Advances in Slag Detection Help Steel Mills Increase Yield While Reducing Environmental Impact

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INTRODUCTION

To remain competitive, steel producers must find ways to increase output, increase safety, and reduce environmental impact. One method of accomplishing these objectives is by limiting the amount of slag that is present in the steel produced by utilizing one of many ladle slag carryover detection systems. The importance of ladle slag carryover prevention during continuous casting is well established.1, 2, 3, 4 Vibration slag detection has been cited as one of the most accurate and economical methods for detecting slag.4 When this technology is properly implemented, improved efficiencies increase yield and decrease environmental impact. This paper provides examples of production improvements in continuous casting attributed to comprehensive vibration slag detection (VSD) implementation over the past two decades.

BACKGROUND

A well-known relationship exists between the vibrational intensity of a pipe transporting a fluid and the physical and dynamic characteristics of that fluid.5 The mass flow rate of the fluid has a proportional relationship with the vibrational intensity of the pipe, and this relationship is the basis of how vibration slag detection works by measuring the vibration of the ladle shroud, a ceramic pipe through which molten steel flows during ladle to tundish teeming operations. During the end phase of the ladle to tundish teeming operation when viscous slag becomes entrained in the highly fluid molten steel stream, momentum is lost resulting in a drop in vibration energy intensity.

In the past, ladle to tundish teeming was performed open stream. The ladlemen would watch the tap stream for subtle changes in flow and colour that were characteristic of slag entrainment. Once shrouded teeming to control reoxidation was introduced for improving steel cleanliness, the ladlemen had to devise alternative methods to detect the transition from pure steel to onset of slag entrainment. On casters with ladle lift capability, some operators continued to use visual methods by raising the ladle before the end of heat to watch the tap stream for slag. On casters without ladle lift, they would simply remove the shroud. Both of these techniques were detrimental to steel quality.

Another technique devised by the ladlemen was to use handheld rods pressed directly against the ladle shroud or one of its vibrationally coupled structures to feel changes in the teeming momentum. Some ladlemen would enhance their tactile reception by resting their chins against the ladle shroud manipulator arm to better feel the vibration through their jawbone and teeth. This technique of human tactile mechanoreception6 is very reliable in highly skilled ladlemen, however, this group is a minority and also susceptible to fatigue-induced inconsistency.

With the emerging advancements of computer and sensor technology, accelerometer sensors mounted on the ladle shroud manipulator arm replaced human senses in the role of vibration slag detection. This automation has allowed for more consistent and reliable end-of-heat detection. The most advanced VSD systems today use micromachined microelectromechanical systems (MEMS-based accelerometers) because of their reliability and imperviousness to noise, extra features such as onboard temperature monitoring, and self-test remote calibration capabilities.