OPTIMUM ALLOCATION OF SILICONE OIL IN FLEXIBLE POLYURETHANE FOAM PRODUCTION

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ABSTRACT

The high cost of purchasing good quality flexible polyurethane foam called for this project work, which examines the possible reduction in the cost of production which will eventually lead to reduction in all overall market cost. Process optimization technique was adopted using gradual chemical variance method for the foam surfactant (silicone oil) to locate the optimum silicone oil quantity required as against the usual practice of 1part of silicone oil to 100 part of polyol for $20kg/m^3$ density foam. Seven different quantities (1.2g, 1.0g, 0.8g, 0.6g, 0.4, 0.2, 0g) of silicone oil were used to 100g of polyol in the experiments. It was discovered that the quality of the foam produced remained the same as the quantity of silicone oil used was gradually reduced from 1 part per 100parts of polyol to 0.76 parts per 100 parts of polyol. Thus the later ratio was obtained as the optimum quantity required for the foam production which was about 24%

reduction but still maintaining same quality as that of 1part to 100 parts of polyol when subjected to all the required physical tests.

INTRODUCTION

All over the world, comfortability has been a persistent need. Polyurethane foam products have been one of the major sources of such comfort. Unfortunately, quality flexible polyurethane foam is only affordable to the rich and high class citizen. Some of the middle class citizens are opportune to use this type of foam. This is because of its high cost, and thus the low class makes do with inferior polyurethane products. From in depth study and observation of the foam industries especially in Nigeria, it has been found out that the high cost of production is associated with inefficient production processes, which does not achieve the optimal production state (1).

The polyether polyurethane foam is a product formed from the condensation polymerization reaction between polyfunctional monomers to give cross linked products. The raw material used in the manufacture of this type of foam include main chemicals like polyol and (toluene di isocyanate) TDI, activators like amine and stannous octate (Tin (II) octate), foam stabilizer like silicone oil, additives which include colourants, fillers and flame retardants and others like water and auxilliary blowing agent. It should be noted that all good foam formulations consist of the main chemicals, activators, foam stabilizers, and water. The additives and auxiliary blowing agents are optional (1 – 3).

Silicone oil used in foam formulations acts as surfactant. In the foaming process, the surfactant plays the following roles of emulsifier, lowers the bulk surface tension, enhances formation of cells (and bubbles) during initial mixing stage, prevents cell collapse during the rising stage and aids introduction of solids (like calcium carbonate) into foam formulation. Fillers are introduced into formulations to increase foam density, load bearing ability and

sound attenuation. However, fillers used must be free of moisture and impurities (2 – 4).

Flexible polyurethane foam is highly flammable, partly because of the petrochemical inorganic compound from which it is made, and partly because of its opened cells which contains air (oxygen). In order to reduce this flammability, certain additives (chlorinated phosphate ester) can be added to the formulation. These additives can help reduce initial ignitability, burning rate and smoke evolution (2 – 6).

The chemical reactions that occur during foaming are quite complex, and they take place in quick succession, but after lots of studies, detail of various stages of reactions have emerged. The reactions occurring in the foaming process can be divided into two parts: polymerization reaction and blowing/gas producing reaction (1, 3 and 5).

The tin catalyst controls the rate at which this reaction takes place. This primary reaction is responsible for the nucleating of the foam cells. The secondary reaction is the reaction between the hydrogen on the nitrogen atom of the urethane formed in the primary reaction and an isocyanate molecule to form an allophanate group. This occurs during the curing stage (1, 3 and 7).

The reaction between water and TDI produces quite a large amount of gas (carbon dioxide) which in turn blows up the foam cells created during the primary polymerization reaction.

The level of amine catalyst introduced into the formulation mainly controls the rate of the primary blowing reaction, where carbon dioxide is generated. It is important to note that the primary polymerization reaction and primary blowing reaction occur in parallel. As the foam cells are nucleated, the generated carbon dioxide diffuses into them. Also, the production of urea in the secondary blowing reaction contributes to the formation of the polymer structure and secondary polymerization reaction and the tertiary blowing reaction are the main contributors to the number

(or extent) of cross linkage and the degree of cross linkage influences greatly the final physical structure of the foam (2, 8 - 10).

The foaming reaction stage is the period between chemical mixing and the full attainment of solid block height. It is during the foaming stages which include: cream time, rising time and curing time that all characteristics of the foam are formed, and for this reason, much understanding of events taking place is necessary if foam qualities are to be manipulated to give good effects (3, 11 – 13).

Thus there is the need to optimize flexible polyurethane polyether foam production processes in order to reduce cost of production which in turn leads to reduction in market price of the virgin polyurethane foam. The main aim of this study was to optimize flexible polyurethane polyether foam manufacturing processes by determining the optimum quantity of silicone oil required to meet quality standard of foam since it happens to be the most expensive but vital raw material.

MATERIALS AND METHODS

100g of polyol was measured into the bowl on the weighing scale. Other measurements into the bowl were 0.15g of amine, 0.25g of stannous octoate, 3.79g of water and 1g of silicone oil. The 5 litre bowl and its content was removed from the scale and replaced with the 2 litre bowl where 46.94g of TDI was measured, the mixture in the 5 litre bowl was stirred adequately to achieve homogeneity and as the stirring continued, TDI was added gradually into the 5 litre bowl. When homogeneity in mixing had been achieved, the mixture was poured into the reaction box and allowed to rise. The foam was allowed to set for 5 min after fully risen position had been achieved. Then the set foam was removed from the box and the box was then prepared for the next experiment. Methylene chloride was used to wash the 5 litre bowl to prepare it for the next measurement.

The procedure was repeated for experiments involving 0.8g, 0.6g, 0.4g, 0.2g, 0g and 1.2g weight of silicone oil respectively.

Physical testing
Physical tests carried out on the foam samples to ascertain their quality are density test, indentation test, compression set test, tensile strength and elongation tests and heat ageing which are standard tests in the foam industry (2 and 3).

RESULTS AND DISCUSSION
The result of observations during curing process is presented in Table I while the result of various physical tests carried out on samples is presented (Table II and Figs. 1a, 1b and 1c). Table III shows the confirmatory test of the optimum quantity of silicone oil.

Experiments with 1g, 0.8g and 1.2g had almost the same characteristics (Table I). The rising time was observed to be about 73 seconds for 1g and 1.2g and 72 seconds for 0.8g. Other values ranged between 70 seconds and 63 seconds for the remaining samples. There was no significant difference noticeable in the rising time of samples 1.2g, 1g, 08g and that of 0.6g but sharp differences began to set in below this range. This was also true of the curing time for the samples. Likewise, observation on the risen height of samples was similar for 1.2g, 1g and 0.8g but start declining from 0.6g downwards. Thus, it was inferred that this experience might be similar just below 0.8g between 0.8g and 0.6g quantity of silicone oil. So, it is likely that the optimum silicone oil quantity lies between 0.8g and 0.6g.

Silicone oil content decreased from 1g to 0.2g, the density increased from $20.14 kg/m^3$ (Table II). Silicone oil content is inversely proportional to density of the foam produced with it. A close observation also revealed that there was a very close hardness index of 161.8KN, 161.5KN and 161KN for 1.2g, 1g and 0.8g of silicone oil used respectively but with a drop to about 149KN with 0.6g of silicone oil used (Table II). This also confirmed the previous observation that the optimum silicone oil quantity was between 0.8g and 0.6g.

The compression set test gave the same value at 1.2g, 1.0g and 0.8g of silicone oil used but changed significantly between 0.8g and 0.6g, that is, 6.89% and 10.34%. This further confirmed that the

optimum silicone oil quantity was between 0.8g and 0.6g. The compression set values increased as the silicone oil content decreased (Table II). This supported theoretical conclusions in literature because high value of compression set is an indication of instability as this is the difference between the initial thickness and the final thickness of foam as a percentage of its original thickness (2, 3 and 6).

Further more, close observations show consistent values $119.44KN/m^2$ and 160% for tensile strength test and elongation respectively for the silicone oil quantity from 1.2g to 0.8g (Table II). This values started declining from 0.6g downwards. These were other indications of the optimum quantity between 0.8g and 0.6g. As the silicone oil quantity was reduced from 1.2g to 0.8g, the tensile strength and elongation values had similar values of $118.06KN/m^2$ and 160% respectively for heat ageing test, but on reduction to 0.6g and below, the tensile strength and elongation values declined. This further confirmed that the optimum silicone oil content was between 0.8g and 0.6g of silicone oil used.

Table I. Observations during experimentation

Mass of silicone oil used	Experimental Setup						
	1g	0.8g	0.6g	0.4g	0.2g	0g	1.2g
Rising time (secs)	73	72	70	68	65	63	73
Curing time (secs)	210	209	215	219	222	225	211
Observation on risen height	35cm No fall back	36cm No fall back	Initial risen height was 37cm but later fell back to 33cm	Initial risen height was 37cm but later fell back to 31cm	Initial risen height was 37cm but later fell back to 30cm	Initial risen height was 37cm but later fell back to 28cm	35cm No fall back

quantity of silicone oil used and 24% reduction in cost of silicone oil used which is a significant amount of the total cost of production. Foam industries are encouraged to adopt the use of optimum silicone oil quantity for production in order to reduce their running cost associated with silicone oil.
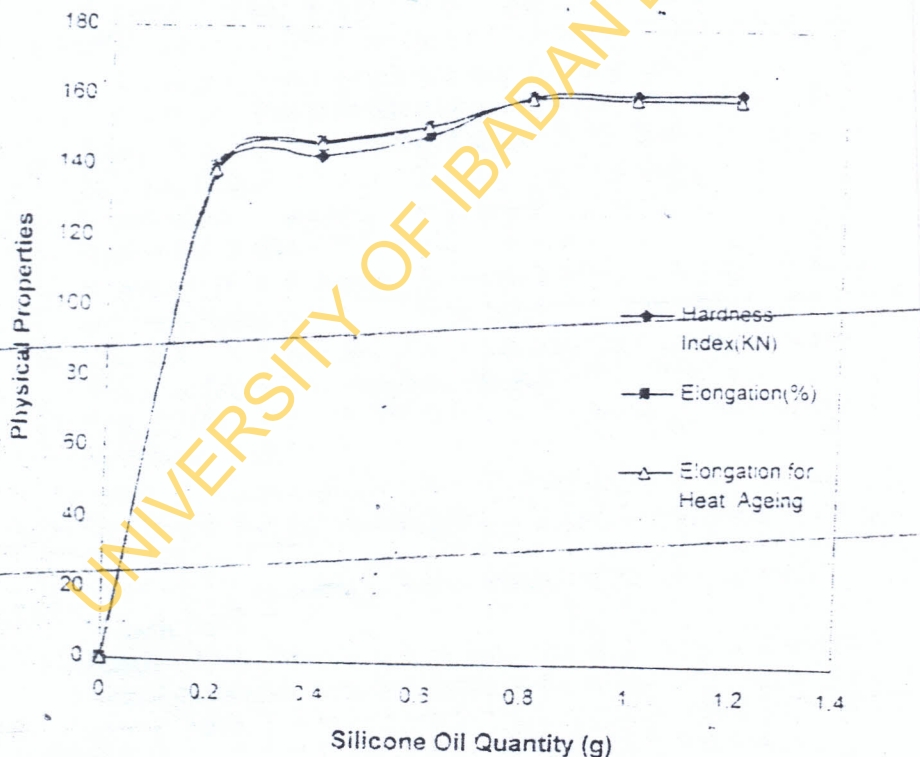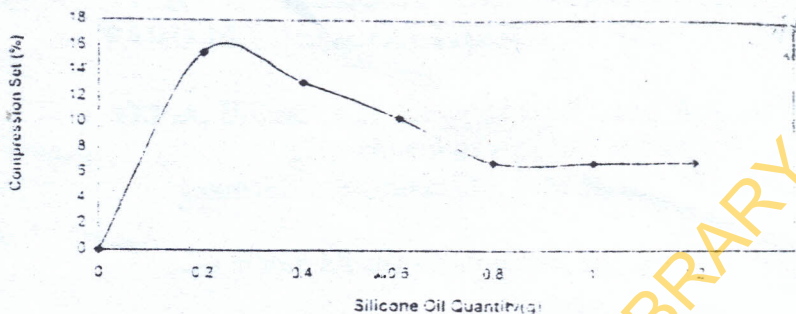
Fig. 1. Graph of physical test
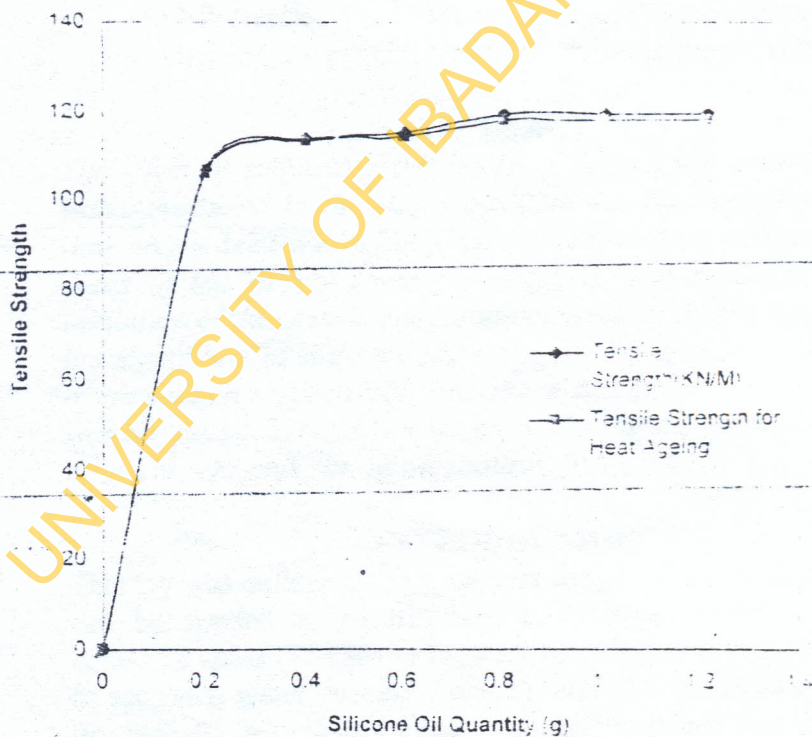
Fig. 2. Graph of compression set

Fig. 3. Graph of tensile strength

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