ON-LINE BUBBLE SIZE MEASUREMENT USING A MULTIPLE LIGHT BACKSCATTERING SENSOR

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ABSTRACT

Foams are the subject of practical interest in a number of major working fields, including the food industry. The relevance of a multiple backscattering light sensor to obtain on-line measurement of the bubbles mean diameter was investigated. A continuous foaming device was used to aerate a gelatin-based formulation. The optical sensor was located just after the mixer, allowing to determine the mean bubble size as a function of process conditions. Data acquired on line were compared with those obtained by optical microscopy and image analysis of the same foams.
The comparison of the mean diameter given by both techniques was satisfactory, taken into account the differences in the methods (such as on-line vs off-line, 3D vs 2D …). The backscattering technique seemed to be a convenient and interesting method for the monitoring of foaming processes, but unambiguous validation requires experiments at larger flow rates and with a broader bubble size range.

1 INTRODUCTION

Foams are the subject of practical interest in a number of major working fields, including the food industry. Bubble size is considered to be of major importance for the properties of the foam, as it influences the texture, the mouth-feel and the stability of the aerated product. It is thus relevant to determine the size of the bubbles according to the formulation and to the process conditions. This has motivated the test of a commercially available sensor (Turbiscan Online from FORMULACTION), whose relevance on the on-line monitoring of foaming process has been investigated.

2 MATERIALS AND METHOD

2.1 Foaming device

A continuous foaming device, consisting in a rotary axis with several units of four blades inserted in a coaxial cylinder has been used to aerate a gelatin-based weak gel formulation, such as used in dairy desserts.
The process conditions tested were a change of the mixer geometry (5 or 10 units of 4 blades, blade length), the whipping rate (from 400 to 1200rpm), and flow rates of gas (between 4 and 77 mL/min) and fluid (between 1 and 4 kg/h), hence leading to a range in gas volume fraction from about 4 to 70 %.
The foaming column and the feed tank were isothermally held at 18°C.
The sensor is located just after the mixer. Due to the moderate viscosity of the incoming fluid and the very low flow rate, the pressure drop below the mixer was negligible and on-line measurements were almost made at atmospheric pressure. Data acquired on line are compared with those obtained by optical microscopy and semi-automatic image analysis of the same foams.

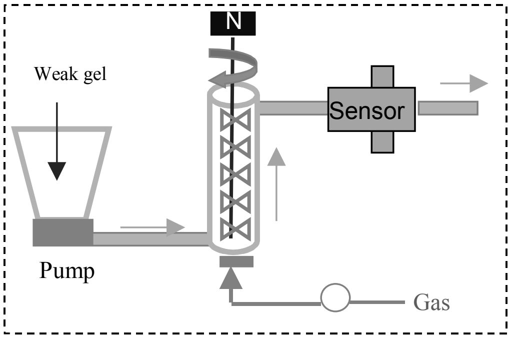

Figure 1 : Scheme of the foaming device.

2.2 Sensor principle

The sensor consists of a pulsed near-infrared light source and two synchronous detectors, a transmission one and a backscattering one. As foams were opaque only the backscattering data were analysed, using the Turbiscan‘s software.

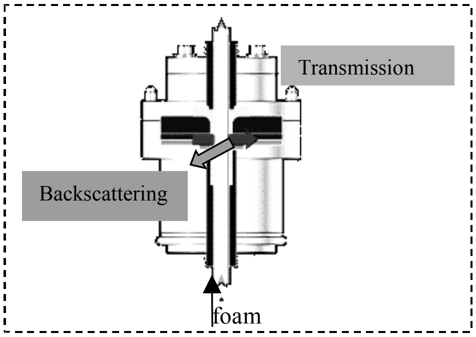

Figure 2 : Turbiscan Online Sensor.

3 RESULTS

3.1 Comparison between optical microscopy and multiple backscattering light technique

The mean diameters calculated by the Turbiscan software were compared to those measured by 2D-image analysis (Fig. 4).

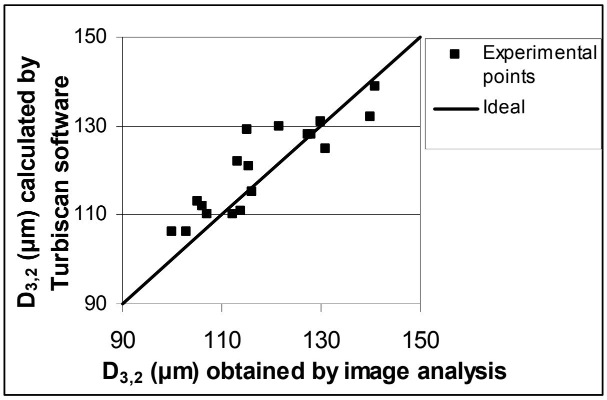

Figure 4 : Comparison of the mean diameters calculated by the two techniques.

The correlation between the two methods is satisfactory, taken into account the differences in the techniques (such as on-line vs off-line, 3D vs 2D …). The backscattering technique seems to be a convenient and interesting method for the monitoring on foaming processes, but unambiguous validation requires experiments at larger flow rates and with a broader bubble size range.

3.2 Influence of different process parameters on bubbles mean diameter

The graph presented in Fig. 5 illustrates the influence of geometric factors (number of blades, length of the blades in the mixer, hence the gap between the rotor and stator units) on the mean bubble diameter of foams as a function of the whipping rate.

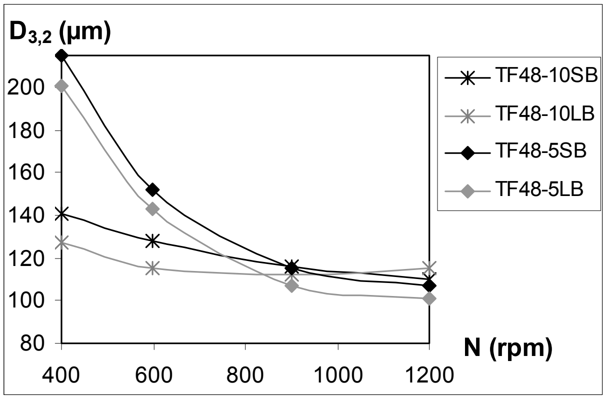

Figure 5 : Influence of process parameters on mean bubble diameters. (TF= gas volume fraction in % ; SB and LB are for Short or Long Blades)

The comparison of curves with the same colour highlights the influence of the blades number, while curves with the same symbol refer to the length of the blades.

Following comments can be made :

- the effect of whipping rate is a classical result, in agreement with the literature [1] : the influence of N on bubble size is marked at low speed, but becomes almost negligible at high rate.
- In this low rate regime, the number of blades has a strong effect on the bubble size (about 200µm for 5 units vs about 130µm for 10 units): if we speculate that the fluid is essentially sheared in the gap between the rotor and stator, doubling the number of blades leads to (at least) an increase in the average strain perceived (ie the average shear rate times the average residence time). The relevance of considering the strain in drop rupture phenomena has been underlined by several authors [2]. Others modifications could also arise, such as modification in the flow velocities, including elongational effects, but these are not straight-forward.
- The increase in the blade length is expected to lead to a rise in the average shear rate between the rotor and stator. This effect does not seem to be very marked, leading only to an average reduction of about 10-20% in bubble size. However, this reduction does not depend on the whipping rate.

Fig. 5 shows that bubble size seems to converge towards a rather constant limit value (±10%) provided enough mechanical energy is supplied in the mixer head. If not, significant variations in bubble size can be visualised.

4 ACKNOLEDGEMENTS

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5 REFERENCES

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