Studies on wear loss and Deformation Morphology in Three Body Abrasion

Hemaraju, Ranganatha S, Shashidhara K N

Abstract:** Machineries which are used in industries involves relative motion between two components called elements. These relative motion between elements is required either to transfer force or motions. In some cases, example material conveying system, relative motions exists between material and conveyor. All the above cases give rise to discontinuities in velocity and displacements. These discontinuities results in volume loss of materials. Loss of materials give rise to loss of durability and reliability of machines. There will be a lot of thrust in reducing the new advanced machines due to loss of materials or wear. Understanding wear and controlling is a strong need for advanced and reliable design of machines. In the present investigation a basic systematic study has been carried out to understand the impact of material and its metallurgical phases on wear behavior. Rubber wheel abrader with different sized sand as abrader is used for conducting the experiments. CA 40 Steel (269 BHN), Alloy cast iron (450 BHN) Ni Hard cast iron (500 BHN) were used as target materials. Experiments were conducted with two loads 53.2 N and 102.4 N. The speed was maintained at 200 rpm. The time of test was 6 minutes, the flow rate was 100 grams/min. The wear loss was estimated and found that for CA 40 Steel was 0.15 at a normal load of 52.3 N and 0.21 at a load of 102.4 N. The wear loss was for ally cast iron is 0.07 and 0.08 which are comparable at two different normal loads. In case of Ni hard cast iron the wear loss was found to be 0.04 at a normal load of 53.2 N and 0.07 at a normal load of 102.4 N. the effect of normal load was found to be less for materials of higher hardness. The morphology of deformation was found to characterize the experimentally observed wear loss volume for material of different hardness.

***Keywords:** Abrasive wear, Deformation, Hardness.*

I. INTRODUCTION

Bingley and schnee [1] studied the mechanisms of abrasive wear for ductile materials in wet and dry three body conditions. They developed a simple model and the validity of the model was checked by conducting the experiments on mild steel and stainless steel using silicon carbide materials. Lapping and polishing machines were used to conduct the tests. They identified sliding cutting was the dominant metal removal mechanisms. Thakare et al [2] tried to understand the effect of abrasive particle size and influence of microstructure on the wear mechanisms in the wear resistant materials. They conducted experiments using a modified ASTM G-65 rubber sand abrader.

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They found that the material removal mechanisms was dependent on size of the abrader. Niko Ojala et al [3] evaluated the effects of composition and microstructure on the abrasive wear resistance steels. Experiments were conducted using pin on disc machine. The wear behavior was correlated with microstructural characteristics and auto tempered microstructures. Jonas allebert et al [4] conducted the experiments using a laboratory drum machine which simulated typical conditions in ore processing operations. They compared the wear resistance of welded high chromium white iron and quenched tempered low carbon alloy steel. They observed that the size of the abrader influenced the wear mechanism. Xiaojun Xu et al [5] conducted multipass dual indenter scratch test for predicting the abrasion resistance of construction steels. An attempt was made to understand wear mechanism by characterizing the subsurface deformation. Xiangtao Deng et al [6] conducted experiments using dynamic abrasive machine. They tried to understand the influence of microstructure on wear mechanisms. They found that microstructures played very important role in determining wear mechanisms. Ronaldo [7] explode the possibility of third abrasive wear mode. He identified micro rolling abrasion as one more modes of wear. Basavaraj and Ranganatha conducted inclined scratch test using EN-8 and different pin materials. Pins were made out of aluminum, copper and lead. They found that the morphology of hard surface and lubricants had a bearing on mode of wear [8, 9]. Sureshgowda et al conducted experiments using four ball tester for identifying the role of lubricants and soft material coating on deformation. They found that lubricants and soft coatings effectively accommodated the displacement and velocity gradients in case of non-confirming contact surfaces [10, 11]. Hemaraju et al [12] studied the role of hardness on wear mode in three body wear conducting experiments on rubber wheel abrader. They found that wear loss is dependent on deformation mode. The wear rate was quantified by different authors and it was observed that it varied over a range of 10^{-15} to 10^{-11} mm^3/ N-m depending the on material selection and operating conditions [13-18]. The quantified wear loss indicates that both materials and operating conditions are critical in determining the wear loss. The literature emphasize the importance of role of material on wear. *Abrasive wear:* whenever two contact surfaces interlocks due to their surface morphology, ploughing takes place which leads to abrasive wear. Different models are develop to estimate the abrasive wear volume. One of the model estimate the wear volume loss V in terms of normal load 'W', length of sliding distance 'L', and hardness value 'H', is given below [19].

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$$V = \frac{1}{3}\frac{WL}{H} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The percentage of wear loss is estimated according to equation no 2 when tests conducted in rubber wheel abrader according to ASTM G 65. Kozi kato [19] conducted the experiment in vacuum and identified the three different abrasive mode which are cutting mode, wedge forming mode and ploughing mode. These modes are shown in the figure1.

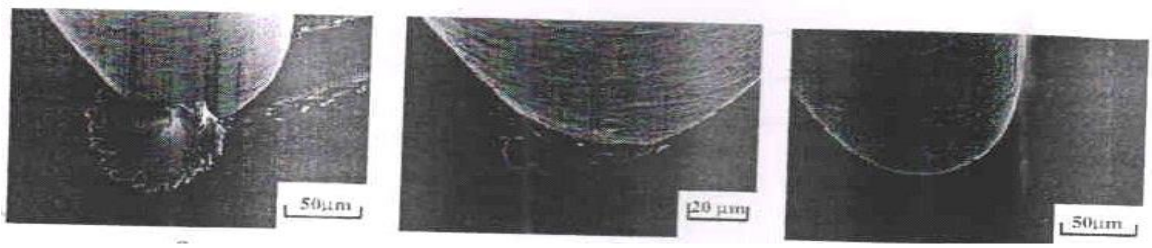

Fig.1 Three different modes of abrasive wear observed by SEM: Cutting mode (A), Steel pin on brass plate; Wedge forming mode (B), steel pin on stainless steel plate; Ploughing mode (C), Steel pin on brass plate

The literature survey indicates a general relationship between wear loss and hardness of the materials. An attempt has been made to find symmetrically how wear loss and hardness are related by conducting the test using rubber wheel abrader by choosing target material of different hardness [19].

II. EXPERIMENTAL PROCEDURE

Experiments were conducted using rubber wheel sand abrader. CA 40 Steel (269 BHN), Alloy cast iron (450 BHN) Ni Hard cast iron (500 BHN) were used to prepare the target specimen. The Brinell hardness of different materials as target are shown in the table1.

Table 1. Brinell hardness of different materials.

Serial no.	Specimen	Brinell hardness number(kg/mm^2)
1	CA-40 steel	269
2	Alloy cast iron	450
3	Ni Hard cast iron	500

Target specimens of above materials were machined to the dimensions as shown in Fig.2.

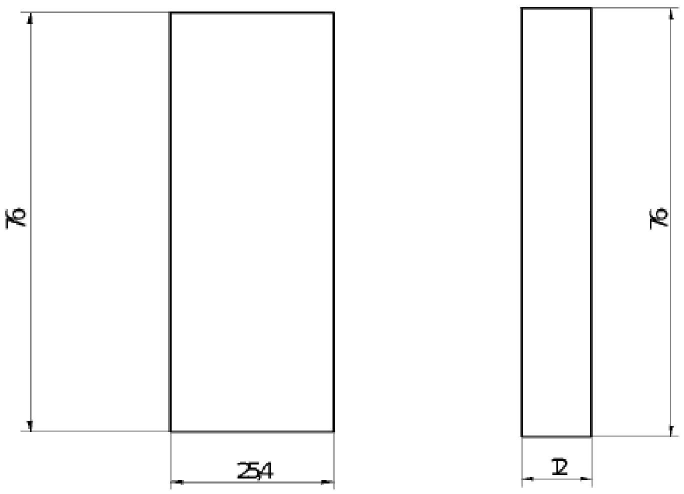

Fig.2. Dimensions of target specimen

Commercially available silica sand was procured & further sieved process by washing & drying. The dry sand analyzed for sand distribution according to ISO 3310/1. The schematic view of rubber wheel abrader test rig is shown in figure 3.

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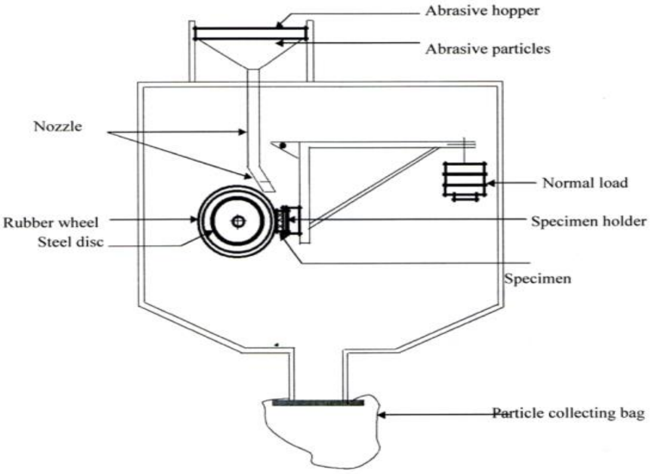

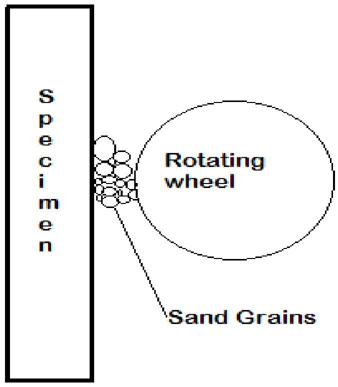

Fig.3. Dry sand wheel abrader

The loading lever was relived from specimen contact and following initial setting was carried out. The target material which is shown in the figure 1 is fixed to the specimen holder of the test rig. The process sand was filled in the hopper and by trial and error the flow rate was adjusted to 100gms/min. The speed of the rubber wheel was maintained at 200 rpm. This speed has further confirmed using stroboscope. After the initial setting, the loading lever was set to impart the load on the specimen. The combination of loads, test duration as given in table 2.

Table 2: Experimental parameters.

Sl no	Load in N	Speed in rpm	Sand flow rate in gms/min
01	102.46	200	100
02	53.22	200	100

The tests were conducted according to ASTM G 65 specifications. The test target specimens were weight before and after test for estimating volume loss using equation no 1. …………………………………….. (2)

The test specimens after experiment were studied in scanning electron microscope for understanding wear mechanisms.

III. RESULTS AND DISCUSSIONS

The volume loss for CA 40 Steel, Alloy cast iron and Ni Hard cast iron are estimated using equation number 2 by finding out the weight of the target test sample before and after experiments. The volume loss for different materials are shown in table 3.

Table 3 Volume loss of Different Materials

Sl No.	Material	Percentage of volume loss for a load 53.2 N	Percentage of volume loss for a load 102.4 N
01	CA 40 Steel	0.15	0.21
02	Alloy cast iron	0.07	0.08
03	Ni Hard Cast iron	0.04	0.07

The volume loss for different materials and different loads are shown in the bar chart figure 4.

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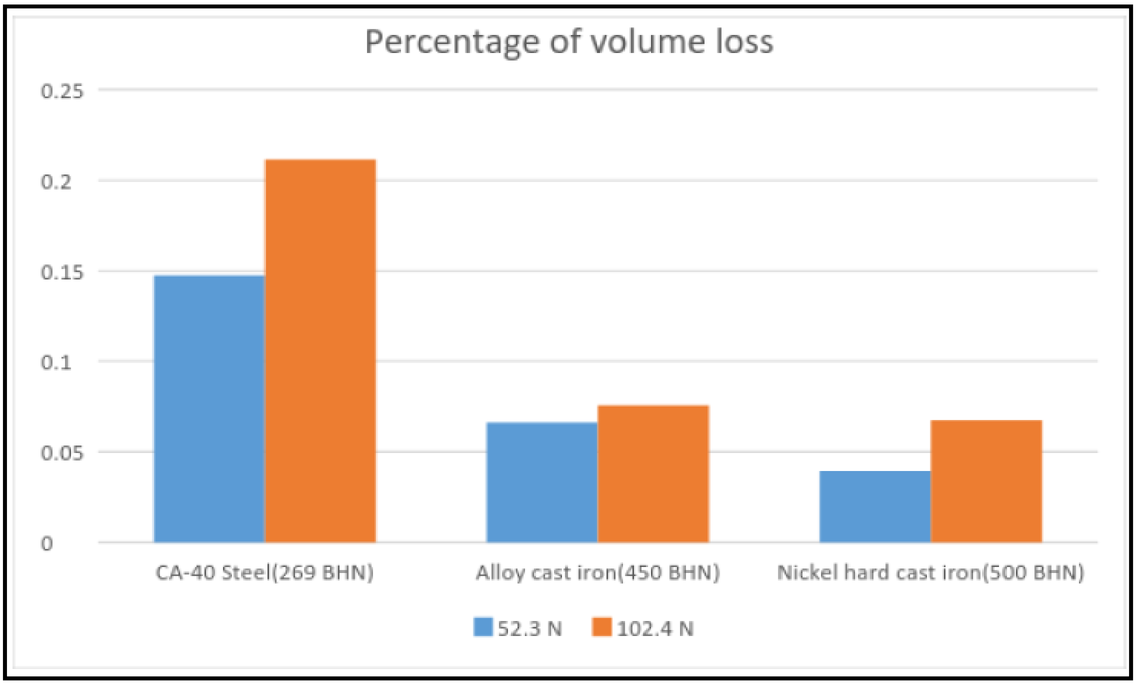

Fig. 4. Bar graph of volume loss for different normal loads.

The volume loss for CA 40 steel is 0.15 at a normal load of 53.2 N and 0.21 at a normal load of 102.4 N. The volume loss for Alloy cast iron is 0.07 at a normal load of 53.2 N and 0.08 at a normal load of 102.4N. The volume loss for Ni hard cast iron is 0.04 at a normal load of 53.2 N and 0.07 at a normal load of 102.4 N. The volume loss for mild steel is 0.15 at a normal load of 53.2 N and 0.21 at a normal load of 102.4 N. The volume loss is found to be minimum for Ni Hard cast iron and maximum for CA 40 for steel.

The volume loss is plotted versus hardness of different materials and shown in the figure 5.

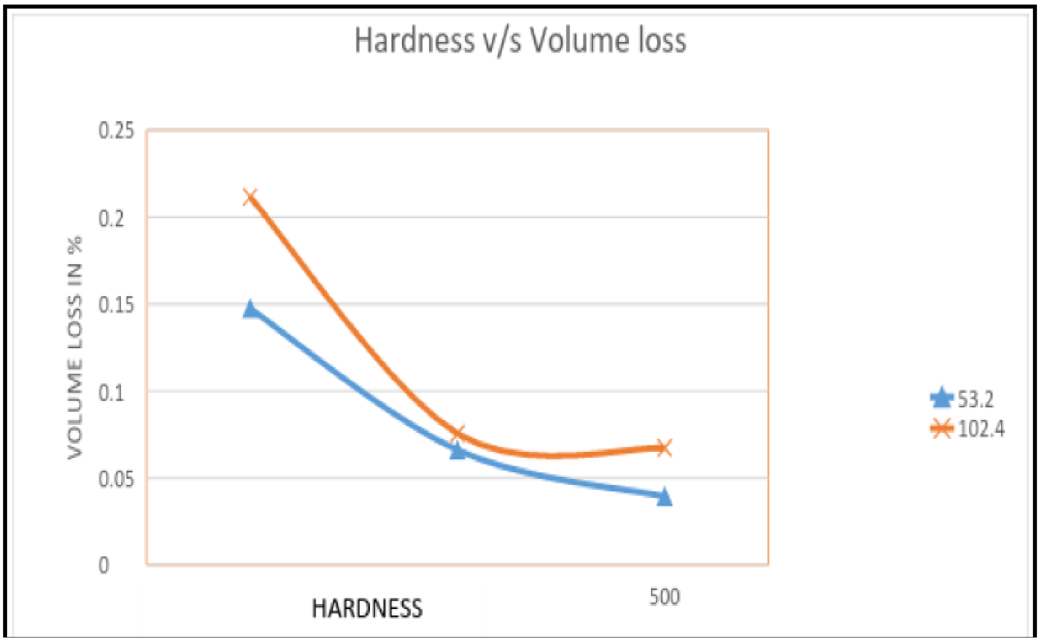

Fig.5. Hardness vs volume loss for a normal load 52.3 N and 102.43 N.

The maximum volume loss was found to be 0.21 when normal load was 102.4 N and hardness was 500 BHN (CA 40 steel). The minimum volume loss was found to be 0.04 when normal load was 52.4 N and hardness was 500 BHN (Ni Hard cast iron). In case of CA 40 steel, volume loss was found to be 0.06 when normal load changed from 102.4 N to 53.2 N. The volume loss is found to be sensitive for normal load at lower hardness. This sensitiveness of volume loss with hardness is found to reduce as hardness increases and eventually found to be insensitive to the normal load at higher hardness within the experimental conditions. Scanning electron micrographic studies were carried out on tested specimens for understanding the dependency of volume loss under different loading conditions and material (hardness).

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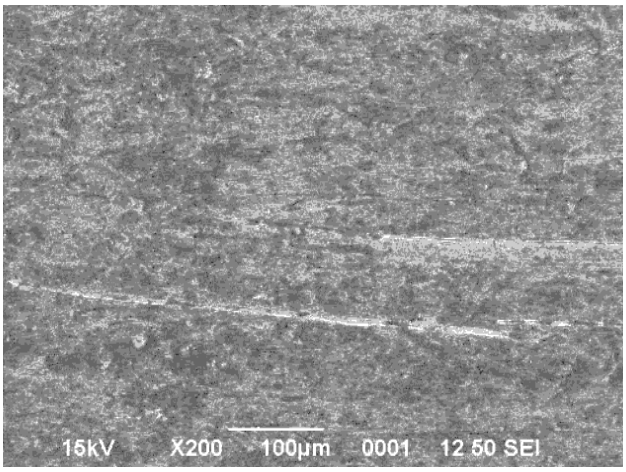
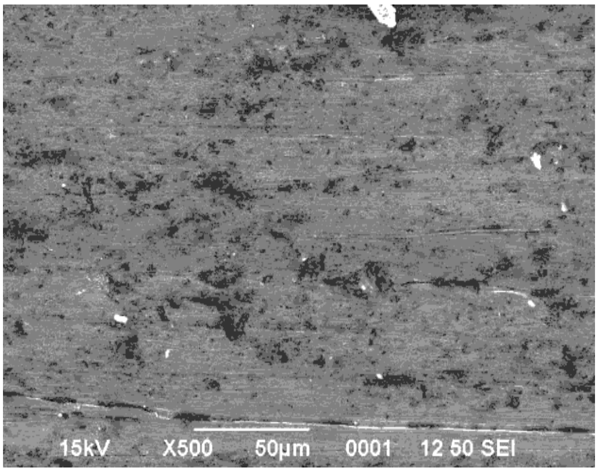
The photographs studied in Scanning electron microscope are shown in figure 6 to figure 10. Figure 6 shows the typical micrographs of wear scar for CA 40 steel at a normal load of 53.2 N.



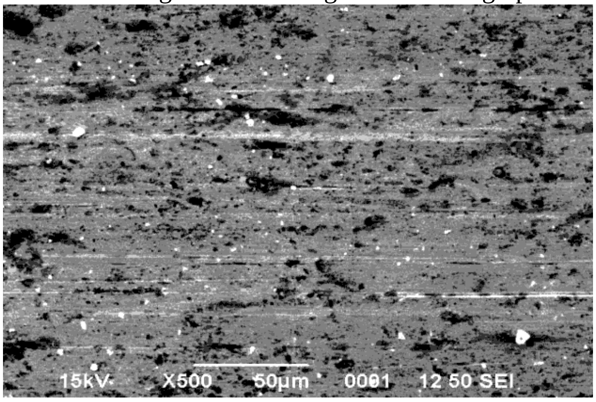
Material: CA 40 steel (a)
Load: 53.2 N
Magnification: 200 X



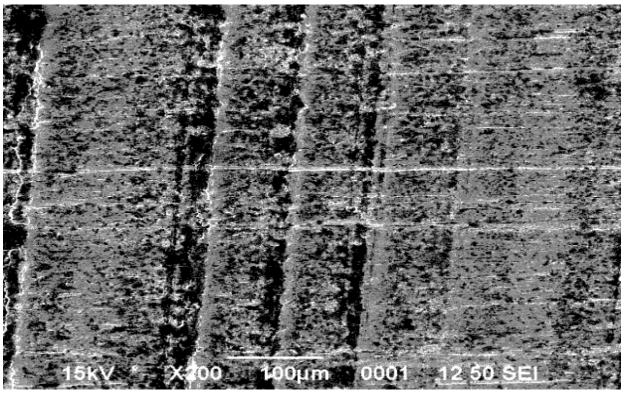
Material: CA 40 steel (b)
Load: 53.2 N
Magnification: 500 X

Fig. 6 (a) & (b) SEM micrograph of wear scar CA 40 steel.

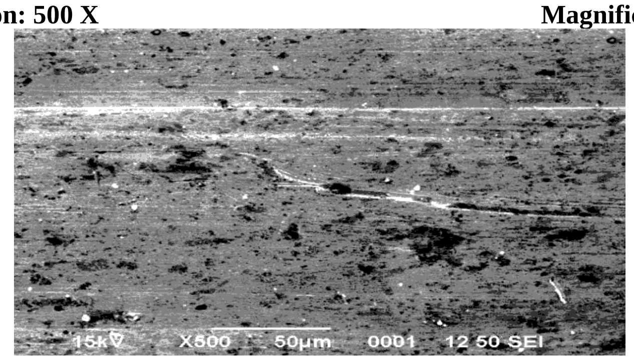
There is a wear groove without any ridges in micrograph (a) of figure 6. The groove was found to exist over a length of 250µm. The micrograph (b) of figure 6 also corresponds to a normal load of 53.2 N. The wear groove was found to be continuous throughout the length of micrograph. Few grooves running over small lengths were also found in micrograph (b) of figure 6. The grooves were found to be well defined and sharp. Figure 7 shows the typical micrographs of wear scar for CA 40 steel at a normal load of 102.4 N.



Material: CA 40 steel (a)
Load: 102.4 N
Magnification: 500 X



Material: CA 40 steel (b)
Load: 102.4 N
Magnification: 200 X



Material: CA 40 steel (c)
Load: 102.4 N
Magnification: 500 X

Fig.7 (a) (b) & (c) SEM micrograph of wear scar CA 40 steel.

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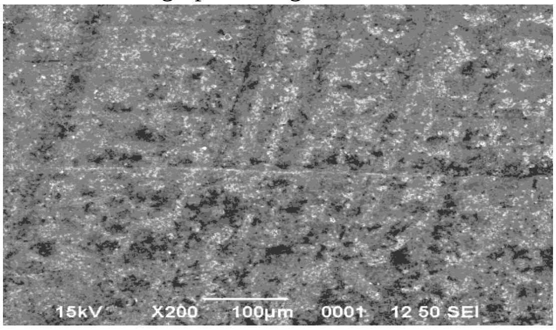
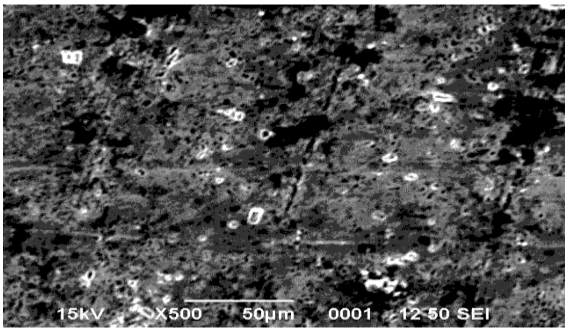
Micrograph (a) of figure 7 shows more grooves whose width are larger when compared to grooves found in micrograph (b) of figure 6. Micrograph (b) of figure 7 also shows more grooves running across the length of micrograph. Micrograph (c) of figure 7 also shows more number of grooves running along the length of micrograph. The grooves found in micrographs of figure 7 are well defined, wider and more in number compared to grooves found in micrographs of figure 6. The difference in morphology of deformation found in micrographs of figure 7 and 8 explain the difference in wear loss in case of CA 40 steel at a load of 52.3 N and 102.4 N. Figure 8 shows the typical micrograph of wear scar for alloy cast iron at a normal load of 53.2 N.



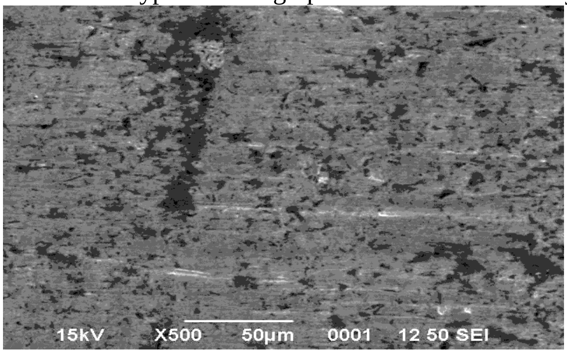
Material: Alloy cast iron (a)
Load: 53.2 N
Magnification: 200 X



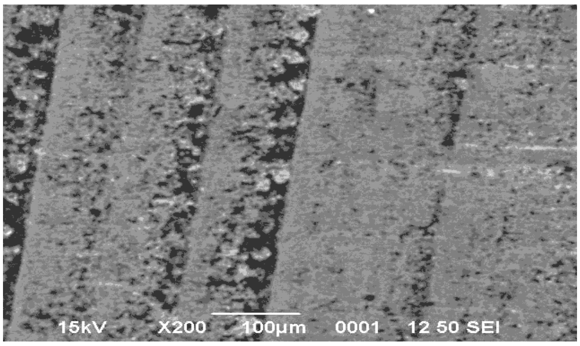
Material: Alloy cast iron (b)
Load: 53.2 N
Magnification: 500 X

Fig.8 (a) & (b) SEM micrograph of wear scar Alloy cast iron.

The micrographs (a) and (b) of figure 8 show negligible number of grooves which are very short in length. Figure 9 show the typical micrographs of wear scar for alloy cast iron at a normal load of 102.4 N.



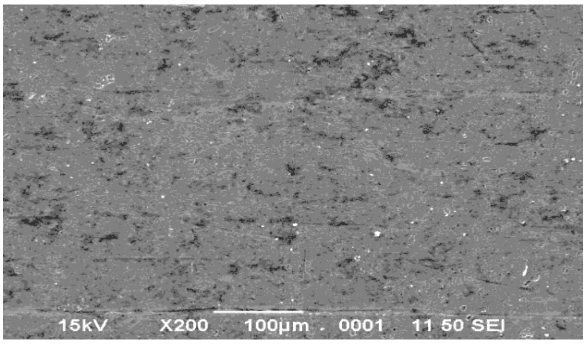
Material: Alloy cast iron (b)
Load: 102.4 N
Magnification: 500 X



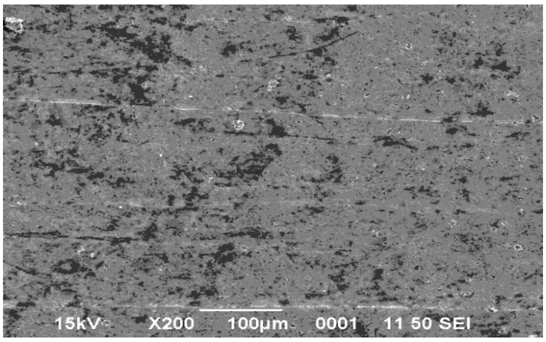
Material: Alloy cast iron (c)
Load: 102.4 N
Magnification: 200 X

Fig.9. (a), (b) & (c) SEM micrograph of wear scar Alloy cast iron.

The micrograph (a) of figure 9 show very few grooves of shorter lengths which are similar to grooves found in figure 8. These morphology of deformation features found in micrographs of figures 8 and 9 explain the in-sensitiveness of volume loss with respect to normal load. Figure 10 shows the typical micrographs of wear scar for Ni hard cast iron at a normal load of 52.3 N.



Material: Ni Hard cast iron (a)
Load: 52.3 N
Magnification: 200 X



Material: Ni Hard cast iron (b)
Load: 52.3 N
Magnification: 200 X

Fig.10. (a), (b) & (c) SEM micrograph of wear scar Ni Hard cast iron.

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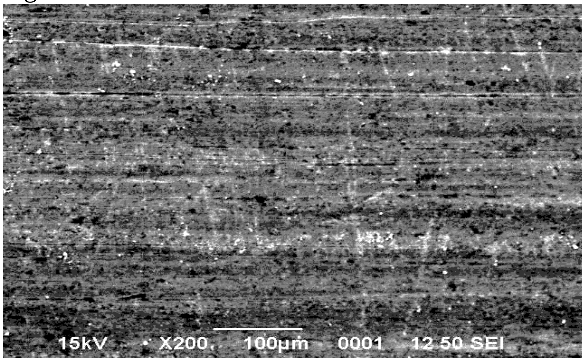
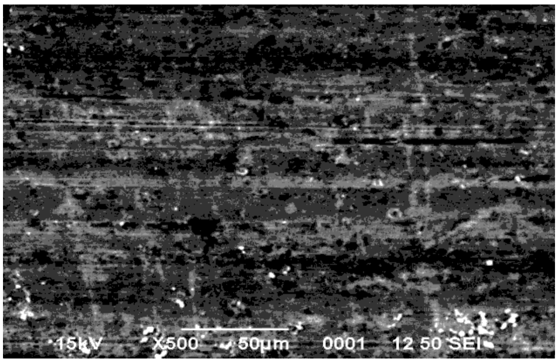
The morphological features of deformations found in micrographs (a) & (b) of figure 10 are comparable with morphological features of deformations found in micrographs of figures 8 & 9. Figure 10 shows the typical micrographs of wear scar for Ni hard cast iron at a normal load of 102.3 N.



Material: Ni Hard cast iron (a)
Load: 102.4 N
Magnification: 200 X



Material: Ni Hard cast iron (b)
Load: 102.4 N
Magnification: 500 X

Fig.11. (a) & (b) SEM micrograph of wear scar Ni Hard cast iron.

The morphological features of deformations found in micrographs (a) and (b) of figure 11 are comparable with morphological features of deformations found in micrographs (a) and (b) of figure 10. The deformation features found in micrographs of figures 6 and 7 are distinct from the deformation features found in micrographs of figures 8 to 11. These difference in morphology of deformation explain the observed wear loss in case of CA 40 steel compared to alloy cast iron and Ni hard cast iron. The morphological features of deformation found in figures 8 to 11 are all comparable. These comparable features explain the less dependency of volume loss with normal load.

IV. CONCLUSIONS

- The volume of wear loss was found to be sensitive for hardness.
- At lower hardness, the wear loss was found to be load sensitive.
- At higher hardness wear loss was found be not much sensitive to normal load.
- The deformation features characterizes the wear volume losses.

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