LADLE METALLURGY USING THE SCANDINAVIAN LANCERS SYSTEM

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INTRODUCTION

The Scandinavian Lancers Ladle Injection Metallurgy System is a metallurgical process that was developed jointly by the Scandinavian steel industry and MEFOS, a foundation for metallurgical research located in Sweden. The development work was initiated in 1972 with MEFOS studying the fundamental principles of ladle injection. Considerable study was done on turbulence phenomena in agitated ladles, heat, mass and momentum transfer. Once the fundamental principles were understood, laboratory tests were conducted in 6-10 ton heats to evaluate the metallurgical results of injecting various powders. At this point the test work was moved to producing plants to determine that the theory and laboratory results could be obtained under actual operating conditions.

Early in 1977 the marketing of the injection system was initiated outside Scandinavia and Scandinavian Lancers AB, a company located in Hoganas, Sweden, was formed. The marketing outside Scandinavia is today mainly handled by Lancers Inc. B.V. and ScanLance Inc. At present almost forty SL plants have been or are being built throughout the world. The Scandinavian Lancers Ladle Injection Metallurgy System is used in the steelworks in duplex with arc furnaces, BOF and OH furnaces to achieve increased productivity, desulfurization, improved cleanliness, slag inclusion shape control, improved fluidity and castability, alloying accuracy and efficiency.

This paper describes the Scandinavian Lancers System and its application in steelmaking.

DESCRIPTION OF THE SCANDINAVIAN LANCERS LADLE INJECTION METALLURGY SYSTEM

A typical SL installation is shown in *Fig.1 and includes the dispensing station, control panel, lance mast, ladle cover and stand and lance magazine. The dispensing station consists of a structural frame which contains or supports the powder dispenser, powder containers, filter and automatic screening device.

* *Figures not received*

A schematic diagram of the system is shown in Fig.2. One of the advantages of the system is the buffer container, filter and receiving powder container. This circuit gives the ability to perform dry runs in order to determine the precise transport parameters of various powders or different lots or batches of the same powder. In dry run tests the transport parameters, i.e. pressures, gas flow rates and powder flow rates are established under conditions identical to the actual injection. It also permits the dispenser to be emptied without blowing powder into the surrounding area. The buffer container permits fast decompression of the dispenser when refilling. During actual injection this circuit is not used and the fluidized powder flows from the dispenser to the ejector and is carried through the transport line to the lance.

The majority of the Lancers installations now in operation are of the single-container system type. As production experience was gained, the desire for increased flexibility was realized. Therefore a multi-container system was developed that would permit the injection of a number of powders without changing powder containers or tube systems. An example of the need for such a system could be a producer who wants to desulfurize and also to recarburize or make trace element additions such as boron. This is referred to as "sequence injection", whereby the powder for desulfurization is added during the first part of the injection and the other powders are added during the last few minutes of the injection. Typically the system is built for four containers; however, it should be noted that the number of powder containers can be varied from two to as many as five or six. The weights of the various powders to be injected can be selected from the control panel. A further development of the system is the multi-container/multi-dispenser system.

Figs.3,4 and 5 show photographs of SL plants at Sandvik AB and Avesta Jernverks AB, Sweden.

It was soon realized that a special injection lance had to be developed. Ordinary lances with fireclay sleeves and a single nozzle in the bottom did not stand up to the severe erosion during injection and they lasted only for one injection treatment. Furthermore, they demanded a considerable freeboard in the ladle to avoid splashing of steel due to lance swinging. The new Lancerex^R monolitic injection lance, Fig.6, is supported from the ladle bottom during injection which eliminates all splashing problems and allows treatment in a ladle with a minimum of freeboard. The Lancerex^R lances last from ten to twenty injection treatments.

DESULFURIZATION

One of the major applications of ladle injection metallurgy is removal of sulfur with lime or calcium containing compounds. Depending on the amount of desulfurizer added, a desulfurization degree between 60 and 90 percent is achieved. A typical desulfurization curve is shown in Fig.7.

Certain precautions must be taken for a successful desulfurization. The steel bath has to be well deoxidized prior to injection. Moreover, the furnace slag has to be removed as completely as possible. Finally, a new synthetic slag is formed in the ladle by adding lime and fluorspar, preferably during tapping. Meeting these requirements it is possible to reach extremely low sulfur contents, below .005%.

INCLUSION SHAPE CONTROL

During hot working, soft inclusions are more or less elongated. These stringers seriously reduce the ductility in the transverse and particularly in the short transverse direction. This is especially true for flat products, where the phenomena of lamellar tearing is well known for heavy gauge plate. Even with the most careful checking of materials and the strictest supervision during the welding of steel plate, structures, fissures and cracks are likely to form in the vicinity of the welds. The boundaries between the steel grains and the inclusions can act as crack initiation points, when the plate is stressed through its thickness in connection with the cooling of the weld. A useful way of avoiding this problem is to use calcium injected steel products, in which the non-metallics have been given an almost spheroidal shape. There are also other applications where sulfide shape is important e.g. HSLA and boron steel in which excellent bending properties are a special feature.

Fig.8 reveals a pair of HSLA samples, sheared from plate in the transverse orientation. The 1/4 inch plate has a yield strength of 66 k.s.i., the 3/8 inch plate a yield strength of 64 k.s.i. The 1/4 inch plate was bent flat on itself using a 1/8 inch radius and the 3/8 inch plate was bent flat using a 1/4 inch radius.

CLEANLINESS

Cleanliness from non-metallic inclusions is for certain products a critical property i.e. hydraulic tube steel. In a Swedish steel plant the total production of this type of steel is now injection treated with CaSi to prevent the formation and facilitate the removal of inclusions larger than 10 microns. Before the use of injection only about 60% of the heats were applied to hydraulic tube application, but now the figure is almost 100%.

It is generally accepted that stirring with a controlled turbulence is advantageous for the separation of oxide inclusions. Hereby it is essential to prevent the formation of new oxides due to reoxidation from the surrounding refractory, slag and atmosphere. Out of these factors the leakage of oxygen from the atmosphere is the most difficult parameter to control. The SL system is designed and operated to minimize reoxidation but maintaining excellent conditions for slag removal.

IMPROVED FLUIDITY AND CASTABILITY

One aspect of injection treatment with calcium compounds is the positive influence on castability of Al-killed steel grades. Normally these grades are sensitive for nozzle blockage due to the formation of Al_2O_3-clusters. In continuous casting the teeming problems are further pronounced during sequence casting and casting of small sections. The standard practice to avoid these problems is to use nozzles of excess size, stopper rod regulation and shrouding the steel between ladle, tundish and mould. In spite of this oxygen rinsing is often necessary.

The injection of calcium compounds into the steel reduces the dendritic alumina inclusions into spheroidal inclusions of calcium aluminate or calcium oxide. The absence of alumina inclusions permits a lower teeming temperature and virtually eliminates the nozzle blockage problem. This has been confirmed by several users of SL plants.

ALLOYING AND TRIMMING

The injection plant is working in duplex with a primary furnace and practically all the alloying is transferred from the furnace over to the ladle unless there is a severe temperature restriction. Bulk alloys as FeSi, FeMn, FeCr are added into the ladle before tapping. During tapping of the steel it cannot be avoided that some of the bulk alloys are oxidized into SiO_2, MnO and Cr_2O_3 to be found in the slag. The subsequent injection treatment causes, however, a very good mixing between slag and steel. The reactions:

$$3\ SiO_2 + 4\underline{Al} \rightarrow 3\underline{Si} + 2Al_2O_3$$

$$3\ MnO + 2\underline{Al} \rightarrow 3\underline{Mn} + Al_2O_3$$

$$Cr_2O_3 + 2\underline{Al} \rightarrow 2\underline{Cr} + Al_2O_3$$

will proceed to the right and the overall recovery of the bulk alloys will be almost 100%. In fact if some slag is carried over from the furnace the recovery is higher than 100% because of reduction of oxides from the melting slag.

Some ferro alloys with a high affinity for oxygen are directly injected into the steel with the SL system to get a high recovery. Carbon can this way be added with a 100% recovery for trimming of the analysis which otherwise has to be done in the furnace. Micro alloys such as B, Nb, Ti are other metals that are preferably injected into the steel. For ferro alloys as Pb, Se, Te where the environmental problems are of great consideration the injection system provides a tool to handle the material as well as to add it with a high and consistent yield.

One great advantage with injection technology is the possibility to adjust the chemistry of the steel with a high precision after it has left the primary furnace. The number of heats out of specification decreases and enables the mill to operate with a smaller and more accurate stock.

INCREASED PRODUCTIVITY AND PRODUCTION ECONOMY

For a modern arc furnace shop a high productivity is essential and to achieve this goal the arc furnace is very advanced and often equipped with strong transformers, water cooled panels and roof, and oxy-fuel burners. All these equipment items are installed to increase the productivity and to shorten the tap-to-tap time as much as possible. Raw material costs are almost as important as the high productivity but unfortunately the cheapest raw materials are also the most contaminated. Until the concept of injection metallurgy was introduced the steel-maker had to find an economic compromise between productivity and raw material costs. He could choose the cheapest raw materials which would give him a high sulfur content in the steel at melt down and necessitate a two slag practice increasing the tap-to-tap time drastically. The other alternative was to choose more expensive raw materials giving a lower sulfur content at melt down and allowing a single slag practice. In some markets only the first possibility would exist due to a non-availability of good scrap. Instalment of an SL system gives the possibility to choose the inexpensive raw materials and still operate with a single practice.

TEMPERATURE CONTROL

The scatter in ladle temperature after tap is in most cases unacceptable, especially for conti-casting. Moreover, the temperature in the ladle rapidly becomes uneven. Homogenization and temperature adjustment are today a necessity for most plants and can easily be accomplished by adding cooling scrap during simultaneous gas stirring at the injection station. Many new SL stations are therefore equipped with two lances, one for injection and one for gas purging.

SUMMARY

The Scandinavian Lancers Ladle Injection System is used for a variety of purposes, all aiming at improving the production economy and the steel quality. With the SL system the steelmaker can operate arc furnaces with a single slag practice. Further the injection of calcium alloys improves the fluidity and castability of the steel. This makes it possible to cast aluminium treated steels through metering tundish nozzles with certain precautions. The bulk alloys added in the ladle give a high and consistent yield. Micro alloys with a high affinity for oxygen or with the risk of contaminating the environment are injected to improve the recovery and the metallurgical effects as well as to avoid handling problems. Finally the SL system is a good instrument for temperature control, most important for conti-casting and provides a possibility to adjust the chemistry from the primary furnace to minimize the number of heats out of specification.