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 0.18-0.29 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

order to keep the space for the submerged entry nozzle at the casting of the tube blanks of thin wall thickness.

Hollow billets, 160mm in outer diameter and 100mm in inner diameter, were produced by the pilot caster followed by performing a set of metallurgical investigations and theoretical analyses.

(1) The wall thickness of hollow billets is uniform due to the completion of solidification by the bottom end of the mold or the core.
(2) The stable drawing and the sound internal surface quality can be achieved by imposing ultrasonic vibration which reduces the friction force between the core and the shell.
(3) The solidification start zone in the IH type hot-top casting has a distribution of fraction solid which is periodically compressed by the mold oscillation to stabilize the initial solidification.
(4) The solidification structure of hollow billets has a high equiaxed crystal ratio and no macrosegregation of solute elements. As a result of solidification analysis, it is clarified that high ratio of equiaxed structure is also one of the major effects of IH type hot-top casting.

(6) High Speed Slab Caster

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Tensile strength of solidifying steel shells of different carbon content (0.004 to 0.70 mass%) has been measured by two methods, which are a *in-situ* measurement similar to Ackermann and Kurz's "Submerged Split Chill Tensile" (SSCT) test and a hot tensile test with temperature gradient, which one side of a specimen is heated to its solidus temperature and other side is cooled like solidifying shell in a casting mold. The tensile strength of shells obtained by the two methods has a good agreement at elevated temperatures. Frictional force between the shell and the mold wall can be calculated from the previously developed lubrication model. The upper limit of casting speed can be predicted by comparing the tensile strength with the frictional force and may be dependent on carbon in steel.