



# **Impact of manufacturing uncertainties on the acoustic properties of 3D printed materials**

Alexis Jamois, Didier Dagna, Marie-Annick Galland

## **► To cite this version:**

Alexis Jamois, Didier Dagna, Marie-Annick Galland. Impact of manufacturing uncertainties on the acoustic properties of 3D printed materials. 29th International Congress on Sound and Vibration, ICSV 2023, Jul 2023, Prague, Czech Republic. <hal-04736429>

**HAL Id: hal-04736429**

**<https://hal.science/hal-04736429v1>**

Submitted on 14 Oct 2024

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL Authorization

# **IMPACT OF MANUFACTURING UNCERTAINTIES ON THE ACOUSTIC PROPERTIES OF 3D PRINTED MATERIALS**

Alexis Jamois, Didier Dagna, Marie-Annick Galland.

*Laboratoire de Mécanique des Fluides et d'Acoustique UMR 5509 - Centrale Lyon - INSA Lyon - Université Claude Bernard Lyon 1 - CNRS, 36 avenue Guy de Collongues, Ecully, France*

*e-mail: alexis.jamois@ec-lyon.fr*

The objective of this work is to study the impact of manufacturing uncertainties on the acoustic behaviour of 3D printed materials. The considered material presents a periodic structure whose basic cell is made of a sphere connected to the spheres of adjacent cells by cylindrical channels. Several sets of 6 samples are printed with the same geometry but with different printing parameters. The cell, sphere and canal dimensions are measured for each sample, using a profile projector. The variability of the dimensions within each set is examined. The difference between the measured and the designed dimensions is then discussed, depending on the printing parameters.

The absorption coefficient in normal incidence is measured for each sample using a Kundt's tube. The dispersion of the acoustic behaviour is compared according to the measured dimensions. Numerical simulations for the Kundt's tube configuration are also performed, using the measured dimensions of every sample in order to confirm the link between the dispersion of the geometrical properties and the absorption coefficients. Two models describing the material are used. The first one is based on a macroscopic description using an equivalent fluid approach. The second model consists in describing the material as a whole at the microscopic scale and solving the linearized Navier-Stokes equations in the material.

Finally, the case of the material placed on the wall of a duct is considered. The precision the prediction can achieve is evaluated based on the study in normal incidence.

---

## **1. Introduction**

With the outbreak of 3D printing technique, it is now possible to design and realize acoustic devices with on request absorbing capabilities. For that purpose the potential of this additive method must be studied with regard to the acoustic performances. In their round robin study [1] Zielinski et al. have investigated the impact of the printing technique and concluded that a higher reliability of the sample was obtained with stereolithography. The motivation of the present work is to evaluate the influence of the printing parameters on acoustic properties of the samples. It will also provide an evaluation of the uncertainties impact on the acoustic behaviour.

Several samples are printed using various printing parameters with the same 3D printer. The key dimensions of the samples are measured and their dispersion is studied. The modelling technique is

presented. The measured dimensions are used to model the acoustic that can be obtained with these samples. Finally, the absorption coefficients of the different samples are compared to those of the modelled samples.

## 2. Realisation and geometric characterisation of the samples

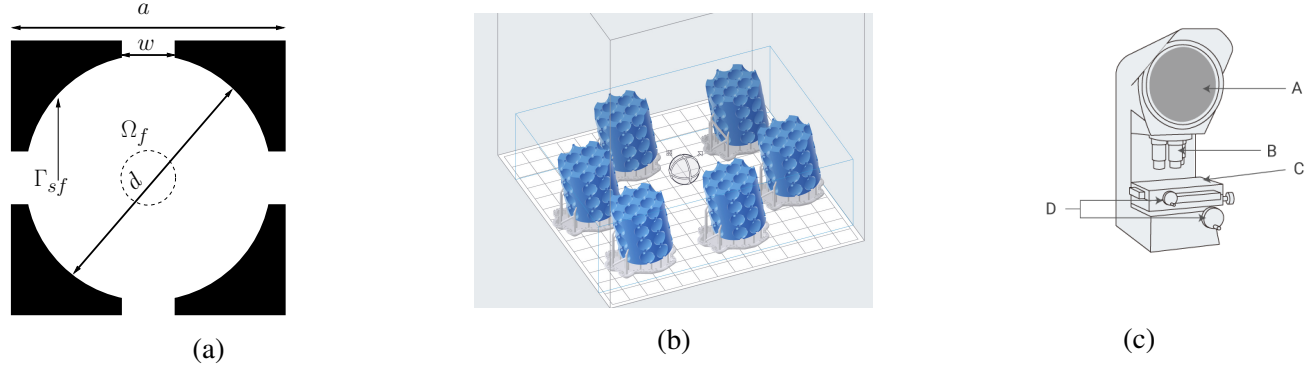


Figure 1: Sample cell (a), realisation plate (Preform®) (b), and measurement device (Keyence®) (c)

The studied geometry is presented in Fig. 1a. It is composed of the repetition of cubic cells made of a central sphere connected to the spheres of adjacent cells by cylindrical channels, where the cell size is  $a = 9$  mm, the diameter of the sphere is  $d = 8$  mm and the diameter of the channel is  $w = 1.5$  mm. The Formlab®Form2 printer is used. Four different sets of printing parameters are used, with two different resin qualities (Clear and Black resin) and two different layer thicknesses (25 and 50  $\mu$ m). Six samples are printed for each parameter set as presented in Fig. 1b.

The diameters of the sphere  $d$  and the channel  $w$  have been determined as critical. These dimensions on the external surfaces of each sample are measured using a profile projector (see Fig. 1c). The limitation of such a method is that these external dimensions are considered as representative of the whole material. The variability of the mean values of these dimensions for each sample dimensions are presented in Fig. 2. The measured diameter  $d_m$  is normalized by the diameter targeted by the conception  $d_c$ , as well as for the channel  $w$ . This figure shows the interest in choosing the set of parameters resin Clear and layer thickness of 25  $\mu$ m. Indeed, the dimensions of this series are closer to the targeted dimensions. This set of parameters also provides the more precise results, as there is less dispersion among the samples.

The average values of the measured dimensions for each samples of this parameters set are presented in Table. 1. The channel size is systematically smaller than the target value. The narrowness of the channels complicates the evacuation of the resin.

Table 1: Values for the sample series Clear25

Dimension	Target	1	2	3	4	5	6	mean	standard deviation
$a$ mm	9	9.059	9.031	9.049	8.995	9.028	8.998	9.027	0.026
$w$ mm	1.5	1.33	1.312	1.312	1.254	1.34	1.306	1.309	0.028
$d$ mm	8	8.012	8.013	8.026	7.980	8.018	8.004	8.009	0.016

## 3. Numerical model

The method used to predict the acoustic properties of each sample is based on an equivalent fluid approach. Following the hybrid multiscale methodology detailed in Zielinski et al. [2] or in [3], the

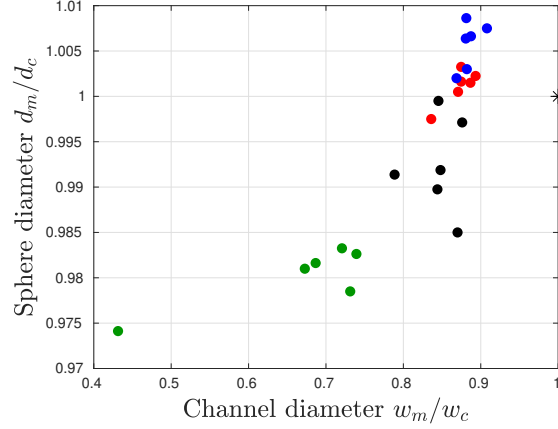


Figure 2: Variability of the channel and sphere diameter dimensions with Clear25 (●), Clear50 (●) Black25 (●) and Black50 (●) with the targeted values for comparison (\*).

8 parameters of the Jonhson Champoux Allard Pride Lafarge (JCAPL) model are determined from the geometry of the elementary cell of the material. The commercial software COMSOL® is used for the calculations. The measured dimensions are introduced to obtain a set of JCAPL parameters for each sample. The implementation of this methodology has been previously validated by comparing the absorption coefficient of a target sample with the one determined by a direct numerical simulation solving Navier-Stokes linearised equations [4].

## 4. Results

The samples are tested under normal incidence in an impedance tube and the absorption coefficients are compared with the predictions. The variability among the samples obtained with the parameter set Clear25 is the lowest. This is the reason why the results are presented for this parameters set in Fig. 3.

The experimental results (in dashed line) shows very few differences in the absorption coefficient due to this low variability. The results for the sample 1 can be explained by a leak around the sample.

The comparison for the modelled samples also shows a low dispersion in the absorption curves. Only the absorption of the modelled sample 4 is significantly different. It can be linked with channel diameters smaller than those of the other samples (see Table. 1). This leads to an increase of the tortuosity and a reduction of the frequency of the absorption peak. The effect of this dimension uncertainty is overevaluated, certainly due to the limit of the dimension measurement technique.

The curves of the acoustic absorption for the 6 samples is shifted by 100 Hz towards higher frequencies, compared to the predictions. The absorption coefficient of this peak is also increased. The most likely reason is a leakage around the sample in the Kundt's tube that is known to have a strong impact on the measurements [5, 6, 7, 8]. The impact on the absorption coefficient is particularly observable with the studied samples due to the low surface porosity and the apertures on the sides of the samples.

The experimental results as well their predictions differ from the one of the targeted sample, mainly due to a difference in the channel diameter.

## 5. Conclusion

Several sound absorbing samples have been printed using the same technique. The impact of the printing parameters on the dimension uncertainties over a set of samples has been demonstrated. This

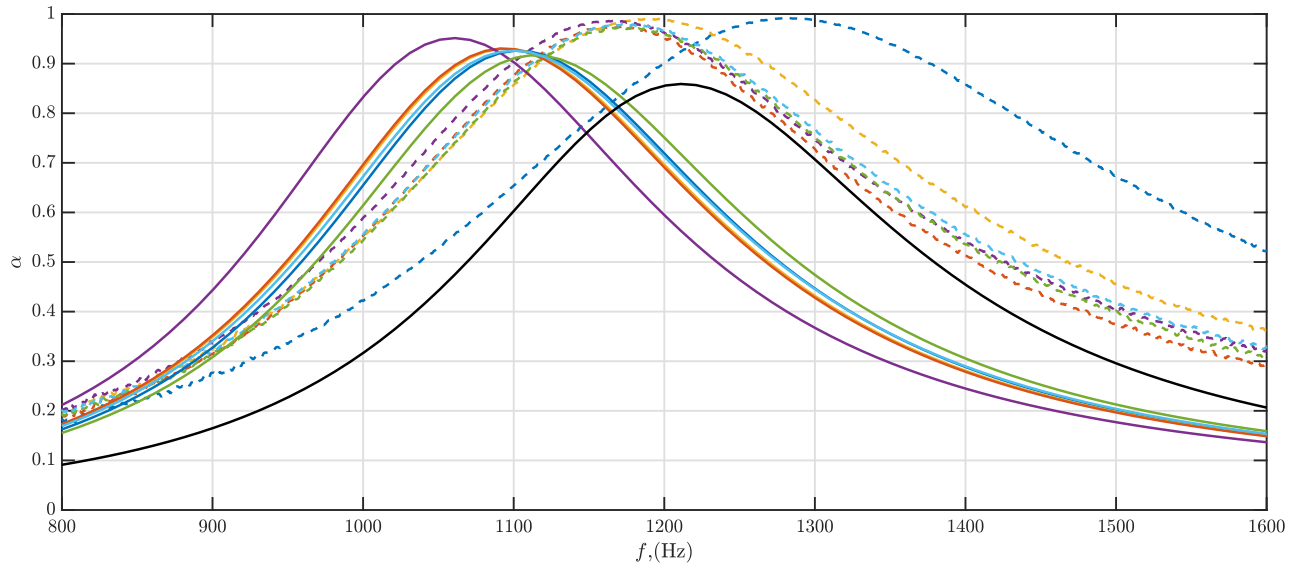


Figure 3: Absorption coefficient for the 6 samples of the series Clear25 obtained from the measurements (sample 1 (- -) 2 (- -) 3 (- -) 4 (- -) 5 (- -) 6 (- -)) and from the JCAPL model (sample 1 (—) 2 (—) 3 (—) 4 (—) 5 (—) 6 (—)). The absorption coefficient for the targeted geometry is also plotted (—).

has led to the choice of the Clear resin and the thinner layer that can be obtained with the used 3d printer. The geometrical uncertainties can have an impact on the acoustic performance. The performance of this geometry as a liner will be studied in a future work.

## 6. Acknowledgments

This work was supported by the LABEX CeLyA (ANR-10-LABX-0060) of Université de Lyon, within the program « Investissements d’Avenir » (ANR-16-IDEX-0005) operated by the French National Research Agency (ANR). It was granted access to the HPC resources of PMCS2I (Pôle de Modélisation et de Calcul en Sciences de l’Ingénieur et de l’Information) of Ecole Centrale de Lyon and PSMN (Pôle Scientifique de Modélisation Numérique) of ENS de Lyon, members of FLMSN (Fédération Lyonnaise de Modélisation et Sciences Numériques), partner of EQUIPEX EQUIP@MESO.

## REFERENCES

1. Zieliński, T. G., et al. Reproducibility of sound-absorbing periodic porous materials using additive manufacturing technologies: Round robin study, *Additive Manufacturing*, **36**, 101564, (2020).
2. Zieliński, T. G., Venegas, R., Perrot, C., Červenka, M., Chevillotte, F. and Attenborough, K. Benchmarks for microstructure-based modelling of sound absorbing rigid-frame porous media, *Journal of Sound and Vibration*, **483**, 115441, (2020).
3. Boutin, C. Rayleigh scattering of acoustic waves in rigid porous media, *The Journal of the Acoustical Society of America*, **122** (4), 1888–1905, (2007).
4. Jamois, A., Dragna, D., Zielinski, T. and Galland, M.-A. Modélisation acoustique d’un matériau obtenu par fabrication additive placé en paroi d’un conduit, *16ème Congrès Français d’Acoustique*,

CFA2022, Marseille, France, Apr., Société Française d'Acoustique and Laboratoire de Mécanique et d'Acoustique, (2022).

5. Cummings, A. Impedance tube measurements on porous media: the effects of air-gaps around the sample, *Journal of Sound and Vibration*, **151**, 63–75, (1991).
6. Mbailassem, F., *Contrôle du bruit par effets de localisation par géométries irrégulières*, Ph.D. thesis, Université de Lyon, Lyon, France, doctoral Dissertation <http://theses.insa-lyon.fr/publication/2016LYSEI095/these.pdf>, (2016).
7. Kino, N. and Ueno, T. Investigation of sample size effects in impedance tube measurements, *Applied Acoustic*, **68**, 1485–1493, (2007).
8. Lee, I., Jeon, K. and Park, J. The effect of leakage on the acoustic performance of reactive silencers, *Applied Acoustics*, **74**, 479–484, (2013).