ABSTRACT

Grinding in tumbling mills is an energy intensive process in the mineral processing industry. Therefore measuring and monitoring the mill parameters helps in increasing their operational and economic efficiency. But the challenge lies in accurately measuring mill fill level, liner wear, size distribution, charge motion profile, ball size distribution, etc., directly, due to the harsh mechanical condition that prevails inside the mill which makes it difficult for any measuring instruments to sustain it. So researchers in the past have resorted to indirect means of assessing mill performance using acoustic sensors, image processing, strain gauge transducers, conductivity probe, numerical methods i.e. Discrete Element Method (DEM), etc. Out of many such indirect means of measurement, use of vibration sensors has received much attention as it is robust to the industrial environment and has shown its effectiveness to estimate certain mill parameters. However, there is still a need to interpret mill vibration signal to gather much more detailed information about mill operation status. Therefore, in this thesis vibration sensing and signal processing have been given importance and the effect of some key mill operating parameters are correlated with the mill vibration signal.

A properly instrumented laboratory scale tumbling mill was designed and fabricated. One industrial scale ball mill was also used for this purpose. In addition to this, the vibration signals were analyzed using simple yet novel signal processing techniques to measure and then understand the effect of different milling parameters such as mill speed, ball load, feed size, and slurry viscosity on the overall process efficiency. It was found that it is possible to correlate the variations in these mill parameters, to some characteristic indicator of the vibration signature that can be monitored for optimization purpose. A new approach of finding out the characteristics of different types of feed ore from the mill vibration signal using feature extraction and clustering technique is proposed. Experimental results support the effectiveness of the proposed algorithm to classify different ore types. This would be particularly helpful in situations where the hardness of the feed ore changes due to improper blending or mining from different sources. Another vibration signal based algorithm is proposed where the product size distribution can be estimated from the features derived from the vibration signals using a neural network. Lastly, the vibration signal of a large industrial ball mill running in continuous mode was analyzed. Interesting results of vibration patterns in relation to some key parameters like feed rate, charge motion profile and mill power were determined to show the overall trends in the mill operation. Overall it has been demonstrated that vibration sensing can be effectively used to monitor mill operation that are not amenable to direct measurement using available instruments and sensors.

Keywords: Tumbling mill, Mill vibration, Mill parameters, Accelerometer, Discrete Fourier Transform, Signal processing, Clustering technique, Artificial neural network.