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Studying of Some Mechanical Properties For Polymeric And Other Reinforced Blends Under The Influence of Chemical Solutions

Dr. Balqees M.D. Al-Dabbagh* **Zaid Ghanem M. Salih***

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Abstract

This work is carried out with using of unsaturated polyester resin mixed with natural rubber (90%-10%) to compose a polymeric blend. This polymeric blend is the matrix, which reinforced with several types of reinforcements (Al powder, Al wires, and glass fibers G.F) with a volume fraction of 20%.Hand Lay-up method is used in fabrication of samples of research.

Four samples are prepared: -

1. Blend (Unsaturated polyester + Natural Rubber).
2. Blend reinforced with hybrid (Al wires + glass fibers).
3. Blend reinforced with Al wires.
4. Blend reinforced with Al powder.

Several mechanical tests are carried out on these samples, and these are:- hardness test, compression test, and impact test**.**These tests are carried out on samples under the influence of normal conditions (room temperature) and after immersion of all samples in the chemical solutions (KOH, HNO_3, and Na_2CO_3) for 1, 2, and 3 months. The normality for all these chemical solutions is 1N.Results show that highest values of impact strength obtained with samples of blend reinforced with hybrid reinforcements (Al wires + glass fibers) at all conditions of test (room temperature and after immersion in chemical solutions).While, highest values of compression strength obtained with samples of blend which is composed from (Unsaturated polyester + Natural Rubber) at all conditions of test.Finally, highest values of hardness obtained with samples of blend reinforced with Al powder at room temperature.

The tests results are affected negatively by all of the chemical solutions, but the base solution KOH is the most effective solution.

دراسة بعض الخصائص الميكانيكية لخلائط بوليميرية وأخرى مدعمة تحت تأثير المحاليل الكيميائية

الخلاصة

أجريَ هذا البحث باستخدام راتنج البولي أستر غير المشبع والذي مُزج مع المطاط الطبيعي بنسبة (90%-10%) لتكوين خليط بوليمري. هذا الخليط البوليمري هو المادة الأساس ، والتي تم تدعيمها بعدة أنواع من مواد التقوية (مسحوق الألمنيوم ، أسلاك الألمنيوم ، وألياف

* **Applied Science Department, University of Technology / Baghdad**

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2412-0758/University of Technology-Iraq, Baghdad, Iraq

الزجاج) باستخدام كسر حجمي مقداره 20%.استخدمت طريقة القولبة اليدوية في تصنيع نماذج البحث.تم تحضير أربعة نماذج:

1. الخليط البوليمري (البولي أستر الغير المشبع + المطاط الطبيعي).
2. الخليط البوليمري المدعم بهجين (أسلاك الألمنيوم + ألياف الزجاج).
3. الخليط البوليمري المدعم بأسلاك الألمنيوم.
4. الخليط البوليمري المدعم بمسحوق الألمنيوم.

تم أجراء عدة اختبارات ميكانيكية على هذه النماذج ، وهي: اختبار الصلادة ، اختبار الانضغاطية ،و اختبار الصدمة.تم إجراء هذه الاختبارات على النماذج تحت تأثير الظروف الطبيعية (درجة حرارة الغرفة) وبعد غمر النماذج في المحاليل الكيمائية (KOH, HNO3, Na2CO3) ولمدة شهر ، شهرين ، وثلاثة أشهر. العيارية لجميع المحاليل الكيمائية كانت مساوية لـــ 1.تظهر النتائج أن نماذج الخليط البوليمري المدعم بهجين (أسلاك الألمنيوم + ألياف الزجاج) تمتلك أفضل خصائص ميكانيكية لمقاومة الصدمة في جميع ظروف الاختبار(درجة حرارة الغرفة،وبعد الغمر في المحاليل الكيميائية).بينما تم الحصول على أعلى قيم لمتانة الأنضغاط للخليط الذي يتكون من(البولي أستر غير المشبع مع المطاط الطبيعي) لجميع ظروف الاختبار.وأخيرا نماذج الخليط البوليمري المدعم بمسحوق الألمنيوم تمتلك أعلى قيم للصلادة في درجة حرارة الغرفة.جميع المحاليل الكيميائية أثرت وبشكل سلبي على نتائج الاختبارات , لكن المحلول القاعدي KOH كان الأكثر تأثيرا.

Introduction

Thermosets**:** Refers to materials that have significant strength and stiffness so as to be common metal substitutes. They have disadvantages of not being recycled and, in general, having fewer variables processing techniques. [1].Polymer blend (PB) is a mixture of at least two polymers. There are two types of blends miscible and immiscible, which lead finally to form polymer alloys. [2].There are several reasons for blending polymers [2]

1.Extending engineering resin performance by diluting it with a low cost polymer.

2. Developing materials with a full set of desired properties.

3. Forming a high performance blend from synergistically interacting polymers.

4. Adjusting the composition of the blend to customer specification.

5.Recycling industrial and/or municipal plastics scrap.

Natural rubber is highly elastomeric, even after moderate crosslinking. The elongation is about 1000 % for most vulcanized natural rubbers. [3].

Compared to other elastomeric materials, N.R. is also characterized by:-[3]

1. High tensile strength.
2. High tear strength.
3. Excellent resilience.
4. Resistant to cold flow.

Resistant to wear.
5. Resistant to fatigue.
6. Low energy loss when stretched and returned to original shape.The term 'polyester resin' is applied to the condensation reaction products of diacids and diols (glycols). They are, therefore, strictly alternating polymers of the type shown below: - [4] __ A __ B __ A __ B __ A __B
Polyesters are non-linear resins. They have a good resistance to oils and solvents. [5]
A composite is any heterogeneous material or structure in which the properties vary with position in the object. Composite consists of two or more physically distinct materials. It can be made by mixing the separate materials in such way that the dispersion of one material in the other can be done in a (some what) controlled way to achieve optimum properties.
The properties are superior and possible unique in some specific respects to the properties of the individual components. [6].

Experimental Part

Hand lay is the mainstay of fiber reinforced plastics (FRP) processing due to its versatility in accommodating many of the difficulties traditionally associated with plastics molding .[4]
Al Mold is used for the preparing of samples. The dimensions of this mold are (25cm * 25cm). Toluene is used for dissolving the natural rubber which composed with UPE for getting the blend. The ratio of blending is (90% for UPE-10% Natural rubber).

This blend reinforced with several kinds of reinforcements using hand lay- up method. Blend reinforced with Al powder, Al wires, and hybrid reinforcements (Al wires+ glass fibers) with one volume fraction (Vf= 20%)

for all kinds of reinforcements.Most of calculations in composite materials related with volume fraction (Vf) for the variable concentrations. So, volume fraction can be combined with weight fraction ψ for variables, as in the following :

$$Vf = \frac{1}{1 + \frac{1-\psi}{\Psi} \cdot \frac{\rho_f}{\rho_m}} \quad (1)$$

Where:- ρ_f is the density of fibers(gm/cm^3).
ρ_m is the density of matrix. (gm/cm^3).
In this work four kinds of samples are prepared. These samples are:-

1. Blend: - In this sample, UPE (made in K.S.A) is blended with N.R. (It must be mentioned that the natural rubber has been made in the factory of tires, Babylon, Iraq).Hardener and accelerator must be used for getting the sample as fast as possible. Contents of blend are mixed very well to avoid bubbles. Optimum ratio of blending is (90%-10%).

2. Blend + hybrid: - The same blend is reinforced with several kinds of reinforcements. The second sample is a blend reinforced with hybrid (Al wires with diameter of 0.08mm + Glass fibers) with a volume fraction of (Vf = 20%). As discussed before,

E-glass is the type of glass fibers used in this work. Glass fibers, aluminum wires are made in Iraq with a purity of 99% for Al.

3. Blend + Al wires: - The third sample, is a blend reinforced with Al wires with a volume fraction of (Vf = 20%). Al wires are cut with the dimensions to be identical with dimensions of mold. i.e. $(25*25)cm^2$, the distribution of the fibers is oriented with$(0\text{-}90^{\circ})$…

4. Blend + Al Powder: - The fourth sample is a blend reinforced with Al powder with grain size of (125-250µm) with a volume fraction of (Vf = 20%). Silica foam that made in Iraq have a grain size of 0.012µm.It is used in this sample to avoid precipitation of powder in mold. Powder dispersion technique is used. Silicafoam is added during the preparation of this sample.Three types of chemical solutions is used in this work(Acid :- HNO_3, Base :- KOH, Salt :- Na_2CO_3). All of these solutions are prepared in laboratory of chemical techniques branch, Dept. of applied sciences, university of technology. The normality for all of these solutions is equal to 1(N = 1).

Special containers made from glass are used to keep these solutions with specimens which are being immerged completely in these chemical solutions for 30, 60, and 90 days. In all these periods, specimens are extracted from these chemical solutions and tested for mechanical properties.

Measurements:

1. Impact test instrument

In this work Charpy impact test is used. It is made in New York, USA. The dimensions of specimens were measured. The test is carried out in accordance with ISO-179. The type of test is destructive and it has a mechanical nature.

Impact strength can be calculated from the following equation:[7]

$$I.S = \frac{\text{Fracture energy}}{\text{Cross sectional area for the specimen}} \ (KJ/M^2) \quad (2)$$

2) Hardness, and compression test instrument

The hydraulic piston was used in this work. Its type is ley Bold Harris, No. 36110. Made in Germany. This device contains a digital micrometer. In hardness test, Instrument can be supplied with a special ball which is used to stick into the specimen and the diameter of impression can be found with a special microscope (the diameter of special ball of instrument used in this work is 2.5mm). While the digital micrometer is used with the compression test for strain measurement. The test of hardness, compression are carried out in accordance with ASTM-E10, ASTM-D695.respectively

Hardness is the resistance of a material to local deformation.[8]

The hardness number BHN is found from the formula:-

$$BHN = \frac{P}{[(\pi(D/2))[D-(D^2-d^2)]^{1/2}} \ (MPa) \quad (3)$$

Where P is applied force in kilograms, D ball indenter diameter in

millimeters, d diameter of impression in millimeters. [9]

Compressive strength, also called compression strength (C.S), is the maximum stress that a rigid material will withstands under longitudinal compression. This strength is measured as force per unit area of the initial cross section of the test piece. [8].

Results and discussion:

1) Impact test

In normal conditions, results show that hybrid composite (UPE reinforced with Al wires and glass fibers) has highest value of impact strength (I.S). Blend reinforced with Al wires has high value of (I.S) but this value is less than the value of (I.S) for hybrid composite.

In general, there is an increase in fracture energy for samples, which are reinforced with fibers as compared with the blend only, see figures (1, 2, and 3). Fibers bear the highest part of impact stress; fibers here act as a crack stopper. [10]

For sample of blend reinforced with Al powder, weak results are obtained of (I.S) because the particles of powder can cause regions of stress concentration so they are not qualified to resist the fast stresses. [7]

For all types of chemical solutions, which is used in this work, results show a decrease of impact strength for samples of blend and blend reinforced with Al powder, see table(1).

While samples of blend reinforced with Al wires and hybrid show an increase in the values of impact strength especially after 30 days of immersion in HNO_3 and Na_2CO_3 then values of impact strength are decreased as shown in figures (2,3). Blend reinforced with hybrid (Al wires and glass fibers) showed, generally, highest values of impact strength as compared with other samples. Chemical treatments is conducted to improve the separation of individual fibers and the adhesion with the composite matrix, undesirable effect such as loss of mechanical performances, restructuration through strong swelling or surface degradation can occur[11].

2) Compression test

In normal conditions, blend, which is composed from (UPE+N.R), possess the highest value of compressive strength, see table (2). This behavior can be explained as the existence of strong interfacial adhesion in order to transmit the applied force effectively between the component phases. [12]

Blend reinforced with Al wires has a compressive strength value lower than the blend as shown in table(2) and figures(4,5,and6). The strength of Al wires plays an important role in obtaining a high value of compressive strength. As compared with other reinforcements. As the metal fibers are ductile, the strength of the composite is usually dominated by the fiber strength.

Hybrid composite here is failed to give a high compressive strength, due to buckling of wires while applying compression stress to the sample [13]. Moreover, adhesion between fibers and matrix is weak, causing an effect on the results of the compression strength for the hybrid composite sample. Generally, the compressive

strength values are decreased after immersion of specimens in chemical solutions, especially the base solution (KOH), which is the most effective factor on samples. Blend (UPE+N.R.) still keeping high values of compressive strength as compared with other samples. Brittle materials like thermoset resins (like polyester and epoxy) have a high compressive strength as compared with their resistance to tensile stresses.

Generally and exhaustive ,for blend reinforced with Al wires, these samples are possessed lower compressive strength as compared with the blend only. The compression strength is affected by the fiber volume fraction (Vf) [13]. In this work a small volume fraction is used (20%) which is greatly affect the results of compression strength. Hybrid composite still has lower values of compressive strength as compared with other samples. The buckling of fibers happened early, which means that the existence of holes in specimen led to a failure finally [14]. Moreover, weak interface between fibers and matrix leads to failure of hybrid composites.

For samples of blend reinforced with Al powder, the decrease of compressive strength is due to the spread and diffusion of chemical solutions in samples [15].

While the increase (some times) of compressive strength for these samples is due to the existence of (N.R.) which has been blended with UPE. (N.R.) may work as a coupling agent. See figures (4, 5, and6)

Hardness test

In normal conditions, the sample of blend (UPE+N.R.) reinforced with Al powder has a highest value of Brinell number as compared with other samples, see table(3).While sample of hybrid composite (blend reinforced with Al wires and G.F) occupying the second order, then the blend reinforced with Al wires, see figures(7,8,and9).

This situation can be explained as the existence of strong bonding at the matrix – particle interface, which leads to high Brinell number for sample of blend reinforced with Al powder. The matrix transfers some of the applied stress to the particles, which bear a fraction of the load,(but the transferred load here is small as compared with fibers). [16]

Another important reason why the blend reinforced with Al powder posses a high Brinell number is that particulate composites differ from the fiber and the flake types in that distribution of the additive constituent is usually random rather than controlled. Particulate composites are therefore usually isotropic.[17]

Generally, fillers are used with polyesters to reduce their cost and improve some of their mechanical properties; increase hardness, thermal conductivity, wear and chemical resistance. [18]

After being immerged in chemical solutions, generally, samples of blend reinforced with Al wires have highest values of Brinell hardness number. Samples of blend reinforced with hybrid (Al wires + glass fibers) occupy the second order. This situation can be explained as:-

The existence of Al wires as a reinforcement material increases the value of hardness for such material because metals are materials that possess a high ratio of plastic deformation.

Moreover, wires distribute the applied load on samples over more area which leads to a decrease in the applied load on a unit area and then an increase (raise) in the surface resistance of the material. [19]

Generally, chemical solutions play a major role in decreasing values of (BHN). As the time of immersion increases, chemical solutions work on degrading the material leading to its failure. Diffusion of chemical solutions through the materials (polymeric materials) led to break bonds with the appearance of bubbles. [19]

Moreover, weak bonding between the filler and the matrix increases the porosity and hence the absorption. [18]

This can be clearly noticed for samples of blend reinforced with Al powder.

Conclusions

1. Results of impact test show that samples of blend reinforced with hybrid (Al wires + glass fibers) have highest values of impact strength at all the conditions of test. Values of impact strength for samples of blend reinforced with hybrid and blend with Al wires increase (some times) even after being immerged in chemical solutions. KOH is the most effective solution on samples due to the obtained values of impact strength.

2. Results of compression test show that samples of blend (UPE+N.R) have the highest values of compressive strength in all the conditions of test. There is a good adhesion between the unsaturated polyester and natural rubber, which gave this result, while samples of blend reinforced with hybrid failed in this test. KOH is the most effective solution in this test due to the obtained values of the compressive strength.

3. Results of hardness test show that sample of blend reinforced with Al powder has a highest value of Brinell number at normal conditions, while after being immerged in chemical solutions, samples of blend reinforced with Al wires possess highest values of hardness of Brinell number. KOH is the most effective solution on samples due to the obtained values of Brinell number.

4. Some times (as shown in tables and figures) the results of (I.S,C.S and BHN) increased even after immersion of samples test in the chemical solutions. Diffusion test must be applied in the future works to obtain more specific expression for the behaviour of composite materials in such cases.

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Table (1) shows the results of (I.S) for the samples of test before and after exposure to chemical solutions.

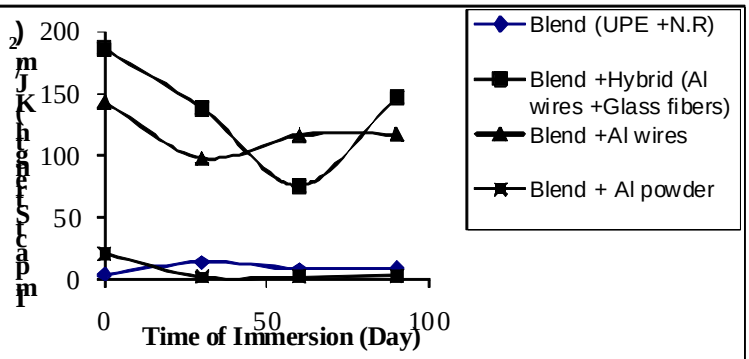
Ambient conditions		I.S (KJ/m^2)			
		Blend(UPE +N.R)	Blend+hybrid (Al wires+G.F)	Blend+Al wires	Blend+Al powder
N.C		4.03963	186.2833	143.3528	20.9933
KOH	30 days	13.9606	138.5076	98.1580	1.9456
	60 days	8.5806	75.8851	116.6000	2.5019
	90 days	9.3251	147.4144	117.4030	2.8392
N.C		4.03963	186.2833	143.3528	20.9933
HNO_3	30 days	4.7893	257.3534	195.4160	2.1026
	60 days	3.9217	201.0031	169.1374	2.0519
	90 days	2.8275	189.1824	113.5168	2.1231
N.C		4.03963	186.2833	143.3528	20.9933
Na_2CO_3	30 days	7.6514	210.3477	255.7188	2.4381
	60 days	4.6230	100.599	248.5294	2.7408
	90 days	4.0551	261.2457	159.6888	1.9161

Table (2) shows the results of (C.S) for the samples of test before and after exposure to chemical solutions.

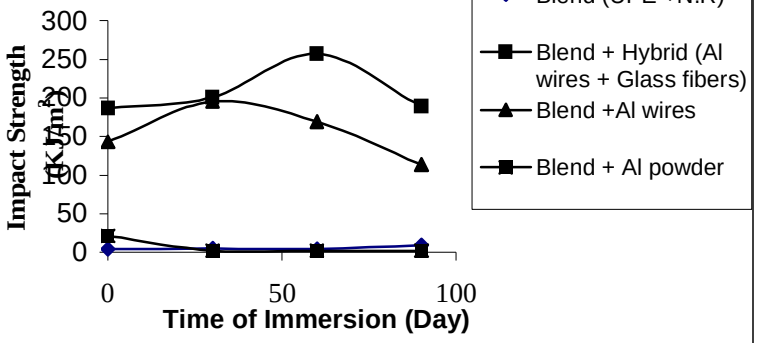
Ambient conditions		C.S (N/mm^2)			
		Blend(UPE+N.R)	Blend+hybrid (Al wires+G.F)	Blend+Al wires	Blend+Al powder
N.C		89.7	29.04	62.35	57.73
KOH	30 days	62.80	48.01	40.28	84.13
	60 days	67.54	13.08	58.31	26.13
	90 days	69.75	10.57	18.62	33.68
N.C		89.7	29.04	62.35	57.73
HNO_3	30 days	80.53	28.87	76.83	91.58
	60 days	70.48	23.10	53.41	50.06
	90 days	75.48	21.49	51.48	55.66
N.C		89.7	29.04	62.35	57.73
Na_2CO_3	30 days	81.83	13.80	63.90	38.88
	60 days	67.27	11.29	44.67	63.86
	90 days	22.28	17.23	36.77	29.35

Table (3) shows the results of (BHN) for the samples of test before and after exposure to chemical solutions.

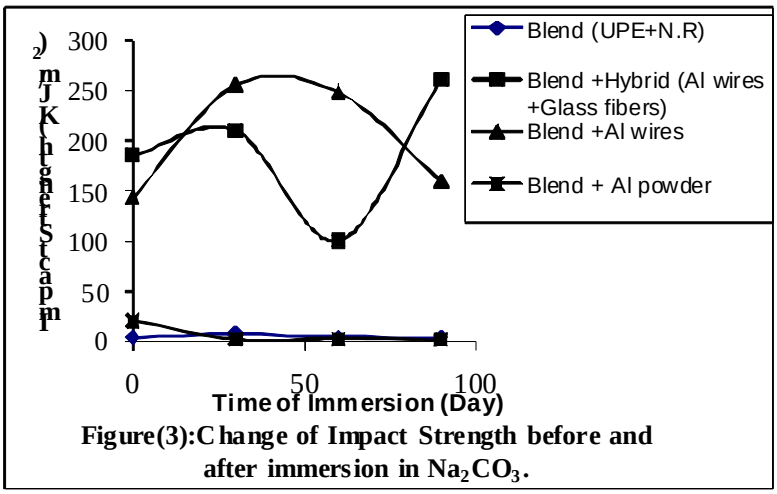
Ambient conditions		BHN			
		Blend(UPE +N.R)	Blend+hybrid (Al wires+G.F)	Blend+Al wires	Blend+Al powder
N.C		97.0506	297.106	254.777	968.8044
KOH	30 days	145.5549	83.7969	254.777	190.9959
	60 days	70.771	297.103	1273.88	166.5068
	90 days	83.7969	190.9959	499.5519	70.771
N.C		97.0506	297.106	254.777	968.8044
HNO_3	30 days	145.554	499.5519	610.3551	136.164
	60 days	83.7969	219.9990	610.3551	166.5068
	90 days	127.388	349.4075	499.5519	111.3989
N.C		97.0506	297.106	254.777	968.8044
Na_2CO_3	30 days	145.5549	166.5068	219.9990	166.5068
	60 days	127.388	166.5068	190.9959	111.3989
	90 days	166.5068	190.9959	254.7770	127.388



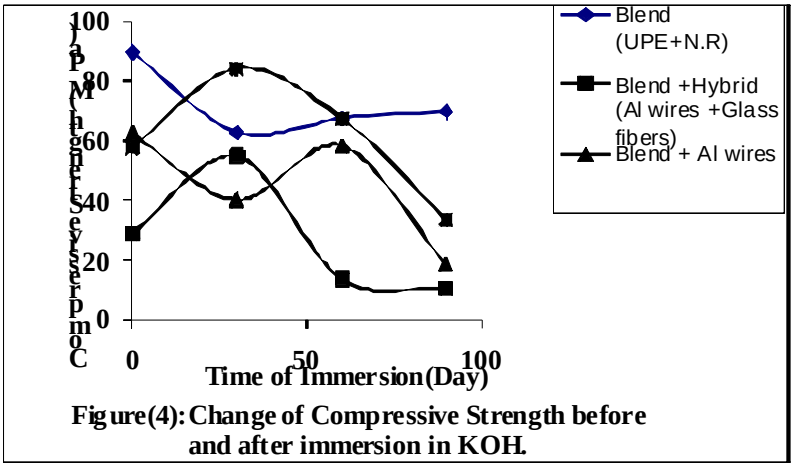
Figure(1):Change of Impact Strength before and after Immersion in KOH.



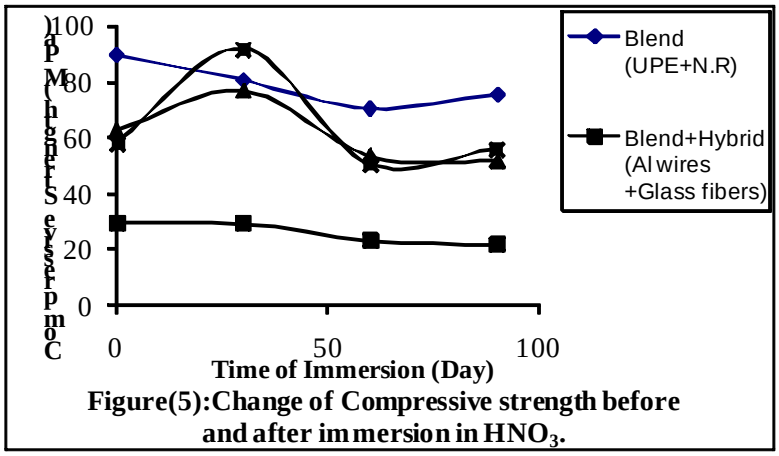
Figure(2):Change of Impact Strength before and after Immersion in HNO_3.



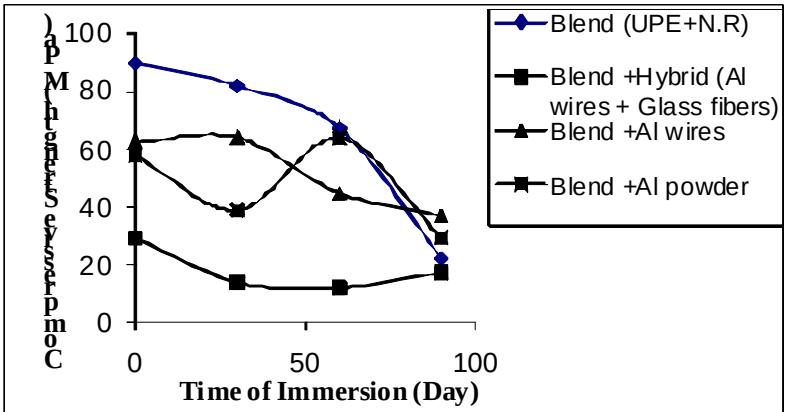
Figure(3):Change of Impact Strength before and after immersion in Na_2CO_3.



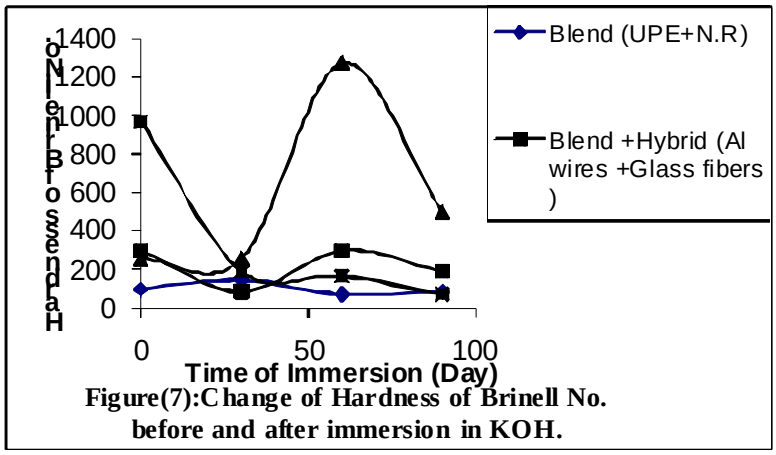
Figure(4): Change of Compressive Strength before and after immersion in KOH.



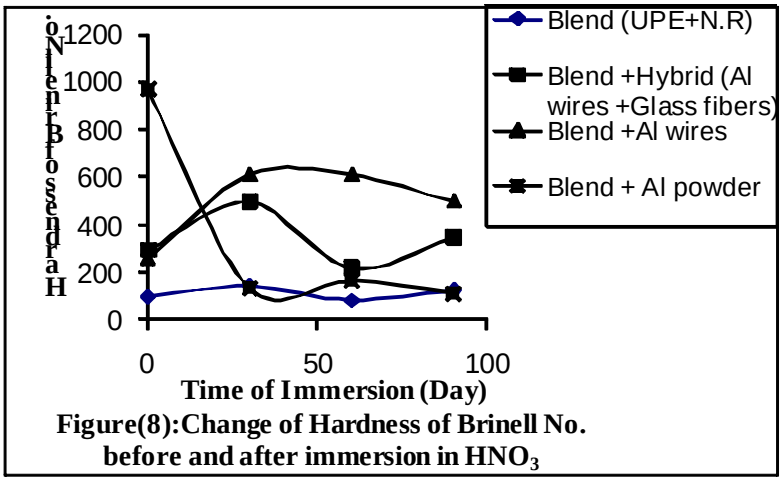
Figure(5):Change of Compressive strength before and after immersion in HNO_3.



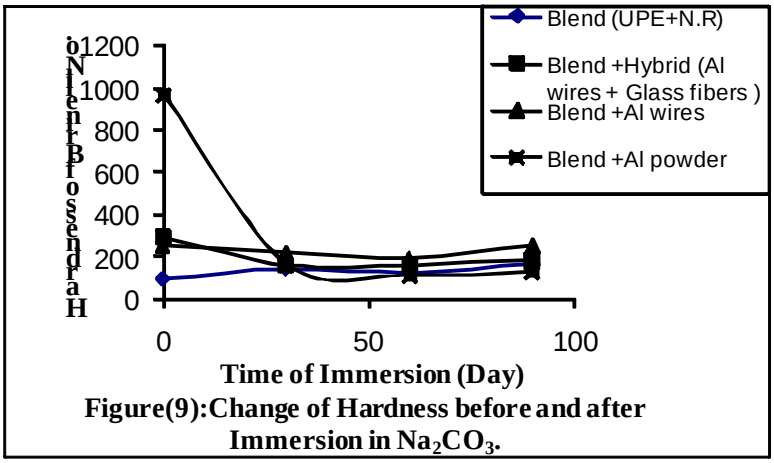
Figure(6):Change of Compressive strength before and after immersion in Na_2CO_3



Figure(7):Change of Hardness of Brinell No. before and after immersion in KOH.



Figure(8):Change of Hardness of Brinell No. before and after immersion in HNO_3



Figure(9):Change of Hardness before and after Immersion in Na_2CO_3.