Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 2458-9403
Vol. 3 Issue 5, May - 2016

Particle Erosion of Epoxy Resin

Atia A. M.
Mechanical Engineering Dep.
El Minia Higher Institute of Engineering and Technology
El Minia, Egypt.
E-mail: a.atia@mhiet.edu.eg

Ali W. Y.
Production Engineering and Mechanical Desgin Dep.
Faculty of Engineering, El Minia University
El Minia, Egypt.

Abstract— **Nowadays much attention is focused on the study of solid particle erosion of polymeric materials. This is due to the high potential use of these materials in many mechanical and structural applications. In this work, the solid particle erosion of epoxy resin filled by synthetic oil is investigated in sand blasting equipment. The impact angles (30º, 60º, and 90º), distance from the sand jet and oil content (2.5, 5, 7.5, 10 wt. %) in the matrix have been studied. The results showed a strong dependency of oil content the erosion behaviour of epoxy resin.**

Keywords: Wear, Erosion mechanism, Epoxy.

I. INTRODUCTION

Erosion is important kind of wear, which the solid particles impinge against a target material and cause damage combined with material removal [1, 2]. The distinct characteristics of polymers make them an important class of engineering materials, which are commonly used as mechanical components, particularly in aerospace applications, because they show high specific strength and stiffness. Because of their high strength-to-weight and stiffness-to-weight ratios, they are extensively used for a wide variety of structural and tribological applications [3, 4].

The wear mechanism is affect in too many industrial components. The direct costs of wear failures, i.e., wear part replacements, increased work and time, loss of productivity, as well as indirect losses of energy and the increased environmental burden, are real problems in everyday work and business. In catastrophic failures, there is also the possibility of human losses. Although wear has been extensively studied scientifically, there are still wear problems present in industrial applications. This actually reveals the complexity of the wear phenomenon [5-7].

However, polymer and its composite exhibit poor erosion resistance as compared to metallic materials. It is also known that the erosive wear of polymer composites is usually higher than that of the unreinforced polymer matrix [4, 8, 9]. For many years the researchers were dedicated their effort to investigate the phenomena of solid particle erosion.

Barkoula and Karger-Kocsis [1] presented in 2002 a review article on the solid particle erosion of polymers and polymeric composites focusing on the dominating mechanisms, the most discussed influencing parameters and the different trends observed in the literature. A detailed analysis was given on the effect of experimental conditions (erodent velocity, erodent characteristics, erodent flux rate) and target material characteristics on the erosive response of polymers and polymer matrix composites. In addition, empirical relationships that attempted to correlate the erosion rate with some of the influencing parameters were reviewed. Finally, averaging rules and predictions were summarized.

Arjula and Harsha [10] studied the erosion efficiency of polymers and polymer composites. The erosion efficiency of these materials was plotted as a function of their hardness in order to create an erosion map. In this map a clear demarcation of elastomers, thermoplastic, thermosetting polymers and polymer composites is reflected. However, within the same group of materials a scatter is found in the efficiency map. Therefore, the erosion efficiency can be used only as base line for estimation of the erosion resistance of these materials.

A research, on the effect of fine erodent retained on the surface during erosion of plastic and another surfaces was conducted [9]. The author was concluded that the response of plastic to erosion depends mainly on energy of eroding particles. Coarse particles induce a higher wear rate. On another hand, metal surface shows a better erosion resistance.

Andreska and et al., [11], investigated the erosion resistance of the galvanic coating the polymer composites examined at two different impact angles and particle impinging velocity. The coatings showed a ductile erosion mechanism under all testing conditions. A higher particle velocity did not change this mechanism, but reduced the time to coating failure. At perpendicular impact angle, the coatings failed through delamination, while this effect was not observed at 20º where failure occurred by local complete removal from the substrate.

In the present work, the solid particle erosion of epoxy resin filled by synthetic oil is investigated in sand blasting equipment.

II. EXPREMINTAL

A. *Material and fabrcation method*

Epoxy specimens have been molded in a die of 80 × 80 mm and 3 mm thickness. Epoxy is product of JOTUN Company with commercial name (jotafloor solvent free primer b20). In this study, synthetic oil (5W40) was added to epoxy mixed by 2.5, 5, 7.5 and 10 wt. % oil content. Lay-up method was used as manufacturing technique to produce composites specimens. This method is rapid and not expensive process especially open mould one.

B. *Sand-blast Equipment*

The tests were carried out at an erosion wear test apparatus, where dry and compressed air is used to accelerate the abrasive particles to strike the test specimen. The sand particles are driven by air pressure at room temperature. The time of the test was 4 min. at approximate steady air pressure.

All the erosion tests were performed in a sand blasting chamber, Figs. 1 and 2. The distances between the sample holder and the nozzle were 60, 100 and 160 mm corresponding to 9.5, 7.2 and 6.5 m/s particle velocities calculated from equation 1. This equation represents the calculation of approximate impinging velocity (v_i) as a function of jet stream velocity, acceleration of gravity and distance from the sand jet (H).The impact angle is adjusted by tilting the sample holder. Three impingement angles are selected 30°, 60° and 90º. The erosion tests are operated at room temperature.

$$v_i = \sqrt{(vj)^2 + 2gH} \quad (1).$$

Fig.1 Sand erosion apparatus.

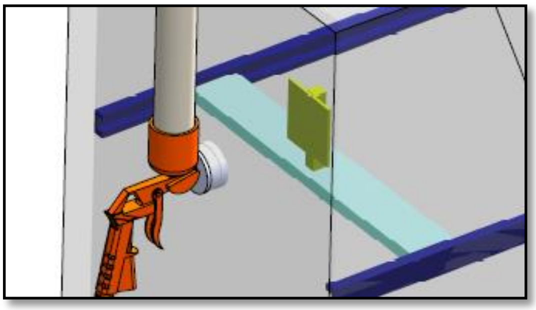

Fig.2 Sand jet and specimen location

III. RESULTS AND DISCUSSION

It is known clearly that the erosive wear can be affected by many important factors, impact velocity, impingement angle, size of particles, their hardness, shape, type and flow rate plus the properties of target material and environmental parameters. This effect tends to show variations depending upon whether the material tested is ductile, semi ductile or brittle. Taking these features into account the studied factors have generally shown that the maximum erosion rate of ductile materials occurs at impingement angle of 30º, whereas maximum erosion rate of brittle materials occurs at 90º impingement angle. The maximum erosion rate of semi ductile materials was found to occur at impingement angle of 60º.

It can be noticed that the transparency of epoxy, which used in the present work is reduced due to the addition of synthetic oil. Obviously, the property of transparency is an advantage of clear epoxy but the benefits of adding oil cannot be ignored, Figs. 3 and 4. Adding oil to the mixture of epoxy before curing made epoxy as a self-lubricant material, where oil is trapped inside pores formed in the matrix of epoxy.

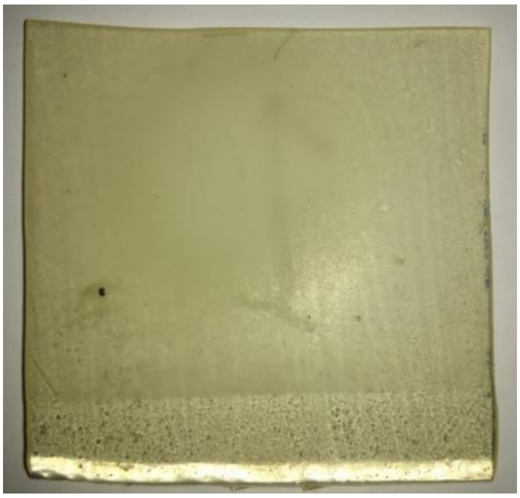

Fig.3 unfiled with oil epoxy specimen

Fig.5 specimen with oil

Fig.6 shows the relation between inclination angle and wear at calculated sand jet velocity of 9.5 m/s. The maximum erosion happened at 2.5 wt. % oil content and the minimum erosion occurs for epoxy resin containing 10 wt. % oil at 90º impact angle. For 7.5 and 10 wt. % oil contents, it has also been observed that, additional to the increase of the impingement angles (60º–90º), the erosion rates tend to progressively decrease. This condition shows that a similar wear was observed for ductile materials. It is clear also from Fig. 6 that wear increases at 30º impact angle. This shows the behaviour of semi ductile material for zero, 2.5 and 5 wt. % oil content in the tested epoxy.

The relationship between wear and inclination angle at 7 m/s calculated particle velocity is shown in Fig. 7. It can be noticed that wear values were decreasing due to change in velocity of the particle comparing to Fig. 3. The minimum wear occurs at 90º at 10 wt. % oil content. On the other hand, the maximum value is presented at 2.5 wt. % oil content at 60º impact angle. However, the behavior of 2.5 and 5 wt. % oil content was the trend of semi ductile material according to the angle of 60º maximum wear. At 7.5 and 10 % wt. % oil contents the trends observed can be described as ductile behaviour because the maximum erosion wear was observed at 30º impact angle.

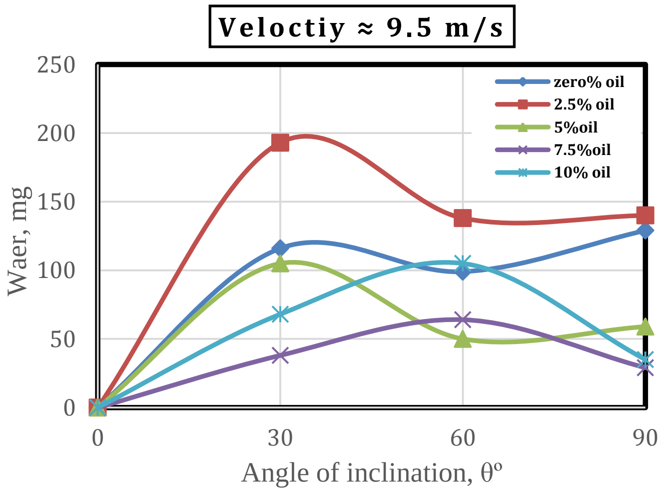

Fig.6 Relationship between impact angle and weight loss for 60 mm distance far from sand jet

Fig.8 demonstrates the effect of impact angle on wear at approximate calculated velocity of 6 m/s. It is obvious that the minimum erosion takes place at 90º for 10 wt. % oil content. However, the maximum erosion occurred in 7.5 wt. % oil at 30º. The cause is attributed to the oil content that transforms epoxy from semi ductile material to ductile one. There was a significant decrease in the values of wear at 6 m/s compared to 9.5 m/s impact velocity. The relative decrease is close to 51 %.

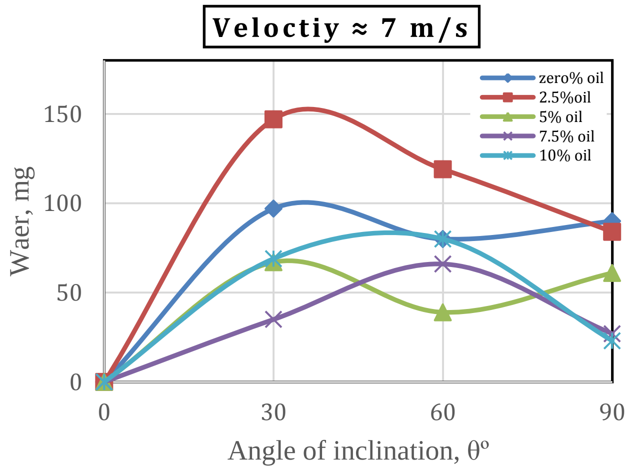

Fig. 7 Relationship between impact angle and weight loss for distance 100 mm far from jet.

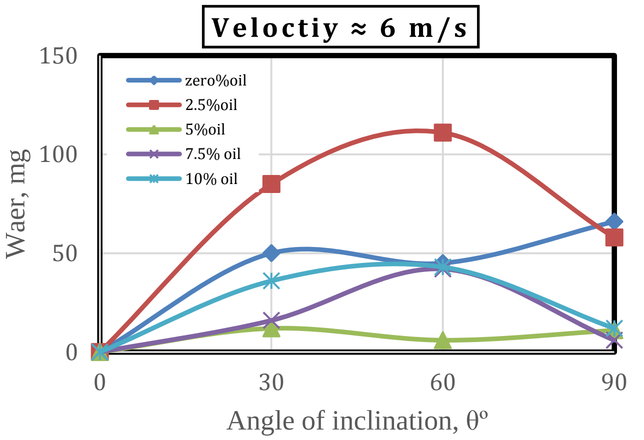

Fig.8 Relationship between impact angle and weight loss for distance 160 mm far from sand jet.

The effect of adding oil to epoxy on wear at calculated impact velocity of 9.5 m/s is in Fig. 9. It is obvious that increasing oil content decreases wear. The maximum wear takes place at 5 wt. % oil at all inclination angles. In addition to that, minimum wear occurs at 90º inclination angle. It can be noticed that 5 wt. % oil shows a significant in wear value for 30º angle.

The effect of adding oil to epoxy on wear at calculated impact velocity of 7 m/s is illustrated in Fig.10. It is noticed that with increasing oil content wear decreases. The maximum wear takes place at 5 wt. % oil. Besides, 90º inclination angle shows the minimum wear for all percentage of oil content. It can be noticed that 5 wt. % oil content shows a reversal in wear value for impact angle 30º.

At 6.5 m/s calculated impact velocity, Fig.11. It is seen that with increasing oil content wear decreases. The maximum wear takes place at 5 % oil wt. % content. In addition to that, minimum wear occurs at 90º inclination angle. It can be noticed that 5 wt. % oil shows a reversal in wear value for impact angle 30º.

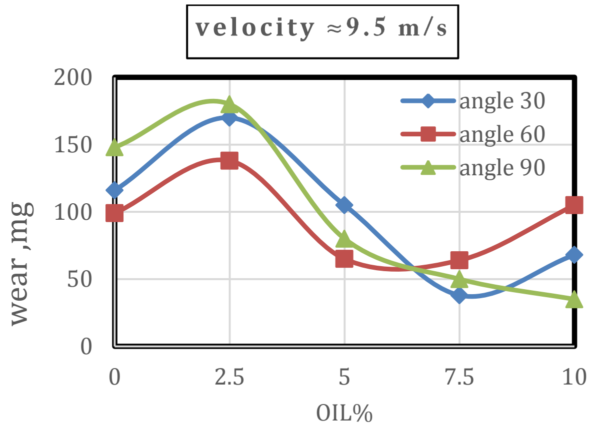

Fig.9 Relationship between oil content and wear at 9.5 m/s particle velocity.

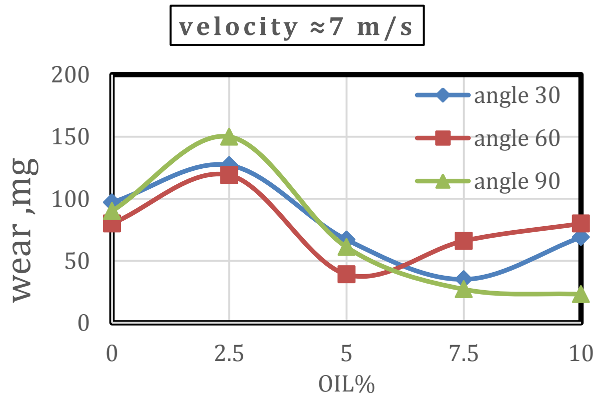

Fig.10 Relationship between oil content and wear at 7 m/s particle velocity.

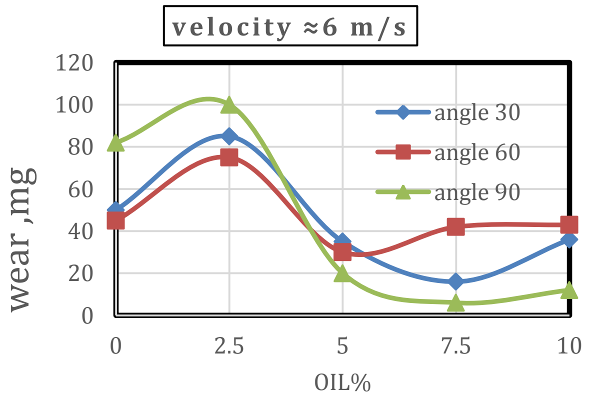

Fig. 11 Relationship between oil content and wear at 6.5 m/s particle velocity.

CONCLUSIONS

Based on this study performed on the solid particle erosion of the tested specimen, the following conclusions can be drawn. (Epoxy/oil) that have 10 wt. % oil content improve erosion resistance. The maximum erosion happened at 2.5 wt. % oil content and the minimum erosion occurs for specimen filled by 10 wt. % oil at 90º impact angle. Increasing oil content for (Epoxy/oil) changes the behavior of the target material from semi ductile to ductile material. The wear decreases with the decrease of particle velocity.

References

[1] Barkoula N-M, Karger-Kocsis J. Solid particle erosion of unidirectional GF reinforced EP composites with different fiber/matrix adhesion. Journal of reinforced plastics and composites. 2002;21(15):1377-88.

[2] Tilly GP. Sand erosion of metals and plastics: A brief review. Wear. 1969;14(4):241-8.

[3] Zhao G, Hussainova I, Antonov M, Wang Q, Wang T, Yung D-L. Effect of temperature on sliding and erosive wear of fiber reinforced polyimide hybrids. Tribology International. 2015;82, Part B:525-33.

[4] Rao KS, Varadarajan YS, Rajendra N. Erosive Wear Behaviour of Carbon Fiber-reinforced Epoxy Composite. Materials Today: Proceedings. 2015;2(4–5):2975-83.

[5] Patnaik A, Satapathy A, Chand N, Barkoula N, Biswas S. Solid particle erosion wear characteristics of fiber and particulate filled polymer composites: A review. Wear. 2010;268(1):249-63.

[6] Bagci M, Imrek H. Solid particle erosion behaviour of glass fibre reinforced boric acid filled epoxy resin composites. Tribology International. 2011;44(12):1704-10.

[7] Atia A. M. AWY. Erosion Behavior Of Epoxy Composites Reinforced By Glass Fibre And Filled By Synthetic Oil. JOURNAL oF THE EGYPTIAN SOCIETY oF TRIBOLOGY. 2015;12(ISSN 2090 - 5882):pp. 50 - 9.

[8] Tewari US, Harsha AP, Häger AM, Friedrich K. Solid particle erosion of carbon fibre– and glass fibre–epoxy composites. Composites Science and Technology. 2003;63(3–4):549-57.

[9] Antonov M, Pirso J, Vallikivi A, Goljandin D, Hussainova I. The effect of fine erodent retained on the surface during erosion of metals, ceramics, plastic, rubber and hardmetal. Wear. 2016;354–355:53-68.

[10] Arjula S, Harsha AP. Study of erosion efficiency of polymers and polymer composites. Polymer Testing. 2006;25(2):188-96.

[11] Andreska J, Maurer C, Bohnet J, Schulz uU. Erosion resistance of electroplated nickel coatings on carbon-fibre reinforced plastics. Wear. 2014;319(1–2):138-44.