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Sound Absorption of Snow

Introduction

Recently fallen snow possesses good sound-absorbing properties. This fact is well-known and confirmed by measurements. Is the filigree structure of snowflakes decisive? In principle we know that the sound-absorbing capacity of a porous material is dependent on its structure. But until now the question as to which structural characteristics are significant has been insufficiently answered. Detailed investigations of snow are to explain this fact by precise measurements of the sound absorption, by tomographic recording of the structure and by theoretical modeling of the acoustic processes.

Preparation of Snow Samples

The experimental part of this study is performed in cooperation with the Swiss Federal Institute of Snow and Avalanche Research SLF in Davos. The snow samples came partly from Flüelapass (Swiss mountain pass) and partly from the snow machine of the SLF. Finally, test specimens of different porosity and various structures, but homogeneous to a large extent, were prepared in the local cold laboratories (by sieving, sintering, watering).

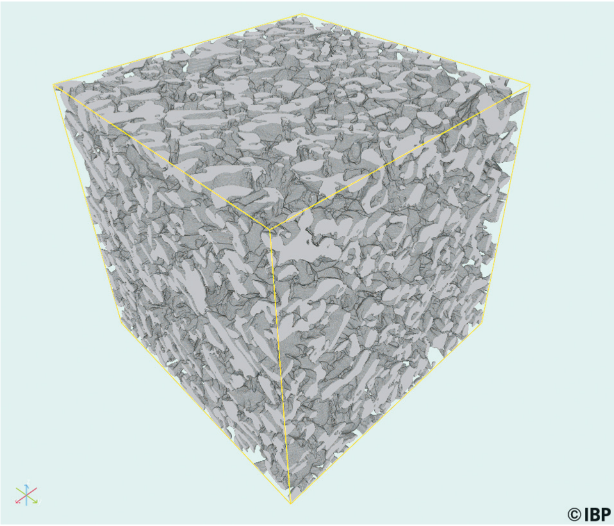

Fig. 1: Snow cube (6 mm)³, porosity 59 % (MAVI image)

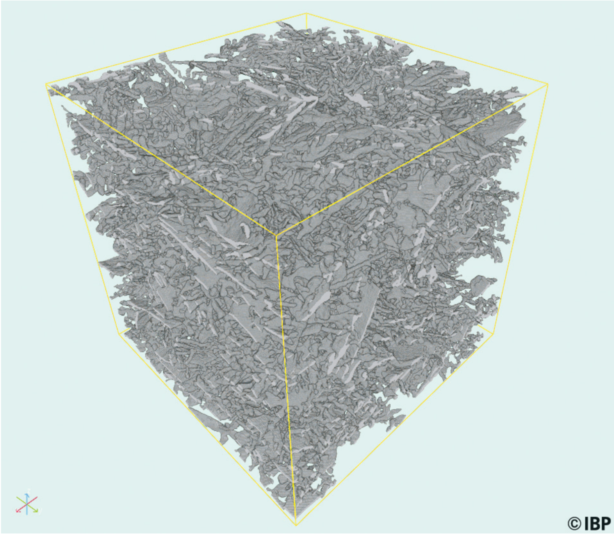

Fig. 2: Snow cube (6 mm)³, porosity 88 % (MAVI image)

Measurement of the Absorption Coefficient

In-situ acoustic measurements were performed in Davos. A Kundt's tube was used in the experiments, which can be positioned vertically, and its software was extended for measurements at low temperatures. All snow samples had a thickness of 5 cm and a volume of 2 liters; porosity was determined by weighing. The temperature of the snow samples was approximately -5 °C or -10 °C when measuring the absorption coefficient. The measurement results at the two different temperatures vary only slightly.

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Micro-Computer Tomography

After the acoustic measurements, small quantities were extracted from the snow samples and analyzed in the micro-computer tomograph of the SLF with a resolution of 0.01 mm. Figures 1 and 2 – produced by the image analysis software MAVI of the Fraunhofer Institute for Industrial Mathematics ITWM – show cubical snow sections of 6 mm edge length from samples with „weighed" porosities of 59 % or 87 % respectively. The porosities of the sections, determined by MAVI, amount to 59 % or 88 % indicating an extraordinary homogeneity of the specimens. It is remarkable that snow crystals cannot be discerned. As in the natural process, the sixfold symmetry disappeared after a short period of time due to the sintering processes.

The Wilson Model

For reasons of simplification, it was assumed for the theoretical simulation of the measured absorption coefficients that the ice frame remains immovable during acoustic excitation. The Wilson model [1] serves as absorber model. The model parameters – with the exception of porosity – were determined from adaptation to the measurement data in the frequency range from 400 Hz to 1600 Hz. Due to the relatively good agreement of measurement and calculation (Figures 3 and 4) it can be concluded that the assumptions of the theoretical model essentially apply.

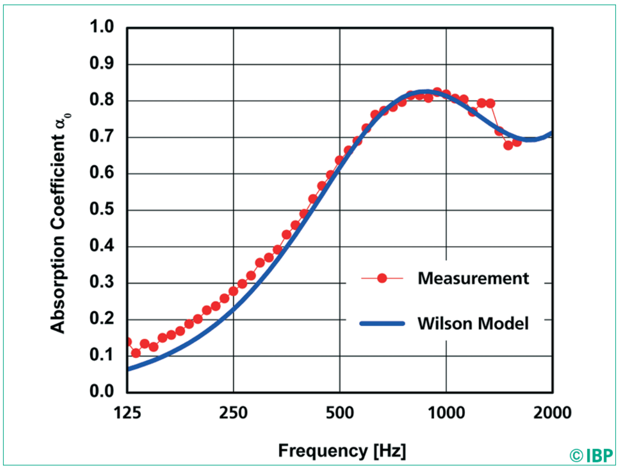

Fig. 3: Absorption coefficient of the snow sample with 59 % porosity

Structure and Absorption

In trying to derive the parameters of the Wilson model as directly as possible from the geometrical structure, it seems reasonable to apply the volume averages calculated by MAVI from tomographical data. The Minkowski functionals are of special interest in this context to characterize – besides porosity – also the surface of pores and its curvature.

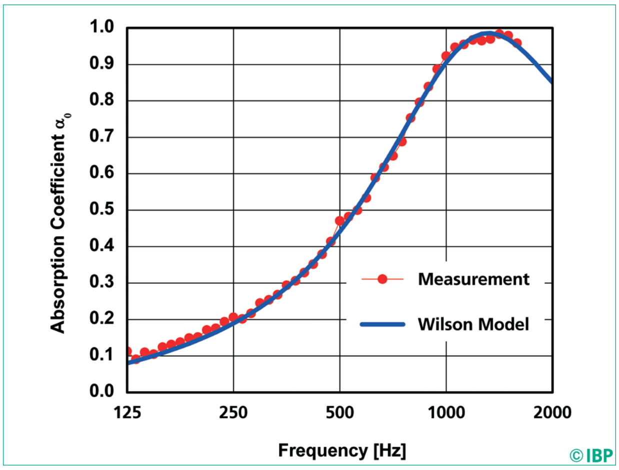

Fig. 4: Absorption coefficient of the snow sample with 87% porosity

Absorbers Similar to Snow

The knowledge of the correlations between structure and absorption should finally result in the development of new porous materials. They will be produced by the Fraunhofer Institute for Chemical Technology ICT in Pfinztal near Karlsruhe as project partner. The ICT is already well-reputed for generating artificial snow („theater snow") made of potato starch or polyethylene aimed at generating optical similarity to falling snowflakes but no acoustic similarity. The objective, however, is now to simulate snow even acoustically.

Summary

The sound absorption of snow was measured for different test specimens with porosities in the range from 46 % to approximately 90 % in a Kundt's tube. The novel approach is the combination with the micro-tomographic recording of the geometrical structure allowing the quantitative correlation of sound absorption and structure. This is a precondition for the targeted development and optimization of sound-absorbing materials.

Acknowledgement

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References

[1] Wilson, D. K.: Simple, relaxational models for the acoustical properties of porous media. Appl. Acoust. 50 (1997) p. 171-188.

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