A NON-DESTRUCTIVE TEST METHOD FOR SANDWICH STRUCTURES

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Early radomes were usually overstrength due to the electrical requirements for sandwich thickness, the double contoured shape of the parts, and the slow speed of the aircraft on which they were installed. This condition of overstrength is gradually being eliminated by more critical weight requirements, by higher speeds and related higher loads, and by higher temperatures which reduce the physical properties of the materials. It is apparent that the "fat" of overstrength radomes is in the fire, and high margins of safety of sandwich structures belong to the past.

The high margins of safety of early radomes was an essential factor of their design. It was known that bonds were weak and inconsistent. Parts were tested by tapping with a coin to detect unbonded areas. Quality control was limited by lack of knowledge of the factors which influenced part strength. Radomes fabricated to early standards would be entirely unacceptable today, primarily because of low and inconsistent bond strength.

The use of sandwich construction in aircraft is increasing, both for radomes and other structural components. The radome itself is fast becoming a primary structural component whose failure would endanger or cause the loss of the aircraft. The radome may be necessary to the shape of the aircraft for controlability, may carry cabin pressure loads, airframe loads, or perform other vital functions. There can be no compromises with quality and no inconsistencies of strength with these primary structures.

Because fabrication methods are complex, consist of many variables, each of which is subject to human error, positive knowledge of quality and strength is needed. In particular, proof of adequate bond strength is required. This paper presents a device and a method which has been successfully used since 1948 for the detection of weak bonds in sandwich structures.

<u>Method of Operation</u>:

Any engineer is familiar with a punch press and the method used in punching holes in a sheet of metal. Referring to Figure I, it can be seen that when the load "P" on the punch exceeds the shear resistance of the material around the periphery of the punch, a plug will be sheared out of the plate. The shear stress at failure is:

$$f_s = \frac{P}{A} = \frac{P}{\pi d t} \qquad (1) \quad \text{(Ref. Figure I)}$$

If the supporting collar be increased in diameter, the plate will be subjected to a bending stress as well as a shear stress. However, the shear stress around the perimeter of the punch will be unchanged. (Ref. Figure II). Furthermore, if the plate be changed to a sandwich, the conditions of equilibrium must still be satisfied. In this case the shear stress will exist principally in the sandwich core material (Ref. Figure III) and will have the following value:

$$f_s = \frac{P}{A} = \frac{P}{\pi d(n-t)} \qquad (2)$$

The shear stress so imposed in the sandwich core material is identical to that produced in the standard flexural test specimen. (Ref. Figure IV). The shear stress in both cases is transferred across the bond between the core and the skin. The bond strength is thus measured by the failing load. It is noted that the shear stress induced by the tester is a maximum at the exact periphery of the foot, and decreases in proportion to the diameters of the concentric circles.

In the beginning the simple device shown in Figure V was used. The weight "W" was lowered onto the panel at the prescribed intervals. Because of the clumsy nature of this device, its constant load, lack of portability, and difficulty of applying it to radome shapes, a better method of applying the load was needed. This better method was found in the vacuum cup. (Ref. Figure VI).

The principal of operation of the cup is obvious on inspection. When the cup is evacuated, load is applied between the foot and the sandwich, thus creating the shear stress in the core. The load on the foot may be calculated as follows:

$$P = \Delta p\ A = \Delta p\ \pi \left(\frac{D}{2}\right)^2 \qquad (3)$$

where p is the vacuum, psi, and other symbols are as noted in Figure VI. Note that this equation neglects the area under the foot.

The shear stress in the core material is approximately equal to the following value:

$$f_s = \frac{\pi D^2 \Delta p}{4 \pi d(n-t)} = \frac{D^2 \Delta p}{4(n-t)d} \qquad (4)$$

A prototype vacuum cup device was delivered to the Forest Products Laboratory in 1950 for evaluation. Report 1832-B was published as a result of this work and reports the following conclusions:

1. Poor bonds in sandwich panels having cores of aluminum foil honeycomb, glass cloth honeycomb, or balsa, can be detected by proper use of the tester.

2. It makes no difference on which side of the panel the poor bond occurs.

3. Cores which fail without sudden failure, such as CCA or cotton honeycomb, cannot be detected.

4. The instrument is approximately as effective as a flexural shear test in detecting poor bonds, but not as sensitive as a flatwise tensile test.

Since publishing the above report, Forest Products Laboratory has fabricated and demonstrated a tester using a large vacuum area and a large number of feet. This variation may be useful if a large number of like parts are to be tested. It is apparent that Forest Products Laboratory feels the device will successfully test the bond strength of sandwich panels. In addition, the author has used the device for approximately five years on various radomes fabricated by Zenith Plastics Company and has shown the tester to be a valuable instrument for quality control or Material Review Disposition work.

Comparative Tests:

In order to compare the results obtained by use of the tester with flexural shear and flatwise tension values, a series of five panels representing typical radome configurations were fabricated and tested. The panels were 36" x 51", and constructed as shown below with glass cloth faces and glass honeycomb core.

Panel Number	1	2	3	4	5
Face Thickness	.025	.035	.036	.025	.035
Panel Thickness	.534	.300	.352	.298	.739
Core Material	$\frac{1}{4}$PE x 6.0	$\frac{1}{4}$PE x 6.0	$\frac{1}{4}$PE x 8.0	$\frac{1}{4}$NP x 4.0	3/16PE x 4.5

Test specimens were cut from the panels as shown on Figure VII. Results from this series of tests are shown in Table I. The ratios of the minimum and maximum to the averages are also shown.

It is noted from a study of the values that the sensitivity of the tester is of the same order as that of the flexural shear tests performed on samples. It may also be noted that in both cases the actual scatter of data is large.

Recommended Method of Use:

If a large number of like parts are to be checked, it is suggested that a flat panel typical of the cross-sectional configuration of the part be made and tested as outlined in this paper. The test value recommended for use in checking the part should be approximately 70% of the failing value for the test panel. If the flexural samples and flatwise tensile samples indicate the panel is considerably weaker or stronger than can be expected of the part, the test value may be adjusted accordingly.

If only a limited number of parts are to be tested, the equations presented may be used to calculate the test values. The value of shear stress to be developed may be taken as the expected value of bond strength or the design values of shear stress in the core. Standard practice at Zenith is to use 70% of the average value of the ultimate shear strength of the core in the TL and TW plane. This value is well below that which will damage the core material, but will show up any large deficiencies in the bond.

TABLE I - RESULTS OF TESTS FROM THE TESTER, SHORT SPAN FLEXURAL, AND FLATWISE TENSION FOR THE FIVE PANELS TESTED

			Panel 1		Panel 2		Panel 3		Panel 4		Panel 5	
			f_s	Ratio	f_s	Ratio	f_s	Ratio	f_s	Ratio	f_s	Ratio
Flexural Test	TW Plane	Min	119	.915	172	.905	209	.95	140	.91	96	.89
		Max	159	1.22	209	1.07	236	1.07	171	1.12	119	1.10
		Avg	130		190		220		153		108	
	TL Plane	Min	234	.96	248	.79	314	.91	285	.95	173	.77
		Max	258	1.02	344	1.10	376	1.09	312	1.04	258	1.15
		Avg	248		312		345		300		258	
Tester		Min	246	.91	397	.915	387	.93	232	.75	224	.90
		Max	305	1.13	470	1.08	447	1.07	386	1.26	260	1.05
		Avg	270		437		417		308		248	
Flatwise Tensile Average			307		390		387		189		420	

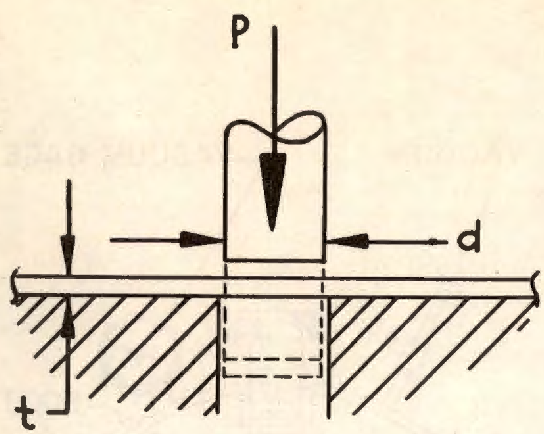

FIGURE I

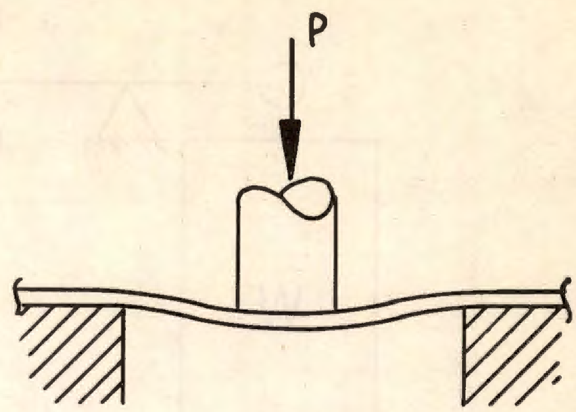

FIGURE II

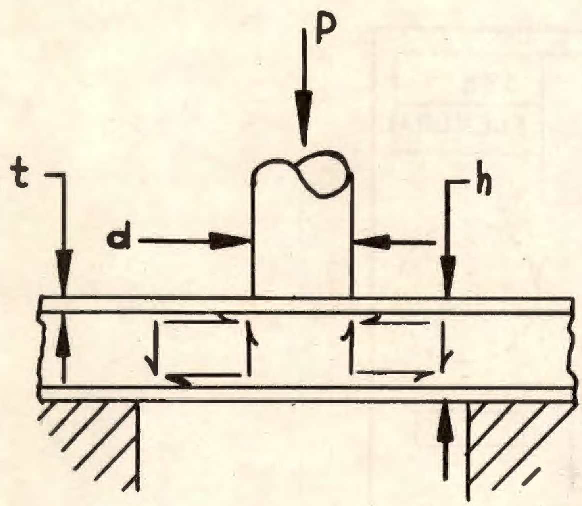

FIGURE III

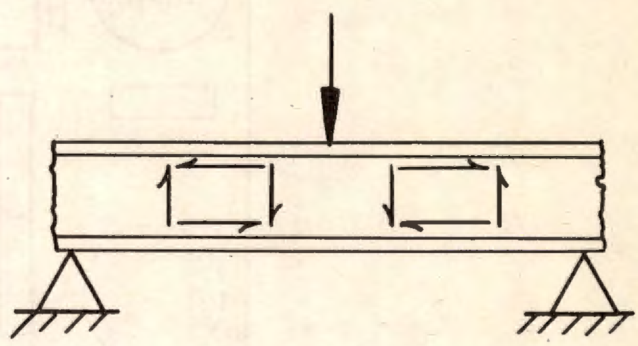

FIGURE IV

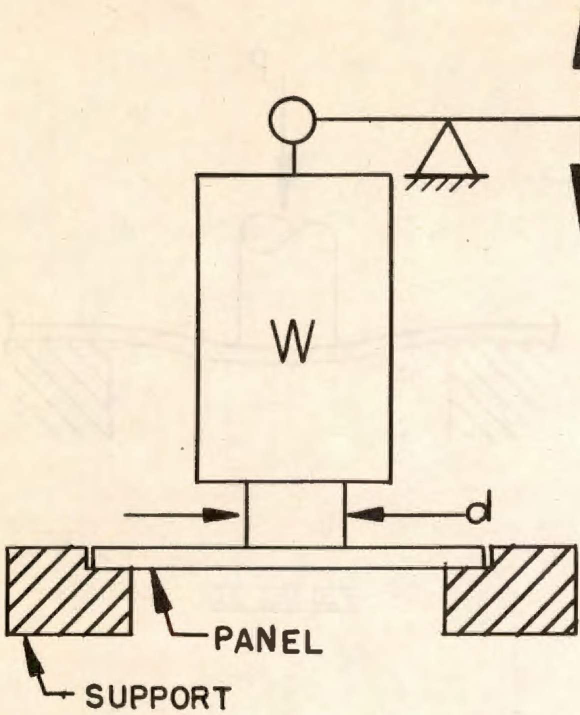

FIGURE V

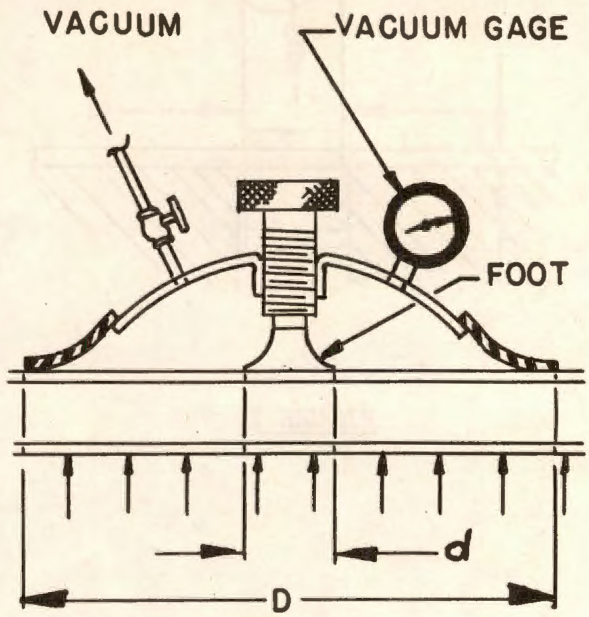

FIGURE VI

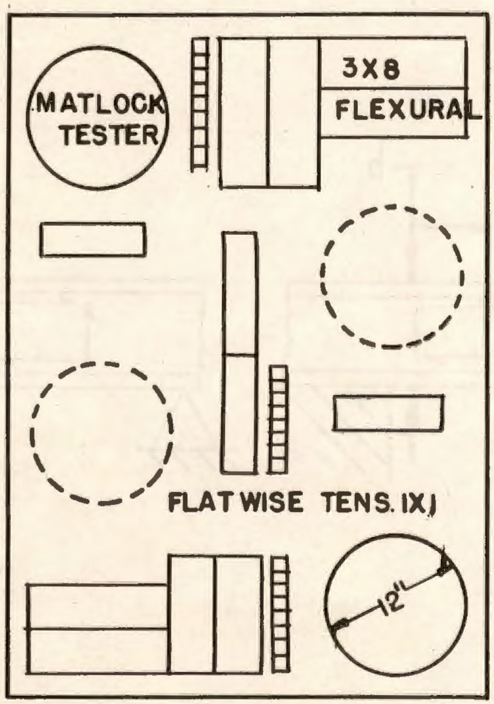

FIGURE VII