

## Acoustic textiles—lighter, thinner and more sound-absorbent

**Michael Coates and Marek Kierzkowski invite you to imagine a textile that is less than 1 mm in thickness and weighs only 50 g.m<sup>-2</sup>, but which absorbs so much sound that it can replace a bulky, high-loft textile more than 100 times thicker and 1000 times heavier.**

**B**y understanding the factors that control sound absorption, it is possible to design thin lightweight textiles that can effectively replace the bulky materials traditionally used in the past. In this article we will introduce you to the basic theory of sound absorption by porous materials and apply it to real life textiles to show that size isn't everything in the world of acoustics.

### What is an acoustic textile?

Almost every textile has some potential for acoustic function. In fact, textiles are used in many applications involving acoustics, including:

- acoustic panels for workstations;
- front panels of speaker cabinets;
- upholstery in concert halls.

An acoustic textile, however, must have acoustic properties in its own right. It must be specifically engineered to absorb sound. In general terms, acoustic textiles fall into two classes of porous sound absorber:

- bulky, high-loft textiles, which essentially behave as a rigid, porous sound absorber;
- lightweight, compact woven and nonwoven textiles that behave as a porous screen.

Bulk porous absorbers, such as fibreglass or mineral wool batts or blankets, and needle punched, resin or thermally bonded fibrous textiles, are well known and all qualify as rigid porous absorbers.

Flow resistive screens can provide similar performance to the high-loft materials, without the bulk. Thin lightweight acoustic textiles, such as INC Engineered Materials' Deci-Tex™ range, act as flexible porous screens.

To appreciate the behaviour of acoustic textiles as sound absorbers, it is necessary to have a basic understanding of the mechanisms that control sound absorption.

### Porous absorbers

High-loft fibrous textiles follow an acoustic model whereby sound absorption is primarily a function of:

- flow resistance (air flow permeability);
- thickness;
- bulk compliance.

Of these parameters, flow resistance is the most critical factor. Compliance is also important in real life, however it is beyond the scope of this article to explore this aspect.

Suffice to say that even flexible materials behave as acoustically rigid in most frequencies of interest.

For porous fibrous sound absorbers, it has been demonstrated that the flow resistance is a function of density. Fibre packing density decreases the air permeability, with a resultant increase in pressure drop and hence flow resistance. For increased sound absorption at a given thickness, a higher-density fibrous material is used. (For simplicity, this

### Sound absorption—the basics

Sound absorption is defined as the ability to prevent sound reflections (echoes). It is measured by:

- the decay rate of sound (reverberation time);
- the ratio of incident to reflected sound;
- the sound absorption coefficient (which is 1 for absolute absorption, 0 for absolute reflection).

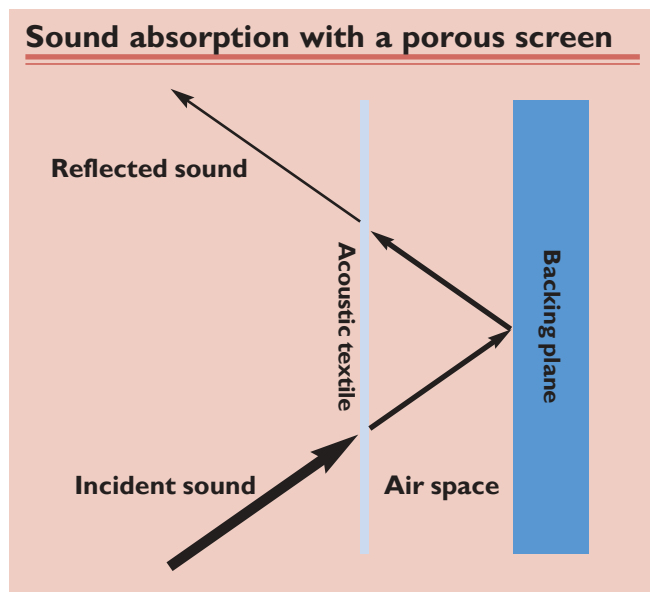
### Flow resistance—the basics

Flow resistance (R) =  $\Delta p \cdot S \cdot V^{-1}$ .

where  $\Delta p$  is the pressure drop across the fabric (in Pa), S is the sample area in m<sup>2</sup>, V is the rate of air flow in m<sup>3</sup>.s<sup>-1</sup>.

R is measured in rayls (Pa.s.m<sup>-1</sup>).

### Sound absorption with a porous screen



assumes that the compliance is not greatly influenced by density, which is not quite true in reality.)

For these materials, flow resistance is achieved through the depth of the material: the thinner the material, the lower the flow resistance.

In general terms, effective sound absorption of a porous absorber is achieved when the material thickness is about one tenth of the wavelength of the incident sound. Peak sound absorption occurs at a resonant frequency of one-quarter wavelength of the incident sound (ignoring compliance effects).

#### Porous screens

The challenge, then, is to overcome the limitation of sound absorption based on flow resistance that is essentially derived from bulk material properties, that is, density and thickness. These properties add cost and are wasteful with respect to resources.

An alternative sound absorber consists of a thin porous sheet (an acoustic textile) located at some distance in front of a rigid backing (in other words, with an air space in front of a wall). If the flow resistance of the porous screen is adequate, substantial sound absorption is achieved.

In contrast to the bulk fibrous absorber, the thin acoustic textile has a high flow resistance in a very thin layer. With the correct flow resistance, a flow resistive sheet absorbs almost as much sound as the bulky fibrous absorber, provided the air space is of similar dimensions to the thickness of

the bulky material. It can, therefore, be an effective substitute for the bulky fibrous absorber.

Thin acoustic textiles follow a similar model to the bulky porous absorbers, whereby sound absorption is primarily a function of:

- flow resistance (air flow permeability);
- compliance;
- mass;
- depth of air space.

Again, flow resistance is the critical material property affecting the sound absorption. In this case, the air space substitutes for the thickness that is required for the bulk porous absorber. Compliance, however, is rather more important than it is for the bulky materials.

#### Textile engineering for sound absorption

From the above, it should be clear that a major difference between bulky porous absorbers and thin flow resistive screens is the ability to tune sound absorption to certain frequencies, by increasing or decreasing the flow resistance of the fabric. For relatively typical parameter values, the resonant frequency of a flow-resistive screen, and hence peak sound absorption, can be more than five times lower than the customary quarter wavelength resonance (and peak sound absorption) of the bulk porous absorber.

For instance, at 100 Hz the wavelength of sound is approximately 3.5 m, requiring a thickness around 350 mm for 100% absorption for a bulky porous absorber, but only around 70–100 mm for the flow resistive screen. At 350Hz, the wavelength of sound is around 1 m, requiring a thickness about 100 mm for 100% absorption for a bulky porous absorber, but only 20–30 mm for the flow-resistive screen.

It must be noted that, in this manner, the low frequency sound absorption is achieved at the cost of reduced sound absorption at higher frequencies. The same is not true of the bulky porous absorber.

In all cases, as the thickness approaches zero, there is effectively no sound absorption (that is, there is total sound reflection).

#### Practical textiles for sound absorption

The permeability of standard textiles is generally too low to offer the properties required of an effective acoustic textile. Accordingly, an acoustic textile must be specially engineered

for sound absorption. For instance, whereas a typical filter fabric will have a flow resistance of approximately 10 rayls, an acoustic textile will have a typical flow resistance of 400–4000 rayls, depending on the design requirements.

To engineer a practical textile for sound absorption requires a clear understanding of the physics involved, as well as the ability to incorporate the required properties into a textile. Computer modelling can accurately predict sound absorption, taking into account variations in the properties of materials and the air space. This allows the designer to engineer the textile to maximize the sound absorption for specific applications.

### Effect of flow resistance

For a given air space (say 100 mm) at a given frequency (200 Hz, for instance) the sound absorption coefficient of a thin porous absorber varies with flow resistance (see figure above right). As the flow resistance increases, sound absorption increases; however once the flow resistance exceeds a certain value (4000 rayls in this example) the sound absorption reduces. At a given thickness, the trend is for the sound absorption curve to shift to a lower frequency range as the flow resistance increases (see below right).

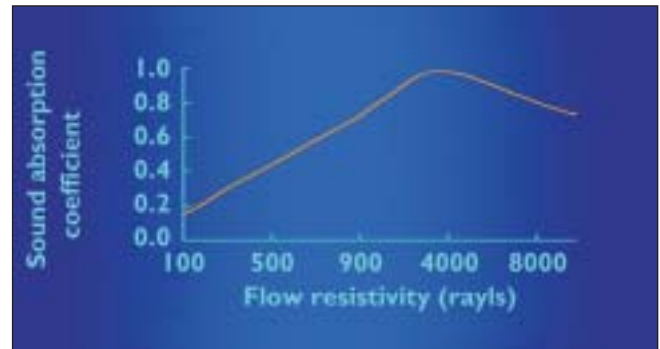
Consequently, it is possible to tune the flow resistance for a required frequency range without changing the depth of the air space behind the fabric.

### Effect of thickness—acoustic ceilings

A suspended acoustic ceiling is a perfect example of an opportunity to use acoustic textiles for broad-frequency sound absorption. The ceiling cavity provides a deep air space, allowing the potential for substantial low frequency sound absorption. High frequency sound absorption can be preserved as long as the flow resistance is selected within the lower range. If the flow resistance is too high, high frequencies will be reflected, rather than absorbed.

Acoustic textiles, supplied with a heat-reactive coating, are laminated to perforated metal ceiling systems as an alternative to bulky traditional absorbers. The result is exceptional sound absorption at frequencies as low as 100 Hz.

Nevertheless, other factors also influence the final results. In turn, this emphasizes the importance of engineering the acoustic textile into a whole system. Clearly, though, this also provides a further means for tuning an acoustic system for maximum sound absorption at a certain frequency.



The effect of flow resistance from a thin, porous absorber on the absorption of sound (200 Hz) with an air space of 100 mm

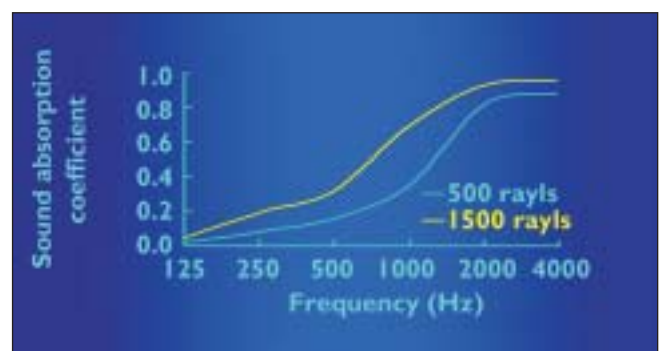
### Sound absorption enhancement—minimum thickness and mass

In original equipment manufacturing (OEM) markets – such as automotive – space and weight are restricted. While it is necessary to maximize the sound absorption (especially at the problematic lower frequencies), the volume of space available is limited. In addition, minimizing the mass of the insulator is desirable, not simply for cost reasons, but also because of energy efficiency.

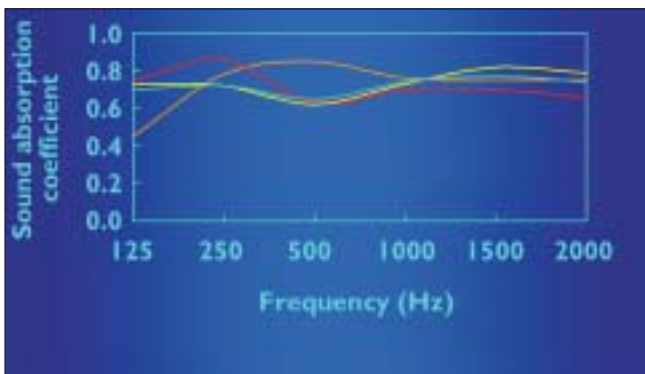
A conventional bulk fibrous sound absorber requires additional density and thickness to move the sound absorption peak to a lower frequency. A thin, tuned, acoustic textile, on the other hand, can be designed to maximize the sound absorption at the required frequency range.

### Automotive hood insulators

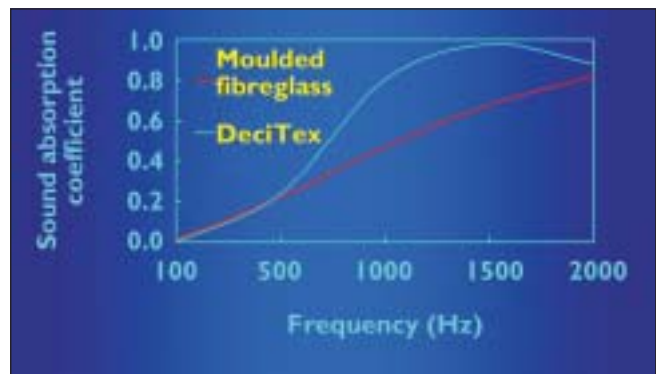
Insulators for motor vehicle hoods are generally made from fiberglass or felt impregnated with resin by compression moulding. These materials release noxious gasses when



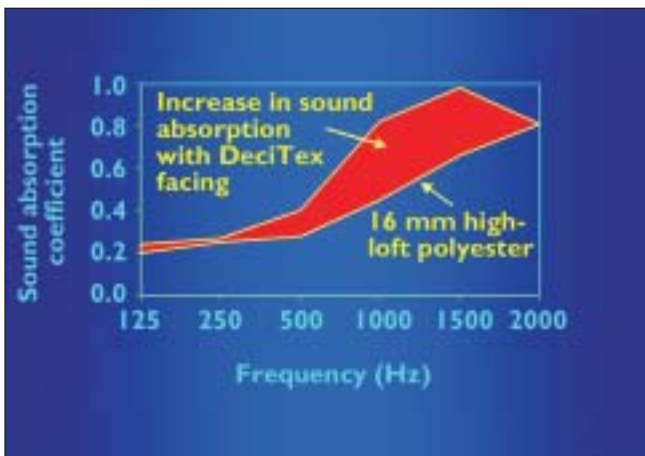
At a given textile thickness, as the flow resistance increases the trend is for the sound absorption curve to shift to a lower frequency range.



The sound absorption of four particular suspended ceiling systems. All use Deci-Tex™ P41 acoustic textiles.



Deci-Tex™ XT (PCT patent pending) is a semi-rigid thermoformable hood insulator based on acoustic textile technology. It is only 1 mm in thickness and weighs as little as 300 g.m<sup>-2</sup>. Using the hood reinforcement ribs act as spacers to provide an air space of 20–25 mm between the acoustic textile and hood, the sound absorption of this new acoustic system is almost twice that of the current fibreglass product.



A thin, tuned, acoustic textile, can be designed to maximize the sound absorption at the required frequency range. This data illustrates a practical implementation using Deci-Tex™ P42. The lower curve indicates the sound absorption of a 16 mm high-loft thermally bonded polyester nonwoven. The red shaded area indicates the increase in the sound absorption by the addition of a thin acoustic textile facing. The result is a product that provides twice the sound absorption of felts of more than three times its density.

moulded and cannot be recycled after use. In particular, the health and safety issues associated with the use of these materials have resulted in more interest being shown in their benign alternatives.

Deci-Tex XT, for instance, is a semi-rigid thermoformable hood insulator based on acoustic textile technology. It is only 1 mm in thickness and weighs as little as 300 g.m<sup>-2</sup>. Using the hood's reinforcement ribs to act as spacers to provide an air space of 20–25 mm between the acoustic textile and hood, the sound absorption of this new acoustic system is

almost twice that of the current fibreglass product. At the same time, Deci-Tex XT provides a dramatic weight reduction of 50–75. Further, this nonwoven is tough, resistant to damage, can be recycled, and has a thin stackable profile.

### Summary

Using computer modelling, engineers can design high-performance acoustic textiles that are lightweight, but still provide good sound absorption. In this article, we have considered how to do so by varying the flow resistance. However, by varying other parameters, such as compliance, it is possible to exploit additional benefits. Today, both the manufacturers of automobiles and white goods take advantage of such textiles, which are also integral components in commercial acoustic-ceiling systems installed around the world.



### Further information

INC Engineered Materials combines more than 30 years experience in acoustic engineering and technical textiles. INC's acoustic textiles are marketed under the registered trade name Deci-Tex™ (note, these materials are subject to patents pending).

Dr Marek Kierzkowski, INC Engineered Materials.

Tel: +61-3-9543-2800. Fax: +61-3-9543-6648.

E-mail: [mk@inccorp.com.au](mailto:mk@inccorp.com.au). Internet: [www.inccorp.com.au](http://www.inccorp.com.au)