Sounds Good

Vibration Analysis is a Valuable Tool for Loudspeaker Development

The Balanced Mode Radiator is a new approach to loudspeaker design with unique visual and acoustic features. Tight control of the membrane properties is essential to providing proper acoustic fidelity from the device. Polytec's Scanning Vibrometer enabled in-situ measurements on operating devices with no contact or loading of the panel membrane, successfully accelerating the development and manufacturability of the new loudspeaker.

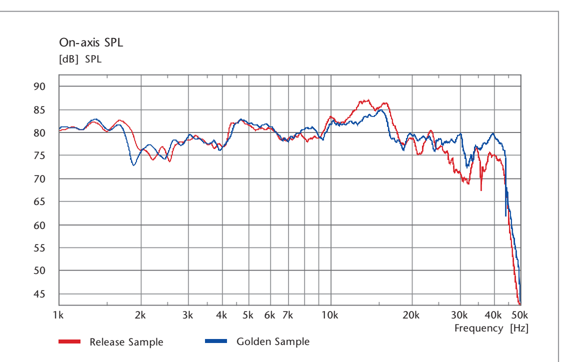

Fig. 1: On-axis Sound Pressure Level (SPL) spectra from tested BMR's.

Introduction

The "Balanced Mode Radiator" (BMR) represents a new class of loudspeaker with distinct design features and acoustical properties that distinguish it from the traditional, well-known electrodynamic loudspeaker design based on conical membranes. The most obvious difference between traditional conical speakers and the BMR is the use of a suspended flat circular disc as the radiating membrane panel (see title image). The drive unit features a clean appearance and a plane front that allows for innovative industrial designs with unique sound properties. Acoustically, the BMR is designed as full-range driver which supports almost the entire audible spectrum. For frequencies above the panel's first eigenmode, the BMR operates as a bending-wave device where its acoustic behavior is predominantly determined by the panel's mass density, bending stiffness, damping, and shear. These parameters are of paramount importance for the acoustic performance of the BMR.

From Prototype to Mass Production

The design of the BMR was done in Germany. But, due to cost constraints in the consumer market, most drive units had to be manufactured in China.

During the product development phase, all required parts were tooled and made in China then assembled and tested in Germany. Each part's geometry and material was changed until satisfactory performance was achieved. A construction manual was written and sent to China together with the final drive unit. This Gold Standard called "Golden Sample" serves as a reference when setting up the production line.

An initial set of prototype drive units known as "Release Samples" were sent back to Germany for approval. In the case study presented here, unexpected changes in the panel's material composition degraded the acoustic performance. A Release Sample was found to produce a less bright sound than the Gold Standard, although both units were built according to the same nominal specifications. Thus, the task was to identify the source of this difference.

On-axis Frequency Response

To begin the drive unit assessment, the acoustic on-axis frequency response was measured (Fig. 1). Above 18 kHz the Release Sample is slightly louder than the Gold Standard, indicating a somewhat brighter sound. This measured result was the opposite of what was subjectively noted when auditioning both units.

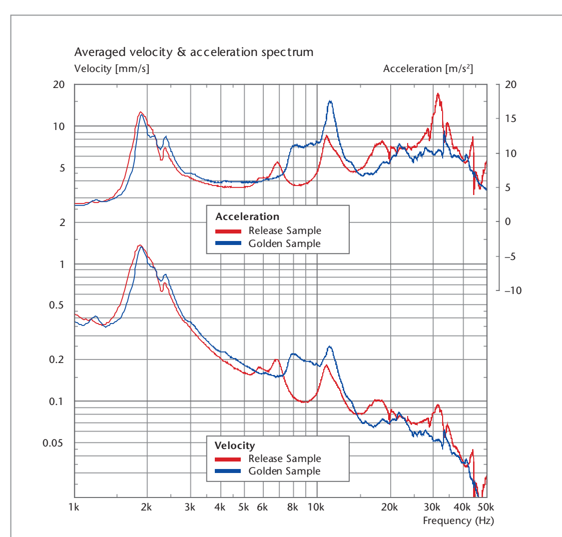

Fig. 2: Average velocity and acceleration spectra from tested BMR panels.

Consequently, the next step was to try to resolve this apparent contradiction by spatially measuring the dynamic response of the BMR panels of both units using the Scanning Vibrometer.

Vibration Analysis of Drive Units

Vibration analysis was performed using a Polytec PSV-300 Scanning Vibrometer. For sample excitation, the vibrometer generated a swept sine wave signal ranging from 150 Hz to 50 kHz, and acquired the velocity frequency response data from 1781 measurement points that were evenly distributed in a circular symmetric mesh across the panel.

The average spectrum calculated using the Scanning Vibrometer software allowed quick access to mean velocity and mean acceleration data. In Fig. 2, the acceleration spectra of both units are plotted in the upper half of the diagram with the associated ordinate axis positioned to the right, while the velocity spectra are located in the lower half with the associated ordinate axis to the left. The most obvious deviations occur in the 7–12 kHz range as opposed to the 12–18 kHz range identified by the on-axis Sound Pressure Level (SPL) measurements. Differences in this frequency range (7–12 kHz) are more likely to be judged as “bright” or “dull”. The brighter sounding Gold Standard shows higher activity in both average spectra than the Release Sample, supporting the results of the informal subjective evaluation.

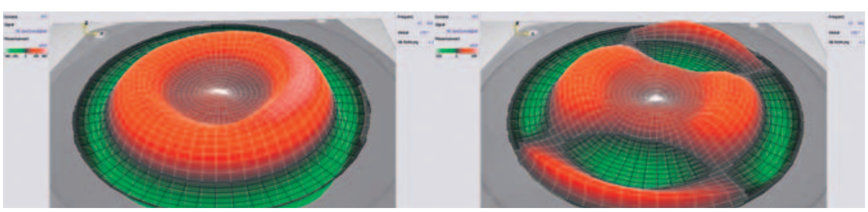

Fig. 3: Out-of-plane deflection shapes for BMR panels at 10 kHz, Release Sample (left), Gold Standard (right).

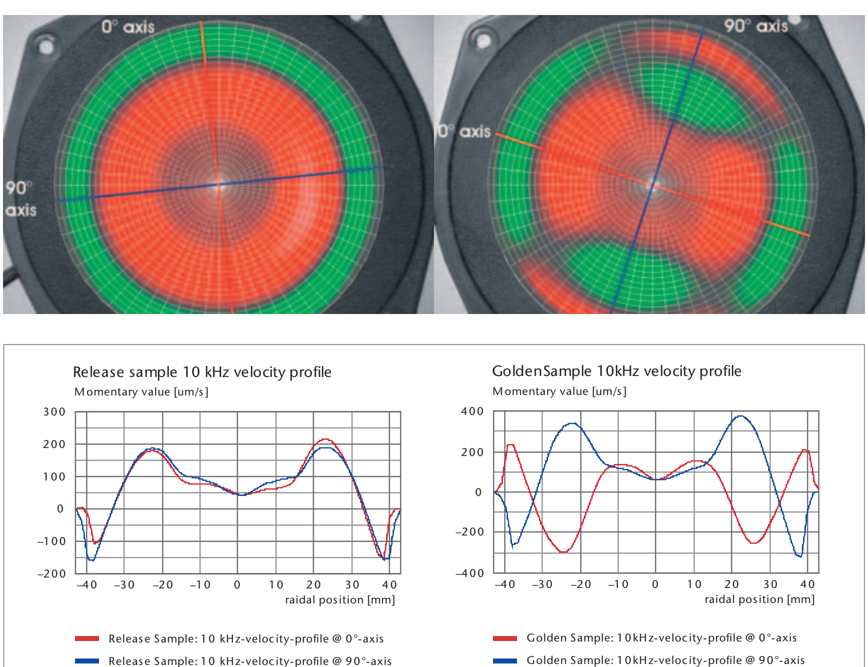

Fig. 4: Plots of orthogonal cuts through Fig. 3 deflection shapes, Release Sample (left), Gold Standard (right).

Modal Analysis

The results shown in Fig. 2 suggest that the two drive units have different panel materials. In Fig. 3, the operational deflection shapes (ODS) at 10 kHz are compared. It is obvious that the Release Sample shows a bending mode with circular symmetry on its panel (left) while the Gold Standard features rotationally symmetric structures that break circular symmetry (right).

The results confirm the previous findings. The Gold Standard BMR panel shows a much less isotropic bending stiffness than the Release Sample panel. Obviously, the panel manufacturer had actually tried to improve the panel quality by making it more isotropic.

Conclusions

Structural response data taken with Polytec’s Scanning Vibrometer allowed in-situ identification and characterization of dynamic material properties in loudspeakers and clarified inconsistent preliminary SPL measurements and auditory tests. The net result of the vibration analysis was an improved understanding of the BMR and reduced development time by eliminating trial-and-error approaches.

Authors – Contact

Dipl.-Ing. Charalampos Ferekidis,
Karl-Heinz Fink

Fink Audio Consulting, Essen, Germany;
AudioPlus, Sutton SM1 2SG, UK

lampos@ferekidis.de;
karl-heinz@fink-audio.com