METHOD OF CONTROLLING MOLTEN METAL-HEIGHT IN CONTINUOUS CASTING

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Related U.S. Application Data

References Cited
UNITED STATES PATENTS
3,457,985 7/1969 Wilson 164/64 X
3,537,505 11/1970 Thalman et al. 164/4

FOREIGN PATENTS OR APPLICATIONS
173,807 1/1953 Austria 164/154

ABSTRACT
A method of controlling the height of molten metal in a continuous casting system of the type having a mold unit having a generally vertical, integral and electrically conductive form, which form defines a shaping surface into which form molten metal is poured and from which form a continuous billet is produced, and a cooling jacket about said form in which an electrically conducting coolant is circulated from which unit a continuous billet is extracted by a drive system therefor, comprising the steps of: providing an inductance level detector; positioning the detector in said jacket adjacent to but outside of the form; developing a time-varying magnetic field employing the inductance level detector positioned within the mold jacket and adjacent to the core; sensing the magnetic field strength of the detector as affected by the height of molten metal in the form, and controlling the drive system to counter changes in the level of molten metal in the mold form so as to tend to maintain that level at or about a predetermined desirable level.

1 Claim, 3 Drawing Figures
METHOD OF CONTROLLING MOLTEN METAL-HEIGHT IN CONTINUOUS CASTING

This is a divisional application of U.S. Pat. No. 3,421 filed Jan. now U.S. Pat. No. 3,670,801.

FIELD OF THE INVENTION

The present invention relates to a continuous casting mold level detection device and control system. More specifically, the present invention relates to a device and system for detecting and controlling the level of molten steel within a continuous casting machine of the type used for producing a continuous billet of steel from molten steel.

BACKGROUND OF THE INVENTION

In one commercial important process of continuously casting steel, a stream of molten metal is poured from a tundish box into a water-cooled mold. The steel is cooled sufficiently within the mold that it may be withdrawn as continuous billet. The level of molten steel in the mold is determined by the rate of flow of the molten steel from the tundish and the rate of withdrawal of cast billet by a drive system. The present invention concerns improved level detection and control in this environment. The position that a continuous casting machine may occupy in one particular steel mill is noted in the article entitled "Steel" by D. R. G. Davies in the McGraw-Hill Yearbook of Science and Technology (1969) at page 325.

Basically, a continuous casting mold functions to take liquid molten steel and to transform it into a continuous billet of steel by passing it through a water-cooled mold that forms it and cools its outer surface to a solid state. Thereafter, the continuous billet is further cooled and cut or sheared into individual steel billets. For a general source on continuous steel castings, reference could be had to the works: "The Continuous Casting of Steel in Commercial Use" by K. P. Korotnov, H. P. Mayorov, A. A. Skvortsov and A. D. Akimenko translated by V. Alford; "Continuous Casting of Steel" by M. C. Boichenko (1957) translated by L. Herdan and R. Sewell; and "Continuous Casting" D. L. McBride in the Proceedings of Technical sections of the Iron and Steel Division of the Metallurgical Society of the American Institute of Mining, Metallurgy and Petroleum Engineers (autumn, 1961).

It should be readily apparent that the working of such a product as molten steel is both extremely dangerous and difficult. In the case of forming it into continuous billet by the continuous casting method, it is desirable to maintain the level of the molten steel in the casting machine within fairly close tolerances. If the level is maintained too high as by pouring excessive amounts of steel in the machine, it may splash over causing loss of steel, perhaps damage to equipment, and possibly danger to the human operators. In addition, if the molten steel is too low in the mold it may have insufficient exposure to the cooling walls to solidify, again resulting in "breakout." This can occur at a point somewhat below the end of the mold as the continuous billet normally is harden or solidified at its outer surface and contains a molten core. Also if the steel is extracted too slowly or remains in the mold too long, the steel may harden too much making it difficult to handle in later stages or, in an extreme case, solidifying within the mold itself. To overcome the tendency of the molten steel to adhere to the sides of the mold or form, it is the normal practice to both add a lubricant, a special oil, at the top of the mold and to oscillate the mold fairly rapidly in the vertical direction. This rapid up-and-down movement, although improving the overall system, makes the problem of detecting and controlling mold level height more difficult.

The importance of maintaining a proper level in the mold has not been overlooked by those familiar with this industry. Complicated devices and complex and expensive machinery have been employed to detect and maintain the proper level. One presently used commercial mold level indicator and control uses a radioactive source such as cesium 137 sealed in a stainless steel capsule which is encased in Mallory 1000 metal for radiation shielding and, which in turn, is housed in a steel cabinet to protect the Mallory metal from molten steel splash-over damage. This source is positioned adjacent to but spaced from the mold, on one side thereof, to direct a beam of radioactive particles through the mold mechanism, its water jacket, the molding core itself, and any molten steel therein. A solenoid operated shutter mechanism is movable provided to interrupt the radiation beam, to provide safe access for the operating personnel around the radioactive source. The radiation is picked up by a detector unit comprising a solid state high-sensitivity radiation detector of the scintillation type encased in a separate water-cooled steel housing positioned outside of but adjacent to and spaced from the mold unit on the opposite side from the source. Normally, two detection units are employed for monitoring molten steel levels, one for normal operation and one for start-up. The signal from the detector is used to vary the rate of speed of the drive mechanism that removes the continuous billet from the steel casting mold.

Despite the shielding and precautions taken with this radioactive source, it has often proved to be unable to withstand the extreme environment in which it is used. It has been the experience of those practicing this steel making process that the occasional and unavoidable spills and splashes of molten steel have caused the radioactive detecting units to fail or be taken out of operation for repairs for extended periods of time. It has been found to be both expensive and time consuming to attempt to repair and maintain in operable condition such units.

When the units are disabled, the most widely employed alternative is human supervision. That is, a worker or operator in protective clothing and shielding is detailed to physically inspect the continuously changing levels of molten steel in the continuous casting machines and to vary the flow of steel to the machine and from machine, based upon his human judgment and vision. Needless to say, this environment, which is extreme for a shielded radioactive detecting system, is far from ideal for the human worker detailed to such a task. Indeed, it is not surprising to find that these workers often make errors in judgment resulting in less than optimum performance and malfunctioning of the continuous casting machinery.

Others have proposed alternative solutions to the problem of measuring and controlling the height of the molten steel within a continuous casting machine. One such proposal is found in a patent to J. A. Milnes, U.S. Pat. No. 3,204,460, for "Continuous System for Indicating the Liquid Level in a Continuous-Casting Mold or the Like" which patent was issued on Sept. 7, 1965.
The Milnes system employs a plurality of thermo-couples positioned within the walls of the continuous casting mold to judge or to indicate the temperature at various positions along its vertical expanse. Based upon the readings of these thermo-couples he arrives at a control voltage for the operation of the billet drive. While the Milnes patent appears to have certain advantages over the radiation system, it involves considerably reworking of the mold core to achieve the desired location and implantation of the thermo-couples either within the molten metal or within the walls adjacent thereto. As the core unit is normally made to be replaceable this requires a much more costly unit and increases the expense of operation. Furthermore, it requires additional preparations to provide for electrical inter-connection of thermo-couples and to provide for electrical insulation from the walls of the mold. Also any malfunction of thermal-couples would require extensive reworking of the mold core to be able to repair the malfunctioning unit. It is not known to the present inventors whether or not the Milnes suggestion was ever employed in a commercial continuous casting system or whether, if so employed, it proved successful or practical. The predominate presently used commercial system is, to the knowledge of the present inventors, the radioactive system described above.

While others have proposed inductive devices for the detection of material levels or continuous flow of material, because of the special problems involved no one has suggested, to the knowledge of the present inventors, the use of this type of detector in the present environment. A level detector using inductive effects is disclosed in U.S. Pat. No. 3,366,873 for measuring the height of a conductive material in a relatively non-conducting and non-magnetic vessel and environment. That detector measures directly the conductivity of the material within the vessel, which material is specified to be an apparently relatively low temperature molten metal. This is, of course, impossible in the environment of a continuous steel casting mold as the intervening necessarily high-conductivity material shields the molten steel from such direct measurement.

It is therefore the primary goal of the present invention to provide a simple and economical molten steel level detector and system for a continuous casting mold that requires neither extensive alteration of the continuous casting mold structure nor complex additional and dangerous equipment, such as a radioactive source and detector, or extensive equipment that must be positioned in the immediate vicinity of the mold.

It is a further more general object of the present invention to provide a molten metal level detector that is less complex than previous detectors.

**SUMMARY OF THE INVENTION**

In accordance with the present invention a method of controlling the height of molten metal in a continuous casting system is provided. The inventive method is for use with such systems which are of the type that have a mold unit with generally vertical, integral and electrically conductive form, to define a shaping surface to receive molten metal and shape it into billet. The surface is cooled by a cooling jacket in which an electrically conductive coolant, such as ordinary water, is circulated and the billet so formed is extracted by a drive system. The steps of the inventive method are providing an inductance level detector, positioning that detector in the jacket, adjacent to the form, developing a time-varying magnetic field thereby, sensing the field strength as affected by the height of molten metal and controlling the drive system to counter changes in the level of molten metal in the mold form so as to tend to maintain that level at or about a predetermined desirable level.

**BRIEF DESCRIPTION OF THE DRAWINGS**

The invention, together with further advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing, in the several figures of which like reference numerals identify like elements, and in which:

FIG. 1 is a block diagram illustrating a mold level detection and control system incorporating the present invention;

FIG. 2 is a perspective view partially cut away to show interior parts of a continuous steel casting mold, including inductive detector of the type that may be used in the system of FIG. 1;

FIG. 3 is a circuit diagram of the system of FIGS. 1 and 2;

**INCORPORATION BY REFERENCE**

Reference is hereby made to the "Brief Description of the Drawings," "Detailed Description" and "Operation of FIG. 3" portions of U.S. Pat. No. 3,670,801 (that is to Column 2, lines 50–75, and all of Columns 3, 4, 5, 6 and 7 and lines 1–14 of Column 8 of U.S. Pat. No. 3,670,801). This subject matter is incorporated herein by reference.

What is claimed is:

1. A method of controlling the height of molten metal in a continuous casting system of the type having a mold unit having a generally vertical, integral and electrically conductive form, which form defines a shaping surface and into which form molten metal is poured and from which form a continuous billet is produced, and a cooling jacket about said form in which an electrically conducting coolant is circulated from which unit a continuous billet is extracted by a drive system therefore, comprising the steps of:
   a. providing an inductance level detector;
   b. positioning the detector in said jacket adjacent to but outside of said form and substantially surrounded by said circulating coolant;
   c. developing a time varying magnetic field employing the inductance level detector positioned within the mold jacket and adjacent to the form;
   d. sensing the magnetic field strength of the detector as affected by the height of molten metal in the form and,
   e. controlling the drive system to counter changes in the level of molten metal in the mold form so as to tend to maintain that level at or about a predetermined desirable level.

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