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Use of Sound Signals in Analyzing Flow Behavior in Steel Vessels

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INTRODUCTION

Mixing operations using gas stirred vessels are encountered widely in industrial processes such as metallurgy, pharmaceutics and food and beverage processing (1). Ladle metallurgy in the secondary steelmaking process is considered as a crucial stage where molten steel from the furnaces such as Electric arc furnace (EAF) and Basic oxygen furnace (BOF) is introduced to the ladles to maintain the compositional and thermal homogeneity. In these ladles, steel is further treated for removal of inclusions and desulphurization to improve the quality. In ladle refining process, argon gas is injected at the bottom of the vessel through porous plugs which promotes bubbling to stir liquid metal (2). Harsh working conditions such as temperature, sparks and dust in the process environment limit the use of sensors that can monitor the quantity of stirring. Currently, this stirring process is predominantly monitored by audio-visual observations of experienced operators. The degree of stirring is often judged by viewing turbulence on the top surface as well as monitoring gas flow meter gauges and listening to audible stirring sounds from the process. This qualitative approach is not always effective in identifying events such as nozzle clogging, changes in flow rate and deposits on the refractory wall of the vessel (3). Researchers have been continuously trying to analyze measurable signals from the steelmaking processes in order to improve the monitoring.

Several researchers have used a vibro-acoustic approach to monitor the ladle stirring process. Commercially developed vibration-based control systems which have been implemented in various steel plants (4). The system was reported to be effective in improving steel cleanliness and reduction in argon consumption. A vibration signal analysis study conducted by Yenus (2) using laboratory based cold models and industrial trials on a vacuum tank degassing (VTD) plant studied how the location of the sensor effected the measurement of stirring in the ladle. They found that useful measurements could be taken from the support structures and the external tank. Triaxial measurements using accelerometers were also used to study how the stirring process is related to bath height and flow rate. In the cold model, certain frequency ranges could be used to establish simple correlations between the variables and the level of stirring could be identified but for plant measurements it was found that the measurements taken from vibration sensors varied considerably over the life of the porous plugs (2). Irrespective of their effectiveness, accelerometers used in vibration-based control systems have limitations such as their restricted placements and their vulnerability to the harsh industrial conditions. Their performance has been observed to deteriorate with time due to undesirable vibratory components, as well as electrical glitches (5, 6). Hence, contactless sensors could be useful in monitoring the stirring process in such industrial harsh conditions.

The use of acoustic sensors in steelmaking industries has increased in recent times. In the experiments conducted by Vidacak and Arvanitidis (7), the slag foam generated during the EAF treatment, was recorded by a condenser microphone during the industrial trial. The average intensity of the sound recorded during the treatment was found to be inversely proportional to the slag foam level. The parameters such as slag composition and temperature are found to be responsible for the variations in the slag viscosity (7). The sensor network containing camera installed below the converter vessel and a microphone placed in the off-gas funnel were used to detect the slag slopping events in a BOF (8). This system was able to detect 80% of slopping events by issuing alarms to the system. The measurement system was tested on 100 heats of the BOF process during the trial. Coordination between process parameters such as lance position, blowing program as well as operator's knowledge was found to improve the detection of slopping events (8). Trials conducted in a Hungarian steel company showed success in the use of microphone to monitor the desulfurization process. A microphone was able to detect the changes in the sound pressure in the ladle due to injection of desulfurizing agents (9).

