An Experimental Research On Friction And Wear Behaviour Of Compact Graphite Iron At Elevated Temperatures

S. Venugopal Rao, M. Venkata Ramana, A.C.S Kumar

Abstract:Compact Graphite iron (CGI) is mainly used in automobile engine cylinder blocks and disc brakes. CGI has interconnected by vermicular shape graphite. Melting of steel and treatment of CGI is useful for getting sound castings. In automobiles the components manufactured by CGI are exposed to friction including wear, abrasion, thermal stresses and fatigue. Friction and wear characteristics at elevated temperatures are studied in the present study. Friction tests on CGI are conducted with pin on disc wear testing machine between CGI and hard steel disc. The deviations in frictional forces and wear behaviour are observed from the experimental results. The results shows that the wear rate and frictional forces of CGI at 400°C and 500°C temperatures was strongly influenced by the variation in induced temperatures. Scanning Electron Microscopy (SEM) is used to examine CGI pins surfaces. Temperature variations during experiments are influenced the CGI coefficient of friction.

Keywords: Compact Graphite Iron, Friction, Sliding wear, High Temperature, SEM Analysis.

I. INTRODUCTION

Wear and friction behaviour studies of CGI cast iron will be useful in making of blow moulding mould materials and in automobile applications. Pin on disc wear testing tribometer was used to conduct wear tests. CGI samples for wear testing were taken from the prepared material and abraded against a hardened steel disc (EN 31). Sliding velocity, frictional force and contact time were taken as test variables. Weight loss of the tested samples was measured after conducting the wear tests at 400°C and 500°C. [1] CGI produced with addition of alloys in the melt to charge. Carbon content is adjusted by adding graphite and after reaching required level of carbon the melt is heated up to 1530°C and treated with magnesium. Holding time at maximum temperature will be reduced to minimize silicon loss, melt oxidation and carbon burn will be minimized by keeping melt holding time as minimum. Modularisation with magnesium treatment and Ferro silicon inoculation have been done with a special care. Production of CGI is includes pig iron as base iron, steel scrap, graphite and Ferro silicon alloy. This CGI material is used in engine piston rings, bearings, brakes, and seals. Y.Lyu [2] studied observations which shown wear behaviour CGI overcome other cast iron materials. Heat treatment processes like induction hardening will increase the wear behaviour of CGI. [3] Grey cast iron is the material which has been used in the applications where wear is considered primly. Dark graphite and bright pearlite matrix structure ferrite is observed. The distribution of graphite contains perlite and ferrite. Mo content is one of the important for the varying pearlite fraction. [4]Production rates and costs are depends on mould materials and its surfaces. [5] Nano crystalline oxide layers called glaze layers are response to low wear rates. Glaze layers are developed between pin and disc metal in pin on disc test. The CGI metal properties like wear resistance, corrosion resistance, machinability and temperature resistance can be improved by addition of copper, molybdenum, chromium, nickel and zirconium in the melt. From the wear spheroidal graphite iron experiment D. Gowda.[6]given that coefficient of friction and wear rates were measured and made conclusions that at initial time coefficient of friction varies and later converge to certain values due to the wear debris. The wear debris generated between pins and disc surface. Spheroidal graphite iron (SGI) shown high wear rates in dry and wet experimental conditions and graphite acts as lubricant.Sugwon Kim (10) studied wear behaviour of compacted graphite cast iron at elevated temperatures and results indicated that CGI can use in high temperature applications. High temperature abrasive wear properties of CGI and SGI cast irons have been studied by by E. Faculty [7] and concluded that SGI shown high wear losses than CGI, in abrasive conditions SGI is more useful. Strain ageing of subsurface layer during wear experiment at 150°C is the reason for increase in wear resistance CGI and SGI. Critical thickness of CGI casting, magnesium content in CGI and oxygen activity are influence the control of crystallization of graphite [8]G. Cui.[9] studied tribological properties of materials and concluded that hardness and solid lubricants like Ag, molybdates, chromates will influence the tribological properties of materials.M.S Skoinski[10] Conducted experiments at 290°C, 340°C and 390°C and concludes that CGI wear resistance is increased by decrease in abrasive as austempering temperature increased. [11] Interactions between metal particles are observed particularly due to the abrasive components of the friction material, like hard oxide particles, MgO. Plastic deformation and oxidative wear are dominantly observed at elevated temperatures.

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These deformations are analysed by Scanning Electron Microscopy and Electro Discharge Spectroscopy. Finer dispersion and coarser dispersions of graphite morphology observed at 150 °C and 250 °C respectively [12], [13]. Dry sliding wear have experimented with different materials and concluded that lubrication will change the wear behaviour at various temperatures. I.Riposan [14] has been experimented the wear at 25°C on metals with various lubricants and studied the surface morphology.

[15] Mathematical formulations are developed for wear protective layers. Sliding wear processes are studied between 20 to 600 °C for various metal layers.

II. EXPERIMENTAL PROCEDURE & RESULTS

CGI material is manufactured and the required specimens are machined as per ASTM standards. CGI chemical composition is depicted in Table 1. All elements in the table 1 are taken on weight basis. Dimensions of the specimen are 10X12 mm2. Pin-on-disc wear tester is used to conduct wear tests.

Table 1. CGI Composition (wt%)

C	Si	Mn	P	S	Mg	Mo
3.60-3.80	2.30-2.36	0.033	0.041	0.0024	0.008	0.002

Sliding wear and frictional forces are analysed after testing the samples 400°C and 500°C. 25 N loads are applied at both the temperatures of 400°C and 500°C. Table 2 indicates the test parameters. Surfaces of tested specimen are analysed for wear cracks.

Table 2. CGI Wear testing parameters

Parameters	400 °C	500 °C
Load (N)	25	25
Disc speed (rpm)	316	316
Track diameter (mm)	60	60
Velocity (m/s)	1	1
Time (s)	16 mins	16 mins

Structural behaviour of the worn specimen surfaces were analysed by Scanning Electron Microscope (SEM). The pin samples are polished with emery sheets of 4/0, 3/0, 2/0 and 1/0 grades and followed by 5 micrometre alumina disc polishing paste to remove all scratches for microstructural analysis.

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III. RESULTS AND DISCUSSION

Table 3. Time, Wear and Frictional Forces at 400 deg C

Time (s)	Wear (micrometer)	Frictional force (N)
0.129	-0.17	0
64.843	-31.36	4.74
100.057	-30.27	4.95
200.05	-30.01	5.42
300.043	-31.92	5.68
400.034	-33.18	5.53
500.17	-33.69	5.23
600.017	-36.02	5.22
700.01	-37.67	5.08
800.003	-40.2	4.9
900.058	-41.5	4.84
1000.051	-42.85	4.9

Table 4.Time, Wear and Frictional Forces at 500 deg C

Time (s)	Wear (micrometer)	Frictional Force (N)
0.065	-0.17	0
0.129	-0.17	0
1.039	-15.48	0.68
100.057	-30.27	4.95
200.05	-30.01	5.42
300.043	-31.92	5.68
400.034	-33.18	5.53
500.028	-33.68	5.23
600.017	-36.02	5.22
700.01	-37.67	5.08
800.003	-40.2	4.9
900.058	-41.5	4.84
1000.051	-42.85	4.9

Fig 1. CGI Wear behaviour at 400 deg c temperature

Fig 2. Frictional Force at 400 deg c temperature

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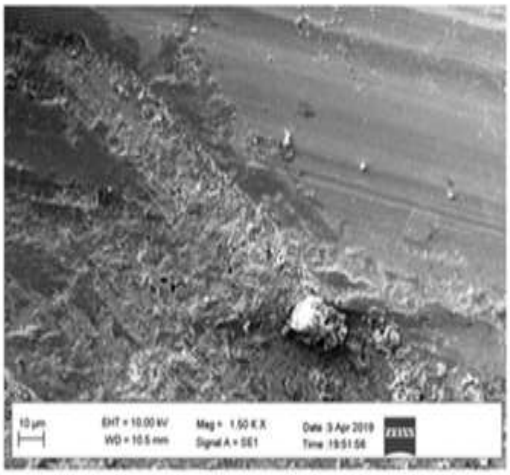

Fig 4. SEM image at 400 deg c temperature

Fig.5 CGI Wear behaviour at 500 deg C

Fig.6 Frictional Forces at 500 deg C

Fig 7. Temperature with time

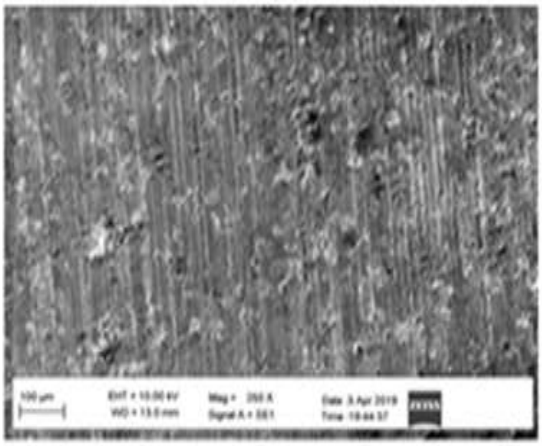

Fig.8 CGI SEM image at 500 deg C

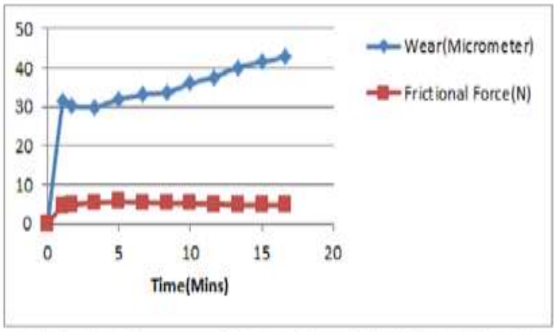

Fig 9. Wear(Micrometer),Frictional Force(N) of CGI at 400 Deg C Temperature

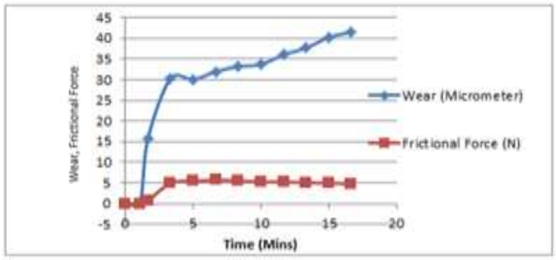

Fig 10. Wear(Micrometer),Frictional Force(N) of CGI at 500 Deg C Temperature

SEM Analysis

Fig 4 indicates the CGI pin wear image at 400oC. Cracks in irregular fashion and voids with different volume are observed CGI pins wear surfaces. Some particles are come out from the particular region. Wear is reduced gradually as time is increased as shown in Fig 1. Carbon particles density affects the ferrous formations. Little variation in frictional force is observed as shown in Fig 2 at 400°C. Wear characteristics decreases with variation in temperatures induced. Main reason of this declination is that graphite may not be uniformly distributed. The wear morphology of CGI sample at 500oC as shown in Fig 8. It is observed that lessor voids and particle deformation in 500oc compared to at 400oc. This observed large track formations. Pulling of carbon particles is one of the reasons for track formations. Due to high temperatures graphite particles not distributed uniformly. This is due to high temperatures the bonding between graphite particles is varied. Fig.3 and Fig.8 indicates the temperatures from start time to end time at 400°C and 500°C respectively. High uniformity in wear is observed at 500°C. Fig.9 and Fig.10 shows wear and Frictional forces are observed in small variations between 2 to 4 minutes of testing process.

IV. CONCLUSIONS

Wear test has been conducted on CGI metal at 400°c and 500°c by using Pin-on-disc test rig Following conclusions were made from the study:

- Higher temperatures promoted higher wear rate.
- Frictional forces are slightly decreased with increasing temperature. This is due to formation of pearlite.
- More mass loss of the CGI pin material at 500°c temperature is observed than at 400°c. Mass loss of CGI is observed 1.1 µm at 400°c 1.3 µm at 500°c.
- Uniform weariness is observed at 500 °c and rough weariness is observed at 400°c.
- Built up edge is observed in the surface profile at 400 °C.
- It is concluded that wear is higher at 500°c is higher than at 400°c.

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