Technical Report No.2 V1
For Woodpecker

1. Development of the Woodpecker

Coin tapping with a small hammer is used extensively at present to detect the debond of honeycomb structures in aircraft. Personal skills that take a long time to acquire are indispensable to keep accurate detection for coin tapping method, which depends on the difference in tapping sound between normal and debonded parts.

Because this traditional method depends on human senses, detection is difficult in a noisy environment and is impossible to continue with satisfactory accuracy over a long time. The inspector becomes used to unusual sounds or simply tired.

The fundamental problem is that the coin tapping method is not quantitative.

Mitsui has developed the Woodpecker to solve this problem. The Woodpecker uses automatic tapping, employing a central processing unit (CPU) to comparatively evaluate the output of a force sensor attached to the hammer, rather than depending on tone colors which are difficult to distinguish from each other in noisy environment.

The quantified evaluations are indicated with light emitting diodes (LED) and its digital values are transmitted to Woodpecker monitoring unit or personal computer.

Development efforts emphasize the achievement of an extremely small size and light weight to permit operation with one hand, a quantitative evaluation and a lower price than similar devices, resulting in a handy detector with excellent cost performance.

2. Applications

1) Detection of debonds in honeycomb structures
2) Detection of damage behind honeycomb structures
3) Determination of moisture in honeycomb structures
4) Detection of the positions and shapes of inserts in honeycomb structures
5) Detection of interlayer debonds in composite boards
6) Detection of debonds of joints in composite structures (debonds of helicopter blades)
7) Location of beams in walls, etc.
8) Detection of debonds in tiles
9) Detection of debonds in clad steel
10) Detection of debonds in coatings
11) Detection of boundaries between different materials, different plate thickness or structures under coated surfaces
12) Characteristics analysis of the sounding boards of musical instruments, such as the KOTO (Japanese harp), pianos and violins (identification of masterpieces)
13) Detection of the water level in a container from outside
14) Detection of dryness (hardening) of bonding agents, etc.
15) Comparison and evaluation of surface hardness (elasticity) of various plates
16) Measurement of the tension of membrane
17) Detection of the unfilled parts of foamed sandwich panels.

[Undetectable items]

A small number of little bubbles or debonds, or cracks in a direction vertical to the surface, which have little effect on surface elasticity, are undetectable. Rough surfaces or surfaces on which sand, dust or oil have accumulated absorb the impacts of the tapping hammer and do not allow the detection of debonding underneath.

It is better for inspection to clean and remove them in advance.

Furthermore, where the debond of test pieces are made by inserting Teflon sheets between skin and core and there is some compression between them, it is hard for WP to detect this type of debonds underneath. Because there is no debond in them but compression.

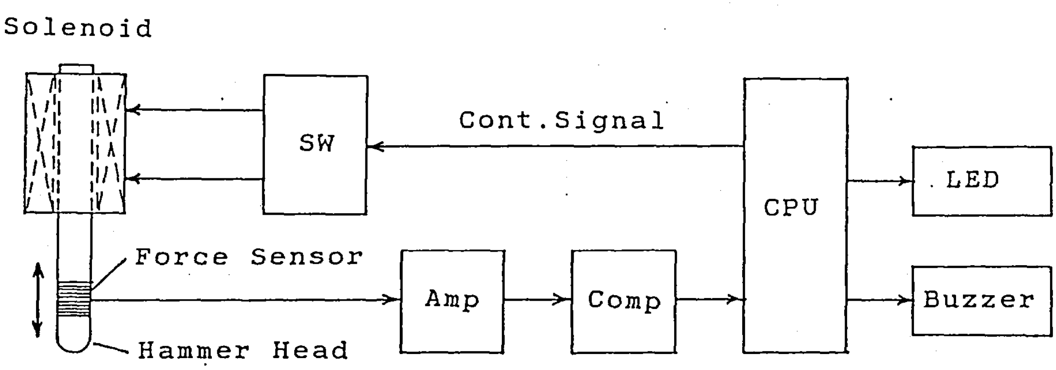


Fig 1 WP Block Diagram

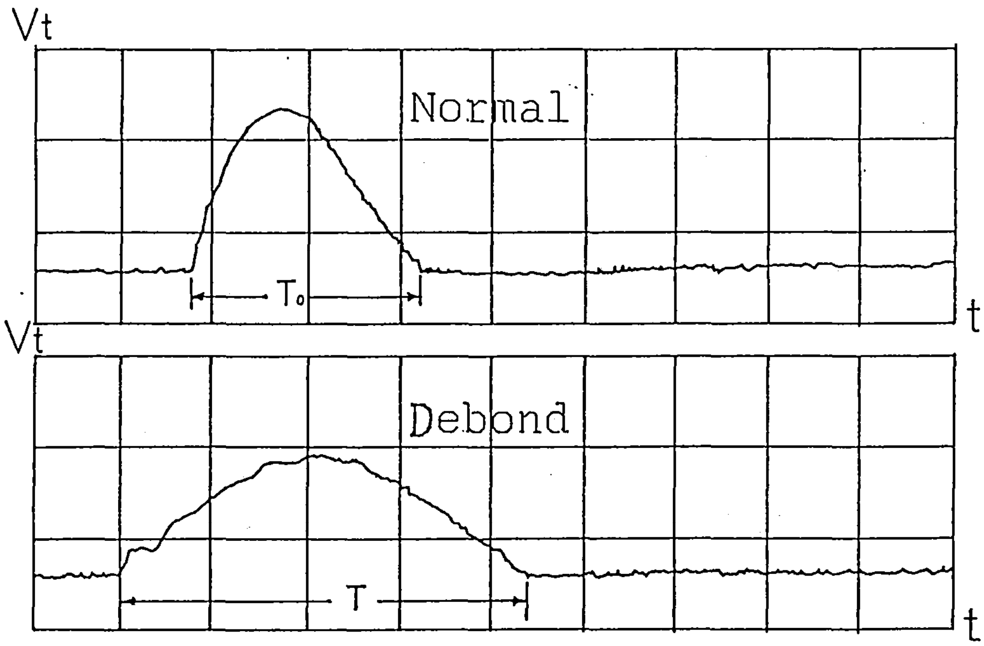


Fig 2 Impulse Wave

3. Principle of Detection

The Woodpecker consists of two main parts, the hammer drive and the control section. The hammer is driven by a solenoid, and the output of the force sensor attached to the hammer is fed to and evaluated by the CPU.

First, the memory switch button is pressed while tapping the apparently normal part of the honeycomb, and the impact time To of the part is memorized by the CPU as the standard value. Then the honeycomb is scanned with the hammer and, when the hammer hits a debonded part, the impact time T at that moment is compared with the memorized standard value.

The LED will then indicate Green, Yellow , Red1 or Red2 according to the degrees of debond detected as follows.

Colors of LED indication and corresponding
Degrees of debonds (R=(T－TO) / To*100)

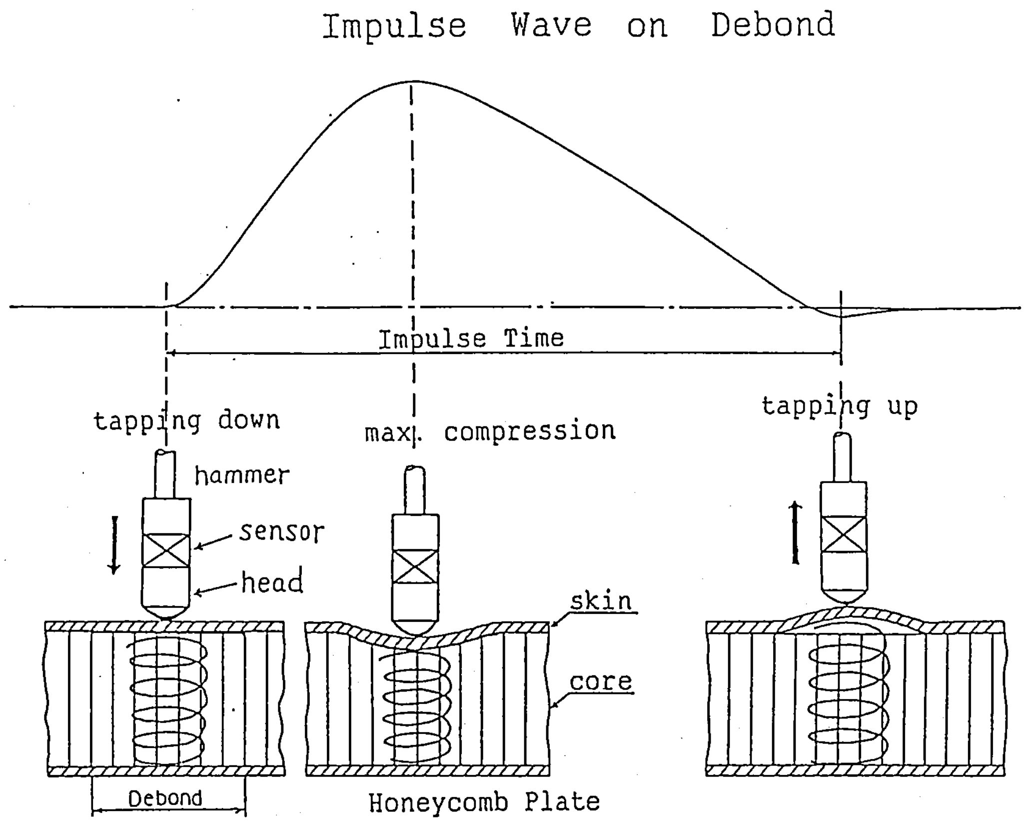
Green	R<8%	Normal
Yellow	8≦R＜16%	Warning
Red 1	16≦R＜40%	Debond (with buzzer)
Red 2	40≦R＜80%	Debond (with buzzer)
Red 1 +Red 2	80≦R	Debond (with buzzer)

Fig.1 is a block diagram of the system.
Fig.2 shows the measured impulse waves of the normal and defective parts. A defective part, which has weaker elasticity, has a longer impact time than a normal part.

4. Advantages of Tapping Method

The tapping method is superior to the ultrasonic nondestructive testing method in the following respects.

There are two types of debonds in the honeycomb or similar structure. The skin becomes debonded from the core and comes up loose, or it remains attached to the core even if debonded. The former debond can be detected with ultrasonic method, but the latter cannot, because the debonded skin and core would transmit the sound waves as if they are still boneded together.



Using the tapping method, however, the Woodpecker can detect the latter type of debonds as well. The underlying principle is illustrated in the above diagram.

In the diagram, the measured wave and the dynamic behavior of the hammer and of the honeycomb are enlarged for comparison. The hammer drops to come into contact with the honeycomb and the waveform rises. Until the maximum compressive road is reached, the spring constant of the debonded part is attributable to the combination of the honeycomb skin and core (though it is smaller than that of a normal part).

Then, as the honeycomb is relieved of the load, its skin comes off the core and becomes convex upward. In this phase until the hammer loses contact with the honeycomb skin, the spring constant is clearly attributable to the skin, the spring constant is clearly attributable to the skin was under load.

Therefore, this part has a longer impact time than a still bonded part and accordingly can be detected.

In other words, if the skin and the core are debonded but remain attached to each other, the latter portion of the waveform indicates that there are many cases (particularly in thin skins) in which the skin and the core come apart because of the difference in elasticity.

Although this type of debond cannot be detected ultrasonically, the Woodpecker can detect this type of debond.

Furthermore, in contrast to the ultrasonic method which concentrates on a single point, the Woodpecker can quantitatively detect the conditions (with spread and degree) of debonds around the point it taps. This is possible because the tapping process always detects the elasticity coefficient, or the spring constants, of the object being tested.

5. Handling Ease and Performance Features of Woodpecker

(1) The Woodpecker is small and light enough for one-hand operation.

(2) It is simple and easy to operate.

The Woodpecker has only two switch buttons, the start button to actuate the hammer (and also to turn on the power supply) and the memory switch to set the standard value.

Even a beginner can use it immediately. What corresponds to the calibration of a usual measuring instrument is achieved by a single press of the memory button.

(3) High detection sensitivity.

The Woodpecker is as sensitive as any other debond detector in current use (see”9. Comparison with Other Nondestructive Testers”)

(4) It can detect the debonds even while moving.

Depending on the surface coarseness, the Woodpecker can detect the debonds even while moving if the speed is not faster than 20 cm/s. A smooth Al honeycomb, for instance, would permit this moving detection.

(5) It excels in wear-resistance.

Unlike other debond detectors which move while maintaining contact with the object surface, the Woodpecker taps intermittently while moving and therefore the hammer head is in itself less subject to wear.