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Study on mold level stabilization techniques in continuous casting machine

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Abstract: In this paper, major factors for mold level variations are analyzed in detail by using the logged data according to the data characteristics(periodic and aperiodic), and the cause and the counteraction of each factor are discussed. In order to minimize these disturbances, new controllers with the advanced control logics are introduced in real caster in POSCO. The effects and limitation of these trials are also addressed.

1. INTRODUCTION

It is well known fact in the steel industry that due to severe mold level variations, defects are entrapped into the slab and this makes the pin-hole or the flaw of the rolled strip (Lamant et al., 1999; Lee et al., 2004). Thus, the level variations are continuously monitored and, in a case, automatically classified as bad slab if the variations deviate the pre-defined limits. Recently, the importance of mold level control becomes higher and higher since the introduction of high speed casting.

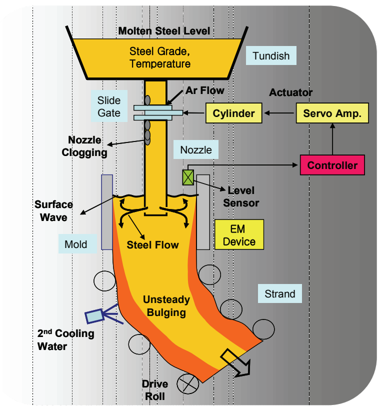

Fig. 1. Typical mold level control system in continuous caster with the indication of disturbances.

In general, the disturbances in continuous caster are classified as periodic and non-periodic. The periodic disturbances comes from bulging when secondary cooling is not enough and from surface wave due to the fluid dynamics in the mold. The non-periodic term comes from the change of casting speed, clogging/unclogging of submerged entry nozzle, the variation of steel contents in the tundish. In addition to these, the time delay and actuator dynamics in flow control device and level sensor are another factors to consider for the design of good controller.

In this paper, above mentioned disturbances are monitored and studied using the logged data in POSCO's continuous caster. Also, in order to minimize the effects of the disturbances, new controllers with the advanced control logics are introduced in real caster in POSCO. The effects and limitation of these trials are also addressed in case by case.

Section 2 describes the analysis result of mold level disturbances and Section 3 shows the result of new mold level controllers and Section 4 concludes this paper with future research topics.

2. ANALYSIS RESULT ON MOLD LEVEL DISTURBANCES

Figure 2 shows the FFT result on the mold level signal logged from high-speed data gathering system.

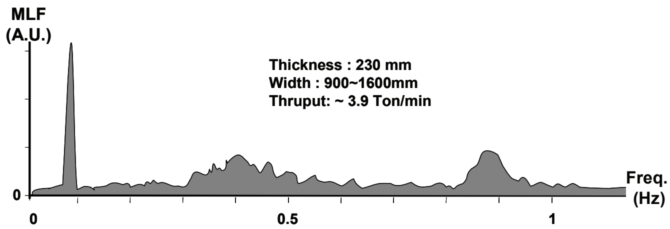

Fig. 2. FFT analysis result on periodic mold level disturbances.

The left big peak in Figure 2 which lies in frequency between 0.05 and 1 Hz shows the bulging disturbance and this generally occurs when the secondary cooling is not enough. The disturbance is with quite long period but big amplitude. In some case, this makes unstable diverging mold level variation coupled with the phase mismatch of the mold level control system. When this occurs, casting speed is normally down and the productivity and slab quality are mainly affected by this. To reduce this kind of disturbance, moderate cooling and change of roll pitch of the secondary cooling zone is compulsory and then comes the improvements of mold level control logic. The middle part of Figure 2 shows the signals from nozzle clogging or Ar bubbling (0.3 ~ 0.7Hz). To reduce this, the improvements for nozzle cleaning and Ar injection method are necessary. The signals between 0.6 and 1.2 Hz comes from surface wave in the mold and this is a kind of A.C. variations from the averaged mold level. To reduce this, optimal design of SEN, the selection of proper position for level sensor, and the filtering techniques are necessary.

3. MOLD LEVEL APPLICATIONS

In this section, the applications for mold level control are explained. First of all, a new mold level controller designed by POSCO is applied to control the mold level in the thin slab caster which is called Mini-Mill. Figure 3 shows the control performance when the casting speed is changing from 4.3 mpm to 4.6 mpm. For this, feed-forward term is applied by using the input-output balance model and the casting speed as an input (Lee et al., 2004). The mold level is controlled very well irrespective of continuous speed changes.

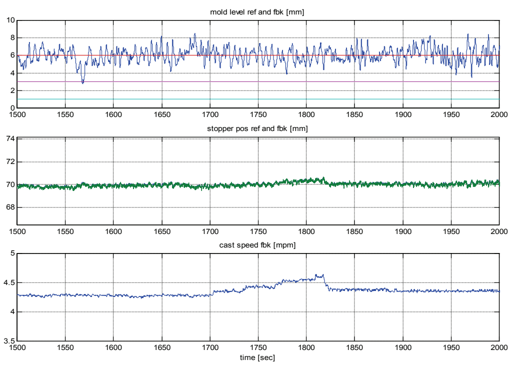

Fig. 3. Mold level control with casting speed change.

Figure 4 shows the results when Notch filtering is used for compensating the bulging disturbance (0.3 ~ 0.5 Hz). It is suppressed well in this case.

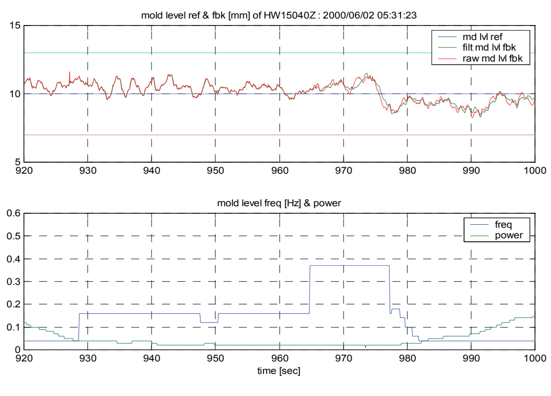

Fig. 4. Mold level control with bulging disturbance in thin slab caster.

On the contrary, in conventional caster, this notch filtering is not useful for the bulging disturbance which shows very low frequency lower than 1 Hz because the caster runs with very low speed(< 1.5 mpm) and rather big roll pitch. To cope with the these, other techniques are tried in worldwide based on disturbance observer and time-delay compensation logic (Furtmuller et al., 2006). Figure 5 shows a result with the similar compensation logic in a continuous caster in POSCO. When control is turned off around 3900 sec, the level varies a lot but the variations decreases when the controller is turned on again.

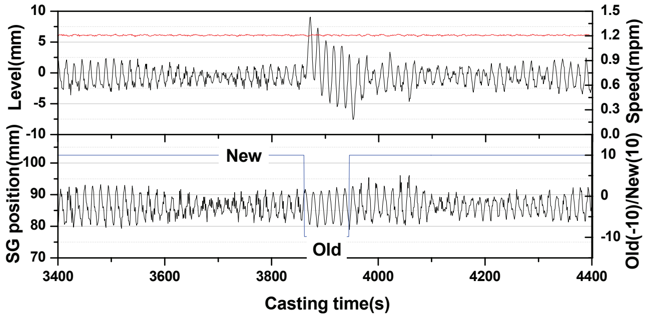

Fig. 5. Mold level control under bulging in conventional caster.

4. Conclusion

In this paper, the cause and counter-actions for mold level variations are described according to its periodicity and also the control efforts are explained with test result in real plant. Among the disturbances, the bulging will be the most important disturbance to consider as the casting speed goes higher and higher for the increase of production. Thus, most of research activities will be focused on this. In addition to this, the new actuator for flow control is necessary. The normal performance of actuator for conventional caster shows 40 mm/sec in average at the speed lower than 1.5 mpm. However, at high casting speed higher than 5 mpm, faster performance is necessary with broad control ranges of steel flow.

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