Institution: University of Bradford

Unit of Assessment: B14

Title of case study: Innovative acoustic material enables economic growth while reducing waste and noise pollution

1. Summary of the impact

University of Bradford research has enabled a material manufacturing company, Armacell, to reuse up to 95% of its production waste to produce new, high-value acoustic products with up to 50% better acoustic performance than any competition products of similar size. We protected the developed IP through several international patents and set up a spin-off company, Acoutechs Ltd, to explore this technology commercially. These materials are now used to reduce noise levels below the recommended limits and to improve the general acoustic quality of spaces at home and work for the benefit of public health. The products generate an annual turnover of more than €4 million for Armacell and prevent more than 500 tonnes of plastic waste from going into landfill annually.

2. Underpinning research (indicative maximum 500 words)

The underpinning research leading to this impact was mainly conducted between 1996 and 2001. The work has resulted in over 10 publications in international peer-reviewed journals, over 10 international conference publications, and 3 patents. This was mainly EPSRC-sponsored research work (EPSRC GR/L54905/01 and QUOTA REF. 96304127) to advance existing analytical and computationally based numerical models for the acoustic and mechanical properties of porous elastic media.

This provided the theoretical base to design “acoustically thin” porous flexible panels applied to vibro-acoustic noise reduction. The original idea proposed by Kirill Horoshenkov (PDRA 1993-1995, Lecturer 1995-2002, Senior Lecturer 2002-2004, Professor 2004-2013) and David Hothersall (Reader 1993-2000, Professor 2000-2011) was that visco-thermal absorption could be enhanced by the vibrations of a poro-elastic plate. The viscosity correction function, which accounts for these effects in the equation of motion for poro-elastic plate, has poles that relate to the frequencies at which the relaxation process are particularly pronounced. Suitable expressions for this function were derived rigorously and accurately approximated to allow for the efficient calculations (1).

The work studied two different mechanisms which can be used to excite vibration in a thin poro-elastic plate: (i) the differential pressure that is applied to the solid surface of the elastic frame (2); (ii) the friction forces that are developed inside the porous frame so that the frame is dragged as the filling fluid oscillates (3). These effects were investigated for porous elastic plates via modifications of the original Biot and standing waves theories for thin porous plates.

New experimental facilities were constructed in the Acoustics Laboratory at the University of Bradford to measure the visco-thermal acoustic absorption and vibration damping phenomena to validate the developed theoretical models. These included a new flow resistivity, pore size distribution, porosimetery (4), and transmission loss rigs. A unique, large impedance tube facility at Fukuoka University (Japan) was used to illustrate the apparent enhancement in the acoustic absorption associated with the frame vibration effects.

The derived theoretical models and experimental facilities paved the way for the design and manufacture of materials with enhanced acoustic absorption and vibration damping properties. This work was sponsored through an EPSRC studentship award.

Many material specimens have been manufactured and characterised in the Acoustics Laboratory. The acoustical properties of these media were predicted using the values of the non-acoustical material parameters, which were measured independently using the developed laboratory setup

(5,6). This work led to the design of a thin, poro-elastic material with commonly required vibro-acoustic performance that could be achieved with a layer which was 2 to 3-fold thinner than any commercial acoustic product available at that time. The production process was designed to be a sustainable technology based on the reuse of industrial polymeric waste. This process was patented in the UK in 2000, in the USA in 2001 and Europe-wide in 2003. This process was scaled up using a DTI SMART award and industrial funding provided by Armacell UK Ltd.

3. References to the research

1. Horoshenkov KV, Attenborough K, Chandler-Wilde SN. (1998) Padé approximants for the acoustical properties of rigid frame porous media with pore size distribution. *Journal of the Acoustical Society of America* 104: 1198-1209.

2. Horoshenkov KV, Sakagami K. (2001) A method to calculate the acoustic response of a thin, baffled, simply supported poroelastic plate. *Journal of the Acoustical Society of America* 110(2): 904-917.

3. Leclaire P, Horoshenkov KV, Cummings A. (2001) The transverse vibrations of a thin rectangular porous plate saturated by a fluid. *Journal of Sound and Vibration* 247(1): 1-18.

4. Leclaire P, Swift MJ, Horoshenkov KV. (1998) Specific area from water-suction porosimetry in application to porous acoustic materials. *Journal of Applied Physics* 84(12): 6886-6890.

5. Horoshenkov KV, Swift MJ. (2001) Acoustic properties of consolidated granular mixes. *Applied Acoustics* 62(6): 665-690.

6. Horoshenkov KV, Swift MJ. (2001) The acoustic properties of granular materials with pore size distribution close to log-normal. *Journal of the Acoustical Society of America* 110(5): 2371-2378.

(1), (2), and (5) are the three most significant publications.

Patents:
August 2000. *Sound Absorbing Materials*, UK patent GB0019913.3. MJ Swift, DC Hothersall, KV Horoshenkov.
August 2001. *Sound Absorbing Material*, US patent 7,721,846 B2. MJ Swift, DC Hothersall, KV Horoshenkov.
August 2003. *Sound Absorbing Material Including a Plurality of Pieces with Pores*, WO/2003/069595. E French, MJ Swift, KV Horoshenkov.

Grants:
Poroelastic Materials for Noise Control, (awarded to KV Horoshenkov & A Cummings (University of Hull)), £133,779. 1997-2000, EPSRC GR/L54905/01.
The Acoustics of Porous Materials, EPSRC Research studentship (Awarded to MJ Swift), QUOTA REF. 96304127, 1996-1999.
Feasibility Study Grant: *To Investigate the Industrial Scale Production of a New Sound Absorbing Material*, £45,000, 2000-2001, DTI, Yorkshire and Humberside Government Office, (Grant YHF/21702/NSObj2, Awarded to Acoutechs Ltd).

4. Details of the impact

Our research enabled us to optimise the porous structure and mechanical properties for several types of acoustic materials produced from industrial waste, which would otherwise have been destined for landfill. We were able to enhance the acoustic absorption and vibration damping performance of these products and to maintain quality and reproducibility of the scaled-up manufacturing process.

To commercialise this technology, the University of Bradford set up a spin-off company, Acoutech Ltd, in 2000 and started scaling up the technology (a). In 2003, the technology was licenced to Armacell (b), which in 2004 started manufacturing a range of products in Europe, the Far East and the USA under the brand name *ArmaSound*. It is estimated that the production of this product created directly at least 20 full-time engineering and manufacturing jobs worldwide, including 4 in the UK. Originally a slow starter, *ArmaSound* soon began to demonstrate its capability as a material unlike any other, offering acoustic benefits that were difficult to replicate with conventional acoustic insulation.

Early projects included acoustic linings for heavy vehicles and equipment as well as telecommunications cabinets and domestic boilers. Later on, it found its way into linings for canopies and enclosures used for housing industrial scale generators and compressors. The jewel in the crown, however, was when *ArmaSound* was approved for use in an acoustic system designed to reduce noise from process pipe-work including very large bore pipes. This product has enabled the design of a compact vibro-acoustic insulation system which reduces the noise levels emitted by petrochemical equipment and machines below the 75 and 80 dB noise limits recommended by the UK national and much international noise control legislation. More specifically, the availability of this range of products has led to a shift in the conventional way in which large pipes at petrochemical plants and offshore platforms are treated for noise, and *ArmaSound* has been specified on many prestigious petrochemical project sites around the world. Following success within the ammonia and ethylene segments, *ArmaSound* achieved approval for use on Liquid Natural Gas (LNG) facilities in 2010. These included the Skikda 'Mega Train' LNG facility with Sonatrach in Algeria and PNG LNG facility with Exxon Mobil in Papua New Guinea.

Sales of *ArmaSound* in 2012 were around €4M, (growing from around €3M in 2011). Despite hard economic times, especially for manufacturing industries, *ArmaSound* bucked the trend by continuing to grow year on year. In early 2012 Armacell were awarded a contract to supply *ArmaSound* to the Gorgon LNG project operated by Chevron/Shell, a $45 billion facility to be constructed on Barrow Island, off the coast of Western Australia (b). The value of *ArmaSound* insulation in this project is estimated at US$23M. This facility is the largest ever constructed and will utilise *ArmaSound* to treat around 200km of pipe-work. *ArmaSound* will experience its largest growth period to date during 2013.

The accessible pipework insulation material market is estimated to be €200m/annum. *ArmaSound* system market penetration is estimated at 5% or €10m/annum in terms of the insulation systems in which this product is specified. Before licencing our technology, the company was not active in this market at all, so our technology has enabled the company to enter an entirely new and lucrative market. Armacell's clients now include Foam Techniques (c) (one of the world's largest insulation contractors), Baxi Potterton, Durabella, and Sterling Generators. Companies who specify this product include BP, Amec, and KBR (d).

ArmaSound products have not only generated revenue for Armacell (e,f,g,h,i), but have also had a significant environmental impact in three ways: firstly the acoustic quality of spaces has been improved through the introduction of a new product with better acoustic properties and durability; secondly as the product is at least half the thickness of conventional sound-proofing material and 95% of it is recycled waste, it provides more environmental benefits than other more conventional products which are made from virgin materials; thirdly the company has significantly reduced its industrial waste.

5. Sources to corroborate the impact (indicative maximum of 10 references)

Spin-off company

a. Director, Acoutechs Ltd. Company Registration No.: 04068829.

Licensee

b. Head of Technical-Engineered Systems, Armacell UK Ltd. Company Registration No.: 03729805.

Users

c. Joint Managing Director, Foam Techniques Ltd. Company Registration No.: 02078810.

d. Senior Technical Advisor, Kellogg Brown & Root Ltd., Company Registration No.: 02021947.

Product details and example applications

e. http://www.armacell.com/www/armacell/acwwwattach.nsf/ansFiles/ArmaSound240TH.pdf/$FILE/ArmaSound240TH.pdf

f. http://www.armacell.com/www/armacell/acwwwattach.nsf/ansFiles/RangeArmaSound240Iran.pdf/$FILE/RangeArmaSound240Iran.pdf

g. http://www.armacell.com/www/armacell/ACwwwAttach.nsf/ansFiles/AUMTrinidadUK.pdf/$FILE/AUMTrinidadUK.pdf

h. http://www.offshore-technology.com/contractors/corrosion/armacell/press3.html

i. http://www.armacell.com/www/armacell/ACwwwAttach.nsf/ansFiles/AUMTrinidadUK.pdf/$FILE/AUMTrinidadUK.pdf