Micro Suspension Part Measurements

Figure 1: Micro Suspension Part Measurement Bench (MSPM)

Application

Component level testing is essential in the transducer industry. Checking stiffness and damping parameters of the spider, surround and other suspension parts is common practice in the design and manufacture of large woofers. A simple and fast test procedure would be beneficial for testing the diaphragm used in micro-speakers, headphones, tweeters and microphones. Meaningful information comparable to Stiffness K_{ms}, Mechanical Resistance R_{ms} of the T/S parameters is the basis for tuning the production process and for the communication between transducer manufacturers and soft parts suppliers.

To consider damping and visco-elasticity in the material (creep) a dynamic measurement is required which uses an AC stimulus comprising signal components in the audio band.

Figure 2: Micro-Speaker

The 'Micro Suspension Part Measurement' technique (MSPM) uses a dynamic identification technique and provides the parameters of a small diaphragm/suspension without utilizing an assembled transducer. This article will discuss the aforementioned measurement method and will compare it to the traditional methods using a micro-speaker (Figure 2) as the target transducer.

Relevant Suspension Part Parameters

Reducing the descriptors of suspension behavior to fewer, more informative, parameters is elemental for a more robust specification of these parts. In this method, the parameters are divided into linear and nonlinear parameters. The linear parameters describe the mechanical resonator at small amplitudes as a damped spring-mass-system. The mass m and stiffness K define the resonance frequency f_{res}. The Q-factor depends on the mechanical resistance R. The linear characteristics of the micro-speaker, divided into the measured parameters, can be seen in Table 1. In this case, the suspension was measured in an assembled transducer; therefore the results include the mass of the voice coil and possible losses caused by the air in the gap.

Symbol	Value	Unit	Description
f_{res}	777.3	Hz	Resonance Frequency
Q	4.343	-	Quality Factor
m	0.029	g	Moving Mass
K	0.701	N/mm	Stiffness
R	0.033	kg/s	Mechanical Resistance

Table 1: linear Suspension Parameters

This technique can be also applied to the separated diaphragm as seen in Figure 3.

Figure 3: Micro speaker diaphragm with voice coil

Due to the geometry and the specific material of the suspension, the stiffness K is usually not constant but rather depends on the instantaneous displacement x, time t (frequency f) and the ambient conditions (temperature, humidity). The dependency of K(x) on displacement x causes one of the dominant nonlinearities inherent in loudspeakers, generating substantial distortion for any excitation signal below resonance. A typical curve K(x) is shown in Figure 4.

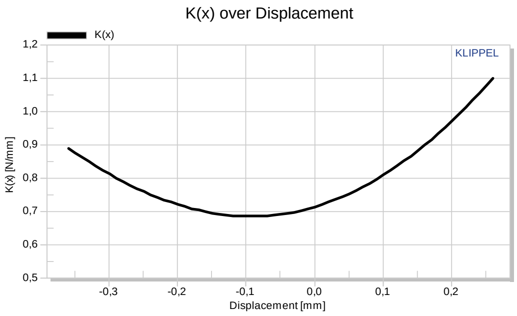

Figure 4: Nonlinear Stiffness K(x) of the micro-speaker diaphragm

Dynamic Measurement technique

Traditional methods calculate suspension by measuring the resulting restoring force caused by a displacement x, using a mechanical device. This method could be found lacking mainly due to the fact that:

- When testing soft parts (e.g. diaphragms), the measurement devices will typically inject force at a point in the middle of the membrane. This will, especially for thin diaphragms (such as the ones used in micro-speakers and headphones) deform the diaphragm, altering the measurement results.
- The visco-elastic creep will create a frequency dependent stiffness. In a static measurement the suspension will be measured at a very low frequency. Therefore a different stiffness is measured, much lower than the final value seen in the end application.

A dynamic measurement is therefore required for an accurate parameter measurement, structured as follows: The suspension part is glued or clamped into a panel and clamped onto a sealed pressure chamber. The diaphragm is deflected by the sound pressure generated by a sensitive midrange transducer as used in horn loaded PA equipment.

The identification of the parameters requires the measurement of some state variables such as force, displacement or pressure in the system. A direct measurement of the total driving force F is not possible. However, the displacement and the sound pressure in the box can easily be measured using a laser triangulation sensor and microphone, mounted inside the box. (Figure 5)

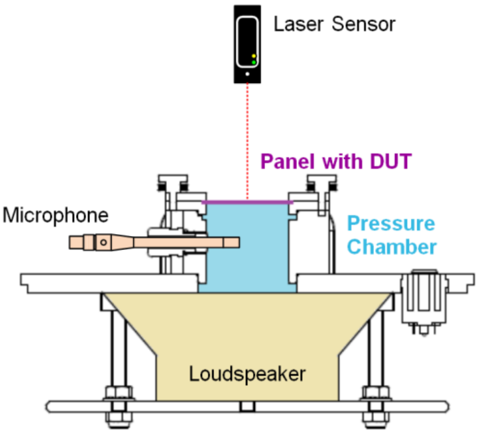

Figure 5: sectional drawing of micro suspension part measurement (MSPM)

The linear parameters are determined using the added mass perturbation method. Applying a sweep signal, the suspension is passively excited, allowing the measurement of the resonant frequency f_{res} and Q-factor. A known mass is then added and the parameters are identified by measuring the resonance shift. (Figure 6)

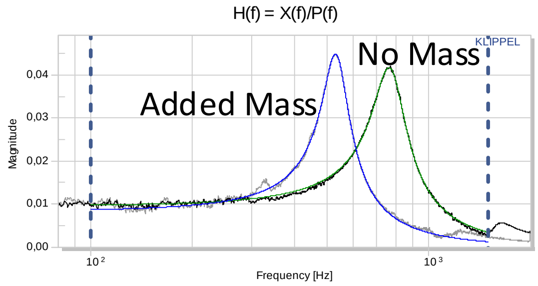

Figure 6: Resonance shift using mass perturbation

Detailed information about the properties of the suspension highlights the stiffness' dependence on displacement K(x). The stiffness curve is calculated using the nonlinear distortion found in the displacement signal, determined by the laser.

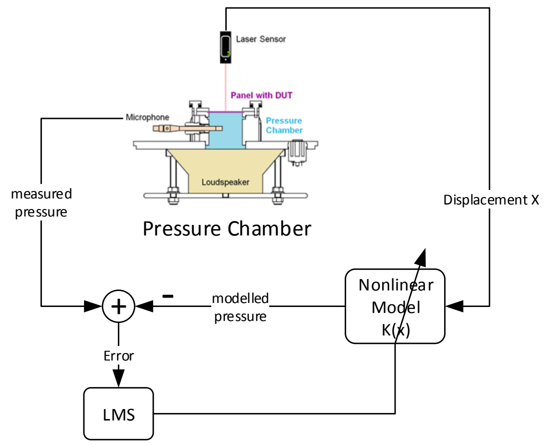

Figure 7: Signal flow chart of nonlinear parameter identification

By identifying the nonlinear model of the displacement varying stiffness, the driving force is modelled, which is proportional to sound pressure inside the pressure chamber. The difference between measured and predicted sound pressure is used as an error signal for nonlinear system identification. Least-Mean-Square algorithm (LMS) minimizes the error and calculates the nonlinear curve shape by exploiting the nonlinear distortion found in the measured displacement as shown in Figure 8.

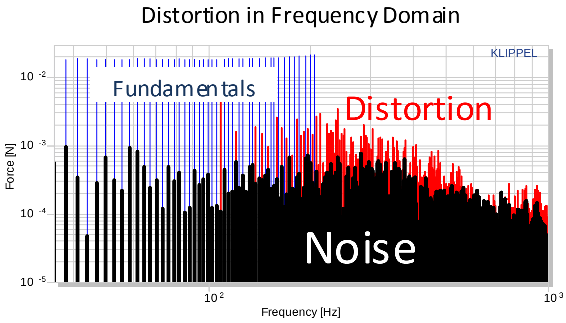

Figure 8: Spectral components of the measured displacement signal

Comparison with Speaker Application

The main goal of this measurement technique is to identify the suspension part parameters in the final driver application.

The results of the Micro Suspension Part Measurement technique (MSPM) show a very good accordance with the parameters measured in the final application (Figure 9).

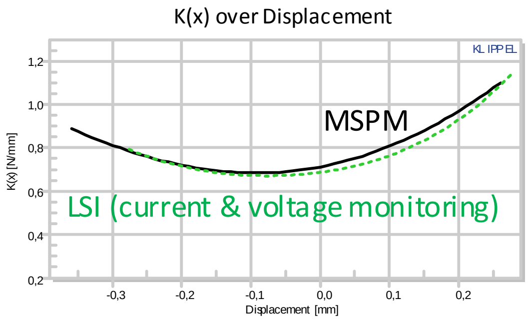

Figure 9: Comparison between LSI and MSPM Measurement

The results generated by Micro Suspension Part Measurement (MSPM) are comparable with the results generated by the Large Signal Identification (LSI) according to Standard IEC 62458 based current monitoring at the loudspeaker terminals.

Figure 9 shows minor differences in the results are caused by different excitation condition, temperature, humidity and visco-elasticity. The electrical excitation of the suspension part generates a force at the voice coil position, whereas the pneumatically excitation of the MSPM generates forces distributed over the membrane area as shown in Figure 10

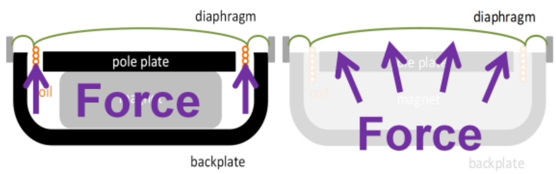

Figure 10: Force injection transducer application (left) versus suspension part measurement (right)

The influence of the measurement technique is negligible for transducers with rather stiff center parts and softer suspension regions on the diaphragm.

Summary

Suspension Part Measurements, for Micro-Speaker, Headphones, Tweeters and Microphones provide the following benefits:

- Enable the individual measurement of stiffness and damping for material and diaphragm producers.
- Enable faster development cycles by measurement of suspension parameters without the need of assembling the speaker.
- Overcome the problems of traditional static measurements (visco-elastic creep).
- Complies with industry standard Large Signal Identification method according to IEC 62458 used for complete speakers
- Measurement of suspension parameters under real clamping conditions.
- Help identify asymmetrical suspension, the major source of substantial DC generation.

For more information on the new Klippel Micro Suspension Part measurement (MSPM) and the products provided by KLIPPEL, visit www.klippel.de