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Investigation of the Epoxy Concentrations Effect on the Mechanical Properties of Polyurethane Foams

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Abstract

Thermosetting foam had a number of advantage in comparison with unfoamed polymer such as lightweights, higher specifics strength, and stiffness. In this work, preparations and characterizations of polymers foams from polyurethanes have carrying out by means of one shot methods for productions of microcellulars polymers that are using in the lower limp application. Many type of polyols (Local commercial market, Quickmast 110, and Quickmast 120) at equivalents ratios of (isocyanate:polyol) [1:1] mixing with 5 drops of distill water as chemicals blowing agent. Different amounts of epoxy resin [2.5, 5, 7.5, and 10 wt%] mixing with polyol using a magnetic stirrer for 30 min at 50 °C and 30 rpm. The hardener mixing with isocyanates in another container. These two solutions were mixing together, then water was added and mixing by hand to form polyurethane/ epoxy blend foam sample. The mechanical characteristics [hardness, tensile and compression] tests were achieved to display the effects of polyol type, epoxy concentration on the mechanical characteristics of the final product. The results of mechanical characteristics increasing with additions of epoxy resin at the best ratio is 7.5 wt%.

1. Introduction

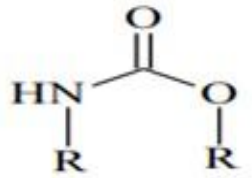
Polymers foam is made up of a solids and gases phases mixing together to produce the foams. The final foams have polymers matrix with either air bubble or air channels incorporating in it, foaming either closed cell or open cell structures [1].

Foam can be prepared by fundamental method. The first methods, gases for example air or N_2 was dispersing in a continuous liquid phases (e.g. an aqueous latex), the second method for generating gases in the liquid phases is the thermal decompositions of chemicals blowing agent which generating either N_2 or CO_2, or both [**2 and 3].**

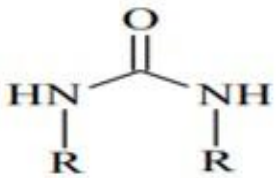
Depended on the average cells size and cells density, it could be dividing into three chief group: conventional foam, fine celled foam, and microcellulars foam. Polymer foam are divided into thermosets foam and thermoplastics foam based on the polymers matrixes. In terms of foams morphologies, polymer foam could also be classifying as open-cell foam and closed-cell foam [4].

Thermosets foam could be defined as foam has no thermoplastics propertie. Consequently, thermosetting foam including not only crosslinked polymers foam, but also several linear polymerics foam e.g., carbodiimide foams and polyimide foams [2, 10].

Polyurethane(PU) was polymers composing of organics units joining by carbamate urethane links(–NH-CO-O-) polyurethane polymer is forming by reactions between a polyisocyanate with a hydroxyl compound (R – NCO + HO-R1↔R1-NH-CO-O-RR). It could be esters, ethers or urea groups [5, 11], Polyure as are similar in reactions to PUs [6].



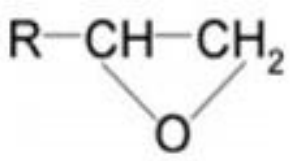
Urethane



Urea

A polymers blends are colleagues of classes of material in which two or more plastics are mixing together for creation new materials with several physicals property at the lower cost, e.g. a combinations of strength, stiffness and solvents resistance, etc [7].

Epoxy resin is one of the greatest significant polymeric or semi-polymeric material, parts of the thermosettings families; which play significant roles in composite material. The structure of an epoxy group is shown below [8]:



Epoxide ring

Epoxy resin was extensively utilized for modification many polymers such as PU or unsaturated polyester to improve its physical and chemical characteristics. Epoxy modified polymers polyol was exclusive types of poly-blend, could basically definition as mixtures of two or more crosslink polymerics network and it could be produced utilizing physical or chemical interconnecting between the polymers chains [9].

This study deals with the preparing and characterization of a cellular polymer using chemical blowing agents that is suitable to use in Prosthetic limbs applications (foot). The effect epoxy resin at different concentrations on the formation of polyurethane samples and its influence on the final properties of the foams were investigated. The tensile strength, compression strength and the hardness were conducted to show the effect of epoxy concentrations on the mechanical properties of samples.

2. Experimental Procedure

The materials used in preparation of polyurethane microcellular is two parts resin (polyol) and hardener (isocyanate). The resin and its hardener were supplied from Don Construction Products (DCP) also used the Iraqi Local commercial type. The main specifications of 110 polyols, 120 polyols are shown in the Table (1).

Table (1). The main specifications of 110 & 120 polyols.

Specifications	Types	Results
Form	110 & 120	Liquid
Color	110 120	Colorless Red Brown
Flash Point (ºC)	110 120	>100 300
Relative Density at 25 ºC (g/cm^3)	110 120	0.957 0.95- 1
Water solubility	110 & 120	Insoluble

The main specifications of the MDI (Methylene diphenyl diisocyanate), hardener that are wanted in the preparations of PU microcellulars are shown in the Table (2).

Table (2). The main specifications of 110 hardener.

Specifications	Types	Results
Form	110& 120	Liquid
Color	110 120	Brawn Yellowish Green
Relative Density at 25 ºC (g/cm^3)	110 120	1.12-1.16 1.1-1.2
Viscosity (cP) @ 25 ºC	110 120	60 – 120 125- 150
Pot life in absence of water	110 120	3 – 4 hr @ 25ºC 2 – 3 hr @ 40ºC 35 – 45 min @ 25ºC 15 – 20 min @ 40ºC
Water solubility		Insoluble
Reaction on time with water	110	5 – 30 sec @ 25 ºC
Gel time	120	40 – 50 min @ 25ºC 18 – 25 min @ 40ºC
Shore A hardness	120	60 – 90

2.1. Preparation of Microcellular Samples

Polyurethane foams were prepared by one-shot method (Chemical blowing action via in-situ reaction during polymerization) or cups foaming. The tools utilized is plastics cup, stopwatch, medical syringe, stirrers, and weight balanced of 0.001 accuracy, foams scheme were saved at 25°C. The general procedure for polyurethane/epoxy blend foam preparation as following for the best ratio [(1:1) (isocyanate: polyol) equivalent ratio]. First, the epoxy resin is mixed with the polyol using a magnetic stirrer for 60 rpm at 30 minutes and a temperature of 50 °C. Secondly, the hardener is mixing with isocyanate for 10 minutes using a magnetic stirrer at 60 rpm in the separate containers then mixed two solutions together followed by adding (5 drops) of water and mix manually for 30 seconds to form foam samples. [The above procedure is applied for "local commercial market polyester and Quickmast 110 polyether" polyols at different epoxy content (2.5, 5, 7.5 and 10 wt%)]. The samples were prepared and poured into a silicone rubber mold for various tests as shown in Figure (1).

Figure (1). Silicone rubber mold.

2.2. Microcellular Polymer Test

2.2.1. Hardness Test

The hardness test is achieved depended on ASTM D2240 by "Dorumeter hardness test" Shore A type, at depressing times of determining is (15 Sec) at room temperature. The surfaces of specimen necessity smoothing, also the depths of indentations extent on scales have graduations from "0 – 100" hardness number. The hardness values are so sensitives to the. Each specimen has a test six time at different location of each specimen at the similar time and the average values were taken. Figure (2) shows the standard specimen for hardness test.

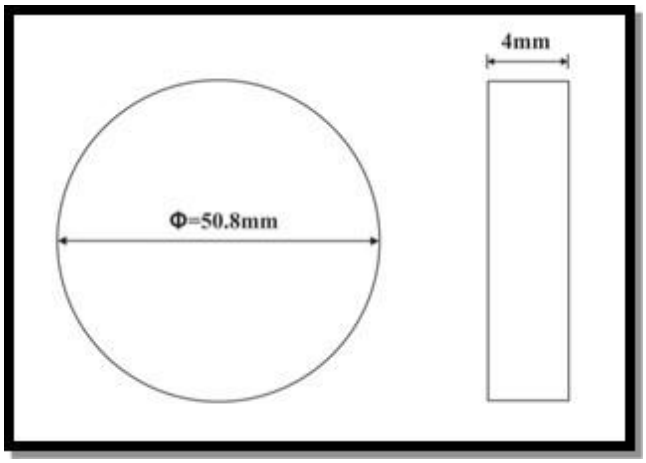


Figure (2). Schematic for Standard Specimen of Hardness Test.

2.2.2. Tensile Test

The tensile test was achieved according to (ASTM D638-IV) utilizing tensile instrument "universal testing machine"type [Instron] at strain rate of 5 mm/min until break of specimen occurs. The foams tensile strength test was like to testing another plastic. The lowest foams thickness during testing is 12.5mm and its public to measure thicker samples. Foams don't typically have higher tensile strength; lower forces capacity grip is finer. The result, which achieved directly from this test, are (stress-strain) curve and tensile properties such as tensile strength and elastic modulus.

2.2.3. Compression Test

The test was achieved depended on (ASTM D 1621-16) utilizing the same tensile instrument at strain rate of (2.5 mm/min) and applied loads till breaking of specimens happens. Compressive strengths of plastics foams are determining by applied compression load to test specimen has circular cross sections. Figure (3) shows the standard specimen of compression test at diameter of 2.5 cm.

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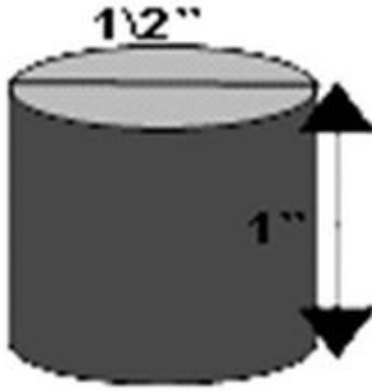

Figure (3). Schematic of Standard Specimen of Compression Test.

3. Results and Discussion

3.1. Mechanical Properties

The mechanical properties of PU foams depend considerably on the parameters of the polymeric matrix composition.

3.1.1. Hardness

It is known that the hardness of materials depends on the resistance to penetration at the outer surface. The applications of the foam required well controlled on the mechanical properties especially hardness.

The hardness of the polyurethane/epoxy blend foam at different concentrations of epoxy for different for (Local commercial market polyester, Quickmast 110 polyether) polyols are shown in the Figures (4 & 5). The results show that the hardness increases with epoxy content increasing this is due to strengthen of the three-dimensional network of the polyurethane/epoxy foam, as a results of a better crosslinking and high miscibility of both individual polymers (PU and epoxy).

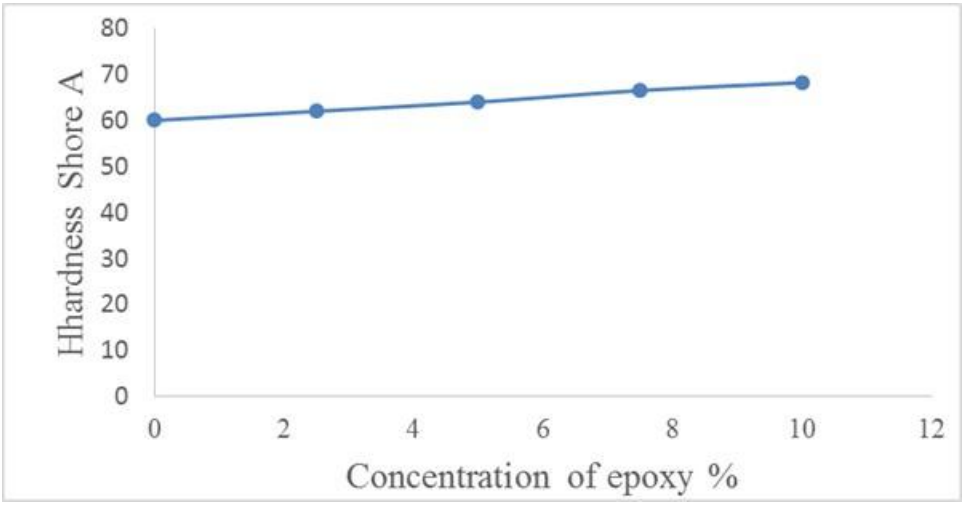

Figure (4). Polyurethane foam hardness as a function of the epoxy concentrations for (Local commercial market) polyester polyol.

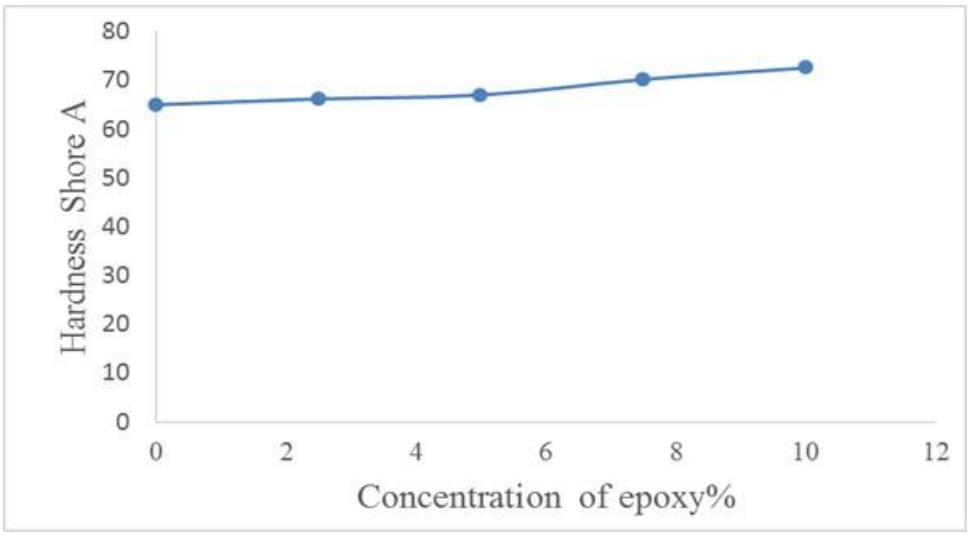

Figure (5). Polyurethane foam hardness as a function of the epoxy concentrations for (Quickmast 110) polyether polyol.

The higher value of hardness of (Quickmast 120 polyether polyol) as compared to other types of polyols makes it undesirable and unacceptable for the manufacturing of highly flexible polymeric foams that are widely used in lower prostheses, which require high flexibility with excellent mechanical properties.

3.1.2. Tensile Strength

Figures (6 & 7) show the tensile strength of polyurethane/epoxy blend foams for both type of polyols at different epoxy content. The results show that the polyurethane/epoxy blend have higher tensile strength than the neat polyurethane foam samples except at lower content. The presences of inter-molecular (H-bond) between the hydroxyl groups of epoxy and isocyanates groups play significant roles in interconnecting networks formations and then the overall properties of final product especially mechanical properties. The blending of PU and epoxy resins is so effective for successful the fractures characteristic of the neat polyurethane samples for both of polyether and polyester polyols.

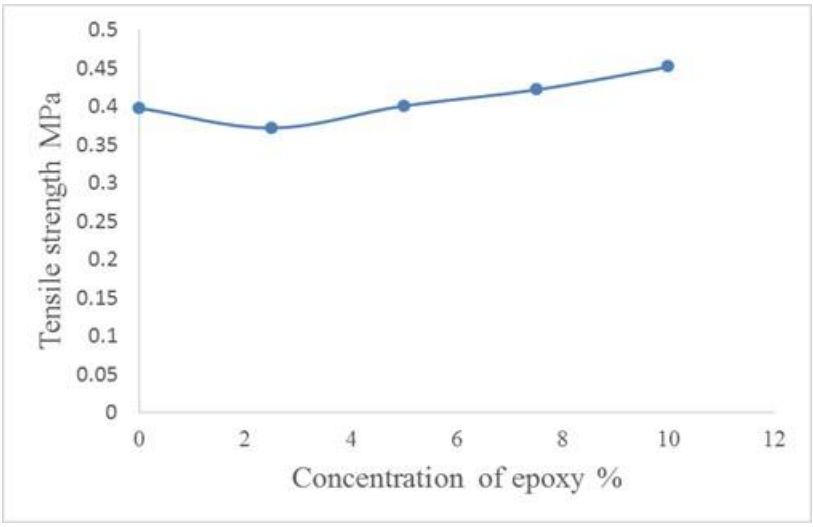

Figure (6). Polyurethane foam tensile strength as a function of the epoxy concentrations for (Local commercial market) polyester polyol.

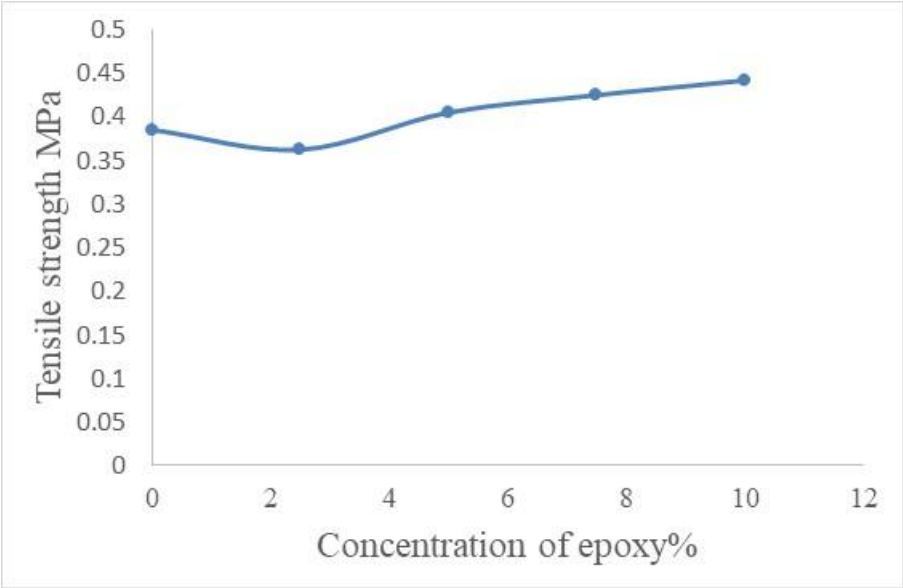

Figure (7). PU foam tensile strength as a function of the epoxy concentrations for (Quickmast 110) polyether polyol.

3.1.3. Elastic Modulus

The elastic modulus of polyurethane/epoxy blend foams increases with epoxy percentage increasing as shown in Figures (8 & 9) and it's higher than that of pure polyurethane foam samples excepted at lower content. It can be established that the two components network was well-matched in the finals (PU/epoxy) blend foam. The compatibility can be recognized to a graft structures of the PU and the epoxy resins network from the reactions of the hydroxyls group of the epoxy resins with the isocyanates group of "MDI", and from the reactions of the hydroxyls group of the polyol with the epoxy group. The mechanical characteristics of "PU/epoxy" mainly depended on the amounts of epoxy in the blends networks. Increasing the amounts of epoxy increasing tensile strengths and tensile modulus extremely since the blends essentially mix the structures and characteristics of these versatile plastics (epoxy and PU). The minimum value of elasticity modulus is observed at the 2.5 wt % epoxy concentration when compared to other content, this was due to weak adhesion between polyurethane and epoxy.

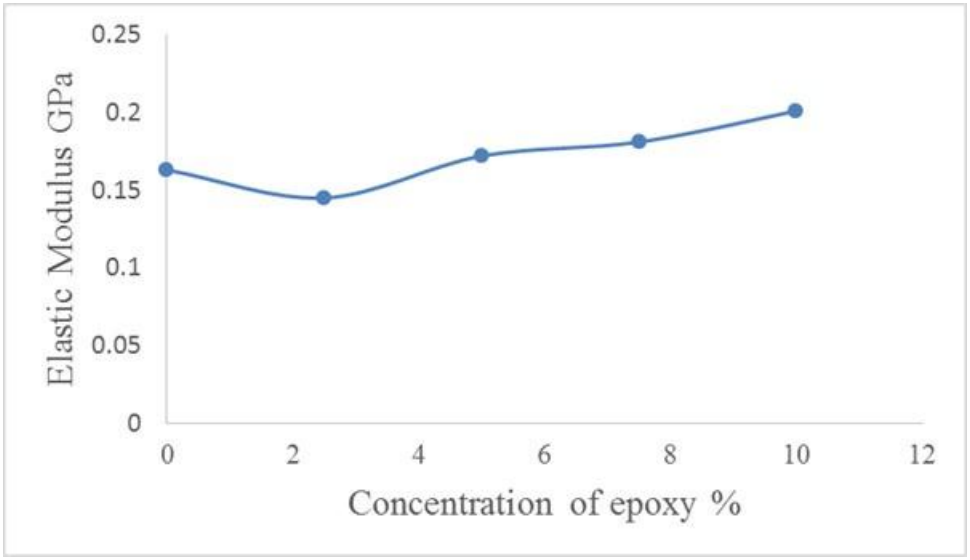

Figure (8). polyurethane foam elastic modulus as a function of the epoxy concentrations for (Local commercial market) polyester polyol.

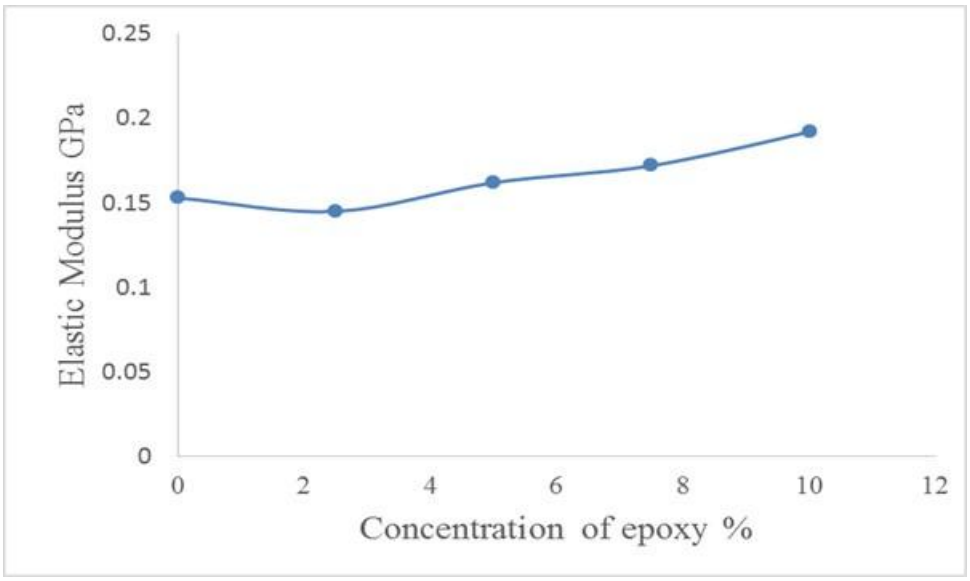

Figure (9). polyurethane foam elastic modulus as a function of the epoxy concentrations for (Quickmast 110) polyether polyol.

3.1.4. Compression Strength

The compressive strength of the (polyurethane/epoxy) blend foams are shown in the Figures (10 & 11) at different concentrations of epoxy for each type of polyols. The compressive strength of the blend foam increasing to a higher values and then decreasing with more increasing in the epoxy content at 10wt%. This behavior was related to the nonhomogeneous cells and more brittle cell walls for the foam samples with high epoxy content because when the amount of epoxy is too large, some of the epoxy fails to produce a timely graft reaction with polyurethane.

Generally, (polyurethane/epoxy) blend shows higher engineering characteristics because of synergetic effects made by the compatibility of separate parts in polyurethane/epoxy network. The existence of inter-molecular H-bonds among the hydroxyl groups of epoxy and isocyanates groups play a significant role in interconnecting networks formations.

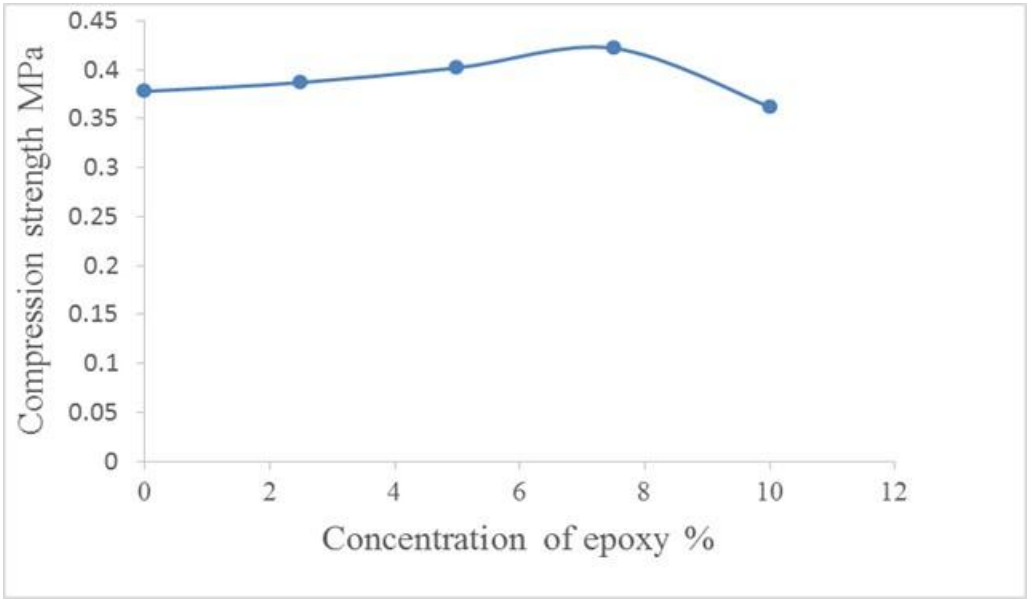

Figure (10). Polyurethane foam compression strength as a function of the epoxy concentrations for (Local commercial market) polyester polyol.

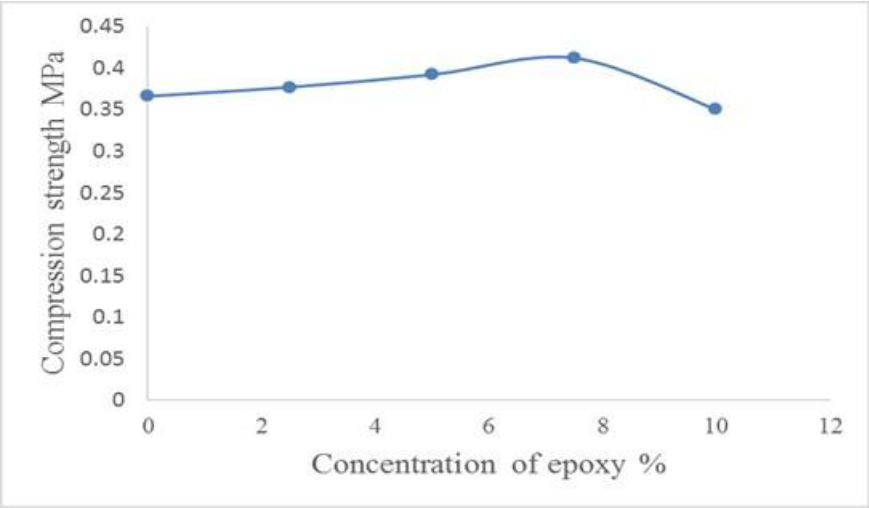

Figure (11). Polyurethane foam compression strength as a function of the epoxy concentrations for (Quickmast 110) polyether polyol.

4. Conclusions

Quickmast 120 polyether is not suitable for the polyurethane foams because the foam formation process was difficult and thus gave relatively large and heterogeneous cell. The properties of PU foam be influenced largely by the type of polyol, as it noticed that the properties of (local commercial market polyester foam are better than Quickmast 110 polyether foam. The mechanical characteristics (hardness, tensile strength, elastic modulus and compression strength increasing with the epoxy contents increases. The best results of epoxy content obtain with the ratio of (7.5) wt%.

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