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STUDIES ON WEAR BEHAVIOR OF WELDED RAIL STEEL

Rajanna S
Department of Mechanical Engineering, Government Engineering
College Kushalnagar, India.

ABSTRACT

Wear is one of the big problems in continuous welded rail. Wear resistance of weld is strongly dependent on the microstructure of materials. The improvement of weld quality has been done using the two different methods of E with HT thermite weld and BTC with SMA weld. Wear rate comparative study made between rail, BTC with SMA weld and E with HT thermite weld. Sliding wear has a great influence on the performance of wheel-weld systems, especially because of the wheel flanges slides over the welded rail in a track. Since wheel-weld induces oxidative wear, high slip ratios strongly affect the rolling contact fatigue wear acting on the surfaces. Sliding wear tests were carried out in a pin-on-disc device to study the behavior of rail and welds. The sliding speeds of 1, 2, 3,4 m/sec and normal loads of 10, 20, 30 and 40N were used at constant sliding distance of 1 Km and track radius of 60 mm for all specimens. The wear resistance was related to the mass loss measured after the tests of worn surfaces. The rail and BTC with HT SMA weld showed higher sliding wear resistance than E with HT thermite weld due to high and even hardness of the weld. Worn surface of rail and two different methods of welds were analyzed with the help of scanning electron microscope.

KEYWORDS: Wear, SMA weld, thermite weld, Rail steel.

INTRODUCTION

Individual rails rolled in India are 13 mts length rails when laid in track can be joined by provision of fish plates. Fish plate's joints in truck contribute to heavy noise and vibration, bad running, track maintenance is very difficult and also inadequate to high speed [6] and load. A welded joint appears to be the obvious answer to this problem. Hence welding of rails is important to converts the rails in to continuous welded rail panels of few kilometers. Because there few joints, gives a smooth ride and less maintenance. Normally thermite welding used in converts the rail in to continuous welded rails because relatively inexpensive cost, in a short period of time to be welded and simple equipment. Welded joints are critical spots in rails, because by their structural and mechanical characteristics they represent discontinuities in rails. Thermite welded joints suffers from inferior mechanical, fatigue and wear properties at the joint. Welded joint are exposed to longitudinal forces, stresses and 45% of all failures [7] on rails at thermite welded joints and also high axle load, operating speed and traffic density on rail roads to increase and cause additional pressure applied on welded joint. These operating condition frequently result in service failure due to a caused by wheel-weld contact and fatigue damage under cyclic loading. In thermite weld joint surface lesser resistance to wear than the rail. More severe problems resulted from negative deviation of the traveling surface. But which occurred in the region of the weld due to reduced resistance of weld in compression to the rail one particularly disadvantages. In case even small ruts load to impact stress on the joint of weld which reduce its useful life. Apart from the reduced traveling comfort due to impact stress and noise when a train passes over a rutted weld. There is also the purely economic aspect of such as a negative deviation in the traveling surface. In the present study to assure the railway vehicles safety, and wear resistance behavior of welded rail steel under higher operating conditions. So that by adapting thermite and SMA welding with three different methods of weld appears to be the obviously answer to this problem. In the present research work is directed to improving the fatigue strength and wear properties of welds in rails using thermite and SMA welding with different methods of welds. In thermite welding improvements has been done with different methods such as thermite weld, HT thermite weld and E with HT thermite weld. In SMA welding improvement has been done with three different methods such as As SMA weld, HT SMA weld, BTC with HT SMA weld. BTC with HT SMA weld exhibited superior mechanical and fatigue properties as compared to E with HT thermite weld. To suit the weld to the railway application wear properties is very much essential so that in the present investigation wear test carried out for both BTC with HT SMA weld and E with HT thermite weld. The selection of rail steels for safe, reliable service involves consideration not only wear resistance. Knowledge of mechanical behavior of materials, fatigue crack growth behavior is of importance to concern with rail safety. Rail welding different from other welding due to chemical composition of rail steel. Carbon content limits are 0.70 to 0.82, while manganese can range between 0.80 to 1.2%. Rail subjected to continually varying loads, forces and stresses and all kinds of importance and environments. It must carry out its tasks without failure for many years. The factors like different grade of rail, welding methods, initially of rail welds and inferior maintenance resulting in loose ties have great influence on the service life of continuous welded rails. Railway engineers have looked for elimination of the normal bolted joints between rails because the maintenance of such joints high and about 55% of failures in plain rails occur of the joints and bolted joints cause dynamic shacks in rail wheels, reducing their useful life and producing noise and vibrations. Rail steel is subjected to severe service conditions. These material experiences complex loading which are generated by the weight of goods, impact of trains, curves of track, friction and wave actions of locomotive wheels as well as thermal stresses in changing climatic conditions and other critical factors. This rail fatigue research will examine the properties of steel in the modern rails. This research will assist in improving rail road safety by expanding knowledge of rail durability. Research on Rail is important because premature rail fatigue failure has been the cause of derailments and other severe accidents. An improved understanding of this failure mechanism is essential to address related issues of railroad safety, reliability and operational efficiency; head hardening of the rails increases the service life considerably. The higher UTS of rail steel is necessary because of the heavier loads and also, to minimize wear from the harder steel used for the cast wheels. The Mechanical properties of metal determine the range of usefulness of the metal and establish the service that can be expected. Mechanical properties are also used to specify and identify metals. The most common properties considered are the strength, hardness, ductility and impact resistance. Experimentation and testing play an important role in suitability of rail steel for railway application. This calls for certain mechanical property requirements and acceptance of the materials under these specifications, which involves thorough understanding of the methods of testing and the significance of testing, can be appreciated with the knowledge of Material science and Metallurgy. Wear, the progressive damage and material loss, occurs on the surface of a component as a result of its motion relative to the adjacent working parts. It involves the replacement of rail in a track. The present investigation directed to improves wear resistance and the damage resistance of welded rail as required for rail track at particularly at sharply curved zone of heavy load to drastically improve the service life of the welded rail. Sliding wear has a great influence on the performance of rail track mainly because the wheel flanges slides over a rail. Since rail wheel sliding introduces adhesive effects, high slip ratio strongly affect the rolling contact fatigue wear acting on the surfaces. Sliding wear test carried out in a pin on disc device to study the behavior of welded rail steels. Wear studies are very much essential to find the deviations from the ideal traveling surface will occur occasionally after welding or the course of traveling over the track.

MATERIALS AND METHODS

Rail trucks were used for the investigation. The chemical composition of rail ascertained with the help of Baird emission Spectrometer to ensure the quality of rails. In the present research work, Improvement of the weld has been made using two different methods of BTC with HT SMA weld and E with HT thermite weld.

E with HT thermite weld

Two rail ends were kept 20mm apart with proper alignment. Pre-heating the rail ends (to about 1000°C) is required to help the poured molten metal in washing away the surface oxidation on the rail ends, as otherwise, the molten metal may chill and solidify immediately on coming in contact with cold rail ends, without washing off the surface oxidation in thermite welding or aluminothermic welding. In this process, the highly exothermic reaction[1] between aluminium and iron oxides results in the production of molten steel which is poured into a mould around the gap to be welded. Thermite welding was carried out to produce a joint. Here 5 parts of Iron oxide red powder and 3 parts of aluminum powder ignited at high temperature. To produce an alloy of the correct composition, alloys like ferro-manganese are added to the mixture along with pieces of mild steel, both as small particles, to allow rapid dissolution in the molten iron, to control the temperature and to increase the 'metal recovery'. Complete slag separation in a short time and better fluidity of the molten metal is achieved by adding compounds like calcium carbonate and fluorspar etc.Highly exothermic reaction took place and released tremendous amount of heat. Exothermic reaction in the crucible after 25 seconds separated the slag from the molten steel. Liquid steel poured down in to the hardened sand mold and got a welded Joint. The superheated molten metal causes the rails to melt at the edges of the gap to be welded [4]. It is also the filler metal, so that the material from the rails coalesces and joins the added molten steel as it in molten state during this period Expulsion method was applied. This expulsion was caused by applying an axial force to the rails to move their ends together in which thermite steel that normally comprises the filler metal of a full fusion thermite rail weld was expelled from between the rail ends while in a liquid or partially solidified state. The excess thermite steel over the head of the rail (head riser) removed after solidification. It was believed that the expulsion would alter the solidification microstructure and decrease the number and size of metallurgical discontinuities in the fusion zone by decreasing the volume of filler metal, thus improving the joint's strength with out changing the hardness. Thermite welded rail steels were subjected to ultrasonic test to check the soundness of the weld. After that the heat treatment involved normalizing was carried out at 8200C for 45 min and air cooling to room temperature (normalized condition). The specimens were cut in the transverse direction from E with HT thermite weld. Wear testing specimens were prepared according to ASTM and AWS D 1.1 standards

Thermite Reaction Details

Aluminium reacts with iron oxides, particularly ferric oxide, in highly exothermic reactions, reducing the iron oxides to free iron, and forming a slag of aluminium oxide.

$3Fe3O4+8Al = 4Al2O3+9Fe$ (3088°C, 719.3kCal↑)

Approximately equal quantities of molten steel and liquid aluminium oxide are separated at about 2400°C, after a few seconds of the exothermic reaction.

BTC with HT SMA weld

The pair of plates of dimension 200x150x14mm were taken and made edge preparation with a groove of 450angle and plates were set about 5mm apart on a steel backing strip about 5mm thick. Initially the plates with double grooves were positioned. The following methodologies were adopted for welding:

1. Cleaning and removal of rust from the rail ends.
2. Eating of rail ends about 10000C with oxy acetylene torch
3. Created a gap of 5mm at bottom and 13 mm at the top surface of the weld group.
4. Using the above welding parameters tack welded and then welding was carried out on edge prepared plate using shielded manual metallic arc welding machine of 500 amps capacity.
5. Five to six welding runs were required to fill the complete weld gap.
6. After welding weldments were subjected to ultrasonic examination to ensure the soundness of welded joint of the rail.
7. The joint is then finally ground to exact profile it is checked for straightness and is brought within the desired tolerance.

During the Shielded manual metallic arc welding, bead thickness was controlled very much accurate of 3mm by using proper utilization of welding parameters and deposition rate was controlled by experienced skilled operator. Welding was carried out with a same procedure of shielded manual metallic arc welded rails. Then joints were subjected to ultrasonic testing to check the quality of the weld. After that the heat treatment involved normalizing was carried out at 8200 C for 45 minutes using muffle furnace capacity of 14000C. Specimens were taken out and cooling to room temperature using normalized condition. The specimens were cut in the transverse direction from BTC with HT SMA weld. Wear testing specimens were prepared according to ASTM and AWS D 1.1 standards.

Test specimen preparation

In the present study, Pins prepared from welded rail steel. Cylindrical wear test specimens of diameter 10 mm and length 35 mm were cut ground and polished to the required size before testing, but the wearing face was prepared at the center of weld rail. A fresh disc and the specimen were used each time before etch and every test. Both the disc and specimen were cleaned with acetone to remove any possible traces of grease and other surface contaminants. Specific gravity measurements of the specimen were conducted in accordance to ASTM Standard C127-88.

Operating procedure

Common methods used to estimate the wear of a specimen are loss of dimension method, displacement method, loss of weight method, wet wear test. In loss of weight method, the specimen is weighed initially and the weight is noted down. Keeping the sliding distance constant, the sliding pressure is varied by increasing the loads and conducting the test. The specimen is cleaned with alcohol [3] and weighed again. The final weight is recorded. The difference between the initial and final weight gives the weight loss of the specimen. The apparatus consists of a rotating disc (EN24 steel of hardness BHN 650) of diameter 60 mm which forms the counter-face on which the test specimens or the pins slide over. Arrangements were made to hold the specimens for application of the load on the specimens. The samples were clamped tightly in the specimen holder and held against the rotating steel disc. The specimens were cleaned thoroughly and weighed accurately using a highly reliable and a sensitive balance to an accuracy of three decimals. The wear volume [2] was calculated from the percentage weight loss. The data for the wear test was taken from the average of three measurements. The deviation was less than 4%. The surfaces of the work specimens were observed using a scanning electron microscope. Since the hardness of the counterface (steel disc) was far greater than that of the specimens and its wear volume was very small, the wear properties of the alloy steel disc are not considered for analysis. In the present investigation, normal loads of 10N, 20N, 30N, and 40N respectively were applied on the specimen and the Sliding speed the rotating wheel was varied from 1 to 4 m/sec for all specimens.

RESULTS

Weight loss of the rail steel, E with HT thermite weld and BTC with HT SMA weld as a function of sliding speed and load obtained from dry sliding metal–metal wear tests are plotted in Figs 1to 16. For the each types of material such as rail steel, BTC with HT SMA weld and E with HT thermite weld, plot the specific wear, volumetric wear, frictional force, volume loss versus various sliding speeds (1to 4m/sec), normal loads (10 to 40N at a step of 10 N) and constant sliding distance of 60mm for three specimen are taken from each types of material as mentioned above.

Wear properties of rail steel

The pearlitic structure of the eutectoid carbon component that has been used as a rail steel has a lamellar structure compressing ferrite layer having a low hardness and a tabular hard cementite layer, as a result of observation of the wear mechanism of the pearlite structure. In the present investigation it has been confirmed that the soft ferrite structure is first squeezed out in a initial sliding and only hard cementite is then built up immediately below the surface and work hardening adds to the former, thereby securing wear resistance. Wear rate have been found out through a series of experiments that the wear resistance has a higher value as compared to welded rails. Increases in train speeds and loading have made railway transportation more efficient however. This increase also means more arduous duty conditions for the rails. In such higher load, speed and sliding distance cases rail steel exhibited higher wear resistance. Wear resistance are required to make them more tolerant and resistant to the increased stresses and stress cycle imposed wear rate of the rail steel decreased due to higher hardness value of rail steel higher hardness value did not caused plastic deformation on the surface of the rail, does not causes loss of the optimum profile of rail head and increased in service life of the rail. Mild wear had taken place slowly in rail. It is seen from the figures that the rail show lower weight loss as quantity of higher carbon content in the rail. It may be because of the presence of carbon which has enhanced the hardness of the material, in turn which decreases the wear loss. The decrease in wear weight loss may also attributed to higher load bearing capacity of hard cementite phase. SEM examination of the worn surfaces of the specimens taken from centre of the specimen, specimen of the rail revealed that the high carbon and manganese. Pearlite is an important feature of the microstructure because it possesses good wear resistance, hence, making carbon an essential alloying elements in rail steels. However, it is not only the amount of pearlite that is important but also its morphology, which means the shape and the distance between the cementite lamellae. And also rail steel is pearlitic structure presumably achieves a high resistance to wear because of the hard cementite and its containment by the more plastic ferrite. Wear resistance is strongly dependent on the microstructure of the metals. In the case of rail steels, wear resistance is achieved through the pearlitic microstructure. Among these steels of the same hardness, the best wear resistance steels possess a completely pearlitic structure.

Wear properties of BTC with HT SMA weld

BTC with HT SMA weld exhibited good wear resistance because of the increased in Carbon content in SMA weld as compared to E with HT thermite weld. The Carbon content directly affects the improvement of the wear resistance. Special attention was given to improve that of weld portion. The present invention pays a specific attention to Si, Cr and Mn as the rail components in order to prevent the drop of the hardness of the joint portion which occurs at the time of welding in the hardness distribution of the weld joint portion. If the Si+Cr+Mn value is less than 1.5% present, the drop of the hardness of the weld joint portion cannot be prevented. If the Si+Cr+Mn value is greater than 3%, the martensite structure mixes into weld joint portion and the proportions of joint portion are determined. BTC with HT SMA weld having good weldability and a wear resistance. Oxidative wear regimes were observed in pearlitic steel as well as in BTC with HT SMA weld. Mild wear had taken place slowly at the joint. The welding process may also influence the wear rate. As seen from figs the BTC with HT SMA weld shows lesser wear weight loss when compared to E with HT thermite weld for all sliding speed and load.

In case of BTC with HT SMA weld shows symmetric hardness traverses along longitudinal direction have been observed and hardness almost all same as the rail steel .Weld metal in the condition could indicate relatively even wear and wear resistance more approximately same as the rail steel.

Wear properties of E with HT thermite weld

Hardness drop at weldment in E with HT thermite welding is due to the presence of Cr and Nb . So that wear resistance is less due to less hardness at weldment as compared to base metal. While in the E with HT thermite weld, one delaminative wear was the main removal mechanism lending to a much more accentuated damage of the surface. In fact, the wear regime for E with HT thermite weld samples was always severe wear for the lower load applied. Severe wear had taken place at the joint is often much faster, similar to adhesive wear. During E with HT thermite weld wearing the tip of the groove will lap and make subsurface crack and separates from the parent metal. Under low load and high speed the delaminative wear mechanism is observed. In case of delaminative type of wear, the loss of material from interacting bodies in the form of wear debris take place by crack nucleation and propagation in and below the sliding surface due to compressive and tangential traction. Surface and near surface material is subjected to severe plastic deformation due to these forces. Consequently, the cracks or voids are nucleated in the deformed layers at the second phase particles. These cracks grow nearly parallel to the surface before eventually branching to the surface and forming loose debris. Ferrite and pearlite structure is a cast structure with some pin holes, hence it shows high wear rate under high operational conditions. In E with HT thermite weld shows non-symmetric hardness traverses along longitudinal direction have been observed in this work. The hardness minimum in the weld metal and on the boundary between the heat affected zone and the base metal, as well as the hardness maximum in the heat affected zone close to the base metal. There is significant difference in hardness between the base metal and heat affected zone. On the one hand, and the weld metal on the other hand. This could indicate that faster wear occur on the weld metal. However, this prediction may be premature if one bears in the mind the finer ferritic- pearlitic structure in the E with HT thermite weld. The pearlite steel showed higher sliding wear resistance and also BTC with HT SMA weld exhibited almost same wear rate of pearlite steel. E with HT thermite weld lower hardness as compared to rail steel and BTC with HT SMA weld.

The wear resistance was related to the mass loss measured after the tests of worn surfaces, as well as particle debris were analyzed by scanning electron microscope. The pearlitic rail steel and BTC with HT SMA weld showed higher sliding wear resistance than E with HT thermite weld due to high and even hardness of the material. Oxidative wear regims were observed in BTC with HT SMA weld, while in E with HT thermite weld one delaminative wear was a main removal mechanism, leading to much more accentuated damage surface. In fact, the wear regime for Ewith HT thermite weld samples were severe, even for the lower load applied. The negative deviation was observed. In this case it is necessary to distinguish between a positive deviation and negative deviation. In E with HT thermite weld surface has observed, which weld joint surface lesser resistance to wear than rail. More severe problems from negative deviation of the traveling surface. But which occurred in the region of the weld due to reduced resistance of weld in compression to the rail one particularly disadvantages. In case even small ruts load to impact stress on the joint of weld which reduce its useful life. Apart from the reduced traveling comfort due to impact stress and noise when a train passes over a rutted weld. There is also the purely economic aspect of such as a negative deviation in the traveling surface.

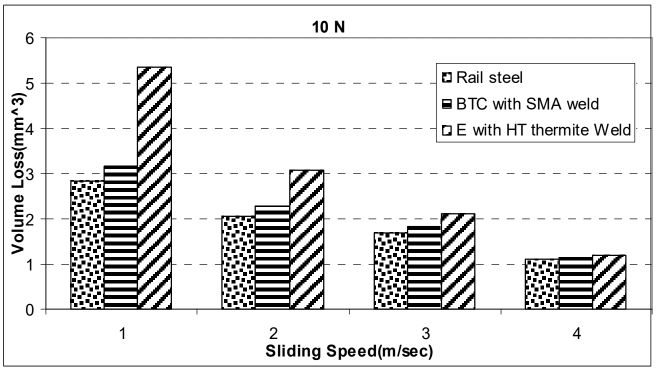

Fig 1: Comparison of Volume loss v/s Sliding speed

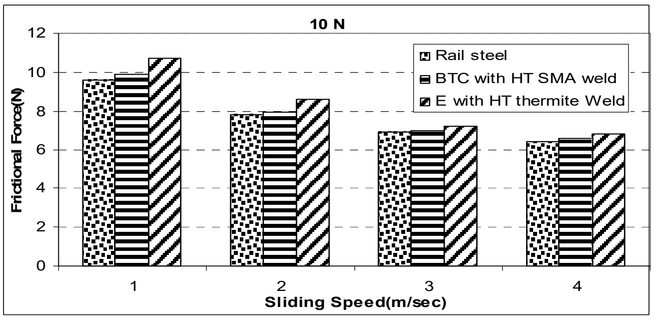

Fig 2: Comparison of Frictional force v/s Sliding speed

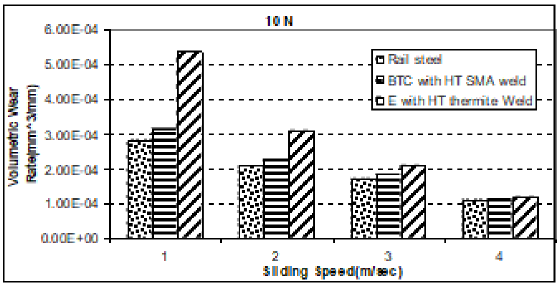

Fig 3: Comparison of Volumetric wear rate v/s Sliding speed

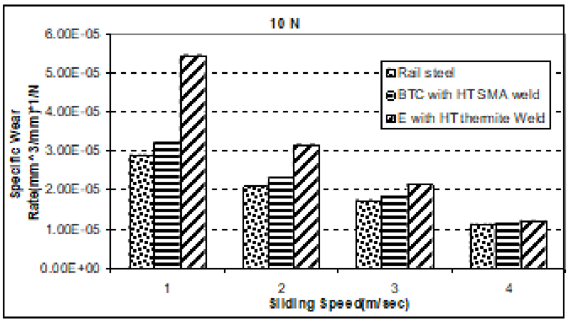

Fig 4: Comparison of Specific wear rate v/s Sliding speed

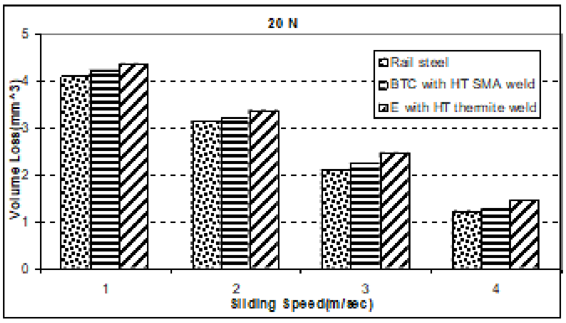

Fig 5: Comparison of Volume loss v/s Sliding speed

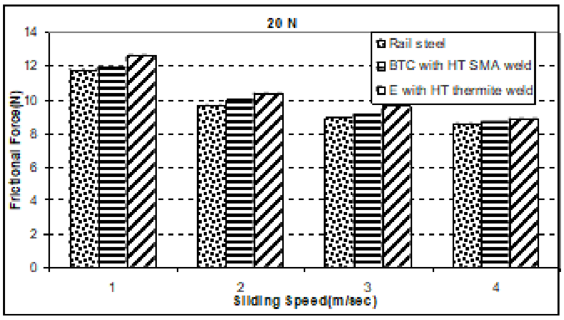

Fig 6: Comparison of Frictional force v/s Sliding speed

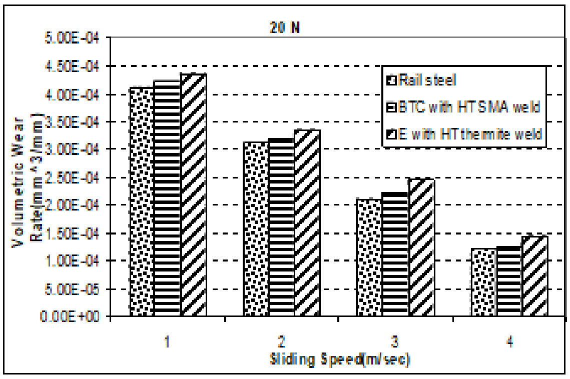

Fig 7: Comparison of Volumetric wear rate v/s Sliding speed

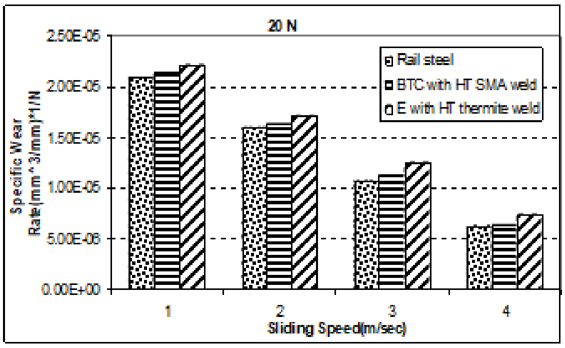

Fig 8: Comparison of Specific wear rate v/s Sliding speed

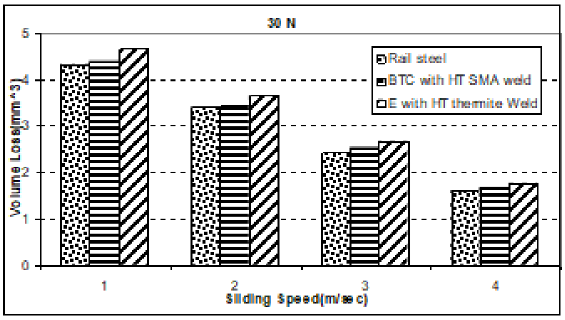

Fig 9: Comparison of Volume loss v/s Sliding speed

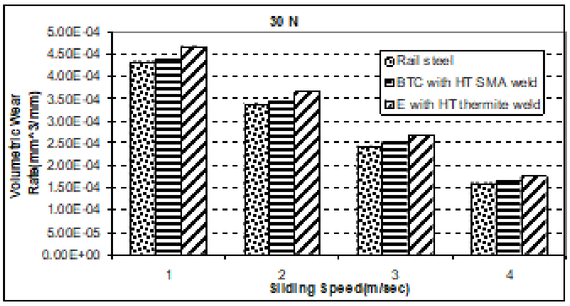

Fig 10: Comparison of Volume Wear v/s Sliding speed

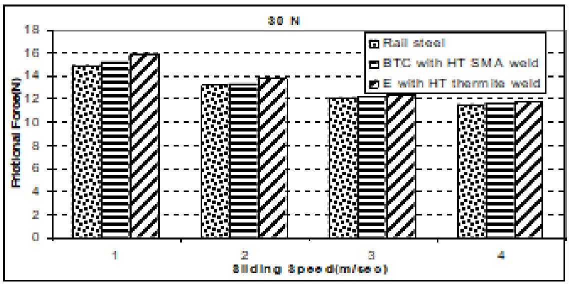

Fig 11: Comparison of Volumetric wear rate v/s Sliding speed

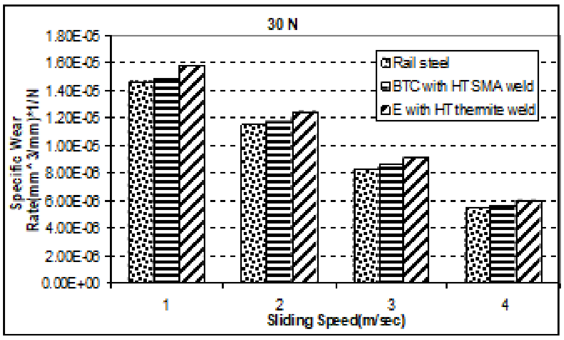

Fig 12: Comparison of Specific wear rate v/s Sliding speed

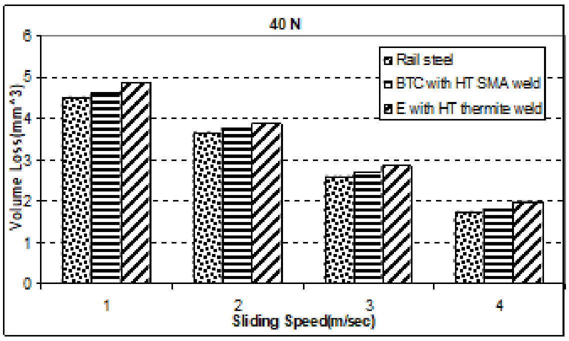

Fig 13: Comparison of Volume loss v/s Sliding speed

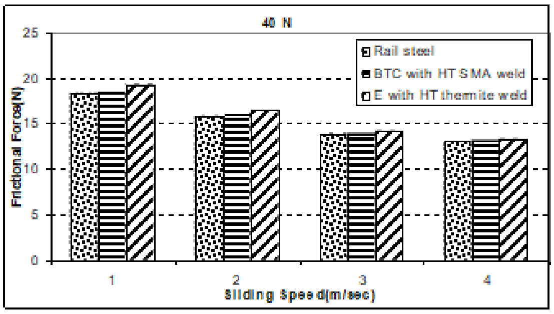

Fig14: Comparison of Frictional force v/s Sliding speed

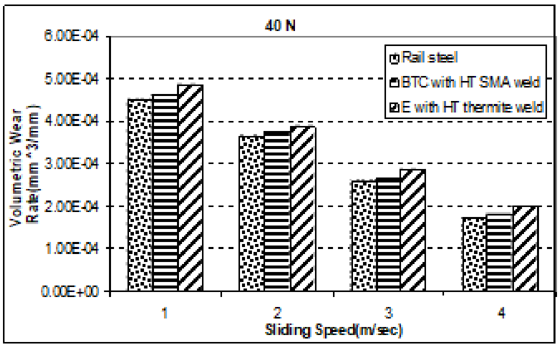

Fig15: Comparison of Volumetric wear rate v/s Sliding speed

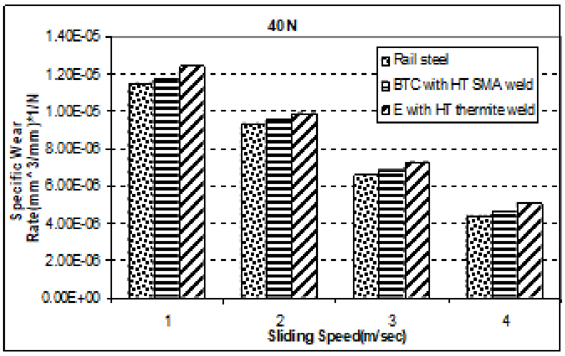

Fig16: Comparison of Specific wear rate v/s Sliding speed

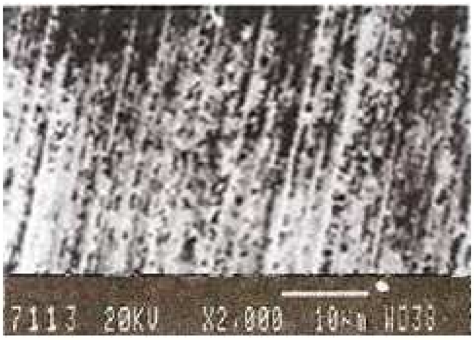

Fig17: SEM of Worn surface of rail steel

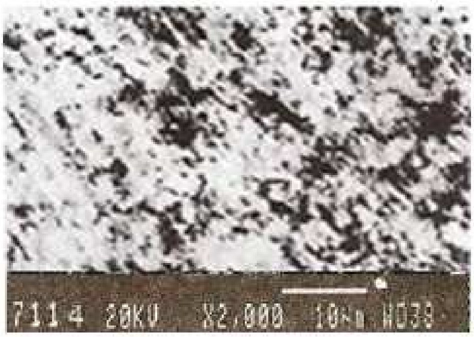

Fig18: SEM of Worn surface of BTC with HT SMA weld

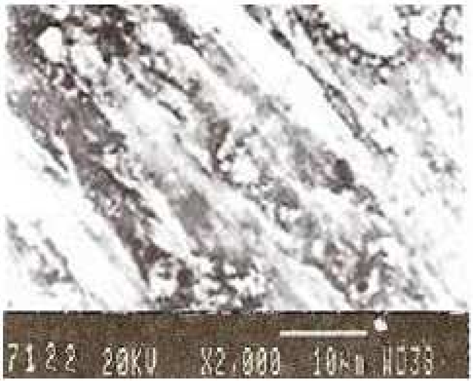

Fig19: SEM of Worn surface of E with HT thermite weld

DISCUSSION

Effect of sliding speed and load on the specific wear rate

The steady state wear rate, when plotted against sliding velocity against rail steel [5], BTC with HT SMA weld and E with HT thermite weld. In all three methods sliding speed increases, wear rate decreases. The first rail steel and the second BTC with HT SMA weld specimens exhibited similar wear rates. E with HT thermite weld show sever wear rate but on the other hand BTC with HT SMA Weld exhibited steady wear rates whose magnitude is much lower. Figures 4,8,12 and 16 shows that the effect of sliding distance on the wear rate at applied loads of 0 to 40 N in steps of 10N for sliding speed of 1to 4m/sec in steps of 1m/sec. The wear rates of three i.e. rail steel, E with HT thermite weld and BTC with HT SMA weld specimens with the sliding distance, but in E with HT thermite weld specimen shows a drastic increase in wear rate, after the sliding distances of 2 km in all the cases. The results show the wear rate of rail steel, E with HT thermite weld and BTC with HT SMA Weld. The wear rate mainly depends on the grain size. E with HT thermite weld shows fine grain structure so that wear rate is more as compared to rail steel and BTC with HT SMA weld. Under high speed the generation of frictional temperature is high. Due to this frictional temperature the hardness of the phase will decrease. Hence, specific wear rate is increased. The wear rate of ferrite is due to its thermal stability even at high temperature.

Effect of sliding speed and load on volume loss

The influence of welding process and methods on the wear properties welded joint under different sliding speeds, normal pressure and at constant sliding distance of 60 mm is shown in figures from 1, 5, 9 and 13.The volume loss decreases with increasing sliding speed in all specimens of welds and also volume loss increases with increasing load. From the figures it is seen that, weight loss increases with increase in the load and also weight loss decreases with increase in sliding speed in all three cases. The increase in weight loss of the wear pin with the increase in sliding distance may be due to more intimate contact time between contacting surfaces between the wear pin and the rotating disc. In higher load and lesser sliding speed volume loss is very high not only volume loss, the temperature is also increases rapidly because of the temperature sub surface stress increasing and protective layer is destabilized. The increase in wear loss attributed the fact, an increases the normal pressure on the pin and disc contact surface which leads to higher wear. However less volume loss was observed in case of BTC with HT SMA weld and in rail steel as compared to E with HT thermite weld due to the higher carbon percentage and hardness.

Effect of sliding speed and load on volumetric wear rate

The improvement in wear behaviour has been observed in BTC with HT SMA weld. From the figures 3,7,11 and 15 shows the effect of volumetric wear rate under different loads, sliding speed and constant sliding distance for rail, BTC with HT SMA weld and E with HT thermite weld. In all three cases the volumetric wear rate increases with increasing loads and decreasing sliding speeds. It is also clear from the figures that volumetric wear rate was less in rail and BTC with HT SMA weld as compared to E with HT thermite weld is due to changes in microstructure. This is due to the change in microstructure from coarse dendritic structure to fine dendritic structure in BTC with HT SMA weld and pearlitic structure in rail steel. The above mentioned structures are very excellent wear resistance properties. This is due to the fact that, at low sliding speeds, more time is available for the formation and growth of micro welds, which increases the force required to shear off the micro welds to maintain the relative motion, due to which volumetric wear rate increases. However, at higher speeds, there is less residential time for the growth of micro welds leading to lesser volumetric rate.

Worn surface studies

Representative SEM micrographs of the worn surfaces of the specimens taken from rail steel, BTC with HT SMA weld and E with HT thermite weld at high sliding speed and higher load.

Worn surface of rail

Figure clearly reveals that in the absence of debris after the wear. However, the increase in wear resistance and less fracture surface was observed as clearly seen in figure17. The plastic deformation[8] of worn surface less. It is observed that the crack propagation along the grain boundary is clearly seen. The dislodging the surfaces and removal of material along the grain boundary. There was no crack formation on the worn surface and wear mode observed was oxidative. Pearlite is reinforced structure of ferrite and cementite which does not vary much under any operational conditions.

Worn surface of BTC with HT SMA weld

Oxidative wear was observed as clearly evident from the figure18. The worn surface consists of numerous long smooth grooves with small dimples. The figure also shows the formation of oxide layer on the worn surface. In case of oxidative wear, oxide layer of micrometer thickness is formed on the worn surface of the wear pin and subsequent sliding actions of hard asperities of steel abrade the oxide layer present on the wear pin surface, however fresh oxide is formed on the contact surface of the pin in the subsequent sliding motion. Thus oxide film prevents metal to metal contact and thus mitigates against the severe adhesion enhanced wear, which would otherwise occur. Increment in the formation of oxide layer, the wear rate falls. Oxide layer is thick, continuous and adhered to the wear pin surface, then it reduces the direct metallic contact between mating surfaces, hence this results in less friction and wear.

Worn surface of E with HT thermite weld

Figure shows the detachments of wear debris and this indicates delaminative wear. In case of deliminative type wear, the loss of material from interacting bodies in the form of wear debris take place by crack nucleation and propagation in and below the sliding surface due to compressive and tangential traction. Surface and near the surface material is subjected to severe plastic deformation due to these forces. Consequently, the cracks or voids are nucleated in the deformed layers. These cracks grow nearly parallel to the surface before eventually branching to the surface and forming debris. For this reason the wear resistance was decreases and in turn leads to the formation of loose debris. Figure 19 shows some large dimples on the worn surface in addition to the detachment of debris.

CONCLUSION

BTC with HT weld exhibited even, uniform and high resistance to wear rate as similar to rail steel and also worn surface shows that the Oxide layer is thick, continuous and adhered to the wear pin surface, then it reduces the direct metallic contact between mating surfaces, hence this results in less friction and wear rate.

Symmetric hardness traverses along longitudinal direction have been observed in a BTC with HT SMA weld and also hardness of the weld almost equal to the rail steel. The existence of approximately the same hardness in the base metal and weld metal. So that BTC with HT SMA weld indicates that uniform, even and high resistance wear

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