EFFECT OF CARBURISATION PROCESS ON THE WEAR OF STEEL

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FACULTY OF ENGINEERING
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DECLARATION

I hereby declare that the material in this thesis is my own except for quotations, excepts, equations, summaries and references, which have been duly acknowledged.

05 February 2016

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ABSTRACT

Electro-carburisation process based on liquid carburisation process had been carried out to investigate the effect of the carburization process on the resulting hardness, microstructure change, and the sliding wear resistance of mild steel under dry and lubrication conditions. The carburisation process was conducted in carbonate salts mixtures of Na_2CO_3-NaCl. The electro-carburisation process was first performed and followed by post-carburisation cleaning where subsequent analysis such as hardness test, metallographic observation, EDX/SEM and XRD were then carried out in order to investigate the effect of the carburisation process on the mild steel. Carburisation process resulted in a remarkedable increase in the hardness leading to an enhancement of adhesive and abrasive wear resistance, as well as load carrying capacity. Increasing the duration of the carburisation process from 1 hour to 3 hours resulted in higher peak hardness (727 HV/795 HV), greater case depth (50-100μm/660μm), higher amount of carbide in the grain boundaries and larger retained austenite grains. The surface of the carburised steel was dominated by retained austenite. Towards the core, the amount of retained austenite reduced while the amount of martensite increased. The austenite microstructure in the steel carburised for 1 hour exhibited higher cracking and fracture resistance as compared to the steel carburised for 3 hours.The low cracking and fracture resistance of the steel carburised for 3 hours could be due to its large grain size and high amount of cementite in the grain boundaries as the fatigue strength reduced with an increase in the grain size and the presence cementite could act as fatigue crack initiators. The superior wear resistance of the martensite, as compared to the austenite, could be attributed to its high cracking and adhesive wear resistance owing to its high hardness and tendency to form oxide. The friction was governed by the wear mechanism and the type of microstructure at the worn scar sliding on the carbide ball. It was found that surface fracture and sliding on martensite resulted in higher friction coefficient. The superior wear resistance and load carrying capacity of the carburised steelwasalso evident under oil lubrication condition. Compared to the austenite, the martensite showed higher tendency to react with the carbon in the oil under extreme boundary lubrication which in turn resulted in a significant drop in the friction coefficient after the running in process.

ABSTRAK

EFFECT OF CARBURISATION PROCESS ON THE WEAR OF STEEL
(KESAN PROSES PENGKARBONAN KE ATAS KEHAUSAN KELULI)

Proses 'electro-carburisation' berdasarkan proses pengkarbonan cecair telah dijalankan untuk mengkaji kesan daripada proses pengkarbonan pada kekerasan yang terhasil, perubahan mikrostruktur, dan rintangan haus gelongsor keluli lembut di bawah keadaan kering dan pelinciran. Proses pengkarbonan telah dijalankan dengan menggunakan campuran garam karbonat Na2CO3-NaCl. Proses 'elektro-carburisation' dilakukan terlebih dahulu diikuti dengan pembersihan ke atas spesimen yang telah menjalani proses pengkarbonan. Analisis berikutnya seperti ujian kekerasan, pemerhatian 'metallographic', EDX / SEM dan XRD kemudiannya dijalankan untuk menyiasat kesan proses pengkarbonan pada keluli karbon rendah. Proses pengkarbonan menyebabkan peningkatan kekerasan yang ketara yang membawa kepada peningkatan rintangan kehausan lelas dan perekat serta beban bawaan yang lebih tinggi.Meningkatkan masa proses pengkarbonan dari 1 jam hingga 3 jam menghasilkan kekerasan puncak yang lebih tinggi(727 HV / 795 HV), salutan yang lebih mendalam(50-100μm / 660μm), jumlah karbida yang lebih tinggi di sempadan bijian dan bijirin austenit yang lebih besar. Permukaan keluli yang menjalani proses pengkarbonan dikuasai oleh austenit tersimpan. Ke arah teras, jumlah austenit tersimpan semakin berkurangan manakala jumlah martensit meningkat. Mikrostruktur austenit dalam keluli yang telah dikarbonkan selama 1 jam mempamerkan rintangan keretakan dan patah yang lebih tinggi berbanding dengan keluli yang telah dikarbonkan selama 3 jam.Rintangan keretakan dan patah yang rendah oleh keluli yang dikarbonkan untuk 3 jam berkemungkinan disebabkan oleh saiz butiran yang besar dan jumlah simentit yang tinggi di sempadan bijian menyebabkan kekuatan lesu berkurangan yang mana peningkatan dalam saiz butiran dan kehadiran simentit boleh bertindak sebagai pemula retak-lesu. Rintangan haus martensit yang lebih tinggi berbanding austenit boleh dikaitkan dengan rintangan keretakan dan perekat yang lebih tinggi disebabkan oleh kekerasan yang tinggi dan kecenderungan untuk membentuk oksida. Geseran telah dikawal oleh mekanisme kehausan dan jenis mikrostruktur yang terdapat di parut kehausan di mana bola karbida menggelongsor di atasnya. Didapati bahawa keretakan permukaan dan menggelongsor di atas martensit menyebabkan pekali geseran yang lebih tinggi. Kapasiti rintangan haus yang lebih tinggi dan beban bawaan keluli yang dikarbonkan juga dapat dilihat di bawah kehadiran minyak pelincir. Berbanding dengan austenit, martensit menunjukkan kecenderungan lebih tinggi untuk bertindak balas dengan karbon dalam minyak di bawah pelinciran sempadan melampau yang seterusnya mengakibatkan penurunan ketara dalam pekali geseran selepas berjalan dalam proses.

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LIST OF ABBREVIATIONS

ASTM	-	American society for testing and materials
BCC	-	Body centred cubic
BCT	-	Body centred tetragonal
CCT	-	Continuous cooling transformation
C1	-	1 hour carburised
C3	-	3 hour carburised
CO	-	Carbon monoxide
CO_2	-	Carbon dioxide
COF	-	Coefficient of friction
DPH	-	Diamond pyramid hardness
EDX/EDS	-	Energy-dispersive X-ray spectroscopy
EHL	-	Elasto hydrodynamic
FCC	-	Face centred cubic
HD	-	Hydrodynamic
HRC	-	Rockwell hardness
HTTP	-	High temperature transformation product
HV	-	Vickers hardness
H_2O	-	Water
ICDD	-	International Centre for Diffraction Data
IT	-	Isothermal transformation
KCl	-	Potassium chloride
LTCSS	-	Low temperature colossal supersaturation
M1	-	1 hour martensite
M3	-	3 hour martensite
Na_2CO_3	-	Sodium carbonate
NaCl	-	Sodium chloride
NC	-	Non carburised
SEM	-	Scanning electron microscope
XRD	-	X-ray diffraction
ZDDP	-	Zinc-dialkyl-dithiophosphate

LIST OF SYMBOLS

%	-	percentage
+ve	-	positive
-ve	-	negative
A	-	amphere
C	-	carbon
Cr	-	Chromium
Cu	-	Copper
E	-	electron
Fe	-	iron
H	-	height
Hr	-	hour
In	-	inches
Ml	-	millilitre
Mm	-	millimetr
Mn	-	Manganese
Mo	-	Molybdenum
η	-	viscosity
N	-	Newton
Na	-	Sodium
Ni	-	Nickel
O	-	Oxygen
R_a	-	Average roughness
Si	-	Silicone
Ti	-	Titanium
V	-	volt
V	-	Velocity
µm	-	micrometer
°	-	degrees
°C	-	Degrees celcius

LIST OF EQUATIONS