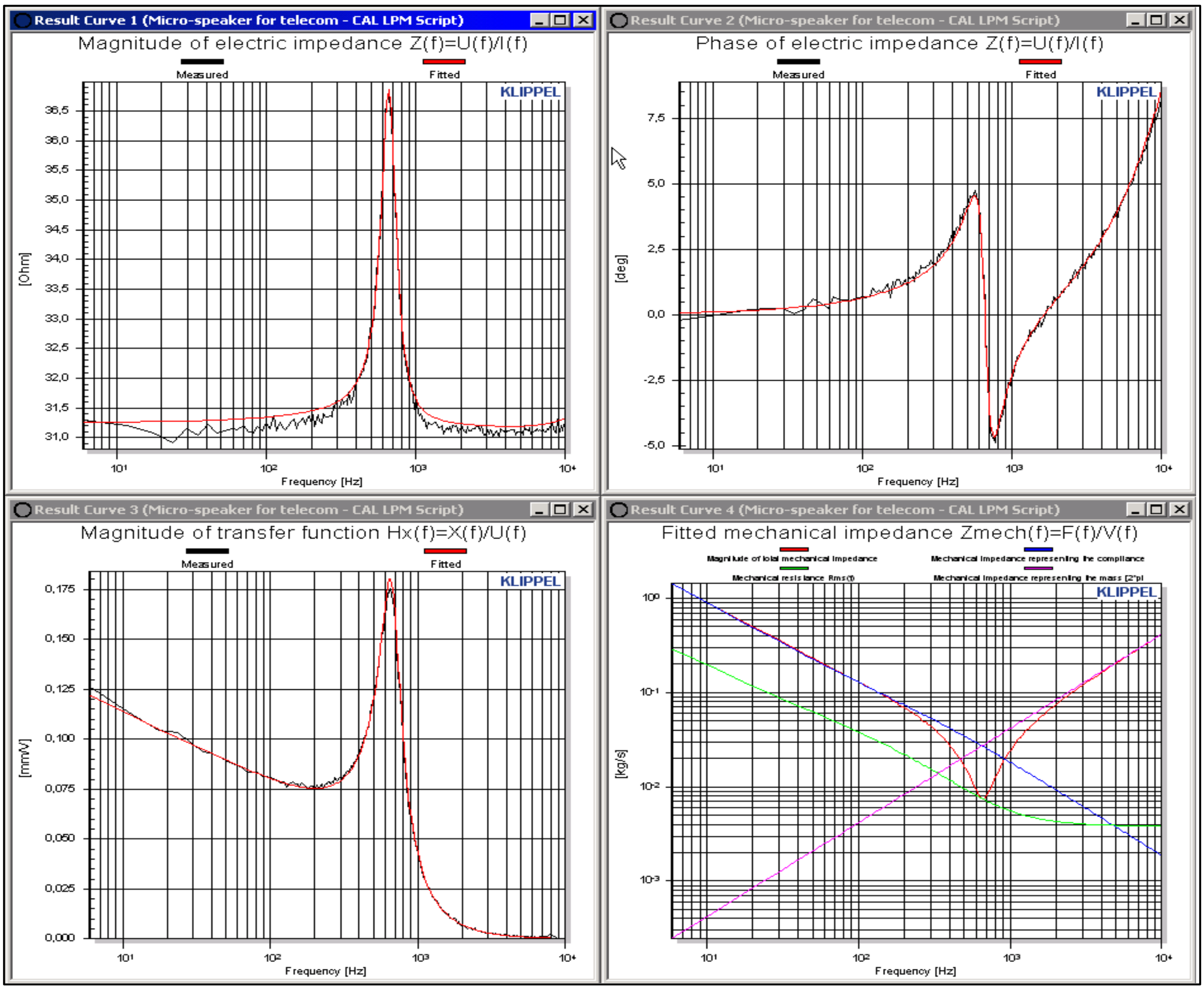
Extended Creep Modeling

AN 49

Application Note for the Klippel R&D SYSTEM

This application note gives an outline how to deploy the CAL LPM Extended Creep Modeling Script to estimate linear transducer parameters with a more sophisticated model for the creep of the suspension. The script offers an improved fitting algorithm and two additional models for the creep of the suspension. This application note shows how to perform a parameter-identification and explains the new models as well as the associated result windows.



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Background

Introduction

The traditional Thiele Small Loudspeaker Model considers the compliance of the suspension (Cms) and the mechanical losses (Rms) constant parameters. Taking the creep effect of the suspension into account, these parameters become frequency dependent.

The current Klippel LPM module (version 206) offers a creep model with a frequency dependent compliance increasing towards lower frequencies, but still constant losses:

$$C_{ms} = C_{ms}(f_s)\left[1 - \lambda \log_{10}\left(\frac{f}{f_s}\right)\right] \qquad (1)$$

This simple model delivers good results for speakers with low creep effect, but yields fitting results of limited accuracy for speakers with a high creep effect. The main improvement of this script is the introduction of two extended creep models, for modeling high creep effect.

Complex Compliance

Both new models consider the compliance *C*(f) to be complex. Thus interpreting the compliance as a spring is not appropriate anymore.

Splitting the complex impedance of the compliance Z_C into its real and imaginary part makes it possible to consider it to be a series connection of a spring and a dashpot:

$$Z_C = \frac{1}{j2\pi f C(f)} = \frac{1}{j2\pi f C_{ms}(f)} + R_{Cms}(f) \qquad (2)$$

with

$$C_{ms}(f) = \frac{\mathrm{Abs}^2\{C(f)\}}{\mathrm{Re}\{C(f)\}} \qquad (3)$$

and

$$R_{Cms}(f) = \frac{-\mathrm{Im}\{C(f)\}}{2\pi f * \mathrm{Abs}^2\{C(f)\}} \qquad (4)$$

The dashpot modeling the frequency dependent losses of the suspension $R_{Cms}(f)$ can be added to the constant losses R_{ms0}, which results into the total mechanical losses $R_{ms}(f)$. Thus the equivalent circuit of the transducer will remain the same, just considering the losses and the compliance to be frequency dependent.

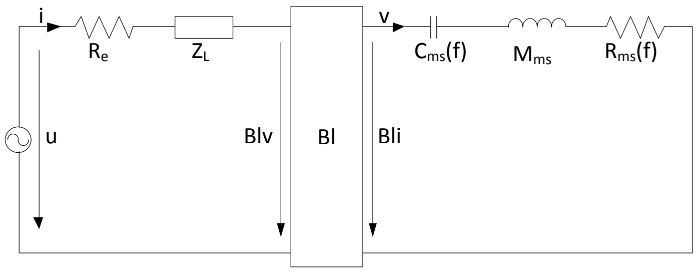


Figure 1 Equivalent electrical circuit used as linear transducer model

Knudsen Creep Model

Knudsen proposed a model for the suspension creep [2] using a logarithm weighted with the creep factor λ:

$$C(f) = C_0\left(1 - \lambda \log_{10}\left(\frac{jf}{f_s}\right)\right)$$

This model is purely mathematical, based on the experience that the creep increases nearly linear towards lower frequencies, when viewed on a semi-logarithmic scale.

The parameter C_0 contains the value of the real part at the resonance frequency f_s but is not equal to the value of the compliance $C_{ms}(f_s)$ when using the notation of formula (2).

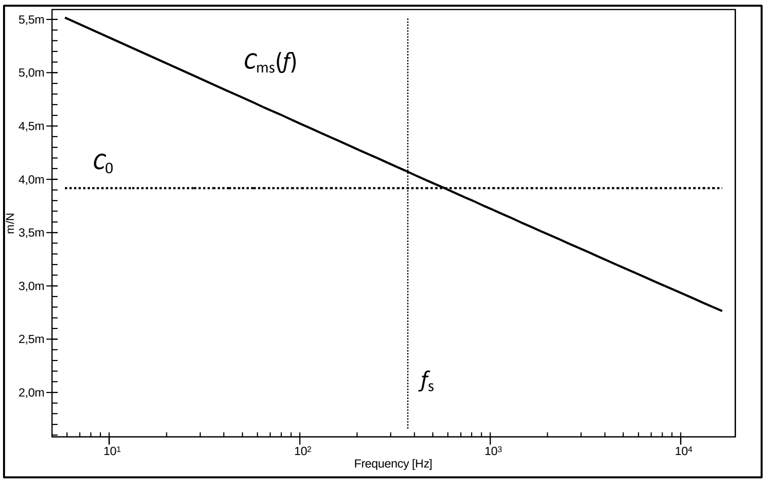


Figure 2 Compliance of suspension Knudsen Model

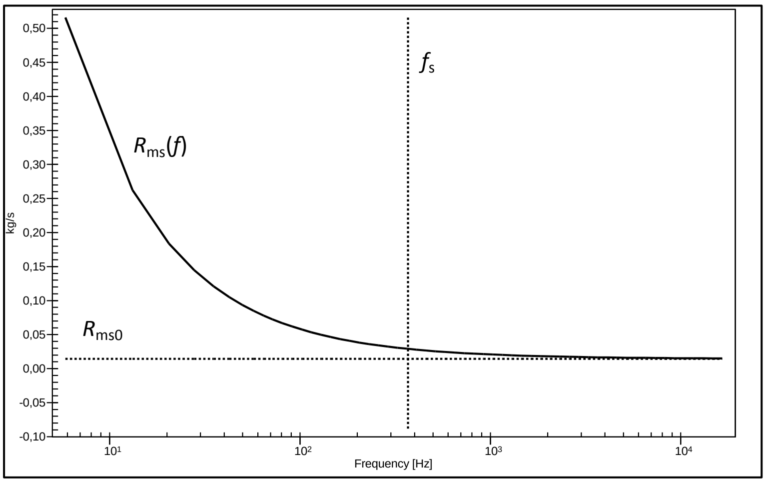


Figure 3 Mechanical losses Knudsen Model

The model integrated in the LPM Module bases upon this model, but neglects the complex argument of the logarithm and thus the frequency dependence of the mechanical losses.

Ritter Creep Model

A three parameter model based on retardation spectra was introduced by Ritter [3].

$$C(f) = C_0\left(1-\kappa\log_{10}\left(\frac{j\frac{f}{f_{\min}}e^{-j\tan^{-1}\left(\frac{f}{f_{\min}}\right)}}{\sqrt[2]{1+\left(\frac{f}{f_{\min}}\right)^2}}\right)\right)$$

Instead of becoming negative towards high frequencies the creep reaches a minimum compliance, which is described by C_0.

The frequency $f_{\min}$ corresponds to the minimum retardation time of the retardation spectra and can be interpreted as the frequency where the creep of the suspension starts to rise.

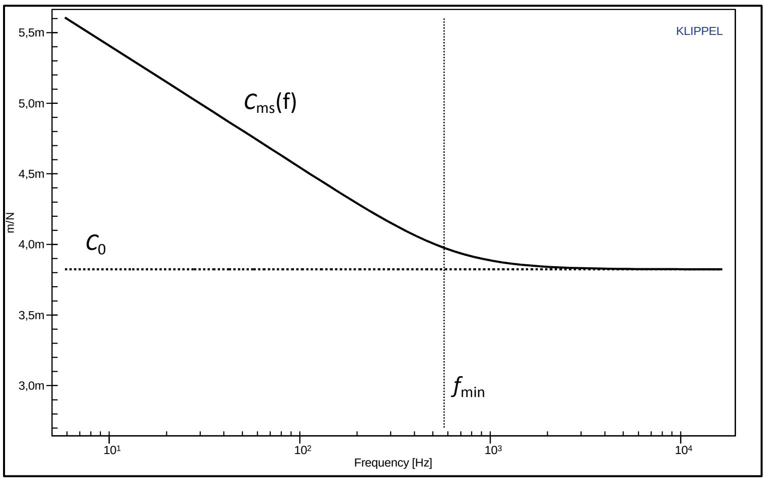


Figure 4 Compliance of suspension Ritter Model

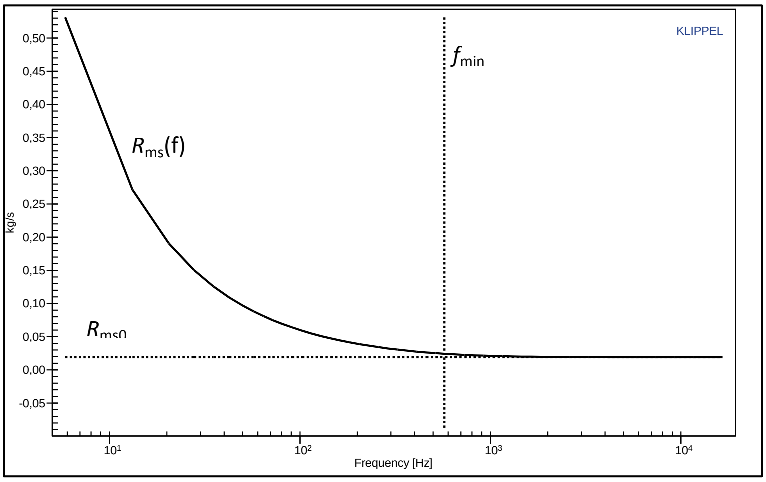


Figure 5 Mechanical losses Ritter Model

This model is rather complex, but delivers best fitting results, with just one additional parameter.

Application

Requirements

Running the script requires dB-Lab 206.15 (or 206.14 Script update), and the LPM Module.

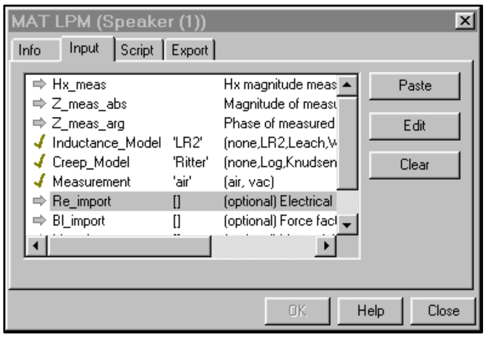
The script will only perform the post-processing to estimate the linear parameters from a previously done LPM measurement including the electrical impedance ($Z(f) = U(f)/I(f)$) and the transfer function ($H_x(f) = X(f)/U(f)$) of the transducer. Hence, this curves must be imported e.g. from a measurement with the LPM Module.

Setup

To use the Extended Creep Modeling, create a new object and select the *LPM Extended Creep Modeling AN49* template.

Conduct the *LPM T/S parameter* as usual to gain the source data for. Please see [8] for further information.

Before running the *CAL LPM Extended Creep Modeling* script, open the properties page and set the input parameters. See the next section for further information.



Input Parameters

The script requires three curves to perform the parameter identification:

- Hx_meas [mm/V] (absolute value of the measured transfer function Hx(f) =X(f)/U(f))
- Z_meas_abs [Ω] (absolute value of the measured electrical impedance Z(f)=U(f)/I(f))
- Z_meas_arg [deg] (phase of the measured electrical impedance Z(f)=U(f)/I(f))

It is recommended to import curves measured in vacuum, hence a joined air volume would distort the estimation of the parameters of the creep model.

The curves should cover the same frequencies. While the phase and the absolute value must be from equal length and frequency range, the length of Hx may differ, but will result in both curves (complex electrical impedance and absolute value of the transfer function) shortened in length covering only the common frequencies.

The following parameters are optional and allow the import of known values:

- Re_import [Ω] (electrical voice coil resistance at DC, importing this value will influence the fitting of all parameters)
- Bl_import [N/A] (force factor, used to calibrate the absolute value of the measured transfer function)
- Mass_import [g] (mass of the suspension, used to calibrate the absolute value of the measured transfer function)

Importing the force factor as well as importing the mass of the suspension will calibrate the absolute value of the transfer function. It's forbidden to import both parameters at the same time to avoid over-determination. An import of both will result in an error message and that the imported Bl value will be ignored. Importing one of this calibration factors will lead into shifting the measured Hx curve in the result window.

The last two input parameters are strings and used to select the creep and the inductance model. The input is not case sensitive. Keeping these parameters empty or typing in an unknown string, results in interpreting the parameter as set to “none”.

Inductance_Model:

- “none” (considers the inductance to be a constant parameter Le)
- “LR2” (shunted inductor model)
- “Leach” (two parameter model by Leach)
- 'Wright” (four parameter model by Wright)
- “Thorborg” (five parameter model by Thorborg see [4])

Creep_Model:

- “none” (compliance is real and constant)
- “Log” (simple, real logarithmic creep model)
- “Knudsen” (complex logarithmic creep model by Knudsen)
- “Ritter” (complex creep model by Ritter

Measurement: (See application note 50 for further information about this issue)

- air -> Measurement was taken in free air
- vac -> Measurement was taken in vacuum

Result Windows

Result Curve 1 shows the magnitude of the electric impedance and Result Curve 2 its phase. There are no differences compared to the traditional illustration in the LPM module.

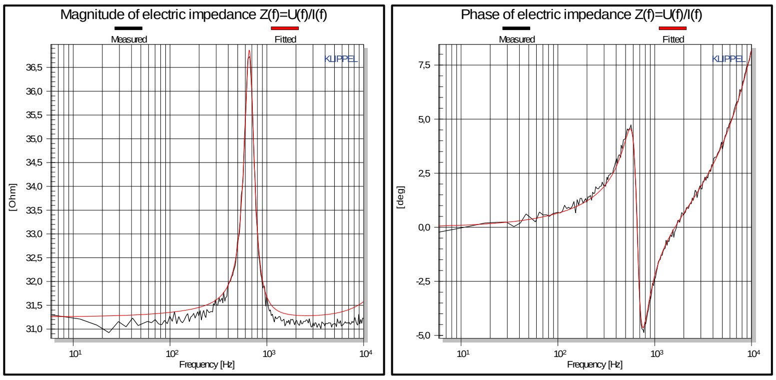


Figure 6 Result Curves 1 and 2

Result Curve 3 displays the magnitude of the transfer function Hx(f). Importing a calibration factor (Mms or Bl) will shift the measured curve and mark it as imported.

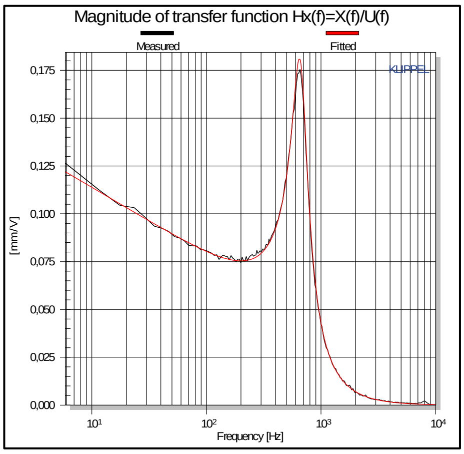


Figure 7 Result Curve 3

Result Curve 4 contains the impedance curves of the mechanical components (Rms, Cms and Mms) and the magnitude of the resulting total mechanical impedance.

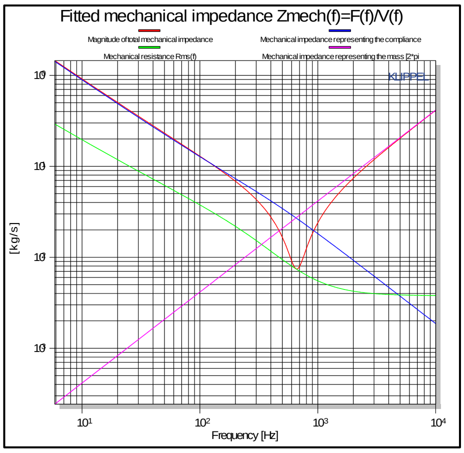
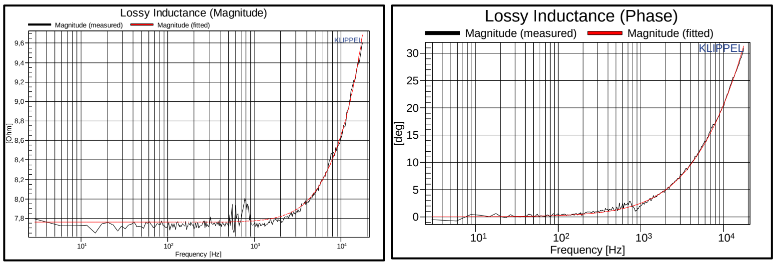


Figure 8 Result Curve 4

The window Result Variables shows status messages and the fitted parameters.

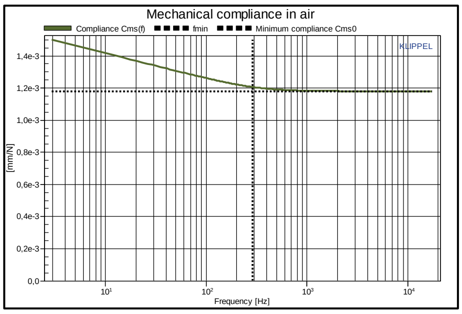
Result Windows (continued)

Result Curves 5 and 6 display the lossy inductance of the driver (magnitude and phase) depending on the selected inductance model.



Result Curve 4 and 5 Lossy Inductance

Result Curve 7 shows the frequency dependence of the mechanical compliance.



Result Curve 7 Frequency dependence of mechanical compliance

More Information

Papers

[1]. W. Klippel and U. Seidel, “Fast and Accurate Measurement of Linear Transducer Parameters,” presented at the 110th Convention of the Audio Engineering Society, Amsterdam, May 12-15, 2001, preprint 5308

[2]. M.H. Knudsen and J.G. Jensen, “Low-Frequency Loudspeaker Models that Include Suspension Creep,” J. Audio Eng. Soc., vol. 41, pp. 3-18, (Jan./Feb. 1993)

[3]. F. Agerkvist and T. Ritter, “Modelling Viscoelasticity of Loudspeaker Suspensions using Retardation Spectra,” presented at the 129th Convention of the Audio Engineering Society, San Francisco, November 4-7, 2010, preprint 8217

[4]. K. Thorborg, A. Unruh and C. Struck, “An Improved Electrical Equivalent Circuit Model for Dynamic Moving Coil Transducers”, presented at the 122nd Convention of the Audio Engineering Society, Vienna – Austria, May 5-8, 2007

[5]. K. Thorborg, C. Tinggaard, F. Agerkvist and C. Futtrup, “Frequency Dependence of Damping and Compliance in Loudspeaker Suspensions”, J. Audio Eng. Soc. Vol. 58 no. 6, June 2010.

[6]. K. Thorborg and C. Futtrup, “Electro-Dynamic Transducer Model Incorporating Semi-Inductance and Means for Shorting AC-Magnetization”, J. Audio Engineering Society, vol.59 September 2011.

Software

User Manual and online help system of the Klippel R&D System

Application Notes	[7]. AN 50 Multipoint Parameter Fitting and Load Separation [8]. AN 25 Maximizing LPM Accuracy

updated June 7, 2013

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