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Study on ultrasonic detection method of a honeycomb sandwich panel

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Study on ultrasonic detection method of a honeycomb sandwich panel

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Abstract: A new material for the structure of the honeycomb sandwiched XinBi board has been in active service. In this paper, structural defects are embedded in the easily damaged parts of this new material, and the ultrasonic method is used to detect the easily damaged parts, and the acoustic signals and defect echo signals of the easily damaged parts are obtained, which provides a reference for damage evaluation of this kind of structures in site detection.

1. Introduction

Carbon fiber composite material honeycomb sandwich structure has higher strength, modulus, good fatigue resistance, vibration reduction performance, and lightweight, heat resistance, and impact resistance.Combined with its design advantages, the honeycomb sandwich won wide application in the field of the aviation industry, so this type of structure of NDT work becomes increasingly important. [1]

The schematic diagram of the honeycomb panel compression test on the tail wing rudder surface of a certain type of aircraft is shown in Figure 1. The upper and lower sides of the honeycomb panel are clamped with inclined aluminum blocks as the compression end face of the test piece. The aluminum block and the composite panel are bonded with a row of bolts, and the left and right sides of the test piece are gummed as the knife-edge clamping surface on the side of the test piece.The upper and lower skin and honeycomb core were co-solidified and formed. The honeycomb tip of the wall panel was filled with foam glue. The skin and the honeycomb core were bonded with strip plate core glue.According to the out-of-tolerance statistics, the out-of-tolerance of foam adhesive in the bottom corner of the honeycomb panel frequently occurs in the manufacturing process of the honeycomb panel. Therefore, such defects are prefabricated as BVID damage during the manufacturing of honeycomb panel test parts on the pilot surface, and two defects of 35mm length are prefabricated at one end of the test parts, as shown in Figure 1.

The test areas of the honeycomb sandwich panel compression test were the honeycomb iso-straight zone, honeycomb transition zone, and honeycomb bottom corner foam defect.In this paper, the test area of the honeycomb sandwich panel compression test piece was studied by the ultrasonic testing method only.

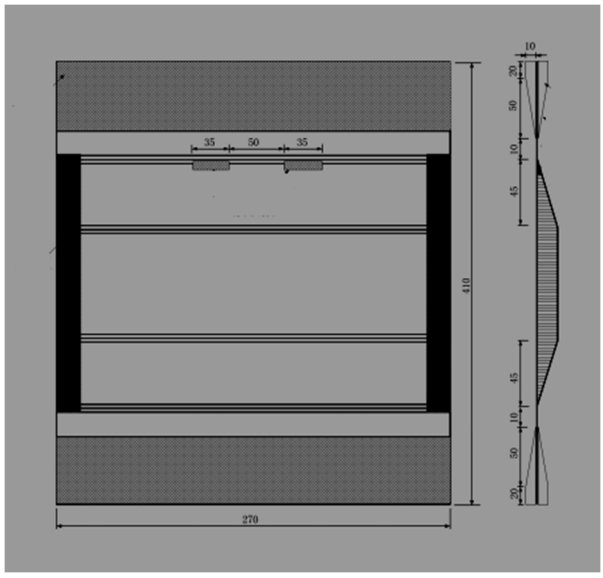


Fig. 1 Schematic diagram of honeycomb sandwich panel compression test piece

2. Conventional test method for honeycomb sandwich structure

The commonly used nondestructive testing methods for honeycomb sandwich structures include ultrasonic testing, X-ray testing, and so on.Ultrasonic testing is mainly used to detect the delamination of skin and the debonding of skin and honeycomb core. It is difficult to detect the defects of the honeycomb core lattice itself.X-ray detection is not sensitive to the defects of delamination and debonding, but has a good detection effect on the defects of honeycomb core lattice itself, such as cracking of core lattice, separation of core lattice nodes, joint bonding defects of core lattice, the collapse of core lattice, inclusions and so on.Therefore, for honeycomb sandwich structure, ultrasonic detection, and X-ray detection have complementary effects, and the combination of them can be used to detect the defects of honeycomb sandwich structure more comprehensively.With the development of new nondestructive testing technologies, infrared thermal imaging has achieved good application results in the detection of honeycomb sandwich structures in recent years. However, infrared thermal imaging detection is greatly affected by ambient temperature and has not been widely used in field detection [2-5].

Ultrasonic detection of large honeycomb sandwich structures can usually be performed by the pulse penetration method.The pulse penetration method can be used to detect the overall quality of honeycomb sandwich structures. In sandwich structure composites, the maximum thickness of sandwich components that can be penetrated by sound waves is limited because the attenuation of core materials is generally large.During the detection, the two probe axes should be kept in a straight line. For planar or curved parts, the connection line of the probe is perpendicular to the surface of the workpiece.For the wedge structure, the probe line is perpendicular to the central symmetry plane of the wedge structure.The automatic water-jet pulse penetration method is suitable for the detection of large quantities of the workpiece after manufacturing, while the manual dual-probe pulse penetration method is limited by how the two probes accurately keep in a straight line, so it is only suitable for the detection of small workpiece [6].

The structural diagram of the honeycomb sandwich structure test parts assessment area is shown in Fig. 2.Although the pulse penetration method can detect the overall quality of the sandwich structure, the test parts of the honeycomb sandwich structure still need to be tested during the test. Therefore, the automatic water-jet pulse penetration method is not applicable, and the test parts are also large, and the manual dual-probe pulse penetration method is not applicable.

Conventional detection should be used in ultrasonic testing, and X-ray detection means for testing, the combination of using high-frequency probe testing layered, skin and skin of the honeycomb core

debonding, scan the bottom reflection wave amplitude will be as shown in Figure 3, beat back and forth between the two wave amplitude.This is normal skin, the skin, and the normal waveform of honeycomb core bonding.The defects of the honeycomb core itself and the defect of foam in the prefabricated honeycomb bottom corner are detected by X-ray. Fig. 4 shows the radiographic film of the defect of foam in the honeycomb core and the honeycomb bottom corner.The combination of ultrasonic detection and X-ray detection can detect the defects of honeycomb sandwich structure in a relatively comprehensive way, but ultrasonic detection requires double-sided detection of honeycomb sandwich structure, and the detection workload is large.The actual X-ray testing will be subject to many conditions. The X-ray equipment is relatively large and bulky.It is inconvenient to move and needs to be equipped with a standard power supply. In addition, it produces radiation that requires special protection, and should not be used for a long time, while the detection cost is relatively high.

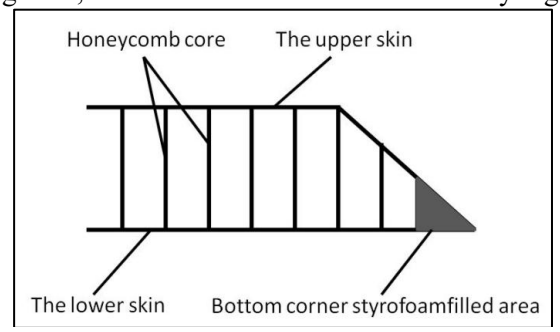


Fig. 2 Schematic diagram of the structure of the test piece assessment area

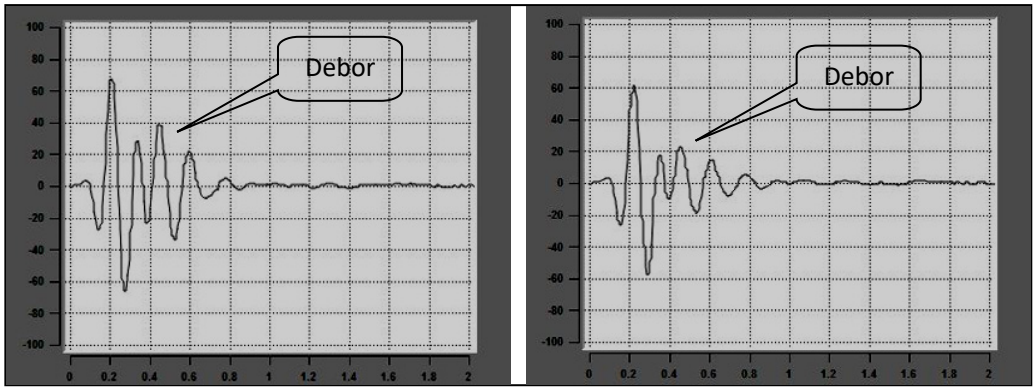


Fig 3 The waveform of normal skin and normal bonding between skin and honeycomb core

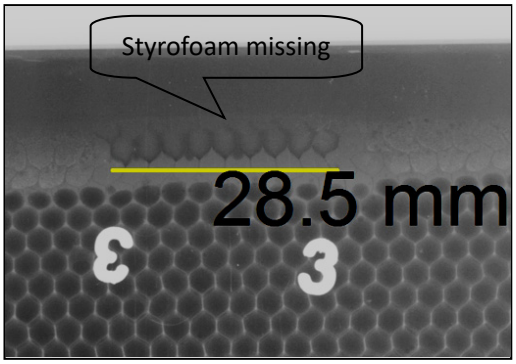


Fig. 4 Radiographs showing defects in honeycomb core and honeycomb bottom corner with missing styrofoam

3. Ultrasonic test method for test parts assessment area

Although the pulse penetration method can realize the detection of the overall quality of the sandwich

structure, the honeycomb sandwich structure test parts still need to be tested in the test process, so the automatic sprinkler pulse penetration method is not applicable.The test parts are also large, and the manual dual-probe pulse penetration method is not applicable.

For a straight area such as cellular, when choosing a suitable low-frequency probe, sound waves can be transmitted through the honeycomb core wall through the transparent skin, and then reflected the original pathfrom the end of the reflection wave probe.By looking at the bottom of the reflection wave, where the amplitude of the high and low wavefront is abnormal,one can determine a cell's quality.It was found that the 1MHz low-frequency probe with a diameter of 12.7mm could penetrate from the upper skin to the lower skin and reflect, and the reflected bottom wave could be separated from the probe's initial wave. Figure 5 shows the normal waveform display of the iso-straight region of an intact honeycomb.By using this detection method, the overall mass of the honeycomb isostraight region can be quickly detected by scanning from one side.When the bottom wave decreases or reflected waves appear in front of the bottom wave, it is an abnormal signal, which can be detected by the high-frequency probe to determine whether the skin is delamination or the skin is unglued with the honeycomb core. If neither is true, the honeycomb core lattice is considered abnormal. If it is necessary to determine the defect type of the honeycomb core lattice, X-ray detectioncan be used.

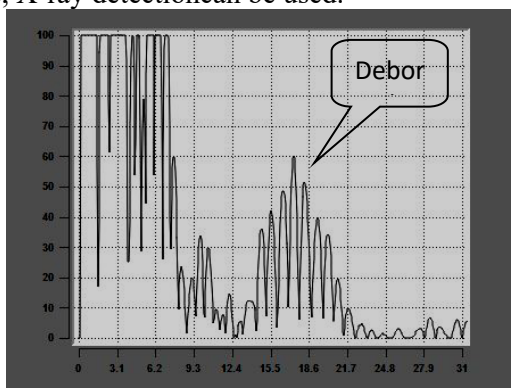


Fig 5. The ultrasonic waveform of intact cellular area

For the transition region, due to the small detection area, the manual dual-probe pulse penetration method can be considered. The author uses a 5MHz probe with a diameter of 6mm to detect the transition region by pulse penetration method.Figure 6 shows the normal waveform display in the thin area of the transition zone.Figure 7 shows the normal waveform display in the middle thickness area of the transition zone.And Figure 8 shows the normal waveform display in the thick area of the transition zone.Suppose there is no display wave, or the displayed wave is much lower than the normal wave. In that case, it is an abnormal wave, which can be detected by the high-frequency probe to determine whether the skin is delamination or the skin is unglued with the honeycomb core. If neither is true, it can be judged that the honeycomb core lattice is abnormal. If it is necessary to determine the defect type of the honeycomb core lattice, X-ray detection can be used.

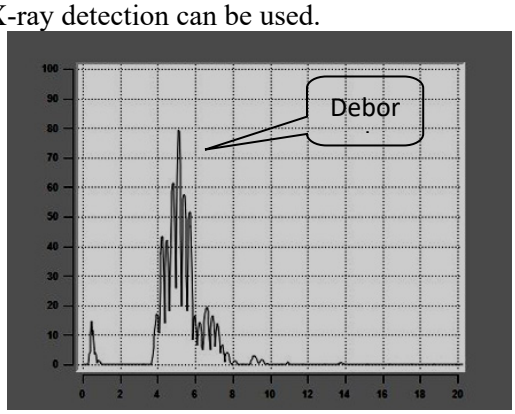


Fig6.The ultrasonic waveform in the thin transition zone

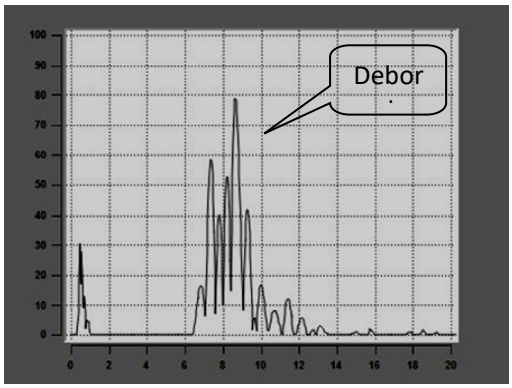


Fig 7.The ultrasonic waveform in the middle thickness of the transition zone

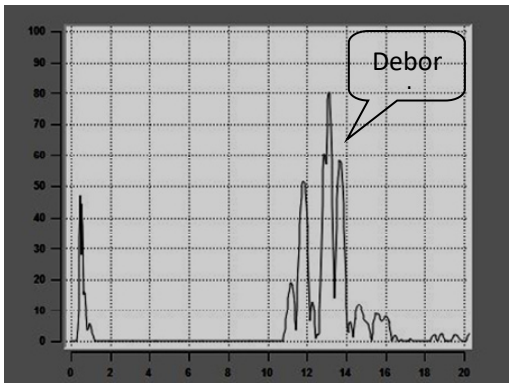
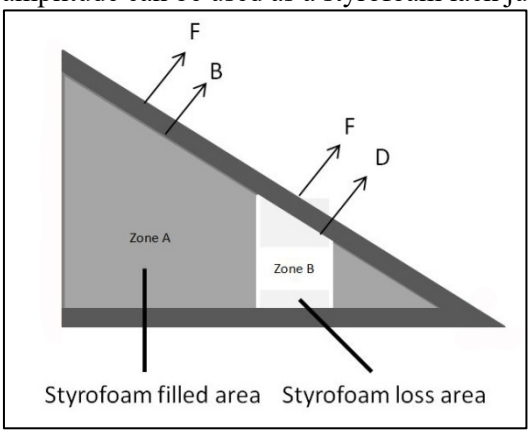
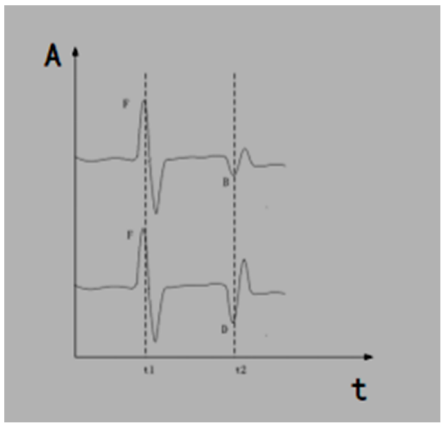


Fig 8.The ultrasonic waveform in the thicker part of the transition zone

Given the lack of foam adhesive filling and partial deficiency for the defect of foam adhesive deficiency at the bottom corner of the honeycomb sandwich structure, it can be regarded as the area defect of skin and foam adhesive debonding.Therefore, ultrasonic detection of such defects is considered.[7] The principle of the pulse reflection method to detect the filling situation of bottom corner styrofoam is shown in Figure. 9. The sound wave is incident from the skin of the oblique wedge area. When detecting the filled area of styrofoam (zone A), the transducer receives the reflected echo F on the upper surface of the skin and the echo B on the lower surface of the skin in the intact area. The transducer receives the echo of the surface echo D F, the echo of thedefect area under the skin surface, and the echo of zone A beneath the skin of styrofoam to B ultrasonic absorption in echo amplitude on the low side. Furthermore, it receives the echo of zone B beneath the skin for air, with sound waves almost completely reflected, so the echo D amplitude is obviously on the high side, and under the skin surface, the echo amplitude can be used as a styrofoam lack judgment.





a) Schematic diagram of structure b) Characteristic waveform

Fig. 9 Principle of pulse reflection method for detecting bottom corner styrofoam filling

A 5MHz focusing probe with a focal size of 1mm was used. To ensure the tight coupling between the probe and the oblique cutting area, a special probe wedge was customized according to the geometrical dimension of the oblique cutting area of the specimen, and the acoustic beam was perpendicular to the foam filling area.Six reference points were selected in the styrofoam-filled area, and missing area of the oblique cutting area of the specimen, and the detection parameters of the ultrasonic detection system were adjusted so that the skin's surface waves and bottom waves could be seen on the screen and distinguished, and that the bottom wave amplitude did not exceed the screen's full scale.The ultrasonic signals of the six reference points in the styrofoam-filled area are shown in Figure 10, and the ultrasonic signals of the six reference points in the styrofoam-missing area are shown in Figure 11.

Under the same test parameters, styrofoam filled area skin bottom back amplitude value is about 30% ~ 40% full-screen height, and the lack of styrofoam area skin bottom back amplitude value is about 60% ~ 90% full-screen height. The results show that ultrasonic testing method applicable to detect these defects, according to the skin base to the amplitude can clearly distinguish the defect area and normal area.Compared with X-ray detection, ultrasonic detection can reduce the work intensity of the detection personnel to a certain extent, and the detection process is more simple and more convenient. In the case of a test block, ultrasonic detection is preferred.

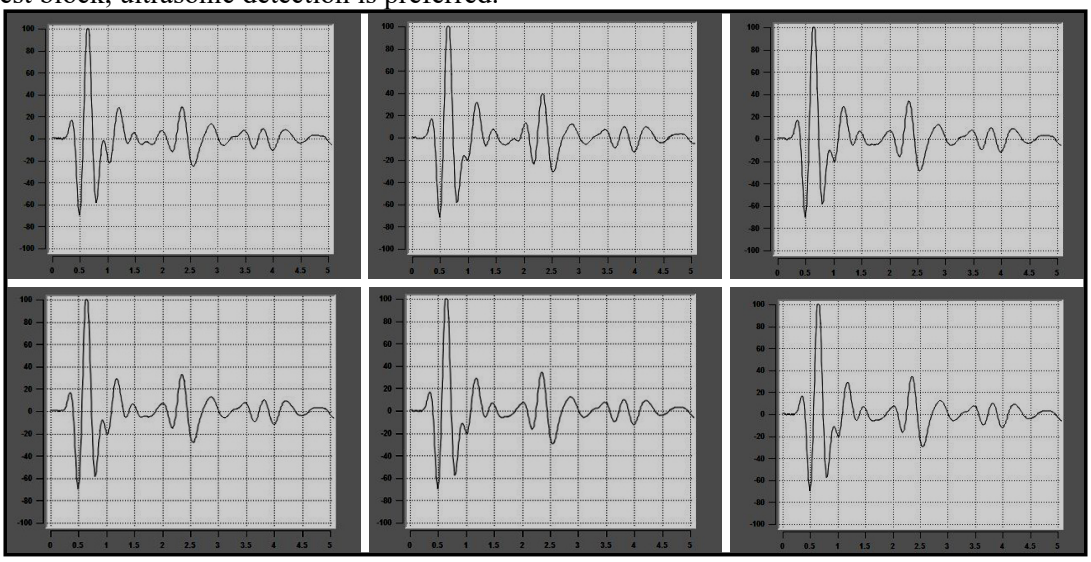


Fig. 10 Ultrasonic signal of reference point in the styrofoam filling area

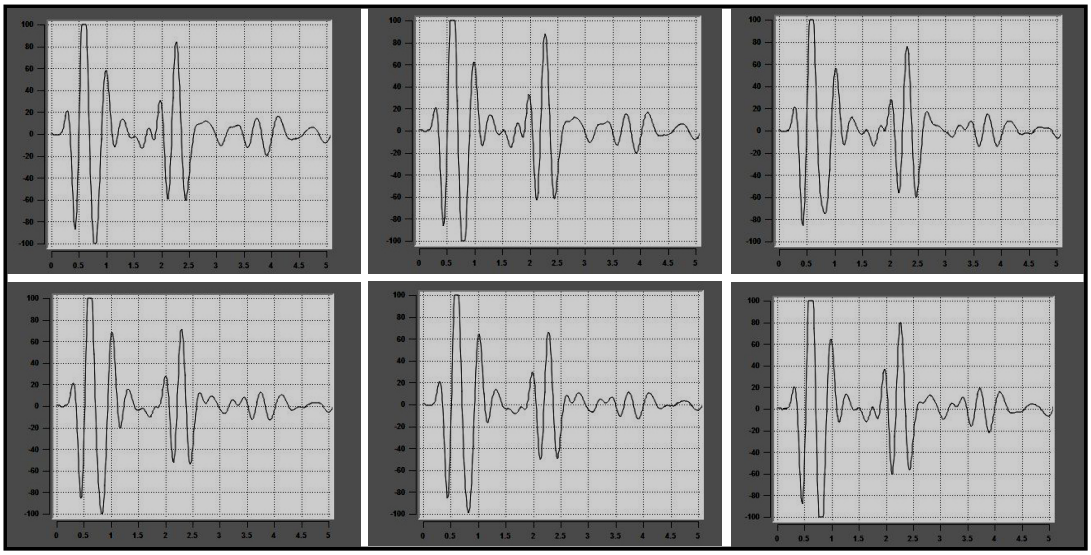


Fig. 11 Ultrasonic signal of reference point in the styrofoam deletion area

4. Conclusion

In this paper, the test area of the honeycomb sandwich panel compression test piece is studied by the ultrasonic testing method only.For the honeycomb iso-straight area, the overall quality of the honeycomb iso-straight area can be quickly detected by using a low-frequency probe with a diameter of 12.5mm, which is scanned from one side.For the transition region, a 5MHz probe with a diameter of 6mm was used for manual penetration detection.For the defect of foam defect at the bottom corner of the honeycomb, a 5MHz focusing probe with a focal size of 1mm can be used to detect the defect quickly and easily.

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