MULTI-LAYER CORE TOPOLOGY SYSTEMS

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ABSTRACT

The purpose of this paper is to describe the major issues regarding the topic ESR-4 and entitled "Multi-layer core topology systems" from the VIPER project (vibroacoustic of periodic media). The objective is to study multi-layer periodic structures to carry out an optimization of each periodic layer allowing to obtain better sound transmission properties. Transfer Matrix Method (TMM) mixed with Wave Finite Element Method (WFEM) is commonly used to model the Sound Transmission Loss (STL) and the Sound Absorption Coefficient (SAC) of periodic structures assuming an infinite plate without boundary conditions. In addition, this structure is designed using one type of periodicity. In the framework of multi-layer periodic structures, each layer has its own periodicity and different to each other, leading to a more complex problem as the extraction of the unit periodic cell. Several simple cases might be exploited to investigate the influence of the periodic layers layout.

Keywords: *TMM-WFE / multi-layer periodic structure / Sound Transmission Loss / Sound Absorption Coefficient / Optimization*

1 INTRODUCTION

The problems related to the periodic structures sound properties are important in aerospace industry. Typically, this kind of structure is lighter whereas its stiffness is higher and lead, generally, to an unsatisfactory Sound Transmission Loss (STL) and Sound Absorption Coefficient (SAC). Modelling these structures is possible using the Transfer Matrix Method (TMM) mixed with Wave Finite Element Method (WFEM) and reduce significantly the computational cost. Nevertheless, the main assumptions define the structure as an infinite plate without boundary conditions. In addition, the topic ESR-4 for VIPER Project deals with muti-layer periodic structures which means that each layer has its own periodicity. Consequently, these periods as well as the possible phase differences between each layer involve extending the TMM to multi-layer periodic structures.
The first step is to consider simple cases with specifics periodicities at each layer to investigate the effect on the STL and the SAC. Secondly, an optimization should be performed to obtain the best configuration for the structure allowing to satisfy the industrial constraints for the STL and the SAC. This paper gives an overview of the literature which will lead to the achievement of the objectives and will explain in details the major issues of this topic.

2 LITERATURE REVIEW

2.1 TMM applied to periodic structures

The following picture (Figure 1) illustrate a multi-layer periodic structure:

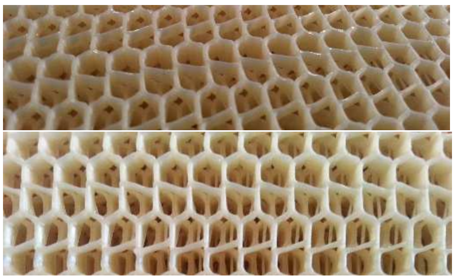

Figure 1. Multi-layer periodic structure.

Each layer is composed by a periodic structure as honeycomb or auxetic cores with a certain periodicity not supposed to be the same as each other. Moreover, the layers' depth could be different. Consequently, one periodic cell cannot be simply extracted from the whole structure to apply the TMM.

Recently, two close methods proposed by [1, 2] released to calculate the STL of a periodic structure manipulating the dynamic stiffness related to the periodic cell. These methods combine the use of the WFEM and the TMM and decrease considerably the computational cost. However, assumptions are required and lead sometimes to noticeable differences, especially at low frequencies since the boundary conditions have a strong effect.

2.2 Periodicity issues

Figure 2 shows 3 different periodicities of different core nature (honeycomb, auxetic and rectangular). A periodic structure with 3 layers is represented. The green figure is the minimal unit cell for the honeycomb layer, which is obviously inappropriate to extract one periodic cell through the depth of the whole structure. One of the issues is to deal with these different periodicities finding this unit cell to be able to model the structure using the methods described in [1, 2].

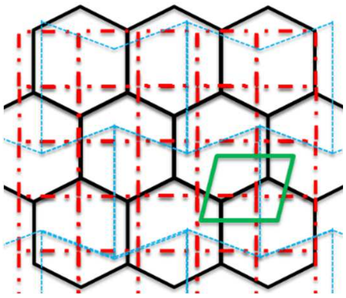

Figure 2. Different periodicities.

Furthermore, added to the periodicity, there is a possible phase difference as well as an angle of rotation between each layer. Those could lead to a more complex problem.

The first maintained approach will be a periodicity effect investigation modelling specifics cases. For instance, periodicities are multiple to each other allowing to model just one periodic cell containing all periodic layers but modifying the phase differences. It occurs that the previous exposed methods could be applied. In a first phase, the plate will be considered as laterally infinite, then, method as [3] is available to account for the finite size effects with a size correction factor.

A new challenge is proposed to extend the TMM to multi-layer periodic structures with boundary conditions and considering the problems previously listed and related to layers, to finally determine the STL and SAC of the structure with an accurate prediction. This model will integrate new types of parameters characterizing the periodicity, the phase difference or the topology of each layer. Then, the next step is the optimization of this structure.

2.3 Optimization

One of the main purpose is to manufacture a new structure with a better sound transmission efficiency characterized by the STL and SAC. Several papers were written trying to describe the effect of meso-scale parameters on the STL of periodic structures as [4]. It is noticed that the cell's geometry could alter the STL especially at the mid frequencies. The optimization will be based on the results of this article. The periodicity of each layer might be defined by several geometrical parameters as shown in Figure 3.

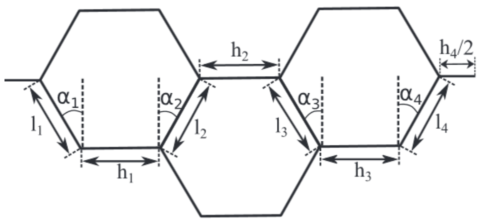

Figure 3. Geometrical parameters for honeycomb cores [4].

Other parameters should be required as the phase difference between two periodic layers, as well as parameters which would define the geometrical period of each periodic layer.

Performing an optimization needs to find out the inputs and outputs of the studied system. In this case, a multi-inputs/multi-output might be considered since the STL and the SAC are investigated. The developed algorithm will be able to identify the optimal geometrical parameters for each periodic layer. The optimization process depends on the frequency since the STL and SAC as well, and thus, will involve a wise choice for the frequency range of the study. Therefore, a relevant number of inputs will reduce the computational cost. For instance, thanks to [4], a conclusion is that the depth of each layer will have a significant effect on the STL but affecting the stiffness-weight ratio of the layer. Consequently, this parameter might be constant for each layer to not influence the mechanical properties of the structure.

3 CONCLUSIONS

An overview of one topic of the Viper Project is proposed. A study is ongoing to model the sound transmission properties of multi-layer periodic structures which will serve to develop an optimization algorithm to manufacture a new optimal structure. The following major issues are exposed: boundary conditions, periodicity and the optimization. Nevertheless, an approach using specific cases at the beginning will lead to a better understanding of the periodicity effect and other parameters as the phase difference or the topology of each layer. The computation will be established according to the recent procedure described in papers [1, 2]. Finally, this topic will have an interest from an industrial point of view since it is useful at early stage of the manufacturing having all the optimal parameters of the structure.

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