ABSTRACT

A detailed mathematical model for the cored wire injection process has been developed for the addition of low-density alloys like calcium alloys into the steel bath. The calcium recovery in the wire injection process is relatively higher than that in the conventional and some other improved addition methods like shooting bullets, 'pouring over' etc. Factors such as minimum interaction with the slag, reduced liquid steel movement, possibility of suppressing the premature evaporation and, thereby, improving utilisation, possibility of preheating the filling material before release and simple and inexpensive operations have given an edge to this method over the others. To realise these benefits, however, it is imperative that the filling material is released at such a depth in the ladle that the resultant residence time is the highest. This work presents an understanding of the dissolution mechanism developed through a numerical approach and thereby suggests modification in the operating and the

design parameters to increase the depth of penetration before the release of the powder.

Prior to the present study, only three independent investigations, on the melting behaviour of cored wire in steel bath, have been reported. All these studies aimed to predict the depth of the ladle where the wire melts and releases the filling powder through mathematical modelling. In none of these studies neither the investigators could present a sufficient detail of their mathematical formulations nor did they come out with a definite guideline for wire injection at different conditions of a steel melt shop. Besides, the formation of a thermal contact resistance and the freezing of the slag on the wire surface have been considered for the first time in a study of cored wire dissolution.

The steady state heat conduction equation for the temperature distribution inside an infinite cylinder has been modified to suit the cored wire injection process. Finally, a one-dimensional unsteady-state heat conduction equation with respect to a moving observer has been obtained and solved in multi-zone domain. Several boundary conditions applied in this model allow the melting or solidification of frozen shells of slag, steel, wire casing, and powder material. The model equations were solved using implicit control volume approach. Model predictions were verified rigorously with simplified analytical solutions, published work and laboratory investigations on the dissolution of static metallic cylinders in quiescent/inductively stirred steel melt. The model was also validated with the plant data with a rather indirect and innovative way.

With reasonable validation obtained, the model was run for several conditions to develop an understanding of the melting behaviour of cored wire. The results were analysed and the different routes of melting have been grouped into four broad categories. Mainly the presence or absence of slag at the ladle top and the bath superheat dictate these melting behaviours. A unique feature of secondary steel shell growth during wire melting route has been identified in presence of slag layer over the liquid steel bath. The effect of design and operating parameters on the melting behaviour of wire which have clarified from the present study are:

a) It has been demonstrated that there exists an optimum speed beyond which increase in speed lowers the distance travelled by the wire
b) It has been observed that the melting of cored wire is more sensitive on the casing thickness than on the wire diameter
c) The dependency of the injection process on the grade of steel to be processed has been assessed. It has been explained why for a low carbon heats the wire penetrates a smaller distance in the steel bath with subsequent lower recovery in calcium. Similarly, it has been shown that for high carbon heats the wire will penetrate relatively larger distance in the melt.
d) Based on several plant trials a nomogram has been made to identify the wire dimensions, speed of the wire for various grades of carbon steel to derive the maximum benefit of cored wire injection.