CHAPTER 6

RECOMMENDATIONS AND FUTURE WORK

6.1 Solid-state batch foaming process

In the batch foaming process experiment, the limitations of the process and the proposal are presented as the following.

1) Controlling of time to transfer the samples;

This is due to the batch foaming process is composed of two steps; gas saturation and expansion steps which cause the process to perform as a non-consecutive process. Therefore, after the gas saturation step the samples are taken out of the pressure chamber in order to be expanded in the heating bath. Therefore, during the transportation of the samples the operator has to do the experiment swiftly and carefully. In addition, the time to remove the samples is necessary to be controlled in order to maintain the same quality of the final foams in each condition and avoid the processing factors that might interfere the production and the foam characteristics. In order to solve this problem, the conventional batch foaming instrument should be modified to have the heating element inside the pressure chamber, and then the samples will be allowed to expand inside the chamber, right after the gas absorption step. However, for safety, the heating step will not be performed at the same time as the samples are saturated with the gas. Moreover, the chamber needs to be closed after the gas releasing in order to prevent the heat lost during the expansion step. However, selection of heating element is very important due to the heating time is depended on the thermal conductivity of the element. This approach will be possible if the swift heating element is available.

2) Hazardous solvent;

In the experiment, chloroform was selected to use as a swelling agent for plasticization of PP matrix prior to the gas saturation step. Using this solvent might harm the health of the operator during the process due to its high volatility. As the environmental and safety concerned, the interesting of the researcher has shifted to the green process for the future research. Recently, it has been found that a supercritical carbon dioxide (Sp-CO_2) is well established for use as a solvent in polymer applications such as polymer blending, formation of polymer composites and also microcellular foaming. This Sp-CO_2 mainly acts as a plasticizer or solvent when contacted with a polymer and its solubility can be predicted theoretically from pure component properties. Moreover, when the polymer is exposed to CO_2 at the critical state the apparent glass transition temperature or melting point of the polymer is reduced, usually near ambient. Depending on processing condition, the polymer may be converted to the molten state as the polymer melt in the continuous process [147]. Therefore, the Sp-CO_2 is a good candidate for replacing the conventional solvent in the batch foaming process.

3) Shaping of the samples;

In expansion procedure, the gas-saturated samples were immerged into the hot oil in the length direction of the samples. Therefore, the initial part of the sample was firstly contacted to hot oil and it was observed to be slightly thicker than a tail end as can be seen in the dot circle in Figure 6.1.

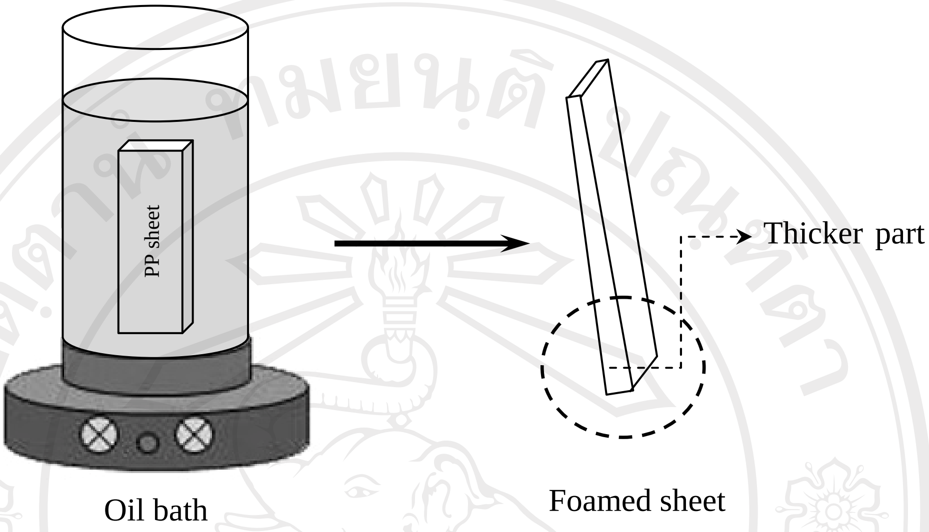

Figure 6.1 Expansion step and the final foamed PP sheet.

According to the requirement of the standard test method, the sample dimension should be constant (in both the width and the thickness) to prevent the error from the shape of sample. Consequently, the heating method should be improved to obtain the uniformity of the sample. As the idea of cooking by microwave oven, the water molecules in food can be vibrated and producing the heat to cook the food by the microwave due to its polarity. In addition, microwave irradiation is a well-known method for heating and drying a material [148]. It offers a number of advantages over conventional heating such as non-contact heating; instantaneous and rapid heating; and highly specific heating [149]. Therefore, this idea can be introduced to the foaming process in order to expand the sample uniformly, and the processing time can be controlled. In the case of polymer material, it might be difficult to heat the sample through the microwave. This is due to the microwave can pass through the plastic material, so the heat cannot be generated. It means that the material which can be processed under the microwave must have the dielectric property which causes the molecules to vibrate and produce heat [148-149]. In the case of non-polar polymer such as PP, using water as a heating media may be a possible method to heat the sample under the microwave. When the material is heated under microwave, the outer layers are heated then the inside is heated mainly by the slower conduction of heat from the hot outer layers. Therefore, the layer foams can be produced via the microwave oven; the large bubbles will be appeared at the outer layer while smaller cells are found inside. However, the rate and degree of heating depend on the depth and the density of the sample. In addition, the corresponding wavelengths of microwave span in a range from 1 mm to 1 m [149]; therefore, the foam production with thick sheet can be processed. However, this approach will be performed at the temperature which is not higher than 100 °C due to the boiling point of the water.

6.2 Continuous foaming process

As the experimental result of continuous foaming process, it was found that the expansion ratios of the PP foams which produced using Honam SMS-514 were decreased as the increment of talc content. This might be influenced by the molecular structure and the viscosity of the polymer. Therefore, utilizing the modified polymer material may be a possible method for the future research to increase the expansion ratio of the final PP foams as previously discussed in Chapter 4. In addition, the agglomeration of talc particles in the polymer/gas solution could be occurred when a high content of talc was used. Some research groups [150-152] reveal the profit of introduction of nanoclays in the manufacturing of polymer composites as a plasticizer. Therefore, this performance of nanoparticles is expected to enhance the uniform mixing of polymer/gas solution in the continuous foaming process. It is well known that the nanoscale dispersion (depending on the dispersion methods; exfoliation and intercalation) in the polymer matrix is the key to prepare the high performance nanocomposites. When nanoparticles are used in the polymer matrix, they give an increased interaction between the particle and the surrounding matrix, resulting in improved mechanical, chemical, and thermal properties due to their high surface area (1 g of particles of 25 nm has a surface area of 20 m^2) and the dispersion pattern of nanoparticles in the polymer matrix. The platelets of the nanoclays result in largely improved performance in these properties; gas barrier properties, recyclability, dimensional stability, heat resistance, and good optical clarity (since particles are nano-size). Many types of commercial plastics such as PE, nylon, PET and including PP are utilized for nanocomposite structure. Moreover, nanomaterial products are finding uses in the automotive industry for a variety of functions with reduced weight. One of the primarily nanoparticles which used in the automotive parts is nanoclay. Natural nanoclays are nanosized and platelet-shaped particles [150-151]. General Motors [151] showed the first commercial use of nanoclays in the automotive parts in 2002. The step-assist was made of thermoplastic olefin filled with 3 % nanoclays. It was much lighter, stiffer, and less brittle at cold temperatures than those made with the conventional talc filler [152]. According to this experiment, the produced PP foams were expected to use for fabrication the lightweight parts in the automotive applications. But due to their expansion ratios were a function of a high aspect ratio of talc thus the final foams with a higher expansion ratio could not be achieved. As many advantages of making nanocomposite, utilizing nanoclay as a nucleating agent may be a solution to improve the foamability; the highly heterogeneous nucleation sites via the surface area of nanoclay and the uniformity of gas solubility in the polymer melt through the plasticization performance of the nanoclay. Consequently, the production of the finer-celled PP foams with higher expansion ratio (more than 14 folds) using nanoclay as a nucleating agent by the continuous foaming process will be proposed as the future work.