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Comparative Mechanical Behavior of Blended and Hybrid Polymers Composites Under Corrosive Environment Experimental and Analytical Study

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Abstract

Two types of polymer-based composite materials were made from locally available materials in the University of Technology-Iraq laboratories. The mechanical behavior of this new composite material (e.g., tensile, hardness and compressive strength as well as wear resistance) were tested under corrosive environment. Results showed an increase in wear resistance of reinforced composites. Composite Iron powder particulate samples showed best wear resistance behavior while chopped asbestos fibers strengthening examples were the worst. Further, hybrid composite showed better wear resistance behavior as compared with composites reinforcing with metallic powder. Tensile test results showed the best results for hybrid reinforced composite polymers while black carbon powder was the worst. Corrosion test showed drop in the wear rate for all selected materials for mono and hybrid reinforcement, with least rate showed by the Iron ad reinforcing material.

Keywords: Polymers, Wear test, Polymer blend, composite polymers, ANOVA

1. Introduction

Polymer blends (PB) are physical mixtures of two or more polymers with/without any chemical bonding between them. Either the main objecting of blending of polymers is achieving practical and commercially viable products through unique properties, or, lowering cost than some other means might provide.

This subject has been the focus of excellent research work, both theoretical and experimental. Properties of the polymer blends are superior to those of mono-polymer.

Blending technology also provides attractive opportunities for reuse and recycling of polymer wastes. Blending has several economic and behavioral advantages, e.g., lightweight, improved mechanical properties like toughness, hardness, etc., extended service temperature range, ability to develop or improve on behavior to meet specific customer needs, the capability to reduce material cost with or without little sacrifice in properties, enhanced ozone, and fire resistance …etc.

In short, unique materials are generating through blending as far as its processability and or performance are concerned. When two or more polymers are mixed, the phase structure of the resulting material can be either miscible or immiscible. Due to their high molar mass, the entropy of mixing of polymers is relatively low, and consequently, specific interactions are needed to obtain blends, which are miscible or homogeneous on a molecular scale [1].

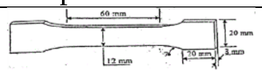
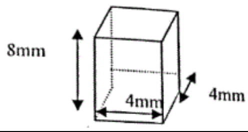
In the case of four immiscible systems, the overall physicomechanical behavior depends critically on two demanding structural parameters [2]: a proper interfacial tension leading to a phase size small enough to allow the material to be considering as macroscopically homogeneous and an interphase adhesion sufficiently strong to assimilate stresses and strains without disruption of the established morphology. Rubber–plastic blends are commercializing as rubber –toughened plastics or as thermoplastics elastomers (TPEs). They bridge the gap between thermoplastics and elastomers [3-9].

This area of research has been the focus of extensive research [10-12] given the properties mentioned above of polymer composites. Bher et al. [13] discussed the possible toughening of Poly (lactic acid) and Thermoplastic Cassava Starch reactive blends using Graphene Nanoplatelets. They reported improvement in the elongation at break and toughness for neat PLA and PLA-g-TPCS reactive blends by addition of GRH nanoplatelets. The mechanism responsible for the development in the mechanical properties of PLA and PLA-g-TPCS in the presence of the nanofiller was the crack bridging.

2. Experimental Work

In this study, two types of polymers were used as base materials for making the composites needed for the study. The polymers selected were the Novolak and epoxy along with their resins. The two polymers were blended and mixed with different types of reinforcing materials, e.g., fibers and asbestos powders as chopped fiber and black carbon as powder and as well as iron. These materials are widely available in Iraq. The percentage of materials blended is a list in Table (1).

Table 1 : Sample dimensions based on ASTM specifications

Test	Sample Dimensions	Standard Specifications
Tensile		ASTM D-638
Compression		ASTM D-695

Mixing was done using a mechanical mixer for one hour for each batch, poured in the oiled wooden mold, and left to harden at room temperatures for 24 hours. After that, the samples were heat treated in the oven for three hours at 60 oC.

The samples then cut according to ASTM standards (ASTM of hardness D-39576, ASTM of tensile D-638 and ASTM of wear D-695) for conducting the three different mechanical tests, e.g., tensile, wear and hardness. The samples are shown below in Fig. 1 and the specifications are shown in Table (1).

Figure 1 :Test samples

Figure 2 : Instron universal testing instrument

Two groups of composites called with letter C and H depending on the concentration of the enforcing materials. Seven groups were making. The groups were first tested for mechanical properties using Instron universal testing instrument for tensile test and shore d hardness tester TH210 for hardness. Wear test was done using sliding wear machine which has a velocity of the iron disc (500 cycles/min.), and disc hardness (269 HB), using grinding paper (silicon carbide) with (1000 degree).

The tensile testing instrument used in this experiment is shown below in Fig. 2. The samples first tested before being immersed in the saline solution to check their properties for comparison. Then, they were dipped in a salt solution (NaCl) having normality (2N) for three months. The samples tested every two weeks to examine the effect of salt solution on their respective properties.

3. Results and discussion

The discussion of the results will be divided into three main parts. The first part will discuss the effect of loading on the wear rate. The second will consider the interaction, from the design of the experiment, between the different parameters. The final section will explain the effect of saline solution on the part's behavior.

3.1 Effect of test parameter on the wear rate

The effect of mechanical loading on the specimen's behavior is shown in Fig. 3. The results show given after 2 hours of the application of the load. Phenol formaldehyde was used as the resin (as a plane) and as composites when reinforced with mono-type materials (e.g., asbestos C1, black carbon powder C2, & with iron powder C3), and the "H" types were enhanced with dual-type of materials as shown in Table (2). The results of testing (wear) show increment of were rate with load change from (10, 15 to 20 N), as a result of the rise in abrasion force with compression load. This force causes the connected bonds in polymers which have (cross-linked structure) with Novolak to be broken.

It was also noticed that for all mono-type reinforcement materials (C- to C3), the wear rate is reduced compared with the plain Novolak. The least wear rate registered was for C3 (using iron powder). The maximum reduction was noticed for C3 material at 15 N loads, which reached 52% and 44% at 20 N loads.

Dual-type material H1 showed an increase in wear rate by 20% at 15N and 2.35% at 20N.

Further noticed from the figure, that, all the mono-type materials were performing much better (i.e., reduction of wear) compared with the dual-type materials.

Table 2 : Reinforcements materials used

Reinforcements Mixture (10%)		Reinforcements Materials		
		Asbestos fibers	Black carbon powder	Iron powder
Single or Mono Composites	C1	10%	0	0
	C2	0	10%	0
	C3	0	0	10%
Binary or Dual hybrid	H1	5%	5%	0
	H2	5%	0	5%
	H3	0	5%	5%

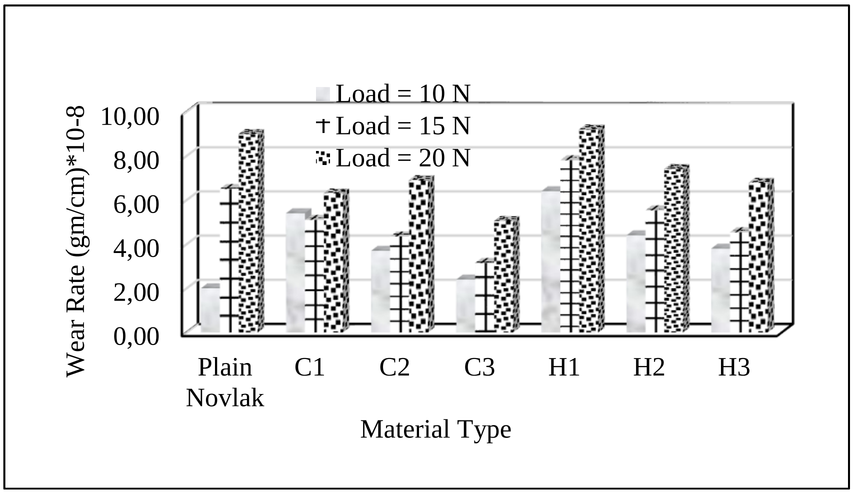


Figure 3 : Wear rate variation for different loads.

3.2 Effect of Immersion Duration

The last section of this discussion is the effect of working under a saline solution on the mechanical behavior of the above-tested materials. In this phase, three types of tests were made every two weeks interval and at 2N load. The tests conducted were the wear rate, hardness test, and stress-strain tensile pressure. It is a well-established fact that the strength of a polymer and its composites against the corrosive working environment depends on many parameters, which are relating to a common condition such as temperatures, normality type of solution and others.

3.3 Wear Rate Test

Wear test is shown in Fig. 4. It is noticing the wear rate values of the sample increased with increasing the time of exposure. This is because of Novolak, and its hybrids are in contact with the solution of low molecular weight, which causes these molecules to pass through the material by filling voids leading to swelling for polymeric composites, degradation and ultimate destruction of the composite bonds.

Also, it is seen that the ability of composite to absorb water is higher than the capacity of Novolak to do this, especially with fiber reinforcement and less from that behavior when mixed fiber or additives. Therefore, the wear resistance increased with hybrid and composites than Phenol formaldehyde resin alone.

Further, as the figure shows, the wear rate for both C3 and H3 materials were the lowest. Keeping in mind that they both contain Iron and Carbon powders, the ability of the saline liquid to penetrate through the bonds of these materials is much less compare with others; hence, less wear is expected.

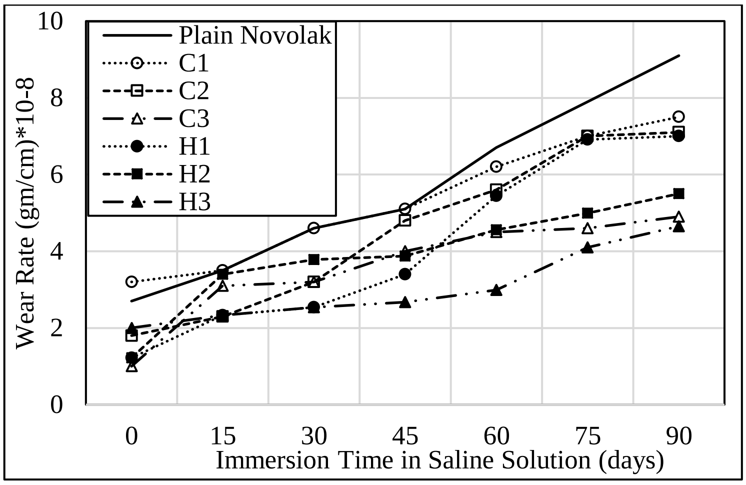


Figure 4 : Wear rate of plain Novolak and composites with load (2N) time (2Hr).

3.4 Hardness No. Test

Hardness test is shown below in Fig. 5. The first thing to notice is the increased hardness of the base material (material with Phenol formaldehyde resin reinforcement) after using both mono and dual type of reinforcement materials. However, this hardness improvement decreases with immersion time for all selected materials. This is because of the affected on the fiber and matrix interface that increases with time, hence, weakness in the bonding between the composite matrix and reduced hardness.

In a similar fashion as that for tensile test, materials containing iron and carbon composites showed the highest hardness values over the whole period of immersion.

3.5 Tensile strength test

Tensile strength test results are shown in Fig. 6. The figure clearly shows that with the Phenol formaldehyde resin, i.e., plain Novolak sample, the material was brittle and it failed with least strain abruptly. Now, with the addition of the mono-type reinforcement materials C1, C2, and C3, the material remained brittle but still more elastic than the plain Novolak and with higher values of stresses at failure. Further, it is noticed that the hybrid or dual-type results showed better tensile strength as compared to other composites or matrix material (Phenol formaldehyde resin).

This is due to the existence of iron powder or asbestos fiber behaviors, excepted black carbon powder show properties against solid carbon as graphite or carbon fibers.

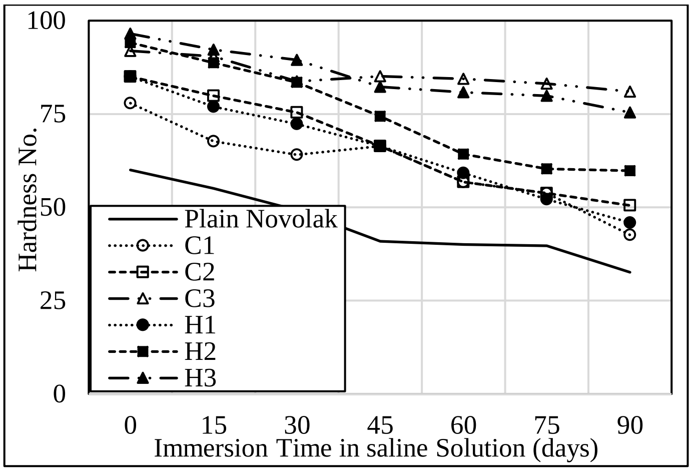


Figure 5 : Hardness of plain Novolak and composites

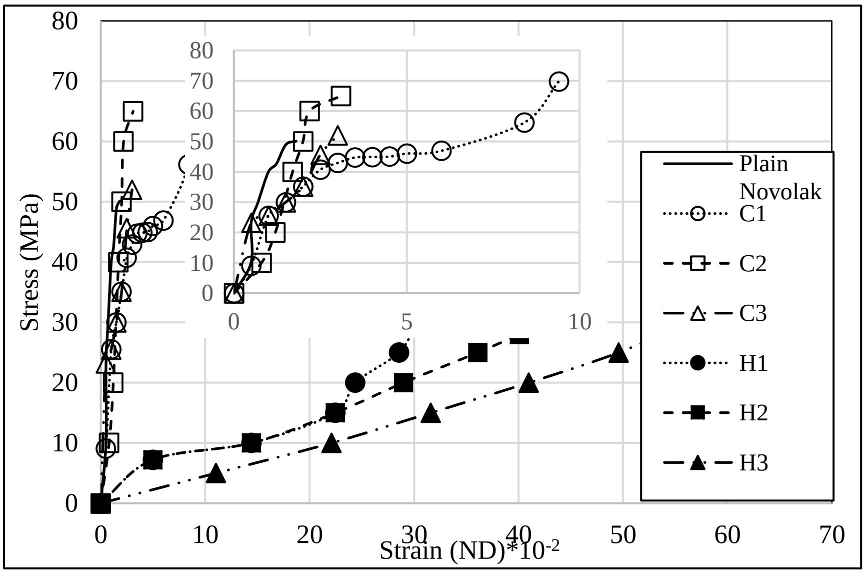


Figure 6 : Stress- Strain curves of plain Novolak and composites

4. Conclusions

1. Composites with loading ratio (10%) of black carbon powder mixed with Novolak decreased mechanical properties, but when mix with other fibers as hybrid composites increased and improved of this value.
2. Composites and hybrid composites have less absorption as compared with Novolak and as composites with asbestos fibers.
3. Obtained the primary goal of this work (improved some of the mechanical properties) under acid conditions by using salt solution.
4. The chosen different types of additives simulate the real applications and industrial uses of Novolak.

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