"PolymerAkustik" Project: Holistic Solutions for Low-Noise Plastic Components

Quiet Please

Whether it is a leaf blower, a drill, a kitchen mixer or another small household appliance like a coffee machine – all these devices have two things in common: an often loud or unpleasant operating noise, and a housing made up of several plastic components. The "PolymerAkustik" project is investigating new material and manufacturing technology solutions for large-series housing components that can reduce noise emissions from housing by various methods.

The know-how gained in the "PolymerAkustik" project can be applied both holistically in an early phase of component design and as an "acoustic problem solver". © Adobe Stock

Plastics are popular housing materials. They are lightweight, cost-effective and can be formed into complex geometries in large-scale production. In addition, they often meet demanding aesthetic requirements. Acoustic properties usually play a subordinate role in practice – material selection is usually based on mechanical, thermal, processing aspects and sometimes aesthetic aspects. In small devices in particular, however, the source of vibration – generally the motor – and the noise-emitting surface of the housing are usually close together; the sound transfer paths within the device structure are short, and the available space for noise-reduction measures is severely limited.

Within the "PolymerAkustik" project, over a period of four years, researchers at several Fraunhofer institutes have developed promising solutions, including characterization methods, material concepts to improve internal damping, new design approaches to improve the damping behavior of large, flat segments of the housing, and novel geometries for the ventilation slits.

These can be used for the holistic acoustic optimization of housing components, and to solve acoustic problems occurring late in the development process.

Characterization of the Relevant Material Parameters

A key challenge in the development of acoustically optimized plastics and components is to characterize the relevant material parameters. Established methods, such as dynamic mechanical analysis (DMA), only work in a very low frequency range, assume higher basic stiffness or require a high level of effort in specimen preparation. Ultimately, the combination of two measurements developed in the "PolymerAkustik" project has proved successful. It involves a specially configured DMA (high-force DMA in tension/compression configuration using the center section of a tension rod) and a modal analysis of tension rod specimens (**Fig. 1**). In modal analysis, the vibration pattern (mode) that develops after the initial excitation, and its attenuation behavior, are examined, and the damping factor is determined as a result.

The combination of the two methods covers a broad frequency range, due to overlapping of the frequency ranges of the DMA (0.1 Hz to approx. 400 Hz) and the modal analysis (approx. 40 Hz – depending on the first mode of the sample – up to approx. 10 kHz). Since the measurement method uses standard test specimens, the effort needed to prepare them is low.

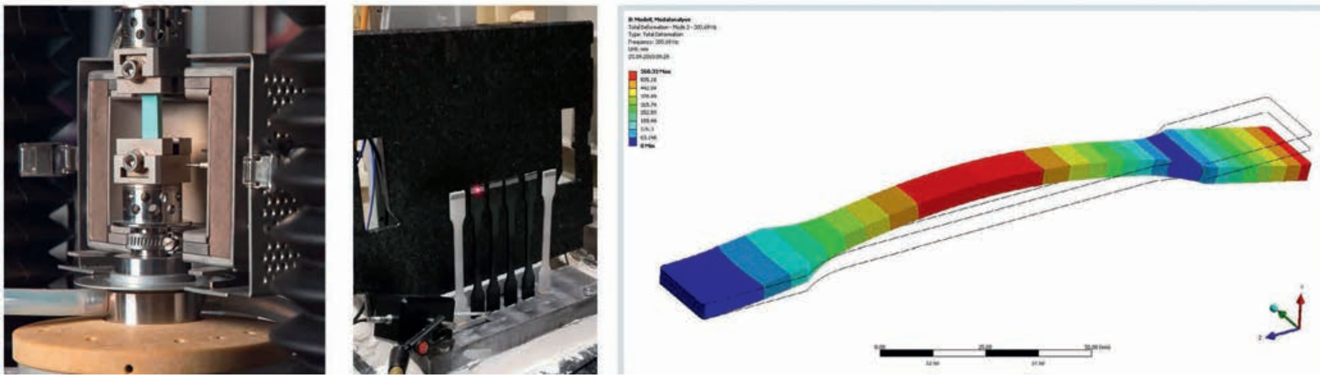

Fig. 1. Measurement setup for the DMA, the experimental modal analysis and visualization of the FE simulation of a specimen (from left). © Fraunhofer ICT/Fraunhofer IWU

Plastic Materials with Optimized Damping

Common injection moldable housing materials include acrylonitrile butadiene styrene (ABS), polypropylene (PP) and polyamides (PA), which are either unreinforced or contain mineral fillers or glass-fiber (GF) reinforcement. The vibration behavior of plastic materials is determined primarily by two factors:

- the mass and
- the internal damping capacity.

The comparatively low density, which is between 0.9 and 1.5 g/cm^3 for common housing materials, results in a low housing mass, which is not good for insulating the sound generated inside the housing. The internal damping capacity of plastic, often referred to as the loss factor tan δ, is a measure of the damping of structural vibrations, and depends on a variety of factors, such as the glass transition temperature (T_g). It can be specifically adjusted within certain limits by blending, or by the use of additives. Extensive know-how in this area has been developed in the "PolymerAkustik" project. Blends of plastics with significantly different glass transition temperatures have proved especially promising.

By careful selection of the mixing partners, good damping can be achieved over a wider temperature range, or, in the case of hygroscopic materials, the dependence of the maximum damping on the moisture content can be reduced. As an example, the researchers investigated the effect of temperature on the damping capacity tan δ of a PA6, a PP, and a 50:50 blend of the two. Even though the material behavior of the blend is still characterized by the influence of temperature on the damping behavior, a strong compensating effect of PP is evident (**Fig. 2**).

Thermoplastic Fiber-Composite Sandwich Structures

Highly rigid fiber-composite structures, such as those used as replacements for metal components, often have unfavorable, almost metallic vibroacoustic behavior that must be damped to meet acoustic comfort requirements. In this context, the principle of "constrained layer damping", which is well established for metallic structures, has already been transferred to thermoset systems and commercialized [1]. An elastomeric, viscoelastic intermediate layer is used, which crosslinks during the curing of the thermoset top layers of the sandwich structure (**Fig. 3**). In the "PolymerAkustik" project, the consortium successfully transferred this principle to thermoplastic fiber-composite structures made of stacked tape structures.

In a case study application, the internal damping tan δ was determined for the material systems PP-GF and PPS-CF (carbon fiber-reinforced polyphenylene sulfide). A commercial elastomeric film [1] was used as the elastic core layer for both the PP and PPS composites. The strong damping effect of the elastomer core layers increases at higher frequencies (**Fig. 4**). In practice, this leads to a clearly perceptible change in the sound quality from metallic bright to dull. »

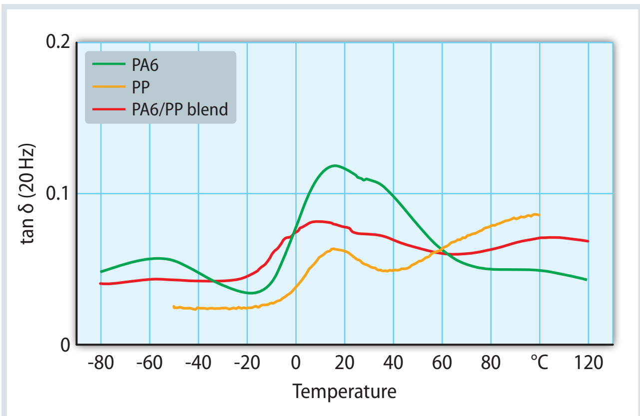

Fig. 2. Effect of temperature on the damping behavior of pure PA6, PP and a 50:50 blend of PA6 and PP. Source: Fraunhofer ICT; graphic: © Hanser

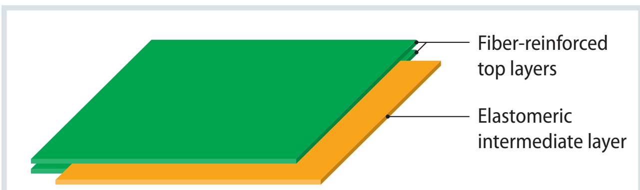

Fig. 3. Sandwich structure consisting of a viscoelastic core layer and fiber-reinforced surface layers. © Fraunhofer ICT

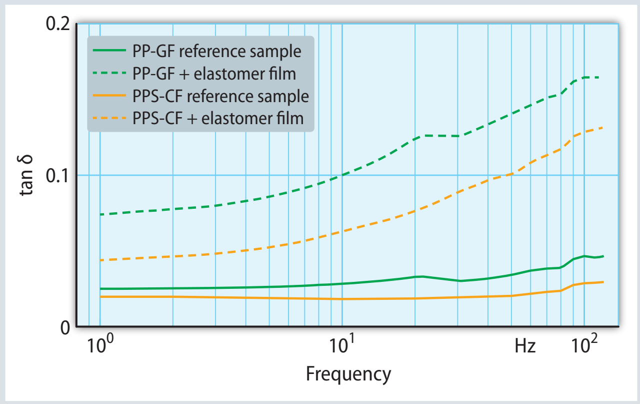

Fig. 4. Influence of elastomeric core layers on the damping behavior of thermoplastic fiber-composite structures. Source: Fraunhofer ICT; graphic: © Hanser

indicate a reduction of more than 10 dB of the emitted sound of the tonal component. An additional broadband reduction of the radiated sound is achieved as the integrated resonators change the geometry of the opening.

In addition to the solutions from the field of plastics engineering, the project group has developed advanced approaches to simulating acoustic behavior. Thus, both new material models and approaches for coupling structural and airborne sound simulation are now available for use in component development.

The housings of most electrical appliances have ventilation slits for heat dissipation. In the noise spectra of many of these devices, there are also individual stationary tonal components in the kHz range that stand out from the other sounds. These are often caused by a fixed controlled engine speed, eigenmodes of the drive components or the power electronics, and are perceived for example as a whistling noise. The partners in the "PolymerAkustik" project have now developed concepts to specifically attenuate these tonal components. For this purpose, acoustic resonators were integrated into the vent slits geometry.

Optimized Venting Slit Geometries Based on Acoustic Resonators

A comparison (**Fig. 5**) shows the sound pressure level measured at the outlet of the slits, when specimens with simple slits and with slits including integrated resonators are exposed to broadband noise and a single tone (here 3.9 kHz). The results

Conclusion

The demand for acoustically optimized solutions for plastic components and housings is increasing. The internal combustion engine, which often dominates the sound and masks a lot of background noise (for example from auxiliary units), is increasingly disappearing, not only in the automotive industry but also for example in the gardening equipment sector. In addition, there is a growing awareness that noise avoidance is fundamentally desirable for health reasons.

The common expectation that "we'll sort out that noise issue later!" can prove an expensive misjudgment, especially for plastic components. The close interaction of component design, expensive injection molds and tight material specifications makes late acoustic optimization risky – not only in terms of cost. The holistic approach of the "PolymerAkustik" project allows the existing potential of plastic as a material to be exploited on a much larger scale with regard to acoustic optimization. ■

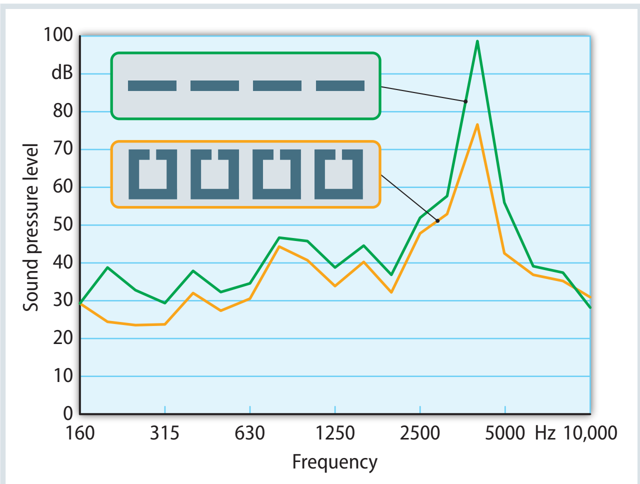

Fig. 5. Sound pressure level on the outside of the ventilation slits: here a simple slot geometry (green line) compared to an acoustically optimized ventilation opening with integrated resonators (orange line). Source: Fraunhofer IBP; graphic: © Hanser

Info

Text

Dr. Jan Diemert is Deputy Head of the Polymer Engineering Department at the Fraunhofer Institute for Chemical Technology (ICT), Pfinztal, Germany, and was Project Manager of the "PolymerAkustik" project; jan.diemert@ict.fraunhofer.de
Dr. Jörg Hohe is Group Manager for Composite Materials at the Fraunhofer Institute for Mechanics of Materials (IWM), Freiburg, Germany; joerg.hohe@iwm.fraunhofer.de
Dr. Jens Rohlfing is Group Leader for Noise Control and Vehicle Acoustics at the Fraunhofer Institute for Building Physics (IBP), Stuttgart, Germany; jens.rohlfing@ibp.fraunhofer.de
Jan Troge is Head of the Technical Acoustics Department at the Fraunhofer Institute for Machine Tools and Forming Technology (IWU), Chemnitz, Germany; jan.troge@iwu.fraunhofer.de

Acknowledgments

The authors dedicate this publication to the memory of their colleague and Institute Director Prof. Dr. Peter Elsner, and thank him for all his contributions and his friendly support.
The "PolymerAkustik" project was funded by an internal research program of the Fraunhofer-Gesellschaft, grant number MAVO 836 974.

References & Digital Version

You can find the list of references and a PDF file of the article at ***www.kunststoffe-international.com/archive***

German Version

Read the German version of the article in our magazine ***Kunststoffe*** or at ***www.kunststoffe.de***