논 문

Ultrasonic Approach of Rayleigh Pitch-catch Contact Ultrasound Waves on CFRP Laminated Composites

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Abstract

최근에는 탄소섬유강화복합재료 (CFRP) 는 우수한 기계적인 물성치와 수월한 설계특성으로 인해 우주·민간 항공산업분야 뿐 만 아니라 여러분야에 응용성이 매우 높다. 그러나 CFRP 복합적층판으로 제작된 구조물은 충격손상을 받을 시에는 50-75% 의 강도가 낮아지는 취약성을 가지고 있다. 따라서 본 연구에는 CFRP 복합재의 구조건전성 및 결함여부를 비파괴적으로 검사 및 탐상을 하기 위해서 시도하였다. 특히, C-scanner 의 수침조에서 충격손상을 받은 시험편을 집어넣어 자동 데이터획득 시스템을 구동하여 현장응용성이 가장 높은 일방향 초음파측정 (one-sided ultrasonic measurement) 방법인 평가기법을 제안하였다. 본 연구에서 제안한 일방향 초음파 피치캐치방법이 CFRP 복합적층판내에서 일반 수직 초음파 탐상기법보다 훨씬 민감함을 알 수 있었다.

Key words : Impact damages, C-scanner, CFRP, Pitch-catch Mode

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1. Introduction

With the high strength, stiffness and low density, composites are currently being considered for many structural applications and they are attractive for a wide range of applications. In particular, the importance of carbon-fiber reinforced plastics (CFRP) has been generally recognized in both space and civil aircraft industries, and CFRP composite laminates are widely used. Unfortunately, CFRP laminates are too brittle under dynamic loading, particularly impact loading [1], which can significantly reduce their properties. Therefore, the impact problems of composites have become important [2-4]. Especially, impacted- damaged areas of composite laminates have been usually analyzed using the backwall echoes of the specimen in ultrasonic analysis. However in the inspection of actual composite structures, the back surface of the part was curved or contained complex geometry and did not provide a usable backwall echo.

In this work, a one-sided pitch-catch setup was used in the detection and evaluation of defect in CFRP composites. Two miniature potted Rayleigh wave transducers were joined head-to-head and used in the pitch-catch mode on the surface. The pitch-catch signal was found to be more sensitive than normal incidence backwall echo of longitudinal wave to impact damages in the CFRP composites.

2. Experimental

Fig. 1 shows a setup of the miniature, potted angle beam transducers with dimensions of 18×16×8.4 mm. The piezoelectric element, 6.3 mm×6.3 mm, is located on the back surface of a plastic wedge. According to the transducer manufacturer [5-6], the angle of incidence in the plastic wedge is 64 degrees for the Rayleigh wave transducer (for steel) and the speed of sound in the wedge is 2.79 mm/μs. The one-sided, pitch-catch configuration shown in Fig. 1 was found to have certain sensitivity advantages in addition to the fact that it does nor require a backwall echo. In the detection of defects, the pitch-catch signal was found to be reasonably effective when compared to other methods. In nominally defect free CFRP laminates, when the pair of pitch-catch transducers is scanned over its surface, the received signal often shows considerably variations that are reproducible while the backwall echo is basically unchanging over the same inspected area. Fig. 2 shows a typically ultrasonic signal at the defect area regardless of back-wall

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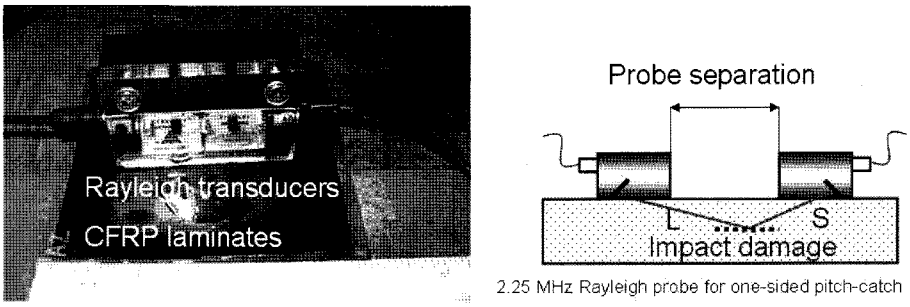

Fig. 1. Rayleigh transducers and pitch-catch measurement in the two plastic edges.

Fig. 2. Amplitude from pitch-catch measurement

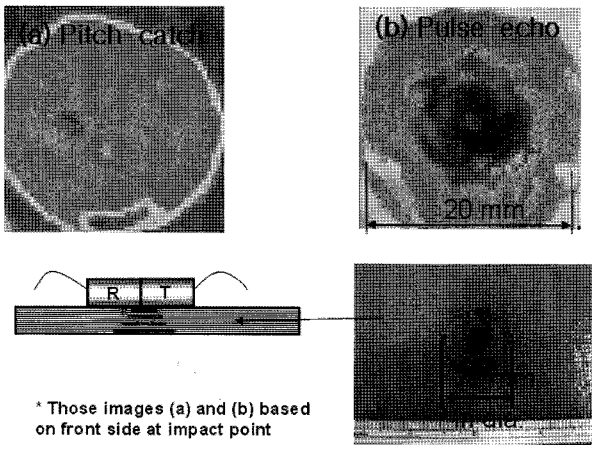

Fig. 3. Pitch-catch images of an impact damage in a composite laminate obtained with a pair of 2.25 Hz transducers using a C-scanner

echo. In the impact detection, the pitch-catch mode is integrated with the motorized Scanner to produce C-scans of composite samples. After impact, the delamination of the specimen interfaces was assessed using a pulse-echo ultrasonic C-scan.

3. Results and Discussion

In this work, most of the tests are carried out using a pair of 2.25 MHz Rayleigh wave probes. To understand the mode of the waves, the angle of refraction, and the propagation speed of the pitch-catch signal, experiments are performed in unidirectional CFRP laminates. To map out the beam path, one-sided pitch-catch experiments are carried out, with a stationary transmitting transducer and a scanning receiving transducer. Based on manufacturer of the transducers, the acoustic path in the wedge is 8.1 mm. The combined time-of-flight in the two wedges is measured to be 5.92 ms, hence the speed of sound is 2.74 mm/μs. The fibers is approximately 12 ms; based on this, the depth of the intersection of the transmitting beam and receiving beam is estimated to be about 4 mm below the top surface. In the detection of defects, the pitch-catch signal was found to be reasonably effective when compared to other methods. The pitch-catch method has been applied to the detection and imaging of foreign object inclusions and impact damage in CFRP laminates. A specimen was tested to demonstrate the test's capability and sensitivity in determining the impact-damaged area for specimens as shown in Fig. 3. Here, Fig. 3 (a) figure shows a C-scan image of impact damages using 2.25 MHz pitch-catch transducers and Fig. 3 (b) figure does the impact-damaged image of CFRP laminates using 2.25 MHz pulse-echo transducers. It was thought that defect of CFRP laminates was very sensitive to ultrasonic Rayleigh wave. So it is found that there exists a good agreement in the impact-damaged size between pitch-catch and pulse-echo results. Therefore those results seem to show a practical use for the field testing and inspection. However, the C-scan image of each ply was usually difficult to determine to some degree. The resultant C-scan image would contain almost exclusively the defect of the ply.

4. Conclusions

In this paper, one-sided measurement techniques were adopted in order to inspect impact damages of CFRP

laminated and the conclusions obtained in this study as follows; 1)Two Rayleigh transducers were nondestructively characterized with one-sided pitch-catch mode to detect the defect in the CFRP laminated composites. 2) It is suggested that a pitch-catch technique is very useful for inspecting composite components when no usable back wall echoes are present. 3) The C-scan images could be obtained using the pitch-catch method for the impact damages, which contain almost exclusively the defect information.

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