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Filtration of fast pyrolysis char fines with a cross-flow moving-bed granular filter

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ABSTRACT

A cross-flow moving-bed granular filter was investigated for its performance to filter the fast pyrolysis char-laden gas with an aim to elucidate the influence of the number of filtration stages, the filter media size and mass flow rate on the collection efficiency of the filter and the pressure drop across the bed. The results showed that the two-stage filtration gave higher collection efficiency than the one stage, especially for small filter media size. The decrease of the filter media size significantly increased the collection efficiency, while slightly increased the pressure drop. In addition, the increase of the mass flow rate led to the reduction in the collection efficiency. Within the scope of the parameters investigated, the maximum collection efficiency of the granular filter was 99.79% which occurred when applying single stage filtration with the filter media size and the mass flow rate of 0.425–0.600 mm and 8 g/min, respectively.

1. Introduction

Fast pyrolysis of biomass is widely regarded as a renewable technology for production of liquid fuel. It is a high temperature process in which biomass is quickly heated in oxygen-deficient environment to form pyrolysis vapour and the residue is char. The vapour is rapidly cooled and condensed to produce a so-called bio-oil product, a mixture of water and organic compounds with trace amount of char fines. Several applications of bio-oil have been proposed [1]. One of the most important characteristics of bio-oil that limit its use as fuel is the change of viscosity after storage for a period of time, which is often known as stability. The bio-oil stability is thought to be related to the solids or char content. Although, the quantity of char particles in bio-oil is very small, they could cause troubles in gas turbines, nozzles or pumping system such as corrosion, erosion or plugging. As a consequence, the presence of char fines in bio-oil is undesirable and their removal is crucial.

Hot gas filtration was promoted as a method for removing the char particles from pyrolysis vapours [2]. Among the available approaches for hot gas clean-up, the ceramic candle barrier filters and granular bed filters are most promising. The granular bed filters have greater advantages over the ceramic candle type as the former could employ low-cost refractory filter for a very high temperature.

The granular bed filters can be classified as fixed bed, fluidised-bed or moving bed. The first one is very efficient, but the pressure drop can increase significantly over time. In addition, the fluidised bed and moving bed have advantages over the fixed bed as they could be continuously operated and regenerated at lower pressure drop. The configurations of the granular bed filters could be co-current, counter-current or cross-flow. In co-current mode, the gas typically enters the bed at the top and flows from the cleanest granules to the dirtiest granules, whereas in the counter-current filter the gas flows from the dirtiest to the cleanest granules. In a cross-flow granular filter, the gas perpendicularly flows through the downward-flow moving bed. Different configurations of the moving bed granular filters have different advantages and disadvantages and a lot of research has been carried out on these filters.

Zevenhoven [3] studied the removal of particulates from gas in coal fire power plant using a counter-flow moving bed granular filter in conjunction with the use of an electrostatic precipitator for improving the collection efficiency. The efficiency of the filter was 80–98% when operated at 850 °C and 10 bar and it decreased with gas pressure. Brown et al. [4] evaluated the performance of a counter-current moving bed granular filter by using similitude theory to devise experiments that were conducted at ambient conditions. They investigated the effect of dust ratio (the ratio of ash flow to the granular filter media flow) and granule size on the performance of the filter. They found that the dust ratio did not influence the performance, but the granule size did. The granule size of 2 mm gave higher collection efficiency and pressure drop than that of 4 mm. They reported that more than 99% collection efficiency could be achieved. In 2007, Bai et al. [5] investigated the performance of a circulating cross-flow moving bed granular filter with conical louvre plates (CGBF-CLPs) in terms of the collection efficiency and pressure drop by varying the mass flow rate and the size of the filter media as well as the dust/collector particle types. They reported the maximum collection efficiency of 99.5% when applying cyclone as the

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dust/collector particle type. They also reported that the dust collection efficiency was relative to the effects of the solids mass flow rate, the collector particle size, the separator type and pressure drop. Chen et al. [6] tested a cross-flow moving granular bed filter and reported a maximum collection efficiency of 99.95% when applying a filtration superficial velocity of 30 cm/s. They also concluded

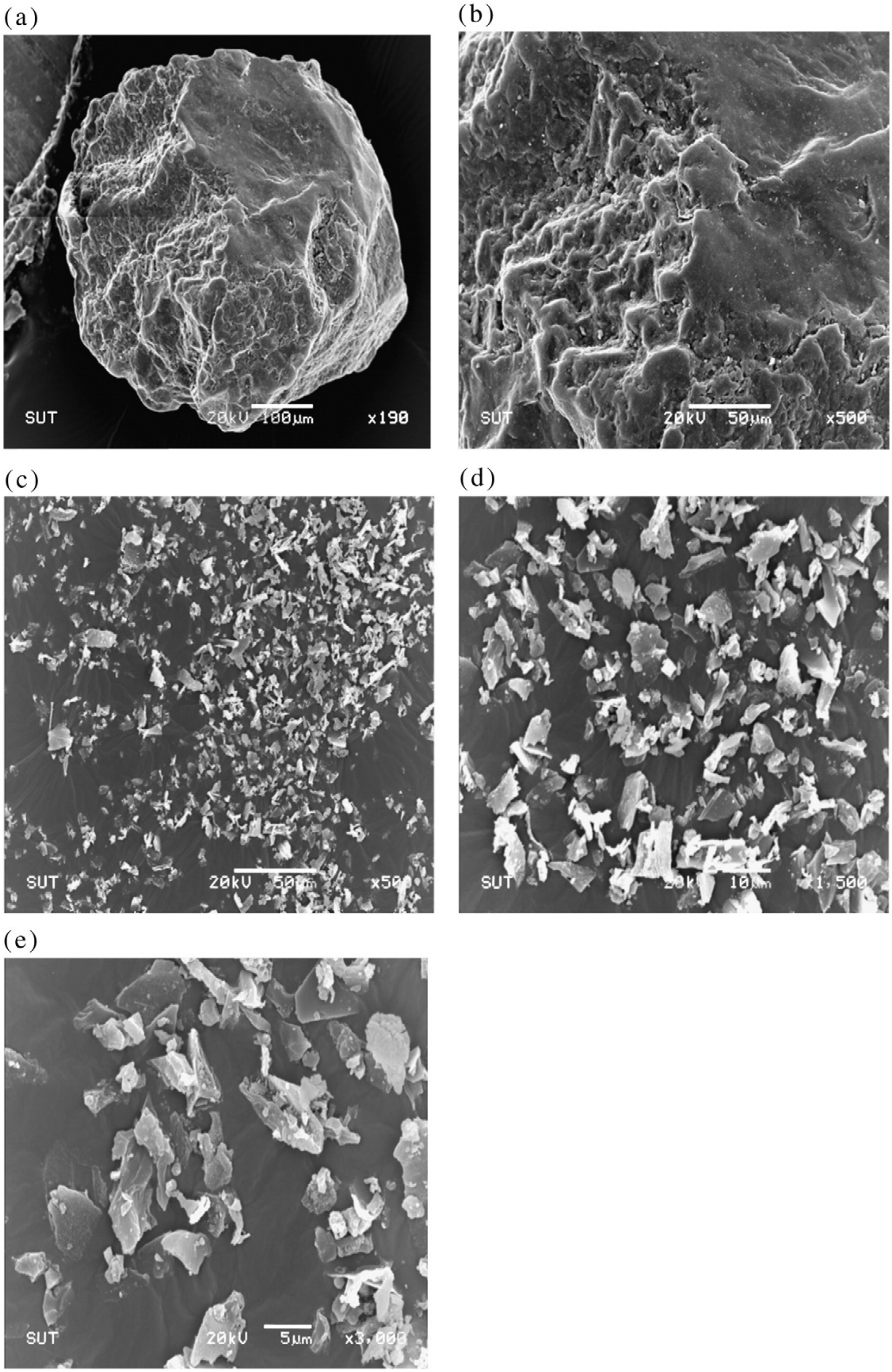

Fig. 1. Scanning electronic micrographs of water gravel (a) ×190, (b) ×500 and char fines, (c) ×500, (d) ×1500 and (e) ×3000.