

# Toughening of Epoxy Polysulfide Binary Blend Composite

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## Abstract

In a composite structure, it is anticipated that high toughening can be achieved by taking advantage of mixing rubber with epoxy. The purpose of this paper is to investigate the toughness characteristics of Polymeric Composites containing Polysulfide Rubber (PSR) as a toughener to a brittle base epoxy resin. Through comparing with neat resin specimens (epoxy, epoxy +PSR), the results showed that the addition of PSR into polymeric resin enhance toughness of epoxy. Similarly experiment showed that the maximum value of mixing ratio is 6% PSR, which cause a noticeable enhancement in composite strain, but a reduction in tensile strength and modulus of elasticity at fracture.

**Keywords:** Epoxy, Polysulfide rubber (PSR)

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## 1. Introduction

Epoxyes are widely used nowadays in a variety of engineering applications due to their unique characteristics of high adhesive strength, relatively high strength, high stiffness, good hardness, and excellent chemical and heat resistance. However, most cured Epoxy systems show low fracture toughness, poor resistance to crack initiation and propagation, and inferior impact strength.

For this reason, Epoxy is modified with a wide range of materials depending on the desired final properties. If two different or similar materials combining together the result is composite materials, one of them is called matrix which is Epoxy and the other is Polysulfide rubber (PSR) as modifying component. Blending Epoxy with different materials causes an improvement in physical, mechanical and chemical properties [1]. Low fracture toughness of Epoxy can be improved by blending Epoxy resins with additives, such as rubbers, thermoplastics, and organic and inorganic particles [2]. The incorporations of rubbers, thermoplastics and the other polymer particles into Epoxyes can effectively increase their fracture toughness [3]. Polysulfide rubber (PSR) is a special kind of rubbers that can be transformed from a liquid state into a solid

elastomer, even at low temperatures, which makes its use convenient for adhesives, coatings and sealants. due to good moisture, solvent and ozone resistance epoxy is a good choice for this applications . However, the improvement gained by the addition of PSR is compromised by the reduction in some basic properties, such as strength, modulus and glass transition temperature ( $T_g$ ) [4]. Increased attention has been paid in recent years to researchers on polymer composites in general and thermosetting composites in particular, from the point of view of their potential uses in mechanical, optical, electrical, thermal and ablative applications.

**In 2003, Abdul Kader** [5] studied the effect of fillers on the mechanical and aging properties of rubber-plastic binary and ternary blends derived from acrylic rubber, fluorocarbon rubber, and multifunctional acrylates. The addition of fillers, changed the nature of the stress-deformation behavior with a higher stress level for a given strain. The tensile and tear strengths increased with the addition of fillers and with loading, but the elongation at break decreased.

**In 2009, M. S. Bhagyashekar**, [6] observed the effects of material and test parameters on the wear behavior of particulate filled composites (sic-epoxy and gr-epoxy composites). Results showed that the wear resistance and coefficient of friction of both the composites increased with sliding distance and contact load (contact pressure) for the range of filler contents (5–40% wt.) c.

**In 2011, Abdouss and Tohid** [7] studied the effect of Epoxy-polysulfide copolymer curing methods on the mechanical-dynamical and morphological properties. The study showed that the addition of Epoxy to polysulfide and curing with amine hardener nearly always leads to improvement in material properties, particularly the development of some mechanical properties and ductility.

**In 2002, Najlaa** [8] prepared two binary blends, polysulphide rubber (PSR) and Epoxy resin (ER), polysulfide rubber and unsaturated Polyester resin (UPS). It was found that all binary blends have one value of glass transition temperature ( $T_g$ ).

**In 2010, Ban Ayyoub Yousif** [9], investigated the development and characterization of

ternary thermosetting polymer blends. The Epoxy and novolac were resins mixed with either polyurthane (PUR) or polysulfide (PSR) rubbers to compose ternary polymer blends. Results showed that the samples of blends reinforced with Titanium oxide (TiO<sub>2</sub>) powder possess better mechanical properties of impact strength, tensile strength, compression strength, hardness and wear resistance. In this paper an experimental work focused on the enhancement in mechanical properties obtained when toughening epoxy with polysulfide rubber.

**2. Experimental Work**

**2.1. Materials**

Epoxy resin type (Quickmast 105<sup>®</sup> (DCP) containing epoxide group which is thermoset resin and manufacture by commercially produce from Quick Mast company, the hardener from the same company are used to achieve curing of the epoxy resin. The mechanical properties of epoxy are shown in Table 1. One of the most properties that distinguishes polysulfide rubber is that it contains sulfur as part of a series of linear polymer whose trademark is( DCP). The polysulfide is supplied in the shape of white dough that changes to elasticity shape by adding Led oxide(PbO<sub>2</sub> )(black dough) in the ratio 1:16 with density (1.35) gm/cm<sup>3</sup>.Table 2 shows The mechanical properties of polysulfide polymers.

Table 1 Epoxy mechanical properties [1].

Test method	Typical results
Compressive strength	70.0 MPa at 20 °C
Tensile strength	26.0 MPa at 35 °C
Flexural strength	63.0 MPa at 35 °C
Young modulus in compression	16 GPa
Pot life	90 minutes at 20 °C
Specific gravity	1.04
Mixed viscosity	1.0 poise at 35 °C

Table 2 polysulfide mechanical properties.

Property	Typical value or description
General chemical structure	-[R-S]- R=(CH <sub>2</sub> CL) <sub>2</sub> or( CH <sub>2</sub> (OCH <sub>2</sub> CH <sub>2</sub> CL) <sub>2</sub> )
Service temperature (C°)	-50 to 95
Mixing ratio	1: 16
Density (g/cm <sup>3</sup> )	1.35
Tg (C°)	292
Hardness (Shore A)	22-39
Ultimate elongation (%)	126-412
Tensile strength (MPa)	0.74 - 0.91

**2.2. Sample Preparation**

The blends were prepared according to the following procedure:-

- 1- the composites to be molded have high adhesion tendency, the mold material should has moderate strength and toughness. Acrylic was chosen since it can be easily formed,the composite can be removed from the mold easily with the assistance of lubrication materials.
- 2- the molds have been manufactured according to the dimensions of the ASTM standards requirements, ASTM D 256-78 for impact toughness , ASTM D 2240 for hardness test.
3. The blend was obtained according to the ratios fixed in Table 3 by adding Epoxy polymer which is still in a liquid state to Polysulfide rubber in a thick liquid state, mixing well by using a mechanical mixer to form a binary blend.
4. Pouring the blend into the mold, since the two components are still have low viscosity liquid, and fastening the mold.
5. The composite materials were left inside the mold at room temperature about 72 hrs to complete curing.
6. After solidification, the samples were released from the mold and charged to oven at 100°C setting temperature for 2 hrs to post cure the considered composite.

Table 3 Composite Materials used in  
 Experiemental Work .

Sample No.	Epoxy %	PSU %
1	98	2
2	97.8	2
3	97.6	2
4	97.4	2

**2.3. Fourier transform infrared spectroscopy (FTIR)**

Characterization and/or morphology of the individual composite components and Epoxy-PS composite was studied by Fourier transform infrared spectroscopy (FTIR).

1.1 FTIR spectrophotometer was used to scan the IR spectra of pure Epoxy, Epoxy-PS .FTIR spectroscopy measurements were performed using FTIR spectrometer type ( TENSON 27) with 128 scans at a resolution of  $2.0\text{ cm}^{-1}$ . Each spectrum was recorded from  $4000\text{ cm}^{-1}$  to  $500\text{ cm}^{-1}$  at room temperature. Spectra were analyzed using a window-based software BRUKER 5.1.The FTIR spectra of Epoxy, PS were obtained in a transmittance mode by using a 10 mm X 10 mm sample In Epoxy systems oxirane ring in transmittance mode has two characteristics which were observed in the range between  $4000\text{ cm}^{-1}$  and  $400\text{ cm}^{-1}$ .

1.2The first peak at  $915\text{ cm}^{-1}$ , is attributed to the C-O deformation of the oxirane group. The second band is located at  $3050\text{ cm}^{-1}$  approximately and is attributed to the C-H tension of the methylene group of the Epoxy ring. This band is not very useful since its intensity is low and it is also very close to the strong O-H absorptions; but in low polymerization degree Epoxy monomers, it can be used as a qualitative indicative of the presence of Epoxy groups. FTIR of Quickmast Epoxy in Figure 1 shows peaks at  $3471\text{ cm}^{-1}$  attributed to C-H stretching aliphatic ,  $2968\text{--}2858\text{ cm}^{-1}$  peaks ascribed to C-H stretching aromatic,  $1608\text{ cm}^{-1}$  attributed to C=C stretching ,  $1246\text{ cm}^{-1}$  ascribed to stretching symmetry,  $829\text{ cm}^{-1}$  peak attributed to stretching symmetry [10, 11].

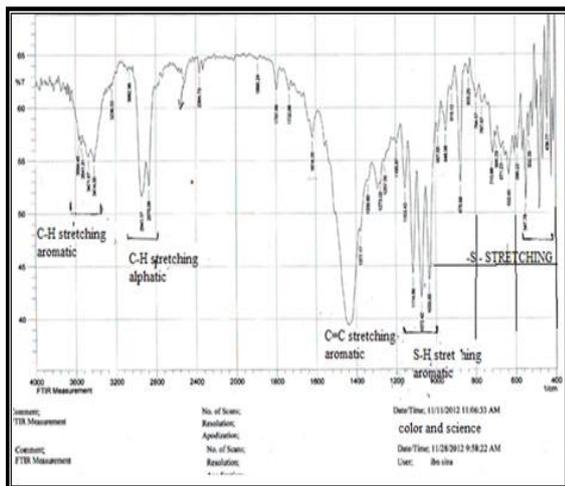


Figure 1: FTIR of Epoxy

1.3 While in Figure 2, the FTIR spectrum of polysulfide shows that the thiol group (-SH group) of PS reacts with the Epoxide group of DGEBA type Epoxy resin to give S-CH<sub>2</sub> linkage and -OH groups [12, 13].

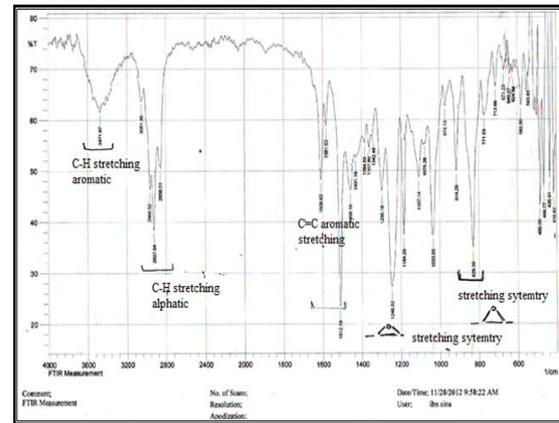


Figure 2: FTIR of Polysulfide

### 3.Resulte and discussion

#### 3.1. Tensile Properties

Tensile test of Epoxy-PS with different percentages of PS were investigated. The addition of PS caused a 30% decrease in tensile strength, as shown in Figure 3 , due to low tensile strength of rubber (PS) and its elastic properties which weaken the strong cross liked network of Epoxy [7]. Figure 4 shows that the addition of PS causes an increase in elongation, and this is expected because of elastic properties of PS which impart flexibility and chain extension to the blend matrix [7].

It is obviously noticed that adding more PS caused a continous reduction in modulus at fracture, as shown in Figure 5. This reduction is because of low strength properties of PS which affect the blend mechanical property [14].

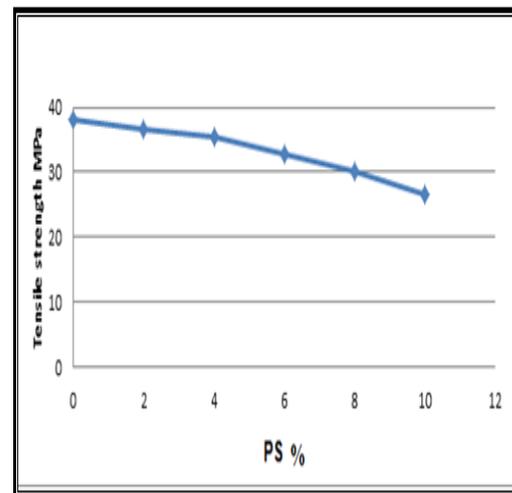


Figure 3: PS% effect on tensile strength of Epoxy

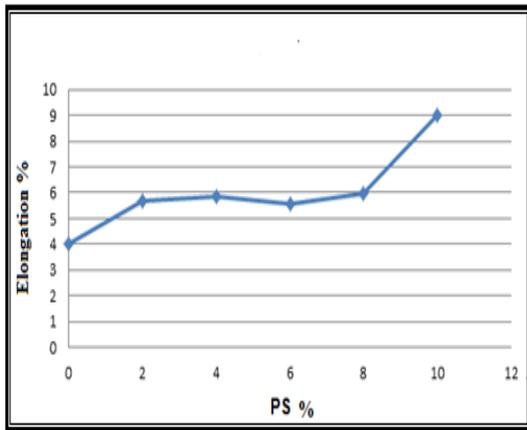


Figure 4: PS effect on Elongation of Epoxy

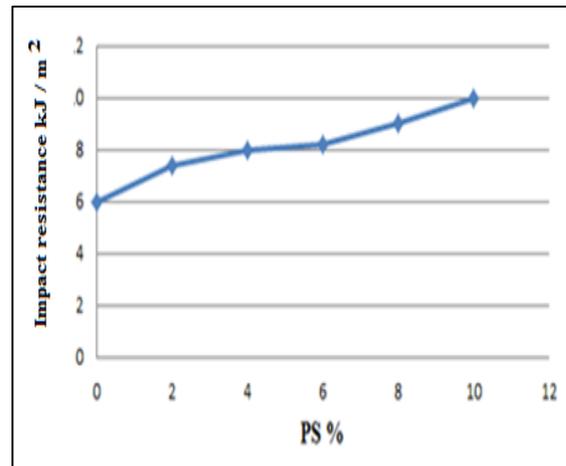


Figure 6: PS % effect on impact resistance

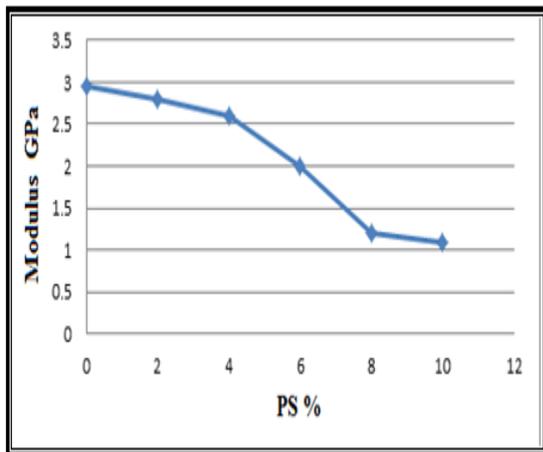


Figure 5: PS % effect on modulus at fracture

### 3.2. Impact Resistance Results

Blending of Epoxy with 2, 4, 6, 8 and 10% PS resulted in an increase about 90% in impact resistance with the increase of 10% (PS Figure 6). This result is agree well with the fact that PS have a good ability to absorb and dissipate energy of impact load before break. The smaller rubber particles in the composite are still large enough to be capable of cavitating under the triaxial stress field at the crack tip [15, 16]. This would be contributing to toughening by initiating shear yielding in the surrounding matrix, which is the conventional mechanism of Epoxy- PS toughening [17].

### 4. Conclusions

- Epoxy is compatible with PS polymer since good dispersion of PS is noticed while mixing the two polymers.
- FTIR spectrum confirmed that the reaction of Epoxy- PS and Epoxy had occurred.
- Shear mixing is the best method for blending Epoxy with PS considering the tensile strength results
- Modifying Epoxy with PS decreases the ultimate strength, while improve elongation, impact resistance.
- The best mechanical results obtained when 4% percentage of PS is blended with Epoxy.

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