THE OPPOSITE MODULI (OM) SPEAKER CABINET

By Hajo Prodan

My interest in speakers goes back to the early 1960s, when I installed some crude music systems into so-called jazz cellars that were much in vogue at that time. In 1988, I tried to improve speaker cabinets by pouring some from ordinary concrete. The results were rather poor, but it made me think more deeply about rigid-body acoustics.

From more experiments, I learned that cabinets made from very hard materials, such as marble, were good in the bass region, but exhibited problems in the mid and high ranges. Boxes made of softer materials, such as heavy cardboard (*Photo 1*) or bituminous fiber board, performed poorly in the bass area, but fine in the higher frequencies.

BLENDING OPPOSITES

One day it occurred to me to try joining two contrasting materials with modern grouting compound. I consulted *Physics for Scientists and Engineers*, by Raymond A. Serway, and a British science data book to learn more about density, expansivity, tensile strength, Young's modulus, the speed of sound, and other information having to do with solids.

I found out that diamond on one side and rubber on the other could be the right partners. Since I could not afford diamonds, I chose quartz sand as a substitute because it has a very high Young's modulus and a high rate of sound transmission. In contrast, rubber shows a low Young's modulus as well as a very low speed of sound in a thin specimen.

A nearby tire-recycling plant provided a free sack of granulated vulcanized rubber. As a grouting compound, I chose an epoxy resin that is normally used for general building repair. I mixed the epoxy concrete with quartz sand, granulated rubber, and ilmenite ($FeTiO_3$) powder, the last ingredient serving as a weight-control additive.

PHOTO 1: Testing a cardboard speaker (right).

The basic formula for 1kg of the mix was 431g of oven-dried quartz sand, 72g of the granulated rubber, 104g ilmenite, and 393g of epoxy resin (two components). You can omit the ilmenite, but you must then replace it with 98g of quartz sand.

PANEL TESTING

The mixture of the ingredients made a nice dough, which I poured into a waxed flat form. After three days of curing, I had a panel that was ready for testing. I named it the Opposite Moduli (OM) panel (*Photo 2*).

The first comparative tests revealed that this was a kind of eureka event. The effect of

PHOTO 2: Artist's impression of an OM box.

ABOUT THE AUTHOR

Hajo Prodan is a free-lance engineer from Germany. During the last 15 years, he has been involved in electronic workshops, communications systems, and radio broadcasting in countries such as South Korea, Indonesia, Peru, and Sri Lanka for Deutsche Welle (voice of Germany). His current activities are mainly room acoustics and international technical consulting.

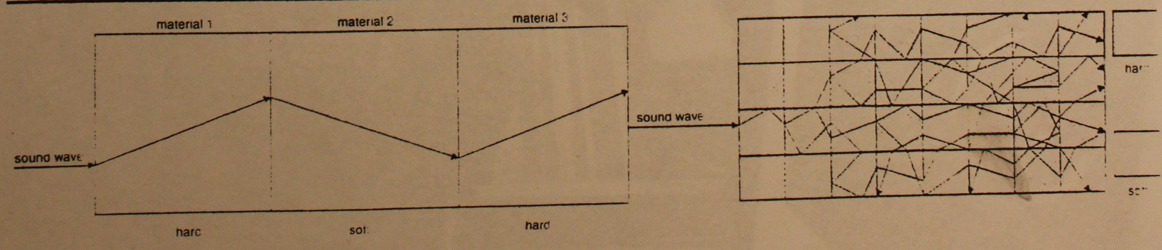

FIGURE 1: Panel effects.

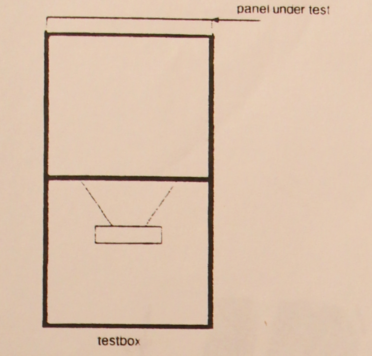

FIGURE 2: Testbox.

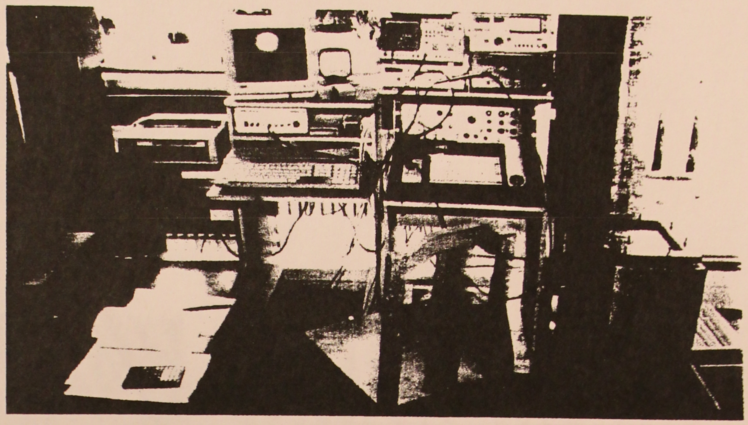
PHOTO 3: Test setup for vibration measurements.

the panel in acoustic terms was much better than I expected.

The explanation of the sound-energy absorption effect is as follows (*Fig. 1*). Basic acoustic theory holds that a sudden change in the properties of a compressible medium alters the speed of sound, resulting in a refraction or change of direction of wave travel. It follows that hard/soft variations occurring continually within a rigid body will cause multiple changes in speed, impedance, direction, and phase. As there remains no dominant direction of wave travel, it becomes "lost" inside the body, and the energy is absorbed at maximum.

In a long sequence of comparative measurements, I checked all conceivable kinds of speaker-cabinet materials, including natural wood, particleboard, glass, plastic, metal, natural stone, concrete, sandwich panels, and designed OM panels.

I performed the measurements using the following equipment (*Photo 3*): vibration transducer (Kemsonic 1628), precision preamp (home-brew), sine-wave generator (Hameg HM 208), distortion meter (Hameg HM 8027), a computer-based audio test system (Kemsonic AMS PC 1656), and a testbox (home-brew).

The testbox was a massive, double-walled cabinet, poured from concrete, with dimensions of 380mm × 620mm × 380mm and weighing approximately 40kg (*Photo 4* and *Fig. 2*). The top consisted of the panels under test—all of them the same size: 300mm square. For absolute tightness, I used two thin, soft PVC gaskets and a fitting high-quality plywood frame. The torque of the bolts was measured and balanced by a torque wrench to achieve equal conditions for each panel.

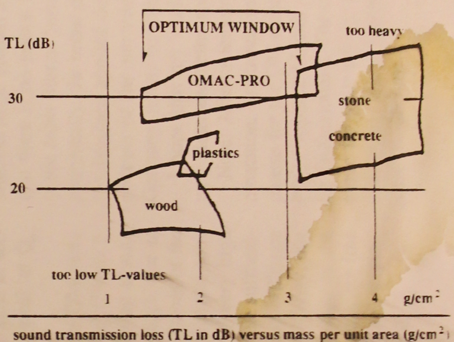

FIGURE 3: Graphing the different materials tested.

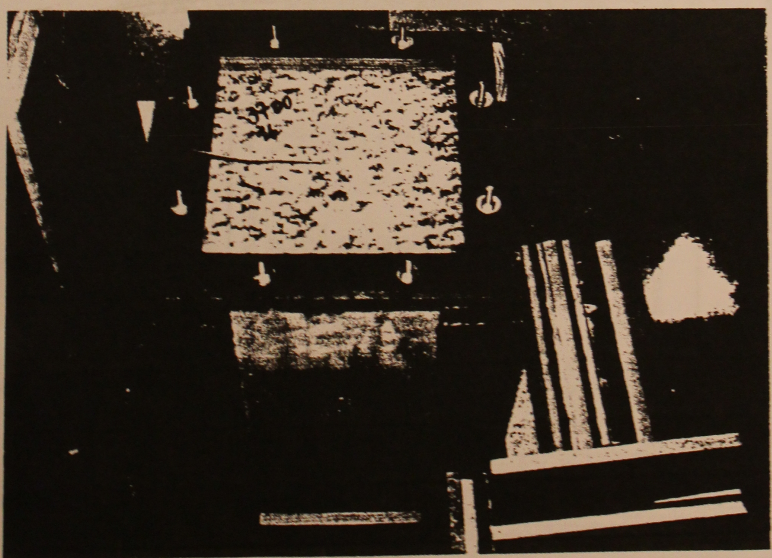
PHOTO 4: Testbox and test panels.


PHOTO 5: OM speaker box.

TABLE 1

CHARACTERISTICS OF SELECTED PANEL MATERIALS

RANK	MATERIAL	THICKNESS	PF
1	OM	16	9.52
2	glass	15	6.93
3	OM	7.8	6.19
4	polyurethane	16	6.03
5	MDF	19	5.47
6	MDF	22	4.83
7	particleboard	22	4.67
8	particleboard	19	4.49
9	acrylic sheet	16	4.21
10	MDF	16	4.21
11	marble	16	3.66
12	hard PVC	15	3.36
13	slate	16	3.03
14	particleboard	16	3.00
15	ceramic	15	2.41
16	concrete	16	2.35
17	polyethylene	16	1.36
18	steel	15	0.17

Note: The extremely poor performance of steel is due to a very high Q at resonance.

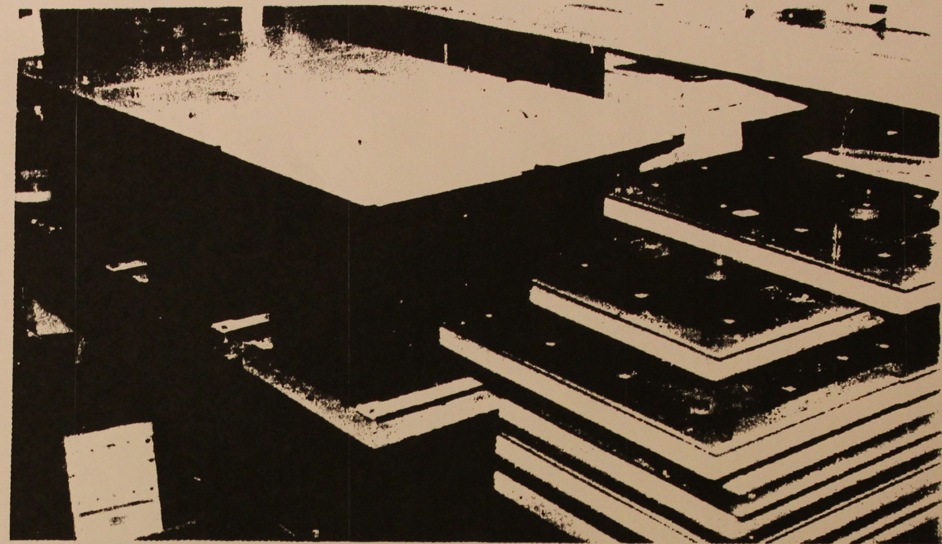

PHOTO 6: Enclosures being manufactured.

TEST RESULTS

The newly designed OM panels turned out to be the winners in all categories: wideband transmission loss, decay time, distortion, and resonance Q. As you can see in *Fig. 3*, there was a gap in mass per unit area between wood and plastics on the one hand, and concrete, stone, and ceramic on the other. OM material closes this gap in high-quality acoustic terms.

For a better understanding and overview of the test results (*Table 1*), I introduced a so-called P-factor (PF), which squeezes the important readings into one number: $PF = T_L/EDF$, where T_L = transmission loss, normalized in dB/(gram/cm^2); EDF = energy decay factor ($Q_{hi} \times T_D \times V_{pp}$); Q_{hi} = Q at highest resonance; T_D = decay time in seconds; and V_{pp} = volts peak-to-peak at Q_{hi} frequency.

Speaker boxes made by the OM technique sound neutral and natural (*Photo 5*; *Photo 6* shows these boxes being assembled). The bass is dry and tough due to rigidity and the absolute air-tightness of the cabinet material. In the fundamental tone range, sound reproduction is of very high fidelity, thanks to the best possible stiffness-ductility ratio. The presence and brilliance ranges are crystal clear and very lively, due to widely spread resonance energy in the cabinet's walls. Finally, treble tones are free and airy, because there are no "eigen-sounds" from the speaker cabinets.

As an interesting side effect of the testing, particleboard peaked at 22mm of thickness, whereas MDF peaked at 19mm. This means that there is no reason to use cabinet walls made from 38mm particleboard; 22mm is, acoustically, the better choice. This is due to the pressure applied during the production process of the particleboard—at least in Germany. It may be different in the US.

I hope that my work helps lead you to new ideas and better speaker cabinets.

Note: After a lengthy period of experimentation, I obtained both German and US patents for the OM technology and OMAC-PRO (Opposite Moduli Acoustic Compound for Professionals). The use of my OM technique for your private purposes is free of restrictions; for commercial use, however, please contact me.