powders

MDPI

Article

Acoustic Sensing and Supervised Machine Learning for In Situ Classification of Semi-Autogenous (SAG) Mill Feed Size Fractions Using Different Feature Extraction Techniques

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A1. Elemental and mineralogical studies

Using the XRF and XRD analysis, both elemental and mineralogical studies of the rock material are provided in Table S1.

Table S1. Elemental and Mineralogical Analysis.

Element	Fe	Si	Mg	Ca	Al	P	Mn	LE
% Wt.	45.23	10.37	8.10	3.82	2.34	0.10	0.39	29.55
Minerals	Magnetite	Hematite	Goethite	Pyroxene	Quartz	Chlorite	Carbonates	
% Mass	37.95	5.39	16.06	5.24	6.81	6.52	14.00	

Note: LE is light elements.

A2. Image of feed size fractions

Figure S1. shows the photograph of feed size fractions used for the study.

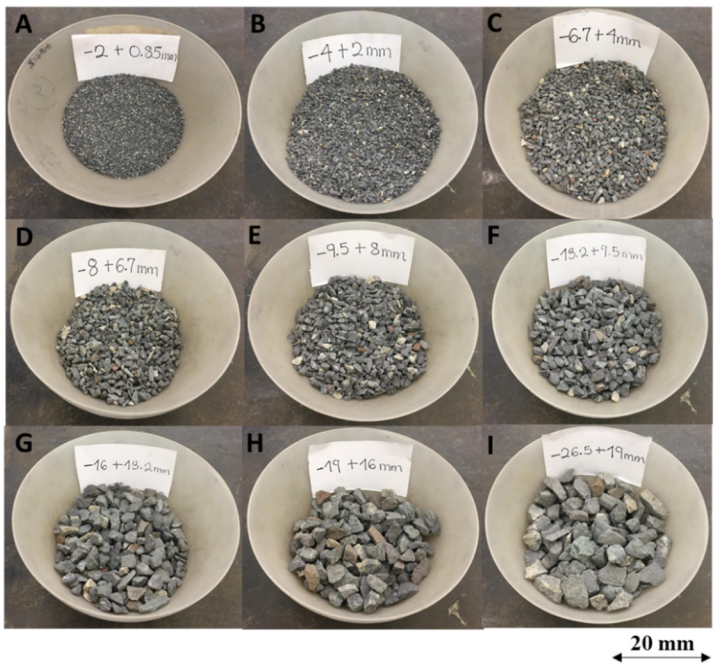

Figure S1. Classes of rock feed particle sizes.

A3. Sensor specifications

Table S2. The specifications of the sensor used for the investigation.

Specifications	AudioBox iOne: PreSonus
Frequency response	10 Hz to 40 kHz (±3.0 dB)
Maximum bit depth /sample rate	24-bit/96 kHz
Microphone type	-
Pre-amp	Class A microphone pre-amplifier
Sampling time	1 second

A4. Mill specification and experimental conditions

Table S3. The detailed mill specifications, feed properties, and experimental conditions.

Mill Specifications	
Mill type	Lab-based AG/SAG mill
Mill diameter (mm)	300
Mill length (mm)	150
Number of lifters	6
Mill volume with lifters(cm^3)	10341.9
Mill volume without lifters (cm^3)	10602.9
Mill critical speed, Nc (rpm)	77.5
Mill speed	Variable
Input Feed Material Properties	
Rock specific gravity (SG)	3.460
Ball specific density (kg/m^3)	7890
Water specific density (kg/m^3)	1000
Ball quality	Alloy steel
Experimental Grinding Conditions	
Operational mill speed (%)	75 critical speed (Nc)
Mill filling volume fraction, J_b (%)	18
Rock loading fraction. J_r (%)	10
Ball loading (%)	8
Water volume (ml)	857
Pulp density (%)	70
Porosity/voidage, ε (%)	40
Grind time (minutes)	5

The mill filling volume, which includes the ball and rock filling fraction, is deduced from the expressions shown in Eq. 1-3 [1, 2]. Due to limited rock material mass, the total mill volume was scaled down to about 18 % mill volume against 26 % of the proposed optimum condition by [3].

$$Ball\ filling\ fraction, J_b = \frac{Mass\ of\ balls / Density\ of\ balls}{Mill\ volume} \times \frac{1}{1-\varepsilon} \quad (1)$$

$$Rock\ filling\ fraction, J_r = \frac{Mass\ of\ rock / Density\ of\ rock}{Mill\ volume} \times \frac{1}{1-\varepsilon} \quad (2)$$

$$Total\ mill\ filling\ fraction, J_t = \frac{Volume\ of\ balls\ and\ rock}{Mill\ volume} \times \frac{1}{1-\varepsilon} = J_b + J_r \quad (3)$$

A5. Characterisation techniques

A5.1 Particle size distribution

After each grinding test, the mill charge was emptied into a bucket, followed by steel ball removals. The discharge slurry was subjected to pressure filtration, and the residue was sent to an electric oven (50 °C) to obtain a dry product sample. Using the Jones–Riffle splitter, the product material was uniformly divided, and the sample was taken for sieve analysis following the Tyler series approach. For experimental reproducibility and accuracy, the sieve analysis was carried out two times. Figure S2 shows the product particle size distribution after grinding.

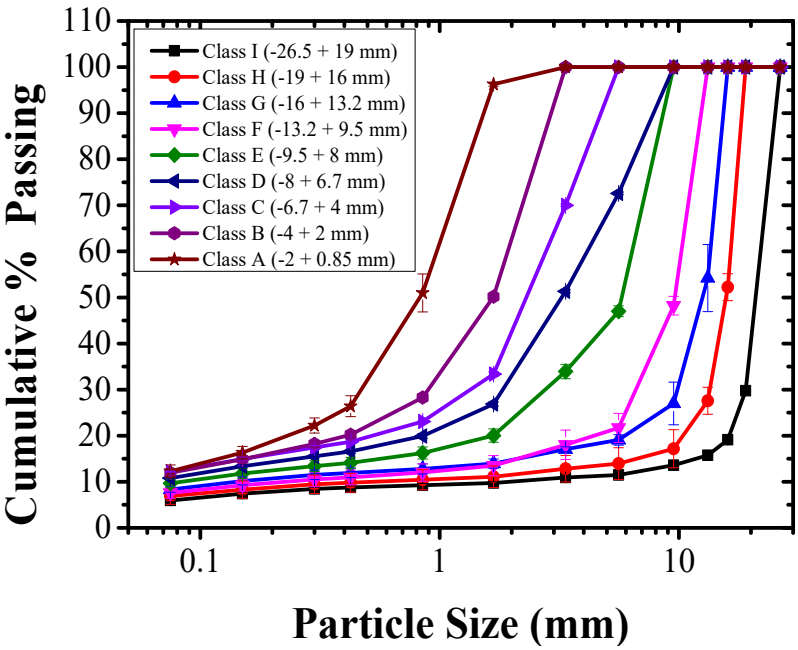

Figure S2. Product size distribution of different feed size fractions after grinding.

A6. Mill acoustic emission processing

A6.1 Time-domain signal

The time–amplitude domain signals of rock-only variations, and their combination with constant ball mass and water volume, are shown in Figure S3.

Rock–Ball–Water mixture

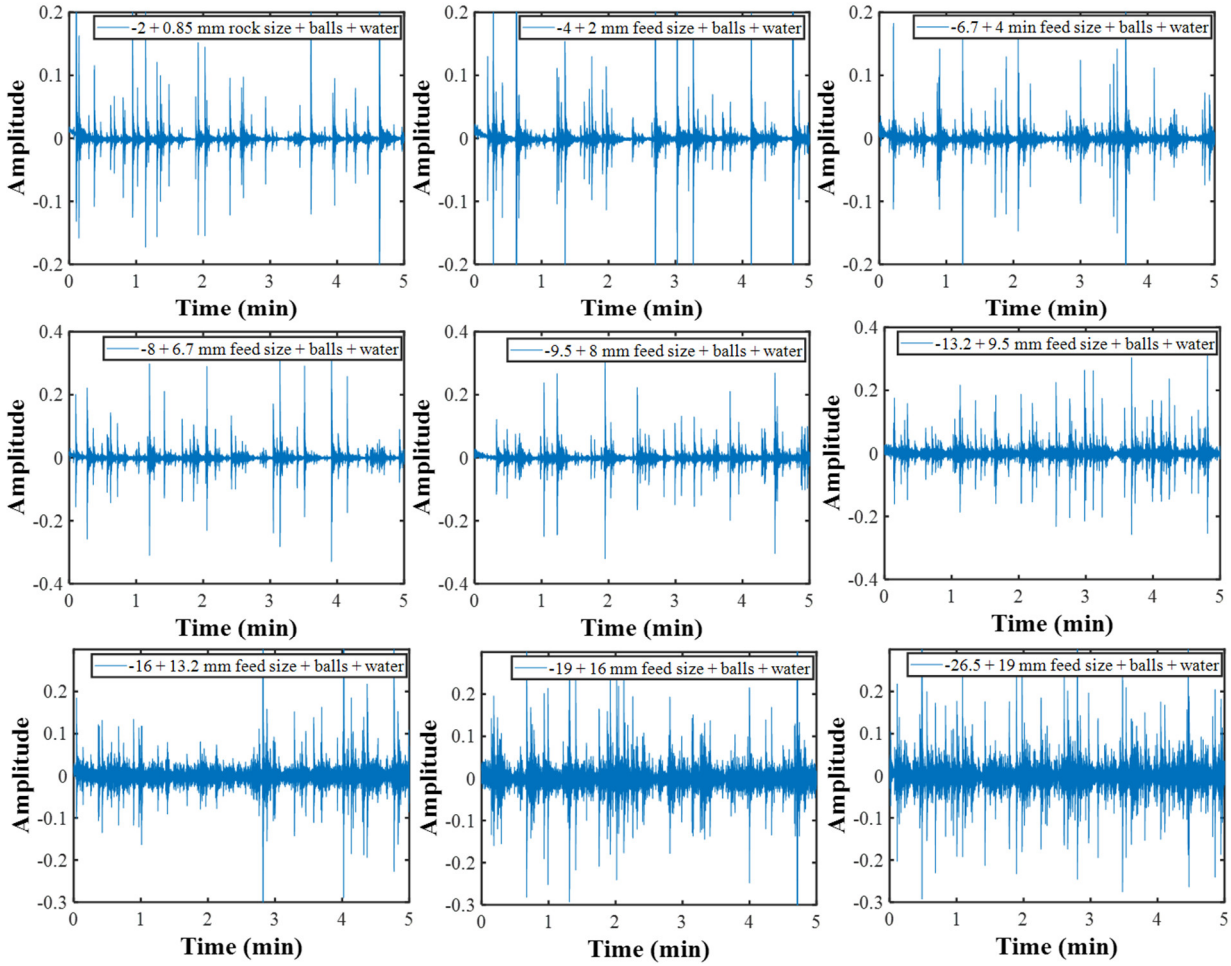

Figure S3. Time–amplitude domain signal representation.

References

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2. Nava, J.V.; Llorens, T.; Menéndez-Aguado, J.M. Kinetics of Dry-Batch Grinding in a Laboratory-Scale Ball Mill of Sn–Ta–Nb Minerals from the Penouta Mine (Spain). *Metals* **2020**, *10*, 1687. https://doi.org/10.3390/met10121687.
3. Starkey, J.H.; Hindstrom, S.; Orser, T. Choosing a SAG mill to achieve design performance. In Proceedings of the CMP Conference, Ottawa, Canada, January 2023