Vibrating Surfaces *Made Audible*

Using Laser Scanning Vibrometry and Binaural Transfer Path Analysis

What kind of a noise is made when the surface of a component vibrates? What path does the noise take to your ear? What component vibration is most undesirable? These are the questions that employees at Polytec and HEAD acoustics are currently trying to solve within the framework of a joint project.

Acoustics are increasingly important in product design. The focus is on how and where are undesired noises generated and at which point or location can countermeasures be taken to eliminate or attenuate the offending noise. Knowing just the vibration characteristics of a component is not enough to describe the acoustical situation sufficiently - the degree of the sound projection, the transmission of the noise to your ear (the so-called transfer function for airborne sound) and the structure of the noise (important for the psycho-acoustic effect on a person) must be considered. Consequently, even though a component's physical vibration might be reduced, the noise that has impact on the listener may not be audibly reduced. Thus, the questions persist: Which vibrations are generating the offending noise? At what location should countermeasures be applied?

A joint project between Polytec and HEAD acoustics aims to answer these questions and make a connection between vibration analysis on the one hand and the noise generated on the other. Polytec has expertise in matters of laser vibrometry and vibration analysis. HEAD acoustics has expertise with regards to auralization of sound sources. The degree of sound radiaition efficiency, of the two companies working together will be a development tool which can be applied to aural acoustic problems in the future.

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About HEAD acoustics GmbH

HEAD acoustics GmbH is one of the world's leading companies in the area of acoustic and vibration measurement and analysis technology as well as speech perceivability. Covering all applications, from sound design to decrease of noise pollution, HEAD acoustics offers hardware and software solutions for aurally-equivalent sound recording and playback, measurement and analysis, jury testing and virtual engineering. Binaural transfer path analysis a featured service highly valued by prominent users all over the world.

Due to HEAD acoustic's intensive internal research and development activities and its close connection to national and industrial research facilities, the products of HEAD acoustics are continuously setting standards. Since being founded in 1986, the company issued more than 30 national and international patents and 400 scientific publications.

The new Test Procedure

Starting with a vibrating surface, the projected sound is transmitted through the air and finally reaches the human "victim's" ear in the form of noise. With the aid of transfer path analysis (Genuit, K., & Bray, W. R., Sound & Vibration July 2002), the path of the sound can be determined experimentally. As an extension of the process, HEAD acoustics determines the airborne sound paths binaurally (Sottek, R., Sellerbeck, P., Klemenz M., SAE Conference 2003).
Thus the shape of the head is included in the analysis, making the auralization of component sound sources possible. How do you practically determine the transfer functions for airborne sound binaurally? For this purpose you can resort to the reciprocity principle and measure the airborne sound transfer paths reciprocally with the aid of a binaural sound transmitter (see explanation in the info box on page 12).

Structure-borne Sound and Airborne Sound Measurements

This new process allows you to link laser vibrometer measurements with reciprocal airborne sound measurements. For visual representation of the component vibration, instead of the vibration amplitude measured directly with the laser vibrometer, the amplitude weighted with the reciprocally measured transfer function for airborne sound is given. This representation is a measure of the airborne sound relevance of the component's surface and shows whether, and to what extent, individual areas are responsible for the noise reaching your ear. The acoustics engineer is then directly shown the locations at which acoustic measures need to be introduced.

User Defined Data Sets

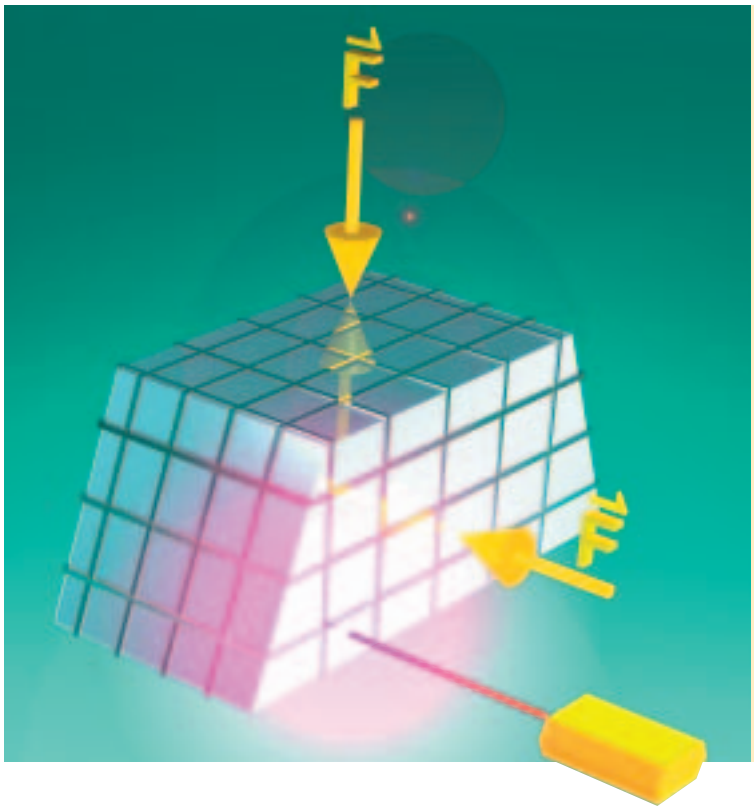
User Defined Data Sets are the technical basis for linking the structure-borne data with the transfer path functions. They are available as a new option in PSV Software release 8.1. The User Defined Data Sets allow the operator to apply any mathematical transformation to the measurement data via a standard interface and to visualize the results directly in the PSV software.

Extensions to this software option are being planned. Future releases should make it possible to view non-stationary events. This refers to the possibility of giving a visual representation of the acoustic behavior of a component also subject to any non-stationary operating conditions. This answers the question asked typically in the car industry with regards to engine noise:
At what engine speed and at which component surface is the source for the noise located?

This is to be attained by visualizing filtered time sequences using acoustic transfer functions.
An appropriate software option is currently in development and will be available shortly for Alpha testing.

First Test Applications

Within the framework of these investigations, the process was tested using a model structure which can be seen in the title picture. The model consists of a steel frame on which metal surfaces of different sizes have been mounted. Two shakers introduce the sound. The experimentally determined transfer paths describe the sound propagation from the position of force application to the ears of the test person located inside the model. As is shown in the title image, the test person is represented by an artificial head or by a binaural sound generator respectively.



The Reciprocity Principle

The transfer function between sound source and receiving location does not change if the sound source and receiving location are exchanged with each other.
This applies subject to the condition that

a) the emission characteristics of the transmitter are the same as the receiving characteristics of the receiver and

b) only linear systems and quantity pairs are taken into consideration, e.g. acoustic pressure and volume flow.

Therefore, if the receiver is a human head, then consequently the sound transmitter must also be in the shape of a human head. Apart from that, it is absolutely imperative to know the volume flow emitted by the sound transmitter. If these conditions are fulfilled, then reciprocity applies in all environments, independent of the spatial properties.

The transfer paths can be linked with arbitrary time data. For example, time data were taken at the points of force application located at the engine mount of a vehicle under operating conditions and linked with the sound transfer paths of the model. The noise which is generated in the interior of the model is made up of sound contributions from the individual part surfaces, which can also been listened to separately.

Since the procedure works binaurally, a stereo signal is generated which gives a spatial conception of the sound and permits a localization of the respective acoustic source, as if a real person was sitting in the model's interior.

For more information and a PDF copy of this article, please visit Polytec's web page at www.polytec.com or HEAD acoustics at www.head-acoustics.de.

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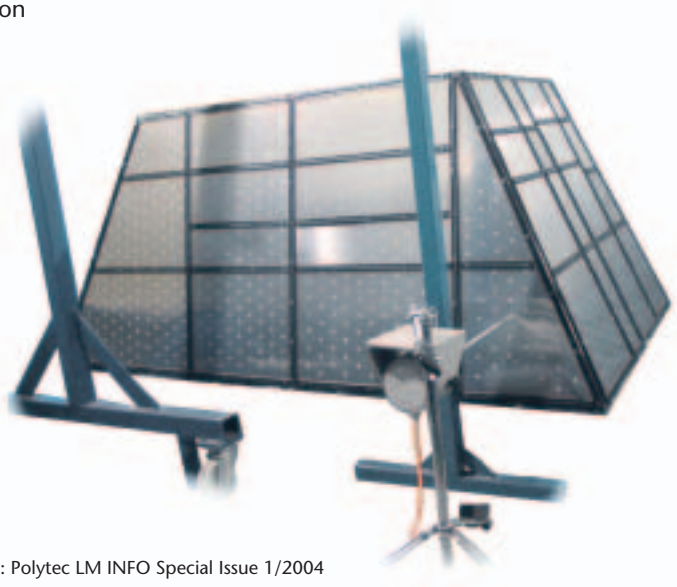

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