

Maximising Binder Functionality in Selective Agglomeration

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Doctor of Philosophy

By

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Roberto Moreno-Atanasio

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ABSTRACT

This study was concerned with improving this process of selective agglomeration using an immiscible binding liquid by maximising the functionality of the binder. In the past, research into the area of selective agglomeration has focussed on the use of only pure oils as binders. Pure oils are highly suitable, in a technical sense, as they are hydrophobic, immiscible with water and will preferentially wet hydrophobic particles in a mixture of hydrophobic and hydrophilic particles. However, pure oils are equally highly unsuitable due to their cost when combined with the dosages required in the agglomeration process. Therefore, to address this issue and thus reduce the costs associated with the organic binder, a high internal phase water-in-oil emulsion was introduced as the binder. This type of emulsion was selected as it possessed the hydrophobic surface functionality of oil while the space filling functionality of the binder was primarily satisfied by the dispersed water droplets within the emulsion. In other words, it was considered that by replacing the majority of the oil with water within the binder and subsequently the agglomerate structure, the overall organic liquid requirement would be substantially reduced.

The solid feed material used throughout all of the work was a naturally occurring mixture of coal and mineral particles, coal being naturally hydrophobic and minerals such as clays, being generally hydrophilic. Initial experiments indicated that the emulsion could selectively agglomerate coal in the same manner as pure diesel. Moreover, by comparing the organic liquid dosage required to achieve agglomeration when using the emulsion with the dosage required when using pure diesel it was established that a 2-fold reduction in the organic liquid requirement was achieved. A series of investigations was then carried out which examined the influence of the composition of the emulsion and process parameters on the performance of the emulsion. It was found that the initial result could be improved by reducing the level of degradation the emulsion experienced during the agglomeration process. The highlight of this work was the result for a 3 wt% aqueous NaCl-in-kerosene emulsion which achieved a 10-fold reduction as compared to the benchmark diesel case. This emulsion achieved agglomeration in only 7 s and thus experienced the lowest level of degradation which resulted from mixing in the turbulent, aqueous environment of the agglomeration process. Moreover, it was shown that if the emulsion was pre-dispersed in water prior to the combination of the emulsion with the coal slurry the mixing time required to achieve agglomeration was only 3 s.

Following on from the development of the emulsion binder, a fundamental investigation into binder functionality was carried out. It was found that the organic liquid requirement to achieve agglomeration was a function of the specific surface area of the material to be agglomerated and the voidage within the agglomerate material. Moreover, it appeared that the dispersed, water droplets within the emulsion played a space filling role within the void spaces, as hypothesised, however the thin film which formed around the particles comprised only of organic liquid and thus the water droplets did not play a space-filling role. That being said, the results indicated that the film formed when using the emulsion was 178 nm which was approximately 4-times thinner than the film formed when using pure kerosene. Therefore, the results from this investigation indicated that the reduction which may be achieved is a function not only of the dispersed phase of the emulsion but also of the surface area of the feed.

Due to the successful development of the agglomeration process using the emulsion a final investigation was carried out to study the potential application of this work in an industrial coal processing setting. It was found that the ash% and moisture content of the agglomerated product was sufficiently low to meet market requirements. In particular it was found that the emulsion binder consistently produced a product with an ash of 10 – 11% leaving behind reject with an ash of 80% from a feed with an ash of 61%, providing that the emulsion dosage was sufficient.

Overall, the work in this study has resulted in the development of a rapid agglomeration process with reduced organic reagent requirements. This work has provided a foundation for further and exciting work in this new area.

PUBLICATIONS

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NOMENCLATURE

<i>Symbol</i>	<i>Definition</i>	<i>Units</i>
<i>A</i>	Area	m ²
<i>a</i>	Assay	-
<i>D</i>	Dosage	wt%
<i>d</i>	Diameter	m
<i>F</i>	Force	mN
<i>f</i>	Scalar variable	-
<i>G</i>	Gibbs Free Energy	mJ
<i>k</i>	First Order Coefficient	1/wt%
<i>l</i>	Perimeter	m
<i>P</i>	Pressure	mPa
<i>R</i>	Recovery	-
<i>S</i>	Entropy	mJ/K
<i>SA</i>	Specific Surface Area	m ² /m ³
<i>s</i>	Liquid Saturation	-
<i>T</i>	Temperature	K
<i>V</i>	Volume	m ³
<i>v</i>	Specific volume	m ³ /m ³
<i>w</i>	Work	mJ
<i>Y</i>	Yield	wt%

Greek Letters

<i>Symbol</i>	<i>Definition</i>	<i>Units</i>
γ	Surface energy	mJ/m ²
γ	Surface tension	mN/m
δ	Film thickness	m
θ	Contact angle	°
μ	Viscosity	Pa s
ρ	Density	kg/m ³
ϕ	Phase volume ratio	-

Subscripts

<i>Symbol</i>	<i>Definition</i>
d_{32}	Sauter mean
σ_{attach}	Energy of attachment
c	Continuous phase
F	Feed
G	Gas phase
i	Index
L	Liquid phase
M	Maximum
O	Organic phase
σ_{oil}	Organic component
P	Product
R	Reject
r	Relative
S	Solid
s	surface
σ_{spread}	Energy of spreading
σ_{void}	Void space component
W	Aqueous Phase