Optimizing Sidewell Furnaces through Mathematical Modelling

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Abstract

Energy requirement for aluminum production through recycling is much less compared to the primary aluminum production, starting from the raw materials. Recycled aluminum is melted in different types of furnaces. For the recycled beverage cans, sidewell furnaces are commonly used. These furnaces have a side well (where the name comes from) in addition to the main chamber. The chips (shreds) are fed to the side well. Melting is carried out through the energy provided by the metal circulating between the two parts of the furnace. Such furnaces have been analyzed using various mathematical models to optimize a number of geometrical and operational parameters. In this article, the modelling tools used for the optimization of the sidewell furnace will be explained, and the results of a number of cases will be presented.

Keywords: Sidewell furnaces, mathematical modelling, aluminum cans, aluminum re-melting, aluminum recycling.

1. Introduction

Energy conservation and environmental protection incentives promoted recycling in many areas in the last few decades. In aluminum industry, recycling always had a strong presence and has become an important component of the overall production [1-2]. There are many advantages in recycling: conservation of natural resources, reduction in waste and pollution, lower energy costs, and consequently lower production costs.

Beverage cans constitute the most important category of recycled material in quantity and quality in aluminum industry. The cans are shredded and fed to a unit where the oil and paint are removed by burning off. Then the shreds are melted and treated in various furnaces for alloy preparation and casting. The recycled alloy composition is not far from what is needed in the final product. Such a high alloy quality makes the metal treatment easier and cost-effective. The energy consumption for the production of cans from recycled material is about 5 % of the energy consumption if the cans are produced starting from the ore (bauxite).

Many different types of furnaces are used for melting and treating the metal. The sidewell furnaces are commonly used for shred melting. These furnaces consist of two sections: a main hearth and a side well from which the name "sidewell" is derived (see Figure 1). The liquid metal circulates between the main hearth and the side well through two arches located in the wall, called hotwall, separating these two sections. The advantage of sidewell furnaces is to be able to melt shreds continuously by feeding them into the side well as opposed to conventional furnaces where the furnace operation has to be stopped in order to feed the charge into the hearth. There is also an impeller in the side well where the shreds are fed which provides a quick submergence minimizing the oxidation of aluminum alloy. The main function of the impeller is the submergence of shreds; however, it also provides some circulation between the main hearth and the side well through the arches [3]. It is important to position the impeller properly to maximize this circulation. In some furnaces, there is also a pump in the main hearth directed towards the inlet arch where the metal enters the side well from the main hearth [3]. The pump increases mixing of the liquid metal in the main hearth as well as the circulation to the side well.

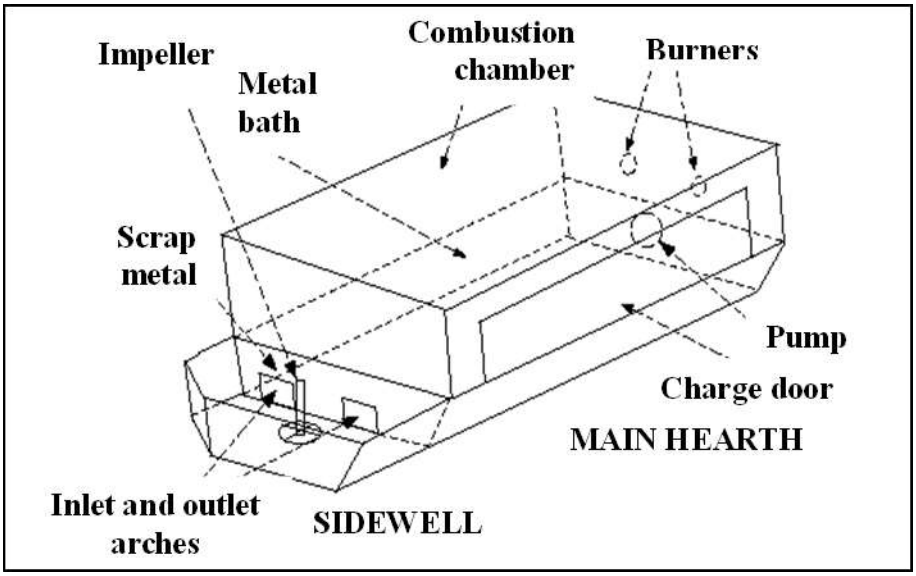

Figure 1. A schematic diagram of a sidewell furnace.

The combustion chamber provides the heat necessary for maintaining the liquid at a certain temperature and melting the solids. Usually, regenerative burners are used in sidewell furnaces to preheat the combustion air. This is important for energy conservation and improved heat transfer in the combustion chamber. A controller ensures that the liquid metal is maintained at a certain temperature level and the refractory temperature does not exceed a certain value to prevent refractory failure. The fuel flow rate is controlled as a function of metal and refractory temperatures as well as air flow rate. Even though a vast literature is available on furnaces in general, publications on sidewell furnaces are limited [3-11].

It is important for the recycling industry to lower the cost and to increase the productivity. Sidewell furnaces are an important part of the recycling plants, and their operation has to be improved. A project was undertaken to develop modelling tools for this purpose. The modelling work is complemented by physical modelling and plant trials for model validation and testing.

2. Mathematical Modelling of Sidewell Furnaces

A sidewell furnace consists of a side well and a main hearth which includes the combustion chamber. From the mathematical modelling point of view, it is better to divide it into two parts as follows: liquid metal bath and combustion chamber. Liquid metal bath covers the metal in both the side well and the main hearth. These two parts have completely different properties (physical, thermodynamic, etc.), and it is much easier to model them separately. The modular approach is very important in modelling. Separate models were built for the liquid metal and the combustion chamber. Then they were coupled through an interface located at the surface of the metal bath in the main hearth. The modular modelling also has a great advantage if only one part of the system is to be studied. The model of interest can be used exclusively by imposing appropriate boundary conditions on the surface where the interface is located. In this project, different models were developed to study different aspects of sidewell furnaces.

Different modes of heat transfer are important in different sections of the furnace (see Figure 2).

validated using data from the water model and the plants. All the model predictions were in good agreement with the laboratory and plant data.
The results of the models showed that:
(a) The dimensions of the different geometrical components of the furnace could be optimized using these mathematical tools. The impeller has also an optimum position. The circulation rates decrease when it is moved away from that position.
(b) The presence of a baffle has a strong effect on metal circulation rates. It is important to have reasonable metal circulation rates between the side well and the main hearth as well as reasonable levels of mixing in the main hearth. The heat transfer depends strongly on these variables. Good mixing and circulation rates result in improved heat transfer efficiencies which would lead to energy savings or increased production.
(c) The preheating of the solids fed and the combustion air increases the furnace efficiency. Air preheating can be realized relatively easily using regenerative burners. The maximum refractory roof temperature should be set as high as physically possible. It creates great potential for increased production.
(d) Thermocouple locations (both refractory and metal) are very important for appropriate temperature readings as well as proper control of the furnace.

5. References

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