Metallic Hollow Sphere Structures – Examples for Future Noise Reduction Applications

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Abstract

Recently, structures made of metallic hollow spheres (Metal Hollow Sphere Structures, MHSS) were successfully tested as sound absorbers for the reduction of noise in several applications, e.g. as silencers and enclosures. Advantageous properties of this new absorber material are the high temperature resistance and the high mechanical strength. Self-supporting structures without any additional housing will be possible in future. Furthermore, the high heat resistance of MHSS made of special steels and the gas permeability of the structures will allow the creation multifunctional components such as combined mufflers and diesel soot filters and/or mufflers and catalysts.
Thus metal hollow sphere structures will enable engineers to strike new paths in the design of noise reduction components in engineering and vehicle construction.
Using an absorber model and measurement data for characteristic values of the structures, an effective acoustic design was carried out. Excellent sound absorbing properties can be expected from MHS for a variety of applications. In this presentation an overview of results for several application areas such as multifunctional mufflers for passenger cars, mufflers for combustion engine driven machines, and enclosures for high speed milling heads will be given.

1. State of the Art and Aim

Due to their excellent sound absorption behaviour and their low price, classical absorber materials like mineral wool or polymer foams are widely-used in a multiplicity of sound absorption and sound insulation applications. Because these materials fulfil the expectations in the most of applications, there seemed to be no need to substitute them by modern absorber materials so far. On the other hand the mechanical strength and the temperature stability of classical absorber materials are limited. So in applications with high mechanical or thermal stress they could have a relatively short lifetime or are not applicable at all. For these applications metal hollow sphere structures constitute a very interesting option.
The aim of our work of the last few years was to combine the very good acoustic properties of metal hollow sphere structures with the high mechanical strength, chemical stability and temperature resistivity of this new material and to create first demonstrators to show their advantages.

2. Basic Investigation of Sound Absorption by Metal Hollow Sphere Structures

First investigations of sound absorption by hollow sphere structures of different cell sizes have been done using a Kundt's tube. The specific sound absorption measurements were carried out according to ASTM-standard E-1050-90. Fig. 1 shows three test samples with different sphere diameters. The diameter of the samples was 50 mm, the height 100 mm. The sphere wall porosity was around 8 %. As shown in Fig. 2 steel hollow sphere structures showed a very specific sound absorption behavior compared to mineral wool. The frequency dependence seems to be a function of the sphere diameter and shows a maximum around 600...800 Hz. Mineral wool on the other hand has not a pronounced maximum but absorbs over a broad range of frequencies which makes it a preferable sound absorbing material despite its hazardous properties. The great differences and the appearance of a pronounced maximum in the graph gave a good reason for assuming more and narrow frequency dependencies of metallic hollow sphere structures which accounts for a possible way of sound engineering: e.g. by combining metallic hollow spheres with different dimensions. (1, 2)

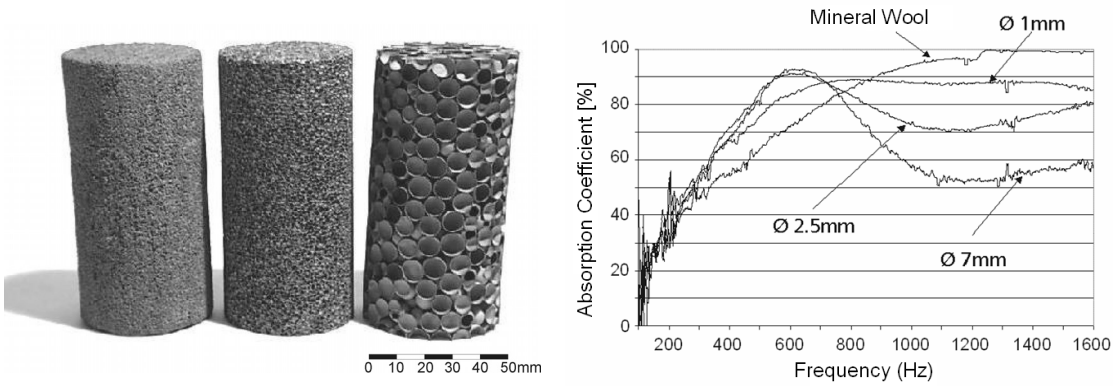

FIGURE 1. Test Samples for Sound Absorption - Sphere Diameter: 1, 2.5, and 7 mm, Density of the Structures: 0.39, 0.37, and 0.57 g/cm³ (left) and Sound Absorption Rate of these Hollow Sphere Structures and Mineral Wool (right)

Akustikforschung Dresden (AFD) have carried out some optimization trials to obtain a broadband sound absorption by MHSS.
Fig. 2 shows the absorption coefficient vs. frequency of an optimized MHSS, compared to a non-optimized MHSS and mineral wool.
As we have shown, homogenous MHSS have a good damping behaviour. On the other hand, the sound insulation behaviour is insufficient in many cases. To increase the sound insulation, covering by dense layers (e.g. sheets of 1 mm thickness or more) at the noise averted surface is necessary. Fig. 3 shows a comparison of the sound insulation of homogenous and covered MHSS.

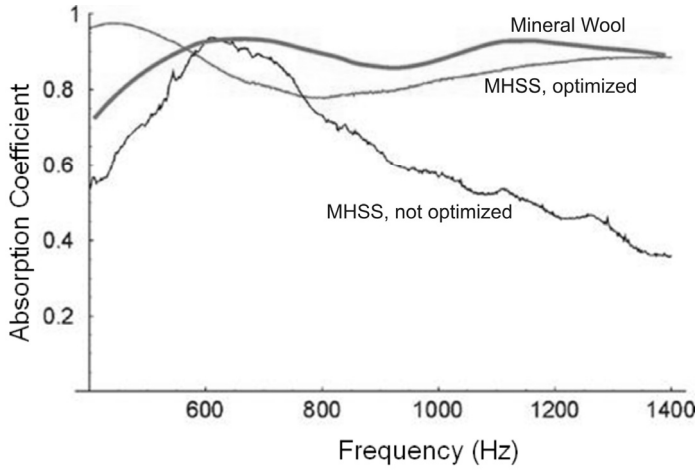

FIGURE 2. Absorption Coefficient of Optimized and Non-Optimized MHSS compared to Mineral Wool

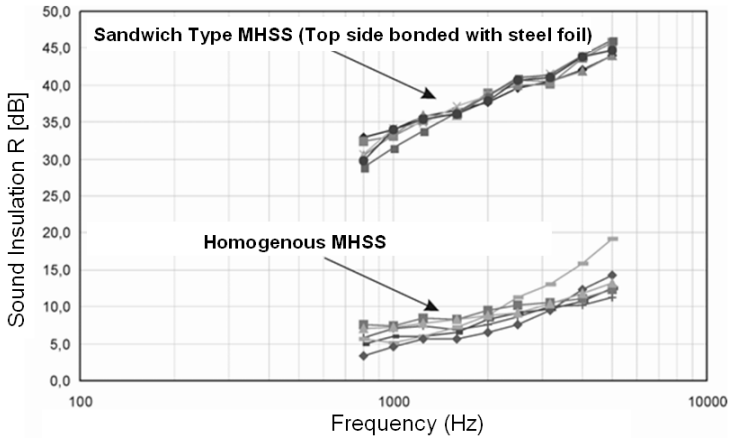

FIGURE 3. Sound Insulation of Homogeneous MHSS and MHSS Bonded with Steel Foil

3. Demonstrators

Based on these basic investigations, several demonstrators were created in the last few years to show the ability of MHSS to be used as sound absorbers in technical applications. Hahnl and Hossfeld (3) are presenting prototypes of passenger car mufflers (Fig. 4). These mufflers have been developed in the course of the joint research project "HEV" between Emcon Technologies (former Zeuna Stärker, Arvin Meritor), Fraunhofer IFAM and other partners. This project was funded by the German Ministry for Education and Research. Using 1.4767 Fe-Cr-Al alloy MHSS, four cars were supplied by differently shaped muffler prototypes. The tests did show very promising results. The MHSS mufflers were used for endurance tests up to 84,000 km on the road without any problem.

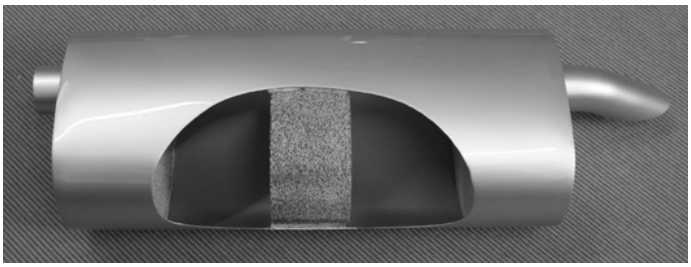

FIGURE 4. Muffler Prototype for Field Tests in Passenger Cars (Sectional Model)

To adapt MHSS to exhaust systems of other types of vehicles and small combustion engine driven work machines like generators, chain saws, power mowers and others, model calculations or experimental modelling is necessary. Because of the multiciplity of influencing factors model calculations can be relatively complex. As an alternative solution Gesellschaft für Akustikforschung Dresden GmbH (AFD) in co-operation with Fraunhofer IFAM and Glatt Systemtechnik have developed a muffler model kit (Fig. 5). This kit allows to test different combinations of built-in components. This way, absorption mufflers and splitter-type mufflers can be created and tested at real machines.

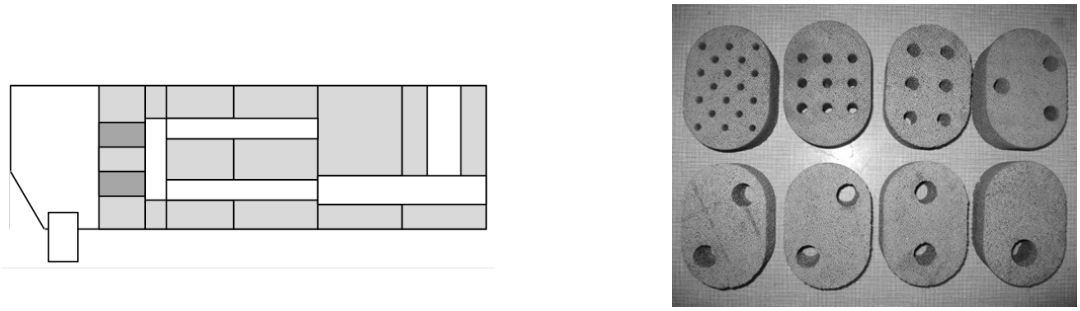

FIGURE 5. Muffler Model Kit: Schematic Diagram (left) and Absorber Modules (right)

Fig. 6 shows the muffler model kit during experiments in a test rig (left) and results of pressure drop and noise level measurements of 5 test runs. Test run 4 – a splitter-type arrangement of hollow sphere structures, is showing the best results. The noise level was decreased about 5 dB while the pressure drop of the muffler did not change. Using this model kit, MHSS containing muffler systems for a lot of small engines could be developed in the future.

During the research project MaScha, sound absorbers were successfully tested in a few other technical applications. The project MaScha, funded by the German Ministry for Education and Research, was assigned for developing a new generation of sound absorbers in engine construction. Industrial dust extraction systems were upgraded with MHSS noise absorbers (Fig. 7). In this application the advantage of MHSS in comparison to classical polymer foam absorbers is their good contamination resistance and higher mechanical stability. The noise level of the extraction system was reduced by 1.1 dB.

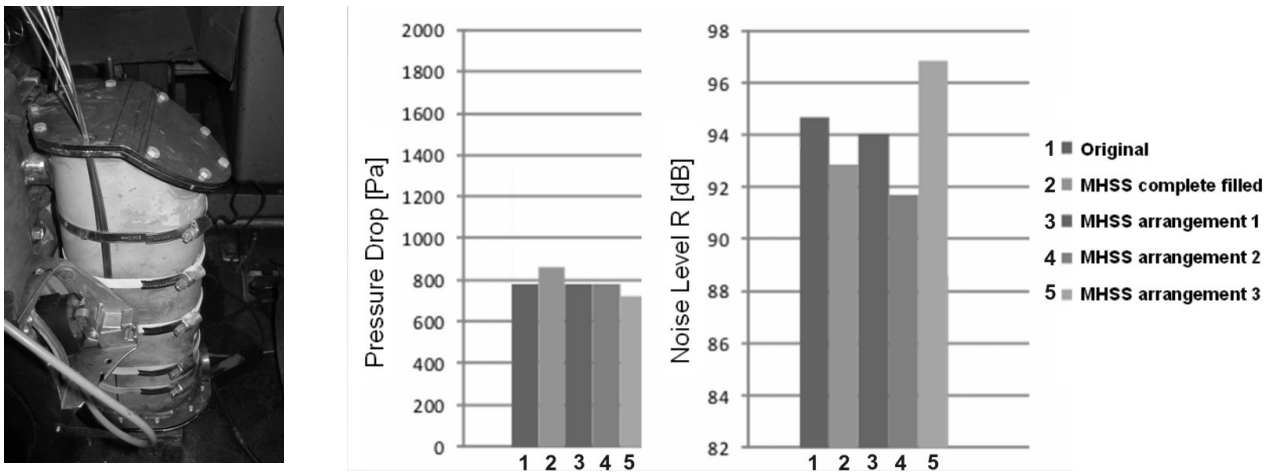

FIGURE 6. Muffler Model Kit: Run at Test Rig (left) Pressure Drop and Noise Level of several HHSS arrangements (right)

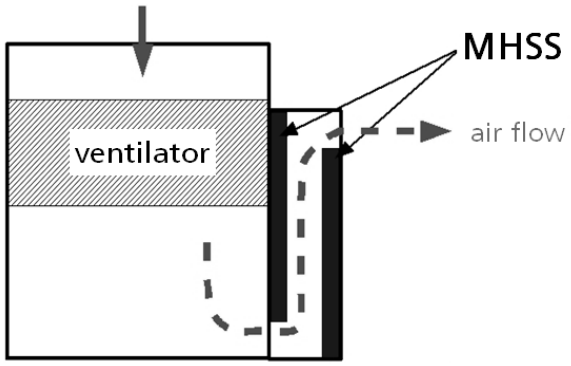

FIGURE 7. Noise Absorber for Dust Extraction Systems (Schematic Diagram)

Another component developed in the project MaScha was a sound absorbing casing of a cutter head of a high speed milling machine. Effective sound absorbing casings for large machines are expensive and complicate the handling of the machines. So the aim was to create a rugged, contamination resistant, sound absorbing housing near the cutter head made out of MHSS. This housing should replace the common compact housing. As shown in Table 1 a good performance was achieved. The noise level of the cutting head supplied by the new absorber was up to 6 dB lower compared to the classical solution.

FIGURE 8. Noise Absorber for High Speed Milling Heads

TABLE 1. Noise Levels at Different Spindle Speeds (Right)

spindle speed	feet rate	Noise Level	
(rpm)	(m/min)	(dB(A))	
		compact housing	MHSS housing
20,000	3.0	74.0	72.0
25,000	3.6	77.0	74.0
30,000	4.5	81.0	75.5
35,000	5.1	83.5	77.5

4. Conclusions and Outlook

Metal Hollow Sphere Structures are an interesting and promising material for sound absorption applications. Because of their high temperature resistivity and mechanical stability they are suitable under higher thermal and mechanical stress than classical absorber materials like mineral wool or polymer foam. By means of several demonstrators the acoustic efficiency of this new material has been shown. Because of the thermal, mechanical and chemical properties of MHSS multifunctional parts like combinations of muffler and diesel soot filter or muffler and catalyst are imaginable. A mass production of MHSS will bring down the price of the structures. This could bring MHSS into many more applications.

References

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