FOUNDRY INSIGHT
Improving Performance in Production
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MOLTEN METAL PUMPS IMPROVE PERFORMANCE OF ALUMINIUM REVERBERATORY FURNACES

In today's difficult economic environment it is more important than ever to operate at the highest possible efficiency. Here, Paul Campbell, International Sales Manager, Metaullics Systems Division, Pyrotek Inc. explains that molten metal circulation technologies have evolved over the years to a point where they have become essential for efficient and consistent molten aluminium processing in reverberatory melting and holding furnaces. One of the most important results from forced circulation is product quality. While the economic benefits of quality can be difficult to quantify for a specific operation, the benefits of improved productivity, reduced cycle time and better thermodynamics can be readily translated into dollar savings.

In many large facilities, the conventional means for melting and holding aluminium is a gas-fired reverberatory furnace. In this arrangement, radiation from the burners, roof and sidewalls heats the bath and solid charge. Forced convection through stirring or pumping overcomes a number of process limitations. Without forced circulation, the concentration of heat at the bath surface readily produces undesirably high temperatures. The high heat flux generated by direct radiation at the bath surface is typically much greater than conductive and natural convective forces, which distribute the heat through the bath. Temperature differentials in an ~3 foot (900 mm) deep bath with a clean surface and without forced convection can typically reach 50–85°C from top to bottom. Without effective heat transfer to the metal, other quality and furnace performance factors will be less than optimum.

Pyrotek is the leading supplier of molten metal pumps to the aluminium industry. The company's Metaullics Division has been providing centrifugal molten metal pumps to the aluminium industry since 1950. Recent developments have improved reliability and performance, extending the life of many components to more than a year. The EMP Division of Pyrotek, on the other hand is the leading supplier of electromagnetic pumps for circulating aluminium reverberatory furnaces. EMP pumps feature no moving parts and therefore require very little maintenance.

The major benefits of forced convection include reduced metal temperature stratification in the bath; improved melting rates, enhanced metal quality through alloy homogeneity, reduced energy consumption as a result of improved heat transfer; longer refractory life; less dross formation, and therefore lower furnace tending requirements, and easier and more accurate alloy adjustments. Today, centrifugal pumps are employed in the majority of forced circulation systems on reverberatory furnaces in the USA. During the last four years, a number of these pumps have been installed in China making it today's fastest growing market. EMP pumps are widely used outside the USA, including several installations in China.

REDUCED TEMPERATURE STRATIFICATION

EMP pump and charge well on tilting furnace

Bath temperature is a key factor that impacts overall product quality. Forced circulation improves bath product quality by insuring the bath temperature will be consistent throughout the furnace. Typical temperature variation from top to bottom in an uncirculated, ~3 foot (900 mm) deep furnace is 50–85°C. Circulation can reduce this differential to 3–7°C. Circulation ensures that the temperature of the metal exiting the furnace is virtually the same as that indicated by the furnace thermocouple. Production parameters can be set and more easily controlled when the metal delivered is at a constant temperature.

INCREASED MELT RATE

Constant circulation of the furnace will increase the melt rate of the furnace as well as improve the thermal profile. The high velocity stream from a circulation pump will increase the melt rate of large submerged solids in the furnace. Insulating boundary layers of molten metal that are formed around large solids as they melt are swept away by the hot metal stream.

In a five-month study of a direct charge furnace in a billet casting process, a circulation pump produced more than a 10% reduction in the time required from charging to tapping the furnace. Cycle times increased between 8.1–20.6% when the pump was not in operation. Charging time reductions of 25–50% have often been observed in side well furnaces when a pump is used, and a major U.S. manufacturer of foundry

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furnaces estimates that the melting capacity of their furnaces will increase by 10–15% when forced circulation is added.

ALLOY HOMOGENEITY

Without forced circulation, alloy additions must be stirred in mechanically to ensure uniformity and this must be done through an open furnace door. But, since mechanical stirring is done over a relatively short period of time, it is difficult to insure that the alloy is mixed uniformly throughout the furnace. When a stirring device such as a pump is used, alloy elements are constantly mixed with the rest of the metal in the furnace. In a typical application, the volume of metal in the furnace passes through the pump every 5 to 10 minutes. Since the pump is operated 24 hours per day, samples taken from any point in the furnace will show uniform chemistry.

One other consideration with foundry alloys is the formation of sludge. This is an iron-chromium-manganese compound that precipitates out of the metal if the temperature drops below a critical point. With a temperature differential of 50–85°C between the top and bottom of the bath, it is easy to see how the metal at the bottom of the bath can cool below the critical point if the furnace temperature is monitored and controlled by a thermocouple located near the top of the bath. Continuous circulation allows for accurate temperature control and the avoidance of sludge formation.

REDUCED ENERGY CONSUMPTION

Constantly stirring the furnace allows heat to be removed from the surface to the rest of the bath by convection. As heat flows more efficiently away from the surface of the bath, the bath surface temperature is reduced. The rate in which energy is transferred into the metal is dependent on the difference between the surface temperature of the metal and the temperature of the heat source, to the fourth power. As the surface temperature drops, the temperature differential between the refractories and the metal increases, which translates into much higher heat transfer rates. Since stirring occurs during the melting process and with the doors closed, energy that would have been lost out the door when the bath is stirred manually is saved. Additional savings are possible from the elimination of through the door fluxing operations if the circulation pump is equipped with gas injection capability.

T-35SD circulation pump in side well furnace

Actual furnace efficiency improvements vary from operation to operation. Experience has shown that a minimum of a 15% improvement can be expected. A 25–30% improvement is possible depending on the furnace.

LONGER REFRACTORY LIFE

By reducing the metal surface temperature, more heat is transferred to the metal and less is absorbed by the refractory. Roof and exhaust flue temperatures are usually reduced by 80–115ºC with constant circulation. These lower operating temperatures translate into longer refractory life. Lower temperatures will also result in less corundum formation at the metal line. Less build-up means less need for mechanical cleaning and therefore less opportunity for refractory damage from cleaning tools.

DECREASED DROSS FORMATION

Another aspect that should not be ignored is melt loss. Oxidation of aluminium increases with temperature, and above 775°C the oxidation rate rises quickly. Reducing the bath surface temperature can significantly reduce the rate of dross formation. Minimising surface agitation with submerged circulation removes another cause. While not widely documented, the typical dross reduction inside the furnace when using a centrifugal pump is about 0.5%. Based on a conservative figure of 0.25%, a foundry that melts and casts 500 t/month of aluminium would save the replacement cost for 1,250 kg of metal every month.

T-45CGI gas injection pump

EASIER ALLOY ADJUSTMENTS

By providing continuous forced circulation, alloy additions and adjustments are easier to control. Silicon and other alloy additions go into solution much faster when exposed to the discharge stream of a pump. Since the bath is homogeneous, metallurgical samples taken at any point in the furnace will accurately represent the alloy in the furnace. This makes it easier to calculate the correct weights of any necessary alloy additions.

BENEFIT OF INCREASED FLOW

Historically it was considered sufficient to circulate the volume of the furnace three to four times per hour. Recent computer modeling of a furnace showed that increasing the circulation rate to seven turns or more per hour had a significant

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positive impact on the melting rate of the furnace. Subsequent tests on actual furnaces showed melting rate increases of between 7–17% when circulation rates were increased from traditional levels to more than 10 turns per hour.

CONCLUSIONS

While some production parameters may be difficult to fully quantify, it is clear that forced circulation in reverberatory furnaces improves many key aspects, which affect the total process. Forced circulation has been demonstrated to reduce energy consumption by 15–25%, extend refractory life, improve recovery rates by a minimum of 0.25%, and reduce melt cycle times by 10–50%.

Quality improvements are difficult to quantify, but the benefit to having a uniform temperature and chemistry during casting is real and will certainly result in better control of the process and end product.

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