폼 유체의 유변학적 특성 측정

임윤미, 윤재륜
서울대학교 재료공학부

Measurement of rheological properties of foamed material

Yunmee Lim, Jaeryoun Youn
School of Materials science and engineering, Seoul National University,

Introduction

Reaction injection molding (RIM) is a method for rapid production of plastic parts directly from low viscosity monomers or reactive oligomers. Polyurethane, polyurea, nylon, epoxy and unsaturated polyesters may be processed by RIM, but 95% of RIM products consist of polyurethane which are produced by the chemical reaction of polyol and isocyanate. A schematic diagram of the RIM process are shown in Fig. 1. Two or more reactive liquid streams which have low viscosity are mixed in the mixing head by utilizing turbulent mixing prior to being injected into the mold where they are polymerized and solidified[1].

Foam materials generally have poor mechanical properties when it compared with solid materials, but they have many advantages such as weight reduction, savings of materials, increase in impact strength, improvement of sound and thermal insulations [2]. Polyurethanes can easily have foamed structure during the RIM process by dissolving the blowing agent in the polyol.

Schematic molding cycle of RIM is shown Figure 2. It consist of chemical reaction nucleation, bubble growth and mold filling and curing. Polyol and Isocyanate are impinged at mix head after metering. And then, bubbles start to growth by nucleation. Mold filling is achieved due to self-expantion of the foam.

Rheological properties of foam material is significantly different from the those of the fluid which contains no bubbles. Bulk viscosity of foam material during the mold filling , which may be affected by bubble size, the number of bubbles in the fluid, the shape of bubbles, and so on, has a significantly effect final product. Thus, measurement and prediction of rheological properties of foam material is important.

In this study, rheological properties of foamed fluid were measure by a rheometer and were predicted by using numerical analysis in order to help determining optimum conditions in the RIM process.

Experiment

Materials and Instrument

Materials that used experiment are polyol(propylene oxide based diols) and MDI(4,4'diphenylmethane diisocyanate) and blowing agent is CFCH-141b (dichlorofluoroethaane). Viscosity of each materials are 933 centipoise(polyol) and 285 centipoise(MDI) repectively. Homogenizer was used to mix polyol and

MDI. Its speed was set 1000 rpm.

Viscometer that used to determine viscosity is Brookfield II HA. It shows viscosity by calculating torque at spindle with respect to shear rate.

Process

Polymeric fluid in which the blowing agent was dissolved was mixed by a homogenizer for about 30s, and then it was foamed by mixing action of the homogenizer. Directly after mixing viscosity and temperature were measured with respect to the shear rate and bubble volume fraction by viscometer at room temperature.

Numerical analysis

Numerical analysis was carried out by assuming that two-phase Newtonian fluids were in the finite plate, and inner radius of the bubble and pressure were known. Viscosity was calculated by shear stress at the bottom plate in simple shear flow condition. No-slip boundary conditions were imposed at the lower and upper plate, and symmetric condition was set along the centerline.

Previous researchers repored the experimental expression for the viscosity of foamed fluid. With small bubble volume fraction, the viscosity of foamed fluid can be determined by the following equation[3,4].

$$\eta_e = \eta(1+\nu) \qquad (1)$$

where η_e is the effective viscosity of foamed fluid, η is the viscosity of continuous phase and ν is the volume fraction of bubble. With large bubble volume fraction, the following relation is reported to be valid.

$$\eta_e = \eta \exp\left(\frac{2.5\nu(\nu_m)}{1-\nu}\right) \qquad (2)$$

where ν_m is maximum volume fraction of bubble.

But, this equation is not valid for more than 70 % volume fraction of bubbles.

Results and discussion

A representative foam material is shaving foam. Its viscosity behavior is shown below(Fig 3.). It behaves shear thinning due to its original property and bubble destruction as viscosity measurement time passed. Rotating speed and temperature was 60rpm and 25.7℃. Measured viscosity was shown from 6700 to 2800 centipoise. Viscosity of shaving solution before foaming is 47centipoise and volume fraction of bubble is 0.941. In this case, since volume fraction of bubbles is more than 70%, a new relation between viscosity and volume fraction of bubbles should be proposed.

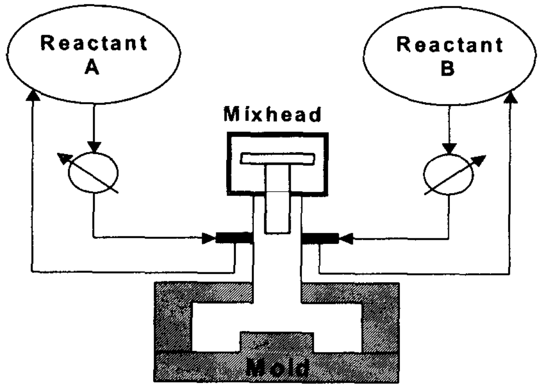

Fig 1. Schematic diagram of RIM machine

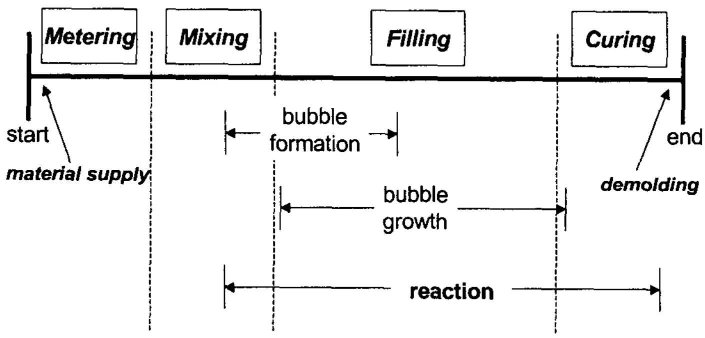

Fig 2. A schematic foamin RIM cycle

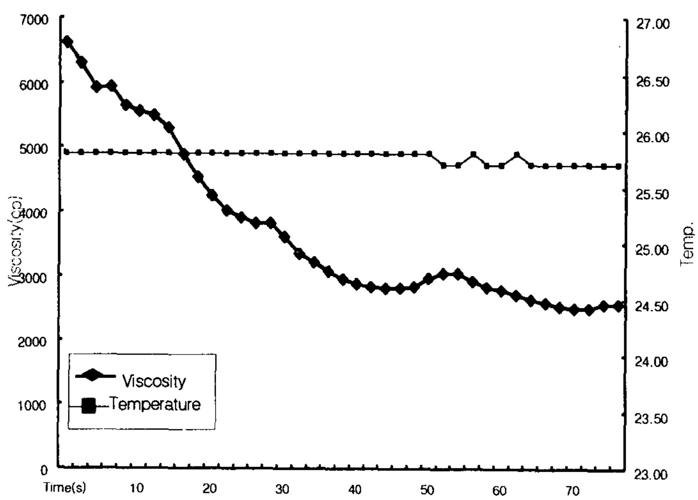

Fig 3. Viscosity of shaving foam

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