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Experimental design for measuring vibration of aluminum sandwich panels

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ABSTRACT: *In this study, an experimental vibration measurement system was developed to investigate the dynamic characteristics of an aluminum A6063 sandwich panel with a corrugated core. Tensile tests were conducted to determine the mechanical properties of each constituent layer, providing input data for material modeling. Vibration tests were carried out using an impact hammer excitation method, and the acceleration responses were measured by a tri-axial accelerometer. The natural frequencies and mode shapes of the sandwich panel were identified from the experimental data. The results demonstrate that the experimental setup exhibits high stability and clearly captures the vibration characteristics of the corrugated-core sandwich structure, thereby providing a reliable basis for validation and calibration of finite element simulation models.*

Keywords: *Aluminum Sandwich Panel, Corrugated Core, Vibration, Modal Testing, Acceleration Measurement*

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I. INTRODUCTION

In recent decades, lightweight sandwich structures have attracted significant attention in engineering applications due to their excellent strength-to-weight ratio, high stiffness, and superior energy absorption capability. Among various sandwich configurations, metallic sandwich panels with corrugated cores have emerged as a promising solution for load-bearing structures in aerospace, marine, transportation, and civil engineering industries, where structural efficiency and dynamic performance are critical requirements [1–3]. A typical metallic sandwich panel consists of two thin, stiff face sheets bonded to a lightweight core. The corrugated core geometry provides directional stiffness, enhanced bending resistance, and improved load transfer between the face sheets while maintaining a relatively low mass. Compared with traditional honeycomb or foam cores, corrugated cores exhibit pronounced anisotropic mechanical behavior, which allows designers to tailor structural performance by modifying geometric parameters such as corrugation height, wavelength, and orientation [4–6]. Extensive research has been conducted on the static and impact behavior of metallic corrugated-core sandwich panels. Li et al. [1] investigated the multi-objective optimization of steel corrugated-core sandwich structures subjected to impact loading, demonstrating their superior energy absorption capability. Schultz et al. [2] studied the compressive behavior of folded-core sandwich structures using experimental testing and finite element analysis, highlighting the influence of core geometry on failure mechanisms. Similarly, several studies have focused on bending behavior and deformation modes of aluminum corrugated-core sandwich panels, confirming the reliability of numerical models through experimental validation [3]. Beyond static loading, the dynamic behavior of sandwich structures is of particular importance due to their widespread use in environments subjected to vibration and dynamic excitation. Vibrational characteristics such as natural frequencies, mode shapes, and damping properties play a crucial role in structural integrity, fatigue resistance, and noise control. Wang et al. [4] investigated free vibration and damping characteristics of laminated sandwich panels with viscoelastic layers, showing that boundary conditions and material configuration significantly affect modal properties. Other studies have demonstrated that corrugated-core geometry strongly influences vibration modes and frequency distributions, especially bending and torsional modes [5–7]. Free vibration analysis of sandwich structures with corrugated, honeycomb, and lattice cores has been explored using analytical, numerical, and experimental approaches. Peng et al. [5,8,9] showed that vibration characteristics can be effectively tuned by altering material properties and core configurations. Magnucka et al. [10] developed analytical models to predict natural frequencies of multilayer sandwich plates with trapezoidal corrugated cores, revealing the sensitivity of vibration response to geometric parameters. More recently, advanced numerical methods such as wave finite element (WFE) approaches and homogenization techniques have been proposed to reduce computational cost while maintaining accuracy for complex core geometries [11,12]. Despite these advances, most published studies focus primarily on static or quasi-static loading conditions, while experimental investigations of vibration behavior remain limited, particularly for metallic corrugated-core sandwich panels. Moreover, the complex geometry of corrugated cores poses significant challenges for finite element modeling, often requiring fine meshes and high computational resources. Experimental data are therefore essential for validating and calibrating numerical models, especially in vibration analysis where results are highly sensitive to boundary conditions, manufacturing imperfections, and material damping.

In this context, the present study aims to develop and implement an experimental vibration measurement system for aluminum corrugated-core sandwich panels. The experimental results are used to identify natural frequencies and mode shapes, providing a reliable basis for validating finite element models and enhancing the understanding of the dynamic behavior of corrugated-core sandwich structures.

II. MATERIALS AND EXPERIMENTAL SPECIMENS

2.1. Research material

The material used in this study is an aluminum A6063 sandwich panel with a corrugated core, consisting of two face sheets made of A6063 aluminum and a corrugated aluminum core layer. The geometry and dimensions of the sandwich panel are shown in Figures 1 and 2. The thickness and mass density of each constituent layer are summarized in Table 1.

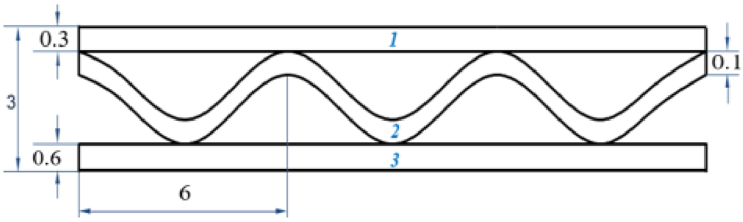

Fig. 1 Geometric dimensions of the A6063 aluminum sandwich panel

Fig. 2 A6063 aluminum corrugated-core sandwich panel

Table 1. Properties of the constituent layers of the A6063 aluminum sandwich panel

Layer	Weight (g/m^2)	Thickness (mm)
1	0.81e-3	0.3
2	0.27e-3	0.1
3	1.62e-3	0.6

2.2 Tensile tests for material property characterization

The purpose of the tensile tests is to determine the mechanical properties of the material, such as tensile strength, yield strength, elongation, and elastic modulus, in order to support material design, selection, and quality assessment in engineering applications. In particular, accurate material properties are essential for finite element modeling and analysis. This section presents the tensile tests conducted on A6063 aluminum specimens.

The specimens used for the tensile tests were designed with the geometry and dimensions shown in Figure 3. To separate the face sheets and the core layer of the aluminum sandwich panel, the specimens were immersed in an acetone solution for one hour to allow the epoxy adhesive to degrade. The layers were then separated, and a cylindrical roller was used to flatten the corrugated core sheet, as illustrated in Figure 4. The aluminum specimens were cut along arbitrary directions. For each constituent layer, five identical specimens were prepared to conduct a series of tensile strength tests and to ensure reliable and repeatable results (Figure 5).

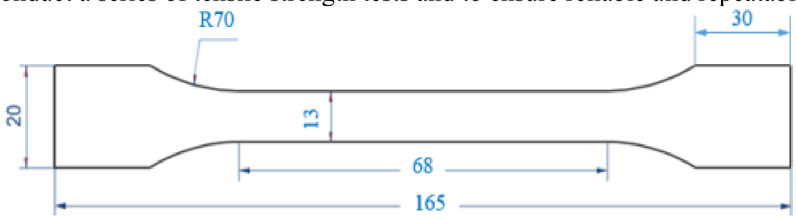

Fig. 3 Geometry and dimensions of the tensile test specimens made of cardboard (top) and A6063 aluminum sheet (bottom).

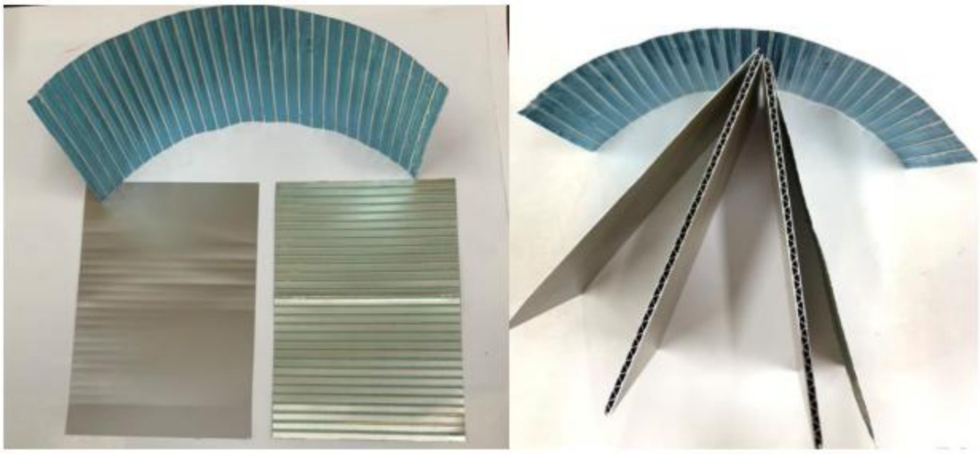

Figure 4. Separating the layers of the sandwich sheet.

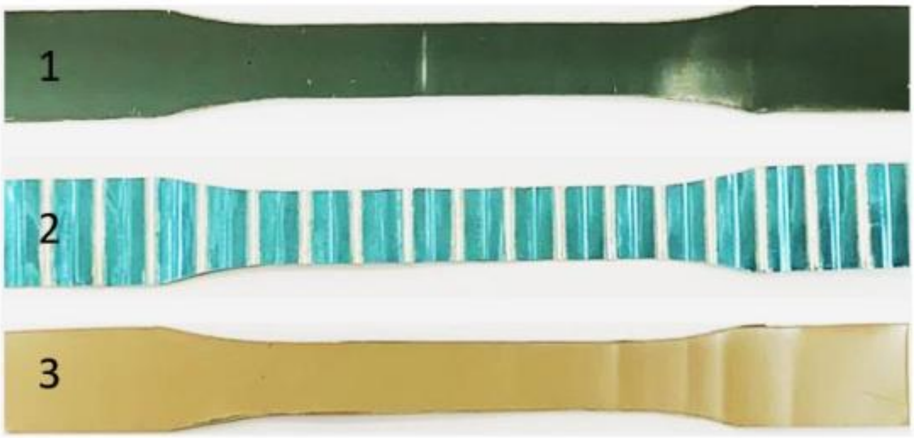

Fig. 5. Aluminum sheet samples 1, 2, and 3

The tensile tests were conducted using a YMH51–H61 universal testing machine. The machine is equipped with a high-performance servo motor and a precision ball-screw transmission system. The control system is operated by dedicated software to ensure consistent accuracy across all tests. The obtained results are presented in Figures 6, 7, and 8. The obtained results reveal a clear difference in mechanical properties between the face sheets and the core layer, reflecting the anisotropic nature of the sandwich structure.

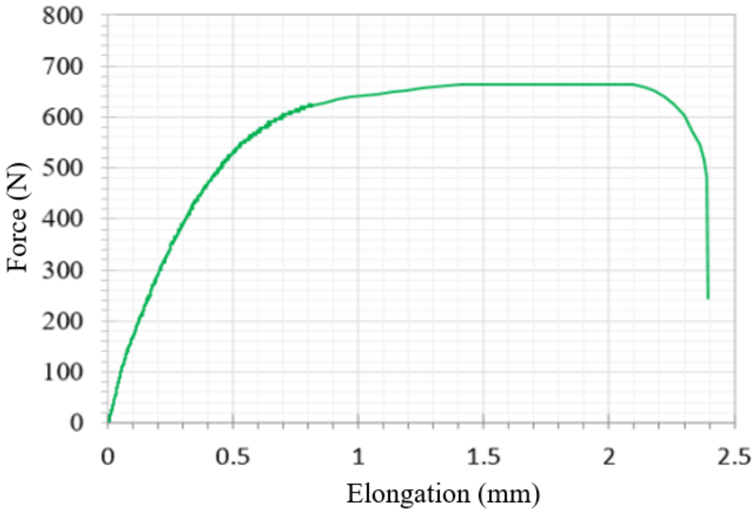

Fig. 6. Force–elongation relationship of aluminum specimen 1.

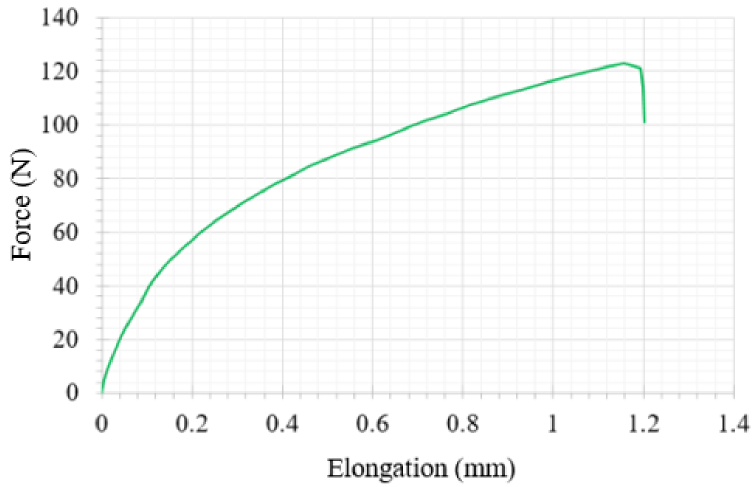

Fig. 7 Force–elongation relationship of aluminum specimen 2.

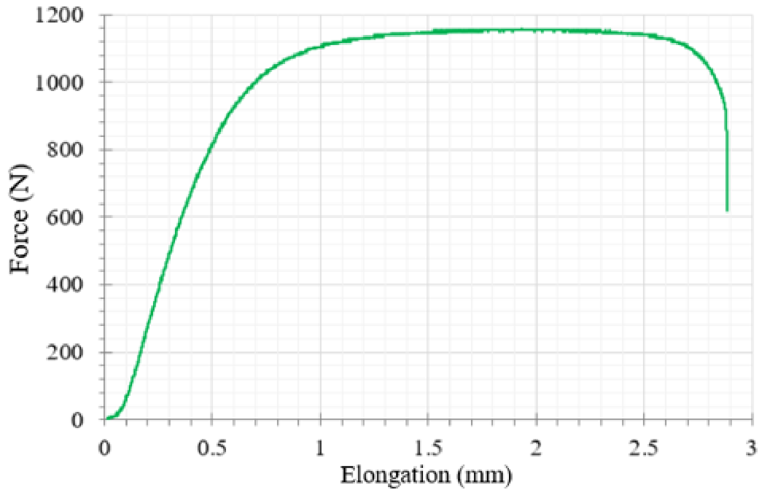

Fig. 8 Force–elongation relationship of aluminum specimen 3.

III. DEVELOPMENT OF THE EXPERIMENTAL VIBRATION MEASUREMENT SETUP

3.1. Experimental principle

The vibration experiment was conducted using an impact excitation–acceleration response measurement method. One end of the specimen was rigidly fixed (clamped boundary condition), while the other end remained free. Vibrations were excited by an impact hammer, and the resulting responses were measured using accelerometers mounted at predefined locations on the panel. The schematic diagram and experimental setup are illustrated in Figures 9.

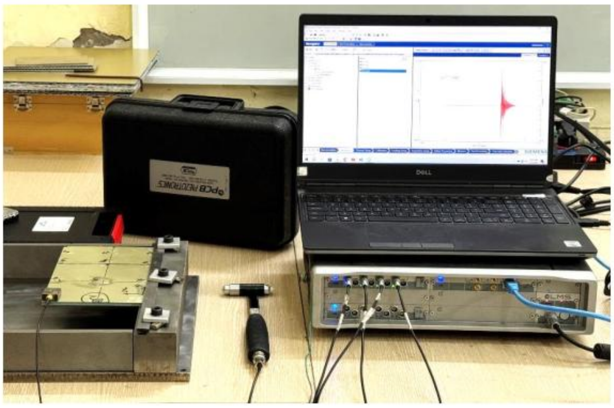

Fig. 9 Experiment setup

3.2. Experimental Equipment and Procedure

The experimental system consists of:

- A Simcenter SCADAS Mobile data acquisition system with a high sampling frequency,
- A three-axis accelerometer MMF KS963B10 (10 mV/g),
- A US4799375A instrumented impact hammer integrated with a force sensor,
- A fixture ensuring high rigidity and stable boundary conditions.

The vibration measurement procedure consists of the following steps:

- Fixing the specimen to the fixture,
- Attaching the accelerometer at the measurement location,
- Exciting the structure using an impact hammer,
- Acquiring the force and acceleration signals,
- Processing the signals to determine the natural frequencies and mode shapes.

The experiment is repeated multiple times to ensure repeatability and reliability of the results.

IV. RESULTS AND ANALYSIS

The measured excitation force and acceleration signals exhibit a clearly damped vibration response after excitation, reflecting the inherent damping characteristics of the sandwich structure. The time-domain acceleration responses are presented in Figures 10–12. Based on the acquired data, the natural frequencies and mode shapes of the sandwich panel were identified. The results indicate that:

- Bending modes dominate at low frequencies,
- Torsional modes appear at higher frequencies,
- The vibration characteristics are strongly influenced by the corrugated core structure.

Representative vibration modes are shown in Figure 13. The developed experimental setup demonstrates:

- Stable signal acquisition capability,
- High repeatability across measurements,
- Suitability for calibration and validation of FEM models.

Minor discrepancies between repeated excitations mainly arise from variations in hammer impact conditions and impact locations; however, these do not significantly affect the identification of natural frequencies.

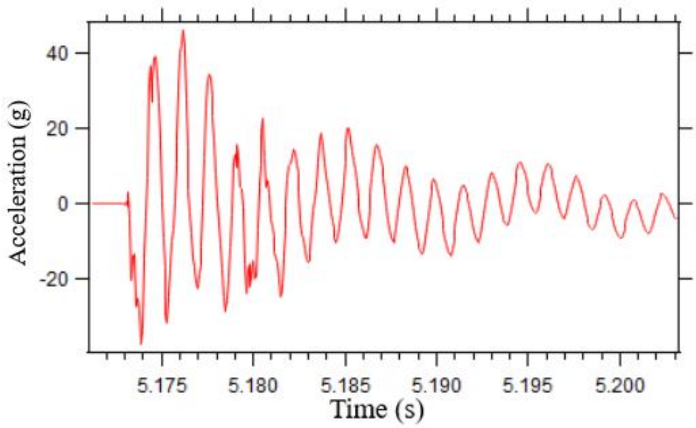

Fig. 10 Acceleration response after the first force hammer strike

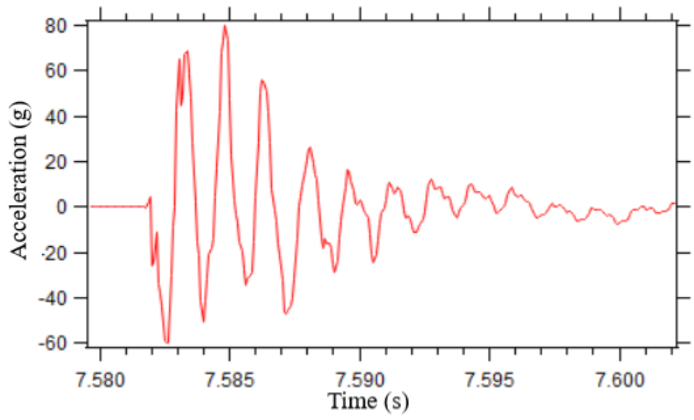

Fig. 11 Acceleration response after the second hammer blow.

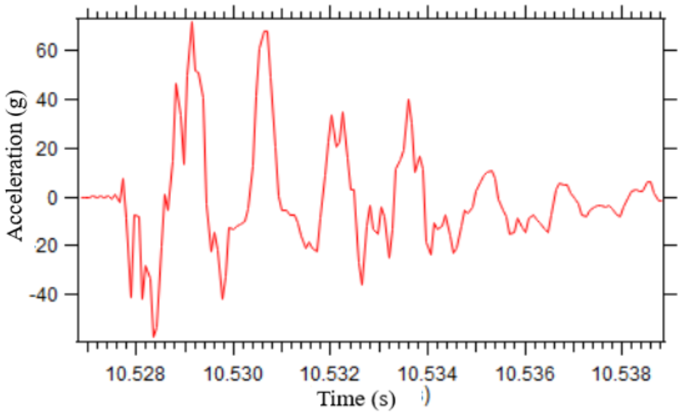

Fig. 12 Acceleration response after the third hammer blow.

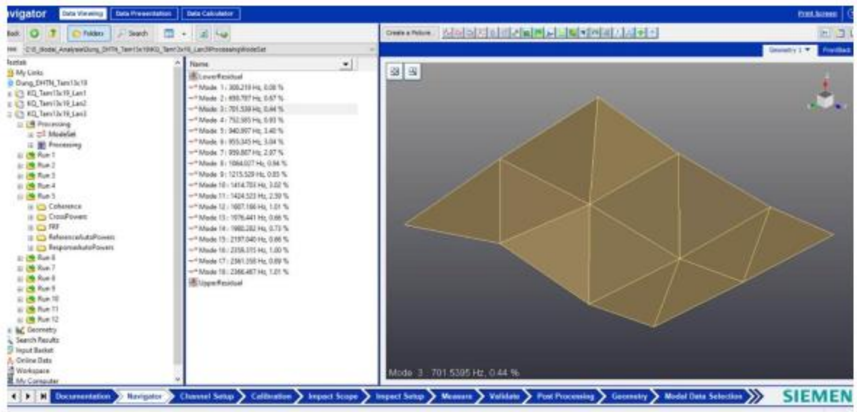

Fig. 13 Oscillation modes of aluminum sandwich panels

V. CONCLUSION

The paper successfully presents the development and implementation of an experimental vibration measurement system for aluminum corrugated-core sandwich panels. The main conclusions are as follows:

1. The experimental setup enables accurate identification of the natural frequencies and mode shapes of the panel
2. The experimental results clearly capture the dynamic characteristics of the corrugated-core sandwich structure
3. The obtained data provide an important basis for validation and calibration of numerical simulation models.

Future research directions

1. Extending the experiments to different boundary conditions,
2. Investigating the influence of core geometry on vibration characteristics,
3. Combining vibration analysis with fatigue damage studies,
4. Analyzing nonlinear vibrations and forced vibration responses.

Acknowledgments

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