INFLUENCE OF THE TECHNICAL PARAMETERS OF OUTSIDE-THE-FURNACE TREATMENT ON REFRACTORY WEAR IN THE SLAG BELT OF FURNACE-LADLE TYPE UNIT LADLES

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Experience in the service of furnace-ladle-type unit ladles has shown that the refractory life in them is very low in comparison with other types of units for outside-the-furnace treatment of steels as the result of the more severe service conditions [1-3]. Therefore, to increase the ladle refractory life it is insufficient to only have refractories with higher service properties but it would also be desirable to determine the influence of the technical parameters of steel treatment on refractory wear for the purpose of optimization of treatment conditions. It was established that these parameters are the chemical composition of the slag, the length of treatment, and the length of vacuum treatment [1, 3].

A study of the combined influence of these parameters on refractory wear under laboratory conditions is very difficult since on a model it is practically impossible to reproduce the actual service conditions of refractories in a ladle. In addition, the methods of studying the influence of technical factors on refractory wear used until the present have made it possible to determine the action of the slag only as the combined action of its constituent oxides. It was impossible to reveal the influence of each oxide individually or of a group of oxides. It was also established that an increased manganese oxide content promotes corrosion of the refractories, but not always, and that the corrosiveness of the slag is determined to some degree by its basicity [4-7].

Therefore, there is special interest in processing of data accumulated in normal operation of the unit. It is natural to process the data by methods of statistical analysis,* particularly with the use of step-by-step regression [8]. However, selection of the quantitative characteristic of wear is complex.

According to the generally accepted method, the wear of refractories is determined as the difference between the initial and the remaining thickness of the refractories at the completion of the ladle campaign, that is, after treatment of several frequently differing heats. With this method it is impossible to determine the influence on refractory wear of the treatment technical parameters either of each heat individually or in different periods of it.

Since the treatment technical parameters change from heat to heat and even in the course of a single heat, determination of the functional relationships of refractory wear to these parameters by methods of statistical analysis is possible only with a method providing measurement of refractory wear during each heat. Taking this into consideration the change in magnesium oxide content in the slag during the course of a heat was selected as the criterion for evaluating refractory wear in the slag zone of the ladle. This choice is based on the fact that periclase-chromite refractories containing about 60% MgO are used in the lining of the ladle slag zone while, with the exception of lime with an MgO content of 1-2%, MgO is present in not one of the heat-forming and deoxidizing components added to the ladle for outside-the-furnace treatment. Consequently, an increase in magnesium oxide content in the slag during the course of the heat may be taken as a qualitative characteristic of the wear of the periclase-chromite refractories.

In this investigation statistical material accumulated from the moment of start up of a unit in 1977 was processed. The course of treatment of more than 300 heats of steel was

*The calculations were made by M. F. Gurari.

studied. The slag band of the ladles is lined with periclase-chromite refractories of a single type with a maximum silica content of 0.5%. Since a statistical analysis makes it possible to take into consideration any number of factors in this work, the problem was set up of attempting to determine the influence of each oxide of the slag and of the most variable factors - the time of vacuum treatment and the total time of treatment of the heat. The remaining technical parameters (metal temperature, length of heating, etc.) vary relatively little from heat to heat and there was no reason for expecting any conclusions from a statistical analysis of their influence.

Tables were set up in which the change in MgO content in the slag ($y$) was the function and the independent variables were the contents of the constituents of the slag $FeO_m(x_1)$, $CaO(x_2)$, $SiO_2(x_3)$, $Al_2O_3(x_4)$, and $MnO(x_5)$, the $CaO/SiO_2$ ratio ($x_6$), the length of treatment of the metal ($x_7$), and the vacuum treatment time ($x_8$).

In the first stage the data characterizing the course of the production operation was subjected to preliminary analysis with determination of the boundaries of variation, the average values, and the standard deviations of the recorded variables (Table 1) and construction of histograms.

An analysis of the histograms showed that all of them have a well-expressed single-maximum form and are quite close to symmetric. As a first approximation this makes it possible to assume normality of distribution of the recorded factors. In this case, as is known [9], the presence of a linear relationship between the increase in the quantity of MgO in the slag and the other factors must be expected. Therefore, with the use of a program for the construction of a step-by-step regression on an ES-1020 computer it was attempted to calculate a first-power equation. However, in operation of the program not a one of the factors was included and the equation obtained was not significant (at a significance level of 0.05), that is, the coefficients with the variables $x_1$, $x_2$, ..., $x_8$ taking into consideration the randomness of the measured values of the independent variables and the function could not on a sound basis be considered to differ from zero. The residual standard deviation, equal to 92.4, was practically no different from the standard deviation obtained in preliminary processing and equal to 103.4.

This result normally means independence of the increase in the quantity of MgO in the slag from the measured parameters.

Since there is no doubt as to the action of the slag on the refractories, it must be concluded that not the factors considered alone but certain combinations of them influence the wear. Determination of them is important for practical reasons since this would make it possible to reduce the corrosive action of the slag on the refractory by regulating the quantity of the less significant components of the slag without reducing the quantity of the significant ones from the point of view of their refining capability.

It is natural to again use step-by-step regression. However, existing programs make it possible to construct only relationships of polynomial form while the true relationship may have another form. Therefore, in determining the combinations step-by-step polynomial regression is used not as an accurate quantitative instrument but heuristically. If the equation is higher than the first power it will include the products of several factors and