OPEN ACCESS
International Journal Of Modern Engineering Research (IJMER)

# Taguchi Analysis of Erosion Wear Maize Husk Based Polymer Composite

Prof. Manish Verma[1], Prof. Rupesh Kumar Malviya[2], Gunwant Sahu[3], Mr. Prof. Ashish Khandelwal[4]
[1]*Assistant Professor and, Faculty of CEC Bilaspur (CG)*
[2]*Assistant Professor and, Faculty of BCE Mandideep Bhopal (MP)*
[3]*Student of M.E. (Pro. Engg) CEC Bilaspur, CG*

***Abstract:*** *Amids the growing concern on environmental issues, science is seeking various alternatives to replace the synthetic and non degradable fibers composites with environment friendly biocomposites of comparable characteristics and performance. Visualizing the importance of polymer composites and owing to issue of ecological concerns, this experiment is an attempt to further investigate possibility of bio composites (Particularly maize husk) as an alternative of available synthetic polymer composites. Taking one leap forward the experiment also approximate qualities the effect of individual parameters on erosion by the application of Taguchi Technique. Experimental system were devised and designed to study the erosion rate of maize husk fiber Reinforced Polymer composites at various impingement angles, with profound variables such as particle velocity, fiber content, and particle size (erodent size) To cast the composite epoxy Resin LY 556 with corresponding hardener HY 551 was used. The erodent size was in range of it irregular shape. The tribological performance of sheets was investigated in respect to set of various variable parameters as suggested by L16 series of Taguchi Techniques. The morphological feature before and after the experiments were studies using SEM.*
***Keywords:*** *Biocomposites, erosive wear rate, brittle fracture Taguchi Technique, impingement angle, erodent size.*

## I. Introduction

**Composites**

A typical composite material is a system of materials composing of two or more materials (mixed and bonded) on a macroscopic scale. **Van Suchetclan [5]** explains composite materials as heterogeneous materials consisting of two or more solid phases, which are in intimate contact with each other on a microscopic scale. They can be also considered as homogeneous materials on a microscopic scale in the sense that any portion of it will have the same physical property.

**Classification of composites**

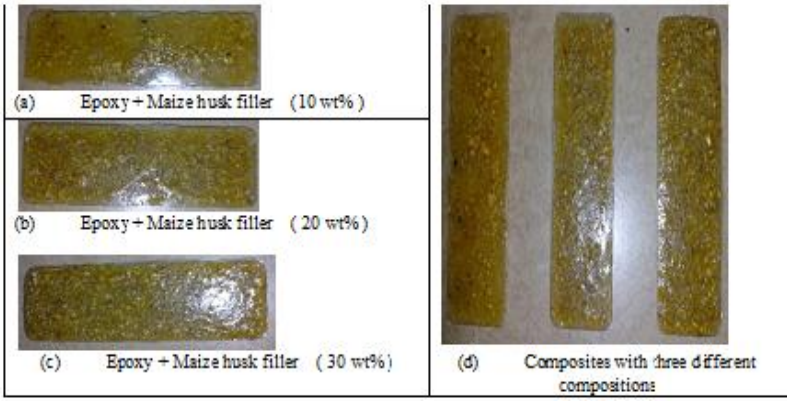
a) Metal Matrix Composites (MMC)
b) Ceramic Matrix Composites (CMC)
c) Polymer Matrix Composites (PMC)

Maize husk (MH) is one of the major agricultural residues produced as a by-product during maize processing. Usually it has been a problem for maize farmers due to its resistance to decomposition in the ground, difficult digestion and low nutritional value for animals. According to researches the lignin and hemicelluloses contents of maize husk are lower than wood whereas the cellulose content is similar. For this reason MHF can be processed at higher temperatures than wood. Therefore, the use of maize husk in the manufacturing of polymer composites is attracting much attention.

## II. Literature Review

Particulate filled polymer composites have been used extensively in various fields due to their low production costs and the ease of manufacturing. Besides, they behave isotropically and are not as sensitive as long fiber composites to the mismatch of thermal expansion between the matrix and the reinforcement **[6-9]**.

The mechanical properties of particulate filled polymer composites depend strongly on the particle size, particle-matrix interface adhesion and particle loading. Smaller particle size yields higher fracture toughness for calcium carbonate filled high density polyethylene (HDPE) [**10-12**]. Many research articles have been published to justify the utility and to establish advantageous features of such natural fibers **[17].** Natural fibers under investigation include flax, hemp, jute, sisal, kenaf, coir, kapok, banana, henequen and many others **[18].** The various advantages of natural fibers over man-made glass and carbon fibers are reported to be low cost, low density, comparable specific tensile properties, non-abrasive nature, non-allergic to the skin, reduced energy consumption, less health risk, renewability, recyclability and bio-degradability **[19-21].**




Maize husk which has become environmentally problematic waste is now being converted into useful industrial materials **[22].** Maize stalk has therefore demonstrated its potential to be used to reinforce natural rubber for shoe sole production **[23].** In the present work, the maize husk has been taken as a particulate filler and epoxy as matrix to prepare a bio-composite, and finding the various properties.

## III. Methodology

Matrix materials are of different types like metals, ceramics and polymers. Polymer matrices are most commonly used because of cost efficiency, ease of fabricating complex parts with less tooling cost and they also have excellent room temperature properties when compared to metal and ceramic matrices. In the present research work, maize husk (collected from Rajaram Maize product, Rajnandgaon,C.G.,India) is used as filler material polymer matrix composites.

**Table**:1. **List of particulate filled composites fabricated by hand-lay-up technique**

| Sample | Composition ( Maize husk as filler material ) |
|---|---|
| 1 | Epoxy + Maize husk filler ( 0 wt% ) |
| 2 | Epoxy + Maize husk filler ( 5 wt% ) |
| 3 | Epoxy + Maize husk filler ( 10 wt% ) |
| 4 | Epoxy + Maize husk filler ( 15 wt% ) |
| 5 | Epoxy + Maize husk filler ( 20 wt% ) |
| 6 | Epoxy + Maize husk filler ( 25 wt% ) |
| 7 | Epoxy + Maize husk filler ( 30 wt% ) |

Fig.1. Fabricated Composite for three different compositions

### 1. Density and Void Fraction

The theoretical density of composite materials in terms of weight fractions of different constituents can easily be obtained as per the following equations given by **Agarwal and Broutman [40].**

$$\rho_{ct} = \frac{1}{(W_f / \rho_f) + (W_m / \rho_m)} \quad (1)$$

Where, W and ρ represent the weight fraction and density respectively. The suffix f, m and ct stand for the fiber, matrix and the composite sample respectively. The actual density ($\rho_{ce}$) of the composite, however, can be determined experimentally by simple water immersion technique. The volume fraction of voids ($V_v$) in the composites is calculated using the following equation:

$$V_v = \frac{\rho_{ct} - \rho_{ce}}{\rho_{ct}} \quad (2$$

### 2. Mechanical characterization

### 2.1 Tensile test

The standard test method according to ASTM D3039-76 has been used; gauge length of the test specimen used is 50 mm. The tensile test has been performed in universal testing machine INSTRON H10KS .The test was conducted with a cross head speed of 5mm/min. For each test, composite of three samples were tested and average value was taken for analysis the Machine used for the test and the sample in loading condition. Tensile strength & Young's modulus were found out using the following formula.

$$\sigma = \frac{P}{A} \tag{3}$$

and

$$E = \frac{\sigma L}{\delta} \tag{4}$$

Where, "σ" is tensile strength, "P" is the load applied, "A" is the cross sectional area, "E" is Young's modulus, "L" is span length of the specimen and "δ" is the deflection recorded.

**2.2 Flexural strength.**

Three point bend test was carried out in an UTM 201 machine in accordance with ASTM D2344-84 to measure the flexural strength of the composites. The loading arrangement for the specimen and the photograph of the machine used .All the specimens (composites) were of rectangular shape having length varied from 100-110 mm, breadth of 50-60 mm and thickness of 2.5-3.5 mm. A span of 100 mm was employed maintaining a cross head speed of 5mm/min. The flexural strength in a three point bending test is found out by using equation (3). The flexural strength of composites was found out using the following equation:

$$FS = \frac{3PL}{2bt^2} \tag{5}$$

Where, 'b' is breadth, 't' is thickness and 'y' is extension of the specimen during experiment.

**3. Micro-hardness measurement**

Micro-hardness measurement is done using a Leitz micro-hardness tester. A diamond indenter, in the form of a right pyramid with a square base and an angle 1360 between opposite faces, is forced into the material under a load *F*. The two diagonals *X* and *Y* of the indentation left on the surface of the material after removal of the load are measured and their arithmetic mean L is calculated. In the present study, the load considered is *F* = 0.245 N and Vickers hardness number is calculated using the following equation.

$$H_v = 0.1889\frac{F}{L^2} \quad \text{and} \quad L = \frac{X+Y}{2} \tag{6}$$

Where, *F* is the applied load (N), *L* is the diagonal of square impression (mm), *X* is the horizontal length (mm) and *Y* is the vertical length (mm).

**4. Scanning electron microscopy**

The surfaces of the maize husk filled epoxy composites are examined by JEOL JSM-6480LV . The specimens are cleaned thoroughly, air dried before being observed under SEM at 20 kV. The composite samples are mounted on stubs with silver paste. To enhance the conductivity of the samples, a thin film (100 Å thicknesses) of platinum is coated onto them in JEOL sputter ion coater before the photomicrographs are taken.

**5. Tribological characterization**

**5.1 Solid particle erosion test**

The set up for the solid particle erosion wear test used in this study is capable of creating reproducible erosive situations for assessing erosion wear resistance of the prepared composite samples. The test rig consists of an air compressor, an air drying unit, a particle feeder and an air particle mixing and accelerating chamber. In the present study, dry silica sand of four different mean particle sizes (40μm, 60μm, 80 μm and 100μm) are used as erodent.

**5.2 Taguchi experimental design**

From a scientific viewpoint, these experiments are either one or a series of tests to either confirm a hypothesis or to understand a process in further detail. In order to achieve a meaningful end result, several experiments are usually carried out. The experimenter needs to know the factors involved, the range these factors are varied between, the levels assigned to each factor as well as a method to calculate and quantify the response of each factor. This one-factor-at-a-time approach will provide the most favorable level for each factor but not the optimum combination of all the interacting factors involved. Thus, experimentation in this scenario can be considered as an iterative process. Although it will provide a result, such methods are neither time nor cost effective. But the design-of-experiments (DOE) is a scientific approach to effectively plan and perform experiments using statistics. In such designs, the combination of each factor at every level is studied to determine the combination that would yield the best result.

**Table 2: Parameter settings for erosion test**

| Command factors | Abbreviation | Constant Parameters | |
|---|---|---|---|
| Impact velocity | Factor A | Erodent | Silica sand |
| Maize husk content | Factor B | Erodent feed rate (g/min) | 10.0 + 1.0 |
| Impingement angle | Factor C | Nozzle Diameter (mm) | 2.5 mm |
| Erodent size | Factor D | Standoff distance | 150 mm |

**Table 3: Control factors and their selected levels**

| Command factors | Level | | | | |
|---|---|---|---|---|---|
| | I | II | III | IV | Units |
| Factor A : Impact velocity | 30 | 40 | 50 | 60 | m/sec |
| Factor B : Maize husk content | 0 | 10 | 20 | 30 | wt. % |
| Factor C : Impingement angle | 45 | 60 | 75 | 90 | Degree |
| Factor D : Erodent size | 25 | 50 | 75 | 100 | Micron |

**Table 4: Taguchi orthogonal array design (L16)**

| Test run | Factor A Impact velocity | Factor B Maize husk content | Factor C Impingement angle | Factor D Erodent size |
|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 |
| 2 | 1 | 2 | 2 | 2 |
| 3 | 1 | 3 | 3 | 3 |
| 4 | 1 | 4 | 4 | 4 |
| 5 | 2 | 1 | 2 | 3 |
| 6 | 2 | 2 | 1 | 4 |
| 7 | 2 | 3 | 4 | 1 |
| 8 | 2 | 4 | 3 | 2 |
| 9 | 3 | 1 | 3 | 4 |
| 10 | 3 | 2 | 4 | 3 |
| 11 | 3 | 3 | 1 | 2 |
| 12 | 3 | 4 | 2 | 1 |
| 13 | 4 | 1 | 4 | 2 |
| 14 | 4 | 2 | 3 | 1 |
| 15 | 4 | 3 | 2 | 4 |
| 16 | 4 | 4 | 1 | 3 |

The impact of these four parameters on the erosion wear rate of these maize husk filled epoxy composites is therefore studied in this work using Taguchi's L16 orthogonal array design. The control factors and the parameter settings for erosion test are given in Table 2. and Table 3 presents the selected levels for various control factors. The tests are conducted as per the L16 experimental design given in Table 4.

The experimental observations are further transformed into signal-to-noise (S/N) ratios. There are several S/N ratios available depending on the type of characteristics as given by following equations:

'Smaller- the- better' characteristic: $$\frac{S}{N} = -10\log\frac{1}{n}\left(\sum y^2\right) \quad (7)$$

'Nominal- the- better' characteristics: $$\frac{S}{N} = -10\log\frac{1}{n}\left(\sum\frac{\bar{Y}}{S_y^2}\right) \quad (8)$$

'Larger- the- better' characteristics: $$\frac{S}{N} = -10\log\frac{1}{n}\left(\sum\frac{1}{y^2}\right) \quad (9)$$

Where, 'n' is the number of observations and 'y' is the observed data. The S/N ratio for minimum wear rate (both for erosion as well as sliding) comes under 'smaller is better' characteristic, which can be calculated as logarithmic transformation of the loss function by using Equation (7).

## IV. Results And Discussion

### 1. Physical characterization

**Density and Void Fraction**

Density is a material property which is of prime importance in several weight sensitive applications. The theoretical and experimentally measured densities of epoxy composites reinforced with maize husk, along with the corresponding volume fraction of voids are presented in Table 5.

**Table 5: Density values along with the void fractions of the maize husk filled epoxy composites**

| S.No. | Filler Content (wt %) | Measured density ($gm/cm^3$) | Theoretical density ($gm/cm^3$) | Voids contents (%) |
|---|---|---|---|---|
| 1 | 0 | 1.1 | 1.1 | ----- |
| 2 | 5 | 0.885 | 0.916 | 3.38 |
| 3 | 10 | 0.736 | 0.785 | 6.24 |
| 4 | 15 | 0.622 | 0.687 | 9.46 |
| 5 | 20 | 0.532 | 0.611 | 12.92 |
| 6 | 25 | 0.459 | 0.551 | 16.69 |
| 7 | 30 | 0.394 | 0.498 | 20.88 |

### 2. Mechanical characterization

**Tensile properties**

The variation of tensile strength of the natural filler polymer composite is presented in Figure 6.

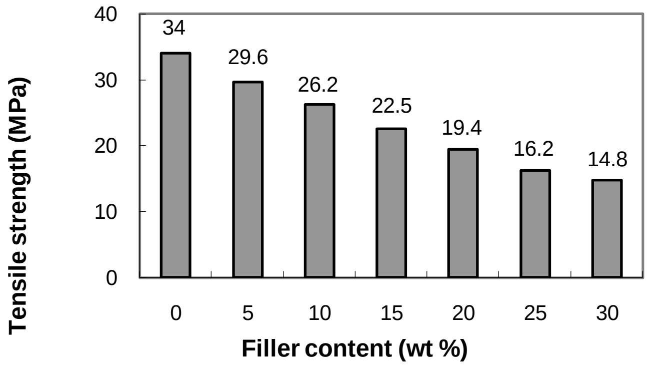



**Fig. 6. Effect of maize husk content on tensile strength of epoxy composites**

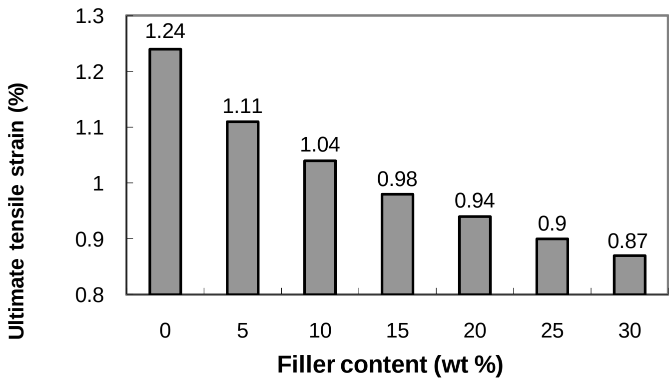



**Fig. 7. Effect of maize husk content on ultimate tensile strain of epoxy composites**

### 2.2 Flexural strength

Composite materials are subjected to bending and shear in many engineering applications. Therefore, it is essential to study the flexural characteristics of the developed new composites.

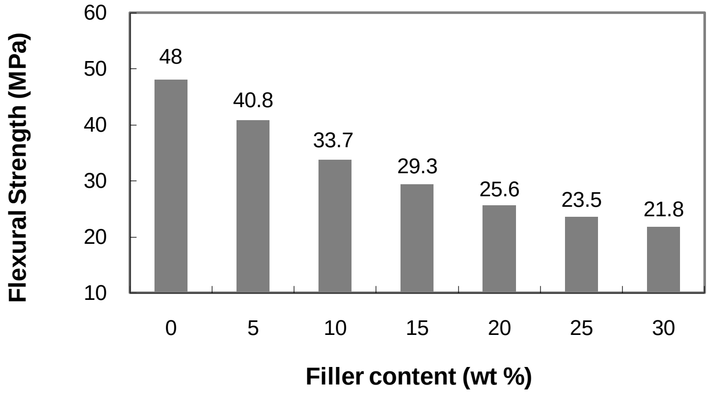



Fig. 8.Effect of maize husk content on flexural strength of epoxy composites

**2.3 Micro-hardness**

Hardness of is considered as one of the important factor which governs the wear resistance of any material. In the present investigation, micro-hardness values of the epoxy composites with maize husk filled in different proportions have been measured and the variation of micro-hardness with the maize husk content in the composites is shown in Figure 9.

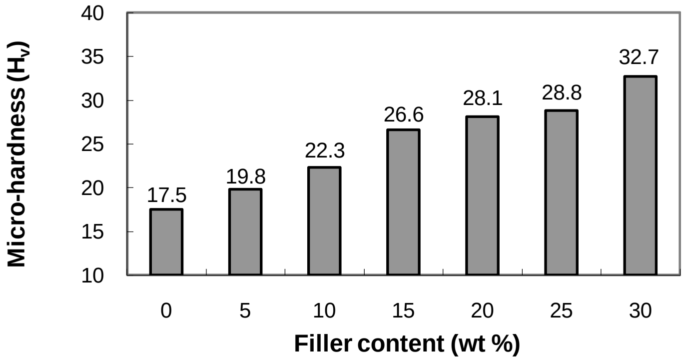
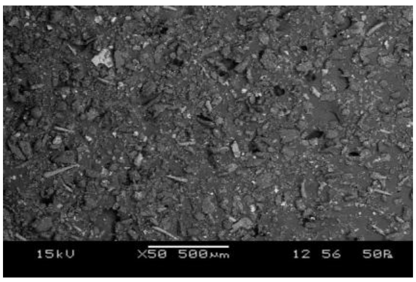


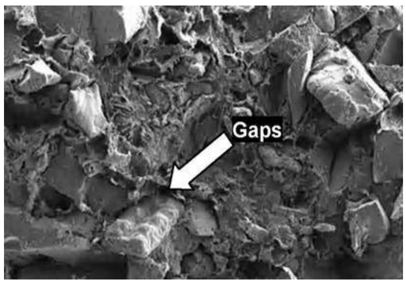

**Fig. 9. Effect of maize husk content on micro-hardness of epoxy composite**

**2.4 Morphological Behaviour**

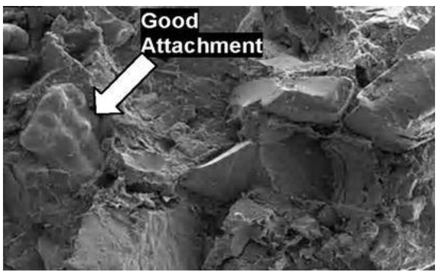
It is clear from the image that the maize husk particles are not of regular shape and similar size which is obvious because the particle used in present investigation are generated by grinding process and no grinding process is as accurate to develop particles of similar shape and size.




(a)




( b)



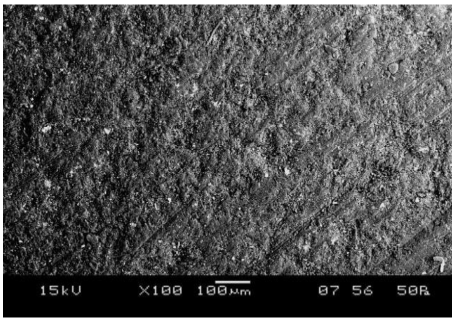

(c)

Fig. 10. SEM micrograph of maize husk particulate filled epoxy composites

**3. Tribological characterization**

**Scanning electron micrograph of un-eroded and eroded composites**

**Fig. 11. SEM micrograph of un-eroded maize husk/epoxy composites**




(a) (b)

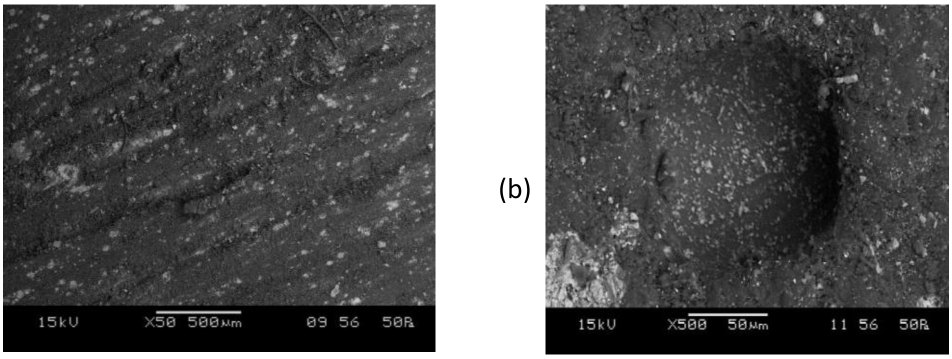



Fig. 12. SEM micrograph of eroded maize husk/epoxy composites

**4. Erosion wear and Taguchi analysis**

Table 6. shows the solid particle erosion wear rates of maize husk filled epoxy composites under various test conditions. The weight of the composite is taken before the erosion test, later after the erosion test again the weight of the composite under study is taken and the difference in their weight is calculated. The weight of the composite after erosion is always less than that of before erosion. The difference in their weight is called mass or weight loss of the sample due to solid particle impact. The ratio of this mass loss to the mass of the eroding particles causing the loss is then computed as the erosion rate. The erosion rate is thus defined as the mass loss of the specimen due to erosion divided by the mass of the erodent causing the loss.

**Table 6**: **Erosion wear test result with corresponding S/N ratios**

| Test run | Factor A Impact velocity (m/sec) | Factor B Maize husk content (wt %) | Factor C Impingement angle (degree) | Factor D Erodent size (microns) | $E_r$ Erosion rate (mg/kg) | S/N ratio (db) |
|---|---|---|---|---|---|---|
| 1 | 30 | 0 | 45 | 25 | 88.92 | -38.980 |
| 2 | 30 | 10 | 60 | 50 | 77.26 | -37.759 |
| 3 | 30 | 20 | 75 | 75 | 64.58 | -36.202 |
| 4 | 30 | 30 | 90 | 100 | 49.34 | -33.864 |
| 5 | 40 | 0 | 60 | 75 | 97.46 | -39.776 |
| 6 | 40 | 10 | 45 | 100 | 86.08 | -38.698 |
| 7 | 40 | 20 | 90 | 25 | 70.87 | -37.009 |
| 8 | 40 | 30 | 75 | 50 | 54.13 | -34.669 |
| 9 | 50 | 0 | 75 | 100 | 118.42 | -41.468 |
| 10 | 50 | 10 | 90 | 75 | 105.89 | -40.497 |
| 11 | 50 | 20 | 45 | 50 | 88.51 | -38.940 |
| 12 | 50 | 30 | 60 | 25 | 72.24 | -37.176 |
| 13 | 60 | 0 | 90 | 50 | 134.73 | -42.589 |
| 14 | 60 | 10 | 75 | 25 | 117.48 | -41.399 |
| 15 | 60 | 20 | 60 | 100 | 106.83 | -40.574 |
| 16 | 60 | 30 | 45 | 75 | 87.57 | -38.847 |

These experimental observations are then transformed into a signal-to-noise (S/N) ratios which is represented in Table . Among various S/N ratios, smaller-is-better is used in present case for minimum erosion rate:

$$\frac{S}{N} = -10 \log \frac{1}{n}\left(\sum y^2\right)$$

where, *'n'* the number of observations, and *'y'* the observed data.

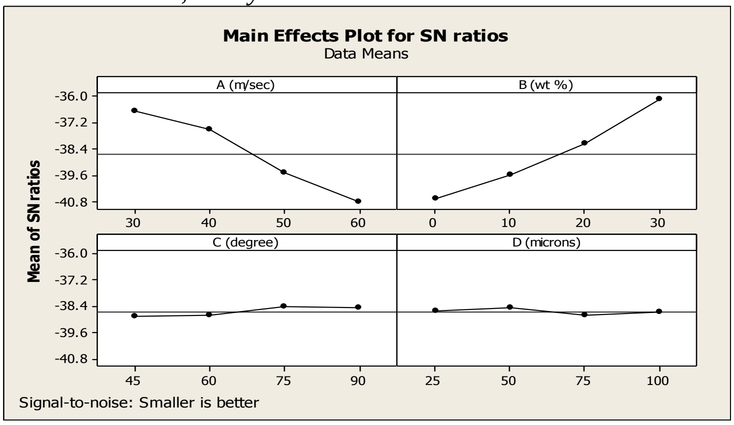



**Fig. 13. Effects of control factors on erosion rate of fabricated composites**

The analysis is made using the popular software specifically used for design of experiment applications known as MINITAB 14.

This present investigation on particulate filled maize husk/ epoxy composites has led to the following conclusions:

1) Maize husk possesses reinforcing potential to be used as a filler material in polymer matrix composites.
2) Successful fabrication of epoxy matrix composites reinforced with maize husk particles is possible by simple hand-lay-up technique.
3) The density of the fabricated composites decreases with increase in weight fraction and it also possesses low void content; even it is prepared by hand lay-up technique.
4) The tensile strength and flexural strength of these composites decreases with filler content because of poor mechanical properties of maize husk.
5) By surface morphology it is clear that there is good adhesion between the matrix phase and filler phase and very less gap is visible between them which results in low amount of porosity.
6) The micro-hardness of this natural filler based composite increases invariably with filler loading and provides improved impact resistance.
7) This study reveals that maize husk possesses good filler characteristics as it improves the erosion wear resistance of the epoxy resin.
8) Erosion characteristics of these composites can also be successfully analysed using Taguchi experimental design scheme. Taguchi method provides a simple, systematic and efficient methodology for the optimization of the control factors.

## REFERENCES

[1] Stolarski T.A., "Tribology in machine design", Heiman Newnes, UK. (1990).

[2] Paivi Kivikyto-Reponen, "Correlation of material characteristics and wear of powder metallurgical metal matrix composites, doctoral theses in materials and earth sciences", Helsinki University of Technology, Laboratory of Materials Science, Espoo, (2006).

[3] Budinski K.G., "Surface engineering for wear resistance", Prentice Hall, New Jersey, (1998).

[4] Robinowicz E., "Friction and wear of materials", John Willey, New York, USA (1965).

[5] Suchtelen Van J., "Product properties: a new application of composite materials", Philips Res. Reports, Vol. 27, pp. 28, (1972).

[6] Ranganath S., "A Review on Particulate-reinforced titanium matrix composites", Journal of Materials Science, Vol. 32(1), pp. 1-16, (1997).

[7] Sawyer W. G., Freudenberg K. D., Praveen B. and Schadler L. S., "A study on the friction and wear behavior of PTFE filled with alumina nanoparticles", Wear, Vol. 254(5-6), pp. 573-580, (2003).

[8] Kim J., Kang P. H. and Nho Y.C., "Positive temperature coefficient behavior of polymer composites having a high melting temperature", Journal of Applied Polymer Science, Vol. 92(1), pp. 394-401, (2004).

[9] Nielsen L. E. and Landel R. F., "Mechanical properties of polymers and composites", 2nd ed. New York: Marcel Dekker, pp. 557, (1994).

[10] Bartczak Z., Argon A. S., Cohen R. E. and Weinberg M., "Toughness mechanism in semi-crystalline polymer blends: II. High-density polyethylene toughened with calcium carbonate filler particles", Polymer, Vol. 40(9), pp. 2347-2365, (1999).
[11] Young R. J. and Beaumont P. W. R., "Failure of brittle polymers by slow crack growth Part 3 Effect of composition upon the fracture of silica particle-filled epoxy resin composites", Journal of Materials Science, Vol. 12(4), pp. 684-692,(1977).
[12] Kinloch A. J., Maxwell D. L. and Young R. J., "The fracture of hybrid particulate composites", Journal of Materials Science, Vol. 20(11), pp. 4169-4184, (1985).
[13] Nakamura Y., Yamaguchi M., Kitayama A., Okubo M. and Matsumoto T., "Effect of particle size on fracture toughness of epoxy resin filled with angular-shaped silica", Polymer, Vol. 32(12), pp. 2221-2229, (1991).
[14] Nakamura Y., Yamaguchi M., Okubo M. and Matsumoto T., "Effect of particle size on impact properties of epoxy resin filled with angular shaped silica particles", Polymer, Vol. 32(16), pp. 2976-2979, (1991).
[15] Pukanszky B. and Voros G., "Mechanism of interfacial interactions in particulate filled composite", Composite Interfaces, Vol. 1(5), pp. 411-427, (1993).
[16] Nicolais L. and Nicodemo L., "The Effect of particles shape on tensile properties of glassy thermoplastic composites", International Journal of Polymeric Materials, Vol. 3(3), pp. 229-243, (1974).
[17] Nabi Saheb D. and Jog J. P., "Natural fiber polymer composites: a review", Adv Polym Technol, Vol.18, pp. 351–63, (1999).
[18] Li X., Tabil L.G., Panigrahi S. and Crerar W.J., "The influence of fiber content on properties of injection molded flax fiber-HDPE biocomposites", Can BiosystEng., Vol. 08(148), pp. 1–10, (2009).
[19] Malkapuram R., Kumar V., and Yuvraj S. N., "Recent development in natural fiber reinforced polypropylene composites", J Reinf Plast Compos, Vol. 28, pp. 1169–89, (2008).
[20] Wambua P., Ivens J. and Verpoest I., "Natural fibers: can they replace glass in fiber reinforced plastics", Compos Sci Technol, Vol. 63, pp. 1259–64, (2003).
[21] Ahmad I., Baharum A. and Abdullah I., "Effect of extrusion rate and fiber loading on mechanical properties of Twaron fiber-thermoplastic natural rubber (TPNR) composites", J Reinf Plast Compos, Vol. 25, pp. 957–65, (2006).
[22] Crespo J. E., Sanchez L., Gracia D. and Lopez J., "Study of mechanical and morphological properties of plasticized PVC composites containing rice husk fillers", Journal of Reinforced Plastics and Composites, 27, pp.229- 42, (2008).
[23] Yang H. S., Kim H. J., Son J., Park H. J., Lee B. J. and Hwang T. S., "Rice husk flour filled polypropylene composites; mechanical and morphological study", Composite Structures, 63, pp. 305- 12, (2004).