Dry Wear Behavior of Heat Treated Eutectic Al-Si Alloy

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Abstract: A Eutectic Al-Si alloy (A413) was reinforced with varied percentage of intermetallic particles like Al_3Ti, AlB_2, TiB_2 and Al_4Sr particles by stir casting using graphite moulds. They were heat treated in induction furnace. The Pin-on-Disc apparatus was used to study Wear behavior at different sliding speeds, pressures, sliding distance and heat treatment. Heat treatment resulted in further improvement in wear resistance. It is concluded that the intermetallic particles influences on wear rate. The higher temperature reveals the wear resistance due to the glaze formation that offers a protection and avoids further wear. Due to combined reinforced alloys to A413 alloy has resulted in minimum weight loss when compared to the individual addition Al_3Ti, AlB_2, TiB_2 and Al_4Sr reinforced intermetallic alloys and in heat treated conditions.

Key words: Composites, Eutectic Alloy, Wear behavior, Heat treatment.

I. INTRODUCTION

Since the early dawn of civilization, the strong and light material has always fascinated mankind for typical applications. An aluminium casting has low strength and hardness and poor machinability [1-6]. With alloying elements like silicon, magnesium and to a lesser extent copper, titanium, boron and strontium improve the properties [4-5]. Silicon is an important addition to aluminium because of its excellent characteristics and these are high strength to weight ratio, excellent castability, pressure tightness, and low co-efficient of thermal expansion, good thermal conductivity, good mechanical properties and corrosion resistance [6-12]. Minor additions of titanium, boron and are normally used for grain refinement and strontium is used for the modification of eutectic silicon [12-18]. Eutectic alloys (A413) [10-13% silicon] are used for pistons, cylinders, blocks and heads of IC engines in automobile and aeronautical industries [18-27].

There is limited study concerning the heat treated sliding wear properties of Al–Si alloys reinforced with Al– Al3Ti, Al–AlB2, Al–TiB2 and Al–Al4Sr intermetallic particles. The latter are mostly used for automobile components like piston and cylinder blocks which operate in general at higher temperatures. It was understood that it is difficult to make a quantitative comparison of the literature data since the wear rate and friction coefficient strongly depends on the test methods, test environment, testing variables, composite manufacturing route and the reinforcement volume fraction, size and hardness [28–31].
In this work to achieve additional improvements in wear resistance, the intermetallic particles of Al_3Ti, TiB_2, AlB_2 and Al_4Sr were added to A413alloy, and sliding wear tests were carried out under dry sliding conditions at room temperature with heat treated.

II. EXPERIMENTAL

The alloy selected for the study is Eutectic Al-Si alloy (A413). The optimized compositions of alloys specimens are prepared for the test is as shown in Table 1. These composite have been studied for their dry wear behavior at room temperature. Melting was carried out in an induction furnace with a graphite crucible held at a temperature of 720 ^{0}C. After degassing with solid hexachlorothane (C_2Cl_6), reinforced optimized intermetallic particle alloy chips (Al-5%Al_3Ti, Al-3%AlB_2, Al-3%TiB_2 and Al-10%Al_4Sr) were added to the melt for grain reinforcement. The melt was stirred for 30s after adding the grain refiner, held for 5 min and poured into preheated graphite mould to obtain the casting diameter of 12.5 mm and height 125 mm. The cast bars were further heat treated in muffle furnace for 120 minutes at 50 ^{0}C and natural cooling was done. The cast bars were turned into 10 mm diameter and 40 mm length for wear test.

Table 1. The optimized compositions of A413 alloy

Sl. No.	Alloy no.	Alloy Composition	Melt holding time (min)
1	A	A413	0*
2	B	A413+0.27% (Al-5%Al_3Ti)	5
3	C	A413+0.6% (Al-3%AlB_2)	5
4	D	A413+0.55% (Al-3%TiB_2)	5
5	E	A413 +0.3% (Al-10%Al_4Sr)	5
6	F	A413+0.55% (Al-3%TiB_2) + 0.3%(Al-10%Al_4Sr)	5

* "0" means No holding time

The experiments were conducted according to a factorial design, W. E. Duckworth, Statistical Techniques in Technological Research; Aid to Research Productivity, Methuen, London, 1968. The experimental parameters are referred to as factors and different chosen values of each parameter are referred to as different levels of that factor. The experiments are carried out in such a way that no two experiments are identical in one set. However, the whole set is replicated to evaluate the errors involved in the measurements. The factors chosen for study are 6 samples i.e. intermetallic content, bearing pressure (3 levels), speed (3 levels) & sliding distance (3 levels) as shown in Table 2. The following are the different levels for each of the experimental parameter.

Table2. Experimental parameters

1	Intermetalic content (wt.%)	A B C D E F	A413 A413+0.275%(Al-5%Al_3Ti) A413+0.6%(Al-3%AlB_2) A413+0.55%(Al-3%TiB_2) A413+0.3%(Al-10%Al_4Sr) A413+0.55%(Al-3%TiB_2)+0.3%(Al-10%Al_4Sr)
2	Load in Kgs Load in N Pressure N/mm^2 (d is 10 mm)		2 4 and 6 19.62 39.24 and 58.86 0.2497 0.4994 and 0.7491
3	Speed in rpm Sliding Speed in m/ s		200 400 and 600 0.942 1.884 and 2.827
4	Sliding time in min Sliding distance in m		5 5 5 282.74 565.48 and 848.23
5	Heat treatment		50 ^{0}c & natural cooling.

III. RESULTS & DISCUSSIONS

a. SLIDING WEAR BEHAVIOR OF AL-SI ALLOY (A413 ALLOY)

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. In the present work the effect of Al-Ti-B grain refiner and Al-Sr modifier on the wear behavior of eutectic Al-Si alloy have been studied with various process parameter, in addition an attempt has been made to throw some light on the mechanism of Al-Si alloys before and after the wear studies. Sliding wear tests were carried out using Pin-on-Disc (Ducom TR-20-PHM-400) type wear testing machine, with a large number of variables. Which affect the wear mechanism and wear rate.

b. EFFECT OF LOAD

The effect of grain reinforcement on weight loss of A413 alloy under different load with constant sliding speed and at constant sliding distance. The effect of load on volumetric wear of A413 alloy under constant sliding speed (0.942, 1.884 and 2.827 m/sec) and at constant sliding distance (282.74, 565.48, and 848.23 m). From figures it is clear that the weight loss of A413 alloy increases with increase in load in all the cases studied and the wear was higher in case of untreated A413 alloy, i.e. addition of intermetallic alloys show less volumetric wear as compared to the absence of grain refiner. It is clear from the Table 3 & figure 1, A413 (A1) of load v/s wear rate for 200 rpm shows that the wear rate of ($6.5431x10^{-6}$ g/m) at load 20 N, as the load increases then the wear rate also increases to ($25.4650x10^{-6}$ g/m) at load 60 N as they do not have intermetallic particles and wear tends to increase. A413+5%Al_3Ti (B1), A413+3%AlB_2 (C1), A413+10%Al4Sr (E1) of load v/s wear rate for 200 rpm which shows that the wear rate decreases slightly as load increases by adding the intermetallic particles. A413+3%TiB_2+10%Al_4Sr (F1) of load v/s wear rate for 200 rpm which as minimum wear rate of ($1.7684x10^{-6}$ g/m) at load 40 N shows the remarkable trend with increasing load. From Table 2 & figure 2, A413+3%TiB_2 (D1) of load v/s wear rate for 400 rpm shows the maximum wear rate of ($6.3662x10^{-6}$ g/m) at load 60 N, by adding intermetallic particles wear tends to be more. A413+5%Al_3Ti (B1), A413+3%TiB_2+10%Al_4Sr (F1), of load v/s wear rate for 400 rpm which shows that wear rate decreases slightly as load increases. A413+3%TiB_2+10%Al_4Sr (F1) of

Table 3. Wear test data at Constant Sliding speed (v) = 0.942 m/s, Track diameter 90mm, Time 5min and Pin diameter 10 mm.

Sl. NO	Alloy composition	Load (N)	Wt. loss in (g) for Heat treated at 50 ^{0}C			
			Alloy No.	Speed 200 rpm , Sliding distance (L) = 282.74 m	Speed 400 rpm, Sliding distance (L) = 565.48 m	Speed 600 rpm, Sliding distance (L) = 848.23 m
1	A413	19.62	A1	0.0018	0.0015	0.0021
2	A413+0.275%(Al-5Ti)		B1	0.0026	0.0016	0.0019
3	A413+0.6%(Al-3%AlB_2)		C1	0.0015	0.0017	0.0016
4	A413+0.55%(Al-3%TiB_2)		D1	0.0008	0.0016	0.0027
5	A413+0.3%(Al-10% Al_4Sr)		E1	0.0019	0.0015	0.0033
6	A413+0.55%(Al-3%TiB_2) + 0.3%(Al-10%Al_4Sr)		F1	0.0006	0.0013	0.0029
1	A413	39.24	A1	0.0035	0.0017	0.0044
2	A413+0.275%(Al-5Ti)		B1	0.0012	0.0010	0.0017
3	A413+0.6%(Al-3%AlB_2)		C1	0.0010	0.0028	0.0018
4	A413+0.55%(Al-3%TiB_2)		D1	0.0009	0.0023	0.0035
5	A413+0.3%(Al-10% Al_4Sr)		E1	0.0008	0.0020	0.0037
6	A413+0.55%(Al-3%TiB_2) + 0.3%(Al-10%Al_4Sr)		F1	0.0005	0.0009	0.003
1	A413	58.86	A1	0.0070	0.0019	0.0033
2	A413+0.275%(Al-5Ti)		B1	0.0014	0.0026	0.0021
3	A413+0.6%(Al-3%AlB_2)		C1	0.0010	0.0024	0.0022
4	A413+0.55%(Al-3%TiB_2)		D1	0.0020	0.0036	0.0038
5	A413+0.3%(Al-10% Al_4Sr)		E1	0.0016	0.0016	0.0039
6	A413+0.55%(Al-3%TiB_2) + 0.3%(Al-10%Al_4Sr)		F1	0.0009	0.0017	0.0042

load v/s wear rate for 400 rpm which has minimum wear rate of ($1.6799x10^{-6}$ g/m) at load 40 N shows the remarkable trend with increasing load. From Table 3 & figure 3, A413 (A1) of load v/s wear rate for 600 rpm shows the maximum wear rate of ($5.2462x10^{-6}$ g/m) at load 40 N, they do not have intermetallic particles and wear tends to be more. A413+5%Al_3Ti (B1) of load v/s wear rate for 600 rpm shows that wear rate decreases slightly as load increases. A413+3%AlB_2 (C1) of load v/s wear rate for 600 rpm which as the minimum wear rate of ($1.9452x10^{-6}$ g/m) at load 20 N, shows the remarkable trend with increasing load. That the higher temperature reveals the wear resistance due to the glaze formation that offers a protection and avoids further wear. Also due to combined addition of reinforced alloys to A413 alloy has resulted in minimum weight loss when compared to the individual addition (Al-5%Al_3Ti, Al-3%AlB_2, Al-3%TiB_2 and Al-10%Al_4Sr reinforced intermetallic alloys) and in an treated condition.

c. EFFECT OF SLIDING SPEED

The effects of sliding speed on the wear rate of A413 alloy under constant normal pressure (0.2497 N/mm^2). From the figures it is clear that the wear rate of A413 alloy decreases with increase in sliding speeds (0.942, 1.884 and 2.827 m/s) and temperature for all the cases studied. From Tables 3 & 4, figure 4, A413+5%Al_3Ti (B1) of sliding Speed v/s wear rate for 19.62 N has the maximum wear rate of ($9.1957x10^{-6}$ g/m) at sliding speed of 0.942 m/s because of adding intermetallic particles and wear tends to more. A413+3%TiB_2 (D1), A413+3%TiB_2+10%Al_4Sr (F1) of sliding speed v/s wear rate for 19.62 N as the sliding speed increases wear rate also increases. A413+3%AlB_2 (C1) of sliding speed v/s wear rate for 19.62 N as the minimum wear rate of ($1.9452x10^{-6}$ g/m) at sliding speed of 2.8274 m/s shows the remarkable trend with increasing sliding speed. From Tables 3 & 5, figure 5, A413 (A1) of sliding speed v/s wear rate for 39.24 N as the maximum wear rate of ($12.3788x10^{-6}$ g/m) at sliding speed of 0.942 m/s because they do not have intermetallic particles and wear tends to more. A413+10%Al_4Sr (E1), A413+3%TiB_2+10%Al_4Sr (F1) of sliding speed v/s wear rate for 39.24 N, as the sliding speed increases the wear rate also increases. A413+3%TiB_2+10%Al_4Sr (F1) of sliding speed v/s wear rate for 39.24 N, as the minimum wear rate of ($1.6799x10^{-6}$ g/m) at sliding speed of 0.942 m/s shows the remarkable trend with increasing sliding speed. From Tables 3 & 6, figure 6, A413 (A1) of sliding speed v/s wear rate for 58.86 N as the maximum wear rate of ($25.4650x10^{-6}$ g/m) at sliding speed of 0.942 m/s because they do not have intermetallic particles and wear tends to more. A413+3%TiB_2+10%Al_4Sr (F1), A413+10%Al_4Sr (E1) of sliding speed v/s wear rate for 58.86 N, as the sliding speed increases the wear rate increases. A413+5%Al_3Ti (B1) of sliding speed v/s wear rate for 58.86 N, as the minimum wear rate of ($2.5346x10^{-6}$ g/m) at sliding speed of 2.8274 m/s shows the remarkable trend with increasing sliding speed. The reduction in wear with the increase in sliding speed may be possibly due to the increased contamination of sliding interface by oxide layer called glaze. The presence of 'glaze' reduces the chance of direct metallic contact and offer protection, therefore asperities interaction is reduced, which is a prerequisite for adhesive wear. Also 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, resulting in more wear rate. However, at higher speeds, there is less residential time for the growth of micro welds leading to lesser wear rate. So less weight loss was observed in A413 alloy containing combined reinforced intermetallic alloys when compared to as cast alloy.

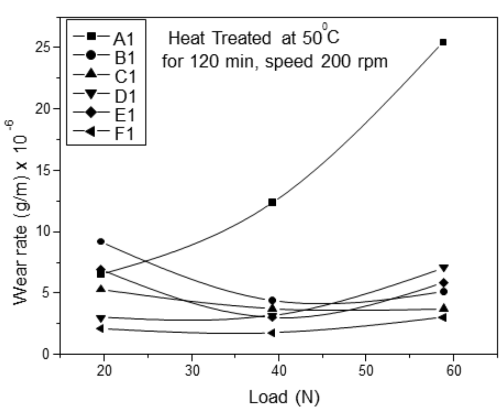

Figure 1. Load v/s Wear rate

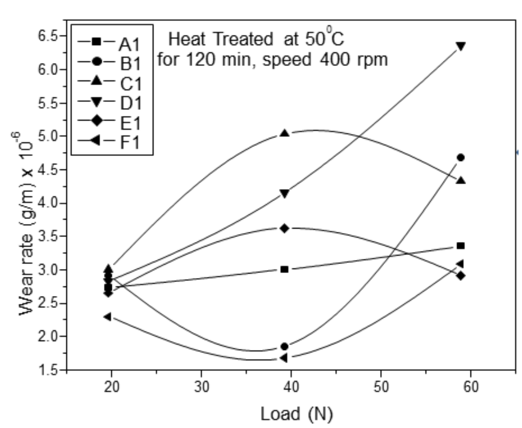

Figure 2. Load v/s Wear rate

Table 4. Wear test data for specimens of various loads at heat treated at 50 0C for 120 min with constant speed (200 rpm), Track diameter (90 mm), Time (5 min), Sliding speed (v) = 0.942 m/s, Sliding distance (L) = 282.74 m, (Pin diameter=10 mm)

Alloy Ref.	Load (N)	Weight Loss (g)	Volume Loss (mm^3)	Height Loss (mm)	Linear wear rate X10^{-6} (mm/m)	Wear rate X 10^{-6} (g/m)	Volume Wear X 10^{-3} (mm^3/m)	Specific Wear Rate X 10^{-3} (mm^3/N-m)	Wear resistance X 10^3 (Nm/mm^3)
A1	19.62	0.0018	0.7115	0.0090	31.8313	6.5431	2.5164	128.2568	7.7968
B1		0.0026	1.0000	0.0127	44.9175	9.1957	3.5368	180.2650	5.5473
C1		0.0015	0.5769	0.0073	25.8187	5.3052	2.0403	103.9908	9.6155
D1		0.0008	0.3269	0.0041	14.5009	3.0062	1.1561	58.9245	0.0169
E1		0.0019	0.7500	0.0095	33.5997	6.8967	2.6526	135.1987	7.3965
F1		0.0006	0.2307	0.0029	10.2567	2.1220	0.8159	41.5851	0.0240
A1	39.24	0.0035	1.3461	0.0171	60.4795	12.3788	4.7609	121.3277	8.2421
B1		0.0012	0.4807	0.0061	21.5745	4.4210	1.7001	43.3256	0.0230
C1		0.0010	0.4038	0.0051	18.0377	3.7136	1.4281	36.3939	0.0274
D1		0.0009	0.3461	0.0044	15.5620	3.1831	1.2240	31.1926	0.0320
E1		0.0008	0.3269	0.0041	14.5009	3.0062	1.1561	29.3476	0.0340
F1		0.0005	0.1923	0.0024	8.4883	1.7684	0.6801	17.3318	0.0576
A1	58.86	0.0072	2.7692	0.0352	124.4960	25.4650	9.7941	166.3965	6.0097
B1		0.0014	0.5576	0.0070	24.7577	5.1283	1.9721	33.5049	0.0299
C1		0.0010	0.4038	0.0051	18.0377	3.7136	1.4281	24.2626	0.0412
D1		0.0020	0.7692	0.0097	34.3071	7.0736	2.7205	46.2198	0.0216
E1		0.0016	0.6346	0.0080	28.2945	5.8357	2.2444	38.1311	0.0262
F1		0.0009	0.3269	0.0041	14.5009	3.0062	1.1561	19.6415	0.0509

Table 5. Wear test data for specimens of various loads at heat treated at 50 ^{0}C for 120 min with constant speed (400 rpm), Track diameter (90 mm), Time (5 min), Sliding speed (v) = 0.942 m/s, Sliding distance (L) = 282.74 m, (Pin diameter=10 mm).

Alloy Ref.	Load (N)	Weight Loss (g)	Volume Loss (mm^3)	Height Loss (mm)	Linear wear rate X10^{-6} (mm/m)	Wear rate X 10^{-6} (g/m)	Volume Wear X 10^{-3} (mm^3/m)	Specific Wear Rate X 10^{-3} (mm^3/N-m)	Wear resistance X 10^3 (Nm/mm^3)
A1	19.62	0.0021	0.8076	0.0102	12.0250	2.4757	0.9521	48.5270	0.0206
B1		0.0019	0.0750	0.0009	1.0610	2.2989	0.0884	4.5056	0.2219
C1		0.0016	0.0634	0.0008	0.9431	1.9452	0.0747	3.8073	0.2626
D1		0.0027	1.0576	0.0134	15.7970	3.2420	1.2468	63.5474	0.0157
E1		0.0033	1.2692	0.0161	18.9807	3.8904	1.4962	76.2589	0.0131
F1		0.0029	1.1346	0.0144	16.9765	3.4778	1.3376	68.1753	0.0146
A1	39.24	0.0044	1.7115	0.0217	25.5826	5.2462	2.0177	51.4194	0.0194
B1		0.0017	0.6538	0.0083	9.7850	2.0041	0.7707	19.6406	0.0509
C1		0.0018	0.7115	0.0090	10.6103	2.1810	0.8388	21.3761	0.0467
D1		0.0035	1.3461	0.0171	20.1596	4.1262	1.5869	40.4408	0.0247
E1		0.0037	1.4230	0.0181	21.3385	4.3620	1.6776	42.7522	0.0233
F1		0.0030	1.1538	0.0146	17.2123	3.5367	1.3602	34.6636	0.0288
A1	58.86	0.0033	1.2692	0.0176	20.7608	3.8904	1.4962	25.4196	0.0393
B1		0.0021	0.8269	0.0105	12.3787	2.5346	0.9748	16.5613	0.0603
C1		0.0022	0.8653	0.0110	12.9681	2.6525	1.0201	17.3309	0.0577
D1		0.0038	1.4615	0.0186	21.9280	4.4799	1.7229	29.2711	0.0341
E1		0.0039	1.5192	0.0193	22.7532	4.6567	1.7910	30.4111	0.0328
F1		0.0042	1.6153	0.0205	24.1679	4.9514	1.9043	32.3530	0.0309

Table 6. Wear test data for specimens of various loads at heat treated at 50 ^{0}C for 120 min with constant speed (600 rpm), Track diameter (90 mm), Time (5 min), Sliding speed (v) = 2.8274 m/s, Sliding distance (L) = 848.23 m, (Pin diameter = 10 mm)

Alloy Ref.	Load (N)	Weight Loss (g)	Volume Loss (mm^3)	Height Loss (mm)	Linear wear rate X10^{-6} (mm/m)	Wear rate X 10^{-6} (g/m)	Volume Wear X 10^{-3} (mm^3/m)	Specific Wear Rate X 10^{-3} (mm^3/N-m)	Wear resistance X 10^3 (Nm/mm^3)
A1	19.62	0.0015	0.5961	0.0075	13.4045	2.7410	1.0541	53.7257	0.0186
B1		0.0016	0.3646	0.0046	8.2054	2.9178	0.6447	32.8593	0.0304
C1		0.0017	0.6538	0.0083	14.7131	3.0062	1.1561	58.9245	0.0169
D1		0.0016	0.6153	0.0078	13.8466	2.8294	1.0881	55.4580	0.0180
E1		0.0015	0.5769	0.0073	12.9801	2.6526	1.0201	51.9928	0.0192
F1		0.0013	0.5000	0.0063	11.2470	2.2989	0.8842	45.0662	0.0221
A1	39.24	0.0017	0.6538	0.0083	14.7131	3.0062	1.1561	29.4622	0.0339
B1		0.0010	0.4038	0.0051	9.0719	1.8568	0.7140	18.1957	0.0549
C1		0.0028	1.0961	0.0139	24.5808	5.0399	1.9383	49.3960	0.0202
D1		0.0023	0.9038	0.0115	20.3367	4.1557	1.5982	40.7288	0.0245
E1		0.0020	0.7884	0.0100	17.8640	3.6252	1.3942	35.5300	0.0281
F1		0.0009	0.3653	0.0046	8.2054	1.6799	0.6459	16.4602	0.0607
A1	58.86	0.0019	0.7307	0.0092	16.4285	3.3599	1.2921	21.9520	0.0455
B1		0.0026	1.0192	0.0192	34.1126	4.6862	1.8023	30.6201	0.0326
C1		0.0024	0.9423	0.0119	21.0440	4.3326	1.6663	28.3095	0.0353
D1		0.0036	1.3846	0.0176	31.1240	6.3662	2.4485	41.5987	0.0240
E1		0.0016	0.6346	0.0080	14.2710	2.9178	1.1222	19.0655	0.0524
F1		0.0017	0.6730	0.0056	9.9915	3.0947	1.1901	20.2191	0.0494

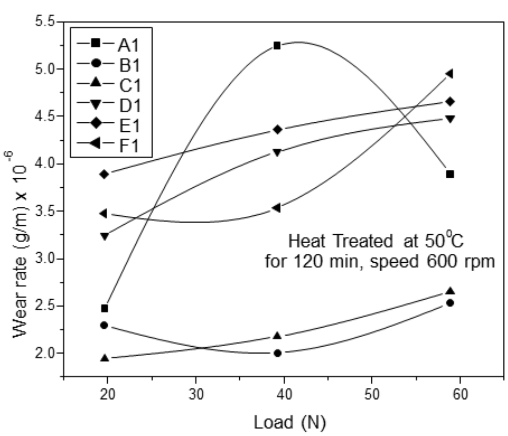

Figure 3. Load v/s Wear rate

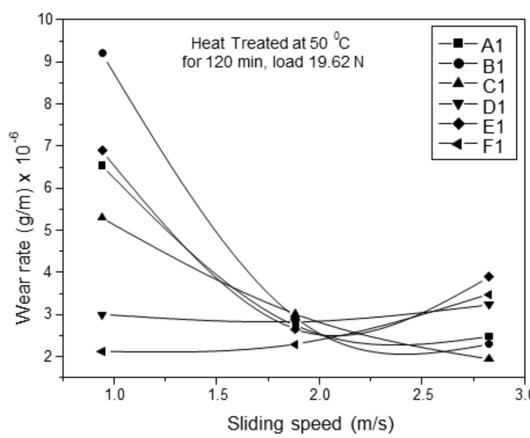

Figure 4. Sliding speed v/s Wear rate

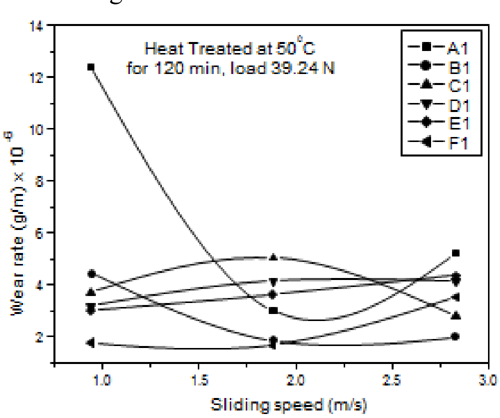

Figure 5. Sliding speed v/s Wear rate

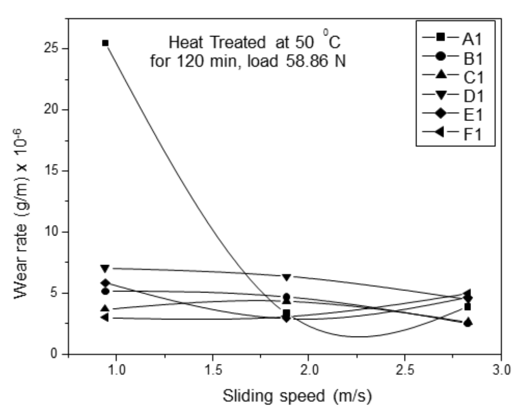

Figure 6. Sliding speed v/s Wear rate

From Table 3 & figure 1 it is observe that A413 (A1) of load v/s wear rate for 200 rpm has the maximum wear rate ($25.4650x10^{-6}$ g/m) at load 60 N. A413+5%Al_3Ti (B1), A413+3%AlB_2 (C1), A413+10%Al_4Sr (E1) of load v/s wear rate for 200 rpm, shows that wear rate decreases slightly as load increases. A413+3%TiB_2+10%Al_4Sr (F1) of load v/s wear rate for 200 rpm has minimum wear rate ($1.7684x10^{-6}$ g/m) at load 60 N, shows the remarkable trend with increasing load. From Table 3 & figure 2, we seen that, A413+3%TiB_2 (D1) of load v/s wear rate for 400 rpm has maximum wear rate ($6.3662x10^{-6}$ g/m) at load 60 N. A413 (A1), A413+5%Al_3Ti (B1), A413+3%TiB_2+10%Al_4Sr (F1) of load v/s wear rate for 400 rpm has the minimum wear rate at 20N as the load increases to 40N wear rate slightly increases. A413+3%TiB_2+10%Al_4Sr (F1) of load v/s wear rate for 400 rpm has minimum wear rate ($1.6799x10^{-6}$ g/m) at load 20 N. shows that the remarkable trend with increasing load

From Table 3, figure 3, we seen that, A413 (A1) load v/s wear rate for 600 rpm has maximum wear rate ($5.2462x10^{-6}$ g/m) at load 40 N. A413+3%AlB_2 (C1), A413+3%TiB_2 (D1), A413+10%Al_4Sr (E1), A413+3%TiB_2+10%Al_4Sr (F1) for 600 rpm. as load increases wear rate also increases. A413+3%AlB_2 (C1) of load v/s wear rate for 600 rpm has minimum wear rate ($1.9452x10^{-6}$ g/m) at load 20 N shows the remarkable trend with increasing load. From Table 4, 5 & 6, figure 4, we got A413+5%Al_3Ti (B1) of sliding speed v/s wear rate for 19.62 N has the maximum wear rate ($9.1957x10^{-6}$ g/m) at sliding speed of 0.942 m/s. A413+3%TiB_2 (D1), A413+3%TiB_2+10%Al_4Sr (F1) of sliding speed v/s wear rate for 19.62 N, as the sliding speed increases wear rate also increases. A413+3%AlB_2 (C1) of sliding speed v/s wear rate for 19.62 N has the minimum wear rate ($1.9452x10^{-6}$ g/m) at sliding speed of 2.8274 m/s, shows that remarkable trend with increasing sliding speed.

From Table 4, 5 & 6, figure 5, it seen that A413 (A1) of sliding speed v/s wear rate for 39.24 N has the maximum wear rate ($12.3788x10^{-6}$ g/m) at sliding speed of 0.942 m/s. A413+10%Al_4Sr (E1), A413+3%TiB_2+10%Al_4Sr (F1) of sliding speed v/s wear rate for 39.24 N, as the sliding speed increases the wear rate also increases. A413+3%TiB_2+10%Al_4Sr (F1) of the sliding speed v/s wear rate for 39.24 N has the minimum wear rate ($1.6799x10^{-6}$ g/m) at sliding speed 0.942 m/s, shows that remarkable trend with increasing sliding speed. From Table 4, 5 & 6, figure 6, we observe that A413 (A1) of sliding speed v/s wear rate for 58.86 N has the maximum wear rate ($25.4650x10^{-6}$ g/m) at sliding speed of 0.942 m/s. A413+3%TiB_2+10%Al_4Sr (F1), A413+10%Al_4Sr (E1) of sliding speed v/s wear rate for 58.86 N, as the sliding speed increase the wear rate increases. A413+5%Al_3Ti (B1) of sliding speed v/s wear rate for 58.86 N has the minimum wear rate ($2.5346x10^{-6}$ g/m) at sliding speed 2.8274 m/s shows that remarkable trend with increasing sliding speed.

IV. CONCLUSION

The intermetallic particles influences on wear rate. The higher temperature reveals the wear resistance due to the glaze formation that offers a protection and avoids further wear. Due to combined reinforced alloys to A413 alloy has resulted in minimum weight loss when compared to the individual addition (Al-5%Al_3Ti, Al-3%AlB_2, Al-3%TiB_2 and Al-10%Al_4Sr reinforced intermetallic alloys) and in heat treated conditions.

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