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Frictional behaviour of AA7050/7.5B_4C_p/Gr hybrid composites fabricated through stir casting

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Abstract. In this research, AA7050 aluminium alloy strengthened with Boron carbide (B_4C_p) and Graphite (Gr) was manufactured by stir casting. The impact of the reinforcing particles on various process parameters on the friction coefficient were thoroughly examined utilizing pin-on-disc apparatus with experiments centred on design of experiments. The outcomes exposed that the coefficient of friction decreases with upsurge in percentage reinforcement and increases with applied load, and sliding distance. With respect to the sliding velocity it decreases until a saddle point, there after it starts to increase. Utilising the response surface methodology, a mathematical model for the friction coefficient was established.

Keywords: Hybrid Composites; Anova; Co-efficient of friction; Mathematical modelling; Stir casting

1. Introduction

Aluminum-based composites are as a rule progressively utilized in car, aviation, and marine ventures because of their improved explicit quality, wear resistance, higher thermal conductivity, and lower coefficient of friction. The hybrid composites showed enhanced wear endurance than the pure alloys [1-4]. The micro hardness just beneath the wear surface is shrill and as the profundity builds, the micro hardness diminishes [5]. The lubricant film proffers a substantial job in augmenting the wear antagonism [6]. The load, sliding distance, and the sliding rate counter face hardness are the overwhelming elements that determine the wear of composites [7-10].

Altered compo casting cum squeeze casting course brings about the finest dissemination of fly debris particles pursued by compo casting alone and fluid metal mix stirred in metal moulds [11]. The arrangement of the Al_4C_3 stage was effectively maintained a strategic distance by the inclusion of the FA in SiC_p [12]. The flexural quality of the crossover composite is 29% more elevated than the solitary composite [13]. The composites strengthened with rice husk debris displays better tribological properties [14 – 16]. A depleted wear rate was displayed in the cross breed composite because of a precisely blended film [17]. It was stated that squeeze casting [18. 19], stir casting [20], and powder metallurgy [21] are typically utilized procedures to deliver particulate metal framework composites. In the present examination, frictional behaviour of recently fostered AA7050/7.5B_4C_p/Gr was exploited.

Table 1. Chemical composition of AA7050

Element	Zn	Mg	Cu	Fe	Cr	Si	Mn	Al
Content %	6.30	2.58	1.83	0.28	0.27	0.06	0.05	Balance

2. Experimental procedure

As shown in **Table 1**, the aluminium alloy AA7050 with a chemical composition was chosen as the matrix product and the reinforcement with a normal particle dimension of 25 μm. In a graphite cauldron, aluminium alloy was melted at the temperature of 850ºC in which preheated B4C and Gr particles was added. For the complete wetting of B_4Cp, aluminum needs a temperature of about 1100ºC. According to the chemical reaction between Al and B_4C, the melt results in the creation of intermetallic compounds such as AlB_2, Al_3BC, and Al_4C_3 at such a high temperature. In order to eliminate it Potassium hexa fluorotitanate (K_2TiF_6) was added as flux.

Table 2. Casting Process Parameters

Parameters	Value	Units
Charging Temperature	850	(ºC)
Preheating temperature of B_4C_p	250	(ºC)
Preheating temperature of Gr	400	(ºC)
Preheating temperature of mould	400	(ºC)
Stirring time	5	(min)
Stirring speed	750	(rpm)

To increase the wettability of the B_4C with matrix material, after swirling the B_4C particles for two minutes, the same weight percentage of K_2TiF_6 flux was mixed to the melt. The melt was decanted into the mould made of mild steel which was preheated at the temperature of 400oC. Then the composites were made with a dimension of 25X300 mm. It was machined to measurements of diameter 20mm and length 250mm to remove surface defects. Composite development for different weight percentage of Gr Particles (2.5, 5, 7.5, 10) was accompanied by a similar method. The parameters utilized for the casting of the composites was shown in **Table 2**. In compliance with the ASTM G99-05 criteria, the dry sliding pin-on-disk experiment was conducted on composites. EN31 steel was the counter disk product. For the present work, for the feature of friction, RSM was applied in the form of multiple regression equations to construct mathematical models. The tests were developed using the central composite model by utilizing a wear path diameter of 100 mm and its retort over the friction coefficient to adjust the system parameters, i.e. charge, sliding speed and sliding length. From the normal load added to the friction force, the coefficient of friction was calculated. The second-order response surface was presumed for the design of regression equations associated to different performance physiognomies of friction.

Table 3. Analysis of Variance for Friction

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	14	0.023998	0.023998	0.001714	7.52	0.000
Linear	4	0.008002	0.007314	0.001829	8.02	0.001
Square	4	0.009756	0.009756	0.002439	10.70	0.001
Interaction	6	0.006240	0.006240	0.001040	4.53	0.007
Residual Error	16	0.003647	0.003647	0.000228		
Lack-of-Fit	10	0.003463	0.003463	0.000346	11.29	0.004
Pure Error	6	0.000184	0.000184	0.000031		
Total	30	0.027645				

3. Frictional behaviour of AA7050/7.5B_4C_p/Gr hybrid composites

This paragraph follows a section title so it should not be indented. The addition of graphite particles on AA7050/7.5B4C composites drastically reduces the co-efficient of friction from 0.315 to 0.261 as shown in **Figure 1**. The decline in the friction coefficient possessed by the hybrid composites was owing to the graphite spill across its wear process that served as the solid lubricant (Rusin et al. 1998). The COF of graphite reinforced hybrid composites was about 50% less than that of boron carbide reinforced composites. As discussed with upsurge in sliding velocity, COF decreases until a limit point and following that it starts increasing. This is attributed by the fact that until the speed of 2.5m/s the composites form tribo rich lubricating layer at the contacting surface which eliminates direct surface contact. With further increase in sliding velocity this layer breaks down which leaves way to the direct surface contact between metals hence COF increases.

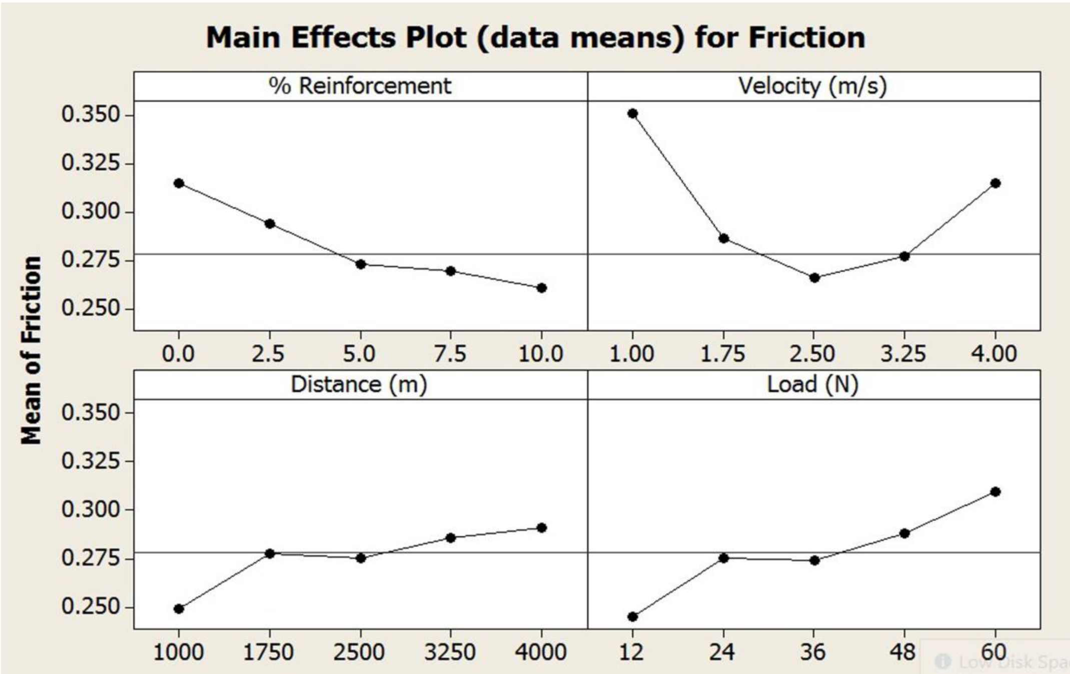

Figure 1. Main effect plot of friction coefficient for AA7050/B_4C_p/Graphite composites

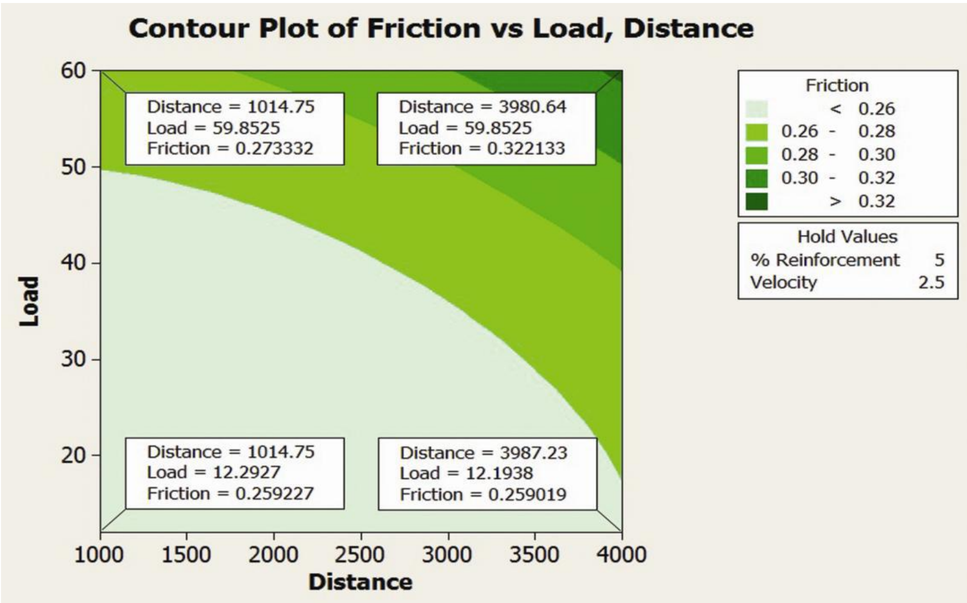

Figure 2. Combined effect of distance (m) and load (N) on coefficient of friction of AA7050/B_4C_p/Graphite composites

The applied load and the distance pursue the same pattern i.e COF upsurges with escalation in either load or distance. The composite pin exposed to higher load exerts high COF (0.31) compared to that of larger sliding distance (0.291). As discussed, in wear behaviour, increase of load deteriorates the tribo layer due to increase of pressure over the lubricating tribo layer which increases COF. At lower sliding distance, due to low temperature the number of oxide layers of graphite formed on the surface was low.

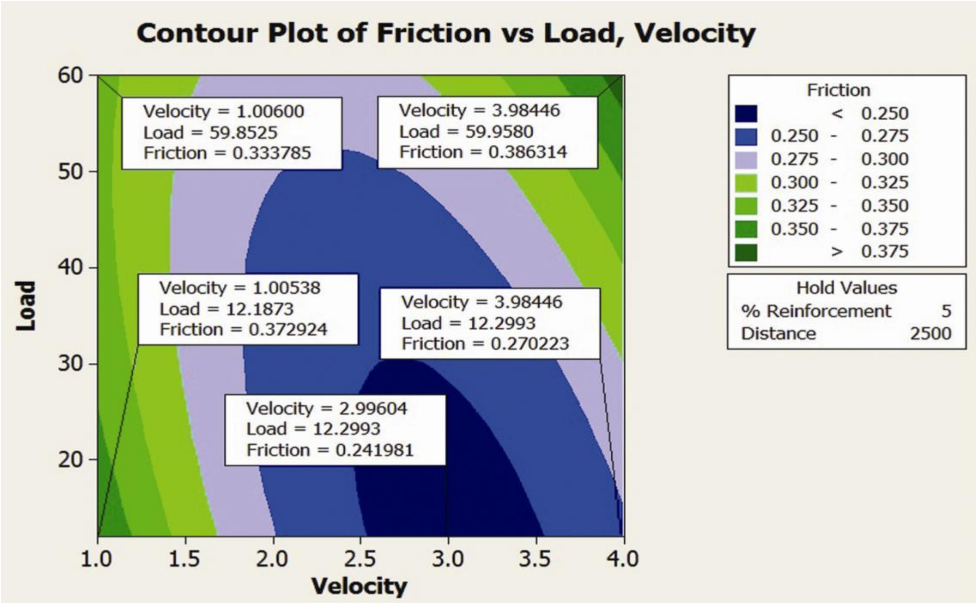

Figure 3. Combined effect of velocity (m/s) and load (N) on coefficient of friction of AA7050/B_4C_p/Graphite composites

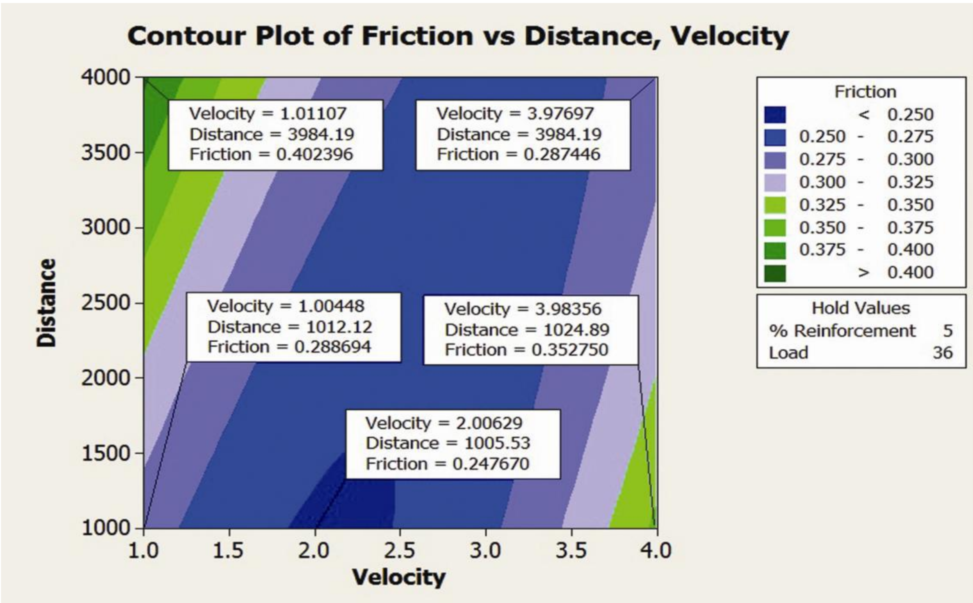

Figure 4. Combined effect of distance (N) and velocity (m/s) on coefficient of friction of AA7050/B_4C_p/Graphite composites

However this formed layer is sufficient to avoid direct pin interaction with counter face. With increase in sliding distance due to increase in temperature the number of layers formed on the surface was higher. But due to the instability, developed in the tribo layer at longer sliding distances, some areas of pins has direct metal to metal contact which increases COF. This eliminates the plastic deformation of composites at higher temperature which is reported on B_4C reinforced composites. Owing to this only minute change in wear rate of graphite reinforced hybrid composites was observed with upsurge in sliding distance.

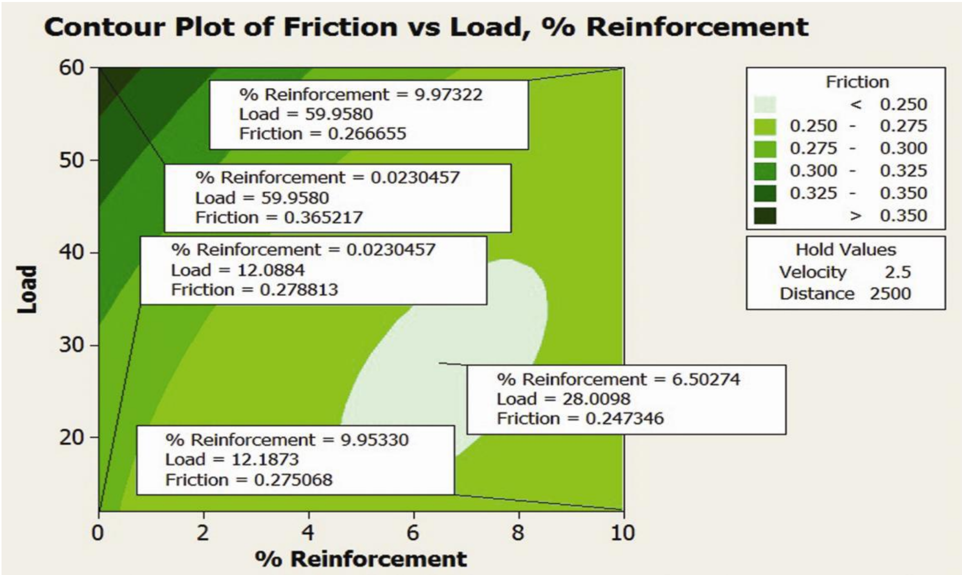

Figure 5. Combined effect of % reinforcement and load (N) on coefficient of friction of AA7050/B_4C_p/Graphite composites

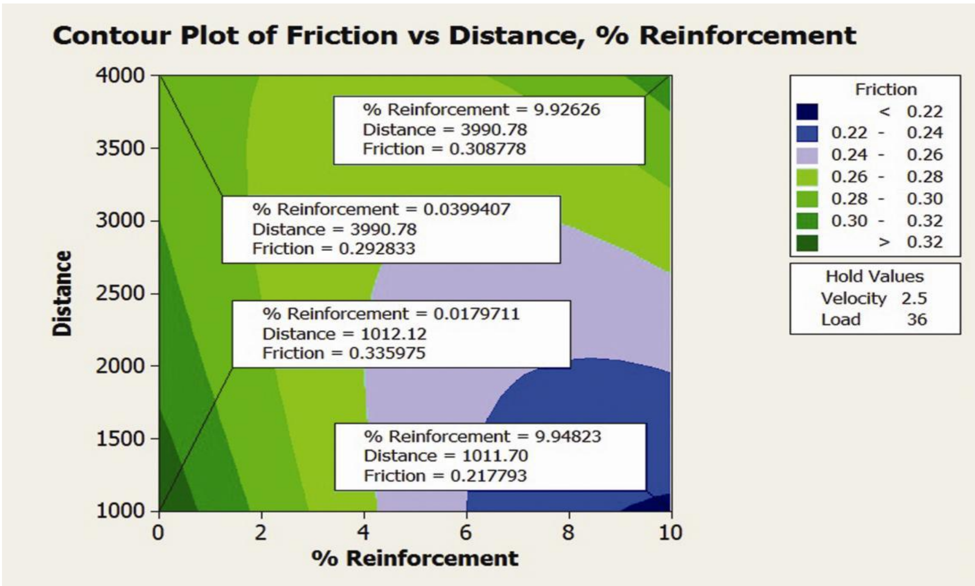

Figure 6. Combined effect of % reinforcement and distance (m) on coefficient of friction of AA7050/B_4C_p/Graphite composites

The amalgamated effect of process variables on COF was shown in **Figure 2 – 7**. Whilst there is concurrent upsurge in distance and velocity the COF decreases. For the un-coded values of applied velocity (2.5m/s) and distance (1000m) the composite pin exhibits low COF. At this specific velocity with increase in distance slight variation in COF was observed. At lower velocity and higher sliding distance composites show high co-efficient of friction and it decreases with upsurge in sliding velocity. The co-efficient of friction increases with either increase in load or distance or combination of both. For the saddle point (Applied velocity, 2.5m/s) the composite pin exhibit low COF for any applied load. With increase or decrease in load, the COF value of the composite pin increases, when there is any deviation from the saddle point.

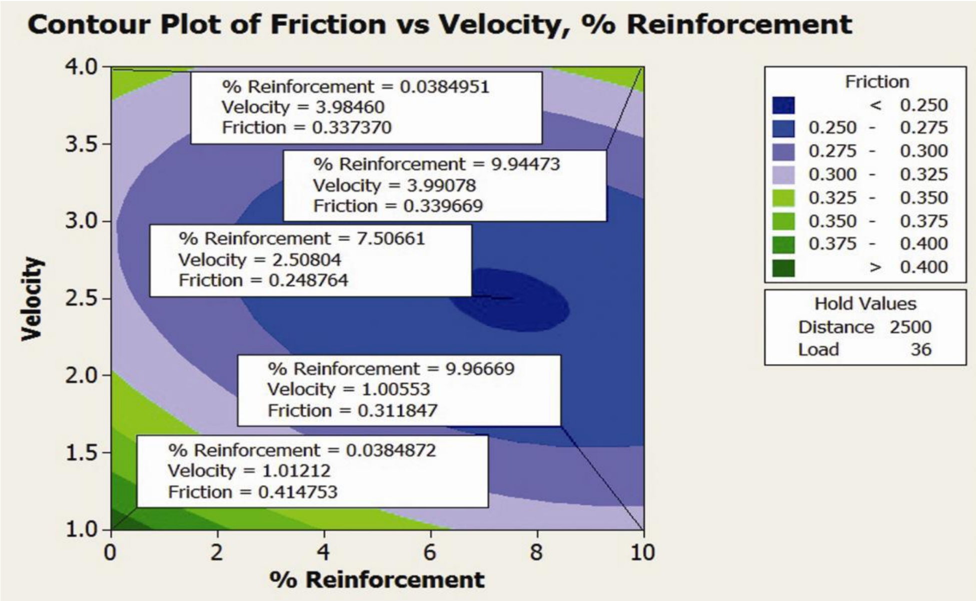

Figure 7. Combined effect of % reinforcement and velocity (m/s) on coefficient of friction of AA7050/B_4C_p/Graphite composites

3.1. Analysis of variance and estimated regression coefficients for friction

The ANOVA and projected regression factors for the AA7050/7.5B_4Cp / Gr hybrid composite friction models that are sliding on a steel disc are presented in **Tables 3 and Table 4**. From Table, It was noted for AA7050/B4Cp/Gr hybrid composites that %reinforcement and square of load have considerable influence on co-efficient of friction.

Table 4. Estimated Regression Coefficients for Friction

Factor	Coef	SE Coef	T	P
Constant	0.601229	0.098403	6.110	0.000
A	-0.028657	0.009649	-2.970	0.009
B	-0.172694	0.035460	-4.870	0.000
C	-0.000006	0.000035	0.158	0.876
D	-0.003748	0.002157	-1.737	0.102
A*A	0.001047	0.000452	2.317	0.034
B*B	0.031631	0.005019	6.302	0.000
C*C	0.000000	0.000000	0.723	0.480
D*D	0.000027	0.000020	1.388	0.184
A*B	0.003570	0.002013	1.773	0.095
A*C	0.000005	0.000002	2.254	0.039
A*D	0.000200	0.000126	-1.588	0.132
B*C	0.000020	0.000007	-3.029	0.008
B*D	0.001091	0.000419	2.601	0.019
C*D	0.000000	0.000000	0.830	0.419

S = 0.01510 R-Sq = 86.8% R-Sq(adj) = 75.3%

$$COF = 0.038+0.011*A-0.027*B-0.0019*D-0.0038*B*B- 0.002*A*B+0.00089*B*C \quad (1)$$

The connexion of % reinforcement with either velocity or load and connexion between velocity and load spectacles substantial impact on the friction, however there are comparatively lower contributions by other input variables on coefficient of friction. The regression coefficients are gotten by utilizing the exploratory information. The relapse condition for the rubbing as an element of four information measure factors was created utilizing exploratory information and was given previously. The coefficients (inconsequential recognized from ANOVA) of certain terms of the quadratic condition have been overlooked.

4. Conclusion

Pin on disc experiments are accomplished on AA7050/7.5B_4C_p/Gr composites with reinforcement of up to 10% of Gr. The accompanying outcomes were obtained from the examination:

1. The percentage of graphite has significantly impact on co-efficient of friction, it shrinkages with upsurge in graphite particles. But, it increases with increasing applied load and sliding distance or blended increase in any of the input variables. In case of sliding speed, friction reduces until a saddle point, there after it tends to increase.
2. A lumber point was eminent at load of 48N and a sliding speed of 1.75m/s on the surface and its accompanying contour plot and its related coefficient value is 0.241. The study states an average friction coefficient of 0.261 for the percentage strengthening, sliding speed, load and sliding distance was considered.
3. In tribological applications, the AA7050/7.5B_4C/Gr hybrid composites may be favored because their coefficient of friction is fairly minimal with an average value of 0.261, which means a demoted energy loss.

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