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Vibration Study of Sandwich Panels by Experiment and Numerical Simulation

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ABSTRACT: *This paper studies the vibration of aluminum sandwich panels with a three-layer structure, consisting of two aluminum surface layers and a corrugated core, by performing impact experiments and numerical simulations using Abaqus software. Characteristic parameters such as natural frequencies, oscillation amplitudes, and response accelerations are determined and compared. The comparison results show the similarity between the simulation and experimental data and indicate the influence of the aluminum sandwich structure on vibration damping and energy dissipation.*
Keywords: *Sandwich Panels, Vibration, Numerical Simulation, Impact, Abaqus, Testing*

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I. INTRODUCTION

Sandwich panels are one of the advanced material structures widely used in the aerospace, automotive, and construction industries due to their light weight, rigidity, and good energy absorption. Aluminum sandwich panels with corrugated cores are often used in structures that are resistant to vibration and impact. Sandwich panels are a type of composite structure consisting of two outer layers with high mechanical properties and a lightweight core layer in the middle. Studies classify sandwich panel structures based on many criteria: According to the core shape: including corrugated core, corrugated core, honeycomb core, pyramid core and foam core; According to the number of core layers: including single core plate, double core and multi-core plate; According to the core layer orientation, including unidirectional and multi-directional core.

The core of sandwich panels is often made of lightweight materials such as polymers, wood, aluminum, or composite materials to reduce the overall weight. Among the types of structures, the single-core corrugated sandwich panel is the most popular due to its simple structure and high mechanical efficiency. This structure is formed by two skins surrounding a corrugated core, with the main directions: longitudinal section (MD), transverse section (CD), and thickness direction (ZD) (Figure 1).

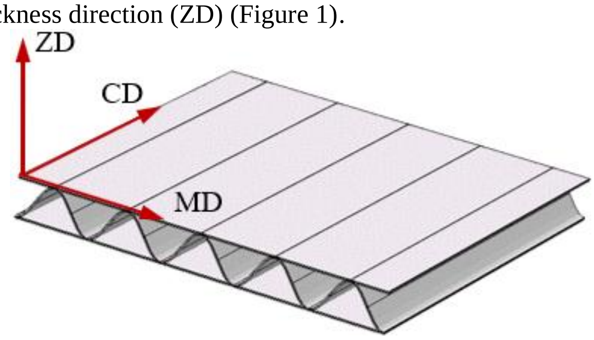

Fig. 1 Corrugated core sandwich panel orientation

Sandwich panels have many applications in which vibration resistance is one of the important properties to be considered in the design. In fact, there have been many studies on the free vibration analysis of sandwich panels with foam core or honeycomb core [1–10] . Li Ke et al. [11] developed a multi-objective optimization method for corrugated core sandwich panels in ship hulls using numerical simulation combined with genetic algorithms. The results showed the relationship between core shape and mechanical parameters such as stress, strain, and energy absorption capacity. Marc R. Schultz et al [12]. investigated the compressive strength of corrugated core composite panels through experiments and finite element analysis (FEA). The study showed the role of local buckling and failure phenomena in the deformation process, especially concentrated at the corrugated grooves. The study of aluminum sandwich panels showed two main deformation modes under bending: local concavity and overall bending. The change in core thickness greatly affected the energy absorption capacity, and a theoretical model based on the energy method was built to predict the crushing force under large deformation.

In the context of structural optimization for dynamic loading conditions, many studies have been extended to vibration analysis and damping characteristics. X. Wang et al [13] studied the effects of polyurea coatings on LASCOR panels. Simulation and experimental results showed that the coatings changed the natural frequency, damping loss coefficient, and dynamic response. Peng et al. [13–15] demonstrated that the vibration characteristics of sandwich panels can be tuned through the design of core materials and geometric configurations. Magnucka proposed a mathematical model to study the stability and vibration of seven-layer sandwich panels with trapezoidal cores. The equation of motion was established based on Hamilton's principle and solved analytically. Guo applied the wave finite element (WFE) method to homogenize the lattice core sandwich beam, transforming it into an equivalent Timoshenko beam to simplify the calculation.

Vibration studies of sandwich panels help to understand the energy dissipation mechanism, optimize structural design, and improve fatigue strength. This paper focuses on evaluating the vibration characteristics of aluminum sandwich panels using two methods: experimental measurement of post-impact acceleration response and numerical simulation using Abaqus.

II. RESEARCH METHOD

2.1. Material

Corrugated core aluminum sandwich panels were utilized in this study. The structure consists of a 0.3 mm thick face layer, a 0.1 mm thick core layer, and a 0.6 mm thick bottom layer (Fig. 2). The dimensions of the sandwich panel are 190 x 130 mm.

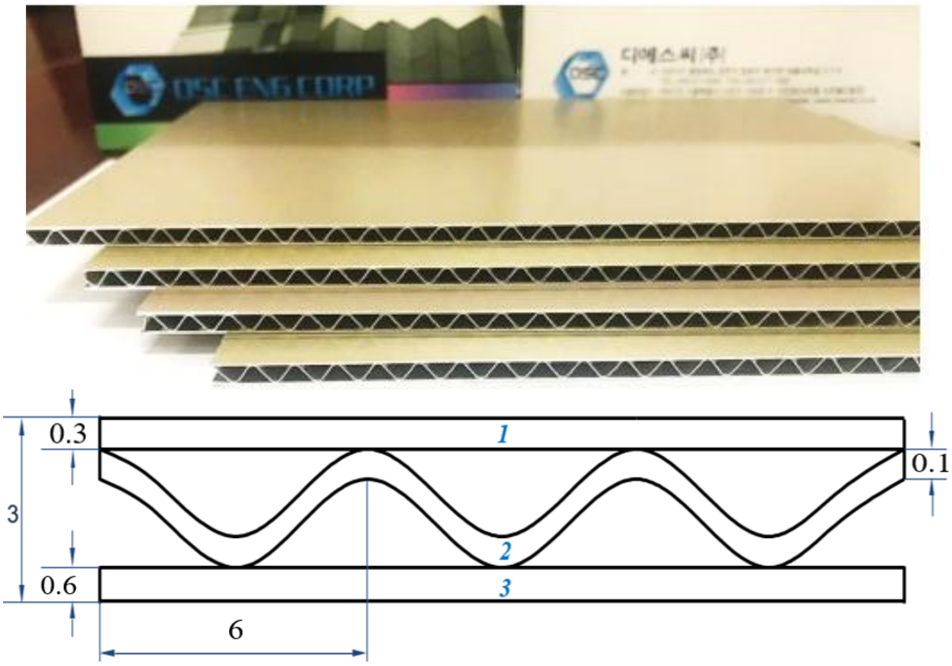

Fig. 2 Corrugated aluminum sandwich panel

2.2. Vibration test

When selecting a vibration-measuring device for vibration measurement experiments, factors such as measuring range, resolution, sensitivity, and frequency response must be carefully considered to suit the technical requirements of the experiment. In particular, vibration measurement experiments on materials such as corrugated aluminum sandwich panels require equipment capable of measuring vibrations at small frequencies and amplitudes to ensure the accuracy and reliability of the data obtained. In addition, depending on each measurement experiment scheme, other supporting equipment must be used. The test configuration is shown in Figure 3. The plate is fixed as a cantilever beam, the free end is subjected to the impact of the impact hammer.

Measuring device: Accelerometer mounted at predetermined points on the beam, connected to a high-speed data acquisition system.

Recorded parameters: Acceleration response over time

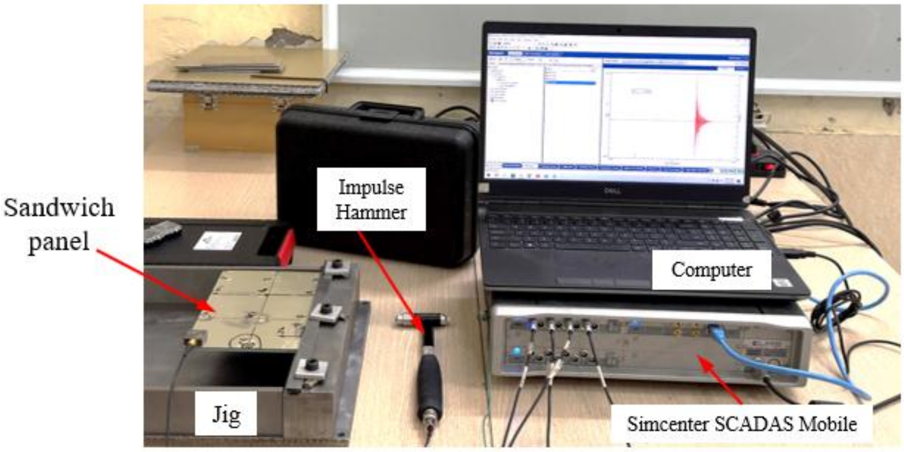

Fig. 3 Experimental setup

The experiment was performed in the case of clamping the sandwich panel in the direction of greater length. The accelerometer was attached to point 2, the hammer force was applied to point 5 (Figure 4). The experimental results obtained are shown in Figure 5.

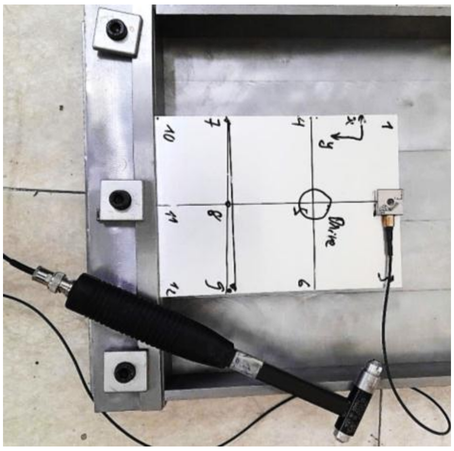

Fig.4 Accelerometer set point and hammer action point

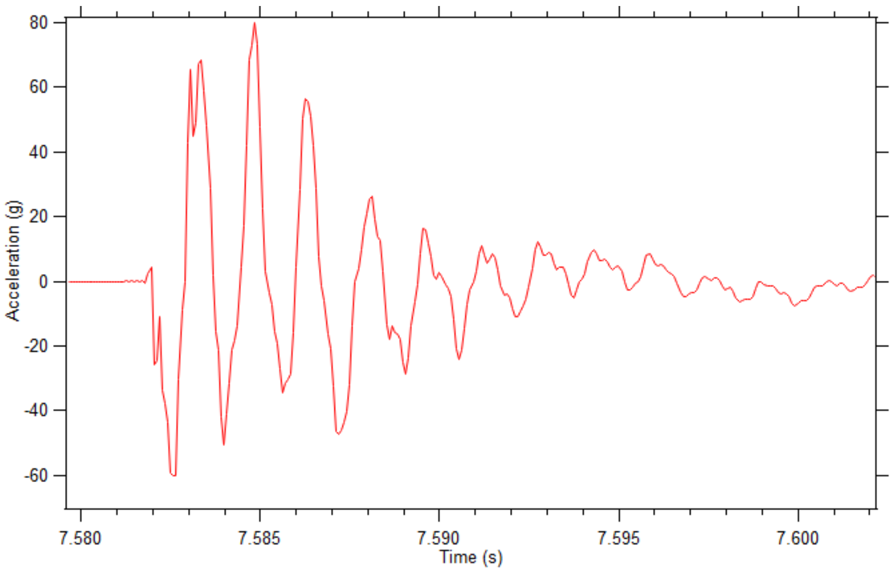

Fig. 5 Accelerometer response

2.3. Experimental numerical simulation

This section focuses on building a simulation model using the finite element method (FEM) using Abaqus software - one of the powerful and popular numerical analysis tools in the field of applied mechanics and structural engineering. The main goal is to reproduce the vibration process of the research object in the simulation environment, thereby analyzing in depth the vibration characteristics such as natural frequencies, vibration modes, and system responses under external forces. Abaqus software is chosen because of its ability to effectively handle nonlinear problems, free and forced vibration problems, as well as support a variety of element types and boundary conditions.

Modeling vibration measurement experiments in Abaqus is performed in a sequential process, including the following main steps:

Step 1: Create a New Model
Step 2: Design geometry
Step 3: Assign materials
Step 4: Mesh
Step 5: Set constraints and boundary conditions
Step 6: Assemble the model
Step 7: Set up analysis
Step 8: Create job and run simulation

The finite element model of the experiment was created, as shown in Figure 6. Model using S4R element with 1000 nodes. One of the important parameters that need to be provided for the finite element model is the parameters in the material behavior model. With the material used in this study being corrugated aluminum sandwich panels, it is necessary to determine the material parameters of each layer. In this model, the mechanical behavior of the material follows Johnson Cook's law.

$$\sigma = (A + B\varepsilon^n)(1 + C\ln\frac{\dot{\varepsilon}}{\dot{\varepsilon}_0})\left[1 - \left(\frac{T - T_0}{T_m - T}\right)^m\right] \quad (1)$$

where A, B, n, C and m are material constants,

$\dot{\varepsilon}$ is the strain rate normalized to the reference strain rate $\dot{\varepsilon}_0$

T_{room} is room temperature, and T_m is the melting temperature of the material at 911^0 K. The parameter n considers the effect of strain hardening, and the two coefficients m and C model the effect of thermal softening and strain rate sensitivity, respectively.

The Inverse Method is used to determine the material parameters in the Johnson Cook model. The material parameters were determined from Tien's et al study [17] (Table 1). The numerical simulation results are obtained as shown in Figure 6.

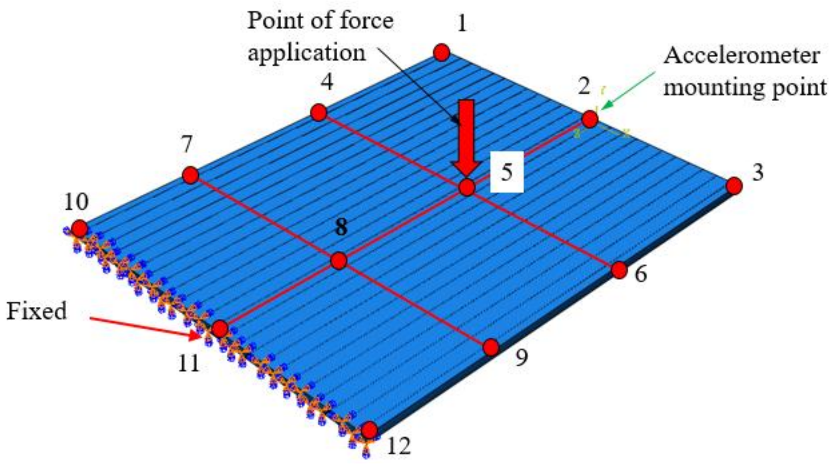

Fig. 6 Experimental modeling

Table 1. Values of material parameters in the Johnson-Cook model of A6063 aluminum sandwich panel

Layer	A (MPa)	B (MPa)	C	n	m	T (^{0}C)
1	137.2	230.6	0.0075	0.542	0.424	20
2	107.3	174.5	0.0009	0.450	0.350	20
3	204.4	346.2	0.01	1.284	0.558	20

III. RESULTS AND DISCUSSION

Numerical simulations were performed with accelerometers placed at position 2 and hammers applied at position 5. A comparison of the results obtained in the three cases of force application shows that the amplitude of the feedback acceleration at the pig peaks is similar (Figure 8). Specifically shown in Table 2. The deviation in average value and time is less than 10%. Therefore, it can be concluded that the finite element model of vibration experiments gives results close to the experiment. This model can be used to replace experiments when studying the vibration of corrugated core sandwich panels.

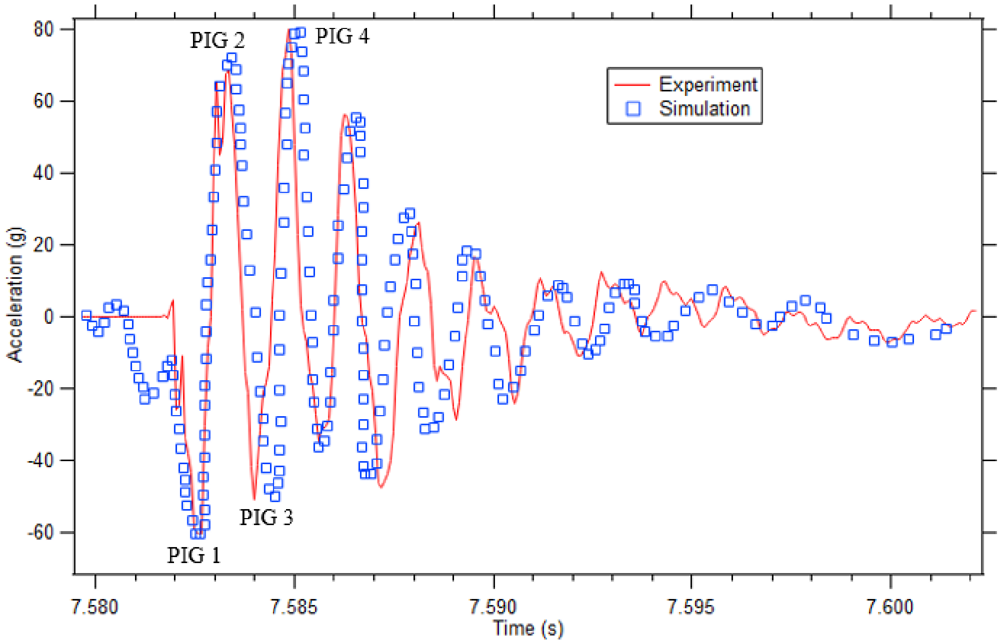

Fig. 8. Compare response acceleration

Table 2. Compare PIG points acceleration responses

PIG Point	1	2	3	4
Numerical simulation acceleration(g)	-60.5090	71.8545	-50.0363	79.1272
Experimental acceleration(g)	-60.2361	68.5457	-50.7413	79.9150
Error (%)	0.45%	4.6%	1.4%	0.99%

IV. CONCLUSION

In this study, a finite element model of an aluminum sandwich panel cantilever beam with a corrugated core was constructed using Abaqus software to analyze vibrations and compare with experimental results. The model was established with configurations and material parameters that accurately reflect the characteristics of a sandwich structure, in which the surface layer is aluminum and the core has a corrugated shape to increase bending stiffness and reduce density. The selection of elements, determination of cantilever boundary conditions, and simulation of excitation effects corresponding to the experiment were performed in the study to ensure high accuracy for the model. In particular, the model considered the geometric nonlinearity of the corrugated core to reproduce the actual vibration response of the beam. The simulation results from the finite element model will be the basis for comparison with vibration measurement data obtained from the experiment, thereby assessing the reliability of the model as well as providing a premise for the calibration and optimization process in subsequent related studies.

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