4. Result and discussion:

4.1 Coating characterization:

The microstructures of the coating were studied with the help of scanning electron microscope. The microstructures of the coating suggest that the splat of the sprayed material does not seem to form a continuous layer but at the cross section, it was observed that the coating was more homogeneous and regular (figure 4.1).

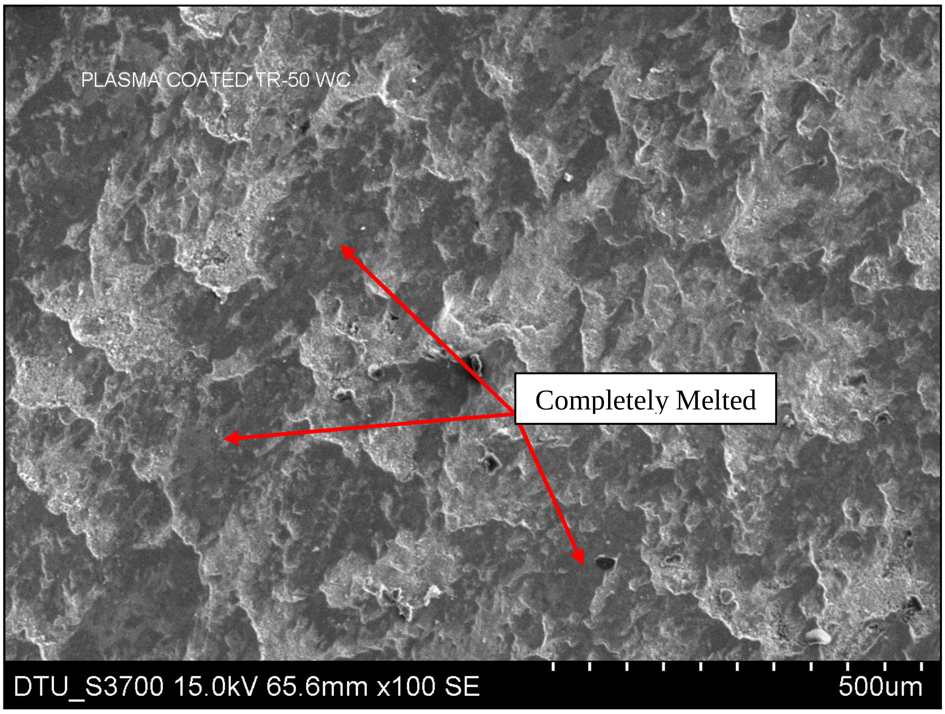

Figure 4.1- (a) Top View of Thermal Sprayed Coating

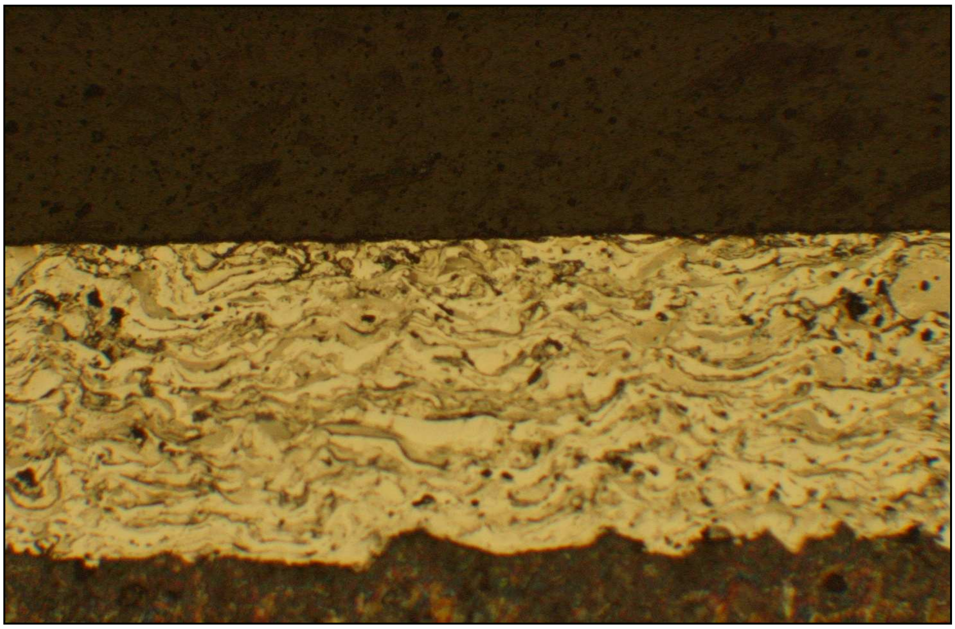

Figure 4.1 (b) – Cross-sectional View of Plasma Spray Coating

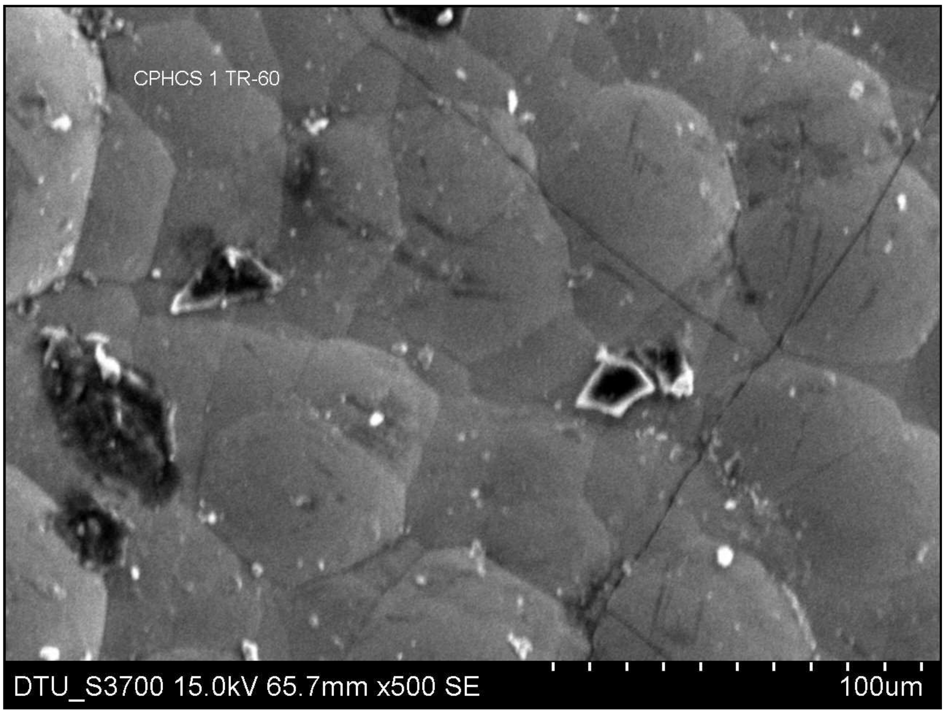

Figure 4.2 - Top View of Hard Chrome plating

All the three coatings (air plasma spray, hard chrome plating, gas nitriding) were homogeneous and in the form of continuous layer, blow holes & porosity were regular but air plasma spray coating have a very little unmelted parts.

4.2. Wear rate of thermal spray coating:

4.2.1. Wear rate of air plasma spray coating with tungsten carbide, En-31 and nickel pin:

The wear rate of the air plasma arc coating in terms of mass loss along with their counter bodies were calculated. To find the wear rate of the coating the one variable was chosen as already described that was load. The load was chosen as 40, 50 and 50 N and the sliding speed was chosen as 500 rpm. By using these variables experiment was designed.

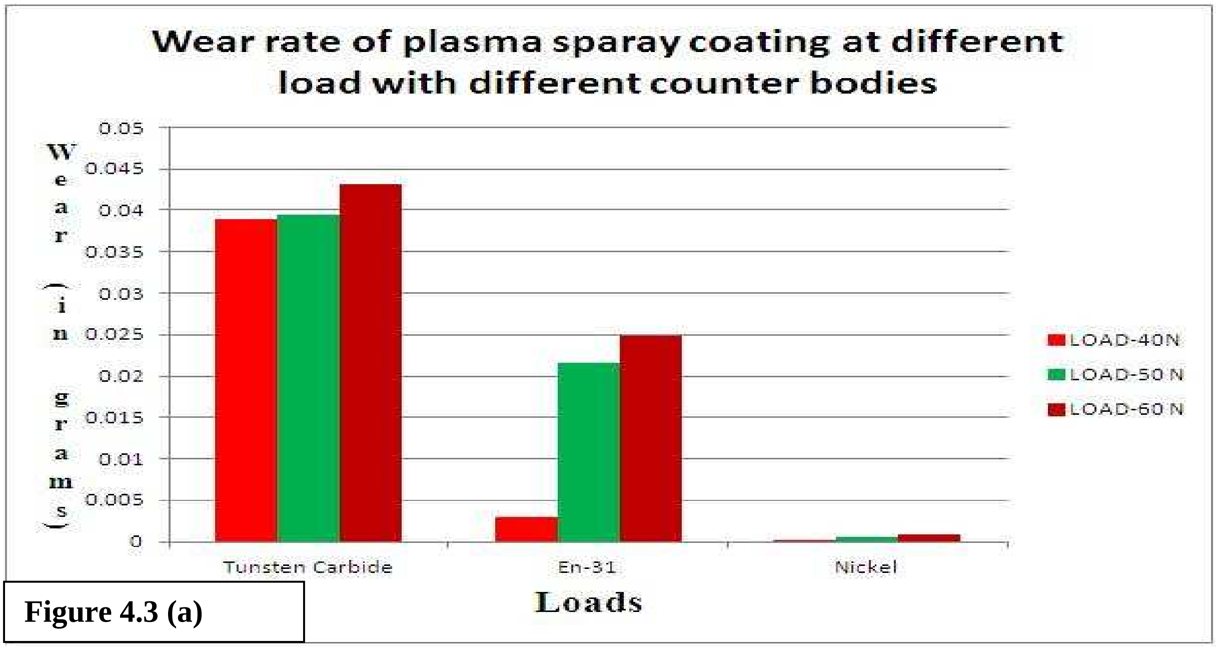

Figure 4.3 (a)

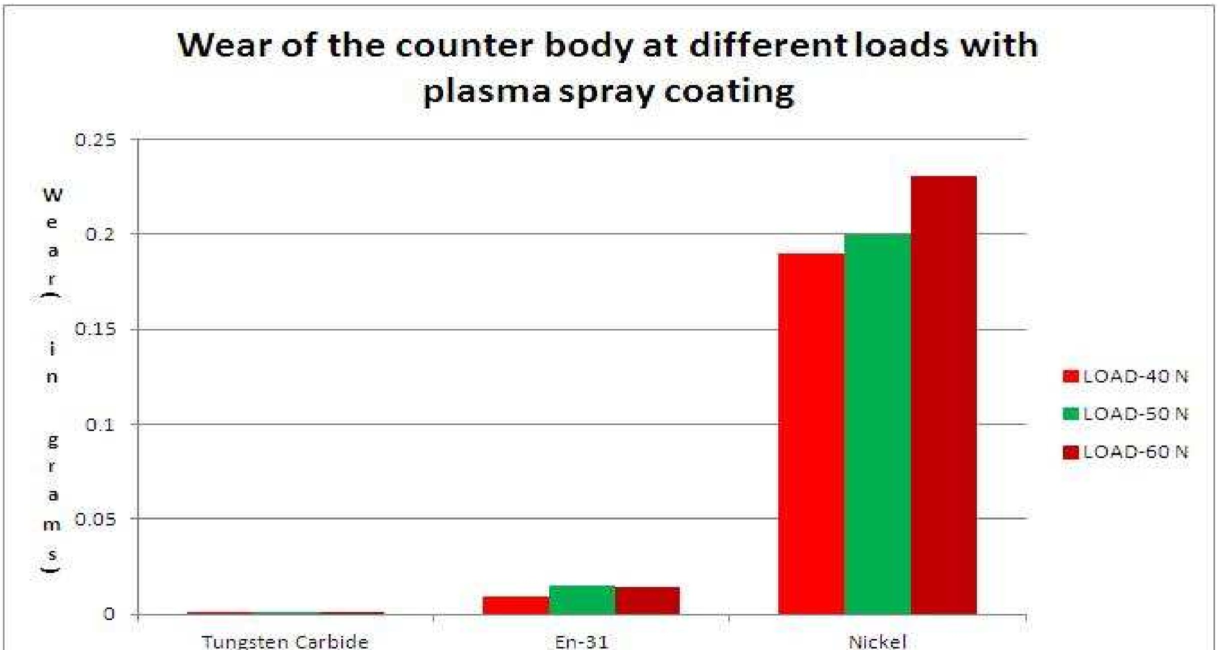

Figure 4.3 (b)

Figure 4.3a) shows the variation of the wear rate of the plasma spray coating at different loads with different counter bodies. b) Shows the variation of the wear rate of the different counter bodies at different loads with plasma sprayed plate.

The wear rate of the plasma spray coating at 500 rpm speed & counter body of tungsten carbide, and 40 N loads was found to be 0.039 g. The wear rate was increased to 0.0395 g when the load was increased to 50.0 N. The wear rate at 60 N loads was further increased to 0.0432 g. The wear rate of the counter body (tungsten carbide pin) at the 40.0N load was found .0001g. The wear rate of the counter body almost remains constant on increasing the loads from 40 N to 50N and 60 N.

The wear rate of the plasma spray coating with the counter body of En-31 at 500 rpm speed and 40 N load was found to be 0.0030 g. When the load was further increased to 50 N at same rpm; the wear rate was found to increase very rapidly 0.0216 g. The wear rate was further found to increase to 0.0248 g at the load of 60 N. The wear rate of the counter body (En-31pin) at 500 rpm speed and 40 N loads was calculated as 0.0096 g. The wear rate further increased to 0.0151 g at the load of 50 N and to 0.0147 g, at a load of 60 N, under the same sliding speed.

The wear rate of the coating with the counter body of nickel at 500rpm speed and 40 N loads was found to be 0.0001g. When the load is further increased to 50 N at the same rpm the wear rate is found to be increased very slightly and similar pattern were seen when the load is again raised from 50N to the 60 N. The wear rate of the counter body (Nickel) at 500 rpm and 40 N load was calculated as 0.1901g. The wear rate further increased to 0.2002 g at the load of 50 N and to 0.2301 g, at the load of 60 N, under the same sliding condition.

The wear rate of the plasma spray coating at low load and with the counter body Nickel was found to be very low. The wear rate of coating increased to a lesser degree with increase of the loads with the counter body of nickel lower. The wear rate increased when the load on the disc was increased with the counter body of En-31. The wear rate was also found to increase with increased load with the counter body of tungsten carbide [8, 41]. The wear rate of the plasma spray coating was maximum with the counter body of the tungsten carbide. The wear rate increased more with increased load. The wear rate with the En-31 counter body was found to be increased very rapidly for the initial increased load after that it's increased in constant manner. It can be concluded that at lower load the wear is caused by adhesion and very less abrasion. When either one of two surfaces of tribo-elements in sliding or rolling contact has thin soft surface layer that can be partly transferred to the counter surface by adhesion relative displacement takes place at the interface between the surfaces of coating and transfer layer with smaller shear strength of the soft material than that of the underlying element material [30]. This was further explained by Subramanian et al. [52] that during wear test of aluminum alloy with a copper pin, a tribolayer of aluminum alloy forms on the copper pin. This tribolayer was formed at low load and low sliding velocity. The wear rate of the coating was decreased by the tribolayer. The nickel pin at low load and high load showed high deformation and low wear rate of the plasma spray coatings because the micro hardness of coating used was very much as compared to hardness of the nickel pin. A.P. Sannino et al. [31] found that the wear rate also depends on the sliding speed; it is low at low speed and increases with increasing speed. The similar behavior that the wear rate increases with increase in load has also been reported by Koji Kato et al. [30].

4.2.2. Wear rate of Hard Chrome plating coating with tungsten carbide, En-31 and nickel pin:

Wear rate of the hard chrome coating under similar loading and sliding conditions were calculated as described earlier. By using loads as variables and three different counter bodies (tungsten carbide, En-31, Nickel), experiment was performed as in the last case.

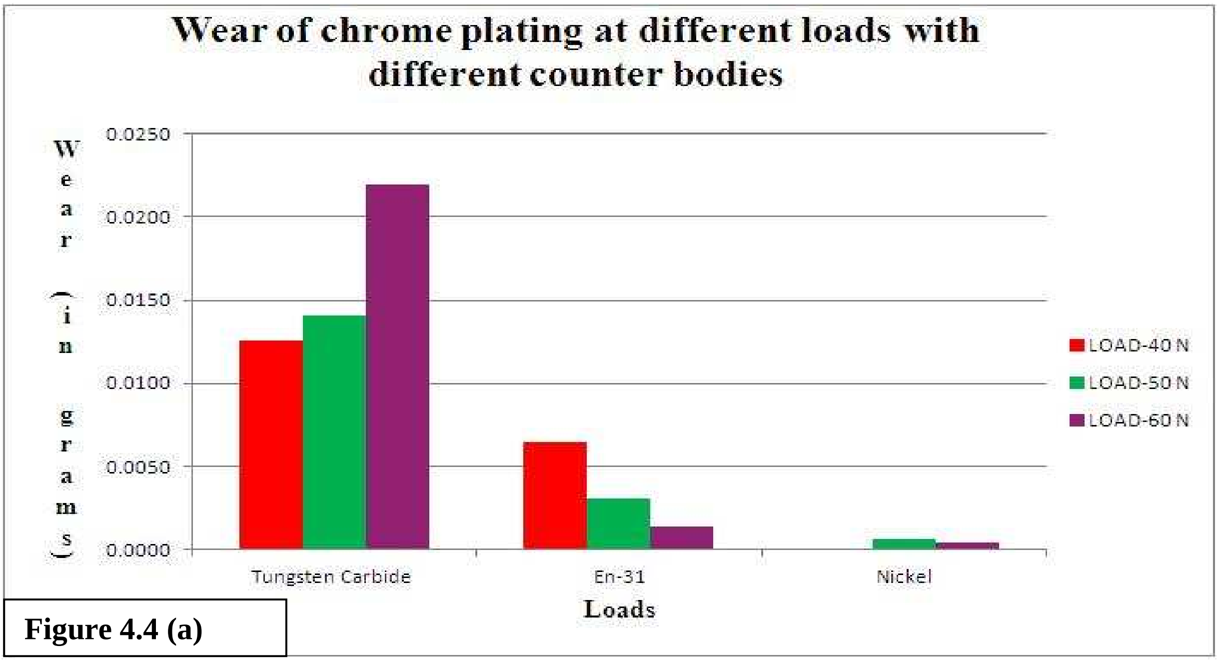

Figure 4.4 (a)

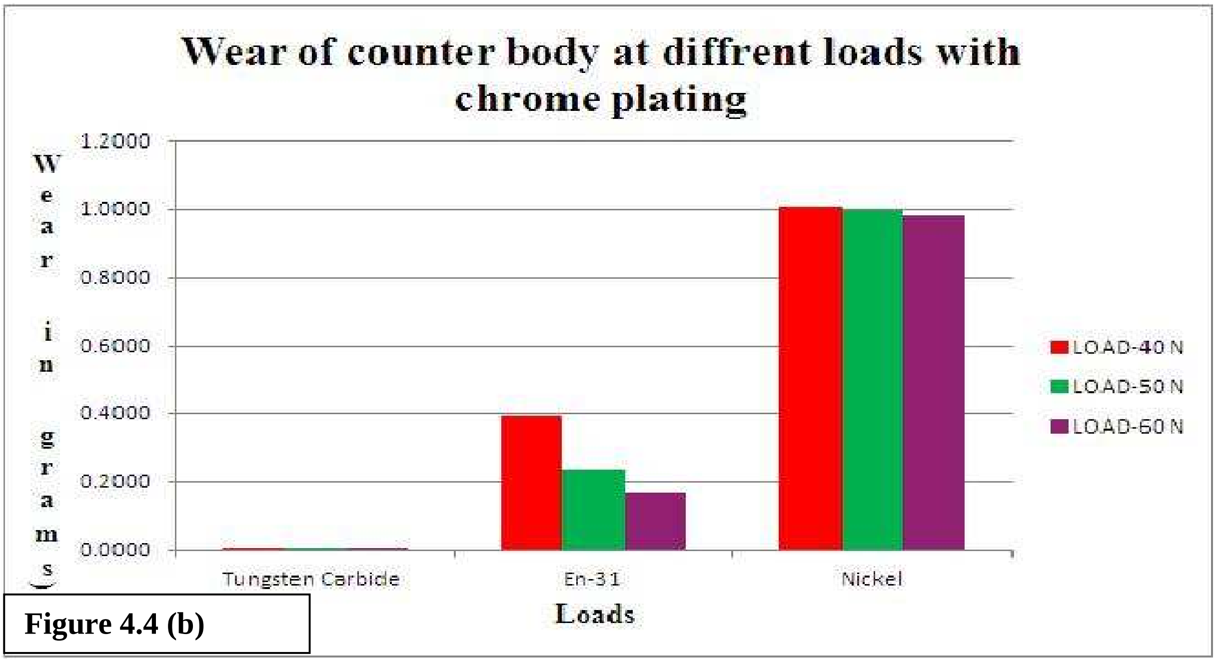

Figure 4.4 (b)

Figure 4.4a) shows the variation of the wear rate of the chrome plating at different loads with different counter bodies. b) Shows the variation of the wear rate of the different counter bodies at different loads with chrome plating.

Figure 4.4 (a and b) shows the variation of the wear rate of the hard chrome plating at different load and different counter bodies (Tungsten Carbide, En-31, and Nickel). The wear rate of the chrome plating with the counter body of tungsten carbide at 500 rpm speed, and 40 N load was calculated as 0.0126 g. The wear rate increased to 0.0141 g when the load was increased to 50 N. The wear rate at 60 N loads further increased to 0.0220 g. The wear rate of the hard chrome plating at 500 rpm speed with the counter body of En-31, and 40 N loads was 0.00640 g. When the load was further increased to 50 N at same rpm; the wear rate decreases to 0.00310 g. The wear rate further decreased to 0.00140 g at the load of 60 N. The wear rate of the coating at 500 rpm speed with the counter body of nickel and 40 N, 50 N, & 60 N loads was calculated as 0.00001 g, 0.00004 and 0.00005 which is almost negligible.

The wear rate of the coating with tungsten carbide pin (En-31) was found to be higher than the wear rate of the coating with En-31 pin and wear rate of En-31 was found to be higher than the wear of the Nickel pin. The wear rate of the chrome plating was found to be decreased with the decrease of load. Similar trends also found in the case of wear of chrome plating with the nickel pin with the increase of load the wear rate decreased. P.L. Ko et el.[60] in 2002 showed the similar trends of the mass lass rate of the chrome plating with the Al-Ni pin with increase of the speed . Giovanni Borelli et el. in 2006 also reported the decreasing trends of wear rate with the increase of no of revolution [23]. The reason for this decreasing trend in the wear rate is explained by Koji Kato et el. in 2000 as When a triboelement made of soft material such as plastics is rubbed and effectively worn by a harder counterpart, its wear can be reduced by forming a transfer layer of the soft material on the counter surface of harder material. Wear rate of the soft material in sliding against itself must be small in this case [30].

When a tribo-element is made of a material having hardness less than the hardness of the counter body, material in the contact region plastically deforms severely under the combined stresses of compression and shear. Large plastic deformation generally introduces large wear rate since wear surface tends to become rough and protective surface layers are easily destroyed.[30]

W. Maa et al. [51] showed that the wear behaviour of different material is different with different counter materials. The wear rate of the coating increased slightly with increased in the sliding speed at low load. But at high load the wear rate increased to a higher value at the increased sliding speed. It case of medium carbon steel pin the material gets eroded fast so the coefficient of friction and the wear rate were found to be more [51, 54]. The wear rate of the coating with tungsten carbide pin was much higher in comparison of En-31 and the nickel pin as the tungsten carbide pin is much harder compared to the hard chrome coating, and the wear mechanism was mainly due to micro cutting. The wear because of the En-31 and nickel was found to be negligible as chrome plating is much harder than En-31 and Nickel pin.

4.2.3. Wear rate of Gas Nitriding with tungsten carbide pin, En-31 and nickel pin:

The wear of the gas nitriding coating was also analyzed with tungsten carbide pin, En-31 and nickel pin under the same loading and sliding conditions.

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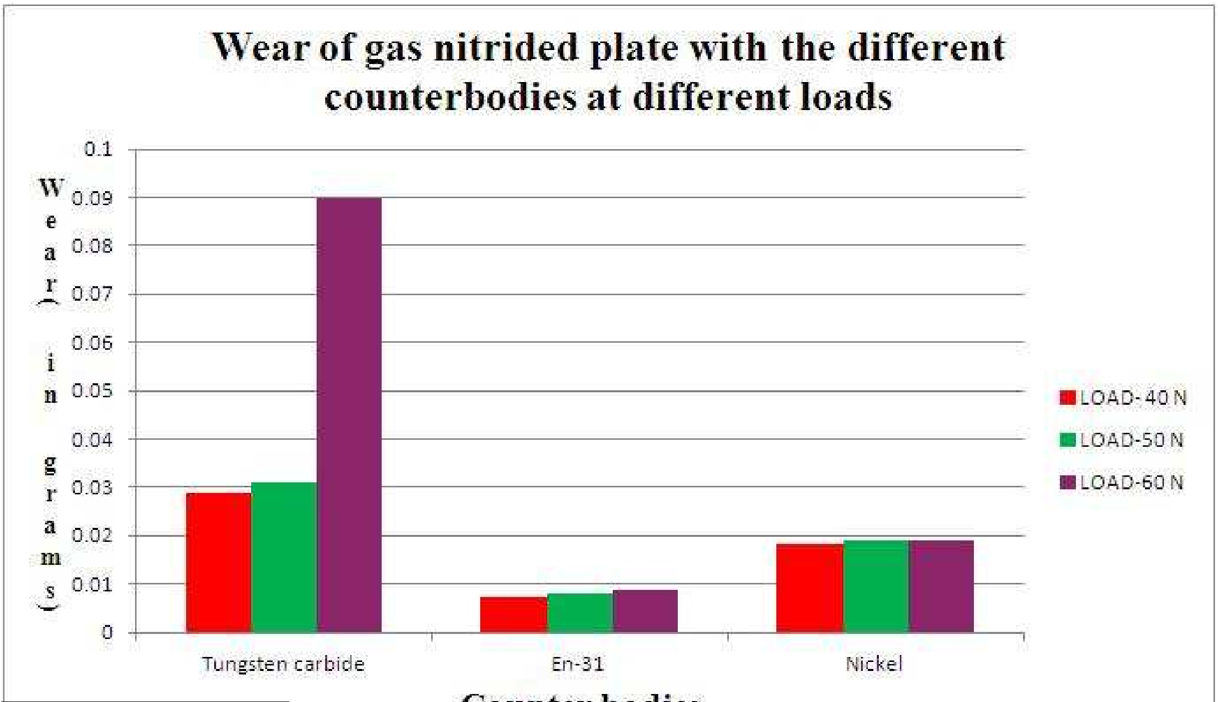

Figure 4.5 (a)

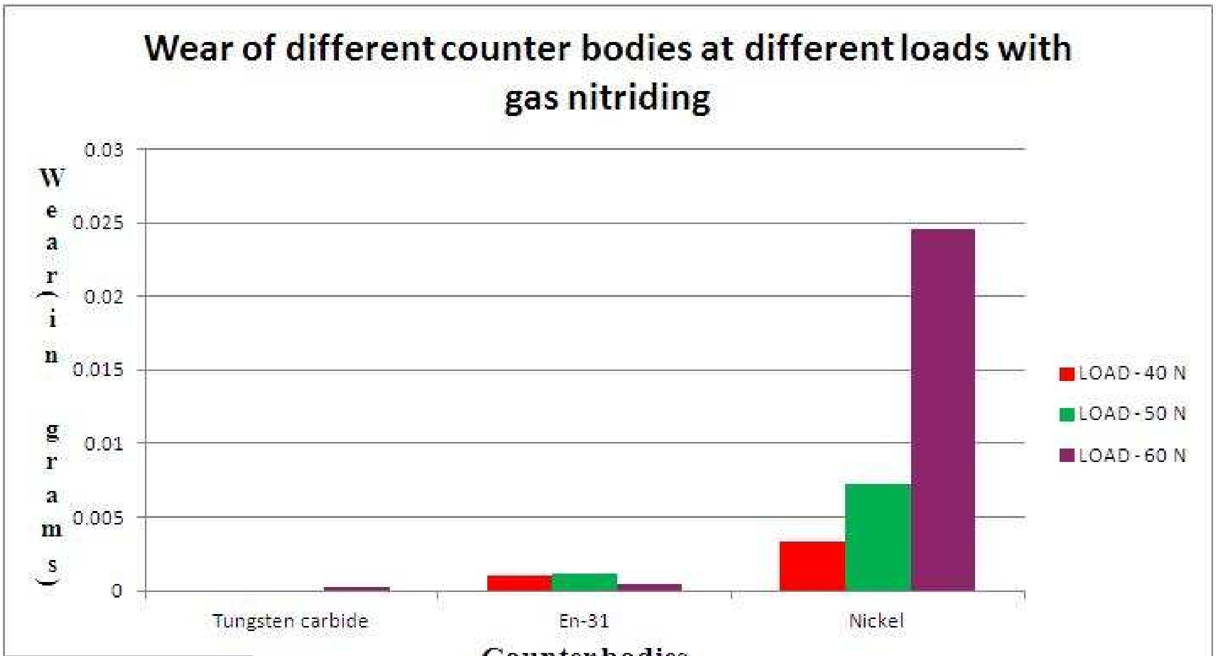

Figure 4.5 (b)

Figure 4.5a) shows the variation of the wear rate of the gas nitride plate at different loads with different counter bodies. b) Shows the variation of the wear rate of the different counter bodies at different loads with gas nitride plate.

Figure 4.5(a and b) shows the variation of the wear rate of the coating at different loading and with tungsten carbide, En-31 and nickel pin. The wear rate of the gas nitride plate with the tungsten carbide pin coating at 500 rpm speed and 40.0 N load was 0.0289 g. The wear rate increased to 0.0312 g when the load was increased to 50 N. The wear rate at 60 N load further increased to 0.0897 g. The wear rate of the gas nitride plate with En-31 pin at 500 rpm speed, and 40.0 N load was 0.0074 g. When the load was further increased to 50 at same rpm the wear rate was 0.0080 g. The wear rate further increased to 0.00860 g at the load of 60 N. The wear rate of the gas nitride plate with nickel pin at 500 rpm speed and 40 N load found to 0.0182 g. The wear rate was increased to 0.0189 g at the load of 50 N. The wear rate was further increased to 0.0190 g at a load of 60 N under same sliding speed.

It is clear from Figure 4.5(a) that the wear rate of the gas nitride plate with tungsten carbide pin was low at low load [41], but as the load was increased to some moderate value the wear rate increased abruptly. However, when the load was further increased then the increase in the wear rate was small. The wear rate also increased with the increased value of the sliding speed [8]. At low speed the value of wear rate increased with load, but the increment was very less. However, at higher sliding speed the value of wear rate increased abruptly with increased loading conditions. It was found that the wear rate of the gas nitriding with the tungsten carbide was more than that with the En-31 pin and the medium nickel pin [51, 54]. It was concluded that at the lower loads, the coating wear was mainly due to adhesion and deformation, and other modes of wear did not observed as reported earlier [55].

4.3. Coefficient of friction (CoF) of the coatings:

4.3.1. Coefficient of friction of the plasma sprayed coating with tungsten carbide, En-31 and nickel pin:

The co-efficient of friction (CoF) of the plasma sprayed coating at three loads (40, 50 and 60 N) and three counter bodies (tungsten carbide, En-31 and nickel) were analyzed.

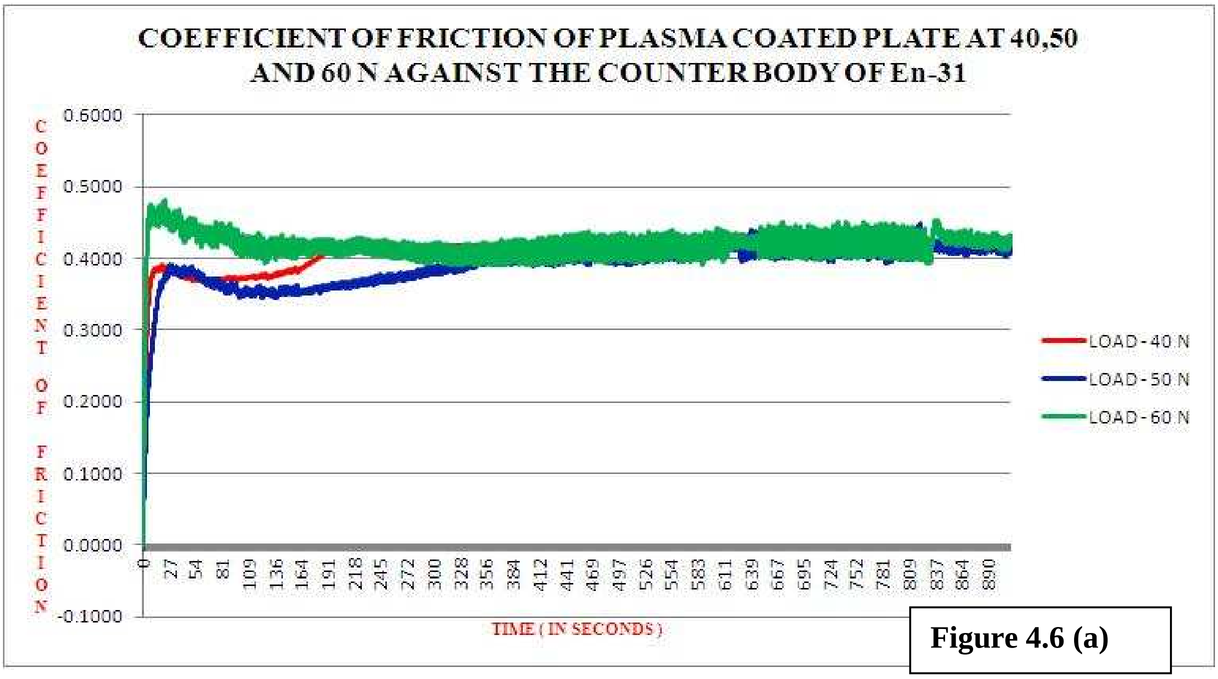

Figure 4.6 (a)

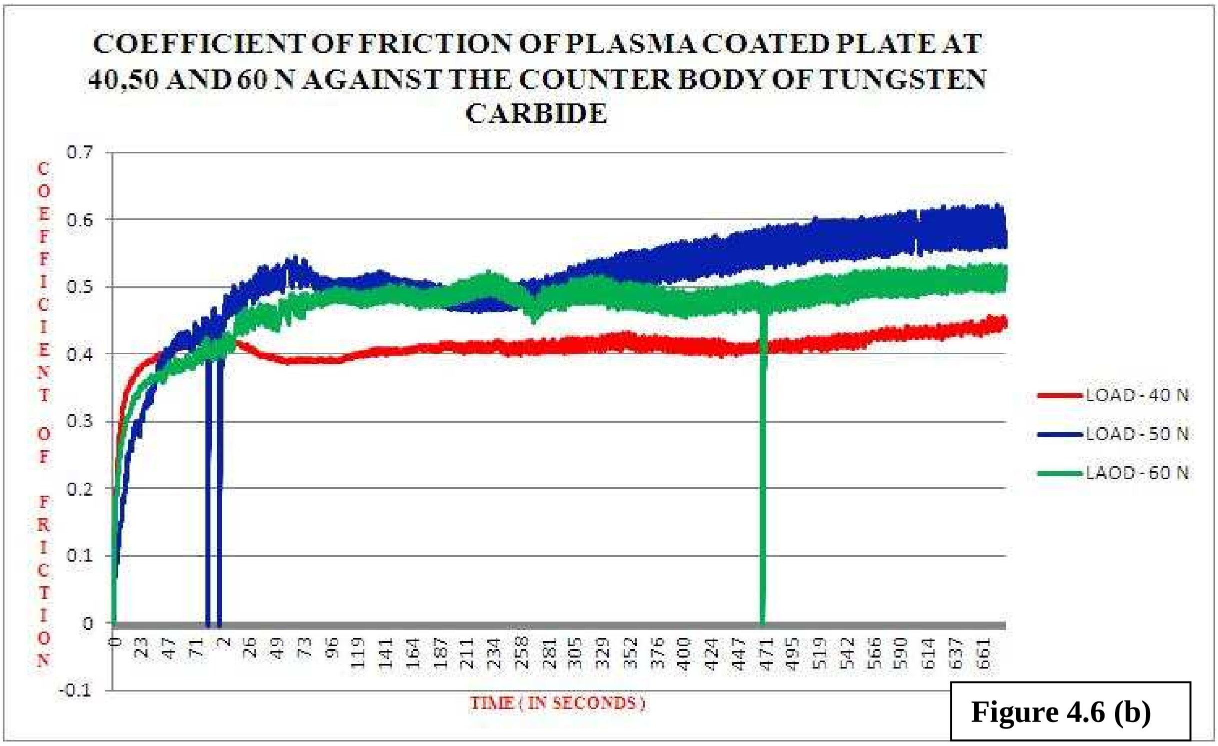

Figure 4.6 (a) Variation of coefficient of friction of plasma spray coated plate with En-31 pin at various loading condition with time. (b) Variation of coefficient of friction of plasma spray coated plate with tungsten carbide pin at various loading condition with time

Figure 4.6 (a and b) shows the variation of the co-efficient of friction of the plasma sprayed coating at different loading and sliding condition with En-31 pin and tungsten carbide pin. The coefficient of friction of the coating at 40 N load and 500 rpm with En-31 pin was calculated as 0.4080. The coefficient of friction decreased to 0.3930, at a load of 50.0 N at the same speed. When the load was increased to 60 N at the same sliding speed the co-efficient of friction was further decreased to 0.3883. The co-efficient of friction of the plasma spray coating at 500 rpm speed with tungsten carbide pin and 40.0 N load was found to be 0.4093. When the load was increased to 50.0 N at the same sliding speed, the co-efficient of friction increased to 0.5066. It further decreased to 0.4701, when the load was increased to 60 N at the same sliding speed. Similar result with the variation of temperature was already reported. In this he discussed that the CoF of NiCrBSiCFe plasma coatings on austenitic stainless steel at 250 ^{0}C was marginally higher than 150 ^{0}C and 350 C. This may be due to the material softening at 250 ^{0}C. The coated samples worn at room temperature possessed relatively higher CoF values than the rest. The oxides formed at 350 ^{0}C act as a protective as well as lubricative film leads to lesser CoF values and thereby eliminating the chances of severe wear.PSP-1 possesses relatively lesser CoF, which may be attributed to the slightly higher wear resistance of the coating[100].

The co-efficient of friction at 500 rpm speed with the nickel pin and 40 N load was found to be 0.5451. The co-efficient of friction was found decrease further when the load increased to 50.0 N and 60.0 N respectively at the same sliding speed.

The coefficient of friction of the coating decreased, when the sliding speed was increased. The decrease in co-efficient was more significant with increase in sliding speed. A. Edrisy et al. [53] has earlier reported that at high sliding speed and high load the coefficient of friction was low. However, the variation in the co-efficient of friction with variation in load was very less which is contrary to Binshi Xu et al. [9] as in general they found that the coefficient of friction of aluminum alloy decreases with an increase in load. This may be because the En-31 & Nickel pins were soft materials, and they deformed during the wear test.

4.3.2. Coefficient of friction (CoF) of the hard chrome coating with En-31, tungsten carbide and nickel pin at different loading condition:

The co-efficient of friction (CoF) of chrome coating with En-31, tungsten carbide and nickel pin at different loading condition was analyzed under similar sliding conditions,

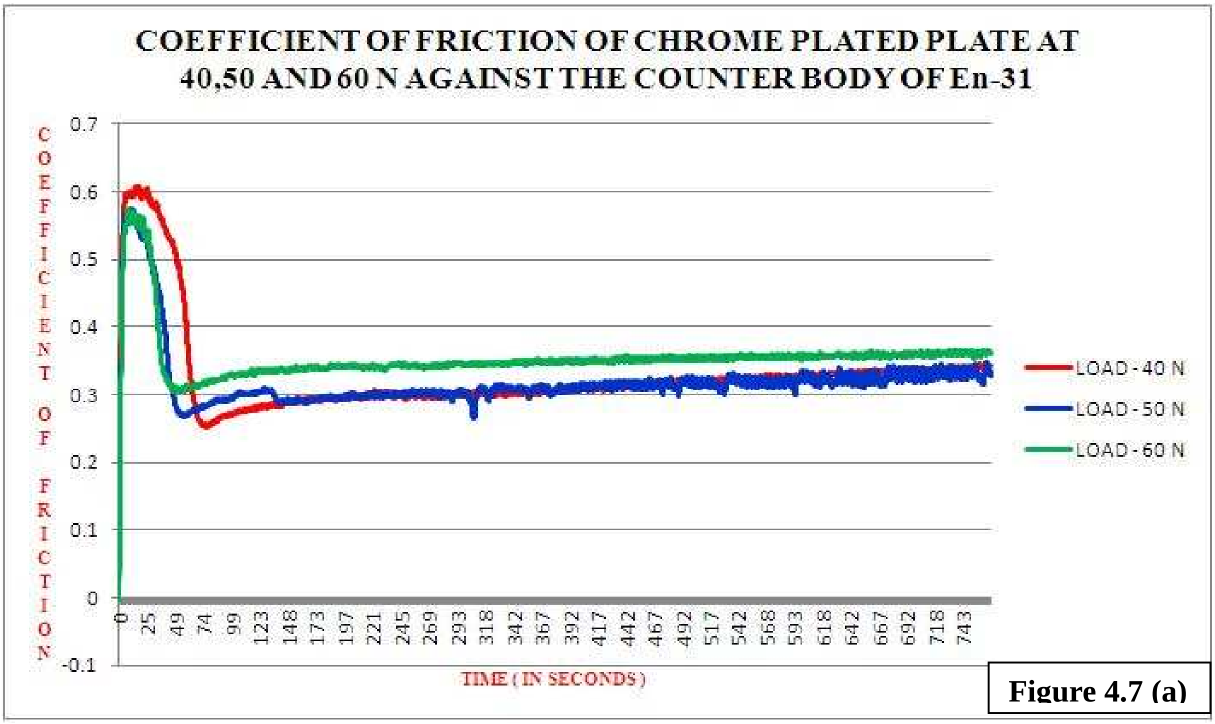

Figure 4.7 (a)

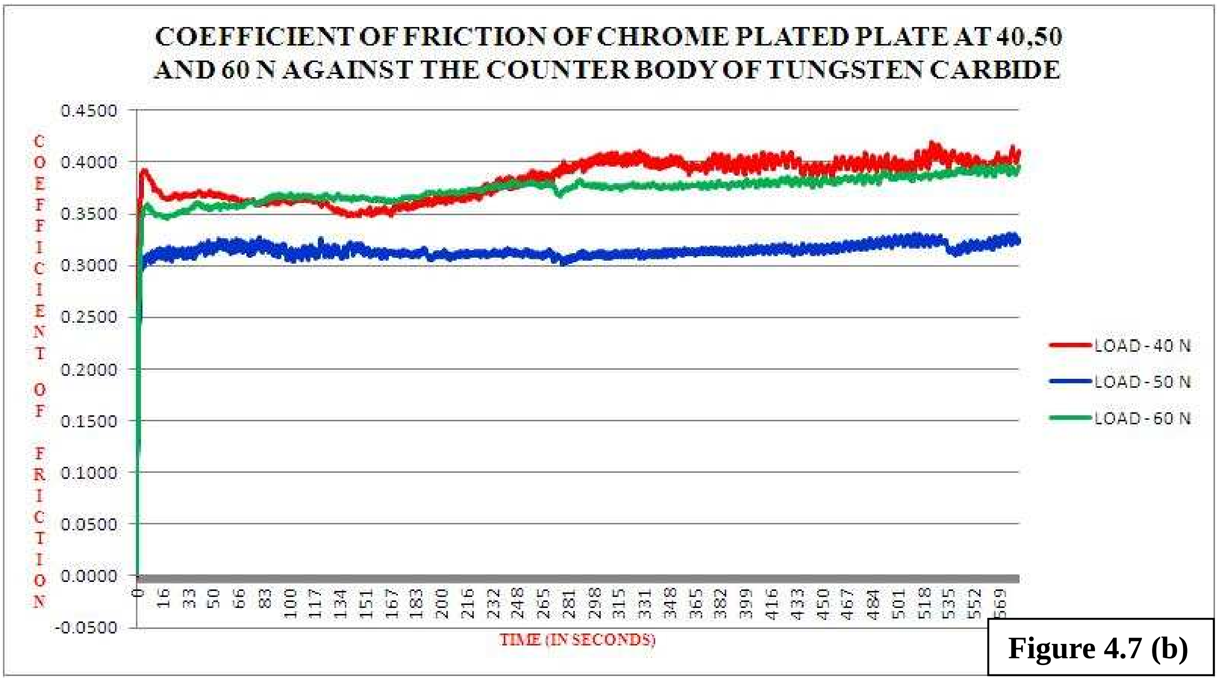

Figure 4.7 (b)

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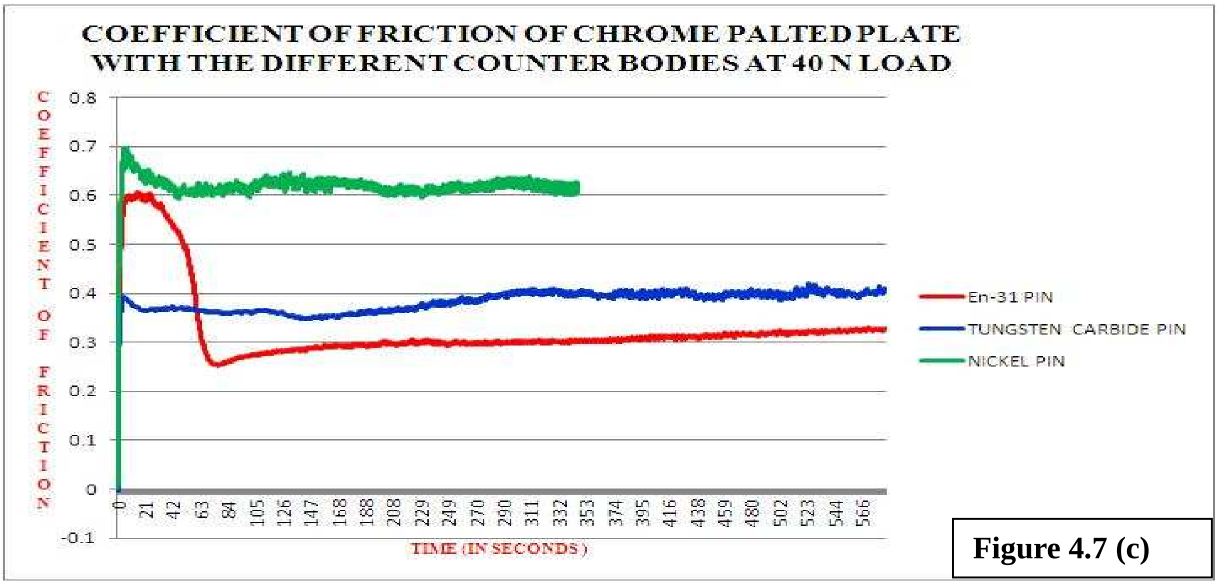

Figure 4.7 (c)

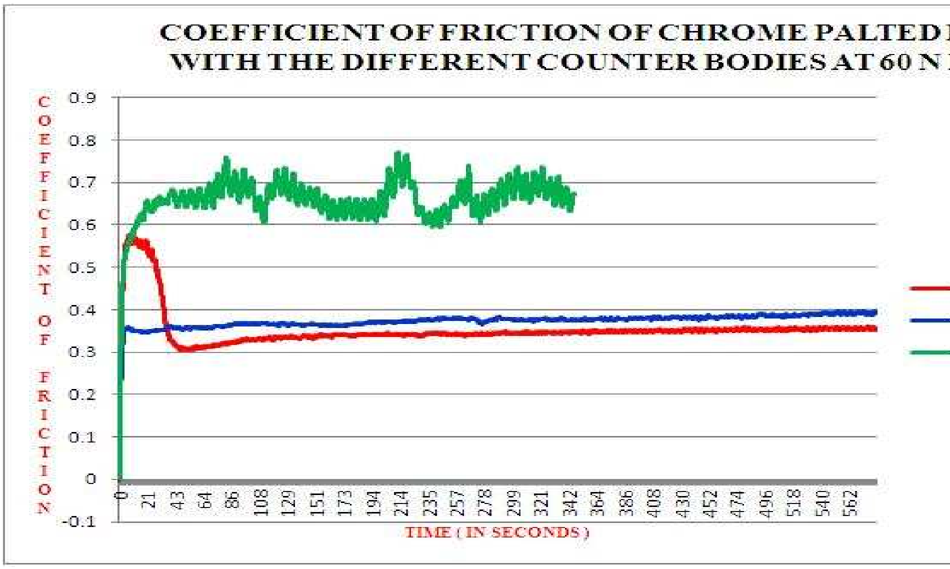

Figure 4.7 (d)

Figure 4.7- (a) Variation of coefficient of friction of chrome plated plate with En-31 pin at various loading and sliding conditions. (b) Variation of coefficient of friction of chrome plated plate with tungsten carbide pin at various loading and sliding conditions (c) Variation of coefficient of friction of chrome plated plate with En-31 pin, tungsten carbide and nickel pin at similar loading and sliding conditions (d) Variation of coefficient of friction of chrome plated plate with En-31 pin, tungsten carbide and nickel pin at similar loading and sliding conditions

Figure 4.7 (a & b) shows the variation of the co-efficient of friction of the chrome coating at different loading and sliding condition with En-31 pin and with tungsten carbide pin. The coefficient of friction of the chrome plating with the counter body of En-31 at 40.0 N load and 500 rpm was found to be 0.3283. The coefficient of friction was found decrease to 0.3198 at a load of 50.0 N at the same 500 rpm speed. When the load was increased to 60 N at the same sliding speed the co-efficient of friction found to be increased to 0.3541. The co-efficient of friction of the chrome coating with tungsten carbide at 500 rpm speed and 40 N load was 0.3828 With the increased of load to 50.0 N at the same sliding speed it again decreased to 0.3140. It found to be increased to 0.3730, when the load was increased to 60 N at the same sliding speed. The co-efficient of friction with nickel pin at 500 rpm speed and 40.0 N load was 0.6188. It decreased to 0.6066, when the load was increased to 50.0, at the same sliding speed. The co-efficient of friction found to be increased to 0.6592 at 60 N load and same 500 rpm sliding speed.

Figure 4.7 (c & d) showed that the CoF of nickel with chrome Coating showed higher co-efficient of friction as compared to tungsten carbide pin and En-31 pin at all loading of 40,50 and 60N.En-31 showed the lowest CoF at the all loading condition at 40,50 and 60N. The coefficient of friction in case of the nickel pin was higher than in case of tungsten carbide pin [51, 54]. The coefficient of friction was decreased with increased loading conditions. It was decreased may be due to reason that at increased load, the wear rate was more, that's why the direct rubbing was less. And it showed less coefficient of friction. The co-efficient of friction at 29.9 N load and 44.1 N load was almost same at 200, and 250 rpm speed. The wear rate was also decreased with increase in sliding speed. The co efficient of friction is low when the load is high and sliding speed is high [12, 53]. The Binshi Xu et al. [9] found that the coefficient of friction of aluminum alloy decreases with an increase in load.

4.3.3. Coefficient of friction (CoF) of the gas nitride plate with En-31, tungsten carbide and nickel pin at different loading condition:

The co-efficient of friction of the gas nitrided plate was also analysed with En-31, tungsten carbide and with nickel pin at similar loading and sliding conditions, as described in the last cases.

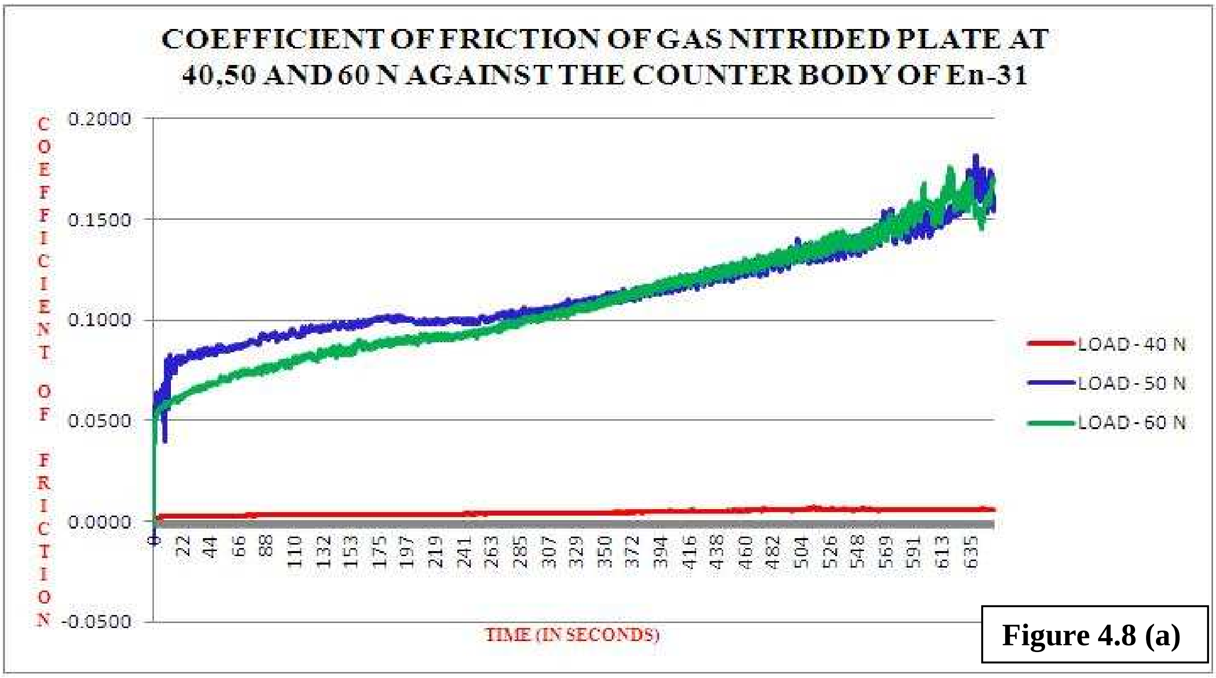

Figure 4.8 (a)

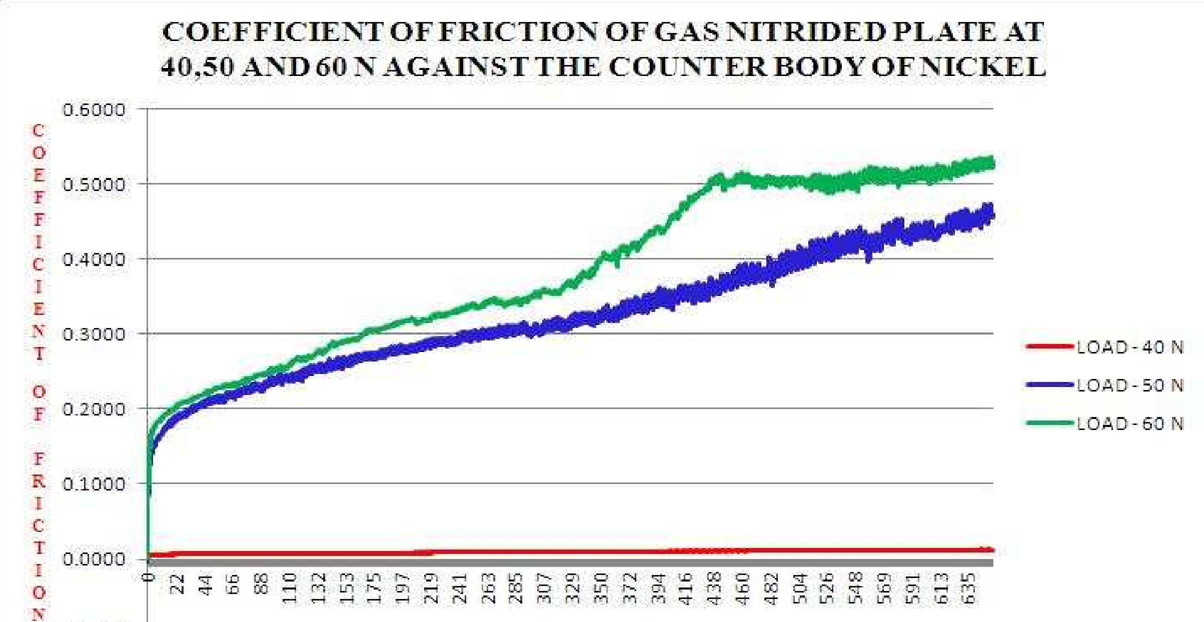

Figure 4.8 (b)

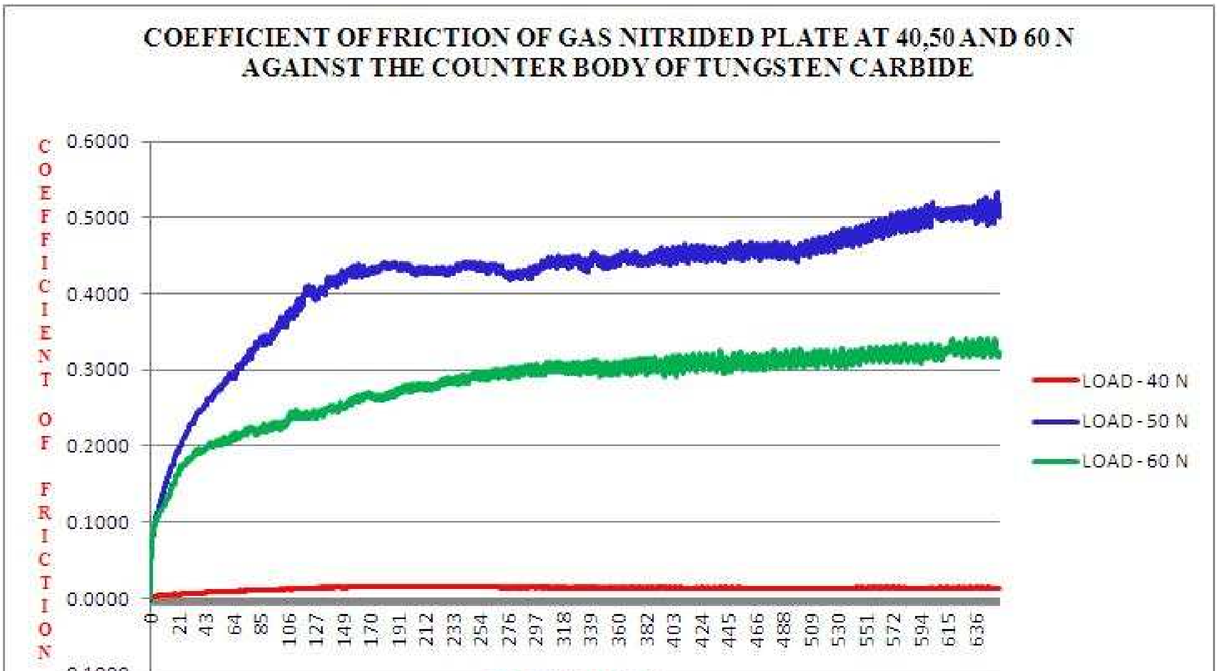

Figure 4.8 (c)

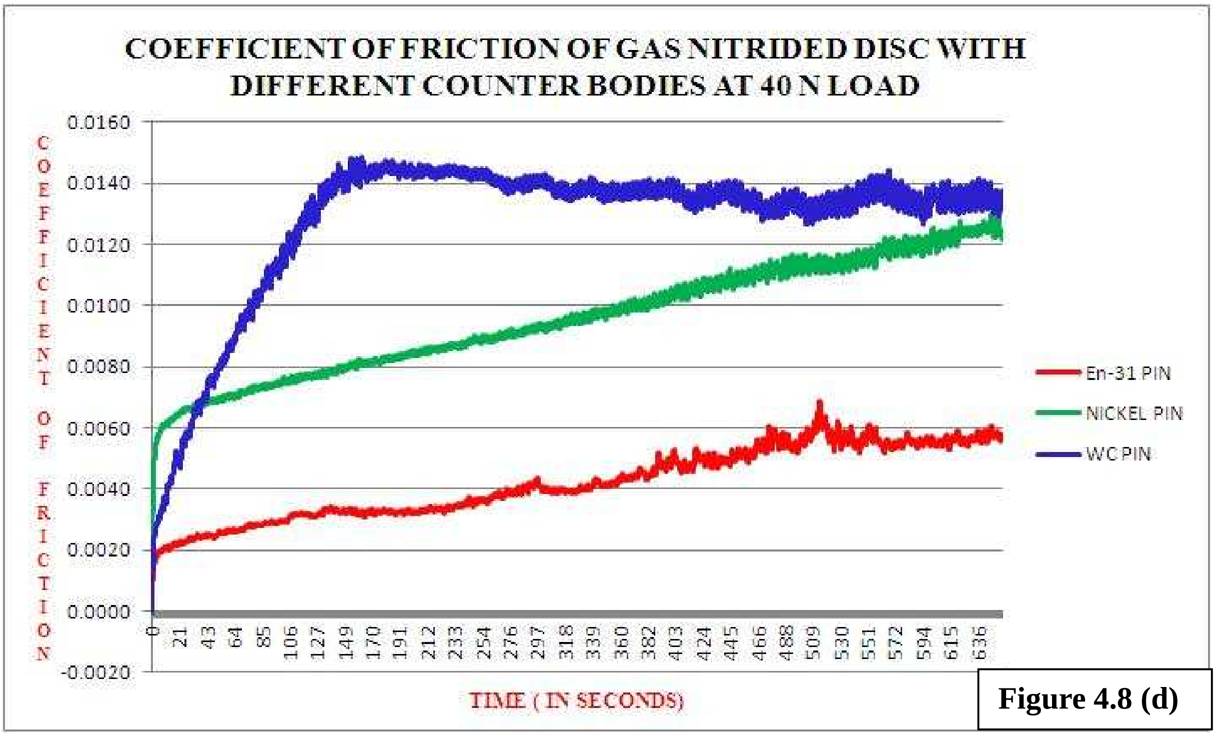

Figure 4.8 (d)

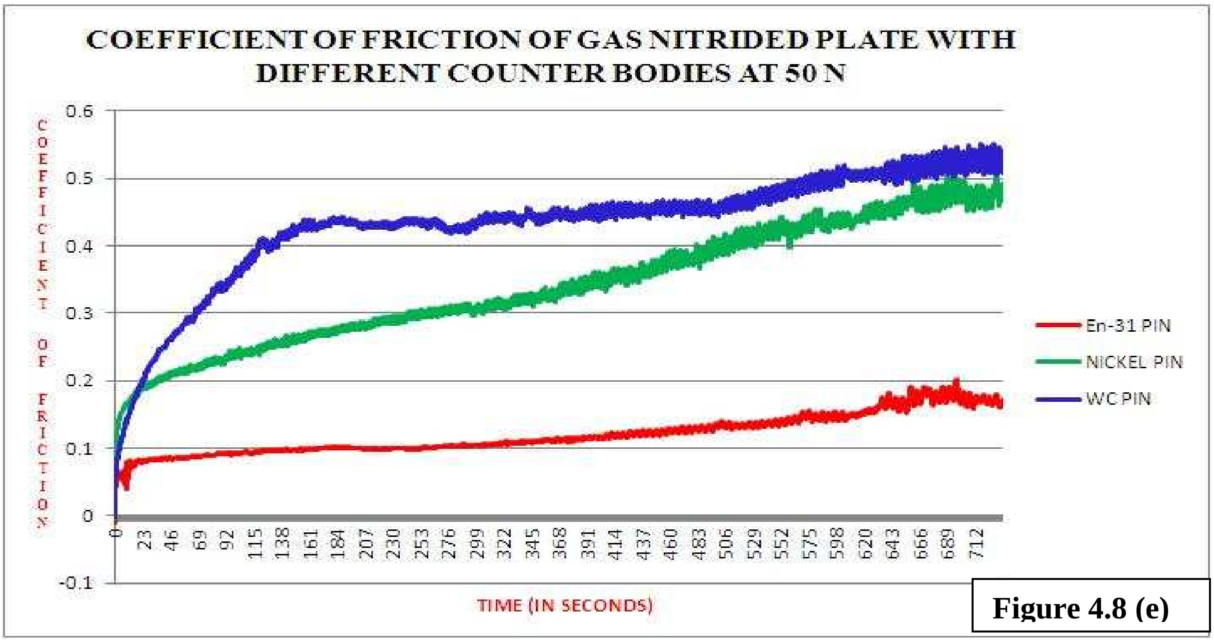

Figure 4.8 (e)

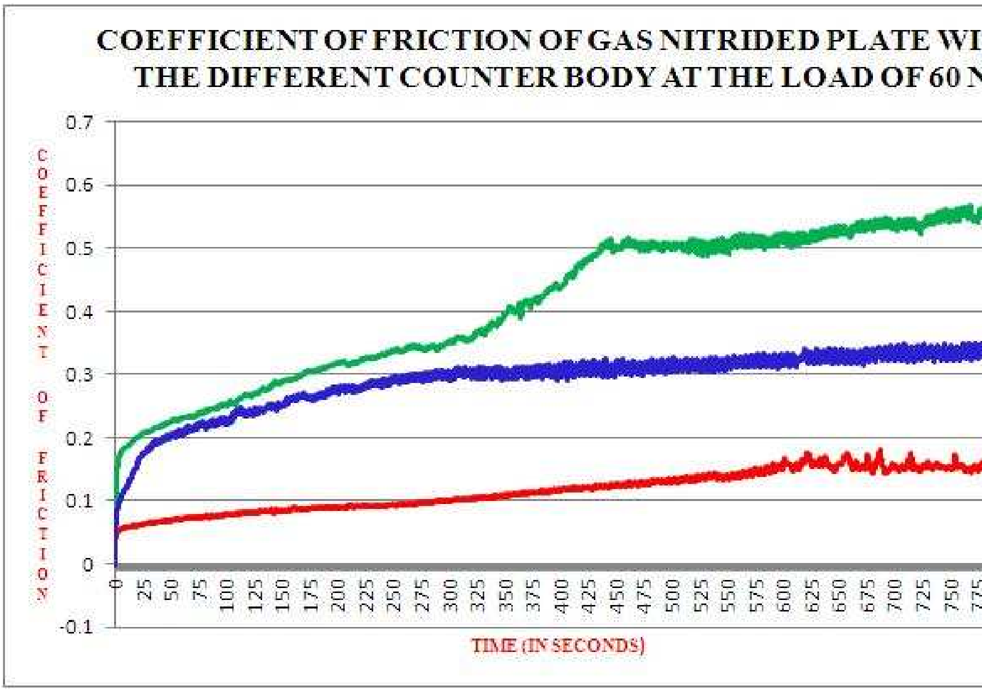

Figure 4.8 (f)

Figure 4.8 (a, b,& c) Variation of coefficient of friction of gas nitrided plate with En-31,Nickel and tungsten carbide pin pin at various loading and sliding conditions.(d, e & f) COF of gas nitrided plate with different counter bodies at 40,50 & 60 N load

Figure 4.8 (a, b & c) shows the variation of the co-efficient of friction of the gas nitriding with En-31, nickel & tungsten carbide at different loading and sliding condition. The coefficient of friction of the gas nitride coating with En-31 at 40 N load and 500 rpm was calculated as 0.0042. The coefficient of friction increased to 0.1128, at a load of 50 N at the same speed. When the load was increased to 60 N at the same sliding speed the co-efficient of friction was decreased to 0.1081. The co-efficient of friction of the gas nitride coating with tungsten carbide at 500 rpm speed and 40 N load was found to be

0.0128. When the load was increased to 50 N at the same sliding speed the co-efficient of friction increased to 0.4203. It decreased to 0.2810, when the load was increased to 60 at the same sliding speed. The co-efficient of friction at 500 rpm speed with nickel pin and 40 N load was 0.0096. It increased to 0.3238, when the load was increased to 50 N at the same sliding speed. It was further increased to .3842, at 60 N load and same sliding speed.

The co-efficient of friction of the coating with high carbon steel was more than coefficient of friction with brass and medium carbon steel pin [51, 54]. The co-efficient of the friction of the coating was decreased with increase in load [9, 12]. The coefficient of friction was also decreased with the increased sliding speed [13, 53]. The coating having hardness 300 Hv at 100 gm load, it was less as compared to hardness of the high carbon steel tool pin. So no deformation of the high carbon steel pin was observed during the wear test.

4.4 Wear mechanism:

4.4.1 Wear mechanism of plasma coating with En-31, tungsten carbide & nickel pin:

In order to study the wear mechanism the worn surface were examined by scanning electron microscope. The scanning electron microscope gives the 3D surface morphology of the wear track which helps in the interpretation of the wear mechanism at various loading conditions and various speeds.

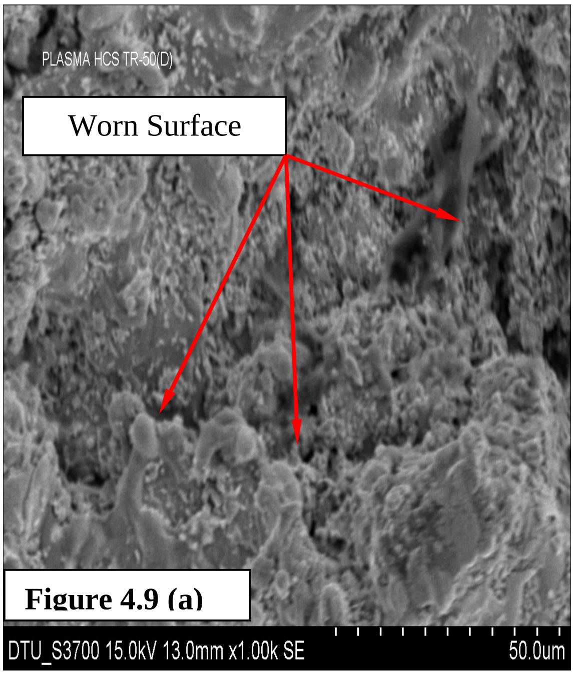

Figure 4.9 (a)

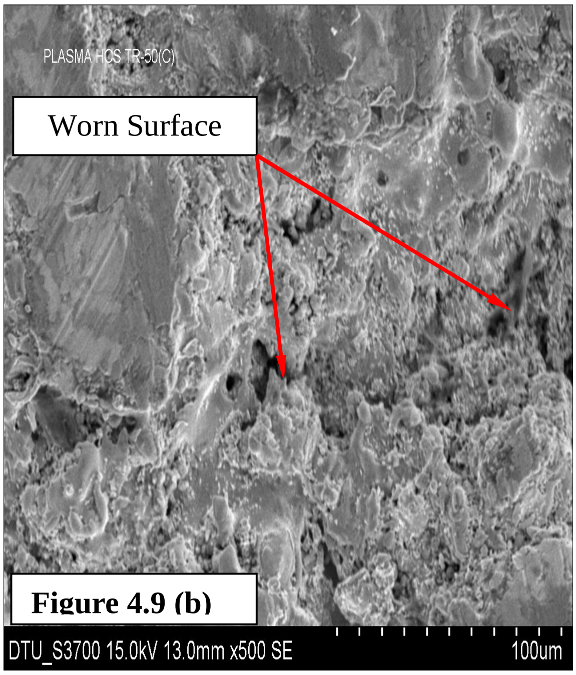

Figure 4.9 (b)

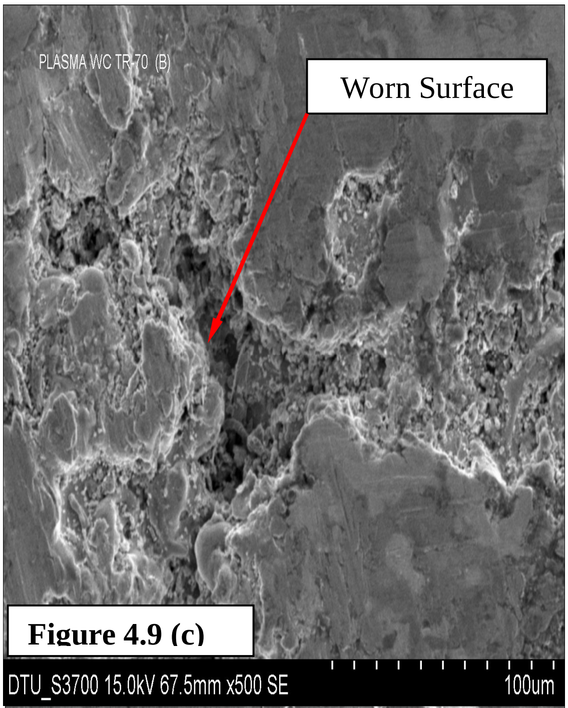

Figure 4.9 (c)

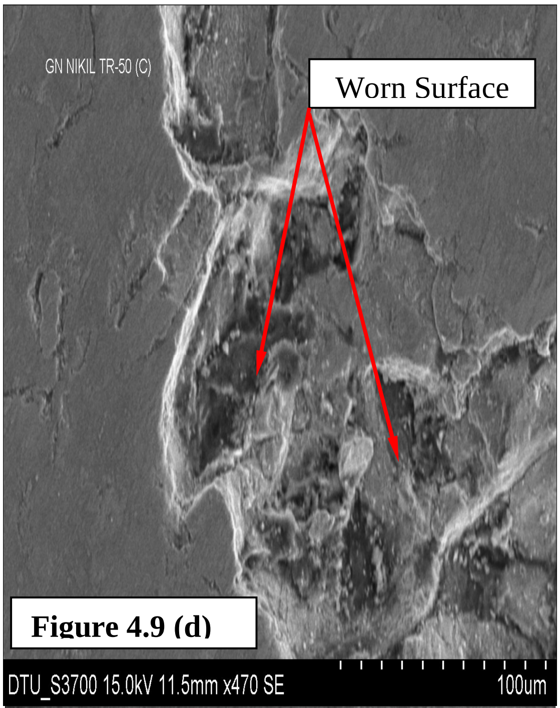

Figure 4.9 (d)

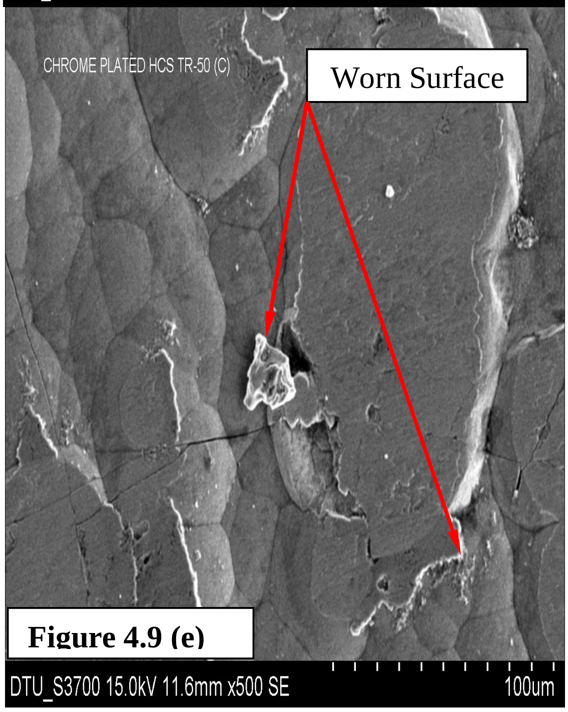

Figure 4.9 (e)

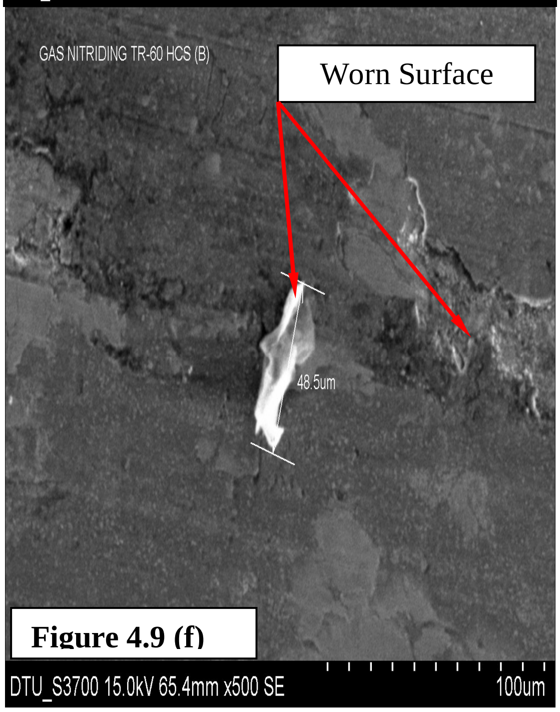

Figure 4.9 (f)

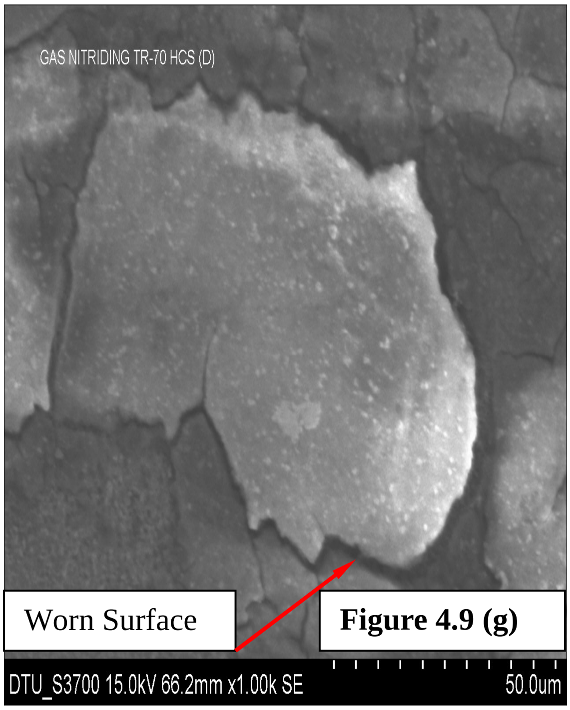

Figure 4.9 (a)Worn surface of plasma spray coating with EN-31 pin at 50N load(b) Worn surface of plasma spray coating with EN-31 at 60N laod (c) Worn Surface of Plasma Spray Coating with WC at 30N Load (d) Worn Surface of Gas nitriding with Nickel Pin at 50 N Load(e) Worn surface of Hard Chrome Plated disc with HCS at 50 N load(f) Worn Surface of gas nitriding disc with EN-31 at 40N load(g) Worn Surface of gas nitriding disc with En-31 at 50N load

The wear mechanism of the thermal spray coating with En-31 pin, at 40 N load and 500 rpm speed was analyzed and it was found that the wear mechanism was mainly due to micro cutting and abrasion (figure 45a). When the load was increased to 50 N at the same 500 rpm speed then adhesion also seems to come into picture. Due to this adhesion some deformation was also observed (figure 45b). The deformed particles get flattened over the coating surface. With an increased load 60 N and the same 500 rpm speed, long worn debris was generated. At higher loads and sliding speeds the occurrences of severe metallic wear by physical metallic failure are more dominating [4]. Due to this deformation was less and the micro cuttings were more (figure 45c). At 500 rpm and the load of 40 N with the tungsten carbide pin the wear was very less, because the pin just slides over the coating material and the adhesion was very less. The main wear mechanism was only due to erosion of the coating (figure 45d). When the load was increased to 50 N, the wear mechanism of the coating was also included adhesion wear as with the micro cutting. So there was deformation of the coating material (figure 45e). The coating at 50 N loads deformed and gets flattened over the wear track. At the 60 N loads and the same 500 rpm it was found that the adhesion was more and the coating material got more deformed and more flattened over the wear track (figure 45f).

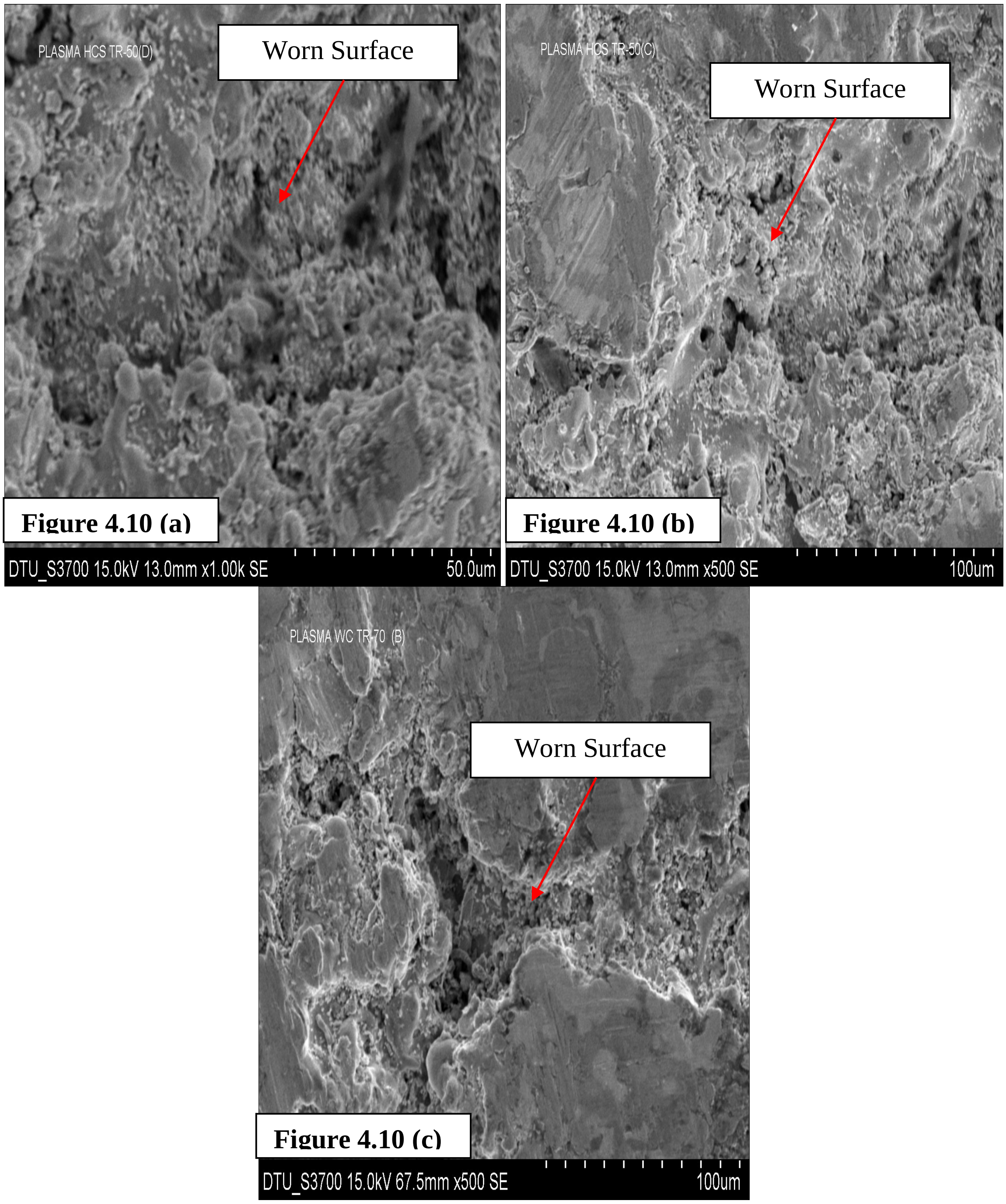

Figure 4.10 Worn surface of plasma spray coating with tungsten carbide pin, at (a) 100 X (b) 500 X (c) 1k X

The wear mechanism of the plasma sprayed coating with nickel pin was also analyzed with 500 rpm speed and 40 N load some deformation was sfound to take place (figure 46a). As the load was increased to 50 N the deformation of the worn surface was more. The worn surfaces were found to be more adhered to the coating surface hence, the wear mechanism was found in case of 50 N load mainly due to delaminating and adhesion (figure 46b). When we increased the load to 60 N over the same speed of the disc, then the adhesion of the coating over the wear track was found to be more (figure 46c). Shunyan Tao et al. [56], has also previously reported that the deformation of the coating with copper pin at high load and low speed was more.

4.4.2 Wear mechanism of chrome plating with En-31, tungsten carbide & nickel pin:

When the En-31 pin slided over the chrome coating at 500 rpm speed and 40 N load then abrasion of the coating was more and the wear debris was in the form of microchips (figure 47a). These microchips were suddenly removed over the track due to high velocity. At 50 N load and 500 rpm speed deformation was found to be more, due to high pressure exerted by the pin. The worn debris also got deposited over the wear track (figure 47b). When the wear load was further increased to 60 N, there was more deformation of the coating surfaces (figure 47c). With nickel pin the pin material got deformed and the diffusion observed was more, whereas in case of tungsten carbide pin the pin did not get deformed.

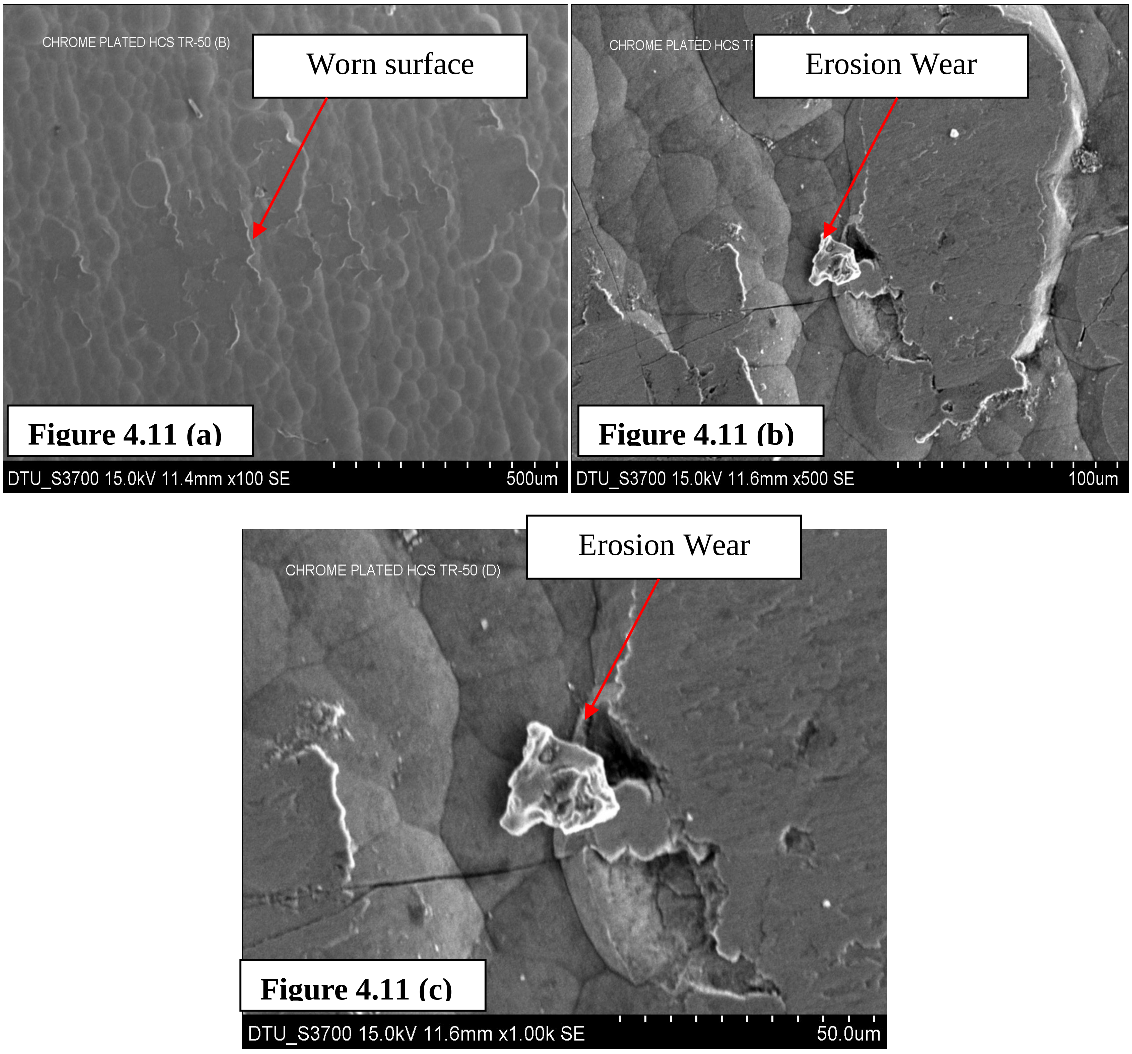

Figure 4.11 - Worn surfaces chrome plating with En-31 at 500 rpm speed and (a) 100 X (b) 500 X (c) 1000 X

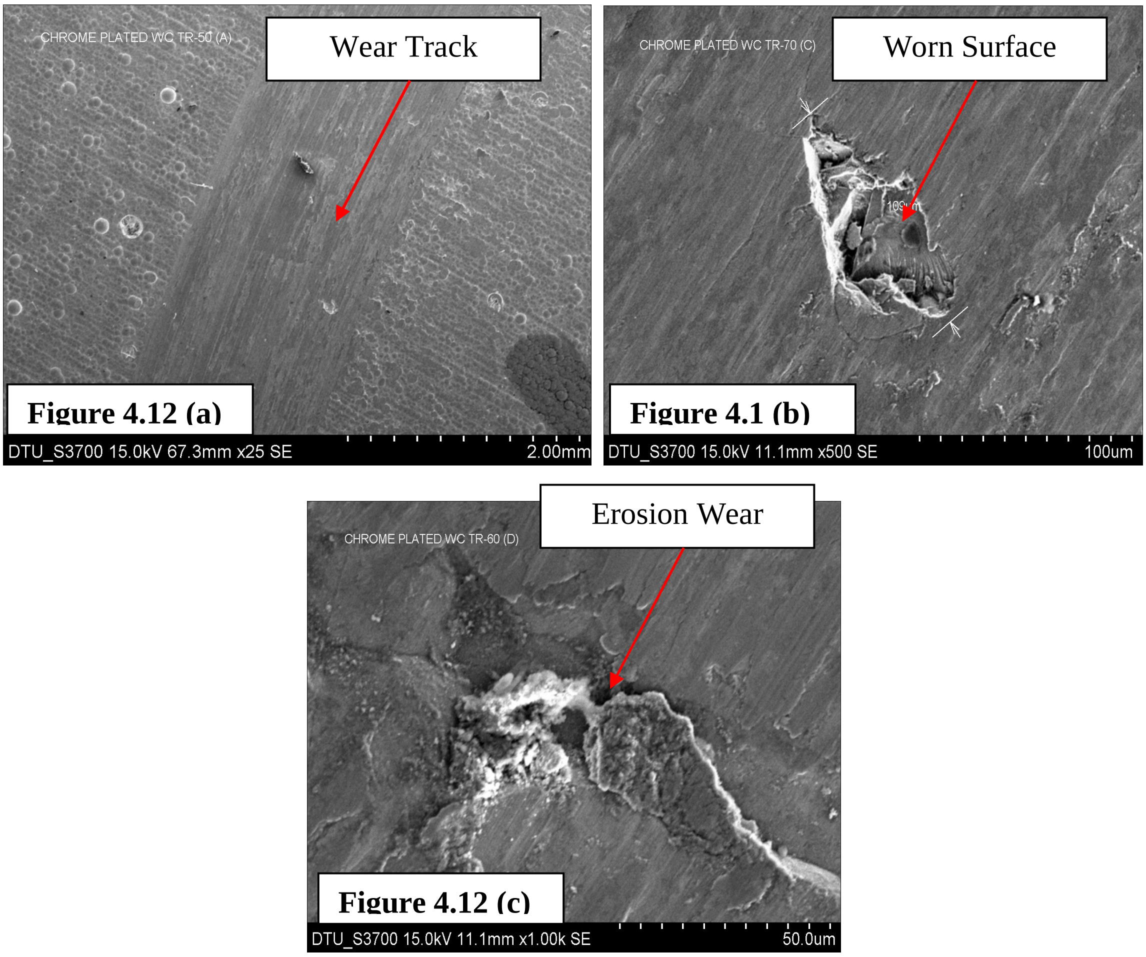

Figure 4.12 - Worn surfaces chrome plating with tungsten carbide pin at 500 rpm speed and (a) 25 X (b) 500 X (c) 1000 X

At this speed with the tungsten carbide pin the wear behaviour was not only due to abrasion but also due to deformation, the coating surfaces get deformed and adhered over the surface. At a load of 40 N load and 500 rpm with the nickel pin deformations were less and micro cutting was the major wear mechanism (figure 48a). If the load was increased to 50 N at the same speed, the deformation of the nickel pin was more (figure 48b). At 60 N loads and 500 rpm speed, the nickel & En-31 got deformed and deposited over the coating surface forming a thin layer hence the surface was found smooth (figure 48c). Slow speed caused more plastic deformation of the coating material and the abrasion of the coating was less. The wear behaviour at 500 rpm speed and a load of 40 N with En-31 was also studied and it was found that at this load, the shear of the coating was more and the coating was more deformed due to slow speed (figure 48d). When the load was further increased to 50 N over the pin then the shear observed was more and the plastic deformation of the coating was high (figure 48e). At higher load of 60 N the wear rate of the coating increased, the micro cutting of the coating was high and the deformation of the coating was less (figure 48f).

4.4.3. Wear mechanism of gas nitriding with En-31, tungsten carbide & nickel pin:

The wear mechanism of the Gas nitride plate with En-31 was analyzed at same sliding and loading condition as in the case other coatings. The wear mechanism at 500 rpm speed and nickel pin having very less deformed surfaces and the worn debris was observed in the form of micro chips (figure 49a). At the En-31 pin and at the same sliding speed, some deformation of the surfaces was observed but the main wear mechanism was due to abrasion and micro cutting, some amount of plastic deformation was also present over the wear track (figure 49b). When the tungsten carbide pin was considered at the same sliding speed, the deformation of the wear track was more and the wear was also in the form of micro cutting (figure 49c). The tungsten carbide is harder as compared to En-31 and nickel pin so the deformation of the wear track was very less and the main wear mechanism observed was micro cutting.

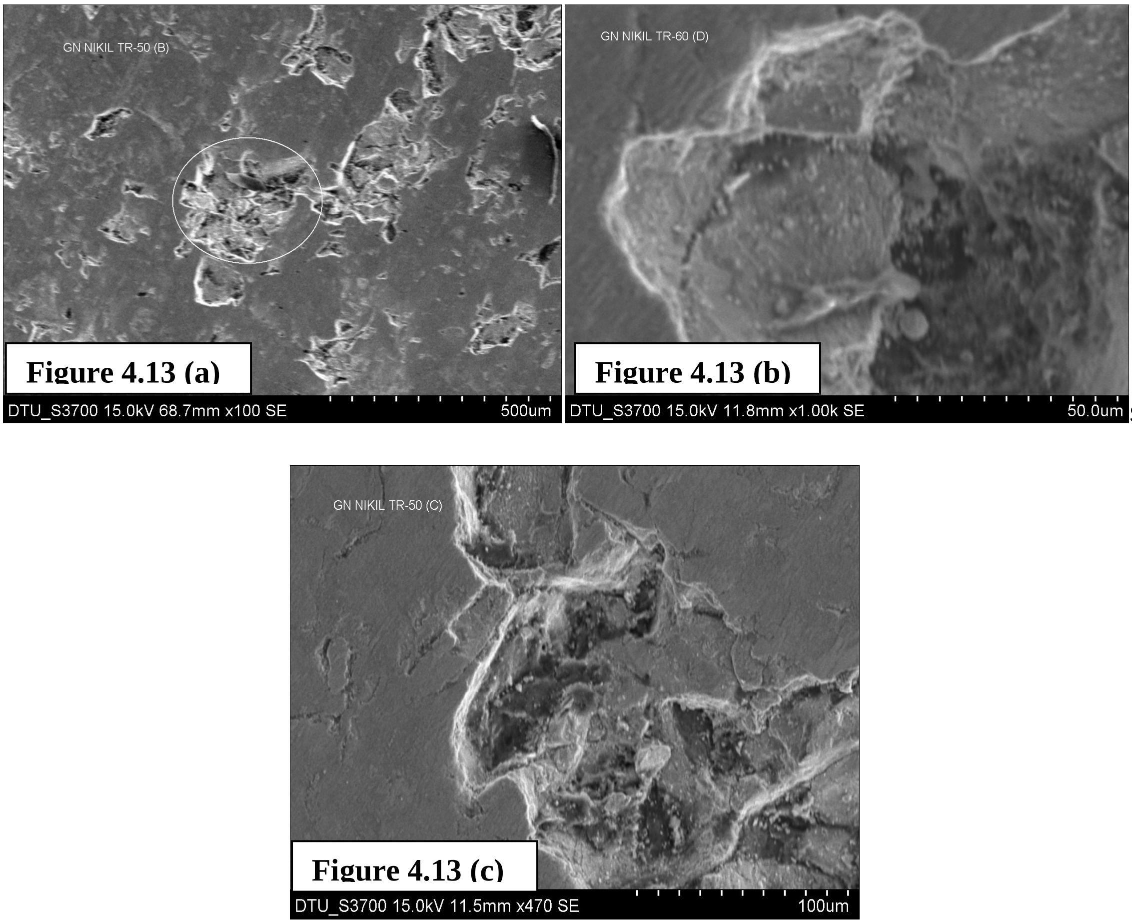

Figure 4.13 - Worn surfaces of gas nitriding with En-31 at 500 rpm speed and (a) 100 X (b) 100 X (c) 500 X

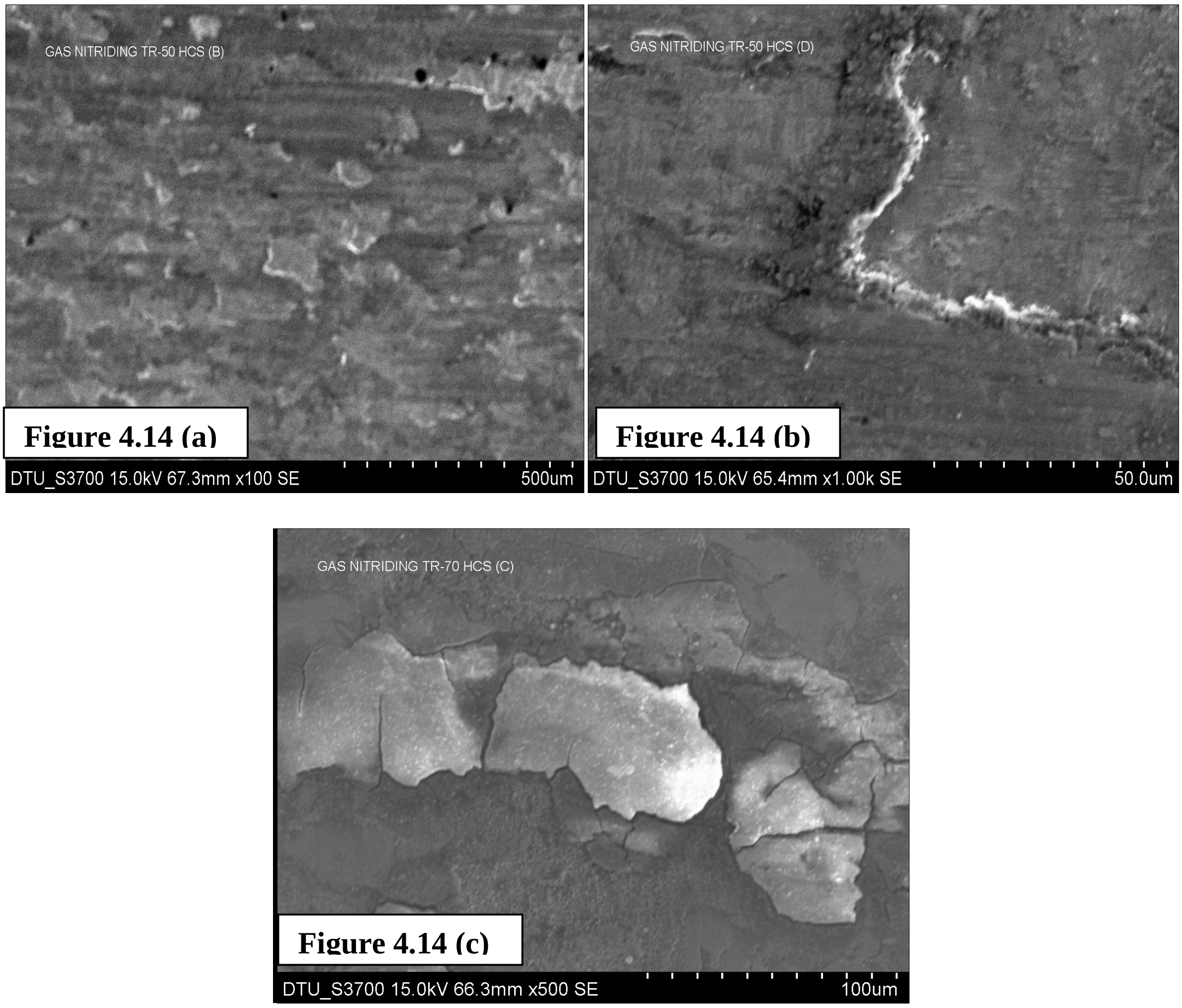

Figure 4.14 - Worn surfaces of gas nitriding with nickel at 500 rpm speed and (a) 100 X (b) 1000 X (c) 500 X

At 500 rpm speed and tungsten carbide pin the deformation was high as compared to deformation in case of En-31 & nickel at same speed (figure 50a). When the load was increased to 50 N at the same 500 rpm speed with the tungsten carbide pin the deformation as well as micro cuttings were also increased (figure 50b). At 60 N load and 500 rpm speed deformation was much higher along with the micro cutting and abrasion (figure 50c).

At 500 rpm speed and En-31 pin the deformation as well as micro cutting was less, along with less deformation of the wear track (figure 50d). At the same speed and load of 50 N the deformation of the coating was more pronounced together with the micro cutting of the coating, but less than that at tungsten carbide (figure 4.20 c).

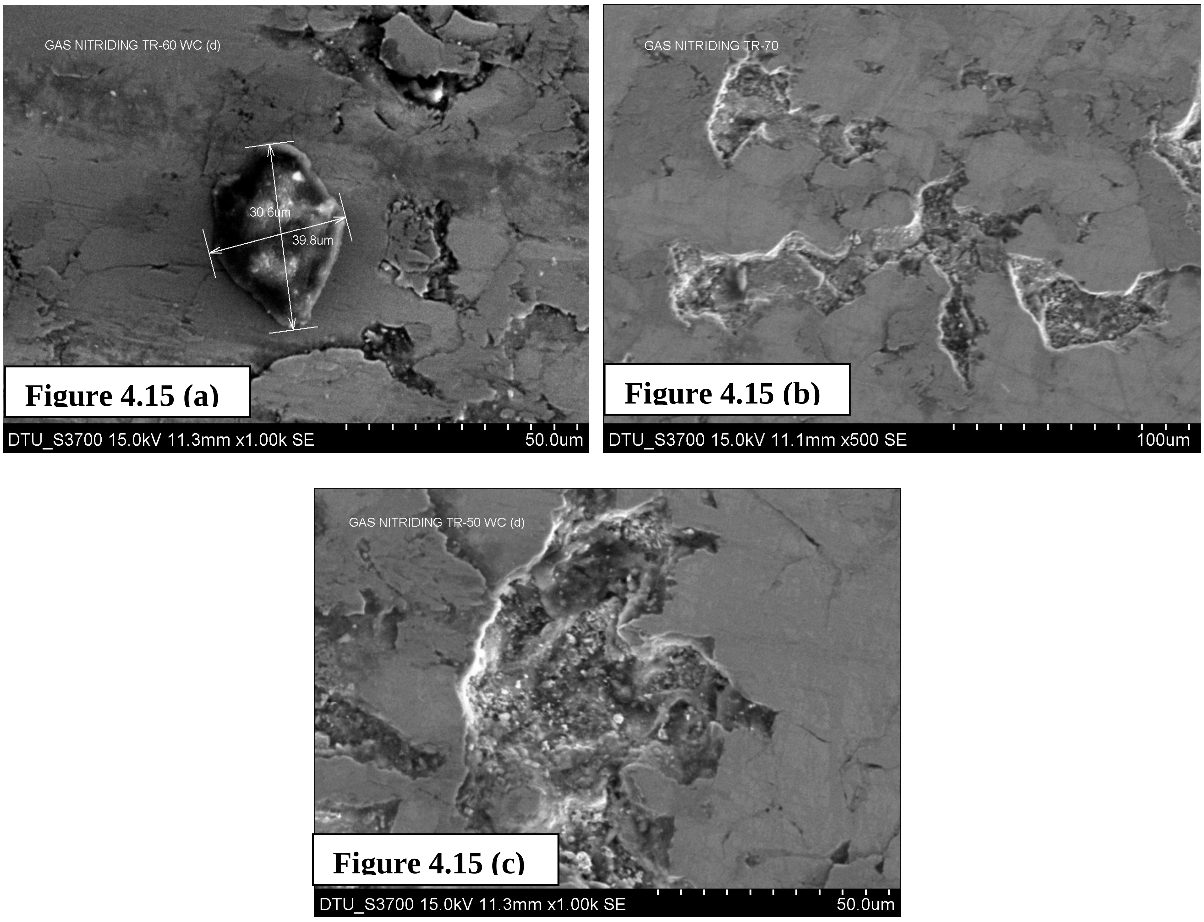

Figure 4.15- Worn surfaces of gas nitriding with tungsten carbide at 500 rpm speed and (a) 1000 X (b) 500 X (c) 1000 X

When the load was increased to 60 N, the wear track surface got more deformed along with more micro cutting and worn debris (figure 4.20 a). However, it was found that with tungsten carbide the deformation of the coating surface was more while the micro cuttings were very less.