International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 10 (2015) pp. 25831-25842

http://www.ripublication.com

Effect of Process Parameters and Cr Addition on Microstructure, Hardness and Wear Rate of Surface Modified Cast Iron

Adithya Sankar[1], R. Sellamuthu[2]
M. Tech. Student[1], Department of Mechanical Engineering, Amrita School of Engineering
Professor[2], Department of Mechanical Engineering, Amrita School of Engineering
Amrita Vishwa Vidyapeetham, Coimbatore –641112, Tamil Nadu – India
[2]r_sellamuthu@cb.amrita.edu

Abstract

In this investigation, the hardness, microstructure and wear rate of cast iron surface modified with Chromium under different process conditions were studied. For performing the surface modification process, Gas Tungsten Arc(GTA) was used as the heat source. Chromium was electroplated onto the substrate surface with a coating thickness of 125μm. The surface was then melted using the GTA heat source. Hardness measurements were taken using a Vicker's micro-hardness tester and microstructure evaluation was performed using a Carl Zeiss metallurgical optical microscope. A pin-on-disc wear tester was used to perform the wear tests. It was inferred from the microstructural evaluation that the modified layer undergoes surface refinement as a result of the surface modification process. Hardness and wear rate measurements were taken for both the simple refined as well as surface modified specimens. It was observed that the hardness increased from 230 HV to 930 HV after the surface modification

Keywords: Cast iron, Surface modification, GTA, Hardness.

Introduction

Surface refining or surface modification is the process of enhancing the mechanical as well as tribologicalproperties on the surface of a material by surface alloying it with another material. It comprises of two steps: the first step is to coat the substrate with a suitable alloying element; the second step involves fusion of the alloying material onto the surface of the substrate using a suitable heat source and allowing it to cool to room temperature. The modified layer formed upon solidification improves the surface properties of the substrate material.

Studies have been conducted to analyse the effect of surface modification on various ferrous alloys, and are as follows. Peidaoet. al. studied the effects of surface alloying of low carbon steel with cobalt using a laser heat source. The authors reported that the hardness, performance under elevated temperatures and fatigue performance in the presence of thermal cycles improved as a result of surface modification [1]. A.Amirsadeghi et. al. conducted a study on the effect of TIG surface alloying of Austempered Ductile Iron(ADI) with Chromium and Molybdenum. It was observed that the surface modification improves hardness and wear resistance of ADI[2]. Fang et. al. observed in their investigation that the wear resistance of cast steel rolls improved after surface alloying with NiCr-Cr_3C_2. The authors reported that the alloyed layers had dense, pore and crack free homogenous structure [3]. Ji-Liang Dong et. al. studied the effect of laser surface alloying of Chromium onto AISI 1018 steel on the fatigue crack growth rate. It was concluded form the study that the fatigue crack growth rate decreases with increase in melt depth and hardness [4]. M. Heydarzadeh Sohi performed a microstructural study of surface melted and Cr surface alloyed ductile iron. It was reported that the hardness of treated layers was higher than that of the base material[5]. R. Arabi Heshvaghani, in his study observed an increase in hardness and wear resistance in ductile iron [6].

Cast iron is a ferrous alloy with 1.7-4.5% carbon. It has a wide range of application and is used in pipes, machines and automotive industry parts such as cylinder heads, cylinder blocks and gear box cases. The uses of cast iron in high wear applications are declining these days due to its high wear rates. Cast iron, if made harder and wear resistant is a suitable material for such applications.From the previous works conducted, it was concluded that the effect of process parameters on hardness, microstructure and wear resistance of cast iron surface modified with Chromium has not been studied yet. Hence, a study was conducted to evaluate the surface properties of simple refined and surface modified cast iron. The feasibility of using GTAas heat source was also evaluated by Arul and Sellamuthu [7], Cherian and Sellamuthu [8,9], Saravanan and Sellamuthu [10,11].

Experimental Procedure

Grade 20 industrial cast iron was machined into bars of dimension 30mm*30mm*150mm. Chemical composition of the substrate was checked by using arc spectrometry and the results are shown in Table 1.

Table 1: Chemical composition of substrate

Specimen	Wt % C	Wt % Fe	Wt % Si	Wt % Mn
Cast Iron	4.371	93.49	1.203	0.249

The substrate was given a chromium coating of thickness 125µm and the other specimens were surface refined using a GTA heat source. The coated specimens were then subjected to the surface modification process. The process parameter, current was varied (125,150,175, 200) while the other parameters like electrode angle(60°), electrode tip distance (3mm), speed (2mm/s), argon flow rate (12 liter/min) and electrode diameter (2.4mm) were kept constant. Thoriated tungsten electrode was used to carry out the surface modification process. A metallurgical optical microscope was used to analyse the microstructure. Vicker'smicrohardness tester was used to take the hardness measurements on the surface of the modified specimen as well as along the depth from the modified surface. Hardness measurements were taken by applying a 100 gmf force for a duration of 15 seconds. The average values of hardness taken at different locations of the respective specimens were used for the study. A pin-on-disc wear tester equipped with a diamond like coated disc as the counter face material was used to carry out the wear tests. The tests were performed under dry sliding conditions in air as per ASTM G99 standard. The following parameters were used to carry out the wear tests.

Table 2: Wear Testing Parameters

Parameter	Unit
Load	20 N
Speed	424 RPM
Track diameter	110 mm
Time	600 s
Velocity	2.5 m/s
Sliding distance	1500 m

The GTA equipment used to carry out the surface modification is shown in the figure below.

Figure 1: GTA equipment

Results and Discussion

A. Microstructure

Cast iron has a flaky structure as shown in Figure 2. Figures 3 and 4 show the microstructures of simply refined and surface modified specimens respectively. It can be observed from these figures that the grains are much more refined compared to that of the substrate. Thus, it is concluded that grain refinement has occurred as a result of the surface modification process. Grain refinement can be attributed to the rapid cooling of the molten surface of the specimens to room temperature.

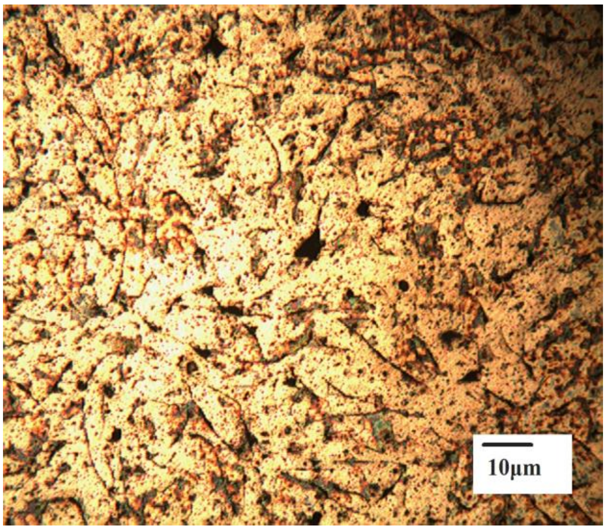

Figure 2: Cast iron substrate

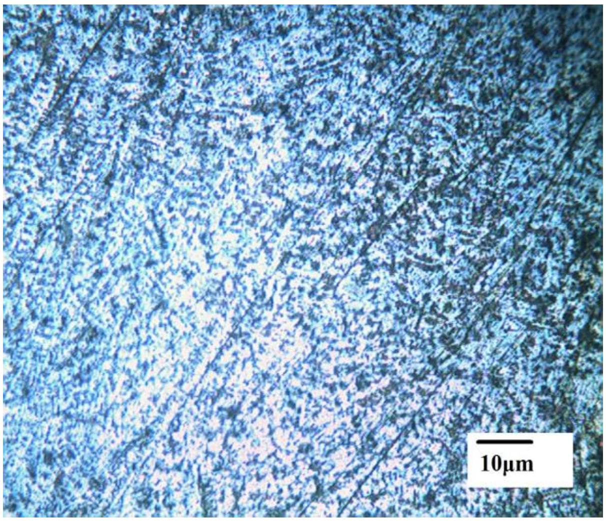

Figure 3: Simply refined cast iron

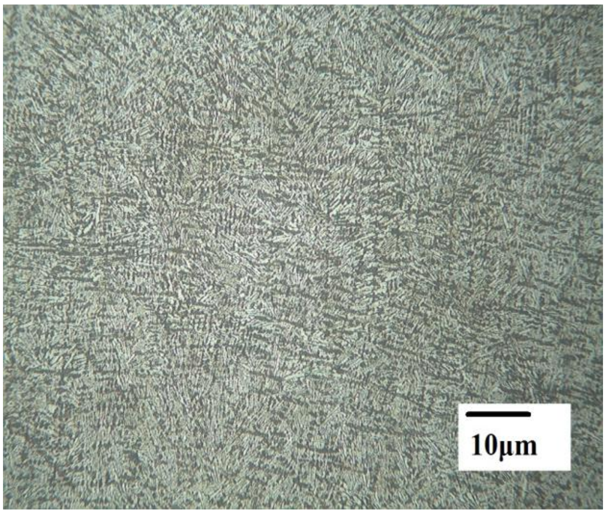

Figure 4: Cr alloyed cast iron

The EDS spectrum of cast iron surface modified with Chromium is shown in figure 5.

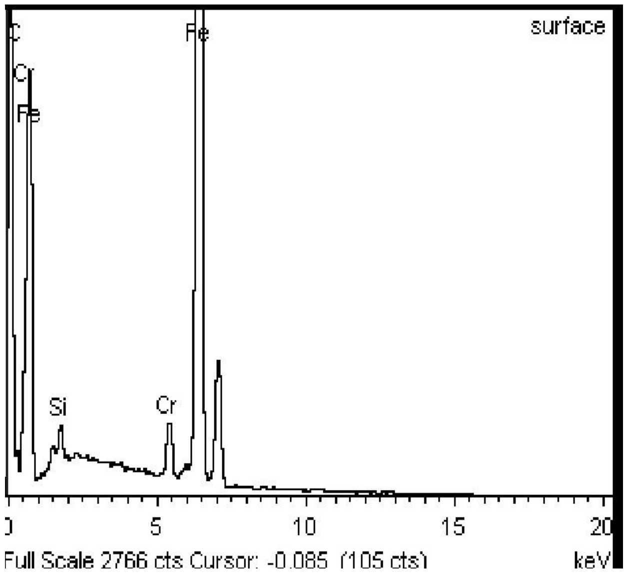

Figure 5: EDS spectrum of modified layer

B. Width and depth

The modified surface of Cast iron surface alloyed with Chromium is shown in figure 6.

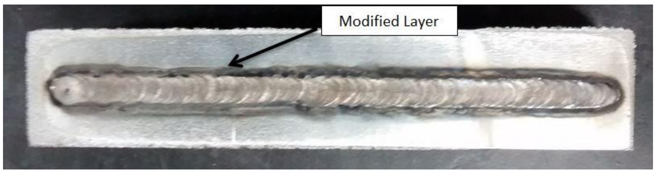

Figure 6: Modified layer

The width and depth of the modified layer is found to increase with current as shown in figure 7. Maximum width and depth were obtained for the highest current (200A). The highest values of width and depth obtained were 15mm and 3mm respectively.

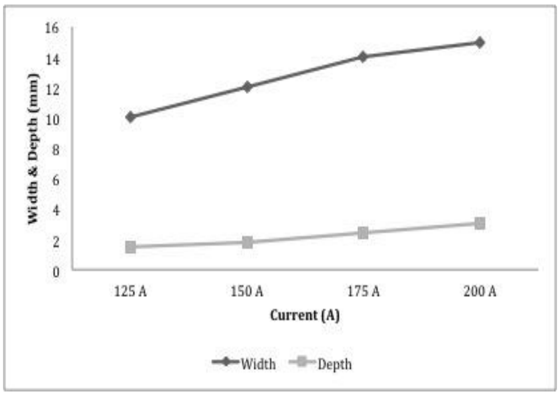

Figure 7: Width and depth variation with Current

C. Hardness

It is observed that hardness as well as the area of refinement increases with increase in current. Figure 8 shows the variation of hardness with current for the simple surface refined specimen. It is found that the hardness increases from 230 HVto 440 HV after simple refining. Rapid solidification during surface refining causes carbide formation resulting in an increase in hardness.

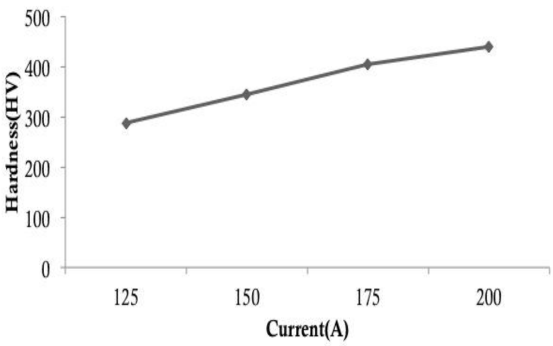

Figure 8: Hardness vs. current (Simply refined)

The variation in hardness with current for the surface modified specimen is shown in figure 9. It can be observed that hardness increases with the current. Surface hardness of 930 HV was obtained for the highest current (200A).

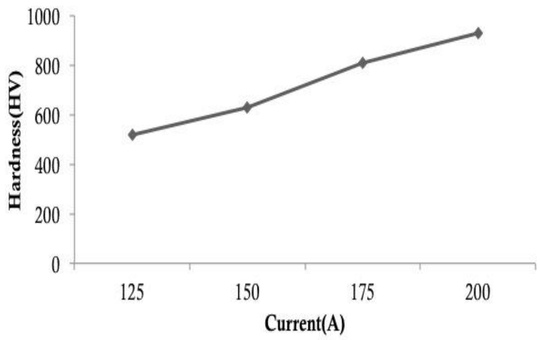

Figure 9: Hardness vs. current (Surface modified specimen)

From the EDS results, it can be inferred that the chromium content on the surface of the modified layer decreases with an increase in current asshown in figure 10. This can be attributed to increased chromium dissolution at higher currents.

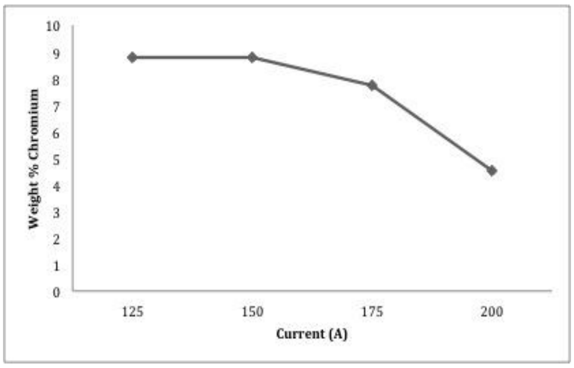

Figure 10: Cr variation with current

Surface modification increases the hardness of cast iron from 230 HV to 930 HV. Thisenormousincrease in hardness is due to the formation of hard carbide phase. At higher currents,the dissolution of Chromium is more, which further leads to an increase in the carbide phase formation.

Hardness along the depth for both simple refined and surface modified specimens are plotted in figure 11. It is found that hardness decreases gradually along the depth from the modified surface. A higher gradient observed in the case of surface modified specimen is a result of Cr addition.

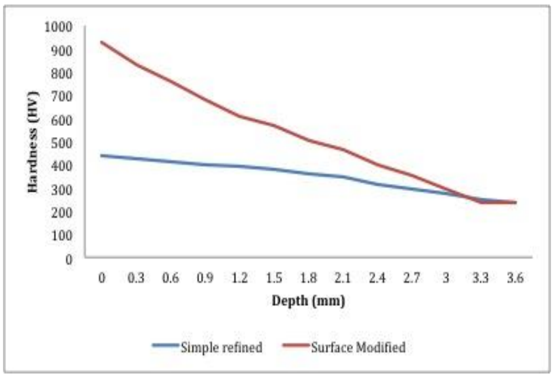

Figure 11: Hardness vs. depth

The comparison between the hardness values for the substrate, simple refined and surface modified specimens are shown in figure 12. Peak hardness was obtained for the specimen surface modified with Chromium.

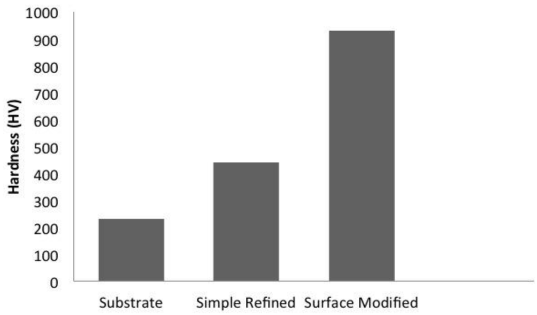

Figure 12: Hardness Values

Comparison between hardness value obtained in this study and those of previous studies is shown in figure 13. It can be noted from the bar chart that the results of this study are in agreement with that of the studies mentioned in the literature.

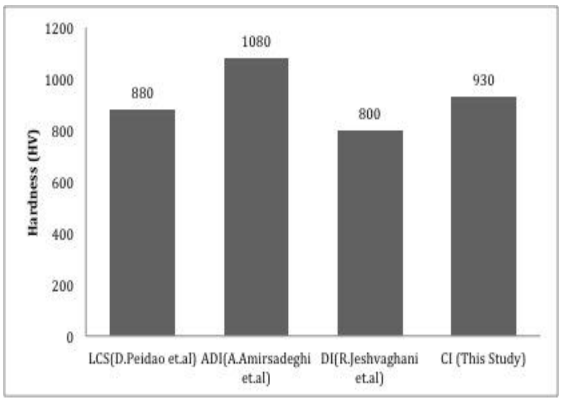

Figure 13: Hardness comparison data

D. Wear Rate

Figure 14 shows the variation of wear rate with hardness. It can be concluded from the figure that wear rate has an inverse relation with hardness, which is in agreement with that of Archard'sadhesion wear theory (Archard J.F, 1953) [12].

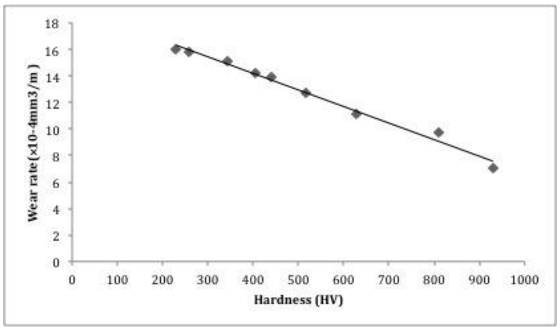

Figure 14: Hardness vs wear rate

The wear rates of as cast iron, simple refined cast iron and surface modified cast iron are compared in figure 15. It can be observed from the bar chart that the highest wear rate is obtained for untreated cast iron and the lowest wear rate for cast iron surface modified with chromium.

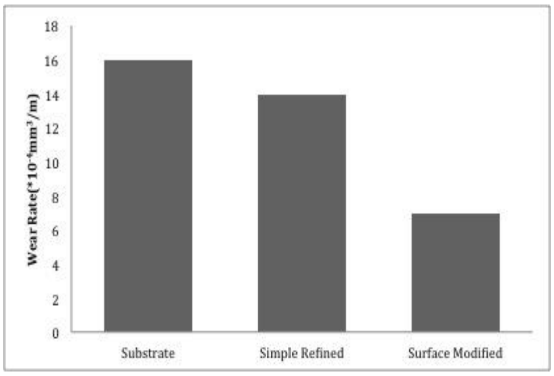

Figure 15: Wear rate

Figure 16 shows the SEM image of the wear debris of surface modified cast iron. It can be concluded from the image that the wear mechanism is adhesive in nature.

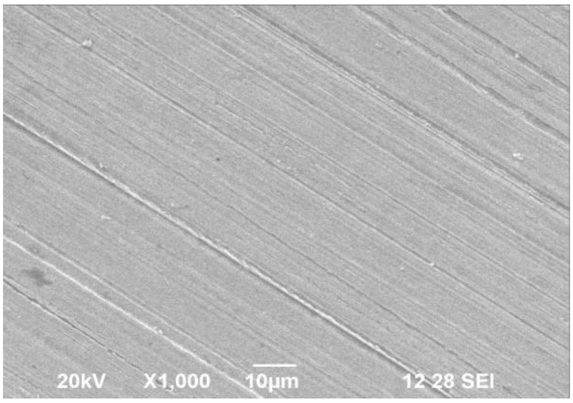

Figure 16: Wear debris

E. Coefficient of Friction

The variation in coefficient of friction with hardness is shown in figure 17. A constant value of 0.45 is obtained irrespective of the hardness.

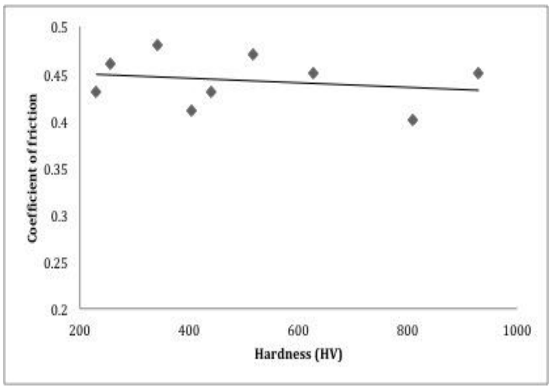

Figure 17: Coefficient of friction

Conclusions

The effect of process parameters on the microstructure, hardness and wear rate of surface modified cast iron was studied and the following conclusions were drawn:

- Surface modification results in grain refinement.
- Increase in hardness after surface modification is due to the formation of hard phase carbides and martensitic transformation.
- Surface hardness increases with current.
- Gradient in hardness obtained along the depth from the modified surface is due to the addition of Chromium.
- Wear rate has an inverse relation with hardness.
- The coefficient of friction is independent of hardness.
- The results of this study are in agreement with that of previous studies.

References

[1] Ding Peidao, Liu Jianglong, Shi Gongqi, Zhou Shouse, Cao Pengjung (1996). " Laser surface alloying of a low alloy steel with cobalt". Journal of Materials Processing Technology 58 131-135

[2] A.Amrirsadeghi, M.Heydarzadeh Sohi (2008). "Comparison of the influence of molybdenum and chromium TIG surface alloying on microstructure, hardness and wear resistance of ADI". Journal of Materials Processing Technology 201 673-677

[3] Gui-fang Sun, Yong-kang Zhang, Chang-sheng Liu, Kai-yu-Luo, Xing-qi Tao, Peng Li(2010). "Microstructure and wear resistance enhancement of cast steel rolls by laser surface alloying NiCr-Cr_3C_2" Materials and Design 31 2737-2744

[4] Ji-Liang Doong, Yen-Hung Tan(1989). "Effect of laser surface alloying chromium onto AISI 1018 steel on the fatigue crack growth rate". int J. Fatigue 11 No.4 239-248

[5] A.Amirsadeghi, M.Heydarzadeh Sohi, S.F. Kashani Bozorg(2008). "Effects of TIG surface melting and chromium surface alloying on microstructure, hardness and wear resistance of ADI". Journal of Iron and Steel Research International, 15(4):86-94

[6] R.Arabi Jeshvaghani, E. Harati, M. Shamanian(2011). "Effects of surface alloying on microstructure and wear behavior of ductile iron surface modified with a nickel based alloy using Shielded Metal Arc Welding". Materials and Design 32 1531-1536

[7] S.Arul, R.Sellamuthu(2011). "Application of a simplified simulation method to the determination of arc efficiencyof Gas Tungsten Arc Welding(GTAW) and experimental validation". International journal of computational materials science and surface engineering, Vol.4,pp.265-280

[8] Cherian Paul, R.Sellamuthu (2014), " An investigation on the effect of process parameters on microstructure, hardness and wear properties of surface modified Cu-Sn Bronze alloy". Applied mechanics and materials, Vols 592-594, pp 58-62

[9] Cherian Paul, R.Sellamuthu(2014). " The effect of Sn content on the properties of surface refined CU-Sn Bronze alloys." Procedia engineering 97,pp 1341-1347

[10] R.Saravanan, R.Sellamuthu(2014). " An investigation of the effect of surface refining on the hardness and wear properties of Al-Si alloy." Applied mechanics and materials, Vols.592-594, pp53-57

[11] R.Saravanan, R.Sellamuthu (2014). “Determination of the effect of Si content on microstructure, hardness and wear rate of surface refined Al-Si alloys”.Procedia engineering 97 pp1348-1354

[12] Archard J. F, (1953), ‘Contact and Rubbing of Flat Surface’, *Journal of applied Physics*, Vol. 24(8), pp. 981-988.