Crater end detection in continuous casting by longitudinal and shear wave hybrid technique with high sensitivity EMAT

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In continuous casting (CC), the crater end (CE: completely solidification point) position is important in terms of productivity and internal quality. To date, ultrasonic CE measurement techniques using EMAT (electromagnetic acoustic transducer) have been tried. For example, measurement of the shell thickness by the longitudinal wave propagation time and detection of the unsolidified region by shear wave transmission have been reported. However, the conventional techniques have the problem that measurement is impossible when the CE position is downstream of the sensor position. Therefore, in order to measure the CE position even downstream of the sensor, we developed a new hybrid technique utilizing both the longitudinal and shear wave modes. The core techniques are as follows: 1) Compact EMAT system utilizing longitudinal and shear waves The horizontal and vertical components of the magnetic field and switching of the applied coils are used to generate longitudinal or shear waves. Chirp pulse compression and synchronous averaging are also applied to improve the S/N ratio. As a result, we realized a compact sensor that can be installed in CC machines, and succeeded in non-contact ultrasonic measurement of hot slabs with 5 mm liftoff. 2) CE measurement calibration method The concept is based on the disappearance of the shear wave, which cannot propagate in the liquid portion. When the casting speed is changed, the CE passes through the sensor position and the transmission signal of the shear wave disappears. In this condition, it is possible to determine that the CE is located directly under the sensor and calibrate the estimation parameters for CE measurement by using the longitudinal wave propagation time. An in-line experiment was carried out at a slab CC, and CE measurement was confirmed both upstream and downstream of the CE sensor position.