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The agglomeration of fine iron particles in a fluidised bed cascade

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THE AGGLOMERATION OF FINE IRON PARTICLES IN A FLUIDISED BED CASCADE

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from

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by

Daniel Laurence Blundell

DEPT. OF MECHANICS, MATERIALS AND MECHATRONICS

2005

THESIS CERTIFICATION

I, Daniel Laurence Blundell, declare that this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Department of Mechanics, Materials and Mechatronics, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

Daniel Laurence Blundell

23rd September 2005

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List of Abbreviations

AFM:	Atomic Force Microscopy
BCC:	Body Centred Cubic
CPA:	Coupled Plasmon Approach
DMT:	Derjaguin-Muller-Toporov
DRI:	Directly Reduced Iron
FCC:	Face Centred Cubic
FIB:	Focused Ion Beam
Gleeble:	Gleeble Thermo-mechanical Simulator
HBI:	Hot Briquette Iron
HLSCM:	High temperature Laser Scanning Confocal Microscopy
JIC:	Jump Into Contact
JKR:	Johnson-Kendall-Roberts
MSD:	Multiple Scratch Decay
SEM:	Scanning Electron Microscope
SSD:	Single Scratch Decay
TEM:	Transmission Electron Microscope
vdW:	van der Waal's

Abstract

The research topic presented here is that of the tendency of iron ore particles in a fluidized bed reactor during the DRI process, to form agglomerates, giving rise to sticking of iron ore particles resulting in the defluidisation of fluidised bed iron ore reactors. The particles are capable of sticking to one another, to reactor walls, and to adhere to the interior of standpipes, as they pass from one reactor bed to another.

The general mechanism of the agglomeration of fine iron ore particles is by sintering. A study of the sticking of iron ore particles has been conducted by delineating the sub-mechanisms involved in sintering such as van der Waal's adhesion and surface diffusion, and endeavouring to quantify these attributes for iron.

In this study, van der Waal's forces and the work of adhesion for iron surfaces in contact has been evaluated using atomic force microscopy. It was shown that the pressure exerted at a local infinitesimal point on one iron particle by another was higher than the yield stress of iron and probably leads to plastic deformation of the surface, giving rise to large contact areas between them.

In this study, a new and more efficient technique of quantifying surface diffusion rates in metals has been developed using confocal microscopy and ion beam milling. Surface diffusion rates in iron were measured and benchmarked against earlier quantities. The new quantities compared well with the old values, considering the difficulty involved in repeating surface diffusion experiments.

It was found that quantities of carbon higher than 0.5%C led to a 100-fold decrease in surface diffusion rates. It is concluded that high carbon content will retard the transport of iron material to a contact site between two particles.

A high-temperature sticking test was developed in this study to test and quantify observations made at BHP-Billiton. It was found that in commercial carbon-steel conforming to a carbon content of approximately 0.8%C, a distinct difference exists between sticking quantities of contacts made below and above the eutectoid temperature. Sticking stress was observed to be higher above the eutectoid temperature and it is inferred that the gamma phase of iron is highly susceptible to sticking. This is in contrast to the high carbon steel. It is shown here that Fe-1.5%C steel shows less potential to stick. Iron powders from port Hedland showing minimal sticking are covered in a thin layer of cementite. Thus, the low sticking strength of the high carbon steel is probably due to its content of cementite.

Sintering diagrams were constructed for iron to study the combined effect of surface diffusion and van der Waal's adhesion between iron particles. Two main insights were gained from this. Firstly, the potential to form inter-particle contacts via van der Waal's adhesion were not constant with temperature and would vary according to the change in plastic yield strength. It was found that over all that inter-particle contacts grew larger with increasing temperature. Secondly, van der Waal's adhesive properties were more significant when operating on smaller sub-micron particle contacts. In larger particles, the formation of inter-particle contacts relies more of the rates of surface diffusion.

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