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Online estimation of electric arc furnace tap temperature by using fuzzy neural networks

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Abstract

Industrial factories require continuous analysis and reengineering over its production processes but always keeping a severe control of material costs and operation emissions. In the past electric steel mills have been subject of some operation models developed in order to improve the control of the arc furnace by means of mathematical techniques and, later on, with finite elements technique (FEM). However, these models have not reached the expected results and applicability. In this case, a model has been developed that allows improving the control through a better prediction of the final temperature and, as consequence, to reduce the consumption of energy in the electric arc furnace. Required information for this new model will be obtained gathering knowledge collected up from data obtained of a certain electric furnace and also considering the plant operators and technicians experience. The model has been constructed by using neural networks as classifier, and with a final fuzzy inference function to return a predicted temperature value.

Keywords: Energy consumption; Electric arc furnace; Neural networks; Fuzzy inference function; Temperature prediction

1. Introduction

Nowadays there are two main industrial processes to produce steel. The first one, which is known as integrated steel plant, produces steel by refining iron ore in several steps. This ore-based process uses a blast furnace. The other one, steel-making from scrap metals involves melting scrap metal, removing impurities and casting it into the desired shapes.

Although originally the steel production in the electric arc furnaces (EAFs) was applied mainly to the special steel grades, the situation has changed with taps size increase and the high productivity that has been reached progressively. This has allowed significant cost reduction, diminishing consumption of energy, electrodes and refractory. At present, electric furnace combined with secondary metallurgy allows to make a very important part of the worldwide steel production on the basis of the massive recycling of the iron scrap. In fact, the share of electric furnace steelmaking technology has reached 33% in world crude steel production and this trend continues although permanently altered by international scrap market. This trend is due of both the capability of this route to produce steel at low cost per unit and to constant improvements in steel quality. According to several studies (Birat, 2000), in an immediate future this tendency will remain, predicting an increase from present 33% to 40% by the year 2010 (Table 1).

1.1. Electric arc furnace process overview

EAFs are used to melt scrap by means of electric energy and oxygen. Production of steel from scrap can also be economical on a smaller scale. EAF technology is most often used within steel minimills, whose basic design includes one or two EAFs, a continuous casting and a rolling mill. EAFs produce steel by melting scrap using electric supply as the main energy source. Scrap is generated from the scrapping of capital equipment or as a by-product of the steel-making process. Small quantities

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of direct reduced iron and pig iron are used as scrap substitutes or in the higher quality steel. By oxygen blowing, the concentrations of carbon and silicon can be reduced, while providing an additional energy source.

The EAF operating cycle is called the tap-to-tap and starts when the furnace roof is initially open allowing to charge the scrap. The solid scrap is charged on top of liquid steel (a ''hot heel''), which was retained from the previous tap. Then electrodes are lowered into the furnace and the heat melts the charge due to electric resistance of the metal and radiation from the arc. Then electrodes are moved down into the furnace and the heat melts the charge due to electric resistance of the metal and radiation from the arc. Chemical energy is also supplied to melt the furnace charge. Oxygen is blown into the molten steel through one or more lances.

The meltdown period is followed by another period in which the impurity levels in the melt are decreased. Also in this period the foamy slag layer is formed and its function is to absorb those impurities (adding lime and dolomite to modify its composition) and to shield furnace walls. Foaming occurs by injecting graphite into the slag layer and due to gas bubbles moving through.

Once the scrap charge is fully melted, flat bath conditions are reached. At this point, a tap temperature and a steel sample are taken. Once the expected steel composition and temperature are achieved to further processing (secondary steel-making) the tap-hole is opened, the furnace is tilted, and the steel poured into a ladle.

Table 1
Steel production prevision

	2000	2010
World steel production (MTm/year)	760	850 (+20/−30)
BOF (basic oxygen furnace) (%)	57	50 (+5/−0)
EAF (electric arc furnace) (%)	33	40 (+5/−0)
Another processes (%)	10	5.5 (+5/−0)

1.2. Improving EAF productivity

In a complex industrial system as an EAF, the ways to improve this process are diverse, such as selection and treatment of materials, the redesign of the facilities and new kinds of energetic contributions to the process. The evolution of electric furnaces is reflected mainly in the progressive reduction of specific consumption of energy, tap-to-tap times (Fig. 1) (Astigarraga, 1998) and improvement of the metallic yield.

A deep study, comparing energy consumed currently in the production of steel with theoretically needed energy, was made by the Carnegie Mellon University (Pittsburg, USA) for the US Department of Energy (Fruehan et al., 2000). Though the direct comparison of different EAFs is difficult due to the operational differences, the disparity between the theoretical energy and the consumed energy contributes to the idea of potential improvement of these

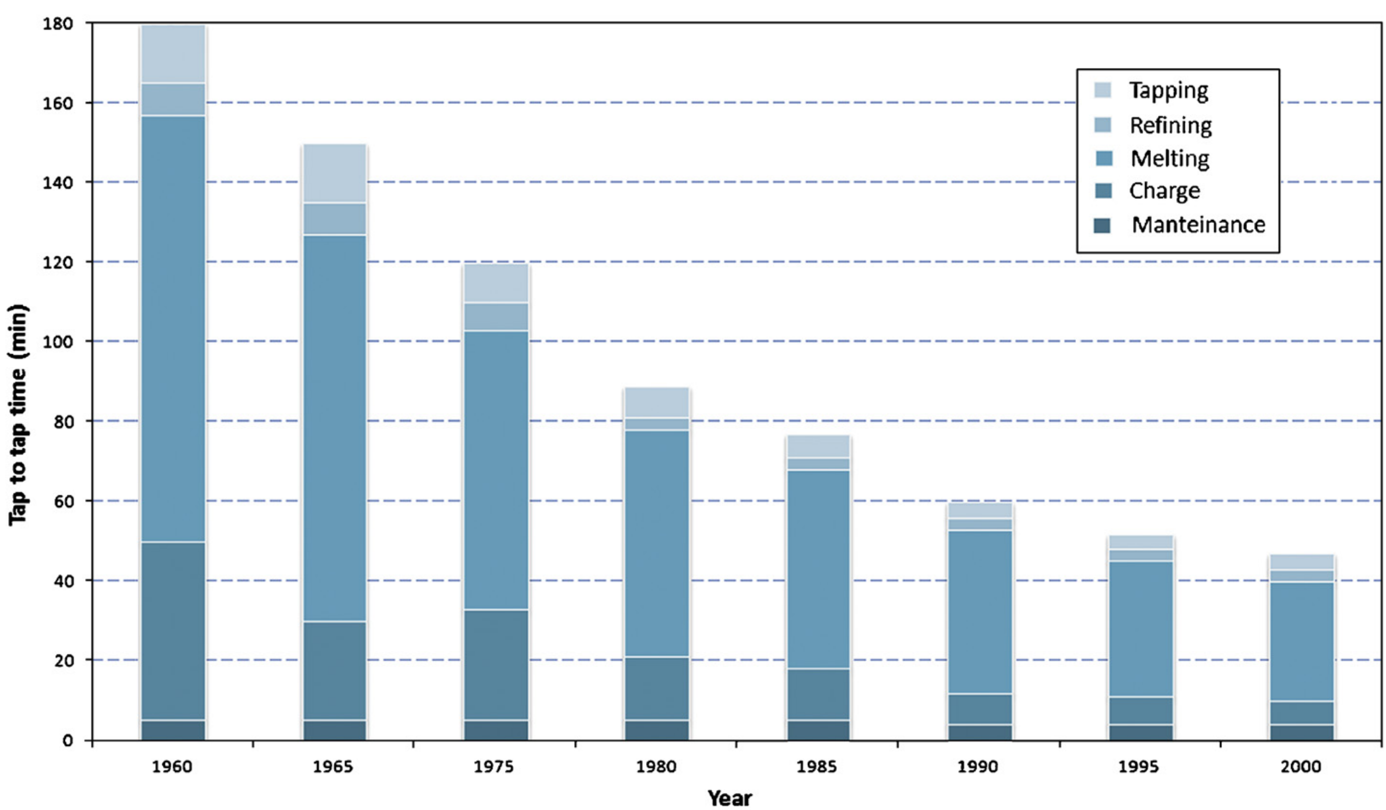

Fig. 1. EAF process time evolution.