Vibration-based assessment of gas-stirring efficiency in ladle treatments

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Introduction

Liquid steel is stirred in a vacuum tank using argon gas injection in order to achieve homogeneous composition and high purity of steel. An open vacuum tank with a ladle inside is shown in **Fig. 1**. The objective of this work was to develop a mechanical vibration-based objective indicator, which can be used for monitoring of the stirring intensity, detection of gas leakage during the stirring process, and condition monitoring of ladles.

Measurement system

Measurement system used in this work is depicted in **Fig. 2**. The system consists of a gas flow controller and a one-axial accelerometer that is installed on the outer surface of the vacuum tank. The accelerometer measures mechanical vibration of the vacuum tank in the vertical direction. The gas flow rate information is generated by the gas flow controller and it is recorded as an average using interval of a one second.

Fig. 1. Open vacuum tank with a ladle inside.

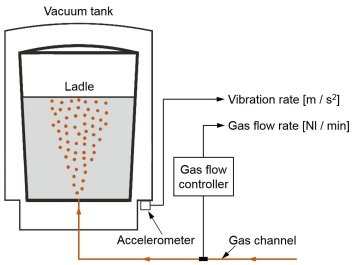

Fig. 2. Measurement system.

Vibration indicator

A vibration indicator is created from the vibration signal by means of signal processing using one second interval. The most adequate vibration indicator having the closest relationship with the gas flow rate is searched by conducting statistical analysis (linear regression) as illustrated in **Fig. 3**.

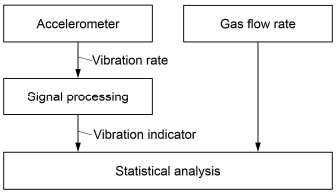

Fig. 3. Schematic illustration of signal processing and statistical analysis of the vibration indicator and the gas flow rate.

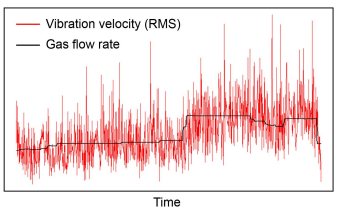

Fig. 4. Vibration velocity (RMS) and the gas flow rate in the stirring process.

According to the statistical analysis, the gas flow rate has the closest relationship with root mean square (RMS) of the vibration velocity. **Fig. 4** shows the behaviour of the vibration velocity (RMS) and the gas flow rate during gas-stirring. It is seen that the vibration indicator follows the gas flow rate very well. Thus the vibration velocity (RMS) was chosen as the vibration indicator describing the stirring intensity.

Detection of gas leakages

Gas leakages occur occasionally ladle treatments. To control the tightness of the gas channel reliably and to secure effective stirring, a leakage indicator was developed for monitoring purposes. The leakage indicator describes the stirring intensity relative to the gas flow rate. As illustrated in **Fig. 5**, it is based on ratio of the vibration indicator and the gas flow rate.

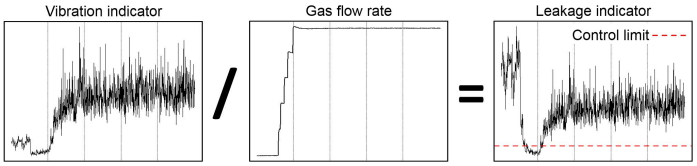

Fig. 5. Definition of the leakage indicator with a control limit.

Control limit acts as an alarm trigger of potential gas leakages (**Fig. 5**). If the leakage indicator drops below the control limit for a longer period of time, it indicates a potential stirring gas leakage. A sudden drop indicates a momentary high gas flow rate relative to the stirring intensity.

Condition monitoring of ladles

In this work, condition of a ladle was determined based on its ability to generate the maximum amount of vibration with minimum amount of gas. The condition indicator is quantified as a ratio of the cumulated vibration and consumed gas during the stirring as described in **Fig. 6**.

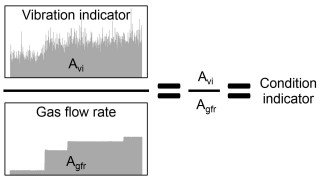

Fig. 6. Definition of the condition indicator.

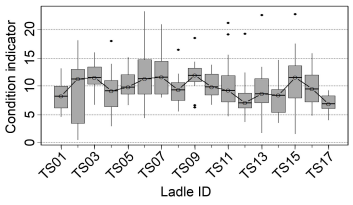

Fig. 7. A condition indicator summary of ladles.

The condition indicator summary presented in **Fig. 7** illustrates the overall condition status of ladle IDs from TS01 to TS17 based on earlier gas-stirrings. Based on the non-overlapped boxes in **Fig. 7** it can be seen that, for example, the overall condition of the ladle TS03 is obviously better than an overall condition of the ladle TS17.

Conclusions

The objective of this work was to develop a mechanical vibration-based indicator for monitoring ladle condition and stirring intensity, as well as detection of gas leakages. Preliminary results suggest that condition of ladles, stirring intensity and gas leakages can be assessed by means of the vertical vibration of a vacuum tank combined with information of the gas flow rate.

Acknowledgements

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