Influence of chromium with rare earth oxide addition on microstructure and corrosion resistance of grey cast iron hard facing alloy.

Mohit Kanyathia  
Student, Department of mechanical engineering,  
Thapar institute of engineering & technology,  
Patiala, Punjab, India.

R.S. Joshi  
Assistant Professor, Department of mechanical Engineering,  
Thapar institute of engineering & technology,  
Patiala, Punjab, India.

Sikanderpal Singh  
Student, Department of mechanical engineering,  
Thapar institute of engineering & technology,  
Patiala, Punjab, India

Vinod Kumar Singla  
Associate Professor, Department of mechanical Engineering,  
Thapar institute of engineering & technology,  
Patiala, Punjab, India.

Vipin Kumar Sharma  
Research Scholar, Department of mechanical engineering,  
Thapar institute of engineering & technology,  
Patiala, Punjab, India

Abstract  
The hardfacing technique for repairing and increasing the life of equipment was one of them in the top of the list. "Preventive hardfacing" is the utilization of hardfacing procedures to the generation of a fresh component. In the current investigation the effect of various rare earth oxide with the addition to chromium was done to calculate the wear and corrosion behavior of hardfacing on grey cast. By using electrode of TENALLOY 16-7016 having a hardness of 150 BHN. First five samples were prepared for EBSD and for microhardness tester with chromium weight percentage of 1.7%, cerium oxide with weight percentage of 0.6% and lanthanum oxide of 0.4% and at last filled them in the groove on grey cast iron sample. The lanthanum oxide showed the refined grain structure in EBSD testing and the sample of chromium and lanthanum oxide showed least mean grain size. Micro-hardness testing done at dwell time of 20 seconds and at a load of 500 gm. Pin-on-disc machine used EN 31 high speed steel and for this experiment six samples were prepared which were operated at 955, 764, 1273,546, 477 and 637 rpm and after every 5 minutes the sample was weighted. From the calculated results it was observed that the chromium sample got less wear than the other samples and the maximum wear found in chromium and cerium oxide sample. For corrosion testing, salt spray chamber for 120 hours i.e. almost for 5 days placed under the spraying of NaCl solution. Results states that chromium and cerium oxide sample showed less corroded area among the other samples with area corroded of 18%. It can be inferred from the experimentation that the chromium and lanthanum oxide sample increased the hardness along with least abrasive size. During corrosion analysis the best sample was the chromium and cerium oxide with weight of 1.57% and in wear analysis the best sample to resist weight loss was the chromium sample with weight of 1.78%.

Keywords: EBSD, welding, Micro-hardness, corrosion testing.

Introduction  
With the increase in the marketing of everything, large number of products are going to be manufactured with a least lap time and the competition among every manufacturing industry was increasing day by day which also effects the quality and the performance of every industry. Repairing the sample was one of the best method to save the cost of inventory. Hardfacing or hard surfacing was the economical method to repair the component with a least...
price and it may also increase the life of the component with 2 to 3 times the life of the newly made component [1]. Several researches was done to examine the effect of various elements or alloys added to the component with the help of using several welding processes. Hardfacing was mostly used for agricultural equipment’s, or the tools related to mining operation [2]. Hardfacing is an application of build-up deposits of narrow alloys [3]. Chromium element was excellent outwit in the region to resist abrasion and also to corrosion resistance. It was easily purchased through any welding electrode shops. Enormous welding techniques including SMAW (shielded metal arc welding), submerged arc welding, Plasma transferred arc welding. Powder spray. Flux core type of welding was used for hardfacing on base metals. Hardfacing can be done to limited base metals that includes Stainless steels, Manganese steels, Cast irons and steels, Nickel-base alloys, Copper-base alloys. Rare Earth oxides such as cerium and lanthanum oxide had large impact on the mechanical properties as well as the microstructure of grey cast iron. TENALLOY 16-7016 commonly used low hydrogen electrodes for welding cast iron samples having composition of C With 0.06%, mn with 1.2%, Si with 0.5%, S with 0.02% and P with 0.02%

The aim of the experimentation was to know the change in the mechanical properties as well as in the microstructure of grey cast iron samples by adding chromium with cerium oxide and lanthanum oxide. Various stereological methods applied to calculate and to compare the impact of rare earth oxides with the mixture of chromium and given an excellent results by having the study of corrosion behavior and wear loss of the samples when subjected to different parameters at room temperature.

Experimental

Material and welding parameters

The grey cast iron sample of GRADE 25(Type A) with a dimension of 150 x 25 x 15 mm was prepared by casting. Initially sample had hardness of 192 BHN along with presence of pearlite matrix of ferrite with 4%. Sample was cleaned and peen with shot blasting machine for 20 minutes. After this grooves with a dimension of 4 x 2 mm was established on all the samples as shown in the Fig.1. Grooving was done by shaper machine and after completing this task the five elements in powder are mixed with potassium silicate liquid to make the paste. These five samples includes the cerium oxide (CeO$_2$=0.65%)lanthanum oxide (La$_2$O$_3$=0.40%), chromium (Cr=1.78%), chromium & lanthanum addition (Cr+La$_2$O$_3$=1.27%) and chromium & cerium addition (Cr+CeO$_2$=1.57%). The paste of specialized alloys was deposited on the grooves made on cast iron samples. Completing the depositing of the elements, all the samples were placed under the sunlight to make it free from the moisture and make it dry so that the welding can be done without any interruption. The SMAW type of welding was acclimated at current of 150 A, with an input voltage of 300 V and frequency of 50 Hzs.

After finishing the operation of welding, surface of the sample flattened by using hand grinding machine. Samples for various analysis like wear, corrosion and for EBSD (Electron backscattered diffraction) was prepared as per the requirement of the machines.

Microhardness testing

The samples was prepared of 30 x 25 x 15 mm for calculating the microhardness by using harness tester (Acme micro hardness tester), one of the precisely manufactured tester having an accuracy percentage of ±1% and depth of throat of 110 mm. The fixed dwell time of 20 seconds along with stifled value of load with 500 gm was applied to all the samples. Four distinct observations were captured for each of samples along with the image of indentation.

EBSD (Electron backscattered diffraction)

A cube of 10 mm was fabricated and after this task all the samples were gone through electroplashing also known as anodic polishing to deburr metal parts. This process was opposite of electroplating technique. Solution of 10 of oxalic acid mixed with H$_2$O of 90% for EBSD measurement. Basically analysis was performed to know more about the crystalline microstructure of the sample along with gain size and misorientation at different angles and the presence of twin boundaries. Refinement of grain was clearly optimized by this technique. Each color of grain represent the number of grain in a microstructure.

Wear Analysis

This test was performed on pin-on-disc machine at same speed of 2m/s with varying sliding distance and varying weight. The samples were machined in such a way that the weld bead should rubbed properly on the disc of high speed steel with a grade of EN 31 steel having a dimension of 120 mm in its diameter and thickness of 10 mm. This high speed steel was much hardened than the grey cast iron samples. The weight loss was calculated after a time interval of 5 minutes. The pin on disc machine for wear analysis was shown in the Figure 1.
Fig. 2 which shows how the sample was being placed on the steel plate for wear analysis.

![Fig. 2 Pin on disc wear test machine](image)

2.5 Corrosion test (Fog chamber)

Salt spray chamber (ASTM-B-117-11) was operated on NaCl solution of 5% with pH value of 7. Some other solution was also used in salt spray chamber that includes the hydrochloric acid, sodium oxide etc. The samples were placed under NaCl solution for 120 hours i.e. almost for five days at room temperature. Each sample was optimized by using optical microscopy after every 24 hours to see the signs of spots occurred on the samples.

Results & Discussions
Fig. 3 Microstructure for all the 5 samples was shown with different grain size where CE- cerium oxide, CCE- addition of chromium & cerium oxide, C- chromium, L- lanthanum oxide and CL- addition of chromium and lanthanum oxide.

**EBSD**

Different samples were examined at 50 µm except chromium sample which was seen at higher magnification of 100 µm. Lanthanum oxide microstructure showed refined structure with the presence of ferrite of fcc structure. Some twin boundaries were also seen in almost all the samples at higher angle of 50° C, these boundaries are nothing but the sharp edges present in between the two or more than two grain boundaries. Chromium showed large grain size structure with homogeneous structure and with an absence of precipitates. Chromium sample consist of austenite with gamma phase above eutectic temperature. The maximum misorientation was observed in chromium and lanthanum oxide mixture sample and also in lanthanum oxide sample. The average grain size was calculated for all the five samples as shown in Table 3.1. It clearly states that the chromium showed large average grain number of 217.025±110.637 and least grain size measured was 2.355±1.944.

Fig.4 Graph plot for Cr with average grain size of 217.025±110.637

Fig.5 Represent grain size plot of chromium and cerium oxide
Fig.6 Graph for Cr+CeO₂ with average grain size of 7.53604±6.00132

Fig.7 Represent the grain size vs area fraction of chromium and cerium addition and lanthanum and chromium addition

Fig.8 Represent the variation of grain size of lanthanum oxide specimen

Above graphs showed the five different samples relative to the grain size variation with the different area fraction. Among these five samples the chromium and lanthanum showed least grain size with respect to area fraction whereas chromium sample resulted the maximum grain size number.

Microhardness tester

As samples were indented at load of 500gm, The Table showed value for each sample. The maximum microhardness was recorded for chromium and lanthanum mixture sample(Cr+La₂O₃=1.27%) with a value of 544 HVN and least microhardness was experienced for cerium oxide sample with 409 HVN.

Agarwal et al.[4] also explained the proof of Hell-Petch equation for using vacuum deposit of Ni-20 Cr films that sample with higher grain size number had maximum microhardness.

\[ H = H_o + K_H x d^{1/2} \]

Where H was hardness, d was grain size and \( K_H \) and \( H_0 \) are constant comparable to yield stress constants.

From the above data it was very much certified that chromium& lanthanum oxide mixture sample showed least
grain size along with maximum microhardness, which proofs the Hell-Petch equation.

![Element vs Hardness](image)

Fig.9 Represent the microhardness of five different samples.

**Wear analysis**

Performed on pin-on-disc at same speed but by varying sliding distance from 600m to 4200m. The graphs were shown for each sample. Three samples that includes Cr with 1.78%, Cr+CeO$_2$ with 1.57% and Cr+La$_2$O$_3$ with 1.27% was examined on EN31 steel disc. After every 5 minutes the weight loss was calculated and sample of Cr+CeO$_2$ sample showed tremendous weight drop of 116s mg and Cr sample resulted in least weight loss of 48 mg. It also proved that the microhardness does not have any co-relation with the weight loss. The wear table was shown.

**Corrosion testing**

After placing the samples for 5 days under salt spray chamber by using NaCl solution. Corroded area was calculated of the weld bead and after every 24 hours the image of sample was checked in optical microscopy to know about the spots formed on the weld bead. The Chromium and lanthanum mixture sample showed maximum corroded area with 70% and least corroded area was recorded of chromium and cerium mixture sample at 18%. The chromium sample corroded area was 20% which was very close to the Cr+CeO$_2$ sample. Secondly the Microhardness does not had any co-relation with the area corroded.

**Conclusion**

Five different samples were prepared with different composition of chromium with 1.78%, cerium oxide with 0.65%, lanthanum oxide with 0.4% and the mixture of cerium and chromium with 1.57% and the lanthanum & chromium sample with 1.27% and four different test were performed to know the mechanical properties of the cast iron sample. The following things were observed while performing the testing.

1. Chromium and lanthanum oxide (1.27%) sample showed maximum hardness as compared to the four other samples with value of 544 Vicker’s hardness number. Least hardness was observed in lanthanum oxide sample with value of 409.
2. EBSD analysis showed the microstructure of five samples with grain size. Among these five samples the chromium with 1.78% showed large grain structure as compared to other samples and chromium plus lanthanum mixture sample with 1.27% showed smallest grain size of 2.35563.
3. Corrosion test took place under NaCl solution for 120 hours and it was observed that chromium and lanthanum showed least corroded area among other samples and chromium and lanthanum oxide sample showed maximum corroded area of 70 %. But the hardness does not have any direct correlation with corrosion resistance. Sometimes sample with more hardness gets more corroded than less hard sample at higher temperature.
4. Wear test analysis proved that wear resistance not proportional to hardness, it was possible that sample with more hardness will give less wear weight loss. Among five samples chromium showed least weight loss about 48 mg. On another side cerium and chromium mixture sample showed maximum weight loss.
5. Chromium and lanthanum oxide sample showed refined grain structure with least grain size with least twin boundaries present.

**References**


