



SURFACE VEHICLE RECOMMENDED PRACTICE

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Friction Material Elastic Constants Determination
through FRF Measurements and Optimization

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FOREWORD

The FRF measurement based procedure described in this standard is intended to provide a set of homogeneous (equivalent averaged values) and anisotropic (transversely isotropic) elastic constants for brake NVH simulations (not for quality control). The objective is to ensure pad assembly vibration correlation between simulation and measurement.

It is an alternative to, and does not require, ultrasonic measurement results. However, elastic constants from ultrasonic method, if available, can be used as initial inputs. It can also be used to improve calculated average elastic constants from ultrasonic methods.

1. SCOPE

This SAE Standard specifies necessary procedures and control parameters in estimating anisotropic elastic constants of friction material based on pad assembly FRF measurements and optimization. It is intended to provide a set of elastic constants as inputs to brake NVH simulation, with the objective of ensuring pad assembly vibration correlation between simulation and measurements.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

Lou, G, Lee, L, and Malott, B., "*Introduction of Anisotropic Lining Elastic Constants Optimization (ALCO) Method for Friction Materials*", SAE Congress, Detroit, MI, 2007; SAE 2007-01-0591

Lee, L., Lou, G., and Malott, B., "*Development and Applications of ALCO Method for Acquiring Elastic Constants of Friction Materials*," SAE Technical Paper 2007-01-3958, 2007, doi:10.4271/2007-01-3958.

Liu, W., "*Improving Finite Element Models of Brake Pads Through Material Optimization*," SAE Technical Paper 2007-01-3946, 2007, doi:10.4271/2007-01-3946.

SAE J2598 Automotive Disk Brake Pad Natural Frequency and Damping Test

SAE J2725 Road Vehicles – Friction Materials – Elastic Properties Measurements

3. GENERAL DESCRIPTIONS

3.1 Main Steps and Flow

There are 3 main steps: (1) Pad FRF measurements; (2) Optimization; (3) Verification (see Figure 1 below).

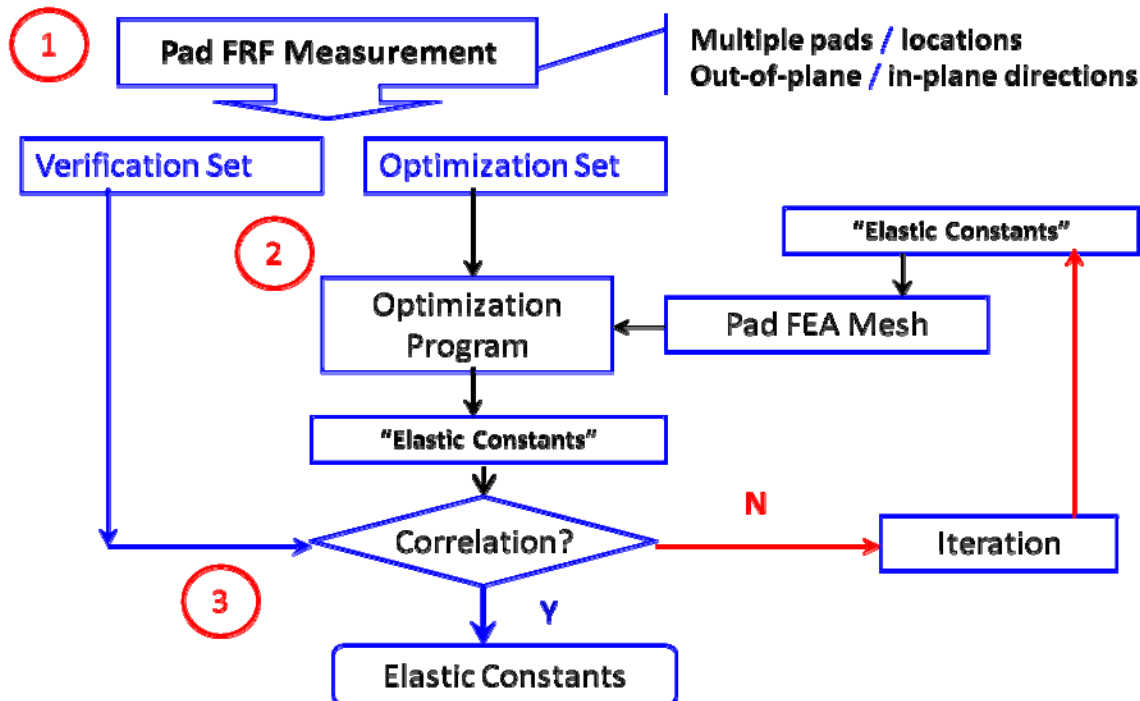


FIGURE 1 - FLOW DIAGRAM OF FRF MEASUREMENT BASED PROCEDURE FOR ELASTIC CONSTANTS

Following sections describe these procedures and criteria more in detail.

4. PAD FRF MEASUREMENTS

4.1 Pad Assembly

Full pad assemblies, without insulator, are used for FRF measurements. It is desirable to use the same pad assembly geometry as those intended for noise testing. If pads without slot and chamfer are readily available, they can be used, as slots and chamfers may add additional part-to-part variations (the variations are small as found in practice. Therefore, it is not advised to make pads just for this purpose).

- Changes in chamfers and/or slots typically do not require reacquiring the elastic constants. However, if and when parts are available, confirmation of FRF correlation between measurements and simulation is always recommended, regardless of how the elastic constants are obtained (whether from FRF measurements or ultrasonic measurements)
- If parts for the intended program are not available yet, elastic constants obtained from a different pressure plate and pad geometry can be used. Even though there are successful application cases (see referenced publications), the overall FRF correlation (of all modes) between measurement and simulation is no longer ensured. When parts become available, FRF correlation should be verified, and if necessary, elastic constants re-measured using the pads for the intended program.

4.2 FRF measurements

Multiple pads (minimum 3) should be measured. Typical pad-to-pad frequency variations are expected $\leq 3\%$, otherwise further investigation is recommended (before using this standard), for example, poor bonding between pressure plate and friction material / underlayer may cause larger frequency variations.

- Excitation: an impact hammer is typically used.
- Response: typically an accelerometer is used, though laser vibrometer can also be used. Full modal analysis is not required, as long as major modes of interest can be identified (bending, torsional and in-plane).
- Refer to SAE J2598 for more information on pad FRF measurements.
- Multiple measurement points (locations), in both out-of-plane and in-plane directions should be considered. The more modes captured and main vibration identified correctly (bending, torsional, in-plane), the better.
- Frequency range ideally should go up to 16,000 Hz. If the quality (and modal information) of a particular mode (or modes) is in doubt, the mode (modes) can be excluded. The user needs to ensure, e.g., in the Verification step (Section 6), that there is no mismatch of modes between measurement and simulation.

4.3 FRF Measurement Results

Measured frequencies from these multiple pads are averaged. These frequencies are then divided into two sets (Optimization Set and Verification Set):

4.3.1 Optimization Set

These modes are used in the Optimization Step (Section 5):

- Since there are 5 independent elastic constants, **at least 6 modes (frequencies) are required**. The more modes used (if available), the better.
- At least one in-plane mode should be included in the Optimization Set.
- The selected modes do not need to be consecutive (in frequencies). The remaining modes (not included in Optimization Set) are used in Verification Set.

4.3.2 Verification Set

The remaining modes are used in the Verification Step (Section 6):

- All remaining modes (not included in Optimization Set) are included in Verification Set.
- At least one mode should be reserved for Verification Set. The more modes in the Verification Set, the higher confidence with the results from optimization process, especially when the elastic constants need to be used for other programs (different pressure plate and pad geometry).