CONTROLLED COLD EXTRUSION OF RECYCLED POROUS MEDIA FOR ACOUSTIC APPLICATIONS

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1 INTRODUCTION

A novel cold extrusion process has been developed to tailor a porous structure from plastic, rubber and fibre particulate waste. The extruder conveys and mixes particulates with a reacting binder and does not require heat. The end result is the continuous production of bound particulates through which the amount of carbon dioxide gas that is evolved during the reaction is controlled to give the desired acoustic properties[1]. The new process consolidates and structures granular and fibrous particles from a range of plastic, rubber and textile waste into new vibro-acoustic composites with unique combination of pore geometry and size distribution that give can be tuned to enhance the acoustic absorption,, thermal insulation or vibrational control performance. The newly developed materials possess the desired physical properties and good acoustic performance competitive with top commercial products. This work not only answers the urgent call to find alternative to landfill and low-impact recycling, it offers a clean, continuous and energy-efficient technology that re-use wastes profitably and in applications that enhance the quality of life by shielding us against environmental noise (with an estimated annual damage in the EU of 38 billion EUR)[2]. The technolgy developed has a low carbon footprint and enables much finer tuning of particles, fibre and binder structure, crucial to high noise control, thermal insulation and impact sound insulation performance.
The new family of these generic poro-elastic materials have a very low manufacturing cost. The cold extrusion process is continuous and a low energy consuming process that re-uses waste plastic and rubber materials that are otherwise dumped in landfills at an increasing cost both to the economy and the environment. Acoustic products will be made using the waste to meet the growing public expectation for a quieter environment and the applications for the new acoustic materials are widespread.
The main objective of this paper is to report on the process of the production of porous media with a controlled proportion of open and interconnected pores and a controlled pore size distribution with possible pore scale separation. These are the key non-acoustical parameters which determine the acoustic absorption performance of the extruded media. The paper presents the relations between the parameters of the extrusion process and the porosity, density and flow resistivity of the resultant material specimens.

2 THE CONTINUOUS PROCESS

The continuous process developed to recycle polymeric waste is cold extrusion based on the hot extrusion technology[3]. The function of a standard extruder is to convert solid feedstock into a homogeneous melt and to pump it through a die at a uniform rate. The hopper is fed by cold polymer granules; the solid feedstock is transported by a screw which rotates within a heated barrel. The melted extrudate is compressed, moulded, homogenised, and pressurised to generate sufficient pressure to pump the melt against the resistance of the die (see Figure 1).
The extruder's performance is related to several aspects which include: (i) the desired quality of the product; (ii) energy consumption; (iii) rate of production; and (iv) the ability of the extruder to homogenise the mixture of granulated waste, binder and additives. The extruder was designed to operate at a range of screw speeds so that the product could be extruded at a range of flow rates to control its density and the stoichiometry of the chemical processes.

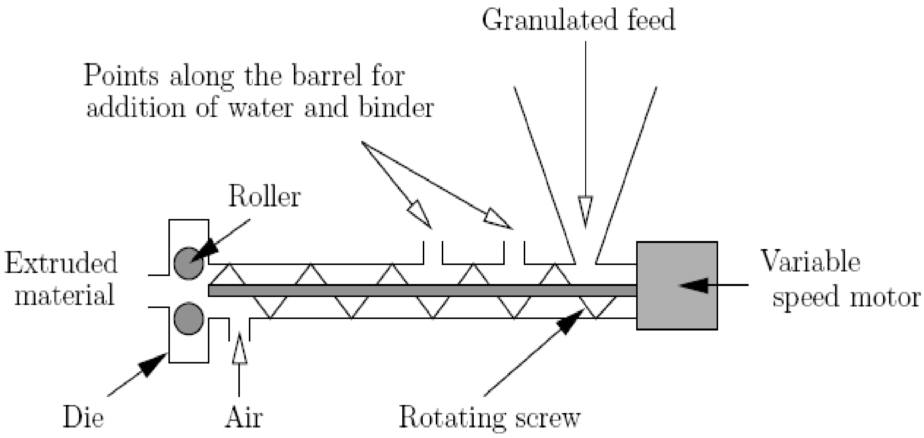

Fig. 1. Schematic view of the extruder

The whole process of curing takes around half an hour at room temperature depending on the amount of water added to the process. In the extrusion process the quantity of binder used is less then the batch technique because the material inside the barrel is compressed allowing the binder to be spread more uniformly and applied more efficiently, this result is achieved by the mixing action of the screw, which also directly compresses the fibres and granules[4].

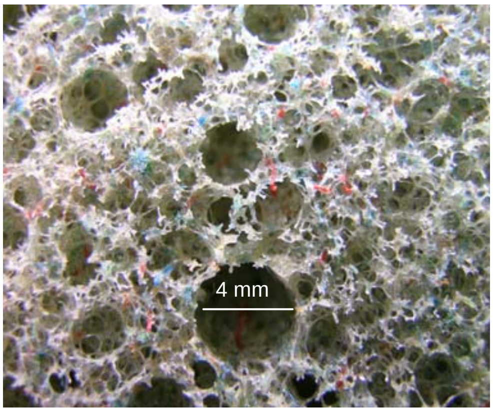

Fig. 2. Sample of extruded material

The porous structure can be composed of pores with very different and visually separable characteristic pore sizes of the order of 0.01mm to 8mm can easily be achieved (see Figure 2). This scale separation has important implications on the acoustic absorption performance[5-8].

3 INFLUENCE OF BINDER LEVEL AND GRAIN TO FIBRE RATIO ON THE PERFORMANCE OF THE MATERIALS

A number of parameters of basic extrusion technology can impact significantly on the sound absorption performance of the extruded materials. These parameters can be categorised as being part of how the material is formulated or defined as part of the experimental conditions under which the system is processed. The variables studied in this work are binder level and grain to fibre ratio.

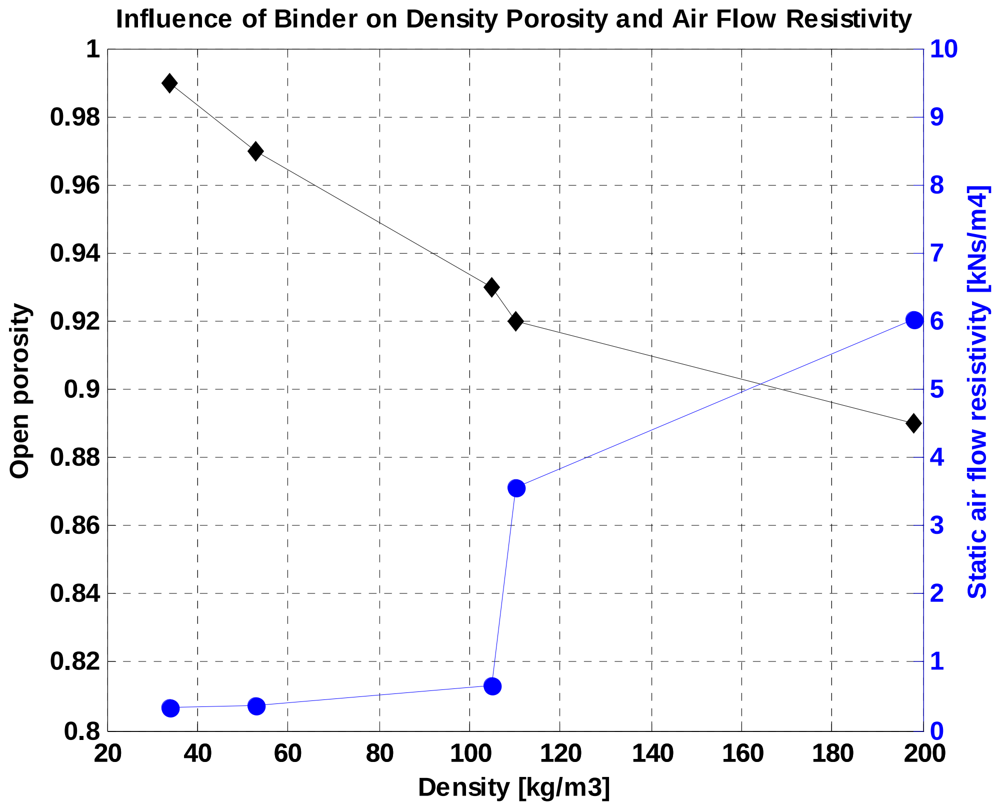

Fig. 3. The relationships between the density, porosity and air flow resistivity of extruded material specimens.

The level of binder controls the material density and this effect is shown in Figure 3. Higher levels of binder results in materials with lower density. A low binder level leads to a high density which is an undesirable effect because of the need to use a relatively large proportion of binder to achieve a relatively high porosity. The relationships between the density, porosity and air flow resistivity in recycled material are illustrated graphically in Figure 3.
It is interesting to note that for binder levels between 20 to 30% maximum change in air flow resistivity is observed. By controlling the binder level density, porosity, air flow resistivity can be tuned to give good acoustic properties.

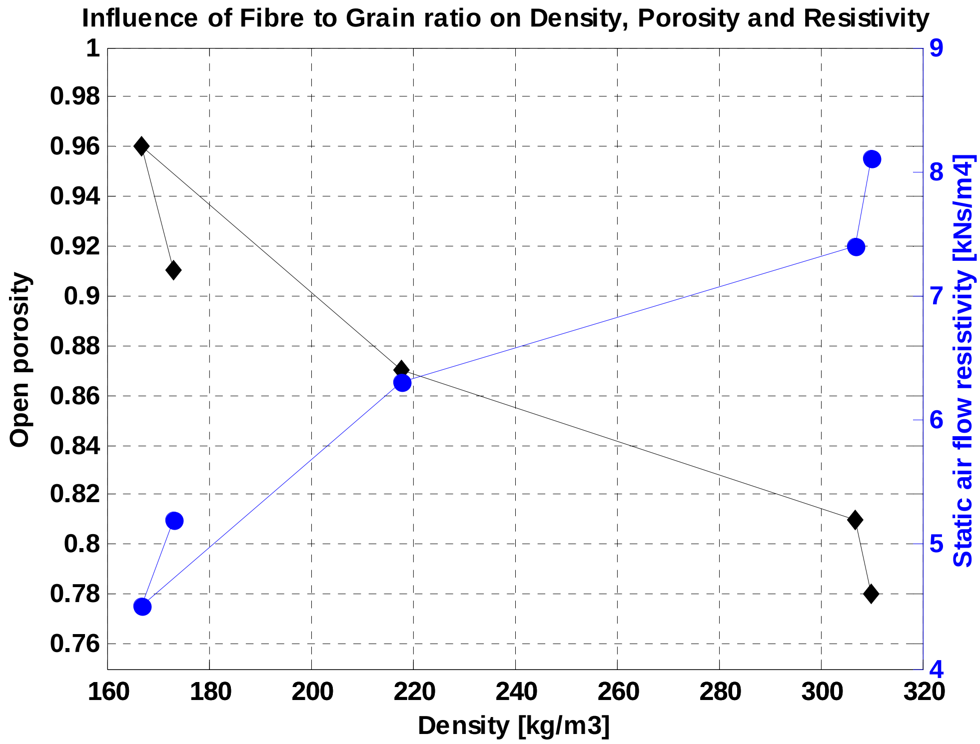

Fig. 4. Influence of fibre to grain ratio on density, porosity and air flow resistivity for fixed binder to water ratio

The graph in Figure 4 clearly shows how porosity is linked to air flow resistivity. The “chaotic” porosity and air flow resistivity curves are observed for various fibre to grain ratios which may be attributed to material heterogeneities coursed due to fibre to grain ratio mixes within the sample which affect the density of the sample.

It is clear the key features that control porosity are high binder concentrations; and an approximately equal fibre to grain ratio. Therefore, by changing the extruder variables the novel chemistry of the material can be controlled to deliver high porosity and optimal air flow resistivity values.

Figure 4 shows the influence of the grain to fibre ratio on the density of the materials. It is clearly observed that if no fibre is present in the material, then density is high due to the grains. The opposite is observed when grains are not present. The best results are achieved when ratios of fibre to grain are approximately equal.

4 CONCLUSION

Cold extrusion technology has been developed to consolidate and structure granular particles from polymeric waste into new acoustic materials with unique combination of pore geometry and size distribution that give good environmental noise control performance. Specifically the key advantages of the cold cure process are relatively low cost through recycling, straightforward design, and the sort time the material takes to cure.

It has been shown that the non-acoustic properties of the extruded materials are influenced by the extruder parameters this could be accurately modelled to obtain the acoustic properties. The pore size distribution of these materials can be controlled so that the desirable porosity and air flow resistivity values can be engineered.

5 REFERENCES

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