MODELLING THE EFFICIENCY OF AN AUTOMATED SENSOR-BASED SORTER

Submitted by

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to

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I certify that all materials in this thesis which is not my work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

(Signature) ……………………………….

ABSTRACT

For future development of automated sensor-based sorting in the mining industry, an improvement in the separation efficiency of the equipment is desirable. This could be achieved through a better understanding of the identification and separation aspects of the automated sorter. For automated sorters that undertake separation through the use of compressed air jets, the problem of poor separation efficiency has been linked with co-deflection losses. Co-deflection losses occur as particles meant to pass on to the ‘accept’ bin are co-deflected with the particles (which are to be deflected) meant to go to the ‘reject’ bin.

To study co-deflection losses and suggest means of improving automated sorter separation efficiency, this research investigates the effects of particle size, shape, throughput, together with the proportion of particles (out of the total test batch) required to be deflected on separation efficiency. The effect of the air valve configuration on separation efficiency was also studied. Presented also is a mathematical model which could be used to predict automated sorter separation efficiency.

All separation efficiency investigations were undertaken using a TiTech Combisense© (BSM 063) automated sorter. Samples of granite were sized into -20+15mm, -15+10mm and -10+6mm size fractions and grouped into cubic and flaky shape fractions. These fractions were then divided into two with one portion painted for colour separation efficiency investigations.

The separation efficiency results confirmed earlier research indicating that particle size and the fraction requiring deflection affects separation efficiency, with separation efficiency decreasing with a decrease in particle size and an increase in throughput. It was observed that co-deflection loss occurs when correctly identified ‘accept’ particles are co-deflected due to their close proximity to ‘reject’ particles that are to be deflected. Observations from the tests indicate that an increase in the proportion of

particles requiring deflection increases the probability of finding 'accept' particles in close proximity to 'reject' particles leading to co-deflections.

Monte Carlo simulations were used to produce a random distribution of particles on the conveyor belt as would be obtained from actual investigations. From these simulations particle proximity relationships and particle co-deflections were studied. Results indicate that the Monte Carlo simulations under-predicts particle proximity associations.

The effect of shape on co-deflection was investigated with results indicating that flaky shaped particles produce higher number of co-deflections compared to cubic shaped particles. It was also observed that the valve sensitivity determined from valve opening and closing times is of importance to the selectivity (precision) of the separating air jets.

A mathematical separation efficiency model is presented which contains two variables, the belt loading (calculated using particle size, shape and throughput) and the particle fraction of the total test batch that are to be deflected (% deflection). The separation efficiency can be calculated once these two variables are determined.

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LIST OF ABBREVIATIONS AND ACRONYMS

2D: Two-dimensional

AOTF: Acousto-Optical Tunable Filter

CCD: Charge-coupled device

CYMK: Cyan-Yellow-Magenta-blacK

DE-XRT: Dual energy x-ray transmission

DMS: Dense medium separation

ELV: End of life vehicle

EM: Electromagnetic

FIR: far Infrared

HDPE: High-density polyethylene

LDPE: Low-density polyethylene

LED: Light-emitting diodes

LIBS: Laser induced breakdown spectroscopy

LIF: Laser induced fluorescence

MIR: mid Infrared

NIR: near Infrared

PET: Polyethylene terephthalate

PP: Polypropylene

PVC: Polyvinyl chloride

RGB: Red-Green-Blue

UV: Ultraviolet

WEEE: Waste electrical and electronic equipment

XRD: X-ray diffraction

XRF: X-ray fluorescence

XRT: X-ray transmission

YUV: Y (luma/luminance/brightness) UV (chroma) colour scale

LIST OF SYMBOLS

A = Absorbance of materials, m

B = Magnetic induction, T

B_L = Belt loading, %

c = Velocity of electromagnetic radiation in a vacuum, ms^{-1}

— = Magnetic field gradient, T/m

ΔE = A quantum (photon) of energy, J

E_{electr} = Energy associated with the electrons in the various outer orbitals of the molecules, J

E_{over} = The overall energy, J

E_{rot} = Energy associated with the rotation of molecules about the centre of gravity of the atom, J

E_{vib} = Energy due to inter-atomic vibrations, J

F = The magnetic force, N

H = Magnetic field strength, A/m

h = Planck's constant, 6.626 x 10^{-34} J

I = intensity of light transmitted through the sample at a given wavelength, m

I_o = intensity of incident light on the sample at a given wavelength, m

k = volume magnetic susceptibility

N_d = blue deflect, %

R_b = Recovery of blue painted particles, %

R_g = Recovery of granite particle, %

S.E = Separation efficiency, %

Tot_E = Total efficiency, %

λ = Wavelength of the electromagnetic radiation, m

μ = Magnetic permeability, H/m