

STUDY OF THE EFFECT OF ACETONE DILUTION PERCENTAGE ON MECHANICAL PROPERTIES OF EPOXY-ACETONE SYSTEM

Dr. Laith Kais Abbas AL-Haidary

Department of Materials Engineering – University of Technology

Abstract:

A series of epoxy-acetone blends have been prepared with different acetone percentages. After stiffening, the prepared epoxy samples are cured in 40°C for 24 hrs. Then a tensile test for the material specimens was performed by a universal computer aided testing machine.

The measured tensile tests for the specimens reveal that as the acetone percentage is increased, the elastic properties are increased. Nevertheless, when the acetone percentage reaches a maximum value, the tensile properties decreases with further increase in acetone percentages.

The results are explained in terms of that the acetone additions reduces the cross linking density and reduce the brittle character of the prepared epoxy. When the acetone content is more than (5%), the strength becomes to decrease due to severe reduction of cross linking density.

دراسة تأثير النسبة المئوية للأسيتون على بعض الخواص الميكانيكية لمادة إيبوكسي -

أسيتون

د. ليث قايس عباس الحيدري

قسم هندسة المواد - الجامعة التكنولوجية

الخلاصة :

تم تحضير سلسلة من خلطات الإيبوكسي - أسيتون مع نسب مختلفة من الأسيتون . وبعد التصلب ، تمت المعالجة الحرارية بدرجة 40 درجة مئوية لمدة 24 ساعة . وبعدها تم إجراء اختبار الشد للعينات باستخدام جهاز فحص قياسي مدعوم بالحاسوب .

وقد أظهرت اختبارات الشد المقاسة للعينات المحضرة انه كلما زادت النسبة المئوية للأسيتون زادت معها خصائص المرونة للمادة . ولكن عندما يصل محتوى الأسيتون الى القيمة القصوى ، تتراجع خصائص المرونة للعينات عند الاستمرار في زيادة النسبة المئوية للأسيتون .

وقد تم تفسير النتائج على اساس ان اضافة الأسيتون يقلل من كثافة التشابك فيقلل من صفة الهشاشة لعينات الإيبوكسي المحضرة . فعندما تتجاوز نسبة الأسيتون (5%) تبدأ مقاومة العينات بالانحدار بسبب الاختزال الكبير في كثافة التشابك .

Introduction:

The prediction of polymer-solvent system properties has received attention in theory and calculations that assist materials design. Among these studies is that by (Ranganathan, 2005) whose Ph.D. project is on predicting the rheological properties of dilute polymer solutions. As well, (Lee and Kapral, 2006) study the Mesoscopic description of solvent effects on polymer dynamics; also, (Afantitis and coworkers, 2006) study the prediction of intrinsic viscosity in polymer-solvent combinations.

Epoxy is a synthetic thermoset polymer with a complex network structure. Depending on the degrees of cross linking or cross link density, the epoxy shows improved resistances to thermal and mechanical loading and hence dimensional stability. Furthermore, epoxy turns less soluble or ultimately insoluble with solvents (Ghosh, 2006).

However, there is a common practice of adding solvents to epoxy matrix before polymerization to decrease its viscosity and make it easier to handle. The lower viscosity facilitates filling the gaps of objects to be repaired and provides better flexibility for forming processes. It is shown (Oki and Nagasaka, 2006) that surface tension of the polymer-solvent system decreased as the solvent percentage is increased. This encourages applying the polymer-solvent dilute in crack curing process. In addition, a self healing phenomenon is observed in epoxy due to the presence of solvent in the matrix (Caruso et. al., 2007). The solvent promoted self healing of the micro-cracks is shown applied for different commercial types of epoxies and solvents.

The dilution experience is extended to copolymer applications too. A study of the effect of water-ethanol solvent combination on dilution properties (Hooogenboom et. al., 2007) is performed. It is found that the copolymer is soluble (i.e. can be diluted) in water-ethanol solvent even when the copolymer is not soluble in water and ethanol separately. Moreover, the solubility can be tuned in a wide range by only changing the composition of the water-ethanol mixtures.

A recent study (Ahn et. al., 2010) shows that the rheological properties for dilute polymers are altered in a way that the elastic properties are enhanced. Their study show good agreement between experimental results and theoretical calculations.

In this study, the rheological properties of the dilute polymer is not attended; but, its concentrate on the experimental measurements of the mechanical properties of epoxy after stiffening. The epoxy under study is prepared starting from diluted monomer matrix with different percentages of acetone. The aim of this study is to monitor the effect of including acetone in the starting matrix on the final mechanical properties of the set epoxy.

Experimental:

KUT Injectopox commercial epoxy resin is used as the starting material. Analar grade acetone is used as solvent. Table (1) shows the composition of the epoxy-solvent system prepared in this study.

The epoxy samples were casted in silicon rubber molds which have the shape and dimensions compatible with the standard tensile test method for plastics (ASTM D 638-03).

Table (1): The composition of the prepared epoxy-solvent system.

Batch no.	wt% Acetone
1	2
2	4
3	5
4	6
5	8
6	10

After stiffening of the samples, they are cured in laboratory oven at 40°C for 24 hrs.

The cured samples are tested for tensile properties using universal test machine (Sanghai Mobis, China). The output charts are analyzed and the tensile properties are calculated.

The morphology of the failure zones is also photographed and studied. An optical microscope (Bel, Italy) equipped with optical camera connected to a computer; is used to obtain these photographs at different magnifications.

Results and discussion:

Figure (1) shows the stress - strain curves measured for all epoxy samples after curing at 40°C for 24 hrs. The figure clearly reflects the advantage of the acetone additions. Both the young modulus and the fracture stress are increased. The increasing of these properties is proportional to the acetone content. These results can be understood in terms that the acetone additions enhance the elastic properties of the cured products. This phenomenon can be explained by that the acetone additions delays the cross linking density so that the cross linking density decreased as the acetone addition increased. The decrease in cross linking density makes the cured product less brittle, i.e., the elastic properties is increased, this phenomenon is predicted by (Caruso, 2007) previously.

As the acetone percentages increased, it is expected to reach some point that cross linking density is low enough that the tensile properties become to decrease at (5%) acetone percentage. This is illustrated in figure (2), where shown that as the acetone percentages increased above (5%), the young modulus and fracture stress decreased.

Table (2) is a summery of the calculated young modulus and fracture stress as function of the acetone percentages added to the epoxy matrix before setting. The table clearly shows the monotonic increase in the young modulus with the increase of acetone percentage and reaches a maximum (at (5%) acetone percentage) then begins to decrease; this is farther illustrated in figure (5) and figure (6).

Table (2): Young Modulus and Fracture stress for the prepared Epoxies.

Sample no.	Acetone percentage	Young modulus GPa	Fracture stress MPa
1	0%	1.8291	1.01
2	2%	2.431	1.12
3	4%	3.011	1.2
4	5%	3.395	1.53
5	6%	3.236	1.5
6	8%	2.943	1.2
7	10%	2.369	0.92
8	14%	2.290	0.89

The optical micrograph for the surface morphology shows the classical two main regions of polymer fracture surface as shown in figure (7). A glassy (mirror like) region which reflects the failure of stretched polymer strands, followed by an irregular (river) region where the polymer strands have not enough time for complete stretch. More explicit, the tensile stress act to stretch the polymer strands and make them aligned, then the stress cross the failure point and crack initiation and fast propagation takes place. The fast crack propagation is responsible for the brittle (mirror like or glassy) fracture. The region far from the crack initiation is still in the stage of void coalescence and the stretch of polymer chains (strands) did not complete, thus, this region did not reflect mirror like morphology.

Resilience factor(R), (William D. Callister, Jr., 2007), (which refers to the capacity of a material to absorb energy when it is deformed elastically and then, upon unloading, to have this energy recovered) was calculated by the equation below:

$$R = \frac{\sigma_f^2}{2E} \quad (1)$$

Where (σ_f) is the proof stress (Mpa) and (E) is the young modulus (GPa), also finding proof stress was done by drawing a straight line which is parallel to the elastic portion of the stress-strain curve at some specified strain offset, usually (0.002), and some references called it yield strength (William D. Callister, Jr., 2007). Figures (3,4,5) and figure (6) shows clearly that the maximum value of acetone percentage is (5%) and all specimens which it's acetone percentage higher than (5%) gives lower mechanical properties, also figure (1) and figure (2) showed that increasing the acetone percentage from (2%) to (5%) gives an improvement in specimens mechanical properties (i.e. ultimate stress, Young modulus,..., etc) but increasing that percentage more that (5%) will decrease these mechanical properties.

Conclusions:

As a summation, the addition of acetone solvent to epoxy matrix enhance the elastic properties of the epoxy. As the acetone percentage increased the elastic properties is improved and reaches a maximum value at acetone percentage (5%) and then begin to became poorer at further increase of acetone percentage due to severe reduction in cross linking density, and it was observed that the best value of acetone percentage was to be at (5%). Using other solvents and studying the role of these solvents in polymer matrix glass fiber composites is suggested for future study.

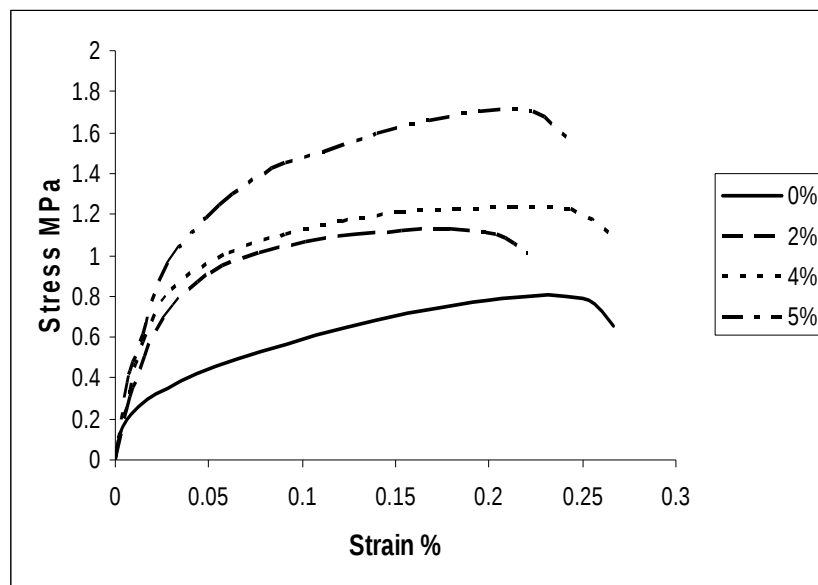


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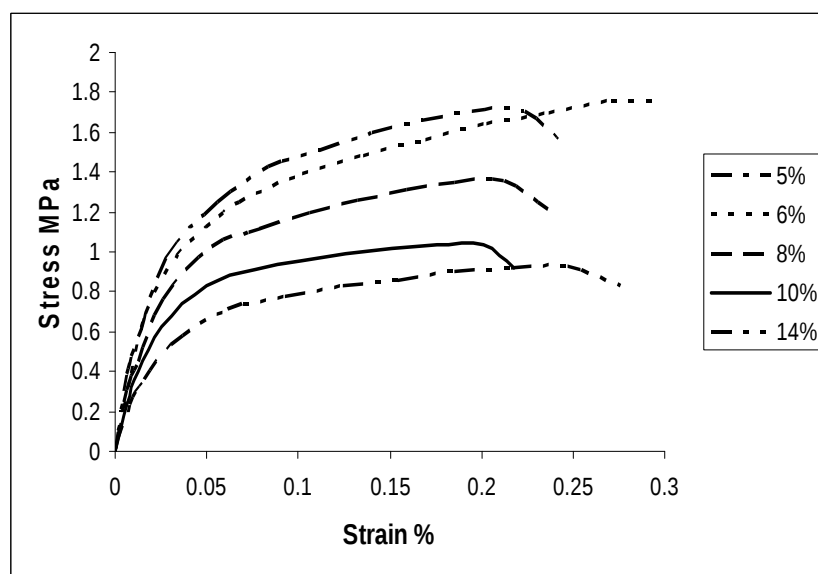


Figure (2): stress-strain curves for the cured epoxy sample, the acetone percentage added to the matrix are as shown (5% to 14%).

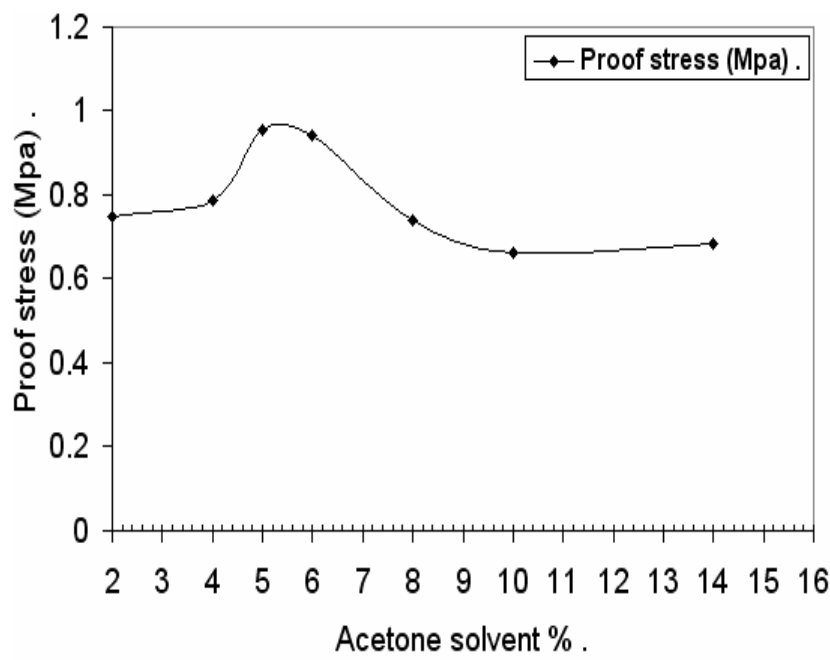


Figure (3): Proof stress – solvent percentage curve.

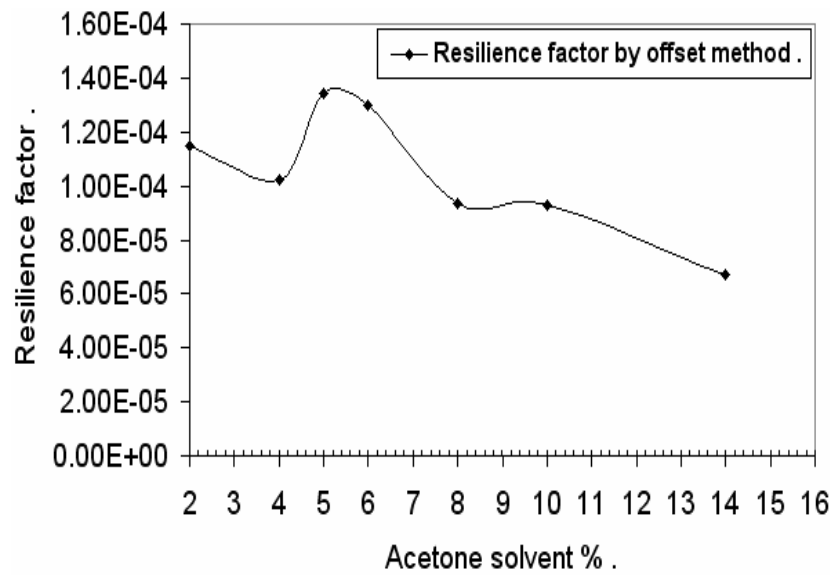


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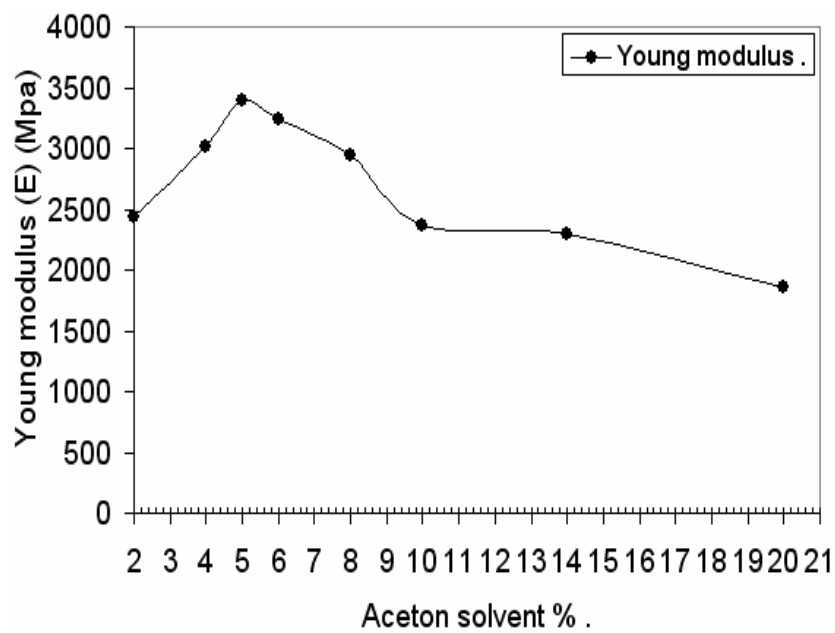


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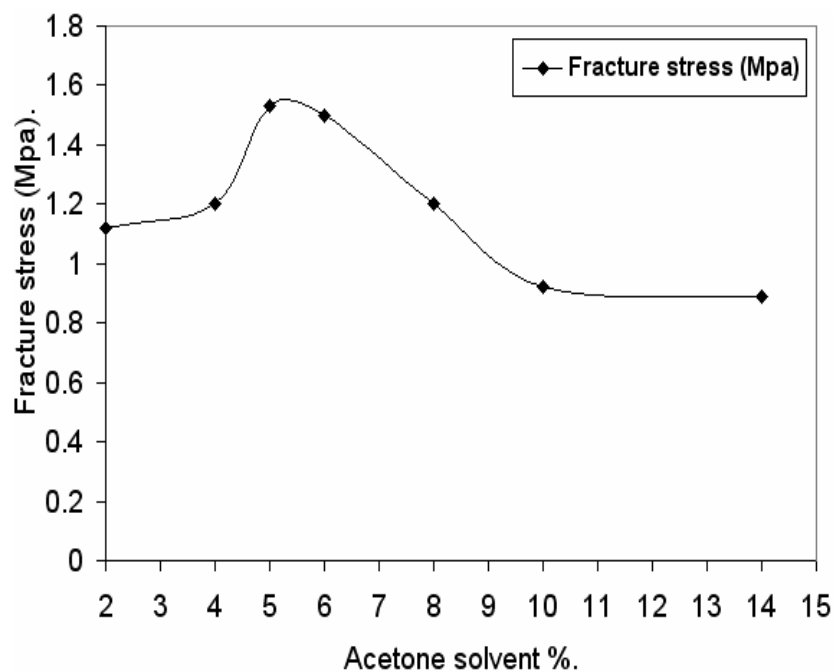


Figure (6): Fracture stress – solvent percentage curve.

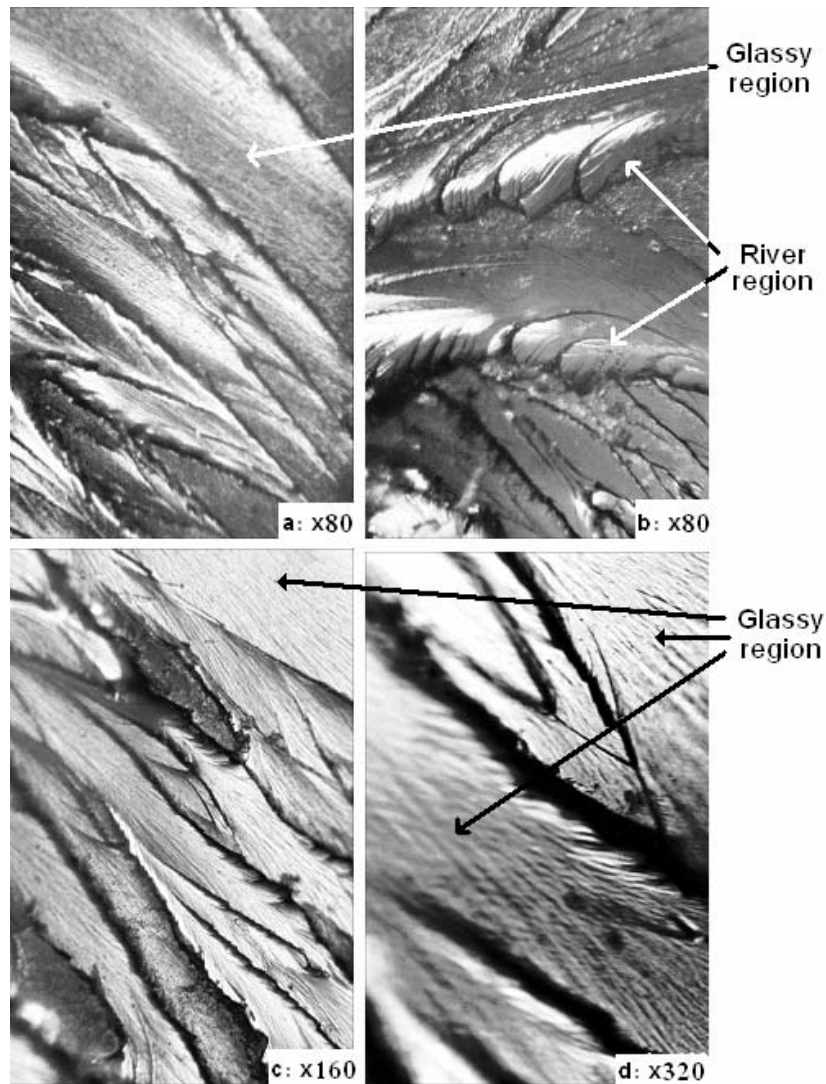


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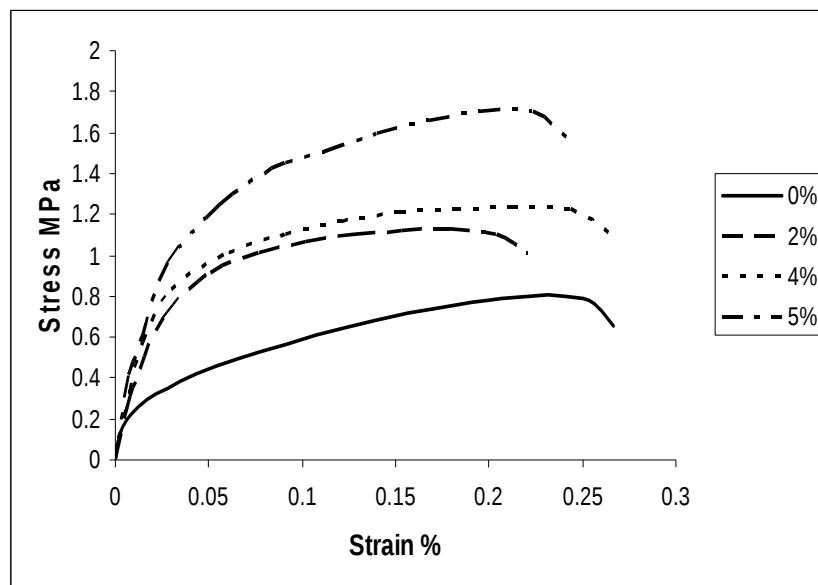


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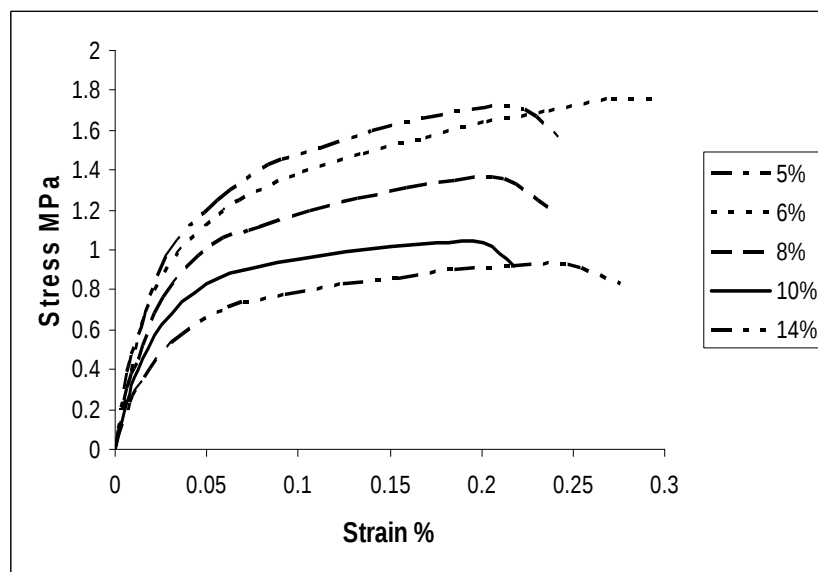


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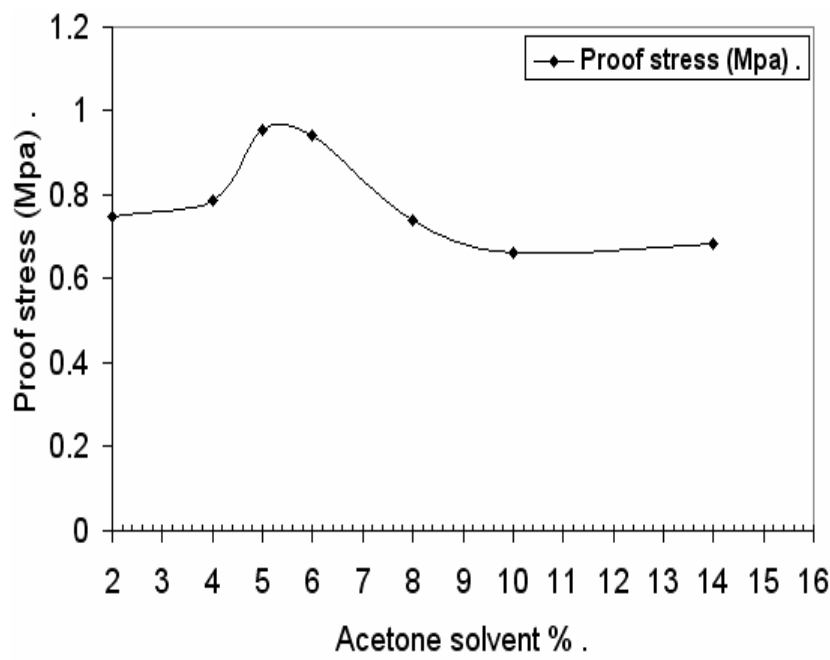


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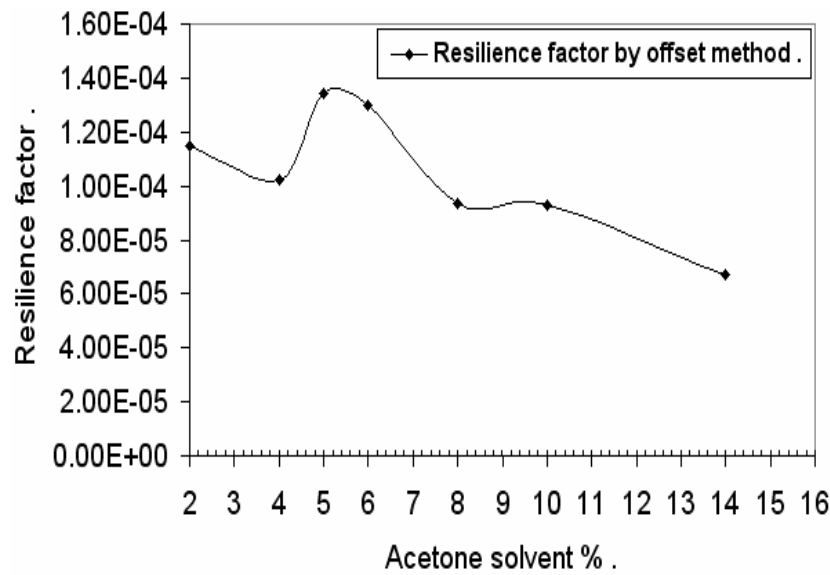


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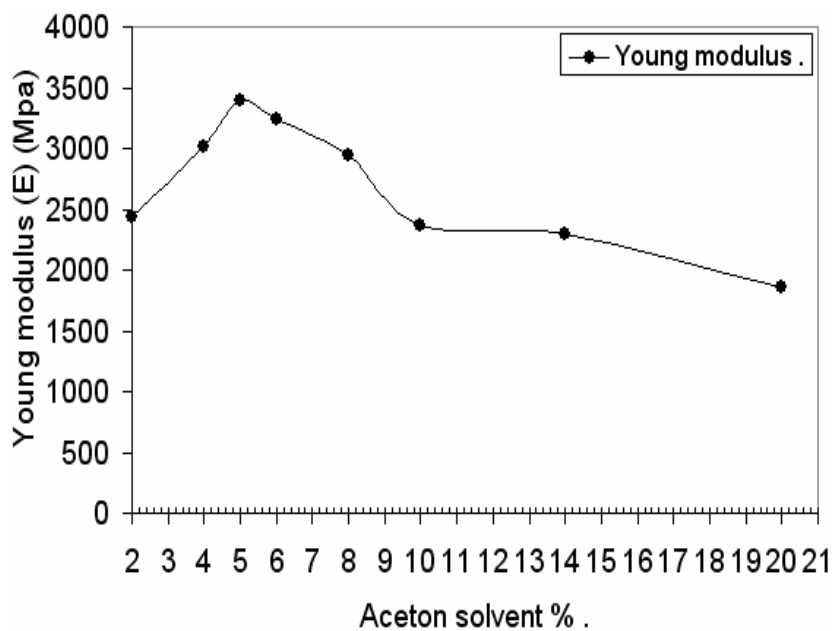


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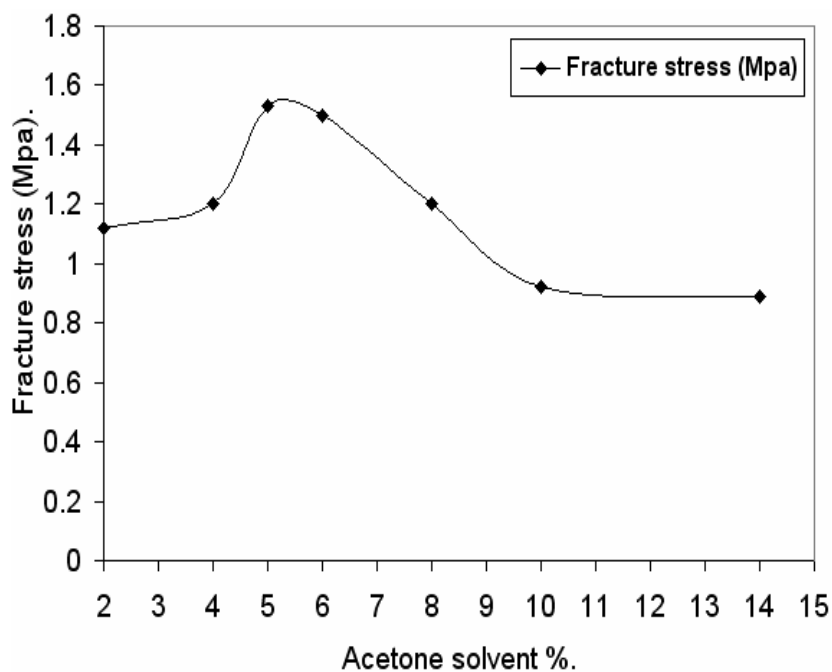


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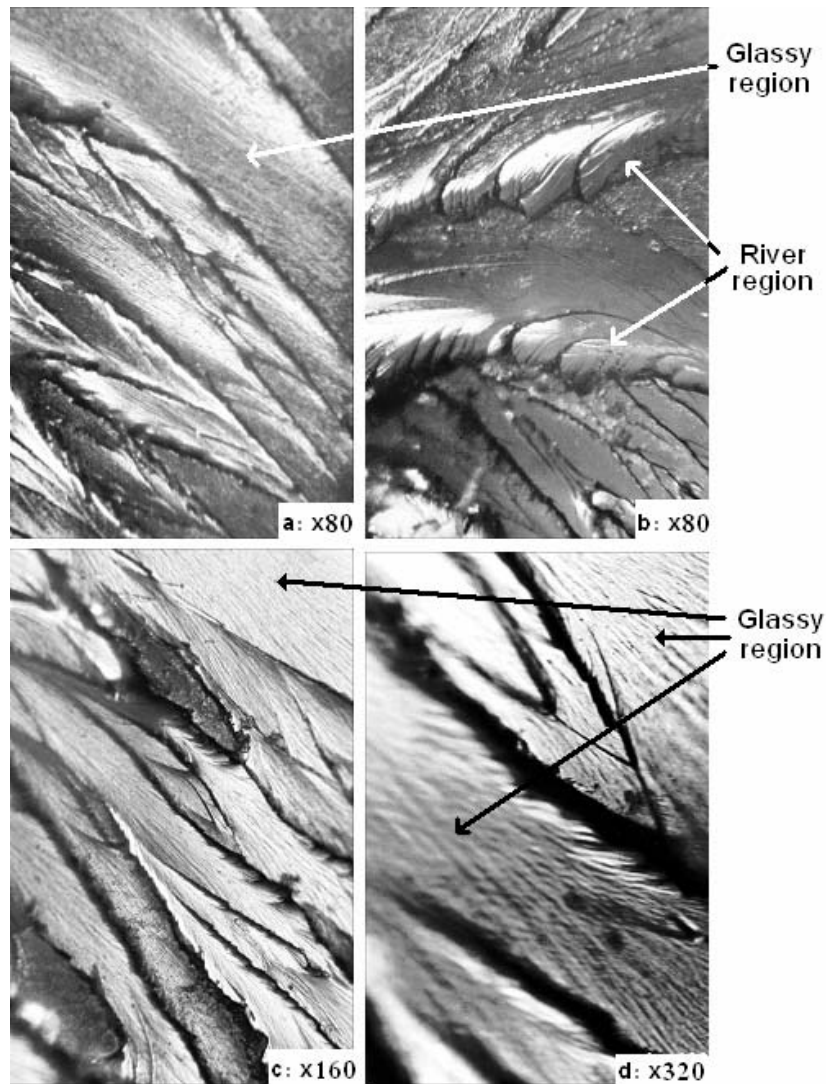


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