EVALUATION OF WEAR PROPERTIES OF Al 7075 ALLOY REINFORCED WITH HERBAL EXTRACTED SiC

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ABSTRACT

This study investigates the wear behaviour of Aluminium 7075 alloy reinforced with silicon carbide (SiC) particles derived from natural herbal sources. Rather than fabricating new composites, the research focuses on evaluating the tribological performance of existing materials under varying operational parameters such as applied load, rotational speed, and test duration. Key output responses including coefficient of friction, wear rate, surface roughness, and frictional force were measured. To determine the optimal combination of these parameters for enhanced wear resistance and surface quality, Grey Relational Analysis (GRA) was employed as a multi-response optimization technique. The findings demonstrate that herbal extracted SiC reinforcement contributes to improved wear properties of the aluminium alloy, and GRA proves to be an effective approach for performance optimization in material studies.

KEYWORDS: - *Aluminium 7075 Alloy, Herbal Extracted Silicon Carbide, Wear Rate, Surface Roughness, Grey Relational Analysis, Pin-on-Disc Test*

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1. INTRODUCTION

In today's engineering applications, improving the durability and performance of materials is a key area of research. Industries such as aerospace, automotive, and defence demand materials that are not only strong and lightweight but also resistant to wear and surface damage during continuous use. Among various metals, aluminium alloys stand out due to their excellent strength-to-weight ratio, corrosion resistance, and good mechanical properties. However, when exposed to high loads, sliding contact, or harsh operating conditions, even these alloys can undergo wear and surface degradation, which affects the performance and life span of components. This has led researchers to explore ways to further enhance the wear resistance of these materials by modifying or reinforcing them with other elements.

One such approach is to use reinforcement particles, especially through eco-friendly means, to improve surface and tribological behaviour. In this context, evaluating the wear characteristics of aluminium 7075 alloy reinforced with herbal-extracted silicon carbide becomes highly relevant. This study focuses on testing such a material under various loading, speed, and time conditions to understand how the composite performs during wear and then uses optimization techniques to identify the best processing conditions.

2. METHODOLOGY

The study was conducted in multiple stages to evaluate the wear behaviour of prefabricated Al7075 alloy specimens reinforced with herbal-extracted silicon carbide (SiC). The aim was to analyse the influence of varying tribological parameters on wear characteristics and to determine optimal conditions using Grey Relational Analysis (GRA). A preliminary literature review was carried out to understand the significance of aluminium matrix composites and the benefits of using eco-friendly herbal extracted SiC as reinforcement. This guided the selection of testing parameters and methodology. Standardized composite specimens were obtained in fabricated form. The samples were precisely shaped using EDM wire cut machining and polished to ensure consistency across all test specimens. Tribological testing was conducted using a Pin-on-Disc wear testing apparatus under dry sliding conditions. The experimental design followed the Taguchi L27 orthogonal array, which allowed for a systematic study of the effects of input variables:

- Load (in Newtons),
- Sliding Speed (in rpm),
- Sliding Time (in minutes).

Each of the 27 experiments used a unique combination of these input parameters, enabling a comprehensive evaluation of their effects on the wear behaviour of the composite material.

During each test, the following output parameters were measured:

- Wear Rate: Determined from weight loss before and after testing.
- Coefficient of Friction (COF): Recorded directly from the wear testing machine.
- Frictional Force: Calculated from the measured load and coefficient of friction.
- Surface Roughness: Measured using a Mitutoyo Surface Roughness Tester, which provided accurate Ra values for surface finish assessment.

The data collected from the 27 experiments were analysed using Grey Relational Analysis (GRA) to perform multi-response optimization. All output parameters were normalized, and Grey Relational Coefficients (GRCs) were computed. The Grey Relational Grade (GRG) was calculated for each experiment to rank the performance based on multiple outputs. The experiment with the highest GRG was identified as the optimal parameter combination, offering the best trade-off among wear rate, coefficient of friction, frictional force, and surface finish. This methodology provided insight into the tribological performance of Al7075–SiC composites and helped in identifying ideal operating conditions for wear applications.

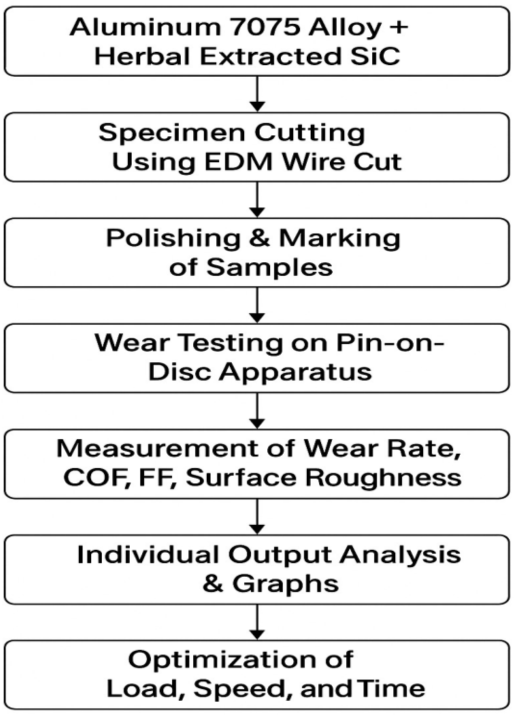

Fig 1- Block Diagram of Project Methodology

3. MATERIAL PROPERTIES

TABLE 3.1: Mechanical Properties Of Alluminium 7075 Alloy

Density (ρ)	2.81 g/cm^3
Youngs modulus (E)	71.7 GPa
Tensile Strength (σ_t)	572 MPa
Poisson's ratio (v)	0.33
Hardness - Rockwell	87 HRB
Elongation at break (ε)	11%

TABLE 3.2: Thermal Properties Of Aluminum 7075 Alloy

Melting Temperature	2.81 g/cm^3
Thermal Conductivity	71.7 GPa
Linear thermal expansion coefficient (a)	572 MPa
Specific heat Capacity	0.33

TABLE 3.3: Electrical Properties Of Aluminum Alloy 7075

Volume Resistivity (ρ)	51.5nOhm*m

TABLE 3.4: Properties of Herbal Extracted Silicon Carbide

Property	**Value / Description**
Appearance	Gray or black powder
Particle Size	10 – 100 µm (depends on extraction method)
Density	3.1 – 3.2 g/cm³
Hardness (Mohs Scale)	~9
Thermal Conductivity	120 – 150 W/m·K

Electrical Conductivity	Semi-conducting
Crystal Structure	Hexagonal (α-SiC) or Cubic (β-SiC)
Source Material	Herbal (e.g., bamboo, coconut shell, rice husk, etc.)
Purity	90 – 98% (after purification and calcination)
Application	Used as reinforcement in aluminum matrix composites

4. CALCULATION FORMULAS

TABLE 4.1: Formulas of Grey Relational Analysis

Step	Formula	Term	Explanation
1. Normalization (Larger-the-Better)	$x_i (k) = y_i (k)$ - min $y_i (k)$ / max $y_i (k)$ - min $y_i (k)$	$x_i (k)$ min $x_i (k)$ max $x_i (k)$	Original data value of the ith alternative in the kth criterion Minimum value in the kth criterion Maximum value in the kth criterion
1. Normalization (Smaller-the-Better)	$x_i (k)$ = max $y_i (k) - y_i (k)$ / max $y_i (k)$ - min $y_i (k)$	_	Used when lower values are preferred (e.g., cost, wear rate)
2. Absolute Difference	$\Delta_i (k)$ $\Delta_i (k) = \lvert x(k)-x_i(k)\rvert$ $\Delta_i (k) = \lvert x_0(k)-x_i(k)\rvert$	$x_i(k)$ $\Delta_i (k)$	Normalized value of the ith alternative in the kth criterion. Absolute difference between reference and current normalized value.
3. Grey Relational Coefficient (GRC)	$\zeta_i (k)= \Delta_{min} +\zeta\cdot \Delta_{max} / \Delta_i (k) + \zeta\cdot \Delta_{max}$	Δ_{min} Δ_{max} Z $\zeta_i (k)$	Minimum of all Δ_{min} values Maximum of all Δ_{max} values Distinguishing coefficient (commonly 0.5) Grey relational coefficient for alternative iii and criterion k

4. Grey Relational Grade (GRG)	$\gamma_i = 1/n \sum_{k=1}^{n} \xi_i(k)$	γ_i n $\zeta_i(k)$	Overall performance of alternative i Total number of criteria Grey relational coefficient for each criterion

5. EXPERIMENTAL RESULTS

The experimental design for evaluating the wear behavior of Aluminum 7075 alloy reinforced with herbal-extracted Silicon Carbide (SiC) involved a structured and methodical approach to investigate the influence of three input parameters: Load, Speed, and Time. The plan was formulated to ensure comprehensive testing of all combinations for better understanding of their effects on the output responses. A total of 27 experiments were conducted using the Taguchi L27 orthogonal array design. This approach allowed an efficient analysis of the three factors at three different levels each, minimizing the number of experiments while maximizing the information gained.

TABLE 5.1: Experimental Results Of Wear Test

Sample No.	Load (kg)	Speed (rpm)	Time (min)	Wear Rate	Coefficient Of Friction	Frictional Force	Surface Roughness
1	2	200	10	92	0.436	7.1	2.897378
2	2	200	20	276	0.448	7.3	3.057398
3	2	200	30	500	0.396	7.0	2.99847
4	2	300	10	77	0.379	6.8	3.360674
5	2	300	20	329	0.461	6.6	3.7592
6	2	300	30	455	0.370	7.4	3.9878
7	2	400	10	127	0.486	9.6	3.7375846
8	2	400	20	163	0.322	5.7	3.149092
9	2	400	30	485	0.381	7.3	3.309874
10	4	200	10	184	0.279	10.4	4.48818
11	4	200	20	308	0.256	8.2	2.592578
12	4	200	30	426	0.268	9.6	3.790442
13	4	300	10	184	0.326	12.3	3.056382
14	4	300	20	285	0.262	10.1	2.74447
15	4	300	30	276	0.295	11.1	3.03403
16	4	400	10	271	0.319	13.8	2.733802
17	4	400	20	331	0.328	10.8	3.086608

18	4	400	30	512	0.394	15.1	4.22402
19	6	200	10	281	0.279	15.5	3.111246
20	6	200	20	494	0.269	15.3	2.371852
21	6	200	30	537	0.267	14	3.959098
22	6	300	10	456	0.267	17.4	3.864356
23	6	300	20	537	0.262	15.3	4.016502
24	6	300	30	621	0.259	15.1	4.006342
25	6	400	10	536	0.350	19.7	2.8194
26	6	400	20	606	0.309	17.5	3.37693
27	6	400	30	536	0.303	15.3	3.235706

Each specimen was subjected to a unique combination of the input parameters as defined by the L27 array. The experimental results were recorded and later used for both individual output optimization and multi-response optimization using Grey Relational Analysis (GRA).

TABLE 5.2 : Normalization Values Of Each Output Parameter

Norm CoF	**Norm W. R**	**Norm S. R**	**Norm F. F**
0.217391304	0.976780186	0.751680269	0.9
0.165217391	0.691950464	0.676068171	0.885714286
0.391304348	0.345201238	0.703912626	0.907142857
0.465217391	1.0	0.532765242	0.921428571
0.108695652	0.609907121	0.344455113	0.935714286
0.504347826	0.414860681	0.23643783	0.878571429
0.0	0.922600619	0.354668747	0.721428571
0.669565217	0.866873065	0.632741239	1.0
0.456521739	0.368421053	0.556769083	0.885714286
0.9	0.913312693	0.0	0.664285714
1.0	0.642414861	0.895703313	0.821428571
0.947826087	0.459752322	0.329692751	0.721428571
0.695652174	0.83465325	0.676548248	0.528571429
0.973913043	0.678018576	0.823913829	0.685714286
0.830434783	0.585139319	0.687109938	0.614285714
0.726086957	0.699690402	0.828972636	0.421428571
0.686956522	0.606811146	0.662265963	0.635714286
0.4	0.326652387	0.124819971	0.328571429
0.943478261	0.684210526	0.6506241	0.3
0.952173913	0.354489164	1.0	0.314285714
0.952173913	0.207430341	0.25	0.407142857

0.952173913	0.413312693	0.294761763	0.164285714
0.973913043	0.287925697	0.22287566	0.314285714
0.986956522	0.157894737	0.227676428	0.328571429
0.591304348	0.289473684	0.788561664	0.0
0.769565217	0.181145511	0.525084013	0.157142857
0.795652174	0.0	0.591846919	0.314285714

TABLE 5.3: Grey Relational Coefficient Values Of Each Output Parameter

GRC CoF	GRC W.R	GRC S.R	GRC F.F	GRG
0.389830508	0.955621302	0.668163593	0.833333333	0.711737184
0.374592834	0.618773946	0.606846322	0.813953488	0.603541648
0.450980392	0.432975871	0.628071762	0.843373494	0.58885038
0.483193277	1.0	0.516937585	0.864197531	0.716082098
0.359375	0.56173913	0.432696302	0.886075949	0.559971596
0.502183406	0.460770328	0.395706687	0.804597701	0.540814531
0.333333333	0.865951743	0.436554926	0.642201835	0.569510459
0.602094241	0.789731051	0.5765292	1.0	0.742088623
0.479166667	0.441860465	0.530092887	0.813953488	0.566268377
0.833333333	0.852242744	0.333333333	0.598290598	0.654300002
1.0	0.583032491	0.827408143	0.736842105	0.786820685
0.905511811	0.480654762	0.427238232	0.642201835	0.61390166
0.621621622	0.751162791	0.607200117	0.514705882	0.623672603
0.950413223	0.608286252	0.739570389	0.614035088	0.728076238
0.746753247	0.546531303	0.615089325	0.564516129	0.618222501
0.646067416	0.624758221	0.745126096	0.463576159	0.619881973
0.614973262	0.559792028	0.596848138	0.578512397	0.587531456
0.454545455	0.426121372	0.363588759	0.426829268	0.417771213
0.833333333	0.612903226	0.588667514	0.416666667	0.612892685
0.8984375	0.436486486	1.0	0.421686747	0.689152683

0.912698413	0.386826347	0.4	0.45751634	0.539260275
0.912698413	0.46011396	0.414857598	0.374331551	0.54050038
0.950413223	0.412515964	0.391504558	0.421686747	0.544030123
0.974576271	0.37254902	0.392981794	0.426829268	0.541734088
0.550239234	0.413043478	0.702766532	0.333333333	0.499845644
0.68452381	0.379107981	0.512864705	0.372340426	0.48720923
0.709876543	0.333333333	0.550548434	0.421686747	0.503861264

TABLE 5.4: Multi Response Optimization Results

S.NO	LOAD	SPEED	TIME	COEFFICIENT OF FRICTION	WEAR RATE	SURFACE ROUGHNESS	FRICTIONAL FORCE	GRG	RANK
1	2	200	10	0.436	92	2.897378	7.1	0.711737	5
2	2	200	20	0.448	276	3.057398	7.3	0.603542	13
3	2	200	30	0.396	500	2.99847	7.0	0.58885	14
4	2	300	10	0.379	77	3.360674	6.8	0.716082	4
5	2	300	20	0.461	329	3.7592	6.6	0.559972	18
6	2	300	30	0.37	455	3.9878	7.4	0.540815	21
7	2	400	10	0.486	127	3.737585	9.6	0.56951	16
8	2	400	20	0.332	163	3.149092	5.7	0.742089	2
9	2	400	30	0.381	485	3.309874	7.3	0.566268	17
10	4	200	10	0.279	133	4.48818	10.4	0.6543	7
11	4	200	20	0.256	308	2.592578	8.2	0.786821	1
12	4	200	30	0.268	426	3.790442	9.6	0.613902	11
13	4	300	10	0.326	184	3.056382	12.3	0.623673	8
14	4	300	20	0.262	285	2.74447	10.1	0.728076	3

15	4	300	30	0.295	345	3.03403	11.1	0.618223	10
16	4	400	10	0.319	271	2.733802	13.8	0.619882	9
17	4	400	20	0.328	331	3.086608	10.8	0.587531	15
18	4	400	30	0.394	512	4.22402	15.1	0.417771	27
19	6	200	10	0.279	281	3.111246	15.5	0.612893	12
20	6	200	20	0.269	494	2.371852	15.3	0.689153	6
21	6	200	30	0.267	589	3.959098	14	0.53926	23
22	6	300	10	0.267	456	3.864356	17.4	0.5405	22
23	6	300	20	0.262	537	4.016502	15.3	0.54403	19
24	6	300	30	0.259	621	4.006342	15.1	0.541734	20
25	6	400	10	0.350	536	2.8194	19.7	0.499846	25
26	6	400	20	0,309	606	3.37693	17.5	0.487209	26
27	6	400	30	0.303	723	3.235706	15.3	0.503861	24

6. **CONCLUSIONS**

The present study successfully investigated the tribological performance of Al 7075 alloy reinforced with silicon carbide (SiC) and herbal extracted SiC particles under varying operational conditions of load, sliding speed, and time. A total of 27 experimental trials were conducted to measure key output responses—coefficient of friction, wear rate, surface roughness, and frictional force.

Using Grey Relational Analysis (GRA), a multi-response optimization technique, the optimal parameter combination was identified as 4 kg load, 200 RPM speed, and 20 minutes sliding time. This setting (Sample 11) yielded the highest Grey Relational Grade (GRG) of 0.7868, indicating superior overall performance across all responses. The optimal sample exhibited a low coefficient of friction (0.256), moderate wear rate (308 μm^3), acceptable surface roughness (2.59 µm), and frictional force (8.2 N).

The study demonstrates that GRA is an effective and systematic tool for resolving the complexity of multiple, often conflicting, tribological outputs. Rather than focusing on individual response optimization, GRA facilitated the identification of a balanced, compromise solution that enhances overall material performance. These findings highlight the potential of hybrid reinforcement and data-driven optimization techniques in advancing material design and surface engineering applications.

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