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Author: S Dong

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Virtual manipulation

S. Dong
University of Wollongong, shen@uow.edu.au

SURFACE COATINGS FOR 3-PIECE FREIGHT BOGIE CENTRE BEARINGS

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requirements for the award of the degree of

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by

Matthew J. Franklin
BEng (Hons)

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Certification

I, Matthew J. Franklin, declare that this thesis, submitted in partial fulfillment of the requirements for the award of Master of Engineering – Research, in the School of Mechanical, Materials and Mechatronic Engineering, 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.

Matthew J. Franklin

8th October, 2008

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Abstract

The research is divided into four related sections of work. The first relates to the rim wall wear of the existing unlubricated steel, and polyethylene centre bearing components. Based on these findings, the second and third sections of work includes materials characterisation of alternative centre bearing surfaces - plasma nitrided molybdenum steel and stellite 6 laser clad layers, respectively. Finally, in the last section of work, the reciprocating pin-on-plate wear test method is used to evaluate the friction and wear of the existing and alternative centre bearing materials.

The worn dimensions of the AISI 1053 steel, Hadfield steel, and polyethylene centre bearing components were determined. The wear of the high density polyethylene centre bowl liner was negligible. The rim wall wear of the unlubricated steel components was greatest in the longitudinal direction, whilst there was negligible wear in the lateral direction. The average wear depth rate for the AISI 1053 steel top centre was approximately twice that of the Hadfield steel centre bowl liner. The cross-sectional microhardness and microstructure of one worn AISI 1053 steel top centre and two worn Hadfield steel centre bowl liners were determined. The worn Hadfield steel centre bowl liners showed significant near surface work hardening. The wear mechanism for the AISI 1053 steel top centre was plastic strain accumulation in conjunction with low cycle fatigue.

The quench and tempered AISI 4016 molybdenum steel samples were plasma nitrided at 450, 500, 550 and 580 °C using 75% N_2: 25% H_2 mixture gas for 5 hours. The microstructures of the coatings were determined using optical microscopy, and scanning electron microscopy. The treated samples were characterised using x-ray diffraction and

microhardness. The optimum condition for this material was achieved at the temperature of 500 ^{0}C.

Stellite 6 multi-track layers were laser clad onto mild and AISI 4016 steel substrates with a continuous wave Nd:YAG laser at 1800 W laser source power using four different processing speeds: 600, 900, 1200, and 1500 mm/min. The laser power, defocused laser spot size, and powder feed rate were held constant. The clad samples were characterised using optical microscopy and scanning electron microscopy (SEM) in conjunction with energy dispersive spectroscopy (EDS). Microhardness profiles of the clad layers and heat affected zones were determined. For both substrates the optimum processing speed is between 600 and 900 mm/min.

Wear testing of Hadfield pin - AISI 1053 steel plate, Hadfield pin - untreated AISI 4016 steel plate, HDPE pin – Hadfield steel plate, Hadfield pin - plasma nitrided AISI 4016 steel (500 °C) plate, and Hadfield pin – laser clad Stellite 6 (600 mm/min) plate material pairs was conducted using the pin-on-plate reciprocating wear test method. The wear test conditions provided a good simulation of the rim wall operating conditions for the Hadfield steel pin – plasma nitrided AISI 4016 steel (500 °C) plate and Hadfield steel pin – laser clad Stellite 6 (600 mm/min) plate material pairs. The Hadfield steel pin – nitrided AISI 4016 steel (500 °C) plate material pair had the lowest wear under these wear test conditions, whilst it’s co-efficient of friction of 0.57 would make it suitable for use in lightly loaded (50 ton wagon mass) 3-piece freight bogies.

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List of abbreviations and symbols

CCSB	Constant contact side bearing
DC	direct electric current.
EDS	Energy dispersive spectroscopy
HAZ	heat-affected zone.
HDPE	High density polyethylene
HV 100g	Vickers microhardness at 100 g load.
OM,	Optical microscopy
PTFE,	Polytetrafluoroethylene
SEM	Scanning electron microscopy
UHMW,	Ultra high molecular weight
UHMWPE,	Ultra high molecular weight polyethylene
XRD	X-ray diffraction

<u>Wear</u>

N	**Normal load**
F	**Tangential frictional force**
A	**apparent contact area**
A_r	**real contact area**
σ^*	**standard deviation of the surface peak height distribution**
r	**asperity radius**
μ	**Co-efficient of friction**
μ_s	**Static co-efficient of friction**
μ_k	**Kinetic co-efficient of friction**
μ_a	**Adhesion component of friction**
μ_p	**Ploughing component of friction**
μ_{plate}	**Centre bearing plate co-efficient of friction**
$\mu_{rim\ wall}$	**Centre bearing rim wall co-efficient of friction**
N_{plate}	**Normal force acting on centre bearing plate**

$N_{rim\ wall}$	**Normal force acting on centre bearing rim wall**
$p_{rim\ wall}$	**Load per rim wall contact height**
p_{ave}	**average contact pressure**
p_{max}	**maximum contact pressure**
R_{plate}	**Centre bearing plate moment arm radius**
$R_{rim\ wall}$	**Centre bearing rim wall moment arm radius**
$R_{centre\ bearing}$	**Centre bearing radius**
D_{tc}	**top centre diameter**
D_{cbl}	**centre bowl liner diameter**
$H_{rim\ wall}$	**Rim wall contact height**
v_{tc}	**Poisson's ratio of the top centre**
v_{cbl}	**Poisson's ratio of the centre bowl liner**
E_{tc}	**elastic modulus of the top centre**
E_{cbl}	**elastic modulus of the centre bowl liner**
E_r	**reduced elastic modulus**
b	**elastic contact length**
M_{plate}	**Moment due to centre bearing plate friction**
$M_{rim\ wall}$	**Moment due to centre bearing rim wall friction**
V	**Worn volume**
H	**Indentation hardness**
σ_y	**Yield strength**
τ	**Shear stress**
k	**Shear flow stress**
K	**Archard's dimensionless wear co-efficient**
α	**Asperity angle**
σ, p_1, p_0	**Normal stresses**
f	**Interfacial film strength**

<u>Laser cladding</u>

R_l	**reflectivity (%)**
A_l	**absorptivity (%)**
E	**laser beam power density (W/mm^2)**
q	**incident laser beam power (W)**
r_B	**laser beam spot radius (mm)**
t_i	**interaction time (s)**
v_l	**laser beam traverse speed (mm/s)**
T_p	**phase transformation temperature,**
T_0	**initial temperature,**
λ	**thermal conductivity (W/(m.K))**

Glossary

absorptivity, the fraction of incident radiation absorbed.

bogie (or truck), collection of components that house wheelsets and supports wagon mass.

bolster, connects sideframes of bogie and supports wagon mass at centre bearing.

case depth, depth where hardness is 10% greater than untreated base material.

centre bearing, point of rotation for bogie underneath wagon. Located at the centre of the bolster. Consists of a top centre attached to wagon located loosely inside a mating centre bowl liner. Supports wagon mass. Consists of centre plate horizontal and vertical rim wall surfaces.

centre bowl liner, centre bearing component. Cylindrical in shape. Attached to bogie bolster. Consists of centre plate horizontal and vertical rim wall surfaces.

constant contact side bearings (CCSB), consists of rubber damping and steel roller elements. Enables constant contact of wagon to sides of bolster on tangent track. Reduces bogie hunting.

curved track, constant radius of curvature.

diametral clearance, the horizontal clearance between the diameters of the cylindrical top centre and centre bowl liner.

dilution, change in the nominal chemical composition of the laser clad material by molten material from the substrate.

frictional moment, the moment due to the frictional forces at the centre bearing. Function of vertical load, co-efficient of friction of plate and rim wall surfaces, and the moment arm radius. Units: kN.m.

interaction time, laser beam interaction time with material.

LASER, light amplification by the stimulated emission of radiation.

lateral, 90 ° to direction of train travel in the horizontal plane.

leading edge, edge of centre bearing closest to front of train.

longitudinal, the direction of train travel.

monochromic, light of a narrow range of wavelengths.

plasma, an ionised gas, sometimes referred to as the fourth state of matter. Consists of gas, ions and electrons.

plate, horizontal circular surface of centre bearing.

reflectivity, the fraction of incident radiation reflected.

rim wall, vertical cylindrical surface of centre bearing.

rock (or sway), rotation around longitudinal direction.

pitch (or roll), rotation around lateral direction.

side bearings, support wagon during curve negotiation and wagon rock. Can consist of greased steel plates, roller bearings, or rubber damping and steel roller elements.

Stellite 6, proprietary cobalt-based wear-resistant alloy from Deloro Stellite.

tangent track, straight track.

transition or spiral curve, curve of varying radius of curvature that joins tangent to curved track.

top centre, centre bearing component. Cylindrical in shape. Attached to wagon.

trailing edge, edge of centre bearing closest to rear of train.

traverse speed, laser beam traverse speed across the sample.

vehicle, consists of a wagon supported on two (2) bogies front and back

wagon (or car) body, steel structural body for containing freight goods. Supported by bogies at front and back.

yaw, rotation around vertical direction (in horizontal plane).

50 ton bogie, bogie that nominally supports half or 25 ton of the 50 ton total wagon mass.

Published and conference papers

The following published and conference papers are based solely on work described in this thesis:

Published paper

1. M.J. Franklin, S.W. Huang, T. Chandra, and K. Tieu, "Microstructural features of plasma nitrided molybdenum alloy steel", Materials Science Forum Vols. 539-543, 2007, pp. 1282-1287.

Conference papers

1. M. Franklin, S.W. Huang, M. Brandt, T. Chandra, K. Tieu, "Continuous wave Nd:YAG laser cladding of stellite 6 multi-track layers on mild and AISI 4016 steel", Proceedings of the 2nd Pacific International Conference on Application of Lasers and Optics 2006, Melbourne, 3rd – 5th April, 2006.

2. M.J. Franklin, S.W. Huang, K. Tieu, and T. Chandra, "Surface coatings for 3-piece freight bogie centre bearings", Conference on Railway Engineering, Melbourne, 30th April – 3rd May, 2006.