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Effect of Boronizing on Erosive wears of Alloy Steel

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ABSTRACT

This study aims to Diffuse boron atoms into the alloy steel. The samples were Boronized using BORAX (Di sodium tetra borate) and Boron carbide as a Boron Source. The advantage of using the BORAX as potential source for boron is to avoid formation of fragile FeB phase over the surface. The Temperature and time for Boronizing was set at 1073 K and 1 Hr respectively. Erosive wear performed in Air Jet Erosion tester TR-470. The result exploited that the boronized samples show improved wear resistance than untreated samples. Mathematical model based on Third order polynomial equation was developed for erosive wear rate as a function of time. Atomic Force Microscopy (AFM) image confirms diffusion of Boron over the steel surface.

Keywords – AFM, Boronizing, Diffusion, Erosion, Mathematical model.

1. INTRODUCTION

Solid particle erosion wear is one of the issues in enterprises, this happens when hard strong particles entrained in air and impinging on the example surface at various points. It includes the slow loss of material in the example surface. The disintegration happens in water pipe, wind factory sharp edges, helicopter rotor edges, aviation, siphon impeller edges and so on. Investigation of disintegration gets imperative for the explanation that it changes the surface just as property of the part. Usually analysts discovered the disintegration wear rate relies upon erodent speed, point of impingement (edge of effect), size of erodent, mass stream pace of erodent, and mechanical properties of erodent. [1-5] K.V.Pool (1986) looked into disintegration on composite material and inferred that the disintegration rate is high at slanted point. [6] In 2003, Q Chen reenacted strong molecule disintegration utilizing PC and uncovered erodent speed and size are prevalent parameters affecting disintegration wear. [7] Tentatively Uttam kumar and Mohammad Asaduzzaman (2017) contemplated disintegration wear on carbon fiber strengthened composites and distributed disintegration wear chiefly relies upon point of effect and stalemate separation. This perpetually says sway point is one of the transcendent disintegration wear parameters. [8] Comparably numerous specialists tested strong molecule disintegration in a controlled situation and proposed, edge of effect, erodent speed, erodent size, deadlock separation are critical parameters affecting pace of disintegration.

In Mechanical industries, Steels are most extensively used and most reclaimed material on earth. From Stainless and high-temperature steels to flat carbon products, steel's various forms and alloys offer different properties to meet in a various field of utilization. Low alloy steels are generally considered to compose plain carbon steels. They are more economical than the highly alloyed materials. Generally, they are used abundantly in heavy engineering industries. Boriding or Boronizing [9,10] is a surface treatment process in which atoms are diffused into the material surface. Boriding can be performed in legion ways, inclusive of gas boriding, molten salt boriding, with and without electrolysis, powder pack boriding and pack boriding. The boriding process involves the diffusion of atomic boron into the base steel. Boronizing is a thermo chemical surface hardening process in which boron atoms are diffused into the surface of a work piece to form complex borides (i.e. – FeB/Fe2B) with the base metal [11,12]. Mainly it enhances the mechanical properties such as high hardness, high resistance, and increased resistance and provides reduced coefficient of friction. The powder pack boriding has the convenience of simplicity and cost effectiveness in correlation with other boriding process. A few advantages that include obvious and large grains in surface hardness of the treated material that means surface wear are mainly reduced. Now there is a current trend towards the use of multi-component boriding. This study mainly focus that the samples were boronized using BORAX (di sodium tetra borate) as a boron source. The advantage of using the BORAX as potential source for boron is to avoid formation of fragile FeB phase over the surface. This study primarily focus on the four parts namely, (i) First one cope up with the identification norms for experimental design, preparation of boronized powder and samples, and also the methodology.(ii) Then boronizing process which is to be followed by the above stated temperature.(iii) Consequently the next process is the erosive wear test which is conducted according to the given properties.(iv) Finally the last process is the characterization techniques specially consists of SEM(Scanning Electron Microscope) and XRD (X-Ray Diffraction) to measure the hardness values and diffusion of boron atoms in the sample on the experimental basis. Ultimately, a mathematical equation is constructed to discuss about the erosive wear value of the surface. Lastly, the diffusion of boron in the boronized and erosive wear samples were evidently considered.

2. MATERIALS

Alloy steel Contains: Primary element (Iron and Carbon), Alloying element (Manganese and Chromium), Traces of (Sulfur and Phosphorus). The conventional name of the alloy steel purchased was the EN24 steel. The material was sliced into the following dimensions. Dimensions of sample: 15mm X 15mm X 3mm.

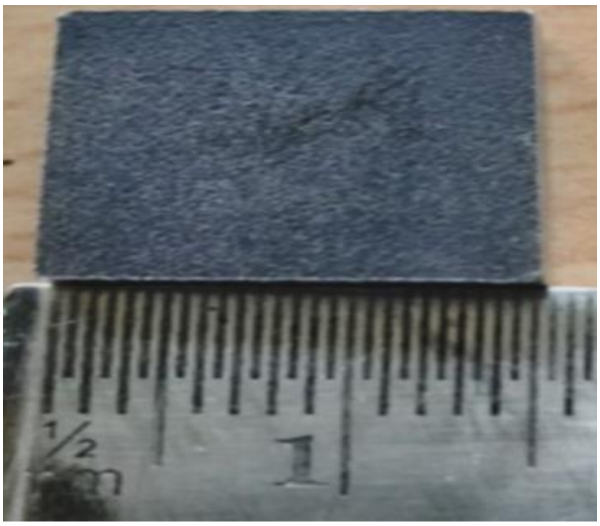

Fig. 1 Specimen for the experimentation

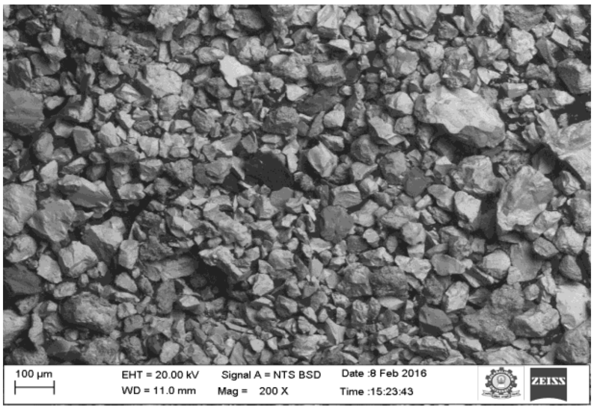

Fig. 2 SEM image of Boron carbide

The specimen was metallographically finished before the boronizing process.

3. METHODOLOGY

Boronizing process was carried out with a boron source in this case it is BORAX powder commercially available in the market. In addition to that Sodium chloride or Ammonium chloride is used as an energizer and silicon carbide is used as a dilutant in boronizing processes. During the endothermic process, the boron atoms liberated from the boron source and interstitially diffused into the steel surface. The diffused boron combines the ferrous atoms and forms an iron boride compound which has an extreme hardness (around 2000Hv), and superior wear resistant [11,12]. The mixture of boronizing process is mixed well and compressed inside the steel container at the bottom and the specimens were kept in the middle of the container ensuring the proper and complete diffusion. The container is moulded with the fireclay to ensure proper heat transfer. The mixture is pre heated to 50 -60ºC to remove the moisture content. The dimension of the container is Ø600mm X 300mm (150mm above sample and 150mm below sample). The container is kept inside the heat-treating furnace of range 1000ºC available at Kalasalingam Academy of Research and Education. The temperature maintained at 1073K (i.e., 800ºC) for the period of 3 Hrs. After 3 Hrs the container was taken outside the furnace and the quenched in the SAE40 lubricant oil.

The mixture used for the boronizing process is in the weight percentage shown below.

BORAX (Di sodium tetra borate)	60%,
B4C (Boron carbide)	15%,
SiC (Silicon carbide)	15%,
NH4Cl (Ammonium chloride)	5%,
NaCl (Sodium chloride)	5%

Fig. 3 SEM image of erodent alumina (Al2O3)

For the conduction of erosive wear test done by considering impact angle as 90^0 , erodent mass flow rate as 2.5gm/min and velocity of the erodent as 100m/s. The process parameter considered for the test is time of erodent flow as 10, 20, 30 and 40 mins. The ASTM G76 standard was used to perform solid particle air jet erosion studies. The sample size used for solid particle erosion test as per the standard was 25 × 25 × 5 mm and it clearly shown in figure 1.

The response, erosion wear was measured as mass change between before and after erosion. The mass of the sample was measured using precision balance with an accuracy of 0.0001gm. All the experiments were repeated for three different time period say 10mins, 20mins, 30mins, and 40mins. Erosive wear rate was calculated using the empirical formula shown in eqn 1 and eqn 2.

Erosion wear rate,

$$E_{wr} = \frac{\Delta m}{M} \qquad (1)$$

Total mass of the abrasive particles

$$T = Q*t \qquad (2)$$

3. RESULTS AND DISCUSSION

The OM image shown the figure 4 shows the diffusion of boron particle. SEM image of boronized sample was clearly seen in the figure 5 and the image represents the saw tooth morphology is clearly seen.

The erosive wear of the specimen is calculated and the same is plotted as the graph for the time of erodent flow as 10, 20, 30 and 40 mins.

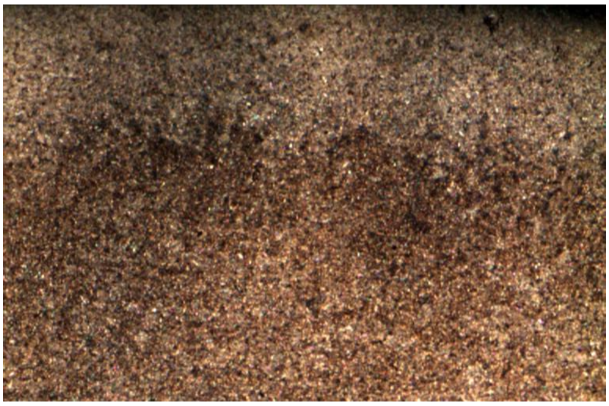

Fig. 4 OM image of boronized sample showing saw tooth morphology

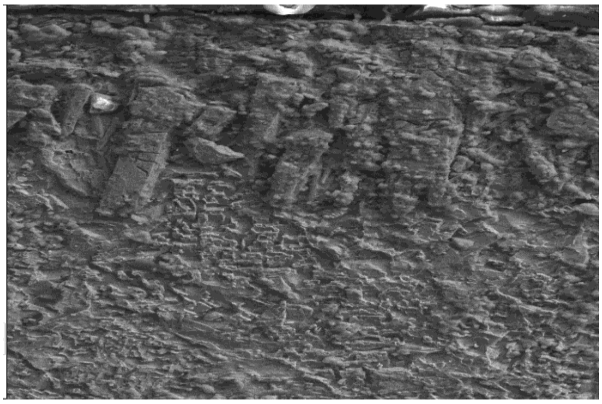

Fig. 5 SEM image of boronized sample showing saw tooth morphology

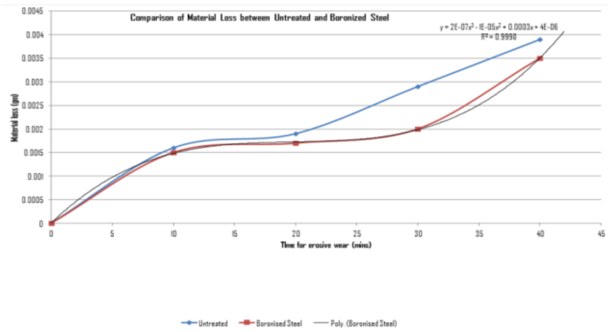

Fig. 6 A Comparative graph showing the weight loss of the specimen for untreated and boronized steel

Form the graph it is evident that the erosive wear increases with increase in time and for the untreated steel the after 20mins it is almost linear and possibly it happens in the rest of the test. For boronized sample the initial condition is almost same as untreated this is because the erodent contact time is very low so the change in mass of the component looks almost similar. But as the time increases the wear increases for untreated but the wear of the boronized is comparably low which clearly portrays that the boronizing withstands the erosive wear. Figure 7 clearly depicts the wear rate of the specimen during the erosion test.

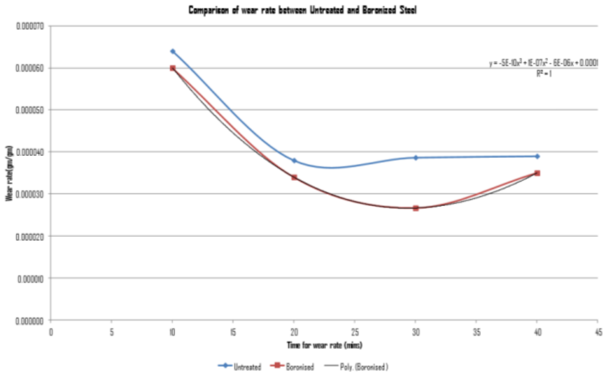

Fig. 7 A Comparative graph showing the wear rate of the specimen for untreated and boronized steel

The mathematical model for the prediction of both weight loss of the specimen and the wear rate of the specimen was shown in the equation 3 and 4, both follows third order polynomial curve.

$$\text{Weight loss} = (2 \times 10^{-7} \times t^{3}) - (1 \times 10^{-5} \times t^{2}) + (0.0003 \times t) + (4 \times 10^{-6}) \quad (3)$$

$$\text{Wear rate} = -(5 \times 10^{-10} \times t^{3}) + (1 \times 10^{-7} \times t^{2}) - (6 \times 10^{-6} \times t) + (0.0001) \quad (4)$$

The model predicts the weight loss and the wear rate accurately.

The atomic force microscopic (AFM) image of the specimen before and the after the erosion test for both the untreated and the boronized steel is shown in the figures 8, 9, 10, 11

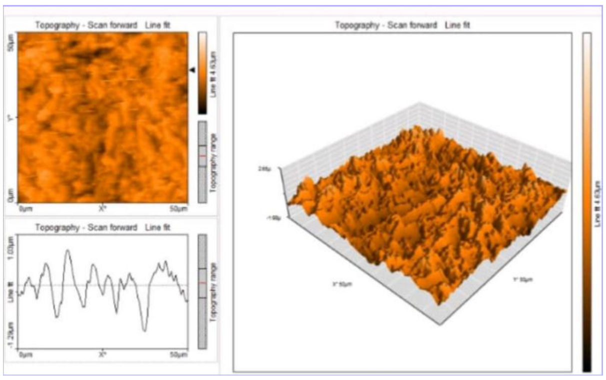

Fig. 8 AFM image of boronized sample before test.

The Roughness of Boronized sample (Sa = 284.37nm & Ra = 230.13nm) is less than that of the untreated sample (Sa = 313.18nm & Ra = 415.97nm) is clearly visible in AFM image. And further AFM image shows formation of craters over the surface due to erosion test.

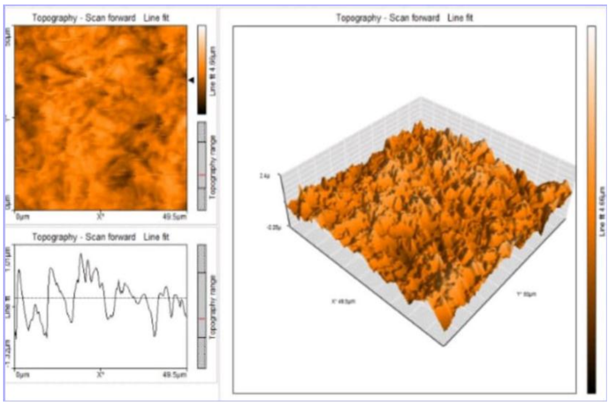

Fig. 9 AFM image of untreated sample before test

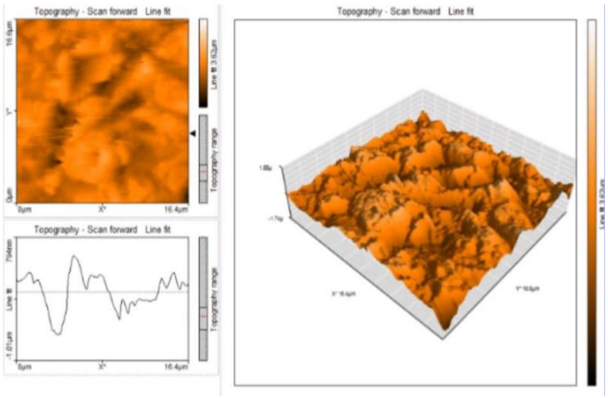

Fig. 10 AFM image of boronized sample after test

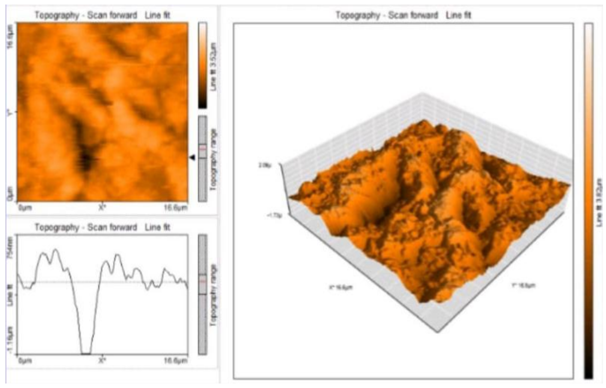

Fig. 11 AFM image of untreated sample after test

4. CONCLUSION

Erosive tests were conducted in Boronizing and Untreated Samples and the following results were concluded.

- Boronized Sample show better erosive wear resistance than Untreated sample.
- AFM results show Boronized sample has better surface quality than Untreated sample. Wear rate decreases with increase in time after 20mins wear rate increases. This is due to

material loss of boronized sample is low as compared to increase in erosion time. Boron particles diffused over the surface resist erosive wear.

- Third order polynomial Mathematical model shows higher correlation with experimental results.

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