CHAPTER I
INTRODUCTION

1.1 Background

Noise, defined as unwanted sound arising from various activities, poses significant health and environmental risks when experienced at or above certain exposure levels and durations[1]. The rapid expansion of industrialization has intensified noise pollution across urban and industrial environments, necessitating effective noise control strategies to mitigate its adverse impacts on human health and the surrounding environment.

In general, there are two methods used to overcome this noise problem: active noise control and passive noise control. The first method is Active Noise Control (ANC), ANC operates by generating a secondary sound field that destructively interferes with the primary noise signal, requiring an external power source to drive electro-acoustic components such as microphones and loudspeakers. The second method is Passive Noise Control (PNC), which only uses passive elements that do not add energy to the system. There are many passive control methods, including surface treatments, mounts, tuned absorbers, and resonators[2].

Among passive noise control methods, absorbers are the most widely applied. Sound absorbers are broadly classified into two categories: dissipative absorbers and resonant absorbers. Dissipative absorbers convert the acoustic energy of vibrating air molecules into thermal energy through viscous friction between air molecules and the pore or fiber boundaries[3]. A dissipative absorber is effective in absorbing noise from medium to high frequencies. Dissipative absorbers can also be classified into three types based on microscopic structure: cellular, fibrous, and granular[4]. The second type is a resonant absorber, which operates on the basis of the mass-spring system, in which the structure's acoustic mass vibrates in opposition to the enclosed air cavity's stiffness (spring). Resonant absorbers are generally categorized according to their vibrating mass and are efficient at certain low-to-mid frequencies: In Helmholtz resonators, such as microperforated panels, the air vibrating inside an aperture serves as the mass, and Membrane absorbers, in which the thin membrane or solid panel serves as the bulk[5].

Micro-Perforated Panels (MPPs) are a specialized class of resonant absorbers, consisting of a thin, rigid panel perforated with submillimeter-diameter holes, backed by an enclosed air cavity. The system operates on the Helmholtz resonance principle, wherein the air within the micro-perforations interacts with the air spring formed by the backing cavity, producing maximum sound absorption at specific resonance frequencies[6]. The acoustic performance of an MPP absorber is strongly governed by its geometric parameters, including perforation diameter, panel thickness, perforation ratio, and cavity depth[3][6].

MPP absorbers have been widely adopted in noise control applications due to their practical advantages, including low manufacturing cost, environmental friendliness, structural simplicity, durability, and suitability for hygienic environments. However, conventional flat MPPs are inherently limited by their narrow absorption bandwidth, which reduces their effectiveness when broadband noise attenuation is required [7].

To overcome the narrow bandwidth limitation of flat MPPs, various geometric modification strategies have been explored in recent literature, including multi-layer configurations, inhomogeneous perforation distributions, and three-dimensional surface profiling [8]. Profiling the panel into an egg-crate geometry modifies the acoustic response by creating a non-uniform distribution of local cavity depths and changing the orientation and number of perforation paths within the same frontal area. These geometric changes may produce overlapping local acoustic responses and alter the effective resistance and mass reactance of the absorber, thereby providing the potential to broaden the sound absorption bandwidth [9]. However, the experimental study was limited in scope due to fabrication constraints, and the quantitative relationship between specific egg crate geometric parameters and the resulting absorption performance has not been systematically characterized.

Finite Element Analysis (FEA) offers a way to systematically extend this work by enabling a wider and more controlled exploration of geometric variations without the need to fabricate and measure each configuration physically. By developing a validated FEA model of an egg crate-type MPP in an impedance tube and performing a structured parametric study, it is possible to investigate how specific microgeometric parameters influence absorption characteristics and identify configurations with improved broadband performance. In this research, three geometric parameters of the egg crate MPP are systematically varied across 36 numerical models: the micro-perforation diameter (d), the egg crate profile angle (θ), and the center-to-center distance between perforations, referred to as pitch (b).

1.2 Problem Formulation

The problem formulation of this study addresses how profile angle, in combination with microperforation diameter and pitch, influences the acoustic characteristics of an egg-crate-type MPP absorber on the peak sound absorption coefficient, resonance frequency, and absorption bandwidth.

1.3 Objectives

The objective of this study is to analyze the effect of egg-crate profile angle, in combination with microperforation diameter and pitch, on the peak sound absorption coefficient, resonance frequency, and half-peak absorption bandwidth of an egg-crate-type micro-perforated panel absorber.

1.4 Benefit

This research is expected to provide quantitative data on how geometric parametric variation influences the acoustic performance. The findings can also serve as a design reference for engineers seeking to optimize egg-crate-type MPP geometries for broadband noise-control applications.

1.5 Scope of the problem

The limitations of the problem in this final project are:

1. The object of research is the egg crate type Micro-Perforated Panel (MPP) absorber with a single backing air cavity.
2. Three geometric parameters of the egg crate MPP are systematically varied in this study: micro-perforation diameter (d), egg crate profile angle (θ), and center-to-center perforation distance or pitch (b), resulting in a total of 36 parametric configurations.
3. The analysis method employed is Harmonic Acoustic Finite Element Analysis (FEA) using ANSYS 2024R2 software.

4. The acoustic analysis is limited to normal sound incidence conditions, and the frequency range of the study is 100–3800 Hz.
5. Model validation is performed by comparing FEA simulation results against the Maa Dah-You analytical model for flat MPP baseline configurations.

1.6 Report Outline

This final project consists of five chapters. The first chapter, the introduction, contains the background explaining the rationale for this research, the problem formulation, the objectives to be achieved, the benefits of the research, and the report writing system. The second chapter then discusses various relevant literature and theoretical foundations that support the research. The third chapter explains the research methodology, including a description of the tools used, the research implementation process, and the detailed steps in conducting the research. The fourth chapter discusses the results and the analysis of the topic. The final chapter, the fifth chapter, discusses the conclusion and the recommendation.