Erosion Wear Characteristics of Polyester Composite Filled with Linz Donawitz Slag

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Abstract - In the present work LD Slag filled polyester composite with filler content from 0 to 30 weight percentage have been prepared in order to improve the erosion wear and mechanical properties of polyester. Erosion wear test was led utilizing Air Jet Erosion Test Rig. Composites having zero, ten, twenty, and thirty weight percentage of LD Slag reinforced polyester are prepared inside the research facility by utilizing a self-designed mould. Each one of the tests was led according to ASTM standard. It is discovered that wear and mechanical properties are increasing comprehensively when filler content increases. Microhardness increases about 4 times for filler content 30 wt % with the neat polyester. The enrichment in these properties is identified with vigorous holding between the L D Slag and polyester which could have happened due to arrangement of an interphase between the L D Slag and polyester-grid. ANN and predictive methods give the erosion rate not more than 15% with the experimental one.

Keywords: L D Slag, Erosion Wear, ANN.

1. Introduction

System is frequently marked by the materials and technology that indicate human potential and brainpower. Cyclic work on the material was started in stone period which cause advancement to the Copper, Iron, Steel, Aluminium and Alloy ages, as modernization in processing, melting took place and science made all these viable to proceed towards detecting more beneficial materials feasible.

Composites are the material created of two or more integral materials with outstanding dissimilar substantial or artificial choices, that on association created a material having completely different properties from original constituents. Composites materials is also one half or purpose materials that a significant of choices of every phases it suggests that by association their choices properties is also obtained. The materials Composites having Mass to high strength relation, inflexible and delicate characteristics has swapped most of the metal and alloys in these days. In current years, polymers and their composites unit quickly work the conventional materials in many engineering and systematic implications. Ancient materials have just a few finite properties with respect to combination of excessive specific modulus, specific strength and denseness etc. These materials area unit used in several engineering spaces ranging from area craft implementation to industrial unit consumptions because of leading specific strength, leading modulus, density and improved sturdiness [1]. In craft industries where sturdy, feather, noncorrodible and non-breakable materials unit needed and to satisfy alike specific wants the composites ought to be ready-made.

Being featherweight, whereas they are the foremost applicable materials for weight delicate operations, their value restricted their usage in common implementation. Use of economical, just attainable fillers is therefore useful to upgrade the properties and to cut back the value of elements [2]. Compact coarse fillers beside ceramic or metal bits area unit getting used of late to update wear resistive properties of polymers [3].The infusion of such particulates into polymers for popularized utilize is very amass at the limiting price and upgrade of solidness [4].

2. Materials and Methods

2.1 Matrix Material (Polyester)

Unsaturated isophthalic polyester provided by Reliance India Ltd. is taken as the matrix materials. Polyester is a class of polymer which contains the ester functional group in their fundamental chain. The term unsaturated polyester polyster is for the most part refer to the unsaturated (implies containing synthetic twofold securities) polysters shaped by the response of dibasic natural acids and polyhydric alcohols. Polyester tar is otherwise called a thermosetting plastic, which infers the plastic sets at high temperatures.

Polyesterpolysters(density1.35gm/cc, versatile modulus 3.25 GPa, warm conductivity around 0.26 W/m-K) are the most temperate and broadly utilized polysters frameworks, particularly in the marine business. Their focal points incorporate low consistency, ease and quick fix time. Likewise, polyester tars have for quite some time been viewed as minimum harmful.

2.2 Filler Material (LD-Slag)

This research is aimed at using an industrial waste like LD slag in the development of wear resistant coatings and polymer composites.

2.3 Micro-hardness:

Smaller scale hardness estimation of the composite examples is created utilizing a Leitz Micro-hardness Tester furnished a screen and a chip primarily based controller (Figure 2.3). A diamond indenter, as an accurate pyramid with a sq. base is affected into the composite surface beneath a heap F. the 2 diagonals X and Y of the area left on the surface of the fabric when evacuation of the heap square measure calculable and their number-crunching mean L is observed. Within investigation, the heap thought of F = 0.493 N for a stacking time of twenty seconds and Vickers hardness variety is computed utilizing the incidental to condition:

$$H_V = 0.1889\frac{F}{L^2} \qquad (2.1)$$

Where,

$$L = (X + Y)/2$$

Here, F is the connected load (N), L is the corner to corner of square impression (mm), X is the flat length (mm) and Y is the vertical length (mm). Around six to seven readings are taken for each example on various optically discernable focuses and the normal esteem is accounted for as the mean hardness. It is then changed over and communicated as far as SI units (GPa).

3. Result and Discussion

This chapter reports the measured values of the physical properties and erosion wear characteristics of Polyester-LDS composites. Erosion wear characteristics have been explored following an arrangement of experiments based on the Taguchi procedure which is utilized to obtain the erosion test information. This Chapter reports the wear rates got from these erosion preliminaries and presents a basic examination of the test outcomes. Further, erosion rate forecasts following an ANN approach for various test conditions are exhibited. A correlation among various control factors influencing the erosion rate has also been proposed for predictive purpose. Possible wear mechanisms are identified from the scanning electron microscopy of the eroded surfaces.

3.1 Density and Void Fraction:

Density may be a material property that is of prime importance in many weight sensitive applications. Thus, in several such applications, compound composites area unit found to switch standard metals and materials primarily for his or her low densities. Density of a composite basically depends on the relative proportion of matrix and therefore the reinforcing materials. There's invariably a distinction between the measured and therefore the theoretical density values of a composite because of the presence of voids and pores. These voids considerably have an effect on a number of the mechanical properties and even the performance of composites within the geographical point. Higher void contents sometimes mean lower fatigue resistance, bigger condition to water penetration and weathering. The data regarding the quantity of void content is fascinating for estimation of the standard of the composites within the . analysis work, the theoretical and measured densities of Polyester-LDS composites area unit according in conjunction with the corresponding volume fraction of voids in Table 3.1.

Table 3.1 Measured and theoretical densities along with the void fractions of the composites

S. No.	Filler Content (wt%)	Theoretical Density (gm/cm³)	Measured Density (gm/cm³)	Void Fraction (%)
1	0	1.35	1.35	-----
2	10	1.467	1.48	0.87
3	20	1.562	1.586	1.53
4	30	1.645	1.679	2.02

3.2 Micro-hardness:

Hardness is considered as one of the most important factors that govern the wear resistance of any material. In the present work, micro-hardness values of the Polyester-LDS composites are measured and the test results presented in Figure 3.1. It is evident that with addition of LD Slag, micro-hardness of the composites are improved irrespective of the matrix type and this improvement is a function of the filler content. The hardness values have been found to have improved invariably for all the composites with addition of LDS and it is obvious as the hardness of LDS is higher than those of the polyster materials. Among all the composites under this investigation, the maximum hardness value is recorded for polyester reinforced with 30 wt% LDS (0.267 GPa) and this value is about 4 times the hardness of neat polyester.

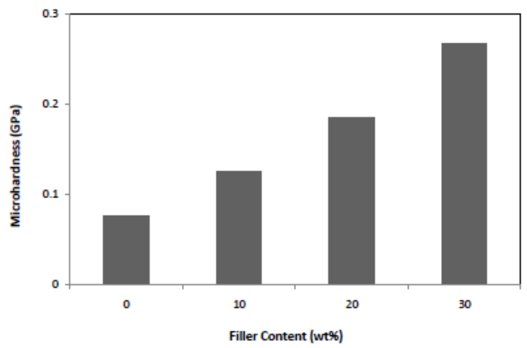

Fig.3.1 Micro-hardness of LDS filled composites

3.3 Erosion Test Results and Taguchi Analysis:

Note: Factor A denotes Impact Velocity (m/sec)

Factor B denotes Impingement Angle (^{0}),Factor C denotes Erodent Size (μm),Factor D denotes Erodent Temperature (^{0}C),Factor E denotes LDS Content (wt%),ER denotes Erosion Rate (mg/kg),S/N Ratio denotes Signal to Noise Ratio (db)

Table 3.3 S/N ratio response table for erosion rate of Polyester-LDS composites

Level	A	B	C	D	E
1	-31.16	-30.96	-32.75	-32.80	32.54
2	-30.94	-32.84	-32.07	-32.07	-31.77
3	-32.39	-32.55	-31.77	-31.65	-32.03
4	33.87	-32.01	-31.76	-31.83	-32.03
Delta	2.94	1.89	0.99	1.16	0.77
Rank	1	2	4	3	5

The S/N ratio response analysis is presented in Table 3.3. This table shows the hierarchical order of the control factors as per their significance on the composite erosion rate.

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Figure 3.3 illustrates the effect of control factors on erosion rate for Polyester-LDS composite. Analysis of the results leads to the conclusion that factor combination of A2 (Impact velocity), B1 (Impingement angle), C4(Erodent size), D3 (Erodent temperature) and E2 (LDS content) gives minimum erosion rate (Figure 3.2) for Polyester-LDS composites.s

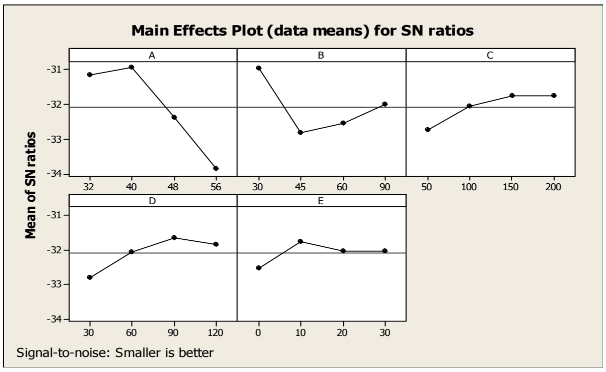

Fig.3.2 Effect of control factors on erosion rate for Polyester-LDS composites

3.4 Wear Rate Estimation using Predictive Equation:

The solid particle erosion wear rate of the composite samples also can be foreseen employing a nonlinear regressive prognosticative equation showing the link between the erosion rate and combination of management factors. This correlation is developed statistically victimization commonplace software package SYSTAT 7.

In order to specific the erosion rate in terms of a nonlinear regressive mathematical equation, the subsequent kind is suggested:

$$ER = k0 + k1 \times A + k2 \times B + k3 \times C + k4 \times D + k5 \times E \quad (3.1)$$

Here, ER is that the performance output term i.e. the erosion rate in mg/kg and ki (i = 0, 1, 2, 3, 4, 5) ar the model constants.

A is that the impact speed (m/sec), B is that the impingement angle (degree), C is that the erodent size (micron), D is that the erodent temperature (^{0}C) and E is that the LDS content within the composite (wt%).By victimization the software system, the values of all of the constants ar calculated and also the final nonlinear regression expressions for the Polyester-LDS composite is obtained by the Equation 3.2.

$$ER = 20.5 + 0.588 A + 0.0450 B - 0.0307 C - 0.0487 D - 0.036 E \quad \mathbf{(3.2)}$$

The correctness of the calculated constants is confirmed as a result of a really high correlation coefficients (r^2) of 0.993 and is obtained for Equation (3.2); so, the models ar quite appropriate for any analysis.A comparison between the damage rate obtained from experimental results and also the prognosticative equation for composite combination ar shown in Table 4.4, that indicates that the share errors related to the expected values with relation to the experimental ones vary within the vary of zero to twelve nothing.

Table 3.4 Comparison between experimental and predicted values for erosion rate

Polyester-LDS		
ER Experimental	**ER Predicted**	**% Error**
39.1209	37.67	3.70
37.8187	34.989	7.48
34.6134	32.308	6.66
33.2634	31.302	5.89
29.1209	27.837	4.40
39.9581	37.946	5.03
37.4123	38.759	3.59
35.3796	39.543	11.76
32.9532	36.265	10.05
43.7709	40.226	8.09
46.9581	45.887	2.28
44.4123	47.523	7.00
41.3796	44.996	8.73
55.9538	49.898	10.82
53.1432	47.214	11.15
48.3712	51.2	5.84

3.5 ANN Based Prediction:

As mentioned earlier, artificial neural network (ANN) may be a technique that involves info coaching to predict input-output evolutions. During this plan to simulate the erosion wear method and to predict the erosion rates of Polyester-LDS composites beneath completely different operational conditions, 5 input parameters (impact speed, impingement angle, erodent size, erodent temperature and LDS content) square measure taken, every of that is characterised by one vegetative cell within the input layer of the ANN structure. totally different ANN structures with varied variety of neurons within the hidden layer square measure tested at constant cycles, learning rate, error tolerance, momentum parameter, noise issue and slope parameter. Supported least error criterion, one structure, shown in Table 4s.5 is chosen for coaching of the input-output knowledge for Polyester-LDS composite.

Table 3.5 Input parameters for training

Input Parameters for Training	Values
Error tolerance	0.001
Learning rate (β)	0.002
Momentum parameter (α)	0.002
Noise factor (NF)	0.001
Number of epochs	1,00,00,000
Slope parameter (£)	0.6
Number of hidden layer neurons (H)	11
Number of input layer neurons (I)	5
Number of output layer neurons (O)	1

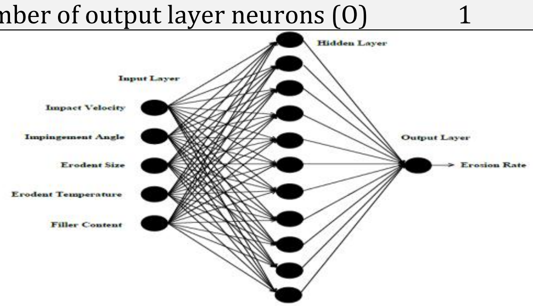

Fig.3.3 Three layer neural network

Table 3.6 Percentage error between experimental result and ANN prediction

Polyester-LDS		
ER Experimental	ER Predicted	% Error
39.1209	37.2126	4.88
37.8187	36.7689	2.78
34.6134	35.1686	1.60
33.2634	32.5706	2.08
29.1209	29.2804	0.55
39.9581	40.9863	2.57
37.4123	40.4489	8.12
35.3796	36.0475	1.89
32.9532	33.0982	0.44
43.7709	44.1969	0.97
46.9581	46.1735	1.67
44.4123	44.8812	1.06
41.3796	41.8818	1.21
55.9538	55.5711	0.68
53.1432	52.8264	0.60
48.3712	47.619	1.56

Figure 4.4 presents the comparison of the measured erosion rates with those obtained from the ANN prediction and from the projected prophetical equation for Polyester-LDS composite. Whereas the errors related to the ANN predictions dwell the vary of 0-8%, an equivalent for results obtained from the projected correlation dwell the vary of 0-12%. therefore it are often finished that each ANN and therefore the projected correlation are often used for prophetical purpose as so much because the estimation of abrasion wear rate of the composites underneath this investigation worries.

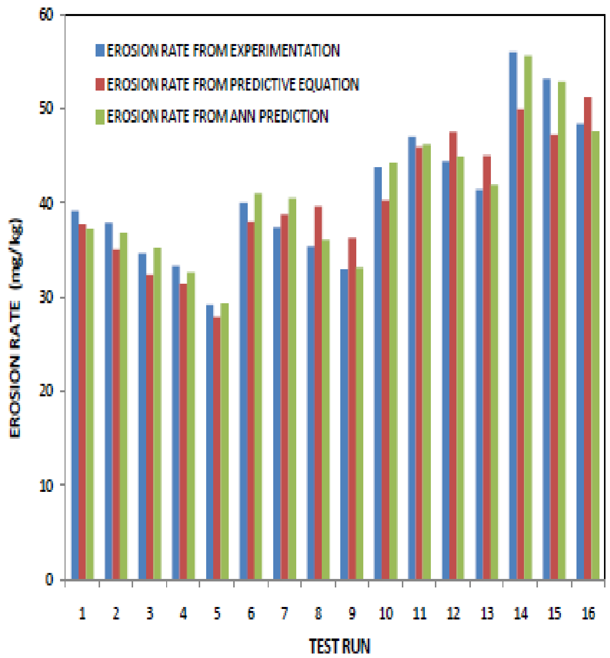

Fig.3.4 Comparison of erosion rates obtained from different methods

Conclusions

This investigation on using LD Slag in wear resistant composites has led to the following specific conclusions:

1. L D Slag has adequate potential to be utilized as a practical filler in thermosetting polymers. It is proved that

with addition of LDS, micro-hardness of the composites get improved.

2. The composites made using L D Slag possess very less voids (maximum ≈ 2%) and can be considered as good composites.

3. The hardness values found to have improved for the composites with addition of LDS.

4. Solid particle erosion wear characteristics of LD Slag filled polymer composites have been successfully analyzed using Taguchi technique. Significant factors affecting the erosion rate of these composites are identified through successful implementation of signal-to-noise response approach.

5. Two predictive models; one based on artificial neural networks (ANN) approach and the other on Taguchi approach are proposed in this work. It is demonstrated that these models well reflect the effects of various factors on the wear loss and their predictive results are consistent with the experimental observations. Neural computation is successfully applied in this investigation to predict and simulate the wear response of these composites under various test conditions within and beyond the experimental domain.

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