PROCESS OPTIMIZATION AND CHARACTERIZATION OF LOW DENSITY POLYURETHANE FOAM

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1 General Introduction

Traditionally, the concept of structural sandwich composite materials has involved the combination of two thin, yet stiff faces of high strength with a thick and relatively insubstantial core [1]. In essence, both the continuous fiber-reinforced polymer composite faces and polymer foam cores are known to enhance the properties of the complete composite sandwich structures [2].

Polymer foams have been used to lighten, stiffen, and strengthen composite sandwich structure [2]. The polyurethane (PUR) foam cores have also been found to prevent and/or resist the following failure mechanisms commonly associated with composite sandwiches: buckling, crimping, wrinkling, intracell dimpling, and crushing [3]. Because of the highly significant roles played by the PUR foam cores, the processing of these materials can be considered extremely influential to the performance of the overall composite structures.

In the past, researchers have used an assortment of mixing techniques to prepare virgin materials such as polymers. Customarily, the mixing of the base polymer has been achieved through sonication processing techniques. Sonication is considered to be a very effective means for the mixing, homogenizing, emulsifying, dispersing, and degassing of liquid materials by means of ultrasonic cavitation [4]. The development of cavitations in the liquid has generated favorable conditions for the intensification of various physio-chemical processes [5]. Previous research has recognized improvements in both the thermal and mechanical properties of PUR strengthened through a sonic cavitation method [2, 6]. Due to the vast applications of the as-mixed polymer materials, it is recognized that the mixing process be most favorable for the intended purposes.

2 Experimental Studies

2.1 Manufacturing of Polyurethane Foams

In the present investigation, sonication has been employed to establish well-mixed polyurethane foam materials. One component of this research effort has been to develop an optimal sonication process for mixing the PUR foam. Once the process optimization of the PUR foam core was found to be successful, the newly developed materials were characterized for their structural applications using various analysis.

Low density (96 lb/ft^3) polyurethane foam composed of dimethyl diisocyanate (Part A) and polyol (Part B) was processed using various sonication amplitudes at 40%, 50%, and 60%, herein referred to as 40A, 50A, and 60A, respectively; the various sonication times utilized were 15, 30, 45, and 60 minutes, herein referred to as 15M, 30M, 45M, and 60M.

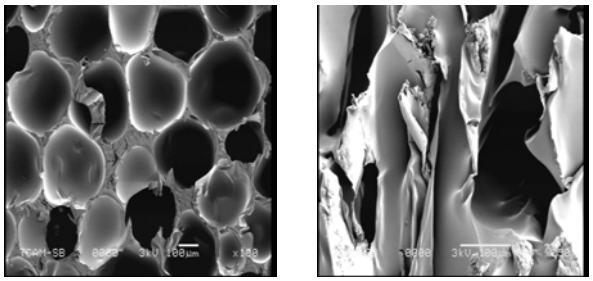
2.2 Characterization

Upon completion of the manufacturing process, test specimens of the PUR foams were prepared for the respective experimental analysis. The diverse sample groups were extensively compared with respect to the specified sonication amplitude and/or time. The as-prepared foams were characterized by scanning electron microscopy (SEM), thermogravimetric analysis (TGA), dynamic mechanical analysis (DMA), density measurements, static compression, and flexural analysis.

SEM studies were conducted to determine cell size and cell density. TGA was done to ascertain the decomposition temperature and decomposition rate. DMA revealed glass transition temperature and storage modulus. Static Compression investigations were done to obtain the compressive peak stresses and compressive modulus. Finally, the flexural peak stresses were obtained from the Flexural Analysis.

3 Results and Discussion

- Overall, SEM has revealed that the 40A samples had the overall highest cell size measurements; the lower times of 15M and 30M gave higher measured cell sizes than the longer time durations. Concerning cell density, Fig. 1(a) has shown a typical SEM micrograph of the as-cast neat PUR foam.
- TGA has revealed almost identical decomposition temperature and decomposition rate for the 40A, 50A, and 60A samples at the varying sonication times.
- DMA studies have shown that overall, the 50A sample had the higher storage modulus (E'), while the 40A gave the highest glass transition temperature (T_g). In reference to the time factor, the 45M sample gave the best overall E', while the lower times of 15M and 30M gave the best values for the T_g.
- The static compression testing showed the 60A samples as having the highest compressive peak stress. Concerning the compressive modulus values, the 60A and 50A, as well as the 15M and 30M, samples gave the higher compressive modulus values. Fig. 2 has shown static compression results for the 50A samples at diversified times. Fig. 1(b) has shown the post-static compression SEM micrograph for the 50A-30M PUR foam.
- Flexure Testing has shown the 50A samples to have the superlative flexural peak stress values, while among the time variations, the 45M samples gave the maximum flexural peak stress values. Fig. 3 has shown the flexural results for the 50A samples at diversified times.



(a) (b)

Fig. 1. SEM micrographs illustrating (a) as-cast neat PUR foam sonicated at 50A-30M (b) neat PUR foam sonicated at 50A-30M post static compression testing.

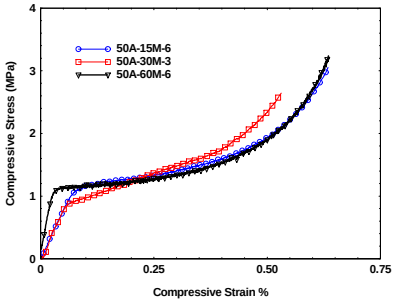


Fig. 2. Static Compression Test – Stress vs. Strain curve for 50A PUR foam.

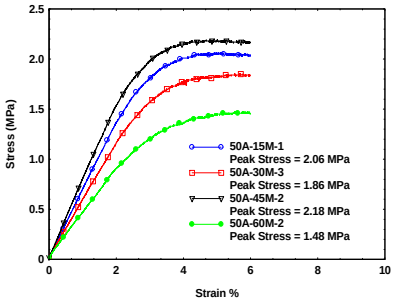


Fig. 3. Flexural Test – Stress vs. Strain curve for 50A PUR foam.

4 References

[1] McGarva L.D. and Astrom B.T. "Experimental investigation of compression moulding of Glass/PA 12-PMI foam core sandwich composites". *Composites Part A: Applied Science and Manufacturing*, Vol. 30, No. 10, pp 1171-1185, 1999.

[2] Mahfuz H., Rangari V.K., Islam M.S. and Jeelani S. "Fabrication, synthesis, and mechanical characterization of nanoparticles infused polyurethane foams". *Composites Part A: Applied Science and Manufacturing*, Vol. 35, pp 453-460, 2004.

[3] Tu Z.H., Shim V.P.W. and Lim C.T. "Plastic deformation modes in rigid polyurethane foam under static loading". *International Journal of Solids and Structures*, Vol. 38, pp 9267-9279, 2001.

[4] http://en.wikipedia.org/wiki/Sonication

[5] Eskin, G.I. "Broad prospects for commercial application of the ultrasonic (cavitation) melt treatment of light alloys". *Ultrasonics Sonochemistry*, Vol.8, pp 319-325. 2001.

[6] Mahfuz H., Islam M.S., Rangari V.K., Saha M.C. and Jeelani S. "Response of sandwich composites with nanophased cores under flexural loading". *Composites Part B: Engineering*, Vol. 35, pp 543-550, 2004.