The effect of stratification on the acoustical properties in open cell porous media

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A major drawback of conventional porous absorbers which are used to control the levels of noise is their poor performance in a low frequency range where the acoustic wavelength is greater than the thickness of the porous layer. In order to improve the low-frequency absorption performance of porous layers, it is common to combine several layers with homogeneous pore structure in a stack to reduce the mismatch between the acoustic impedance of air and the input impedance of the resultant material stack. The benefit of having an acoustic layer with pore stratification has been well understood. As a result, there has been a number of theoretical works which studied the acoustic performance of materials with stratified porous structure (e.g. Brouard et al, JSV, 183(1), 129-142 (1995); De Ryck, APL 90(18), 181901 (2007); De Ryck JASA, 124(3), 1591-1606 (2008)). These and other similar works, have been mainly focused on the theoretical treatment of sound propagation in materials with pore stratification. As a result, there has been a lack of experimental evidence demonstrating that materials with stratified pore structure can actually be produced, characterised and provide an improvement to conventional homogeneous porous layers used for the purpose of noise control.

This paper presents new experimental data that illustrate that materials with continuous pore stratification can be produced and its behavior can be explained with a relatively simple theoretical model. The experimental methodology for material characterisation and presents the data on the material micro-structural properties is described. The theoretical model adopted in this work is based on the pore size distribution data which is a key non-acoustical property that controls the acoustical behavior of the obtained material specimen. It is shown that the pore distribution in the developed material specimen is the prime non-acoustical property that has a strong effect on the other three key non-acoustical parameters: flow resistivity, porosity and pore tortuosity. These three non-acoustical parameters, together with the pore size distribution, influence sound propagation in the porous materials and have a direct effect on their acoustic absorption coefficient. These parameters were carefully measured as a function of material sample depth. The variation of the flow resistivity, porosity and tortuosity between top and bottom layers of the developed material specimen is found to be 590%, 21% and 71%, respectively. It is shown that continuous pore stratification can improve the acoustic absorption performance of a porous layer without the need to increase the layer dimensions. The acoustic absorption coefficient of a material with pore stratification can be modelledaccurately provided the depth variation in the four non-acoustical properties is known. In the presented case, the agreement between the directly measured and acoustically deduced values of the four non-acoustical parameters is close and sufficient for modeling of the acoustical properties of the materials with pore stratification.

Keywords: pore stratification, porous media, acoustic absorption, modelling