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Influence of a threshold value on estimating the level of particle aggregation by image analysis

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ABSTRACT

This paper investigates the influence of a threshold value on estimating the level of particle aggregation based on digital image processing technology. The number of pixels in a binary image is used to estimate the level of aggregation via a threshold value for the mixing patterns, which is a helpful parameter for characterizing the homogeneity of the mixture. The stability time can be characterized by the evolution of the pixel aggregation in the binary image. This method can be used to measure the particle aggregation of the mixture, and to obtain the mixing homogeneity time.

KEYWORDS

Image analysis; Multiphase mixing; Mixing time; Threshold.

INTRODUCTION

Mixing is one of the key operations in pharmaceutical, material, metallurgical. The purpose of mixing is to lower the levels of non-homogeneity in the materials within a system, achieve the proper level of homogeneity as soon as possible, and promote reactions. Many experiment-based studies[1-5] have shown that stirred reactors do not give optimum blending results. It is important to develop a method that makes it easy to measure the level of multiphase mixing and aggregation. In addition, the design of agitation reactors should be optimized to achieve efficient mixing and energy usage. The purpose of the present study is to propose a new method that addresses these issues. This paper presents a technique for measuring the level of mixing and aggregation in gas-agitated reactors being stirred via top-lance gas injection. This method is widely used in the chemical and metallurgical industries[6,7]. Measuring the aggregation behavior and homogeneity of mixtures is an interesting and challenging area of study. Many evaluation methods can be used to measure the mixing effects[8-15], such as the stirring power method, heat transfer coefficient method, mixing time method, and so on. Mischaikow and colleagues[16,17] proposed the use of Betti numbers for characterizing the geometric properties of fine-grained and snakelike microstructures generated during spinodal decomposition. Although box-counting with erosions[10] and Betti number evaluations[11] can measure the homogeneity of mixtures, these two methods cannot be used to measure particle aggregations. As seen in our previous experiments, there are still some agglomerates (i.e., large clusters and holes) in the mixing vessel. These affect the mixing results, even after an extended stirring time. To measure the homogeneity and aggregation of the mixture simultaneously, this paper suggests a novel analysis method based on digital image processing.

METHODOLOGY

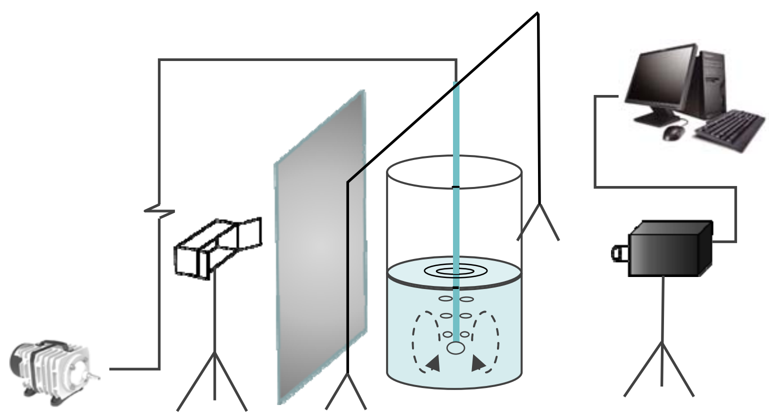
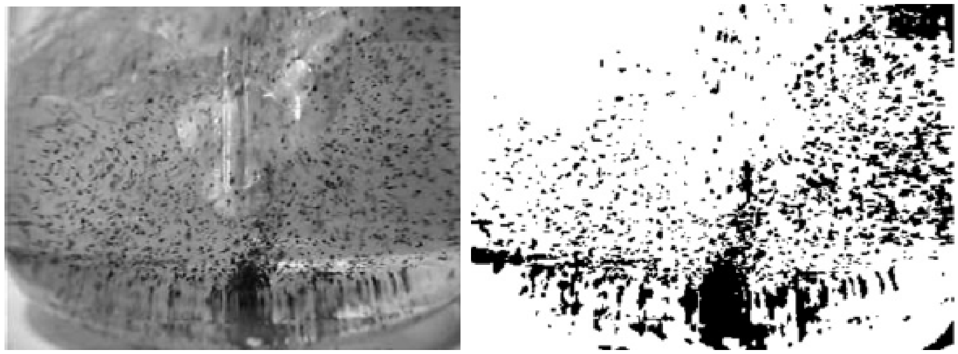


Figure 1 : The real-time monitoring and control system of the mixing process

Figure 1 shows the real-time monitoring and control system for the fusing process. There are many interesting patterns in these experiments. The image acquisition card can be used to obtain patterns at a speed of 30 frames per second, with 10,000 images considered during each experiment. Each icon corresponds to the state of the mixture at a particular moment. The binarization of these patterns is carried out in the MATLAB software environment depicted in Figure 2. The bwlabeln function is used to obtain the number of pixels in each eight-connected region of an image. These are calculated and sorted in ascending order, as shown in Figure 3. Note that there is a turning point in the curve. To determine the location of the turning point, the curve is divided into two sections by a threshold that determines the particle aggregation using a least-squares fitting method. For example, the point marked by the thick line in Figure 3 shows that the threshold value. Figure 4 shows the aggregation pattern determined by this threshold and the bwareaopen function.



Capture **Binarization**

Figure 2 : Binarization of one image

The aggregation level of the pixels in the binary images is computed for various lance depths and gas flow rates. We can also obtain the time T (in seconds) and number of pixels M in the binary images at which the pixel aggregate is equal to the average of the aggregates for all binary images produced by each experiment. The time T at which the average aggregate level is reached can be used to calculate the stability time. The sum of the pixels in the binary images, as determined by the threshold, can be used to quantify the level of aggregation.

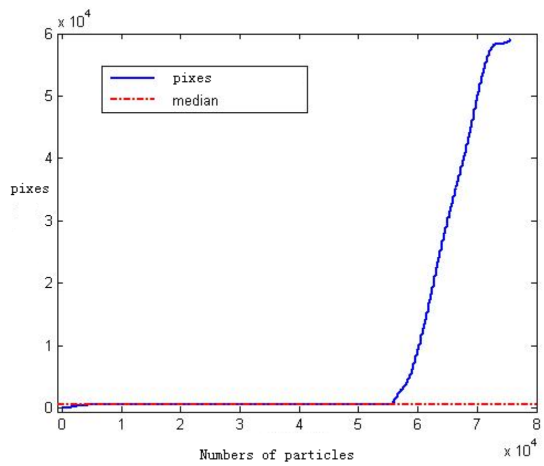


Figure 3 : The evolution of pixel aggregation for each image

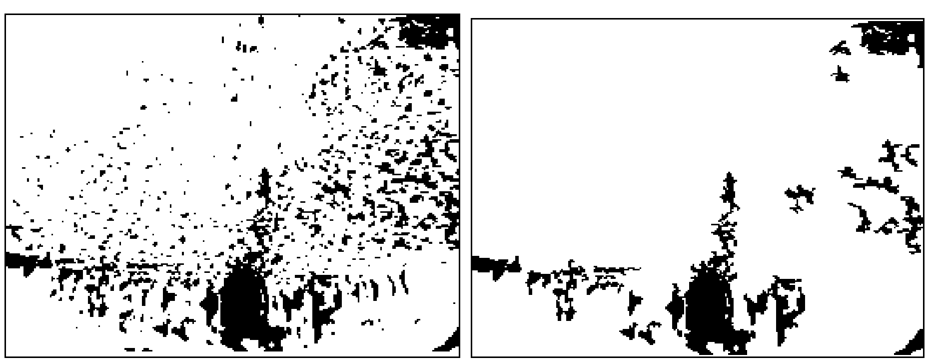


Figure 4 : The aggregation patterns given by different threshold values

RESULT AND DISSCUSS

In Figure 5, the aggregation patterns processed using a threshold value are plotted to show the evolution in the number of pixels in the binary images for l = 8 cm and different flow rates. We can easily acquire the stability time T. Figure 6 plots the original data for the number of pixels in the binary images for l = 8 cm and different flow rates. The red curve shows the mean value, but the stability time is not obvious. Thus, we propose a method for measuring the particle aggregation behaviors level of mixtures. The number of pixels in a binary image is used to estimate the level of aggregation via a threshold value for the mixing patterns, which is a useful parameter for characterizing the homogeneity time.

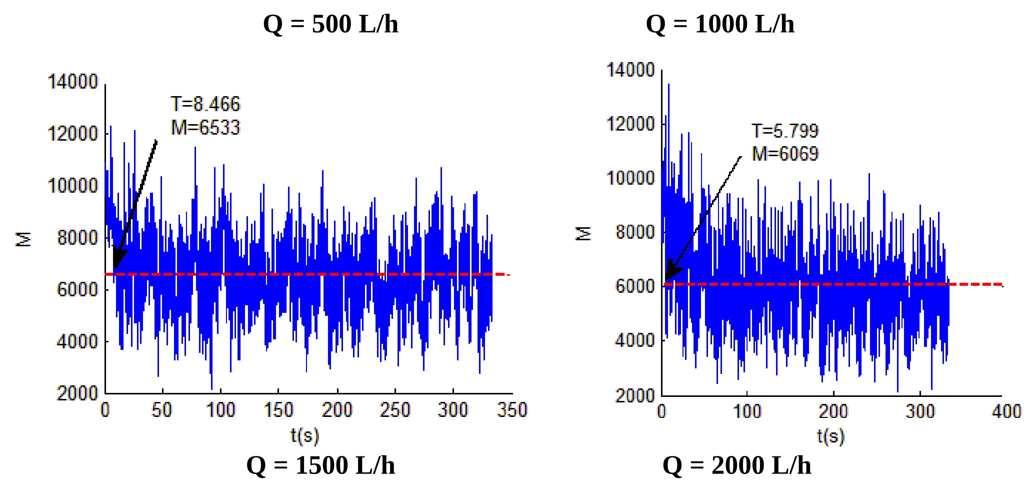


Figure 5 : Evolution curves of the number of pixels in binary images for l = 8 cm and different flow rates

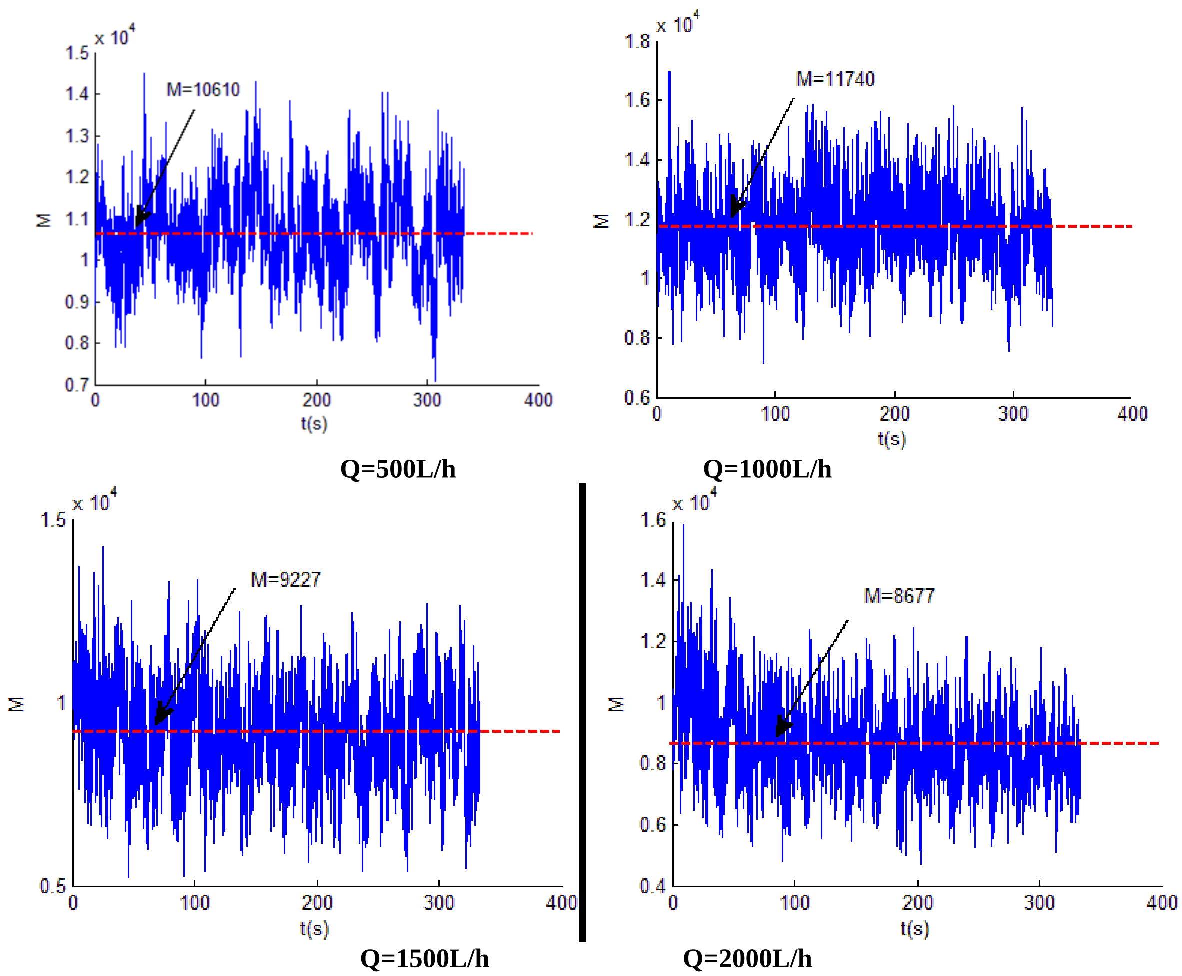


Figure 6 : Evolution curves of the number of pixels of binary image for l = 8 cm and different flow rates with no threshold value

TABLE 1 : The stability time *T* at different lance depths and flow rates.

l (cm)		Q (L/h)			
		500	1000	1500	2000
5	T	85.791	16.565	11.732	13.432
6	T	36.463	12.999	10.332	8.799
7	T	29.364	14.099	10.532	9.399
8	T	17.198	9.932	8.466	5.799

From TABLE 1, the stability time T was obtained by this method. And then the method was used to investigate the influence of gas flow rate and lance depth on the homogeneity level of the solids and liquids in a mixture. The computational results are presented in Figure 7, where l (cm) is the depth to which the lance is submerged and Q (L/h) is the gas flow rate.

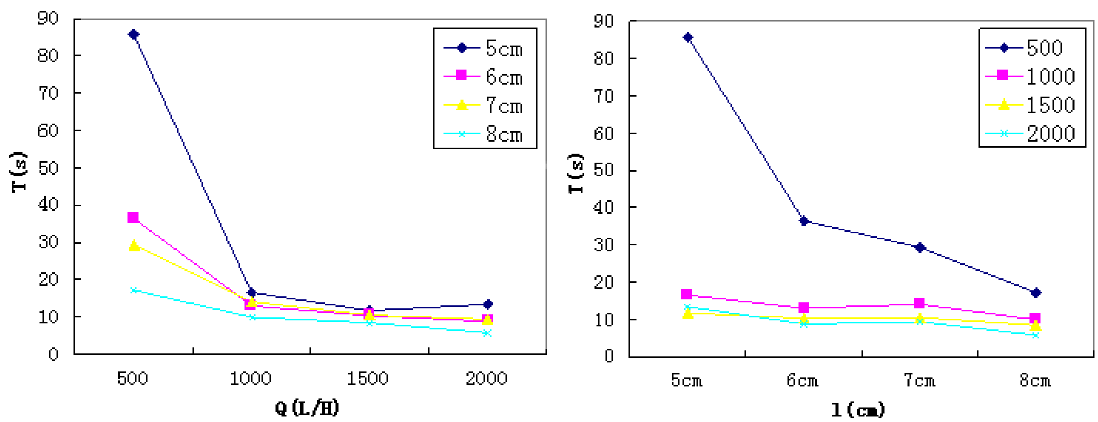


Figure 7 : The tendency of the stability time

Figure 7 shows the trend of the stability time, illustrating these irregularities. It can be seen that poor mixing occurs at a lance depth of l = 5 cm and a flow rate of Q = 500 L/h.

CONCLUSIONS

In this paper, the visualization of multiphase mixing in gas agitated reactors stirred by top-lance gas injection was investigated using an image-processing technique. A method was developed based on the number of pixels in a binary image processed according to some threshold. It was found that the temporal variation in the number of pixels in the binary images is representative of homogeneity time in the reactor, and that the variation of pixels in binary images represents a full description of the aggregation behavior of the mixture. Therefore, this method can be used to measure the aggregation behavior of the mixture simultaneously.

Tomography techniques have great potential for evaluating mixing effects, because they are non-invasive and applicable to a wide range of materials (i.e., opaque or transparent materials), and can be used for real-time measurements (i.e., measurements with short data acquisition times). As a result, it will not be difficult to obtain mixture patterns from real gas agitated reactors. This makes our method applicable for quantifying particle aggregation behaviors in real gas agitated reactors.

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