MELTING EFFICIENCY - F2A

Energy eco-efficiency opportunities in Queensland Foundries

Charge preparation, energy management and metal reduction

The metal casting industry is one of Queensland's most energy-intensive manufacturing sectors.

As Table 1 shows, the melting process can account for over half of its energy consumption.

Table 1: Typical energy use in non-ferrous and ferrous foundries[1]

Activity	Non-ferrous foundry (%)	Steel foundry (10 kt/yr good casting) (%)
Melting (incl. holding)	60	44
Plant actuation (activating mechanical devices)	15	
Air compression	14	10
Tool heating	3	
Heat treatment (gas)		7
Others	8	39

Melting involves heating metal into a liquid ready for pouring. The process involves a number of steps that incur material and energy losses. Theoretically the minimum amount of electrical energy required to melt one tonne of steel to a temperature of 1600 °C (ready for pouring) is 377 kWh. However, most steel foundries consume between 500 – 800 kWh per tonne due mostly to energy (heat) loss during the process. When these losses are multiplied by yield losses in rework during casting and finishing, steel foundries can be using three to six times the theoretical energy requirement.[2]

Most of these energy losses result from conduction, radiation and convection heat losses from the furnace, stack loss (flue gases), and metal loss. The extent of the losses will depend heavily on the furnace design, level of process control, the type of fuel used and operator practice. There are two fact sheets in this series discussing melting efficiency:

Melting efficiency – F2A: Charge preparation, energy management and metal reduction; and

Melting efficiency – F2B: Furnace efficiency

This fact sheet (F2A) will discuss some eco-efficiency opportunities that may help to reduce energy losses and improve productivity through better charge preparation and energy management and reducing metal content of products and runners. The fact sheet on furnace efficiency (F2B) outlines energy reduction that can be gained through furnace efficiencies.

1 Sustainability in Industry, Energy and Transport European IPPC Bureau, 2005, Integrated Pollution Prevention and Control Reference Document on Best Available Techniques in the Smitheries and Foundries Industry
2 USA Department of Energy, 2005, Melt Efficiency Improvement, www1.eere.energy.gov/industry/metalcasting/pdfs/umr22_fs.pdf

Charge preparation

The practice of cleaning, carefully storing and preheating charge to remove dirt, rust, oils, lacquers and moisture (especially by foundries melting iron and aluminium) has a number of benefits.

Reducing slag formation and increase electrical efficiency

Most Queensland foundries are now working with their suppliers to ensure their scrap is pre-cleaned. Dirty charge and the addition of oxides and non-metallic compounds to remove impurities significantly affects the type and quantity of slag formed. When slag makes contact with the refractory lining of the furnace it cools and adheres. The gradual slag build up increases the furnace wall's thickness (through which heat is transferred to the metal) which can greatly reduce the furnace's overall electrical efficiency and capacity. For example, in a 5 tonne coreless induction furnace a slag build-up to an overall thickness of 15.5 cm reduces the furnace capacity to 4.5 tonnes.[3]

Dirty charge also wastes energy that could be utilised for melting the charge. Sand for example has twice the heat content of iron. Therefore every kilogram of sand in the charge heated with the metal uses the same amount of energy as it would take to melt two kilograms of iron.

Undercover storage ensures the charge remains dry. When moisture comes in contact with molten metal it can flash to steam with sufficient force to damage equipment and cause injuries to workers. This risk can be reduced by storing metal in waterproof areas and/or slowly preheating the metal to evaporate the water before putting it into the furnace.

WORKING WITH SUPPLIERS BRINGS EFFICIENCY

Tyco Water at Currumbin is a ductile iron foundry, machining, coating and assembly plant for large diameter pipeline components. Tyco Water is aware of the additional energy consumption associated with dirty charge and work with its scrap suppliers to ensure that the scrap they purchase has been pre-cleaned to remove dirt and oil.

Preheating to reduce the melting time of the furnace

Preheating charge cuts melt time and can reduce the energy required for melting by around 55-83 kWh per tonne.[4]

If the pre-heater uses natural gas, in place of electricity that would have been used in the melting furnace, it may also help to reduce emissions as well as energy costs.

A small engineering and manufacturing foundry, R.J. Cyr Co. based in Ontario Canada installed a gas pre-heater with an exhaust fan to funnel combustion gases and particulates to a high temperature afterburner. Preheating the scrap reduced the metal melting time by 17 per cent which allowed the foundry to use its electric furnace more efficiently. This increased productivity by 18 per cent. The pre-heater's afterburner also reduced fugitive emissions (volatile organic compounds and related hydrocarbons) by 90 per cent allowing the foundry to meet current and foreseeable government emissions standards.[5]

For more information on furnace efficiency refer to the Furnace efficiency fact sheet (F2B) of this series.

3 D. Williams et al, 2009, Coreless Induction Improves Efficiency, and Reduces Electricity
www.foundrymag.com/archives/feature/83605/coreless_induction_improves_efficiency_and_reduces_electricity

4 BCS, 2005, Advanced Melting Technologies
www1.eere.energy.gov/industry/metalcasting/pdfs/advancedmeltingtechnologies.pdf

5 Natural Resources Canada, 2008, An Efficient Scrap Metal Pre-heater for Foundries
canmetenergy.nrcan.gc.ca/eng/industrial_processes/industrial_energy_systems/publications/200853.html

Recovering waste heat

Heat recovery from hot flue gases

Some foundries are utilising the heat in hot flue gases from melting or holding furnaces to provide the energy for pre-heating systems. The operation of pre-heaters should be synchronized with the furnace so excessive temperatures or holding times do not lead to oxidation and energy losses.

Stack furnaces

Stack furnaces send hot exhaust gases from the melting zone up a shaft loaded with incoming charge thereby improving the energy efficiency of the furnace by 40-50 per cent.[6]

For more information on furnace efficiency refer to the Furnace efficiency fact sheet (F2B) of this series.

ALUMINIUM FOUNDRY RECOVERS WASTE HEAT FROM MELTING FURNACE TO PREHEAT CHARGE[7]

PBR Australia manufactures a range of aluminium brake systems. The foundry used reverbertory gas furnaces which are typically only 40 per cent efficient. The plant decided to capture some of the wasted energy being lost in hot flues gases (temperatures typically exceeds 700°C in these types of furnaces) to pre-heat its charge.

The plant fed charge material automatically into the furnace via a chute that also acted as the exhaust flue for the melting and holding chambers. As the charge reached the base of the feed chute it had melted. Once the metal charge had become fully molten it flowed into the holding chamber where the temperature was maintained.

The initiative saved the foundry 11,040 GJ of energy every year and reduced annual CO_2 emissions by 596 tonnes. Other benefits included an increase in metal yield by 4 per cent from lowering the production of dross and reduced the hazards associated with moisture on the charge.

Twin Shell Systems

Twin Shell Systems is a heat recovery option for steel foundries where one side of the furnace melts while the other half is being loaded. The hot off gases from the melting side are piped to the other side to pre-heat the charge. Twin shell systems are cheaper than two separate electric arc furnaces because they require only one set of electrodes to achieve similar production rates. Nippon Steel in the USA reported a 30 per cent energy reduction compared to conventional melting with an energy consumption of 287 kWh/tonne steel and pre-heating to around 900 °C.[8]

Heat recovery from cogeneration systems

Some foundries are using waste heat from cogeneration systems for pre-heating charge. For example Techni-Cast Corp in California employs 100 people and produces products such as cylinders, washers, bearings made from aluminium, copper, iron, nickel and cobalt base alloys. The site uses a natural gas-fuelled co-generation system to produce 82 per cent of its own electricity. The site uses the treated exhaust from the cogeneration system in its pre-heating oven which raises the temperature of metal to 800°C. The cogeneration emissions control system also cuts NO_x by more than 90 per cent and has reduced other regulated air pollutants to less than half the regulated cap.[9]

6 BCS, 2005, Advanced Melting Technologies
7 Sustainability Victoria, 2002,Tower Melting Furnace at PBR Australia, Energy and Greenhouse Management Toolkit, Module 5 **www.sustainability.vic.gov.au/resources/documents/Module5.pdf**
8 BCS, 2005, Advanced Melting Technologies
9 Distributed Energy, 2005, Overcoming the Hurdle of Emissions Control, Creative Co-Generation Cuts Californian Foundry's Costs **miratechcorp.com/images/data/attachments/0000/0015/MIR_26618_Technicast.pdf**

Energy demand management

As foundries are large electricity users many electricity retailers charge not only for electricity use but also peak demand. Demand is the amount of current being drawn by the electricity user at any one time. Often electricity services are provided at a tariff rate which increases if an electricity demand exceeds a predetermined amount. Electricity use from this point onwards (for the rest of the day, week or even month) may be charged at this higher tariff.

Depending on the foundry's type of electricity contract, operators can significantly reduce their costs by managing their electricity use and reducing their peak demand.

Start-up of equipment

The start-up of equipment draws more energy than when it is operating at a stable rate. Staggering equipment start-up times can reduce peak demand by distributing the demand over a longer period.

Power demand controllers

Power demand controllers constantly measure the power a foundry is using. The operator sets the controller to a maximum demand peak and when the power load reaches that maximum, it adjusts preselected electrical devices to reduce the peak. When the power consumption returns to an acceptable level the controller automatically allows the loads to turn back on.

The Californian iron foundry, Gregg Industries, for example, installed a power demand controller to optimise the energy consumed by its induction furnaces (energy used ranged from 1200 kW to 4500 kW). Real time information was used to manage its energy consumption achieving an average monthly peak demand reduction of around 2300 kW resulting in an overall reduction of 24 per cent. The payback period was 18 months.[10]

While considerably less accurate, foundries can also benefit from manually monitoring their daily energy demand as the case study below demonstrates.

DAILY MONITORING SAVES ENERGY

Bradken Foundry at Ipswich makes medium to large components for the rail and mining industry. The site receives daily energy consumption reports from their energy supplier. This daily monitoring alerted the site to a spike in energy consumption over a weekend when there was no production. When investigated it was found to be the result of several leaks in the compressed air system which when fixed resulted in a saving of 106.7 MWh or $10,000 annually.

Multiple output power supplies to multiple furnaces can split power usage between a number of furnaces rather than feeding separate lines to each furnace. This means a foundry can melt in one furnace while simultaneously maintain the temperature in another furnace being poured.

The D & L Foundry in the USA, for example, was able to melt in one furnace at 3,000 kW and simultaneously use the remaining 250 kW to maintain temperature on the furnace being poured with its dual-output power supply. In a normal operating cycle, the company melts 4082 kg of iron in one furnace in 40 minutes and empties the pouring furnace in 35 minutes. Previously this meant the site was only achieving a power supply utilisation of 50% where with the dual supply system power-supply utilization is around 90%. It has enabled the site to take advantage of the full value of its load factor power charges while increasing production by 80% with no increase in demand charges.[11] Refer to fact sheet Furnace efficiency (F2B) for more tips in reducing energy use within furnaces.

10 Foundry Management and Technology, 2005, Reducing Energy Consumption Without Reducing Output www.foundrymag.com/archive/search/feature/49787/reducing_energy_consumption_without_reducing_output

11 C. Fink, 2005, Modern Induction Melting, Foundry Management and Technology www.foundrymag.com/feature/feature/49795/modern_induction_melting_improves_process_and_productivity

Melting process control can manage the melt cycle by using load cell feedback on the charge weight in the furnace to calculate the energy required to bring the bath to pouring temperature and then turn off the power supply, or lower it to a holding mode, to reduce electricity charges and to avoid overheating.[12] Overheating not only wastes energy but can damage the lining of the furnace and can cause quality problems as some alloys can burn out at high temperature or with time. A 10 per cent increase in molten-metal temperature results in a 33 per cent increase in radiated heat losses.[13] For more information on furnace efficiency refer to the Furnace efficiency fact sheet (F1B).

Control management systems can also record a wide variety of operational data to help melt operators maximise production and identify operational delays. Much of the information can also be used by maintenance and service staff for diagnostic purposes.

Harmonic protection filters minimise the negative influence of electrical furnaces on power supplies including low power factor and high frequency harmonics.

Spectroscopy technology uses a laser and spectrometer to measure the make-up of the melt in-situ and in real time.[14] A New England stainless steel foundry in USA, for example, was investigating increasing its melting capacity when it identified that it was taking 30-35 minutes to return the analysis of the metal samples to the melt deck. The purchasing of a spectrometer allowed production to increase sufficiently by saving 30-35 minutes every melt.[15]

Production scheduling

Energy savings can be achieved in some foundries through production scheduling. For example, it may be possible to operate furnaces for longer periods nearer to their optimum output while also utilizing cheaper off peak electricity rates.

Reducing the amount of metal in castings

Despite the need to reduce production costs to stay competitive, foundries must also meet increased demands for high quality castings. Foundries are now investigating opportunities to reduce energy consumption for melting by reducing the amount of metal in their casting and gating (runner) systems without sacrificing quality.

Football risers at Bradken Foundry at Ipswich.

REDUCING RUNNER SHAPE SAVES MONEY AND METAL

Bradken Foundry in Ipswich investigated the possibility of reducing its runner shape to reduce feed metal requirements and to improve yields. They changed from a traditional cylinder riser to a football riser. The trials successfully reduced riser weight by 44 per cent, increasing yield by 14 per cent and saving approximately 1450 tonnes of metal per annum. Other benefits include:

- shorter solidification times and hence shorter knockout times
- reduced feed metal costs and feed times
- smaller mould boxes that has reduced the sand to metal ratio resulting in a higher percentage of sand reclamation, reduced consumption of sand additive and less wear and tear on mixers and machinery.

Computer aided systems can be used in the design of the patterns. Some of these systems include:

- CAD (computer aided design) to design patterns
- CAM (computer aided manufacturing) to design cutter tool paths
- CNC (computer numerical control) machines to cut out the pattern.

12 Modern Casting, 2005, Built-in Melt Automation Technology Boosts Induction Power Supply www.thefreelibrary.com/Built-in+melt+automation+technology+boosts+induction+power+supply-a0136456465
13 Modern Casting, 2006, 10 Ways to Improve Melting www.thefreelibrary.com/10+ways+to+improve+melting:+achieving+perfection+may+be+too+much+to...-a0152259924
14 USA Department of Energy, 2004, In Situ, Real Time Measurement of Melt Constituents, Energy Efficiency and Renewable Energy, Industrial Technology Program, Aluminium IOF
15 M. Eckert, 2007, Reduce Power Consumption Without Sacrificing Production Foundry Management and Technology

Many design programs can also help to predict the properties of the product including tensile strength, fracture strength and ductility.[16] This allows the patterns to be streamlined and lightweighted removing material that is unnecessary for the performance of the product. This can reduce the testing phase bringing the product to market more quickly.

LIGHT WEIGHTING BRINGS HEAVY BENEFITS

Tyco Water in Currumbin implemented a project to light weight all of its products. Using 3D modelling technology and coating the castings with an epoxy that increased the castings resistance to corrosion it has been possible for the site to reduce the cast weight of many of its small diameter fittings. This was achievable by reducing the casting wall thickness to the minimum allowable thickness as specified in the standards and eliminating any unnecessary metal. To ensure the casting maintains its integrity and lifespan, all product designs are subjected to computer aided quality tests.

The site estimates that these improvements have resulted in an approximate reduction of 11-13% in melting energy and is on average melting 5 tonne less metal a day to manufacture the same amount of product.

The use of **filters** to strain molten metal ahead of casting in non-ferrous foundries can also help to reduce casting defects and energy required in rework or excessive machining and finishing. The disposable ceramic filter is placed just ahead of the mould to reduce inclusions, flow velocity and turbulence. Some foundries are now using a direct-pouring unit which consists of a cup with an integrated ceramic foam filter so everything from the sprue to gate is replaced by one unit that can deliver the metal efficiently while removing inclusions and regulating the stream.[17]

This series of fact sheets provides examples and suggestions to the modern foundry operator on how to achieve both economic and environmental benefits from eco-efficiency. Visit the project website www.ecoefficiency.com.au for more ideas and case studies.

16 USA Department of Energy 2001, Models Ensure Lighter Weight Chassis Components with Fewer Defects www1.eere.energy.gov/vehiclesandfuels/pdfs/success/castlightmetals3_21_01b.pdf

17 Foundry Management and Technology, 2007, Direct Pouring is Indispensable for Competitiveness www.foundrymag.com/feature/feature/49995/direct_pouring_is_indispensable_for_competitiveness

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