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The process for making low density LAS surfactant detergent agglomerates using microwave heating

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ABSTRACT

The internal structure of detergent surfactant agglomerates is modified using electromagnetic heating to produce a lower bulk density final product. The agglomerates are heated in a 1.8 KW microwave waveguide heating applicator operating at license-free ISM frequency band of 2450 MHz. The density of the agglomerates reduces significantly when exposed to high power electromagnetic fields. The effect of number of process variables such as input power initial moisture content over bulk density of detergent particles is studied. Three different input power levels (500 W, 1 KW & 1.6 KW) are applied to the agglomerates and it has been observed that higher input powers raise the temperature of the agglomerates very quickly, hence reducing the required residence time of the sample. Agglomerates exposed to the highest input power (1.6 KW) had the lowest bulk density. The temperature profile and residence time of the agglomerates during heating was continuously recorded. Experimental results obtained in the lab-based process will be used to design a full scale continuous mode applicator.

1. Introduction

Microwave drying of the materials has gained considerable attention in food, chemical and pharmaceutical industries and academia [1–6]. It has many benefits including short heating times, instantaneous on/off control, selective nature of heating etc. The rapid heating rates achievable with dielectric heating can result in higher yields in production, better quality and improved reproducibility which make it perfect candidate for some industrial drying applications. Besides drying applications, electromagnetic energy can be used to modify the internal structure (porosity) of the material being heated. Microwave "puffing" is the process of getting a lower density material by generating higher internal pressures within a particle by means of rapid heating [7]. The high internal pressure is generated due to formation of water vapour inside the material and this can result in significant deformation of the material. Microwave energy is well suited for reducing the bulk density of the materials due to its instantaneous rapid heating directly from inside the material [8]. This generation of pressure uniformly throughout the particle can alter the internal structure in a different manner compared to other, more conventional drying/heating techniques such as spray-drying. The generation of internal pressure inside the material helps to create a lower density material. It can also help the solubility of the material by creating internal pores that are better connected to the external environment. In granular detergent materials this can allow for the easier ingress of water and improved solubility.

This paper presents a study of change in the bulk density of LAS (Linear Alkylbenzene Sulphonate) surfactant detergent agglomerates using electromagnetic energy. Various process variables such as input power, residence time and initial moisture content of the agglomerate samples are discussed in detail to optimize the bulk density reduction.

2. Microwave equipment

A lab-scale 1.8 KW continuous wave microwave waveguide heating experimental setup has been designed as shown in Fig. 1. The microwave power generated by the SM845 (MKS instruments) microwave magnetron head is supplied to a waveguide applicator using WR-340 standard waveguides. A 6 kW isolator is placed between the magnetron and the waveguide applicator to protect the magnetron from any strong reflections. A GA6004A universal waveguide applicator from Gerling Engineering is used as the waveguide applicator (see Fig. 2). This is a standard WR-340 waveguide section with a 5 cm diameter removable adapter ports on the top and bottom walls. This set-up allows for the use of this applicator either in batch mode or continuous flow applications. There are a number of 3 mm diameter holes in one side wall of the applicator. These are used to insert fibre-optic temperature probes in the sample. The holes also allow for the videoing of the sample heating and the removal of water vapours during heating. The sample

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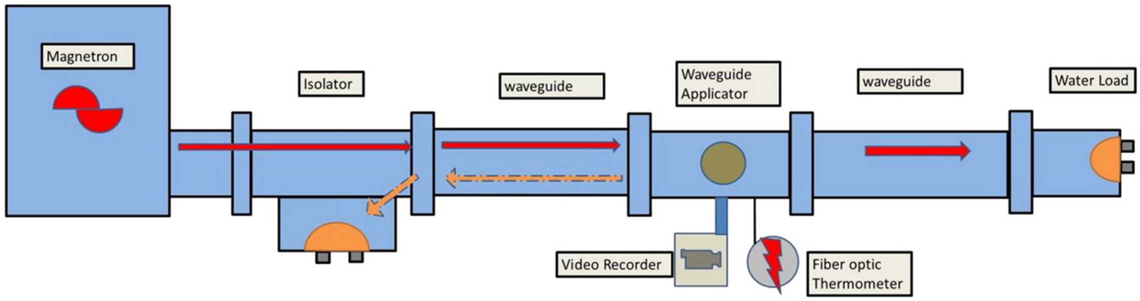
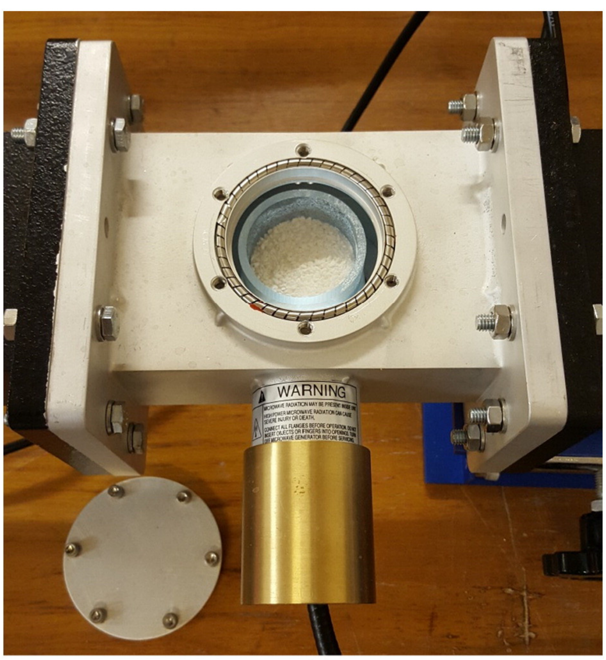


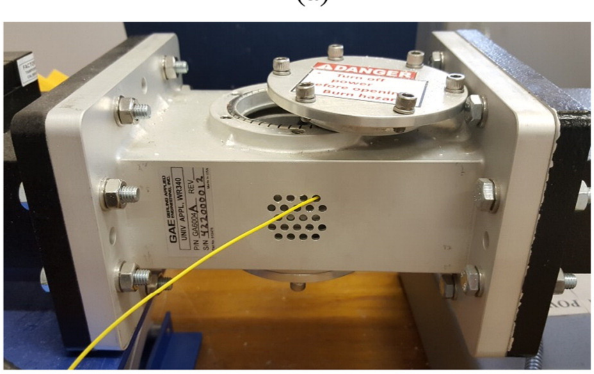
Fig. 1. Waveguide heating experimental setup.

is contained within an Acrylic holder when placed inside the waveguide applicator.

A four channel fibre optic thermometer (FOB-100 from Omega Engineering) is used to continuously monitor the temperature of the samples during exposure to microwave radiation. The fibre-optic probe is placed within the sample via one of the 3 mm holes in the side wall of the applicator as shown in Fig. 2(b). A digital video recording borescope from Maplin is used to record the visual changes in the volume of the sample.



(a)



(b)

Fig. 2. Waveguide applicator (a) Top view with Acrylic sample holder & HLAS sample (b) Side view - 3 mm perforations for fibre optic probes.

3. Materials

The starting material used in this study was a detergent agglomerate containing 33% LAS surfactant, 63.5% inorganics (sodium carbonate, sodium sulphate, zeolite) and ~3.5% water and miscellaneous.

4. Experiment procedure

Separate samples of the above agglomerate were conditioned to different moisture levels by exposure to a range of ambient humidities. Following conditioning, the dielectric properties of the different agglomerate samples were measured and the samples then exposed to electromagnetic fields. Heating time and temperature profile of the samples were recorded over time. The bulk density of each sample was measured before and after microwave heating. The density values reported here are for a bulk density measurement based on filling a sample of known volume in a consistent manner and measuring the weight of powder used. The bulk density was used because it is the most helpful in an industrial and consumer context. The bulk density is a result of the packing arrangement, the particle size distribution and the envelope density and how the materials are handled. Bulk density is a crude combination of factors but is what is important in terms of how a consumer handles and experiences detergent products. Since the sample had been placed inside a cylindrical sample holder, it could only expand in a vertical direction. The following section discusses the results in detail.

5. Results

5.1. Dielectric loss measurement

Besides other factors, microwave heating strongly depends upon the dielectric properties of the material of interest [9]. At microwave frequencies, the dielectric heating is caused by molecular dipole rotation within the material when placed in electromagnetic fields. The polarisation of a permanently polarized dipolar material arises from the finite displacement of charges or rotation of dipoles within the material when influenced by an external electromagnetic field. This colliding of dipoles creates thermal agitation and heating takes place [10]. Dielectric properties of the material define its capability to absorb electromagnetic energy and convert it to heat. The electromagnetic power absorbed per unit volume in a dielectric can be expressed as [11]

$$p_v = \frac{1}{2}\{\sigma(\omega) + \omega\varepsilon_0\varepsilon''(\omega)\}|E|^2 Wm^{-3} \quad (1)$$

where p_v is the total power absorbed per unit volume, ε'' is loss factor of the material and $|E|$ is the magnitude of electric field. The materials with higher loss factors absorb more electromagnetic energy and heat up more quickly.