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Progress Report No. 9

Project Title: Measurement of Damping of Graphite Epoxy Material

Sponsor: NASA George C. Marshall Space Flight Center
Huntsville, AL 35812

Period: June 1 - June 30, 1985

This letter reports the work done during the month of June 1985 on this project. The Auburn research team consisting of Dr. M. J. Crocker, Dr. P. K. Raju, Mr. G. Zhu and Mr. M. D. Rao attended the Noise-Con 85 Conference held at the Ohio State University June 3-5, 1985 at Columbus, Ohio. A paper entitled "Experimental Evaluation of Damping of the Graphite Fiber Composites" was presented. The paper was authored by the members of the Auburn research team along with Mr. S. H. Guest of the George C. Marshall Space Flight Center, Huntsville, Alabama. Mr. M. D. Rao made the presentation. The paper presented results of the work done on the project. In the discussions that followed many participants felt that measurement of the damping of the graphite epoxy specimen was a difficult task and commended the effort made in making the damping measurements in a systematic way.

During the second week of this month the FFT was sent back to the manufacturers, Bruel & Kjaer, for servicing. The FFT was held up at the servicing center for about three weeks. In this period work on the construction of the vacuum chamber was expedited. The vacuum chamber has been constructed according to the design whose details were discussed in the earlier progress reports. Figure 1 shows the fixture designed for exciting the tube specimen in the chamber. The excitation force from the shaker is transmitted to the composite tube with the help of a thin steel rod and the metallic bellows assembly. The end flanges of the bellows were connected to the mating flanges of the half nipple by using copper gaskets and screw nuts. A stainless steel half ring with an inner knife edge will be used to support the tube specimen, as was done earlier in the forced vibration experiments. The vacuum chamber is almost ready for use except fr some minor details which need attention.

In the meantime, some more experiments were conducted on the tube specimen in atmosphere to confirm the previously reported results. Figure 2 and Table 1 show some results for forced vibration tests using the half ring and free-free boundary condition. The main purpose here was to study the effect of the frequency resolution on the damping ratio measurements. All the plots shown are for the first resonance frequency of the tube. Figure 2(a) was obtained from a baseband analysis in the frequency range 0-800Hz, using broad band random excitation. From Table 1 it is seen that for this case the resonance frequency is 551Hz and the half power band width is 3Hz. A damping ratio value of 0.272 % was obtained using these data. It might be tempting to accept this result, since the curve looks good with a sharp peak. However, because of the poor frequency resolution, the half power points are not exactly 3 dB below the maximum amplitude. There is an error of about $\pm$ 20% in the estimation of the half power points. Figure 3(a) confirms this doubt, in view of the poor coherence and signal to noise ratio. At resonance, the value of the coherence function which should ideally be 1 was about 0.4. The signal to noise ratio at resonance was about 2 dB. In order to improve on these results, measurements were repeated with zoom FFT with various frequency resolutions ranging from 0.5 Hz to 0.0313 Hz. Table 1 shows the natural frequencies and damping ratio values for these cases, and Figure 1 shows the corresponding resonance curves. From the table it is seen that for a frequency bandwidth (FBW) of 0.5 Hz, the estimated value of the damping ratio is 0.18%, for a FBW of 0.25 Hz the value is 0.136 % and for a FBW of 0.0625 Hz it is about 0.13%. Finally for a frequency resolution of 31.3 mHz, the estimated value of the damping ratio is 0.127%, which is probably the most accurate result with the least error in the estimation of the half power points. Furthermore, for this case a plot of coherence and signal to noise ratio is shown in Figure 3b. From this figure it is seen that a value of about 0.91 for the coherence function and a signal to noise ratio of about 14 dB was obtained at resonance. This is a marked improvement when compared with the results of case 1 (with 1 Hz frequency resolution). For the case where the frequency resolution was 0.125 Hz and less, a variable sine-wave sweep type of excitation was employed, since random excitation did not yield a sharp peak.

The use of a half ring to connect the impedance head and the shaker to the tube specimen has one drawback. It leaves a small scratch on the tube each time the ring is assembled or disassembled because of the knife edge in the interior surface of the ring. Hence in order to overcome this difficulty it was decided to design a different type of ring to hold the specimen. Figure 4 shows one view (side view) of the new ring used for attaching the tube to the shaker assembly. In this design, a thin steel rod (bicycle spoke rod) is wrapped around the tube at a point midway along the length of the tube. The two ends of the rod are connected to a small aluminum rectangular block which has a tapped hole for connecting the impedance head and the shaker. The mass of this ring assembly is about 64 grams compared with a mass of 172 grams of the half ring assembly. Hence, by using this design we have eliminated the problem of scratches on the tube with the additional advantage of reduced mass.

Figure 5 and Table 1 show some preliminary results obtained using this new ring. It is seen that the damping ratio value in this case is estimated to be 0.167%. This is a slightly higher value compared with the 0.13% value obtained using the half ring. This increase may be attributed to the fact that the new ring system is contributing some more damping to the total system damping, since the new ring system cannot be simplified as a simple lumped mass, unlike the half ring. Work is in progress in extracting the damping value of the tube specimen alone from the total system results using a sub-system approach. This will be reported in the future progress reports.

Table 1. Free-Free test results for the tube specimen using a half ring for connecting the shaker.

No.	Frequency Range (Resolution Hz)	First resonance Frequency-Hz (Frequency Response Amplitude m/N x 10^{-6}) Frequency	Amplitude	Half power point Frequency to the left of Resonance (Amplitude m/N x 10^{-6}) Frequency	Amplitude	Half power point Frequency to the right of Resonance (Amplitude m/N x 10^{-6}) Frequency	Amplitude	Half power Band Width-Hz	Damping Ratio (%)
1	0 - 800 (1)	551.00	(38.7)	550	(21.0)	553	(18.0)	3.0	0.272 %
2	304 - 704 (0.5)	551.50	(44.2)	550.5	(28.3)	552.5	(26.3)	2.0	0.1813%
3	500 - 700 (0.25)	551.25	(43.3)	550.5	(30.8)	552.00	(29.1)	1.5	0.136 %
4	500 - 600 (0.125)	551.50	(53.2)	550.625	(35.2)	552.125	(36.3)	1.50	0.136 %
5	525 - 575 (0.0625)	551.50	(60.5)	550.625	(38.8)	552.125	(42.4)	1.437	0.130 %
6	537.5-575 (0.0313)	551.47	(55.0)	550.687	(38.9)	552.093	(38.7)	1.406	0.127 %

Table 2. Free-free test results for the tube specimen using a new type of ring for connecting the shaker.

	Frequency Range (Hz)	First Resonance Frequency (Hz)	Half power Bandwidth Hz	Damping Ratio
1	500-700	597.750	2	0.167 %
2	550-650	598.125	2	0.167 %
3	575-625	598.125	2	0.167 %

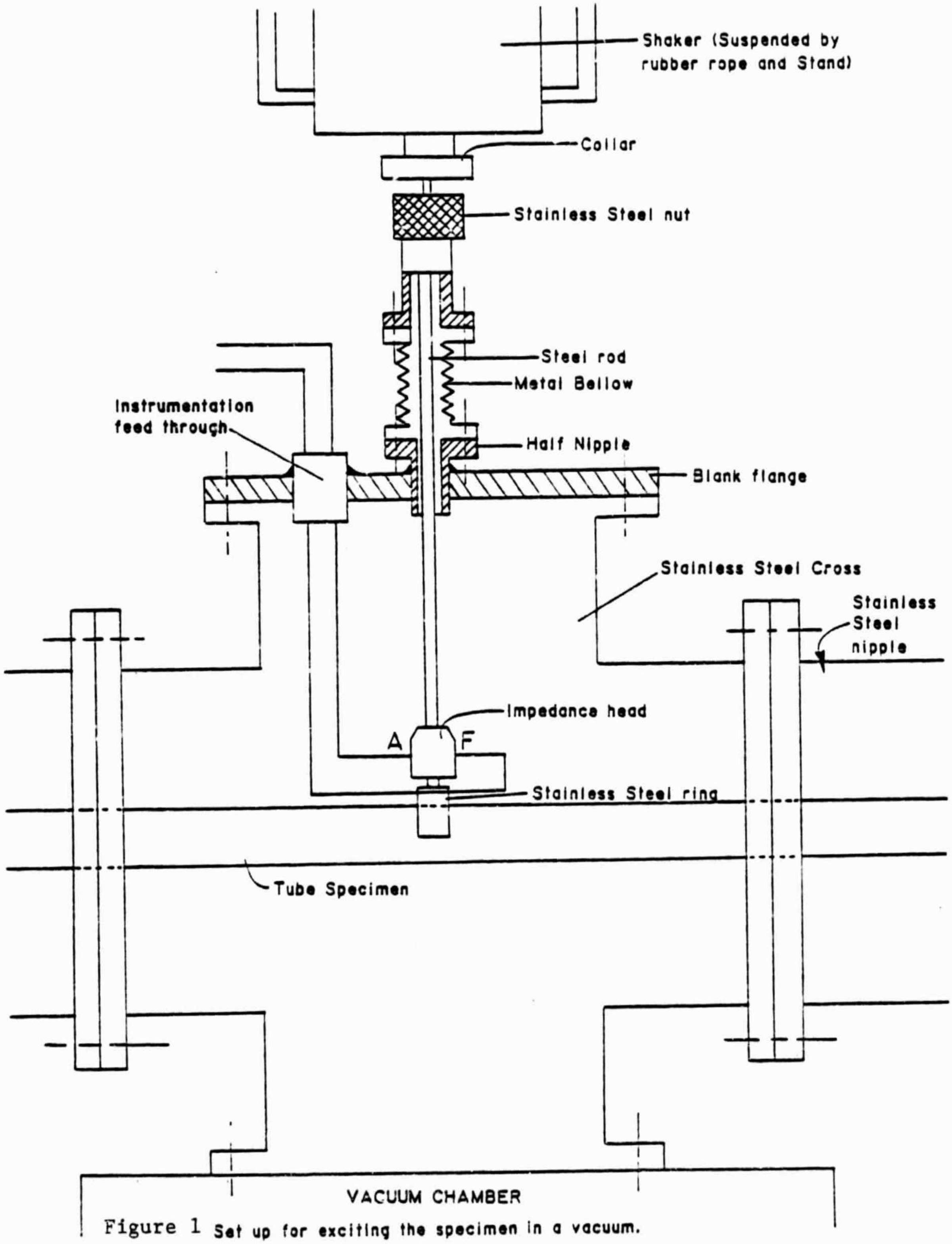

Figure 1 Set up for exciting the specimen in a vacuum.

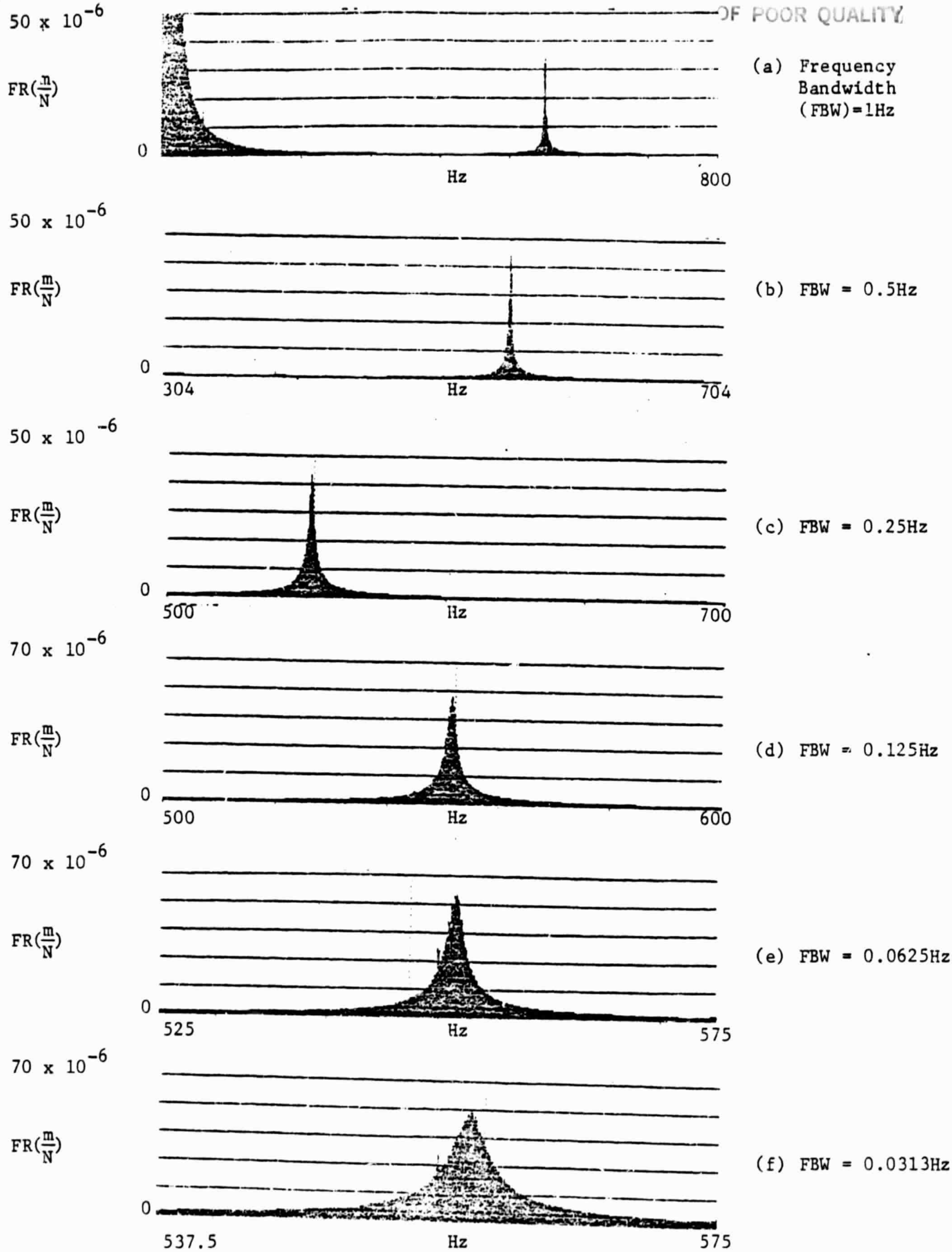

Figure 2 Frequency response FR(Displacement/Force) magnitude versus frequency for the tube specimen with half ring for various frequency bandwidths FBW.

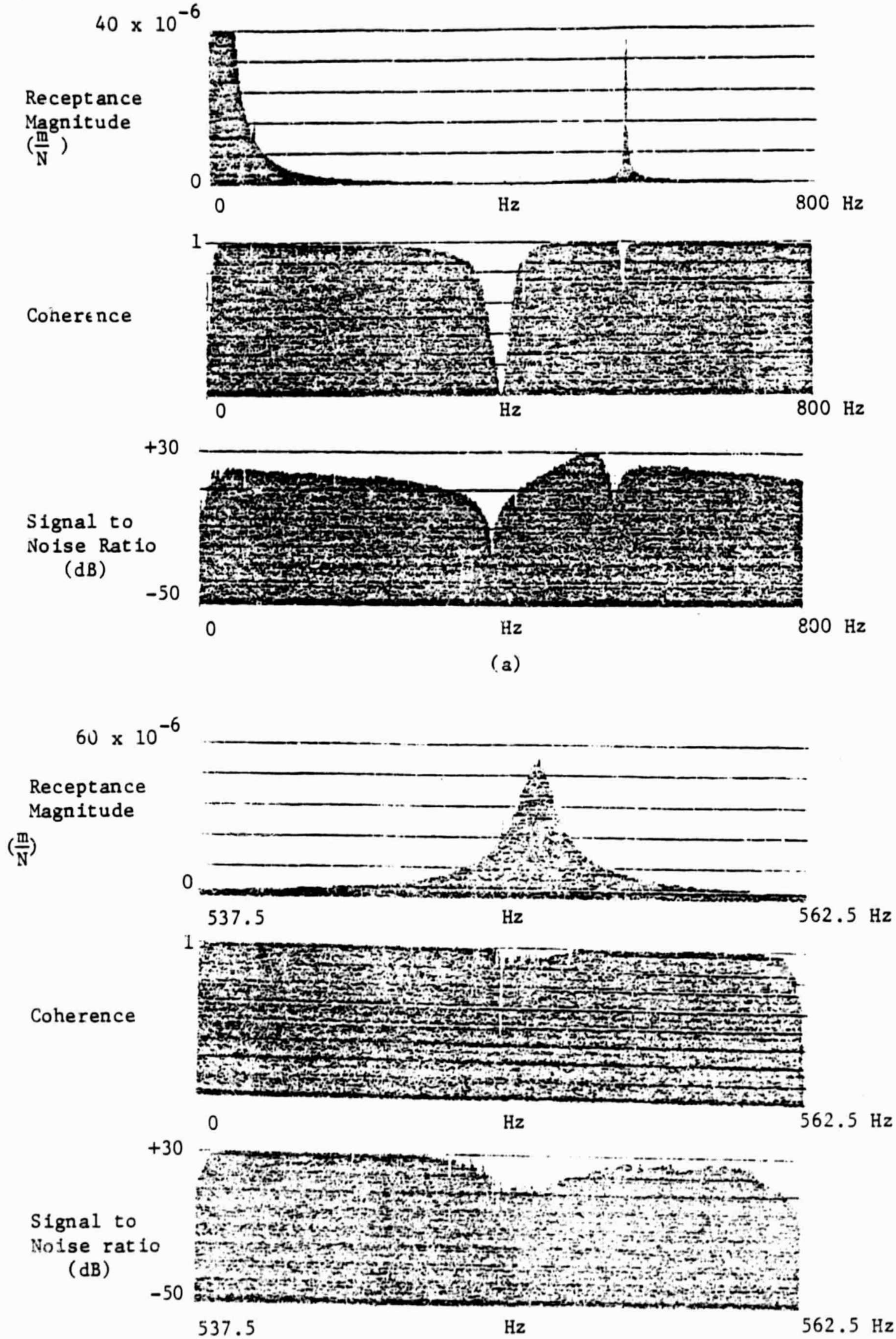

Figure 3 Frequency response (receptance), coherence and signal to noise ratio versus frequency for tube specimen with half ring for two different frequency ranges.

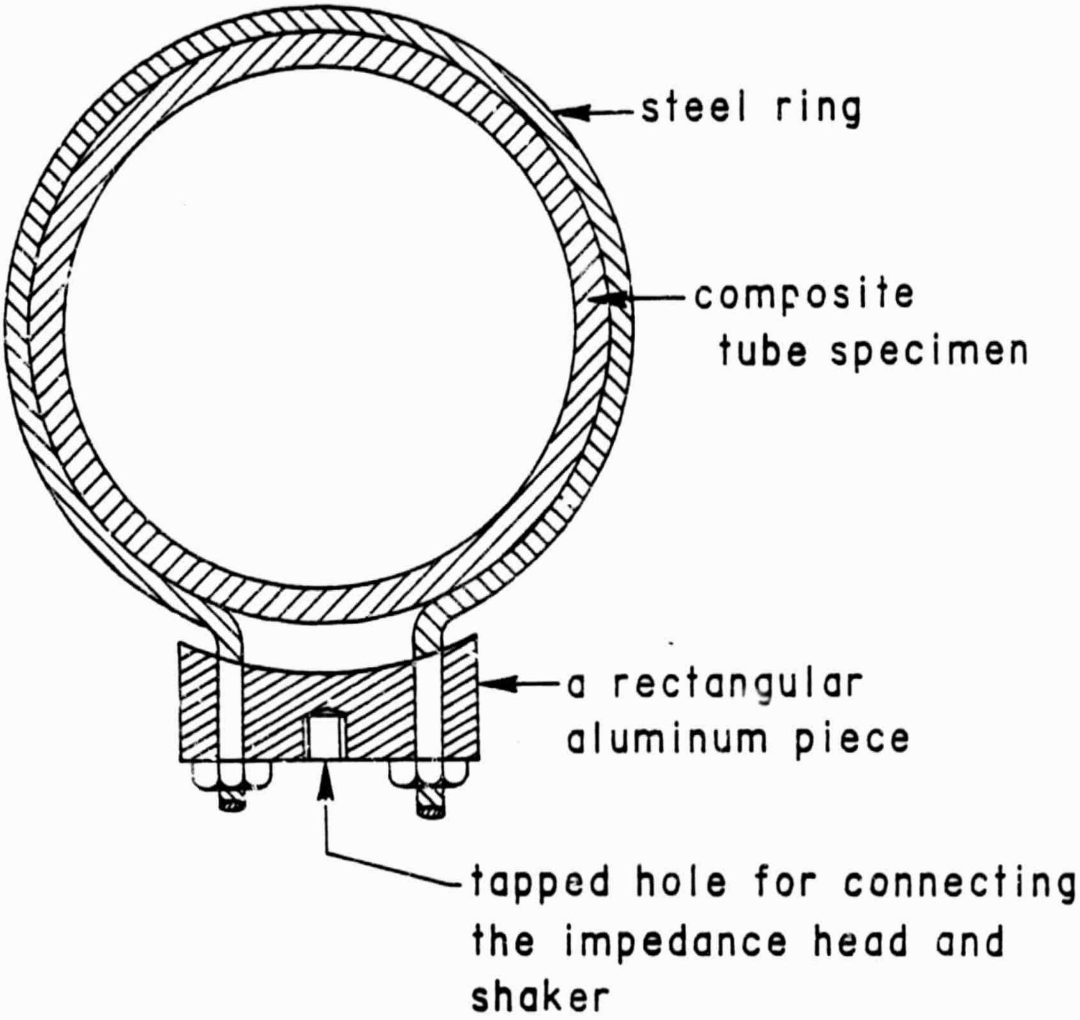

Figure 4 A Method of attaching the Composite tube to the Shaker for Conducting Free-Free Vibration Test.

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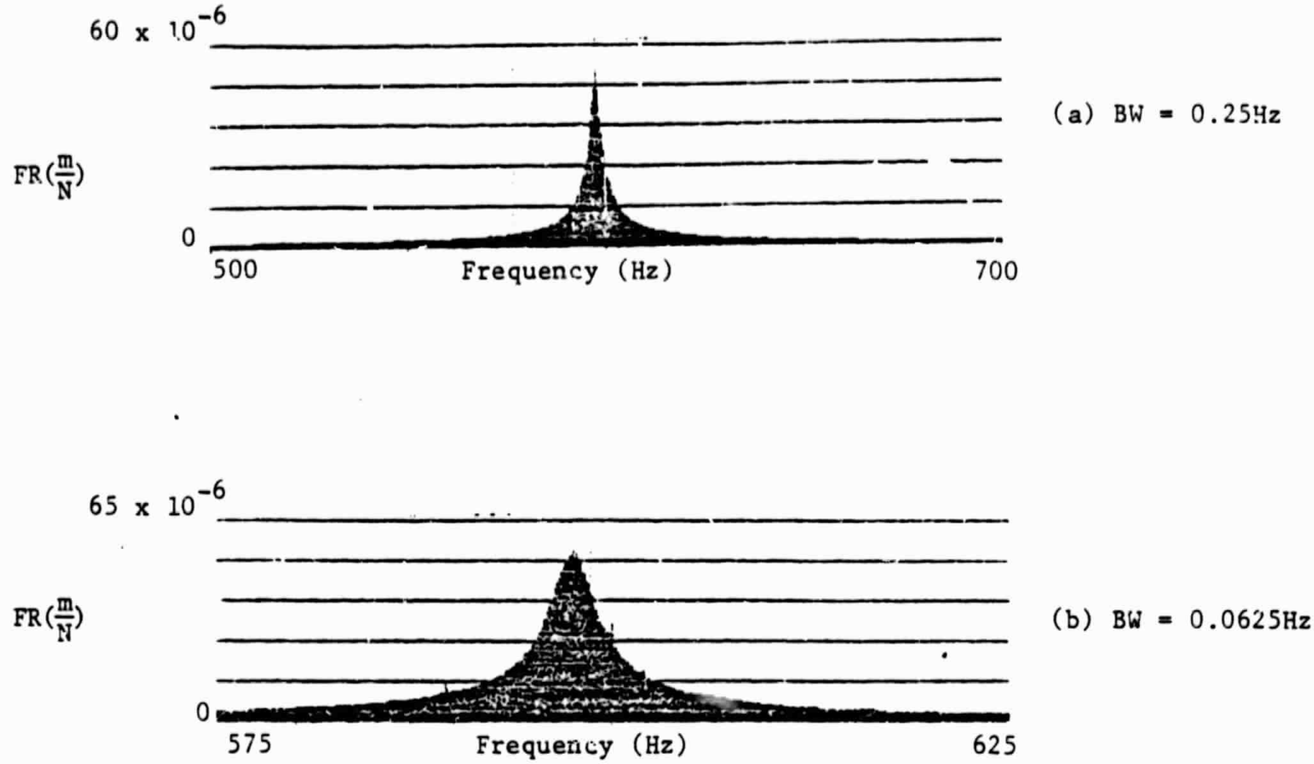

Figure 5 (a) and (b) Frequency response-receptance (FR) VS frequency for the tube specimen with new ring for 0.25 Hz and 0.0625 Hz bandwidths respectively.