Experimental Investigation of Friction Coefficient and Wear of sheet metals used for Automobile Chassis

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Experimental Investigation of Friction Coefficient and Wear of sheet metals used for Automobile Chassis

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Abstract: Sheet metals are used to manufacture automobile components under forming processes with good mechanical properties like hardness, strength, friction, and wear resistance. In this study, five sheet metals that are continuously used to manufacture automobile components such as SAPH440, CR2D, D HR2, Fe510, and Fe410, were used for experimental investigation of friction coefficient and wear rate of sheet metals on pin-on-disc. In experimental investigation, dry sliding test was used at constant speed of 50rpm with 6kg, 10kg, 14kg, and 18kg load. To perform the wear test D2 was used as a disc material and SAPH440, CR2D, D HR2, Fe510, and Fe410 as the pin material. Selection of sheet metals was performed based on product FMEA and Process FMEA. Overall study samples are prepared with ASTM standards, performed tensile test as well as check chemical composition of all the sample materials, and select D2 as disk materials by referring brinell hardness numbers of tool steel. After experimental investigation it was observed that SAPH440 grade material maintained maximum life of component with minimum wear compared to other sheet metals. It will directly affect the overall performance as well as life of the Automobile Chassis to manufacture component by referring specific type of sheet metal.

Keywords: Pin-on-Disc, Wear Test, FMEA (Failure mode and effect analysis)

1. Introduction

Friction is the most important parameter that can affect the performance of components because friction creates resistance between any two moving surfaces leading to the start of component wear. Friction can reduce the overall effectiveness of components and reduce the life of components due to the effects of wear. In most cases it is observed that wear could not be removed completely it has to be minimized by adding suitable additives in base materials. The tribological characteristics of material like Wear, friction coefficient, and frictional force can create an alternative solution for the selection of steel material for different types of manufacturing operations. Chowdhari and Helali experimentally investigated the frequency of vibration variation and relative humidity with the variation of wear on mild steel disc specially designed using a special tribometer testing machine as a pin on disc to vibrate disc at different frequencies.[1] Chowdhary M.A., Helalib M.M. examined the effect amplitude of vibration on coefficient of frequency for the different materials. It is observed that friction coefficient decreases with increase in amplitude of vibration within observed range.[2] The values for a wear increase and decrease in the frequency of vibration. According to Gupta et.al. 0.13 % weight percentage of carbon in plain carbon steel directly affect wear resistance and it is observed in morphology as well as microstructure at different phases of materials.[3] In the automobile industry now-a-days composite materials can perform an important role in wear resistance, durability, strength, and hardness of materials.[04] Huang et.al. Used the heat treatment process and studied the tribological properties of low carbon steel up to the plastic deformation of materials. They reported that steel 20 with the addition of oxygen content on the surface of materials by strain hardening can increase wear resistance and decrease friction coefficient.[5] Wei and Wang in dry sliding conditions for 45, 4Cr5MoSiV1 and 3Cr13 steels at 25-400°C.[6] At 25°C trace tribo-oxides formed on worn surface of 45 steel, at 200°C tribo-oxides layer reaches to 10μm for low and medium Cr steel and at 400°C great amount of tribo-oxides appeared to covered worn surface of all steels.[7] Sivkumarana and alankaram describe the importance of manganese phosphate heat treated coating in high-temperature conditions, corrosion, oxidation, and wear have to be followed loading conditions. The comparison between Cr contents in steel and oxidative wear explained in detailed.[8] Wear resistance properties are totally enhanced in medium carbon micro-alloyed bainitic steel is explained by Chattopadhyay C. et.al. [9]

Dewan MN et. al shows that copper has a lower wear rate and friction coefficient than aluminum materials at variable sliding velocity and normal load. The sliding wear mechanism of metals and alloys at elevated temperatures is affected by different wear conditions.[10)]

Amit K Gupta et.al investigated with 0.131% C, 0.246% C and 0.358% C steel in contact with EN-31 observed that wear of steel linearly related to load.[11)] M.A. Chowdhary et.al experimentally shows that, friction coefficients of gear fiber mild steel rough pair higher than that of glass fiber mild steel smooth pair.[12)] Chowdhary et. al performed an experimental investigation on friction and wear of SS304 against gunmetal, Cu, Al and brass varies with duration of rubbing load, normal load and sliding velocity. In the final result, it is concluded that with an increase in normal load, both friction coefficient and wear decreases with a decrease in normal load and sliding velocity in all sliding pairs.[13)] B. K. Roy verify that friction coefficient varies with duration of rubbing and after certain duration of rubbing, friction coefficient becomes steady for the observed range of normal load and sliding velocity.[14)]

Kapil Chawla et.al studied tribological behavior of stainless steel 304 and observed higher wear rate and frictional heating led to more severe surface damage.[15)] In internal gear maximum wear occurs in the region of tooth tip where internal gear begins to mesh with pinion teeth.[16)] Wear loss of break shoe rings raises with increasing velocity and pressure, while wear loss of wheel rings decreases with a rise of pressure.[17)] Yezhe Lyu studied environmental conditions and Iron oxides shows increase in relative humidity to 85%, clean wheel/rail contact tests at room temperature and experienced transition of wear mechanisms from adhesives to oxidative wear.[18)] M. Venkatesan et.al. Performed experimental investigation and analyze the wear properties of glass fiber and CNT reinforced hybrid polymer composites. The result shows that, increase in volume % of CNT in glass fiber reinforced polymer composites decreases the wear rate.[19)] Mastoshi Yshoda et.al verify the results of three points using stretch bending test with various punch radii on three types of aluminum sheets and found that predicted limit wall stretch as well as limit height were in good agreement. [20)]

Hanief M. et.al. Performed experimental validations of surface roughness on wear rate during running-in of EN-31 steel and experimental prove that model is adequate and wear rate strongly depends on surface roughness.[21)] J. C. Thippeswamy and N. Sathisha performed fabrication and characterization of aluminum 8011 alloy and a nano Zro2 metal matrix composites. The results showed that mechanical properties are enhanced by increasing weight percentage of nano Zro2 particles in matrix of aluminum.[22)] Renjish Vijay et.al. Analyze the wear characteristics using finite element method of Zirconia coated aluminum 6061 alloy. The archard wear model numerically evaluated in ANSYS and observed that contact pressure, friction stress create effect on aluminum alloy 6061.[23)] Rajesh Godse et.al. Checked the tribological behavior of high fraction carbon steel alloys and observed that, wear rate increases with the increase in normal load.[24)] B. Prakash performed investigation on multiwall carbon nanotubes reinforced composites by powder metallurgy route using scanning electron microscope. 1.5 wt% of multiwall carbon nanotubes in Al6061 alloy offered better mechanical properties compared to Al6061alloy and 1.5wt% reinforced Al6061 composites.[25)] Chetan Kulkarni et.al performed experimental and FEM analysis on the mechanical properties of Al-8011 Alloy Reinforced with Fly-Ash and E-Glass Fibers. Maximum tensile and composites strength is observed for Al-8011+6% fly ash+5% + E-glass fiber composites.[26)] Aiman Y. studied the friction characteristics of flat surface embedded with micro pit using two types of lubricants. In experimental results it is observed that RBD palm oil can minimize friction much lower than SAE40 engine oil. [27)] Shashi Dwivedi and Manish Maurya investigated Mechanical, Physical and thermal behavior of SiC and MgO aluminum based composite material and found that addition of preheated SiCand MgO lead to increase tensile strength and hardness.[28)] Norfazillah Talib et.al. Studied tribological activated carbon Nano particle in nonedible Nano fluid for machining application and conducted test on four ball tester. Experimentally analyze that, lowest coefficient of friction mean wear scar diameter produced the smoother surface with low surface roughness value.[29)] Ashishkumar Shrivastava and Manish Maurya performed statistical optimization of response surface methodology of processes parameters during CNC turning operation of hybride metal matrix composites.CNC lathe provides better surface finishing but at high tool wear.[30)] Mohamed Egiza et.al. Checked the Si and Cr doping effect on growth and mechanical properties of ultra-Nano crystalline diamond/ amorphous carbon composite films deposited on cemented carbide substrates by coaxial arc plasma deposition. They found that doping of Si and Cr for deposition of UNCD/a-C films deposited on WC-Co by CAPD is not effective for the improvement of hardness and modulus. [31)]

Mario Dib et.al. Take a new machine learning perspective to choose best model for defect prediction of sheet metal forming processes. In the results it is conclude that learning algorithm scores differently depending upon type of defect and conditions of experiments. [32)]Devraj M.R. et.al study on wear behavior and Mechanical properties of ferrous based chilled castings. Investigators made an attempt to induce carbon atoms on surface of test specimen by surface heat treatment process foe better wear performance.[33)] Rajan Kumar et.al performed wear behavior analysis of medium carbon high silicon alloy steel at different process parameters. Design dual wear tribometer has been designed and developed which is perpendicular to each other of two identical disc are rolling contact thereby resulting in symmetrical interaction of one point to another point.[34] Abdelwaeb Zeidi et.al analyze the damaged of AISI D2 punch head whose main part is used halting production. Final results can be shows that, back up plate wear and fatigue, low toughness of AISI D2 steel, poor heat treatment as well as non-optimize punch-gun drill clearance are main causes for tool premature damage.[35]

Till now automobile components such as SAPH440, CR2D, DHR2, Fe510, and Fe410 were not experimentally investigated for friction coefficient and wear rate using pin-on-disc. The main objective of this experimental investigation is to select the best material to manufacture the parts with minimum wear and maximum life of the part.

2. Sample Preparation

Fig.1: Sample materials

As stated above pins are to be prepared with a Lathe machine having standard dimension diameters of 10 mm and 30 mm in length. Images of samples are shown in Fig. No.1. As per the standards of the American society for testing and material (ASTM G99) norms samples are prepared under a surface grinder to maintain the appropriate surface finish, microstructure, processing treatments, and composition.

2.1 Chemical Composition of Materials

Chemical composition checked percentage of base material and alloy elements to identify type and grade of material easily. The chemical composition of all pin materials is tested under ASTM E415-17at Physi Chem Material Testing Laboratory Nashik.

Table 1. Chemical Composition of SAPH440, Fe410, Fe510, CR2-D, DHR2 pin materials

Contents	Fe 510	Fe 410	D HR2	CR2-D	SAPH 440 (CF)
C	0.12	0.15	0.062	0.064	0.077
Mn	0.96	1.12	0.27	0.33	0.6
Si	0.012	--	--	--	0.12
S	0.009	0.012	0.01	0.011	0.01
P	0.014	0.017	0.015	0.019	0.014
Cr	--	--	--	--	0.024
Ni	--	--	--	--	0.022
M	--	--	--	--	<0.0047
Co	--	--	--	--	<0.0055
N	--	--	--	--	<0.0047
Al	--	--	--	--	0.048
V	--	--	--	--	0.036
Nu	--	--	--	--	<0.0010
Ti	--	--	--	--	0.0011
CE Value	--	--	--	--	0.18

2.2 Tensile Test

Mechanical properties of materials can show the yield stress, ultimate tensile load, ultimate tensile strength, and percentage of elongation. All sample materials are to be tested under IS 1608(Part 1) 2018 standards method. A disk can be manufactured with hardened tool steel as a D2 with Brinell hardness. Overall experiments follow track diameter as 100mm and 1mm steps at each sample. All samples are to be tested at a constant disc speed of 50 rpm.

Table 2. Mechanical Properties of Sheet Metal Samples

Materials	Fe 510	Fe 410	D HR2	CR2-D	SAPH 440 (CF)
Thickness (mm)	3.16	4.96	3.96	1.48	3.19
Width (mm)	20	20	20	20.1	20
Area (mm^2)	63.2	99.2	79.2	29.75	63.8
Orignal Gauge Length (mm)	45	56	50	80	45
Final GL (mm)	57.55	7.75	71.05	113.45	62.2
Yield load (kN)	26	33.4	24	6.55	23.25
Yield Stress (MPa)	411.39	336.69	303.03	220.8	364.42
Ultimate Tensile Load (kN)	33.55	44.5	31.45	10.1	29
UTS (MPa)	530.85	448.59	397.1	339.52	454.55
% Elongation	27.89	38.84	42.1	41.81	38.22
Fracture	W.G.L	W.G.L	W.G.L	W.G.L	W.G.L

3. Experimental Results

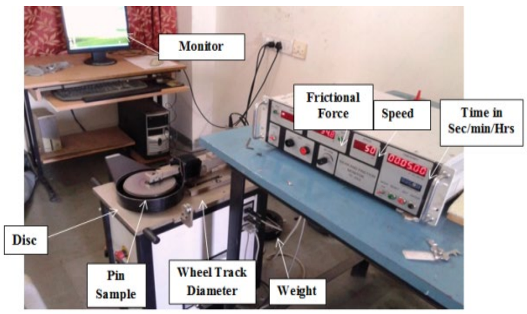

Fig.2: Experimental setup of Pin on Disc machine

Experimental results are obtained with the help of a pin-on-disc machine. Frictional force, Wear, and coefficient of friction for SAPH440, Fe410, Fe510, CR2-D, and DHR2 material at different loading conditions such as 6kg, 10kg, 14kg, and 18 kg at constant 1.5 m/s sliding velocities was calculated.

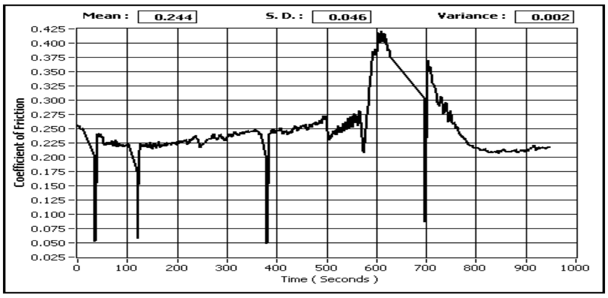

Fig.3: Coefficient of friction and time for SAPH440 at 6kg

In pin on disc machine performed experimental procedure for coefficient of friction and resulted values are note down from 0 to 900sec with used of graphical representation. Initially the rubbing value of the coefficient of friction is 0.250 and it will slowly increases up to 0.420 at 600 sec. and then again it is reduced to 0.210 after 900 sec it is still constant.

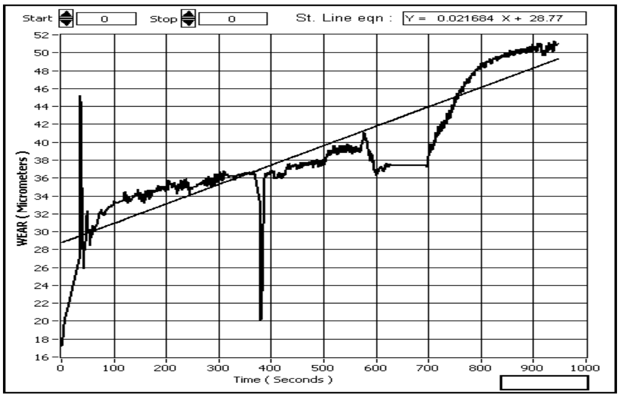

Fig. 4: Wear and time for SAPH440 at 6kg

In the above figure, 4 is seen initially at rubbing wear rate starting from 16 micrometers and it is increasing gradually up to 44 micrometers at 40 sec. and then again it is continually increasing up to 50 micrometers at 900 sec.

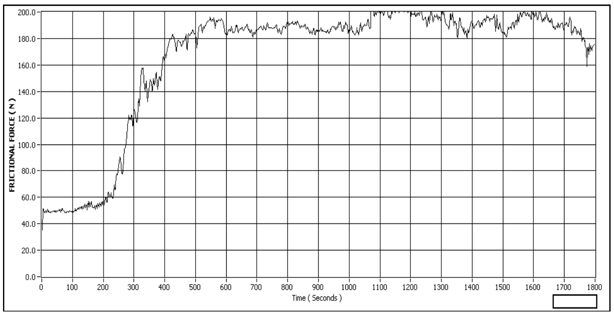

Fig.5: Friction Force and time for SAPH440 at 6kg

In the above figure 5 seen that initially at rubbing frictional force is 36 N and it is increasing gradually up to 195 N at 550 sec. and then again it shows a small variation up to 1700 sec. after 1700 sec frictional force starts to decrease. The above procedure continues for the remaining samples and results are compared with each other.

Table 3. Coefficient of friction for steels with different loading conditions

Materials	**6kg**	**10kg**	**14kg**	**18kg**
SAPH 440	0.420	0.430	0.465	0.538
Fe410	0.425	0.454	0.525	0.595
CR2-D	0.625	0.755	0.85	0.955
Fe510	0.445	0.525	0.695	0.765
D HR2	0.515	0.665	0.715	0.805

In the above Table coefficient of friction of SAPH440, Fe410, Fe510, CR2-D, and DHR2 materials are summarized at different loading conditions such as 6kg, 10kg, 14kg, and 18 kg respectively.

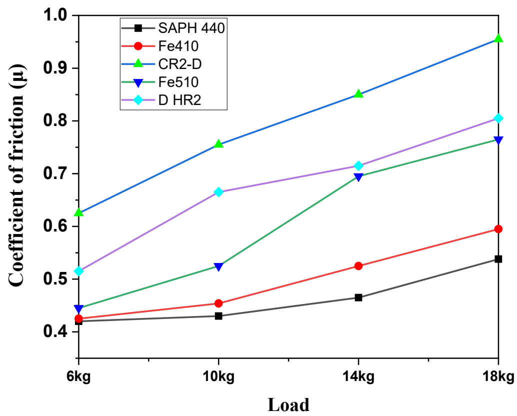

Fig.6: Friction coefficient and Load

Table No. 4. Wear at different loading conditions

Materials	6kg	10kg	14kg	18kg
SAPH 440	51	53	-56	70
Fe410	95	182	234	305
CR2-D	180	295	357	485
Fe510	135	202	247	367
D HR2	147	236	278	407

Table No. 4 indicates that, Wear in micrometers of SAPH440, Fe410, Fe510, CR2-D, DHR2 material, and different loading conditions such as 6kg, 10kg,14kg, and 18kg.

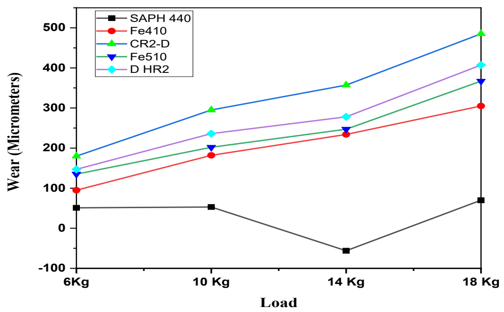

Fig.7: Wear and Load

From the above figure 7, it is observed that the wear behavior of SAPH440, Fe410, Fe510, CR2-D, and DHR2 material is varied for all materials. SAPH440 shows maximum wear of 51 Micrometers at 6kg and 70 micrometers at 18kg. At 14kg load SAPH 440 represents negative wear because of wear particle entrapped in between pin and disc and shows negative wear as -56. In Figure 4 it is noted that material CR2D has a higher wear as compared to SAPH440, Fe410, Fe510, and DHR2 materials are 180 micrometers at 6kg and 485 micrometers at 18kg.

Table 5. Wear at 6kg load on Variation of time

Time	SAPH 440	Fe410	CR2-D	D HR2	Fe510
100	33	36	51	43	38
200	35	38	62	56	42
300	36	40	87	59	58
400	36	45	114	68	65
500	38	55	134	76	71
600	36	62	136	82	72
700	37	78	143	95	86
800	48	95	163	103	97
900	51	94	180	147	115

The above table indicates the Wear of SAPH440, Fe410, Fe510, CR2-D, and DHR2 material with different time intervals from 100 to 900 sec for a 6kg load.

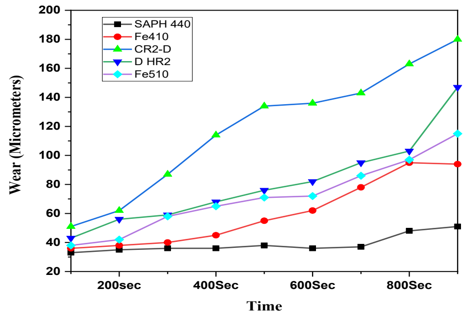

Fig.8: Wear and time for SAPH440, Fe410, Fe510, CR2-D, DHR2 material at 6kg

Figure 8 represents the wear of SAPH440, Fe410, Fe510, CR2-D, and DHR2 materials at a 6 kg load and a time duration of 100 sec. to 900 sec. Figure 8 understood that wear can be an increase from 33 to 51, 36 to 94, 51 to 180, 43 to 147, and 38 to 115 micrometers for SAPH440, Fe410, CR2D, DHR2, and Fe510 respectively from the time duration of 100 sec to 900 sec. At 6 kg load, CR2D possesses a higher wear as compared to SAPH440.

Table 6. Wear at 10kg load at different time intervals

Time	SAPH 440	Fe410	CR2-D	D HR2	Fe510
100	36	39	87	52	46
200	36	42	107	78	68
300	38	54	134	85	77
400	36	96	146	104	89
500	37	110	198	123	114
600	48	123	230	151	151
700	51	151	244	184	178
800	51	182	270	222	187
900	53	190	295	236	202

The above table indicates the wear of SAPH440, Fe410, Fe510, CR2-D, and DHR2 material with different time intervals from 100 to 900 sec. for a 10kg load.

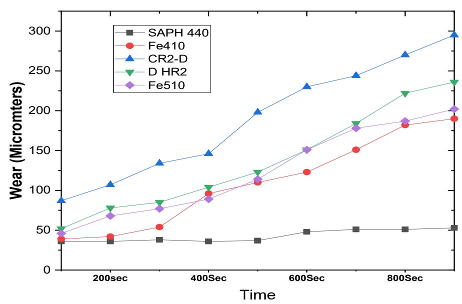

Fig.9: Wear and time for SAPH440, Fe410, Fe510, CR2-D, DHR2 material at 10kg

Figure 9 represents the rate of wear and time interval SAPH440, Fe410, Fe510, CR2-D, and DHR2 materials for a 10kg load at different time intervals. From the figure 6, it is understood that wear can be an increase from 36 to 53, 39 to 190, 87 to 295, 52 to 236, and 46 to 202 micrometers for SAPH440, Fe410, CR2D, DHR2, and Fe510 respectively, with an increase in time from 100 to 900 sec, CR2D and DHR2 possess higher wear 295, 236 as compared to SAPH440.

Table 7. Wear at 14kg load at different time intervals

Time	SAPH 440	Fe410	CR2-D	D HR2	Fe510
100	38	54	96	75	62
200	42	79	134	96	93
300	56	92	174	112	126
400	75	106	227	137	173
500	-25	129	255	162	187
600	-36	168	286	166	203
700	-56	195	290	205	213
800	-55	205	321	225	233
900	-56	234	357	278	247

The above table indicates the wear of SAPH440, Fe410, Fe510, CR2-D, and DHR2 material with different time intervals from 100 to 900 sec. for a 14kg load.

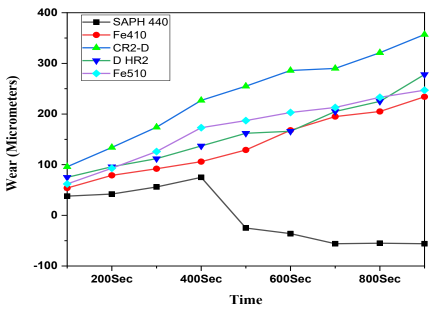

Fig.10: Wear and time for SAPH440, Fe410, Fe510, CR2-D, DHR2 material at 14kg

Figure 10 represents a wear for SAPH440, Fe410, Fe510, CR2-D, and DHR2 materials for a 14 kg load at time intervals. From the figure it is understood that wear can be an increase from 38 to -56, 54 to 234, 96 to 357, 75 to 278, and 62 to 247 micrometers for SAPH440, Fe410, CR2D, DHR2, and Fe510 respectively, with an increase in time from 100 to 900 sec. CR2D possesses a higher wear as compared to SAPH440 because SAPH440 shows a negative trend of wear because of wear particle entrapped in between pin and disc. It is also noted that for SAPH 440 with increasing time wear has been decreasing.

Table 8. Wear at 18kg load at different time intervals

Time	SAPH 440	Fe410	CR2-D	D HR2	Fe510
100	44	76	135	108	86
200	58	84	190	128	121
300	62	98	176	176	149
400	15	128	212	214	168
500	35	152	264	267	210
600	48	215	317	296	242
700	64	274	378	327	287
800	69	290	412	373	338
900	70	305	485	407	367

The above table indicates the wear of SAPH440, Fe410, Fe510, CR2-D, and DHR2 material with different time intervals from 100 to 900 sec. for an 18kg load.

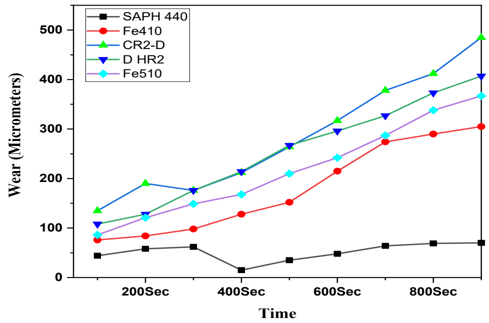

Fig.11: Wear and time for SAPH440, Fe410, Fe510, CR2-D, DHR2 material at 18kg

Figure 11 represents a wear for SAPH440, Fe410, Fe510, CR2-D, and DHR2 of selected materials for a 6kg load at different time intervals. From the figure it is understood that wear can be an increase from 44 to 70, 76 to 305, 135 to 485, 108 to 407, and 86 to 367 micrometers for SAPH440, Fe410, CR2D, DHR2, and Fe510 respectively, with an increase in time from 100 to 900 sec, CR2D and D2HR possess higher wear as compared to SAPH440 and other materials.

Table 9.Wear and Chemical content on different materials

Materials	Wear (Micrometers)	% of Carbon
D HR2	407	0.062
CR2-D	485	0.064
SAPH 440	70	0.077
Fe510	367	0.12
Fe410	305	0.15

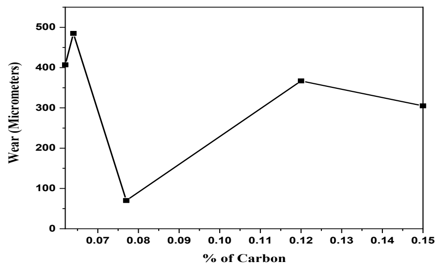

Fig.12: Variation of Wear and % of carbon content for DHR2, CR2-D, SAPH440, Fe510, and Fe410 material[11)]

The figure 12 can illustrate varying wt. %of carbon in different materials shows different Wears. In above diagram represents 0.077 % of carbon in SAPH 440 shows the minimum wear because other alloying elements improve ultimate tensile strength and reduce the percentage of elongation. Whereas Fe410 and Fe510 with 0.15% and 0.12% carbon content shows wear up to 305 micrometers at 18kg load.

Amit K Gupta et.al also investigated with 0.131% C, 0.246% C and 0.358% C steel in contact with EN-31 observed that wear of steel linearly related to load.[11)]

4. Conclusions

In this paper frictional force, coefficient of friction, and Wear were experimentally investigated and the results of each sample were compared with each other. Following are the conclusion written from the experimental investigation.

1. The coefficient of friction increases with an increase in normal load from 6 kg to 18 kg for all the samples.
2. For Fe510. Fe410, CR2D, and DHR2 wear rapidly increases as compared to SAPH440 from 6kg to 18kg.
3. Whenever load increases then an actual area of contact between pin and sliding surface also increases which can directly affect frictional force between two sliding surfaces.
4. For material CR2D shows a higher wear at 6kg to 18kg load as compared to other materials and SAPH440. SAPH440 shows that very slow Wear. The SAPH 440 shows negative wear at 14kg load from 500 sec to 900sec because of entrapment of wear debris or particle between disc and pin.
5. Wear performance is also affected significantly because of carbon content and other alloying elements in SAPH440 Material.

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