How to Cite:
Raheem, A., & Subbaya, K. M. (2022). Tribological characterization of hybrid polymer composite using neuro-fuzzy model. *International Journal of Health Sciences*, *6*(S9), 3848–3857. Retrieved from https://sciencescholar.us/journal/index.php/ijhs/article/view/13491

Tribological characterization of hybrid polymercomposite using neuro-fuzzy model

Abdul Raheem
Assistant professor at Mechanical Engg. Dept in PESCE, Mandya, Karnataka
Email: abdulraheem3030@gmail.com

Dr. K.M. Subbaya
Professor at Industrial & Production Engg. Dept in The N.I.E Mysore, Karnataka

***Abstract*---**The tribological behaviour of g-C3N4 and Si3N4 nano fillers hybrid Carbon fiber reinforced with vinyl ester (C-V) Composite is investigated in this study. Hybrid polymer composites are popularly used as a substitute to metals because of their light in weight, low price and high strength to weight ratio. Thus, in this present work, hybrid C-V were fabricated using hand layup procedure with g-C3N4 and Si3N4 as Nano fillers. The experiments were designed according to Taguchi (L27) orthogonal array. The sets of 27 experiments were performed by varying the parameters of abrasive grain size, abrading distance travelled, applied load and percentage of fillers. Experiments are carried out using slurry abrasive wear testing machine to inspect the wear rate. Composite with optimum value is most suitable for lowest possible sliding wear of hybrid composites. Further, a fuzzy logic model is adopted for the estimation of sliding wear in hybrid composites by the experimental data. Estimated fuzzy modeling outputs are compared with experimental results, which is very much satisfied with an average error estimation of 0.27% which represents that the fuzzy logic model can be efficiently used to compute the wear performance.

***Keywords*---**Abrasive wear, Fuzzy logic, Hybrid composites, Taguchi Method, wear rate.

Introduction

In recent times, hybrid polymer composite materials application has been considerably increased in aerospace, medical, electrical and automotive industry due to high strength, low density and low cost. Hybrid composites exhibits

Manuscript submitted: 9 May 2022, Manuscript revised: 18 July 2022, Accepted for publication: 27 August 2022

superior mechanical and Tribological properties than FRP. Influence of several fillers like silicon carbide, MoS_2, and Gr were reinforced in epoxy composite coating for industrial applications. It was found that several fillers in epoxy coating considerably decrease its wear [1]. Three- body abrasive wear characteristic of carbon-epoxy composite with and without Silicon Carbide filler was studied by Subbaya et al.[2]. They have used Taguchi L2 orthogonal array. By using grey relational analysis, carried out the experiments and optimized the process parameters. Following results were obtained; Grain size and filler content are the influencing factor in the abrasive wear of composites. Dry end milling experiments and Mamdani fuzzy inference system to was conducted by Azmi[3] to perform fuzzy logic correlation between machining conditions and tool life. Rajasekaran et al.[4] optimized the process parameters of surface roughness in turning of CFRP composite by using CBN tool associated with fuzzy logic system. D. Rajamani et al.[5] developed a fuzzy logic model to calculate the wear rate of selective inhibition sintered high density polyethylene and observed good agreement of experimental value with predicted value. Rajesh Prabha and Edwin Raja [6] developed a model called fuzzy logic in order to calculate the wear rate in Al composite. Results showed that good agreement with real results. Ambigai and Prabhu [7] have carried out the study on tribological behaviour of Aluminium-Graphite-Si_3N_4 hybrid composite. Aluminium-Graphite-Si_3N_4 hybrid composite was fabricated under dry sliding conditions by the stir casting method for frictional and wear characteristic. Aluminium-Graphite-Silicon nitride hybrid composite wear rate is optimum with fuzzy logic investigation compared with experimental results. Low prediction errors of Aluminium-Graphite-Silicon nitride hybrid composite is 4.27%. Almotri had applied neuro-fuzzy model for experimental work and theoretical works for composite materials in order to study the physical property. The outcome in the test of neuro fuzzy model showed that good agreement between theoretical work and experimental work [8]. Stalin examined the use of tamarind seed filler as reinforcement with vinyl ester composites. Outcome showed that there is an enhancement in physical and mechanical properties [9]. Agnivesh Kumar et al [10] build a fuzzy model for prediction of sliding wear in hybrid abaca-epoxy composites. Experimental result showed that in sliding wear, accuracy of hybrid composite is 87%.

In this work, the objective is to predict the wear rate from fuzzy logic rule expert system for hybrid C-V composites. Using Fuzzy logic model, the experiments was conducted. The fuzzy model includes the process parameters as abrasive grain size, abrading distance, applied load and percentage of fillers and response is wear rate.

Experimental Methodology

I. Composite Fabrication

In the present work, the matrix material is Vinyl ester supplied by Sathyam Fibertex Tamilnadu, India. High strength carbon fibers was used as reinforcement are supplied by RPI, Bangalore. The Si_3N_4 and g-C_3N_4 supplied by Nanowings Enterprises Tamilnadu, India. The average size of g-C_3N_4 and Si_3N_4 are 10-30 nm which is used as filler materials. The process begins with the mixing of vinyl ester resin with hardener at a ratio of 10:1 .The fabrication was done by hand layup technique. First the silica gel is provided in order to avoid the sticking of resin with mould. Fibers were cut for a required size of 400x400 mm. For each layer of the carbon fiber mats, resin mixture was applied with the brush and a roller. Rollers was used to eliminates any air bubbles from the mould and maintain the uniformly thickness throughout. This process is repeated until the required thickness is achieved. The weight percentage of reinforcement was kept constant 60%. Table I shows the details of composite selected in the present work. From the laminate using a tipped cutter, slurry abrasion wear test sample size of 75x25x6 mm^3 was prepared.

Table I Composite selected for the present work

Composite	Vinyl Ester resin (wt.%)	Reinforcement Carbon Fiber (wt.%)	Nano filler g-C3N4 (wt %)	Nano filler Si3N4 (wt %)
C-V	40	60	-	-
1 C-V	38	60	1	1
2 C-V	36	60	2	2

II. Manufacturing process

Composite material utilize in the present work were manufactured by hand layup procedure followed by vacuum bagging method. Initially applied mold release sheet to the granite. Vinyl ester and hardener are mixed by the weight ratio. Then, Nano fillers are added in this mixture and enforced to release sheet. Carbon fibers are placed in mold, one above the other, and vinyl ester resin mixture is applied to the mat in the mould measuring 457*457*5 mm. Then a eliminate air bubbles by using brush, roller. The desired thickness is obtained by following the above procedure. Then mold was placed inside the bag and the bag was then evacuated. All the laminates have been cured post cured at 80 ^{0}C for 1 h.

III. Abrasive wear test

The Abrasive wear experiment was carried out using slurry abrasion test rig as per ASTM G105 standard and supplied by DUCOM Instruments Pvt.Ltd. Test rig schematic diagram as shown in the Figure I. The rubber wheel diameter is 178 mm and width of 12.7 mm. A mixture of

0.94 kg of silica sand and 1.5 kg water is fed between the rotating wheel and sample. With the help of electronic balance machine, mass loss of the specimens is measured before and after each test.

Specific wear rate (Ks) of the specimen is calculated from equation.(1).

Ks = ΔV/ (LxD) m3/Nm....................(1)

ΔV =volume loss in m^3L = load in N

D = abrading distance in mts.

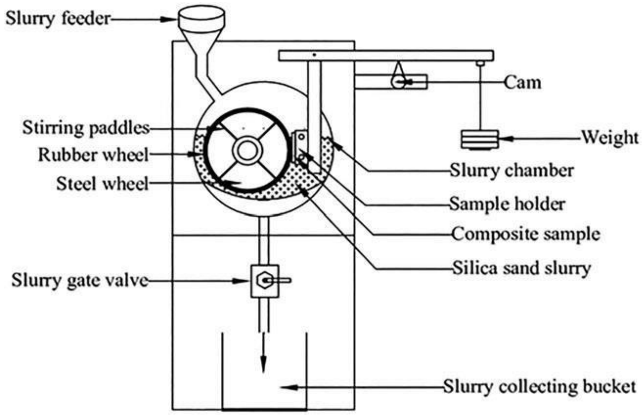


Figure I. Schematic diagram of abrasive wear test rig

Design of Experiment

Taguchi technique is used for conducting the experimental work and correlating the model between the input and output variable for estimation of specific wear rate. The input parameters are load, sliding distance, filler and Sand size. Wear rate is the output response. The set of Twenty seven experiments were carried out under cutting environment by DOE. Table II shows the parameters and levels to study the specific wear rate.

Table II Parameters and Levels

Parameters	L1	L2	L3
Load (N)	130	170	210
Sliding distance (m)	200	400	600
Filler (wt%)	0	1	2
Sand Size (μm)	106	212	425

Fuzzy Logic based Modelling

Fuzzy logic is a soft computing tool which is used to solve the complex problems. Figure II shows the parts of fuzzy logic system. The input parameters are load, sliding distance, filler and sand size. Conversion of input data into fuzzy quantities through the Fuzzifier. Based on rules to build the fuzzy logic modelling and each rule leans on the fuzzy input and then fuzzy output is achieved. Fuzzy output is transferred into the defuzzifier unit and converts the fuzzy output into crisp data. In this study, input parameters are load, sliding distance, filler and sand size and output variable is wear rate which is found from experiment. Define membership functions, used in between inputs, and output response is determined. In the current work the triangular membership function is selected because of its mathematical efficiency and its extensive use in the real time work [13]. The experimental and predicted wear rate as shown in the Table III.

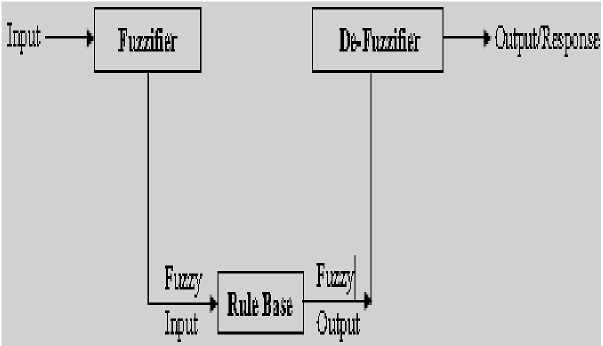


Figure II. Components of fuzzy logic system

Table III Experimental, Predicted wear rate values and Error

Expt. No	Sand size (µm)	Load (N)	Distance (m)	Filler (wt %)	Experimental wear rate (x10mm3/N-m)	Fuzzy wear rate (mm3/N m)	Error %
1	106	130	200	1	2.94	3.03	- 3.0612
2	106	130	400	2	72.87	74.9	- 2.7858
3	106	130	600	0	57.12	55.2	3.3613
4	106	170	200	0	35.85	34.65	3.3473
5	106	170	400	1	33.43	35.52	- 6.2519
6	106	170	600	2	26.98	28.85	- 6.9311
7	106	210	200	2	27.14	29.26	- 7.8113
8	106	210	400	0	25.07	26.14	- 4.2680
9	106	210	600	1	17.49	16.8	3.9451
10	212	130	200	1	18.79	17.8	5.2688
11	212	130	400	2	38.21	37.32	2.3292
12	212	130	600	0	14.47	13.6	6.0124
13	212	170	200	2	40.81	39.78	2.5239
14	212	170	400	0	25.58	24.48	4.3002
15	212	170	600	1	20.97	19.99	4.6733
16	212	210	200	0	56.87	55.91	1.6881
17	212	210	400	1	22.12	21.25	3.9331
18	212	210	600	2	22.05	21.15	4.0816
19	425	130	200	2	34.22	33.32	2.6300
20	425	130	400	0	8.83	8.93	- 1.1325
21	425	130	600	1	12.39	13.05	- 5.3269
22	425	170	200	0	75.48	74.5	1.2984
23	425	170	400	1	44.81	43.90	2.0308
24	425	170	600	2	35.23	34.32	2.5830

25	425	210	200	1	57.39	56.47	1.6031
26	425	210	400	2	28.74	27.86	3.0619
27	425	210	600	0	42.63	41.73	2.1112

Centroid technique is used to developing the model by Defuzzification method. Membership function for output factor is shown in Figure III. Membership function for prediction wear rate, sand size, load, distance travelled and filler is shown in figures IV, V, VI, VII and VIII. Figures IXand X shows Rules and rule viewer.

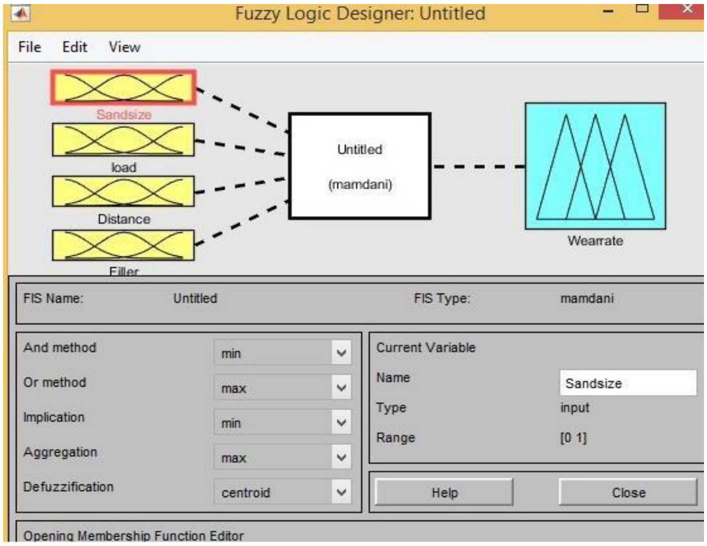


Figure III Fuzzy Logic Construction

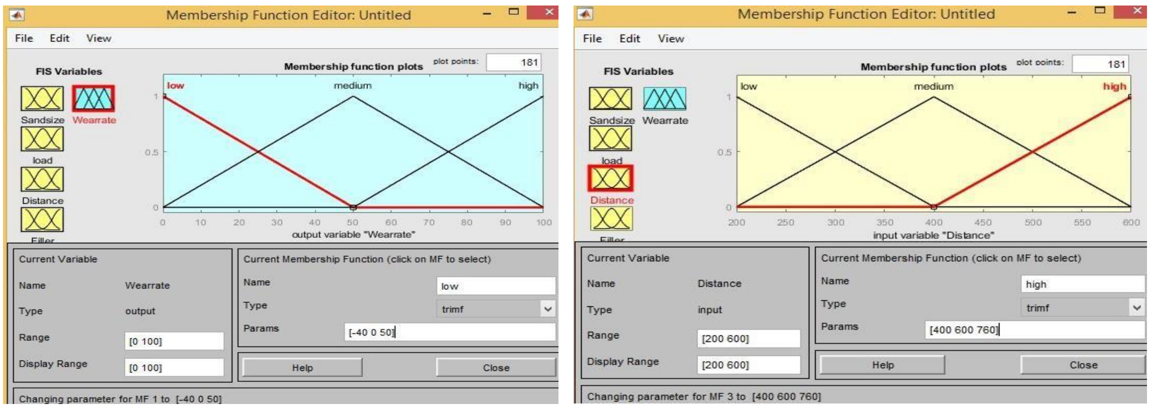
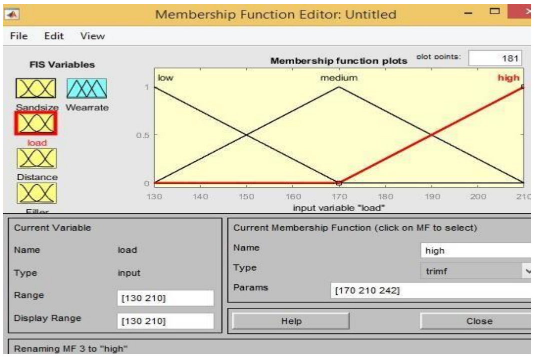


Figure IV Membership function for wear rate



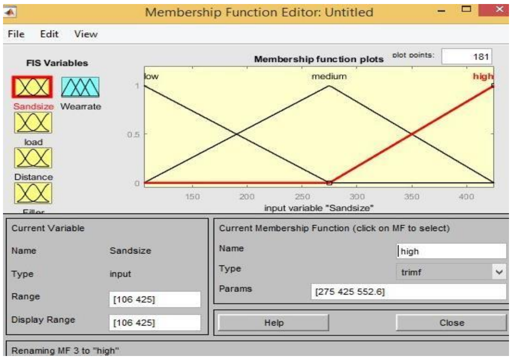


Figure V Membership of sand size

Figure VI Membership Function For Load

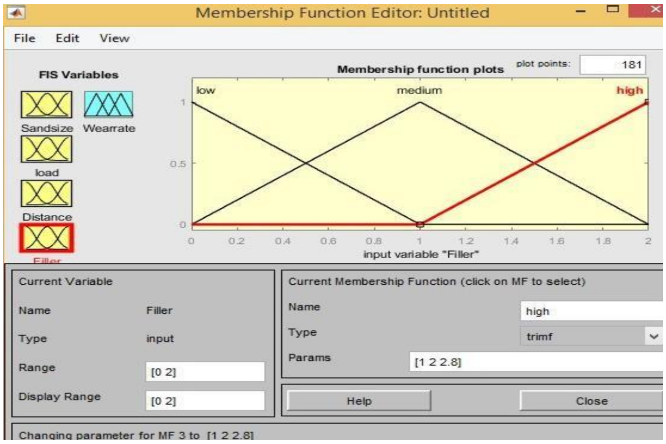


Figure VII Membership function for distance travelled

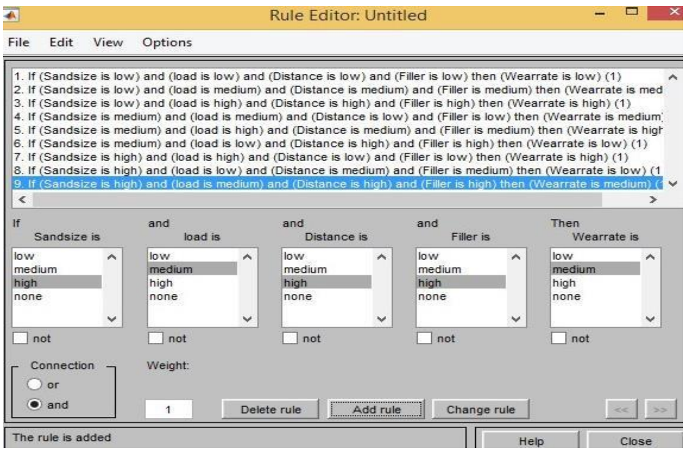


Figure VIII Membership function for filler

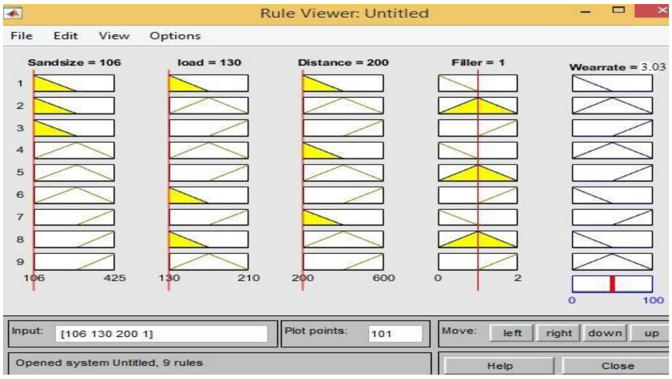


Figure IX Rules For Wear Rate

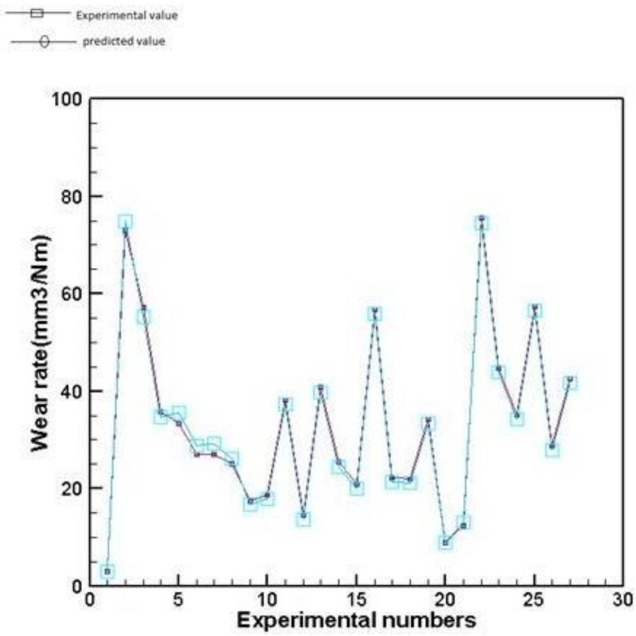


Figure X. Wear rate prediction by rule viewer

Results and Discussions

The tribological performance of hybrid Carbon fiber reinforced with vinyl ester with g-C3N4 and Si3N4 nano fillers fabricated by hand layup method was investigated using slurry abrasive wear test equipment by changing the process parameters of sand size, load, distance travelled and filler respectively. A prediction of wear rate determined from fuzzy logic system to build model is tested by requiring of different values using fuzzy rule viewer. When the input parameters are changed, the corresponding output value also changed and developed the model. Experimental, predicted wear rate results and percentage of error are shown in the Table 3. The wear rate errors estimation very hardly exceeded by 8 %. Hence the obtained fuzzy model was capable to compute with considerable accuracy. Obtained fuzzy model was suggested for computing wear rate under changed conditions.

Conclusion

Conducted the design of experiments and build the fuzzy logic model for finding out the wear rate. From taguchi method using L27 orthogonal array procedure the behaviour of sliding characteristic of hybrid composites was optimized. Experimental results were compared with the proposed model. Estimated fuzzy modelling outputs are compared with experimental results, which is very much satisfied with average error estimation 0.27% which represents that the fuzzy logic model is efficiently used to compute the wear rate. Predicted results represents fuzzy model is developed which shows the good relation with actual data. Further trials wear conducted to evaluate the proposed approach.

Figure XI. Relationship between experimental and fuzzy Predicted values

Figure XI. Relationship between experimental and fuzzy predicted values for wear rate Comparative evaluation was conducted between experimental work and predicted value which is as shown in Fig. It was found that average error in wear rate is 0.27 % which is quite less. Hence, good agreement exists between experimental work and predicted value of wear rate.

Acknowledgment
Authors would like to thank our Research guide for their continuous support and encouragement

References

1) Hao.Y.;Zhou, X:Shao,J; Zhu Y: Surface & Coatings Technology The influence of multiple fillers on friction and wear behaviour of epoxy composite coatings. Surface Coat. Technol. 362,213-219,2019.
2) K.M. Subbaya, N.Rajendra, Y.S. Varaddrajan, and B. Suresha,"Multiple response optimization of three-body abrasive wear behaviour of graphite filled carbon-epoxy composites using grey-based Taguchi approach. Journal Of Minerals And Materials Characterization And Engineering, 2012, 11, 876-884
3) Azmi, A.I. Design of fuzzy logic model for the prediction of tool performance during machining of composite materials, Procedia Engineering 38 (2012) 208 – 217.
4) Rajasekaran Thangaraju Kayaroganam Palanikumar S. Arunachalam. "Investigation on the Turning Parameters for Surface Roughness using Taguchi Analysis Procedia Engineering 51(2.):781-790. 2013.
5) D. Rajamani*, Balasubramanian Esakki, P. Arunkumar, R. VeluFuzzy Logic-Based Expert System for Prediction of Wear Rate in Selective Inhibition Sintered HDPE Parts. Materials Today: Proceedings 5 (2018) 6072–6081.

6) Rajesh Prabha[1], Edwin Raja Dhas. J[2], Fuzzy logic- A decision Making tool for wear rate prediction in Aluminum Composite, ICRAAE 2017.
7) Ambigai, S. Prabhu.," Fuzzy logic algorithm based optimization of the tribological behaviour of Al-Gr-Si3N4 hybrid composite. Measurement 146(2019),736-748
8) Safaa A.S. Almtori a, Imad O. Bachi Al-Fahad a,⇑ , Atheed Habeeb Taha Al-temimi a , A.K. Jassimb, Characterization of polymer based composite using neuro-fuzzy model Materials Today: Proceedings 42 (2021) 1934–1940
9) Balasubramaniam Stalin, Nagaraj Nagaprasad, Venkataraman Vignesh, Manickam Ravichandran, Evaluation of mechanical and thermal properties of tamarind seed filler reinforced vinyl ester composites, Journal of vinyl and additive technology 24 January 2019
10) Agnivesh Kumar Sinha, Harendra Kumar Narang, Somnath bhattacharya, "Experimental determination, modelling and prediction of sliding wear of hybrid polymer composites using RSM and Fuzzy logic. Arabian Journal for Science and Engineering. 26 October 2020.