Effects of silicone surfactant on the water absorption and surface morphology of rigid palm oil-based polyurethane foam

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Keywords: polyurethane, rigid foam; palm oil polyol; silicone surfactant, water uptake, cell size

Abstract. Polyurethane (PU) foams are widely used today in automotive and as insulation system. Due to environmental issues, efforts have been made to replace petrochemical polyol with natural-based polyol in PU foam production, without sacrificing any properties. This study aims to produce palm oil-based PU rigid foam for non-load bearing applications such as wall panel or insulation for buildings. Two parameters studied were percentage of water uptake and surface foam morphology. Palm oil-based polyol (POP) was reacted with polymeric 4,4-diphenylmethane diisocyanate (*p*-MDI) at 1:1 NCO:OH ratio. Water was used as blowing agent and silicone surfactant was added to produce stable rigid PU foam. The content of silicone surfactant was varied at 2 and 3 part by weight (pbw). The percentage of water uptake increased slightly with increasing surfactant contents due to siloxane portion of the surfactants, is thought able to reduce the surface tension of the cell, thus absorbing more water than 2 pbw surfactant content. The findings were supported with micrographs of scanning electron microscope (SEM) that showed a larger cell window area and thicker strut.

Introduction

Usage of polymeric foams in industries is not a new thing. Polymers like polyurethanes (PU), polyvinyl chlorides (PVC), and polyimide are widely utilized as insulation, acoustic damper, furniture, aircraft and automotive parts [1-4]. Among them, PU foams account for the largest global market of 53%, with 23% of total production are rigid PU foams. Like any other polymeric foams, PU relies on petrochemical feedstock. Due to environmental and sustainability issues, as well as depleting petroleum crisis all over the world, efforts have been made in recent years to develop a bio-based PU foam by using vegetable oils such as castor oil, soybean oil, canola oil, rapeseed oil, and palm oils [1-10]. Among all of these oils, palm oil polyol has attracted interest for study, due to its economic price range and abundance in Malaysia.

To date, quite a number of researches were reported the utilization of palm oil-based polyol in the production of PU foam. [1, 2, 4, 5, 7, 9]. But there is no study has been conducted on relation between the percentage of water absorption and surface morphology with the amount of silicone surfactant used. Silicone surfactant imparts the stability to foam as it is able to form crosslink network. In this research, PU foam was prepared at 1:1 NCO:OH based on previous work done by our group [12]. We found that at this ratio, PU foam exhibited the highest density and compressive strength. We designed the foam for non-load bearing applications such as wall panel or insulator for building. To be a good wall panel or insulator, it is important to study the ability of foam to absorb water since water leads to deterioration of mechanical properties of rigid foam.

Experimental

Materials. Palm oil-based polyols was purchased from Maskimi Polyol Sdn. Bhd. Polymeric diphenylmethane-4,4'-diisocyanate (p-MDI) was obtained from Merck. Silicone surfactant Tegostab B-8404 was supplied by Goldschmidt Chemical Corporation and distilled water was obtained from Polymer Laboratory, Department of Polymer Engineering.

Preparation of foam. Palm oil- based polyol, silicone surfactant and distilled water were stirred for 2 minutes at 1500 rpm for homogeneity. Later *p*-MDI was added 1500 rpm for 45 seconds before transferred into mould with a diameter of 100mm x 200mm x 30mm. The foam was left for self-rising. The foam was conditioned at room temperature for at least 24 hours before demoulded prior to further conditioning for another 24 hours before cut into test specimens. The formulations of all samples were tabulated in Table 1.

Testing and characterization

Water absorption. Water absorption test was conducted to determine the amount of water uptake by foam, since water leads to deterioration of mechanical properties of rigid foam. The specimens were cut at dimension of 50mm x 50mm x 30 mm. The weight of each sample was taken prior to immersed in distilled water for 14 days, followed by drying at room temperature and re-weighing the specimens to determine the amount of water absorbed. Averages of the three samples were calculated by using the Eq 1.

$$\text{Percent water uptake [wt. \%]} = \frac{W_a - W_i}{W_i} \times 100 \qquad (1)$$

Where; WA = Weight of sample after immersed
W_i = Weight of sample before immersed

Scanning Electron Micrography (SEM). Morphology of the cell structure was observed using a Phillips ZL 40 model. Specimens were prepared by sputter coating with thin film of platinum and opening voltage of 10 kV. Computerized image analyzer Zeiss KS300 Imaging System software is used to analyze the obtained result.

Table 1 formulation of PU foams in this study

Sample	NCO:OH ratio	p-MDI [g]	POP [g]	Water [pbw]	Surfactant [pbw]
S1	1:1	50	50	0	2
S2	1:1	50	50	1	2
S3	1:1	50	50	2	2
S4	1:1	50	50	1	3
S5	1:1.5	40	60	1	2
S6	1:0.82	55	45	1	2
S7	1:0.67	60	40	1	2

Results and Discussion

Water Absorption. Fig. 1 shows the water uptake behavior of PU foams with two surfactant compositions. The test was conducted in 14 days. Both samples exhibited the increase of water absorption with time. However, both samples did not show significant changes in absorbing the water. This is probably due to siloxane portion of the surfactants, which imparts more hydrophobic character, thus restraining the absorption of water into the polymer galleries. Sample S2 shows a little decrease, probably due to smaller cell size than sample S4.

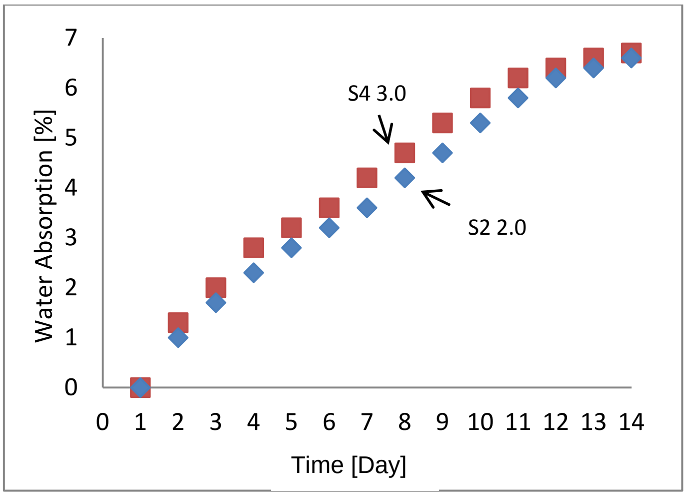

Figure 1 water absorption tests of PU foams with two surfactant contents

Scanning Electron Micrograph (SEM). Scanning electron micrographs of the foam surface in the vertical direction indicate that the obtained foams are closed cells. Fig. 2 shows the micrographs of samples S2 and S4 that have 2 pbw and 3 pbw silicone surfactants contents, respectively.

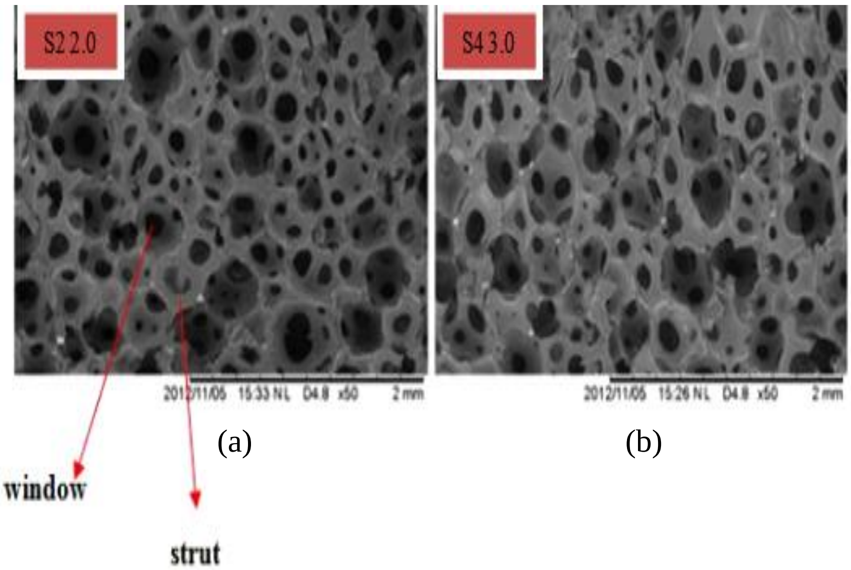

Figure 2 SEM micrographs of PU foams for a) 2 pbw (sample S2) and b) 3 pbw (sample S4) surfactant contents

It can be seen that, sample S4 has larger cell window area and thicker strut, which contributed to more water absorption. It is expected that beyond 3.0 pbw, may lead to increase in cell size, due to the self aggression of surfactant-polymer within the system, which increase the pressure in the bubbles due to low surface tension [11].

Conclusion

By increasing silicone surfactant content from 2 pbw to 3 pbw has slightly increased the percentage of water absorption. This is probably due higher siloxane portion will reduce the surface tension of the cell, thus absorbing more water. The findings were supported by SEM images that showed sample S4 with 3 pbw surfactant has larger cell window area and thicker strut which indicated more water absorption.

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