

(3) Production Technology of Clean Steel (Miscellany)

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主題：二次精錬・連続鋳造分野の最近の進歩

(1) Simulation of Melt Flow and Inclusion Flotation in Continuous Casting Tundishes

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This presentation consists of two aspects of simulation of melt flow and cleanliness in tundishes. The first part deals with characterization of melt flow by a combined model which is normally used to analyze the residence time distribution of fluid in continuous casting tundishes. In this model, the fluid volume in tundish is considered to be consisting of the plug flow, well-mixed flow, and dead volumes. Although this model was proposed over 20 years ago, most researchers have either used it incorrectly or made an assumption in analyzing the melt flow in tundishes. Both approaches may lead to incorrect and misleading calculations of the dead volume. In this presentation, the combined model will be discussed and its correct application to tundish melt flow will be outlined. The second part of this talk deals with simulation of inclusion flotation in water models. The choice of model inclusion to water density and the model inclusion size needed for proper simulation of a given inclusion size in molten steel will be discussed. Thus, a procedure for flow characterization and

inclusion flotation and removal will be outlined.

(2) Prospect of Materials Processing Using Electromagnetic or Magnetization Force

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An Electromagnetic Processing of Materials, so called EPM which was born out of the rich association between Magnetohydrodynamics and Materials Processing has been developed in a worldwide scale during the last past years. EPM is spurred on success in various metals technology. Now EPM is going to face a new stage where a magnetization force instead of an Electromagnetic force is applied on not only metals but also electro non-conducting materials.

At first, as a typical example using the electromagnetic force, electromagnetic elimination of non-metallic inclusions is demonstrated in molten tin containing Al_2O_3 inclusions. A travelling magnetic field is imposed on the molten tin flowing through a tube with a small diameter in which the motion of molten metal is considerably so suppressed as to enhance the electromagnetic effect. Succeedingly, curious phenomena relating to the magnetization force are shown and possibility of the development of a new EPM is discussed.

(2) Production Technology of Clean Steel

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A new process was devised for promoting inclusion separation in the continuous casting tundish to produce high cleanliness steel. The process utilizes electromagnetic force to rotate molten steel in a cylindrical tundish. The centrifugal force caused by the rotational flow promotes separation of inclusions from the molten steel. This tundish is referred to as the Centrifugal Flow Tundish (CF tundish). In this study, the mechanism for separating inclusions from molten steel stirred with a rotating electromagnetic field was clarified in a hot model experiment. Subsequently, the application of this method to the removal of inclusions in the tundish were investigated in pilot plant test and industrial plant test. The results obtained are as follows.

- (1) The high deoxidation capability in the CF tundish results from the increase in the probability of collision caused by the large input of stirring energy and from the high concentration of inclusions in the vicinity of the axis of the rotating molten steel.
- (2) Industrial plant test carried out at Chiba Works showed that the CF tundish has the high deoxidation capability. The deoxidation rate constant was estimated to be $0.18\text{--}0.29\text{ min}^{-1}$. Total oxygen content in slabs with the CF tundish is reduced to about half of that with the conventional tundish.

As a result, it was revealed that the CF tundish was useful to the production of high cleanliness steel.

- (4) Toward the Creation of an Intelligent Billet Casting Mould

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We were content to publish our research findings on continuous billet casting in the open

literature, and organized short course to explain them to individual minimills on their turf. But most of the literature could not be read and once the lectures leave, the immediacy of the knowledge is diminished.

Developments in artificial intelligence and the personal computer led us logically to the next stage of technology transfer. The expert system focuses on the achievement of quality in cast billets and was designed to either teach the principles of billet casting and quality or to diagnose quality problem, much like a consultant. It promises to full a strong need for knowledge transfer.

The billet caster should be empowered with knowledge through an on-line expert system analyzing sensor signals from the machine and communicating with the operator on the state of billet quality and the health of the machine. Hence we arrived at the concept of the "smart" mould to maximize both billet quality and productivity for the enhanced creation of wealth.

This paper reviews the progress of our work, specially the development of the fundamental knowledge base, the creation of the expert system and the status of the smart mould. Comments are also made on the problem of the technology receptor capacity of minimills.

- (5) Continuous Casting of Hollow Billets

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As a near-net-shape casting of pipe, the continuous casting technology of hollow billets has been developed. A cylindrical water cooled copper mold with ultrasonic vibration generators was implemented as a core to make a hole at the center of round billet, while the IH (Induction Heating) type hot-top casting technique was applied in