Volume 4 Issue 4 (2014) 784-790 ISSN 2347 - 3258
International Journal of Advance Research and Innovation

A study of Surface wear of Hardened Cast Iron

K. Srinivas
Department of Mechanical Engineering, Delhi Technological University, Delhi, India

Article Info

Article history:
Received 15 October 2014
Received in revised form
30 November 2014
Accepted 05 December 2014
Available online 15 December 2014

Keywords
Cast Iron, Wear, Laser Surface Hardening

Abstract
Grey cast iron is one of the most prominent iron products that has its application worldwide. The foundations of the machine tool and the body of an internal combustion engine are the critical cast iron applications. But one of the problem in cast iron is the wearing of surface, which generally occurs in grey cast iron. Various researchers have investigated this phenomenon and have put forward their observation. This paper pen down their investigations on wear effect and discusses some investigations on laser surface hardening to improve the cast iron's characteristic..

1. Introduction

Cast iron is a binary Fe-C or a multicomponent Fe-C-X alloy rich in carbon and exhibits a considerable amount of eutectic in the solid-state**.** The Percentage of carbon in the cast iron is generally more significant than two and have low welding capability. Based on the composition and the microstructure, there are four cast-iron types: Grey Cast Iron, White Cast Iron, Malleable Cast iron, and ductile cast iron. When we talk about grey cast iron, the Graphite is arranged in the form of flakes. Due to the presence of Graphite, it is called grey cast iron. It has about 2.5 to 4 per cent of carbon and about 3 per cent of silicon. The tensile strength and the shock resistance of grey cast iron are lower than that of steel, and the compressive strength is also comparable to steel. Figure 1 shows the microstructure of the grey cast iron with the arrangement of Graphite as flakes.

The wear test is easily possible on grey cast iron; hence most of the Researchers have done it on the grey cast iron.

When we talk about white cast iron, carbon composition lies between 2.5 to 4 %, and that of silicon is less than 1 per cent. Due to the rapid cooling, there is a presence of pearlite and cementite. It is hard, brittle and non-weld able compared with the grey cast iron. This alloy's fracture surface has a white appearance, and hence it is called white cast iron. Figure 2 shows the arrangement of Graphite in white cast iron.

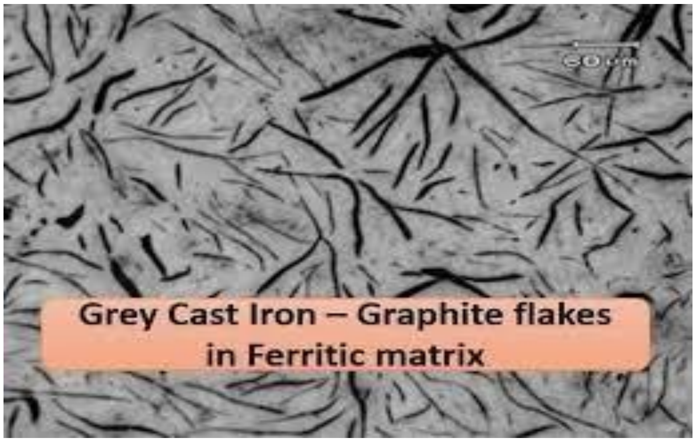

Fig. 1: Arrangement of Graphite in Grey Cast Iro [internet source]

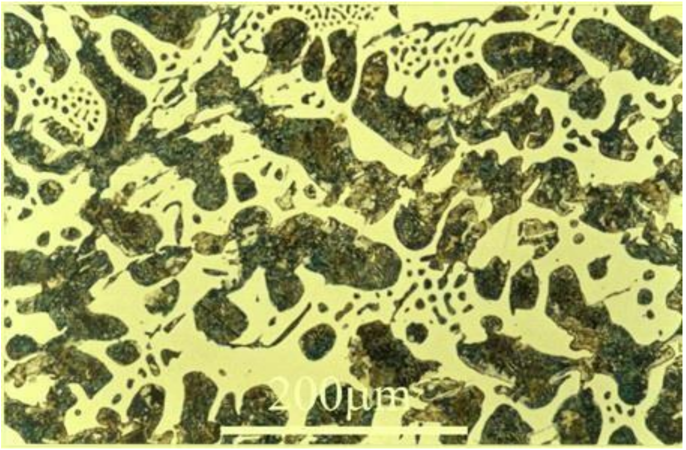

Fig 2: Arrangement of Graphite in white Cast Iron [internet source]

When we talk about the malleable cast iron, it is generally prepared in a two-stage annealing process. In the first stage, the white iron casting is slowly

---

*** Corresponding Author,**
E-mail address: srinivaskrovvidi9@gmail.com

reheated to a temperature between 1650 F and 1750 F. Figure 3 shows the arrangement of Graphite in the malleable cast iron Matrix.

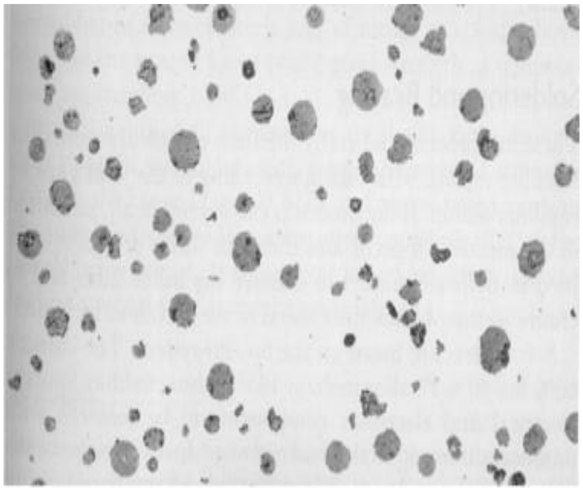

Fig. 3: Arrangement of Graphite in Malleable Cast Iron [internet source]

In this type of cast iron, the Graphite is present in the form of a tiny sphere. Figure 4 shows the structure of Graphite in the ductile cast iron Matrix.

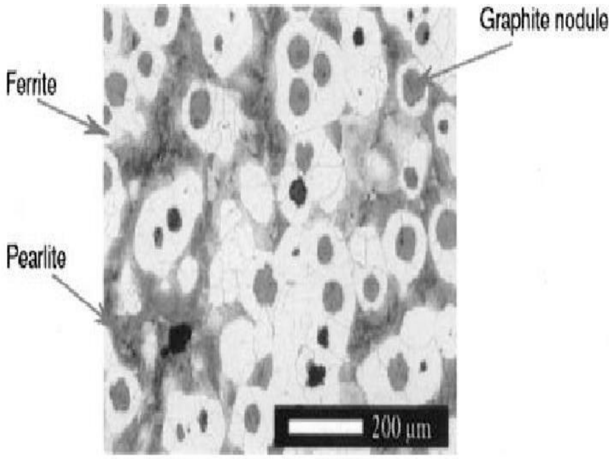

Fig 4: Arrangement of Graphite in Ductile Cast Iron [internet source]

2. Literature Review

As compared with steels and other cast irons, grey cast iron (GI) has some superior mechanical properties such as high machinability, vibration adsorption and castability. The presence of graphite flakes in the matrix enhances the wear resistance of GI. It is frequently utilised to manufacture crankshafts for compressors, guide rails, gears, piston rings and cylinder liners for diesel engines.The tribological behaviour of material pairs commonly used in air-conditioning compressors under the presence of CO2 has not been extensively studied, and only limited published works are available. Evaluation of typical Tribo-contacts included Al390-T6, grey cast iron, and Mn-Si brass (UNS C67300). Suh et al. [1]tested against 52100 hardened steel pins using a pin-on-disk configuration. The tests were performed using a High-Pressure Tribometer (HPT) in CO2 and polyalkylene glycol (PAG) lubricant. They found that the scuffing resistance of grey cast iron and Mn-Si brass was similar and that both materials performed better than Al390-T6. Keller et al. [2] studied the chemical composition and the microstructure of grey cast iron using heavy-duty diesel engines cylinder liners. Two kinds of lamellar grey cast iron are studied: a classical grey cast iron and a micro-alloyed grey cast iron. Reciprocating friction tests with the configuration steel ball against a flat sample, extracted from a cylinder liner, in lubricated contact are carried out on a Cameron Plint test rig. The friction coefficient and the electrical contact resistance are measured during all tests. The tribochemical film formation on the samples' wear scars and the steel ball is studied after different friction periods. The wear volume evolution of the cylinder liner part and the steel ball are determined. The influence of hard phosphorous eutectics on tribochemical film formation and cast iron wear behaviour is identified.The micro-alloyed cast iron shows a better wear resistance than the "classical" cast iron. However, no tribo film is formed on hard phosphorous eutectics and carbides. Truhan et al. [3] did Laboratory tests to evaluate piston ring and cylinder liner materials for their friction and wear behaviour in natural engine oils are described to support the development of new standard test methods.

A ring segment was tested against a flat specimen of grey cast iron typical of cylinder liners. The extent of wear was measured by weight loss, wear volume and wear depth using a geometric model that considers compound curvatures before and after testing. Wear volume by weight loss compared well with profilometry. Laboratory test results are compared to engine wear rates. Test temperatures ranged from 25 to 100 °C. A stepped load procedure was used to evaluate friction behaviour using a run-in ring segment. At 100 °C, all lubricants showed boundary lubrication behaviour. However, differences among the lubricants could be detected. Demas et al. [4] studied the friction and wear between the piston and cylinder liner, which significantly affects internal combustion engines' performance. The researchers tested the segments from a commercial piston/cylinder tribologically using reciprocating motion. The tribological contact consisted of aluminium alloy piston segments, either uncoated, coated with a graphite/resin coating, or amorphous hydrogenated carbon coating contact with grey cast iron liner segments. Tests were conducted in commercial synthetic motor oils and base stocks at temperatures up to 120°C with a stroke length at reciprocating speeds up to ^{1}. The friction dependence of these piston skirt and cylinder liner materials was studied as a load, sliding speed and temperature. Specifically, an increase in the sliding speed led to a decrease in the friction coefficient below approximately 70°C. In contrast, above this temperature, an increase in sliding speed led to an increase in the friction coefficient. The presence of a coating played an important role. It was found that the graphite/resin coating wore quickly, preventing the formation of a

coating exhibited a low friction coefficient and provided significant improvement over the uncoated samples. The effect of additives in the oils was also studied. The interface's tribological behaviour was explained based on viscosity effects and subsequent changes in the lubrication regime, the formation of chemical and tribochemical films. Balachandran et al. [5] examined three hyper eutectic cast irons alloyed with Cu, Ni and microalloying additives like Ti and Nb. These examinations were based on its hardness and wear resistance in the austempered (360 °C/3 h) and quenched and tempered conditions at varying tempering temperatures. It is observed that the cast irons in the quenched and tempered condition showed good wear resistance and moderate hardness at 400 °C. it was comparable with the wear resistance in austempered condition. The study also showed that in quenched and tempered condition, increasing Cu content in cast irons improved its wear resistance moderately while increasing Ni content has decreased its wear resistance. Strong carbide formers (Nb, Ti) did not significantly improve wear resistance in quenched and tempered condition. Even in austempered alloys, higher Cu content increases its wear resistance, and higher Ni content decreases its wear resistance. The austempered alloys showed ausferritic microstructure with 20% austenite phase which enhances wear resistance through transformation induced plasticity effect. On the other hand, the quenched and tempered alloys showed good wear resistance at 400 °C due to finely tempered carbides in the matrix. Viadraj et al. [6] carried forward there experiment on the same line one year before. The researcher studied the austempering behaviour of a series of hyper eutectic alloyed grey iron compositions with carbon equivalent from 4.37 to 5.14 to understand the influence of microstructure on its mechanical and wear properties. The alloying elements in the alloys included Ni, Mo, Cr, and inoculation by Ti, Nb, and Ce's micro-constitution. The alloys were austempered at 360 °C, and upper bainitic type feathery ferrite was observed in the matrix. While the graphite content determined by optical metallography varied between 16 and 24 vol%. The volume of austenite determined by XRD analysis showed values between 20 and 26%. The ferrite lath size was determined using XRD peak broadening. The tensile property varying between 188 and 270 MPa, showed no significant variation with volume percentage of carbon or austenite in the ausferrite. However, the wear rate varying between 0.5 and 2.6 × 10^{7} g/Nm, showed a decreasing trend with graphite content attributed to the higher lubricating effect of released carbon during sliding wear. The specific wear rate of hyper eutectic alloys increased with increasing ferrite lath size due to the enhanced softer ferrite phase on the sliding surface. The wear rate was found to increase with austenite, austenite carbon content and austenite lattice parameter, which is attributed to increased stability of austenite against strain-induced martensite formation the increased formation of bainitic carbides in the second stage tempering. The various technical aspects in correlating the microstructure with the mechanical and wear properties of hypereutectic austempered grey iron are described. Roy et al. [7] evaluate the scope of enhancing wear resistance of austempered ductile iron (ADI) by laser surface melting (LSM) and laser surface hardening (LSH). A detailed study concerning microstructural evolution and mechanical properties following LSM and LSH indicates that LSM develops a relatively low micro hardness at the near surface region and a predominantly austenitic microstructure in the laser melted zone. On the other hand, LSH, compared to LSM, results into a higher and more uniform micro hardness profile due to a primarily fine martensitic microstructure in the laser hardened zone. Careful X-ray diffraction analyses coupled with microstructural studies, reveal that diffusion of carbon from Graphite is responsible for a higher volume fraction of retained austenite and lower hardness in the laser-irradiated zone following LSM than those after LSH. Furthermore, LSH develops residual compressive stress, while LSM produces residual tensile stress on the surface. Finally, adhesive wear tests with a pin-on-disc machine and subsequent microstructural analyses show that LSH is more appropriate than LSM to enhance ADI's adhesive wear resistance. Soriano et al. [8] studied the laser surface hardening process of two austempered ductile iron grades, with different austempering treatments has been carried out. Hardening was performed with a continuous infrared wave Nd: YAG laser in cylindrical specimens. The laser hardened samples' microstructure was investigated using an optical microscope, micro hardness profiles were measured and surface and radial residual stresses were studied by an X-ray diffractometer. Similar results were achieved for both materials. A coarse martensite with retained austenite structure was found in thetreated area, resulting in a wear resistant effective layer of 0.6 mm to 1 mm with a microhardness between 650 HV and 800 HV. Compressive residual stresses have been found at the hardened area agreeing with the microhardness and microstructural variations observed. The achieved results point out that laser surface hardening is a suitable method for improving the mechanical properties of austempered ductile irons. Slatter et al. [9] used a laser to treat a cast iron cylinder head's valve seat area. To optimise the laser parameters for use on the head, preliminary tests were carried out to investigate the fundamental wear characteristics of untreated cast iron and cast iron with a range of laser treatments. Previous work has identified the predominant wear mechanism in the valve and valve seat contact due to valve closure. Two bespoke test machines, one for testing basic specimens and one for testing components, were used to identify the laser parameters most likely to yield acceptable results when applied to a cylinderhead to be used in a fired dynamometer test. The problem raised by the shelter was genuine. There was significant wear between the valve and valve seat in the internal combustion engine, which has to be managed by properly selecting valve material and proper hardness treatment. Selvan et al. [10] experimented on the Microstructural features occurring in CO_2 laser hardened En18 steel with the use of optical microscopic and scanning electron microscopic analysis. Also, the correlation between the surface temperature and cooling rate on the resulting hardness was explained. Theoretical thermal profile studies were made, and theireffect on the coupling coefficient values, hardness and the microstructural changes observed were discussed. The effect of laser hardening on wear resistance was described. The researcher did this investigation because Laser surface hardening is an effective technique used to improve the tribological properties and increase the service life of automobile components such as camshafts, crankshafts, and lorry brakes drums and gears. High power CO_2 lasers and Nd YAG lasers are employed for localised hardening of materials and hence are potential applications in the automobile industries. All steel surfaces can be hardened with high power laser sources, the degree of hardenability and finenessin microstructure obtained depending on the laser processing variables and on the absorption coatings employed. Giorleo et al. [11] designed the experimental campaign to analyse the effects of the process parameters (laser power, workpiecerotational speed and workpiece diameter) on the hardened tracks in width,thickness and hardness values when the AS is applied to the circular laser hardening. Going in this area was back tempering, a well- known problem in laser hardening of steels, occurs when multiple overlapping passes harden a large area.The overlapping passes partially temper the previous hardened material in the overlapped zone. Back tempering also occurs in circular laser hardening, a typical laser surface treatment used in the Case of cylindrical workpieces since the treated starting/ending surfaces are slightly overlapped. To avoid the back tempering phenomenon, the clear spot (AS) technique is addressed and investigated. In the Case of circular laser hardening, the AS technique is based on imposing a high rotational speed to the work piece since a clear circular spot is generated, which contemporaneously heats all the work piece's annular surface. Tursun et al. [12] Existence of back tempered regions in laser hardened materials is a common industrial problem. As a result of back tempering, the areas have a lower hardness than hardened areas, becoming a potential breakage starting point. In the research, Laser hardening is applied to AISI 1060 to analyse the relationship between laser beam parameters and the back-tempered region. An analytical model for the thermal cycle similar to the experimental condition is built, and results from the experiment and modelling are compared. Hsu et al. [13] studied the ductile irons with and without one wt% copper alloy were austempered to become austempered ductile irons (ADIs). Microstructure, impact toughness, and fracture toughness were evaluated to determine how both the copper alloying and austempering treatments influenced ductile irons' toughness properties. The results show that, because copper increases the retained austenite content in ADI, the Cu-alloyed ADI has better impact toughness and fracture toughness (KIC value) than does the unalloyed one. In particular, the impact toughness and the fracture toughness of ADI could be efficiently improved by treating the Cu-alloyed ductile iron at a higher austempering temperature (360°C) to obtain more retained austenite in its microstructure. After the successful investigation, the researchers highlighted that Austempered ductile iron (ADI) with one wt% copper addition could increase the retained austenite content in its microstructure. The fracture toughness (KIC value) and impact toughness properties of ADI depend on retained austenite content. For ADI, the correlation between the KIC value and the impact toughness seems to reveal a line proportion. A Rac [14] studied the dry wear through the dry sliding condition of grey cast iron (containing flakes and nodular Graphite), using the pin on disc machining. The experiment aimed to determine the influence of working conditions on the wear rate and find the speed and load condition subjected to low wear. The researchers concluded that the wear characteristic was the same for both flakes and nodular Graphite cast iron for the dry sliding test. The second observation was that the wear rate initially diminishes with the increasing sliding speed, and then the wear rate started again. The wear resistance of flake graphite cast iron is lower than the nodular at a speed greater than four m/s, and if the speed is lower than the wear resistance of nodular cast iron is more. Theresearcher also characterised the region of lower wear in the paper. Terrace et al. [15] studied the wear characteristic of grey cast iron used to study the cylindrical liner. The researchers studied various mechanisms that may influence the material's wear characteristics (truncation, adhesion, delamination and ploughing).The researchers explored the parameters like the relationship between the measurement of friction and wear load and the number of cycles. Also, it wasobserved that the load is the most sensitive factor for friction and wear. Prasad et al. [16] discussed sliding wear characteristics of a grey cast iron over a range of applied loads in oil-lubricated condition Effects of MoS2 and graphite addition to the oil lubricant in governing the wear Behaviour have also been studied. Thewear rate increased with load in general with a few exceptions in the Case of oil plus 5% MoS2, wherein it tended to show a reverse trend in the intermediate loadrange. Addition of 5% graphite to the oil brought about a decrease in the wear rate without affecting seizure Resistance. The increasing quantity of Graphite in the oil from 5 to 10% practically did not affect the lower loads' wear rate. However, it led to significantly lower wear rates at higher loads and also offered higher Seizure resistance. In the Case of oil plus 5% MoS2 lubricant mixture, thesamples' wear rate was higher than that of the lubricant with 5% graphite when tests were conducted at lower loads, while an identical Response was observed athigher loads in both cases. The samples' seizure resistance was not affected by the addition of 5% graphite and MoS2 to the oil. The frictional heating also increased with load in general, except in the oil containing 5% MoS2 and 10% graphite, wherein it remained practically unaffected in the intermediate load range. The presence of 5% graphite and MoS2 in the oil lubricant brought about Reduced frictional heating, except in the Case of oil plus 5% graphite mixture wherein the trend reversed, and oil plus 5% MoS2 leading to comparable frictional heating during specimen seizure Increasing test Duration caused higher frictional heating. Adhesion was observed to be the principal wear mechanism, while Micro cracking assisted delamination and abrasion also contributed to material loss. Prasad [17] studied the effects of suspended solid lubricant (Graphite and talc) particles in oil on a cast iron's sliding wear response. He analysed the role played by the changing concentration of the talc and graphite particles added to the oil separately as well as in combination toward controlling the wear Behaviour of the cast iron the investigation strongly suggests beneficial effects of the Solid lubricant particles suspended in lubricating oil in terms of decreasing wear rate, frictional heating, And friction coefficient. Interestingly, increasing concentration of the suspended lubricant particles in oil led to a reduction in the mentioned properties initially followed by the minimum attainment at a specific Concentration of the solid lubricants. At still higher concentrations, the trend reversed in the Case of wear Rate and friction coefficient while it remained unaffected as far as the influence on frictional heating is concerned. The formation of a stable lubricating film/layer was noted to be responsible for the samples' improved wear Performance. In contrast, rupture of the lubricant film led to the deterioration in wear behaviour. Childs et al. [18] Performed the Boundary-lubricated pin-on-ring tests with cast iron materials to produce specific wear rates between lo-l3 and lo-i0 mm3 mm-' N-l, which is the range observed in practically operating machine elements such as automotive piston rings on cylinder liners. The tests were also done to study the wear mechanisms responsible, particularly the relative importance of high cycle metal fatigue and chemical reaction film wear. Two types of cast iron used as piston rings (a grey and a carbide iron) were used as pins, and a cylinder bore material was used as the ring. Specific loads were varied from 20 to 400 MPa, and the sliding speed was 0.4 m s-l. Boundary lubrication was achieved with light medicinal paraffin oil and with the paraffin added 1% by weight of zinc dialkyl dithiophosphate

(ZDDP). No attempt was made to reproduce engine gaseous atmospheres or temperatures. There were differences in the wear resistance of thepin materials. When paraffin alone was the lubricant, wear occurred by removingoxide films: these were more protective on the grey than on the carbide iron. Theaddition of ZDDP changed the nature of the film for both materials. An insulating film developed on the grey iron reduced the wear rate. This film did not build upon the cardiac iron, the wear of which remained relatively high. It is suggested that the matrix carbides in the carbide iron scraped away the film as it formed.

B.K Prasad [19] studied the role played by an externally added solid lubricant like Graphite towards controlling the sliding wear behaviour of a zinc-based alloy. The influence of dispersing hard silicon carbide particles in the alloy was also investigated by testing the composite in identical test conditions. The wear performance of the zinc-based alloy and its composite was compared with that ofgrey cast iron. Wear tests were performed in an oil-lubricated environment. The lubricant composition was changed by adding various quantities of Graphite (particles) to the oil. The study suggests that the wear response (in terms of wearrate, frictional heating and friction coefficient) of the samples improved in the presence of suspended graphite particles in the oil lubricant. However, this improvement was noticed up to graphite particles' critical content only, and the trend reversed at still higher graphite contents. The zinc-based (matrix) alloy revealed the highest wear rate. Dispersion silicon carbide particles showed a significant improvement in the wear performance of the matrix alloy. The cast iron performed in between the matrix alloy and composite. The frictional heating and friction coefficient were the highest for the composite, while the cast iron andthe matrix alloy showed a mixed response. Examinations of wear surfaces, subsurface regions, and debris particles helped to substantiate the samples' observed wear response. Prasad et al. [20] made the observations during sliding of a grey cast iron against a steel counterface over a range of sliding speeds, applied loads and test environments. The nature of the environment was altered through the presence of oil and suspended graphite particles therein. The presence of oil improved the samples' wear characteristics in terms of lower wear rate and decreased frictional heating in general. An additional presence of suspended graphite particles in the oil lubricant brought about a further improvement in thesamples' wear response in all the test conditions except at the highest speed at high applied loads; the trend reversed in the latter case. Increasing speed and loadled to the deterioration in the wear behaviour. The material's behaviour has been explained in terms of the specific response of different micro constituents such as pearlite, ferrite and Graphite and corroborated with the observed features of wear surfaces, subsurface regions and debris particles.

3. Conclusions

At present, heat treatment and surface hardening treatment are two standard methods to increase cast iron and steel engineering components' wear resistance. Austempering is one of the most effective heat treatments to enhance ferrous materials' performance, especially Graphite ductile iron (DI). It is well-known that austempered ductile iron (ADI) has outstanding mechanical properties such as high strength-to-weight ratio, fatigue resistance and toughness, which is associated with its unique ausferritic structure. Laser surface hardening is a useful technique used to improve the tribological properties and increase the service life of automobile components such as camshafts, crankshafts, lorry brake drums andgears.

References

[1]. Suh A, Patel J, Polycarpou A, Corny T. Scuffing of cast iron and Al390-T6 materials used in compressor applications. Wear 2006; 260(7-8):735 44.

[2]. Keller J, Fridrici V, Kapsa P, Vidaller S, Huard J. Influence of chemical composition and microstructure of gray cast iron on wear of heavy duty diesel engines cylinder liners. Wear 2007; 263(7-12):1158 64.

[3]. Truhan J, Qu J, Blau P. A rig test to measure friction and wear of heavy duty diesel engine piston rings and cylinder liners using realistic lubricants. Tribol Int 2005; 38(3):211 8.

[4]. Demas N, Erck R, Fenske G. Tribological evaluation of piston skirt/cylinder liner contact interfaces under boundary lubrication conditions. Lubr Sci 2010; 22(3):73 87.

[5]. Balachandran G, Vadiraj A, Kamaraj M, Kazuya E. Mechanical and wear behavior of alloyed gray cast iron in the quenched and tempered and austempered conditions. MaterDes 2011; 32 (7):4042 9.

[6]. Vadiraj A, Balachandran G, Kamaraj M, Gopalakrishna B, Rao K. Structure-property correlation in austempered alloyed hypereutectic gray cast irons. Mater Sci Eng A 2010; 527 (3):782 8.

[7]. Roy A, Manna I. Laser surface engineering to improve wear resistance of austempered ductile

iron. Mater Sci Eng A 2001; 297 (1-2):85 93.

[8]. Soriano C, Leunda J, Lambarri J, Navas V, Sanz C. Effect of laser surface hardening on the microstructure, hardness and residual stresses of austempered ductile iron grades. Appl Surf Sci 2011; 257 (16):7101 6.

[9]. Slatter T, Taylor H, Lewis R, King P. The influence of laser hardening on wear in the valve and valve seat contact. Wear 2009; 267 (5-8):797 806.

[10]. Selvan J, Subramanian K, Nath A. Effect of laser surface hardening on En18 (AISI 5135) steel. J Mater Process Technol 1999; 91: 29 36.

[11]. Giorleo L, Liu A, Previtali B. Apparent spot in circular laser hardening: effect of process parameters. Int J Mater Form Mach Process 2010; 3 (1):1119 22.

[12]. Tursun M, Gheni M, Amrulla G, Nijat Y. Experimental Study of Back Tempering Problem of Laser Hardening. Key Eng Mater 2011; 462-463:1367 72.

[13]. Hsu C, Lin K. A study on microstructure and toughness of copper alloyed and austempered ductile irons. Mater Sci Eng A 2011;528(18):5706 12.

[14]. A Rac.:" Influence of load and speed on wear characteristic of grey cast iron, in dry sliding-selection for minimum wear", TRIBOLOGY international, 0301 679X/85/010029-05 $03.00 © 1985 Butterworth & Co (Publishers) Ltd.

[15]. Terheci, M., Manory, R.R.,. Herder, J.H.:" The friction and wear of automotive grey cast iron under dry sliding conditions Part 1 - relationships between wear loss and testing parameters", Wear 180 (1995) 73-78, Received 13 June 1994; accepted 15 September 1994.

[16]. Prasad, B. K., Rathod, S., Yadav, M. S., & Modi, O. P. (2011). Sliding wear behaviour of cast iron: influence of MoS 2 and graphite addition to the oil lubricant. Journal of Materials Engineering and Performance, 20(3), 445-455.

[17]. Prasad, B. K. (2010). Lubricated sliding wear behaviour of a cast iron: effect of graphite and/or talc fraction in oil. Journal of materials engineering and performance, 19(3), 413-420.

[18]. Childs, T. H. C., & Sabbagh, F. (1989). Boundary-lubricated wear of cast irons to simulate automotive piston ring wear rates. Wear, 134(1), 81-97.

[19]. Prasad, B. K. (2005). Effectiveness of an externally added solid lubricant on the sliding wear response of a zinc aluminium alloy, its composite and cast iron. Tribology letters, 18(2), 135- 143.

[20]. Prasad, B. K. (2008). Sliding wear characteristics of grey cast iron as influenced by sliding speed, load and environment. Tribology-Materials, Surfaces & Interfaces, 2(3), 128-138.