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Re-use of scrap polyurethane in manufacturing of new product applications.

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Abstract

Environmental value for recovering and reusing scrap foam (polyurethane), with information on how this scrap material costs, and alleviate solid waste disposal problems. A new and simple techniques has been developed to a chemical recycling of foam waste polyurethane (PU) that is economically and environmentally sustainable and this complimentary, the rebonding this foam scrap in an industrial applications. Then a lab-scale reactor is designed to chemical treatment of (100 gm) scrap foam (PU) at 200º c for 3 hours with continuous stirring (135 cycle/min.) in a chemical solution solvent .Afterward a two matrix systems were used to investigate the application of this recycled polyols final products in adhesive melamine-formaldehyde MF) system and plastic poly vinyl chloride (PVC)-fiber (f) system.

Keywords: *scrap polyurethane, melamine-formaldehyde (MF), plastic poly vinyl chloride (PVC)-fiber (f) system.*

1. Introduction

Polyurethanes are one of the most versatile materials in the world today. There are many uses range from flexible foam in upholstered furniture, to rigid foam as insulation in walls, roofs and applications to thermoplastic polyurethane used in medical device and foot wear to coating adhesives sealants and elastomers used on floors and automotive intellors [1-4]. Years of research and study have resulted in a number of recycling recovery methods for polyurethane that can be economically and environmentally valuable. By chemical recycling mechanical recycling and energy recovery [5-9].The opportunity to generate additional revenues while eliminating costly waste removal has caught the attention of many home furnishing manufactures, such as fabrication of this foam to carpet installers, and the use of more efficient product formulation and manufacturing processes to minimize the amount of process scrap. Where 30% of these foams become scrap after cutting and shaping in product fabrication [10-14].The recycling issue is a double edged word having the technology to recycle a material since 1990 polyurethane recycle and recovery council (PURRC) has aggressively work to identify demonstrate and promote commercially valuable technologies for recycling and /or recovering of polyurethane. The flexible polyurethane foam industry fortunately has developed a bonded carpet under lay used as stuffing for pillows and plush [15].Many researchers try to reploymerized scrap foams (PU) under heat and pressurized conditions in a supercritical or a sub- critical water saturation [7, 16]. Also ICI polyurethane company has been developed a chemical recycling route for waste from slab stock foams that is economically and environmentally sustainable and is a complimentary technique to rebounding of foam scrap. Additionally a pilot plant will be designed to quantify the effect of contamination on the quantity of the products, also evaluate the suitability of various foam recovery schemes and the associated contamination [7, 9, and 12].Different techniques batch and continuous processes are used for rebond to compress mold, and achieve a desired density of final prepared product for peeling .Also many authors has been studied the continuous process for melt–processable them extrusion as molding equipment in order to form a solution coated and weather methodologies [17].

The aim of present work:

It is already clear that the challenge will be:

1. Use simpler and more standardized formulations for recycled polyurethane, at the same time achieving improved performance.
2. Made a significant contribution to utilize the recycling convince and economic technique for final product application.
3. Try two types of polymer system (MF, and PVC) for application this waste and test these chemical, thermal, and mechanical properties.

2. Experimental

2.1Materials:

1. Scrap polyurethane (RPU) collected from Local Street, separated and classified.
2. Use available and commercial component for polymerization glycol.
3. Use of available and commercial component for materials manufacturing asbestos fiber, formaldehyde (F), melamine (M) and polyvinyl chloride (PVC).

4. Use of available laminate of plastic to apply the matrix systems then utilize these systems in a convince applications.

2.2Methods:

2.2.1 Preparations of polyols reploymerized of scrap foam (PU):

The glycolysis reaction is achieved by the use of a reactor designed to take 100gm of scrap foam (PU) lab scale glycolysis system , where , the classified fine particles of foams (PU) with additives (catalyst barium oxide) at 0.5 wt% then a decomposition for these scrap and additives accrued at 200 ºc for 3 hours under atmospheric pressure .Afterward particles of impurities are removed by a filter (44 mesh) with high temperature saturation water (super critical condition) for 5 min in order to promote a separation stage at additive ratio of 5.0. Then a final polyols product has been separated to a second stage of rebonding and synthesis of matrices system. Figure (1) shows the block diagram of manufacturing repolymerization process.

2.2.2 Preparation of matrices system:

After the glycolysis process and separation of bottom phase polyols then a use of different formulation system adhesive and plastic to improvement of final polyols produce where 10gm of polyols were added to a different additives of adhesives (melamine-formaldehyde) (1, 2, 3, 4, 5) wt% for formaldehyde and 3/2 wt% for melamine, then curing this adhesive matrix system at 100º c for an hour to stabilize its properties before any test. The second plastic system were prepared by the additive of different mass ratio of plastic PVC (1, 2, 3, 4, 5) wt% to 3/2 vol. % ratio of asbestos fiber to a 10gm of reploymerized polyols then curing the matrix system at 110º c for an hr to stabilize its properties before any test occurred and the experimental additives for both matrices system is shown in table (1) .Where both matrices applied to a prepared laminate of plastic sheet in order to check the characteristic properties such as mechanical resistance, tensile, and bending test [17].

2.3 Methodology:

2.3.1 Mechanical properties:

Both tensile strength test and bending test were achieved by the use of zwick tester tensile instrument and three point tester as the procedure in 256-60-ASTM for tensile [18].

2.3.2 Thermal properties:

A thermal conductivity coefficient (K) is measured by the use of Lee-disk tester then recorded the output temperatures after the stability occurred T_1, T_2 and T_3 at specified energy supplied use the two equations below to calculate this coefficient [19].

$$IV= \pi r^2 e (T_1 + T_3) + 2 \pi r e [d1 T_1 + ds (T_1 + T_2) + d_2 T_2 + d_3 T_3] \quad (1)$$

$$K [T_2 – T_1 / ds] = e [T_1 + 2/r (d_1 + 1/2 ds) T_1 + 1/r ds T_2] \quad (2)$$

Where:

e= loss of heat per m^2.

IV= rate of energy supply.

d= thickness of disk m.

r= radius of disk m.

ds = thickness of sample m.

T_1, T_2, T_3= temperatures through of copper disk.

2.3.3 TG analysis (thermo gravimetric analysis):

This test was achieved by the use of a homemade system in order to record the loss weight at elevated temperature for bulky samples under a nitrogen flow rate at 0.35 m3 /hr. The sample to be analysis was placed in stainless steel basket of (5 cm diameter , and 20 mm length), and this basket was hung to the bottom of send micro balance (0.0000) gm by a 100 cm stainless steel wire as shown in Figure (2) . And the temperature was measured at specified point along the reactor of test (center wall) during constant time interval (10 min) where both temperature and weight loss were recorded.

2.3.4 Thermal stability:

This type was achieved for a specimen of 3 cm diameter and 3 mm thickness in an oven elevated at 30ºc/min until the temperature of distortion occurred.

3. Results and Discussion

For the repolymerization and preparation matrices systems it could notice that:

1. The water is added for the repolymerization in a volume ratio of 0.4-0.5 to liquefy the rigid recycle polyurethane (RPU) foam obtained in the glycolysis reaction.
2. The quality of the bottom layer product polyols depends upon the time allowed for phase separation after the glycolysis.
3. The products of the repolymerization have dark color than base one then it's required to give other color.
4. The preparation of materials system required a pressure application in addition of catalyst to promote this reaction between base polyols and matrix material M and PVC to the plastic laminate sheets.
5. Curing step is required to homogenate and completes the reaction of manufacturing for matrices systems (RPU-M-F, RPU-PVC-f) to the laminate plastic sheets.

3.1 Properties for final matrices system:

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3.1.1 Mechanical properties:

Both tensile and bending test were achieved to investigate the effect of contaminate in recycled polyurethane on the mechanical properties of final matrices system and gave a suitable application for this prepared system. Figure (3) shows the effect of contaminate contents on the mechanical properties of recycled polyurethane, where the values of tensile strength is increased with increasing the amount of both adhesive promoter formaldehyde and binder of melamine to give strong matrix system, with preference for plastic –fiber system of polyvinyl chloride and asbestos fiber due to compatibility of microstructure between the recycled polyols (RPU) and PVC-fiber system [16,17,20] .Figure (4) indicates the effect of contaminate contents in the recycled polyurethane (RPU) on the distortion properties of final matrices system prepared. Where, the values of bending test is increased with increasing the additive of promoter adhesion system formaldehyde and polyvinyl chloride with preference of plastic–fiber system which gave high bending load required to gave a noticeable distortion than other adhesive system only of melamine–formaldehyde system due to good compatibility in microstructure with base system (RPU) and laminate sheet applied of plastics [17, 20].

3.1.2 Thermal properties:

3.1.2.1 Thermal conductivity:

Figure (5) indicates that the effect of promoter additives on the recycled polyurethane prepared (polyols) where , the values of thermal conductivity coefficient is decreased with increasing the amount of promoter (formaldehyde and poly vinyl chloride) additives applied for both matrices (RPU-M-F,RPU-PVC-f) with preference for (RPU-PVC-f) due to low thermal conductivity of base plastic promoter and fiber used in addition of good compatibility microstructure of these additives and base polyols occurred [17].

3.1.2.2 TG-Analysis:

Figure (6) shows the TG-analysis for first matrix system of (RPU-M-F). This figure prove that an approximate stability for high temperatures reached with preference for sample (3) that will give high stability and less loss in weight at 580ºc and 0.36 weight fraction losses .And Figure (7) shows the TG-analysis for matrix system of (RPU-PVC-f) where , this results indicate that high stability occurred for three samples (3,4,5) than other one with preference for sample (3) which give high stability at 600ºc and less loss in weight reached 0.42 weight fraction. Figure (8) indicates the comparison of TG-curved for optimum samples of two systems (RPU-M-F) and (RPU-PVC-f) where, this comparison shows high stability of (RPU-PVC-f) system than other (RPU-M-F) due to high stability for plastic PVC and asbestos fiber than adhesion promoter system of formaldehyde at 580 ºc and 0.32 weight fraction due to high insulated property of PVC and asbestos [17, 20].

3.1.2.3 Thermal stability:

Figure (9) shows the results of thermal stability for all samples of two matrices systems (RPU-M-F) and (RPU-PVC-f) which agreement with results of TG-analysis of high stability for (RPU-PVC-f) system than other (RPU-M-F) due to high insulated properties of plastic PVC and asbestos than other adhesion promoter system of formaldehyde [17].

Table 1: experimental additives for matrices system

Sample no.	*Wt. Ratio for RPU-M-F system*	*Wt. Ratio for RPU-PVC-f system*
1	*1.5*	*1.7*
2	*3*	*3.9*
3	*4.5*	*5*
4	*6*	*6.9*
5	*7.5*	*8.5*

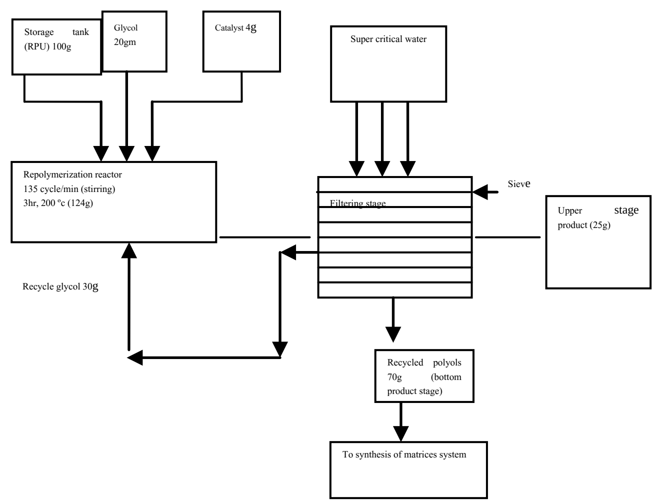

Fig.1 Schematic blocking diagram for repolymerizing RPU scrap foam

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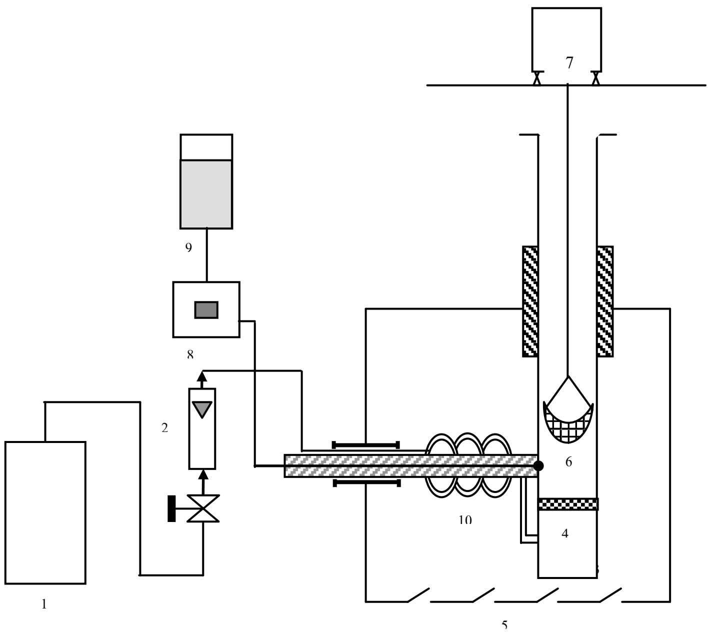

Fig.2 Experimental apparatus for TG-analysis.

1- Gas source with regulator .2- gas rotameter. 3- Stainless steel reactor. 4- Gas distributor. 5- Electrical furnace.6- Stainless steel basket. 7- Sensitive balance. 8- Selector switch. 9- Digital thermometer. 10- Stainless steel coil. 11- Stainless steel wire.

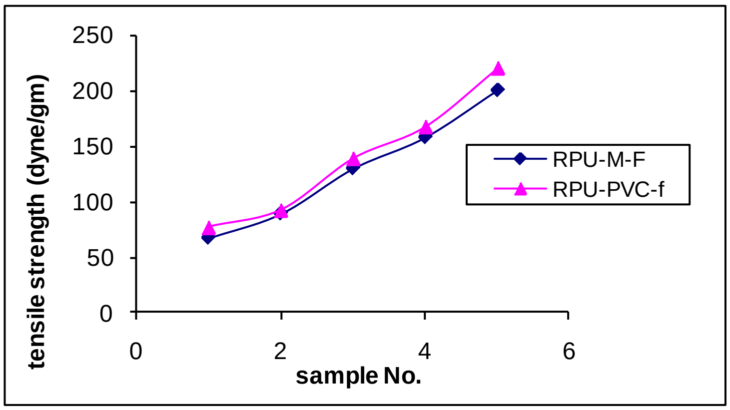

Fig.3 Effect of contaminant content on the mechanical properties of RPU.

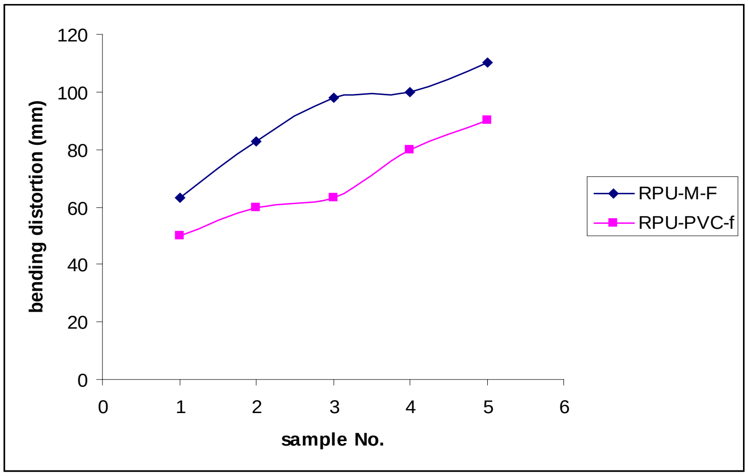

Fig.4 Effect of contaminant content on the distortion properties of RPU

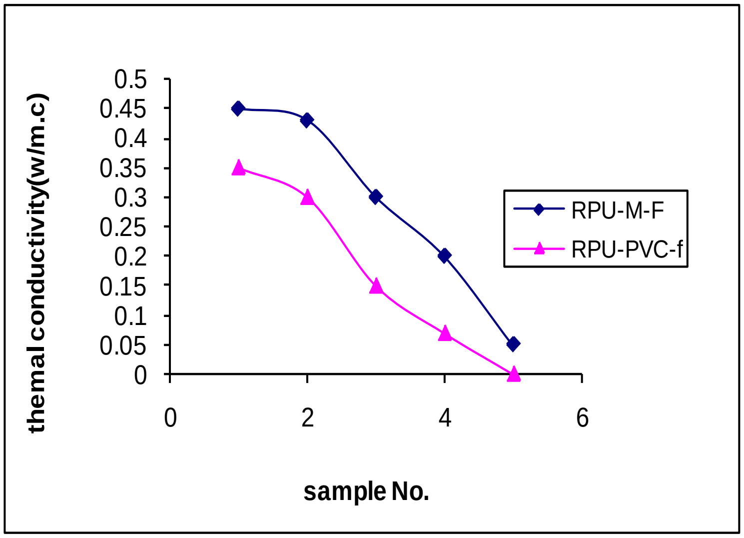

Fig.5 Effect of promoter additives on the thermal properties of RPU.

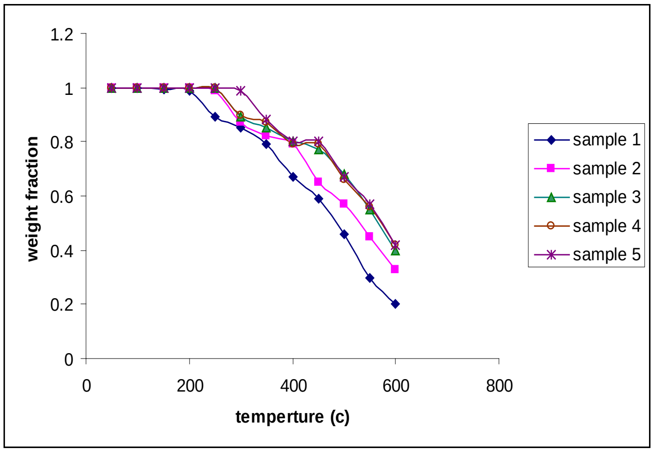

Fig.6 TG – analysis for matrices system RPU-M-F.

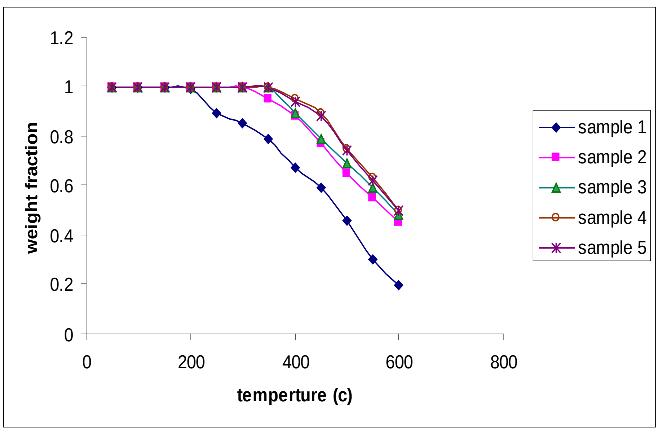

Fig.7 TG – analysis for matrices system RPU-PVC-f.

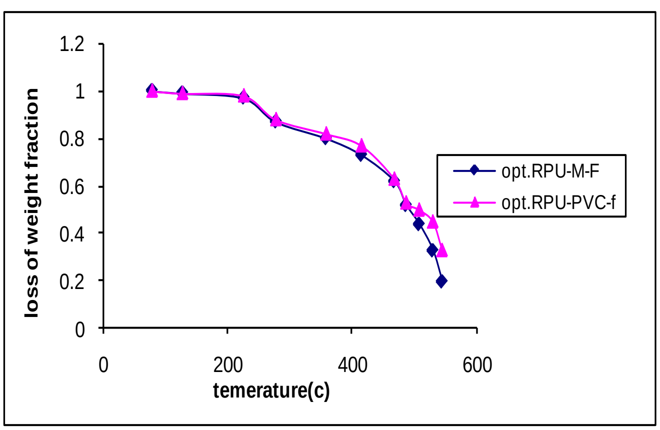

Fig.8 a comparison between TG – curves of two matrices system (RPU-M-F, RPU-PVC-f).

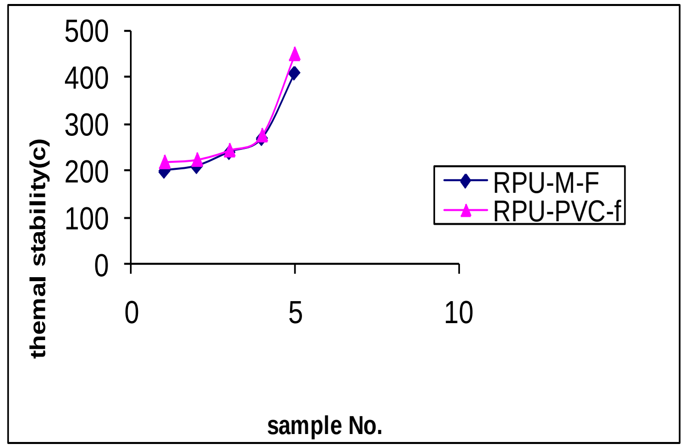

Fig.9 a comparison of thermal stability between two matrices system (RPU-M-F, RPU-PVC-f).

4. Conclusions

From the above results studied of new recycling techniques for RPU it could concluded that:

1. A new and simple technique of environmental value for recovering and reusing scrap foam (RPU) was developed to solve the waste disposal problems.
2. From the results of mechanical and thermal properties it could notice that the plastic matrix system (RPU-PVC-f) is more efficient than other adhesion promoter system (RPU-M-F) as application for cushion under lay carpet
3. The results indicate that optimum sample for both systems (RPU-M-F) and (RPU-PVC-f) is sample No.3.
4. The results of stability test is improved by TG-analysis curve for both systems (RPU-M-F) and (RPU-PVC-f) with preference for (RPU-PVC-f) system.
5. The chemi-lysis of glycolysis process is an economic and environmental aspect technique than others of incineration of aminolysis of high pollutant and loss of volatile compounds.
6. Modification of these recycled scrap RPU and applied it in a matrices system of M-F and PVC-f to suitably applied afterward as underlay cushion carpet.

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