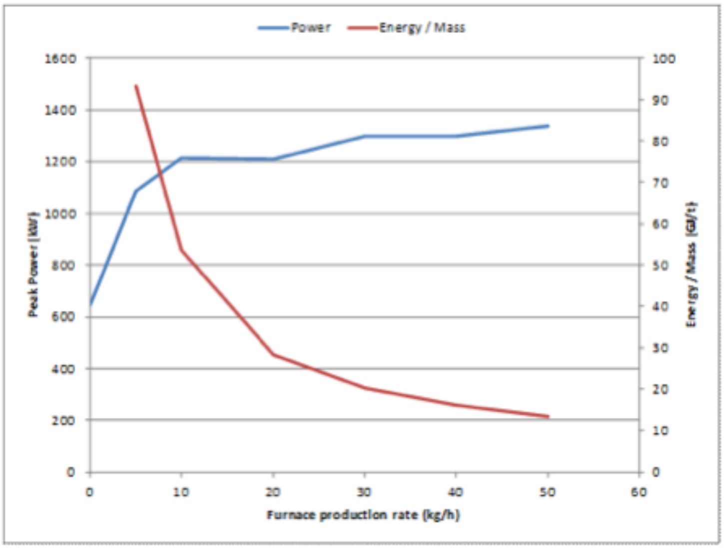
Besides daily production graphs as shown in **Figures 2 & 3**, typical output information also includes total monthly electricity cost as well as a complete breakdown of these costs. Other information include metal weighted energy cost for each base-alloy used.

In order to ensure that the model was predicting realistic results, the foundry's actual month's energy cost figures were compared with the model's predicted figures. The model was first setup with the production data collected from a specific month's operation. Estimations were used for peripheral equipment usage. Comparisons between a month's predicted simulation and actual data were within 4 % accuracy.

An initial study involved comparing process conditions using holding furnace lids (insulation). Scenarios such as, using normal process conditions, not using lids at all, using furnace lids in idle time only and using lids in both production and idle time. The results of the study showed that it was possible to make up to a 20% saving by efficient use of furnace lids.

In a second study, a comparison was made between the energy usage costs for normal production using 11 holding furnace, and that of combining the production requirement into fewer holding furnaces. More specifically this meant switching off 4 of the holding furnaces and in order to ensure that the production requirements remained the same, all the active furnace's casting rates and times were increased. The results of the study showed it was possible to make a further 10% saving on electricity.

Figure 4: *Production rate (per furnace) verses total plant peak power used and energy per ton.*



Lastly, a study was made by progressively increasing the production rate per furnace and then evaluating the effects on peak power usage as well as on the energy per ton. The results, as shown in **Figure 4**, show that the peak power has a minimum of 650 kW at zero production and plateaus out at between 1200 kW and 1350 kW above 10 kg per hour furnace rates. Furthermore, the energy usage per ton can vary starting from infinity at zero production and quickly dropping hyperbolically and flattening out at around 12 GJ/t. It must be born in mind that the production includes both Al-based and Cu-based alloys. Studies such as this can help analyse the specific capabilities of a process and link this to energy usage.

4. Conclusion

SysCAD, a dynamic plant modelling software, has been adapted and used to simulate energy usage in a foundry operation. The time based modelling approach allows one to simulate energy and power demand costs. Typically, a foundry operation involves batching processes such as storage, melting, liquid metal transfer with level management as well as other processes such as metal conditioning, casting, recycling of gates, cast finishing etc. All these use energy and are accounted for in the model. The ability to simulate accumulated power demand offers a novel approach to addressing energy efficiency in the foundry environment.