Auxetic composites expand when they are stretched

It is rare in nature for materials with an entirely new range of properties to be discovered. Researchers at the University of Bolton (UK) are leading research into auxetic materials which expand when they are stretched. These materials are set to revolutionise composite structures.



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We may not realise it, but we are all familiar with Poisson's ratio. Very simply, it is the measure of the amount a material shrinks when it is pulled. Just hold an elastic band between your fingers and pull it: the elastic band shrinks as it is extended (fig. 1). While it has been known for some time that materials having a negative Poisson's ratio can exist, manu-facture of such materials has only taken place recently, as a result of work done by researchers at the University of Bolton in the UK and a handful of other research groups throughout the world.

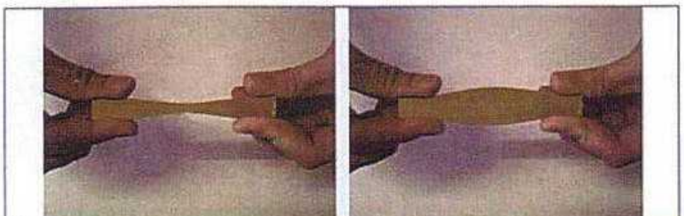

Fig. 1: Left: Pull a material with a positive Poisson's ratio and it shrinks, this is normal behaviour.
Right: Pull an auxetic material with a negative Poisson's ratio and it expands, this is counter-intuitive

The auxetic effect is counter-intuitive, but it is real. How does it happen?

In effect, an auxetic structure can be produced at any scale so that within the structure any links in that structure rotate as the strain is applied. This can happen at a macro scale in structures such as honeycomb and rope, to a molecular scale where polymeric molecules can rotate when strained to create an auxetic effect.

The best example of this effect is an auxetic honeycomb core which is similar to the cores used in most advanced composites, except that the cells have a re-entrant structure instead of the familiar hexagonal shape (fig. 2).

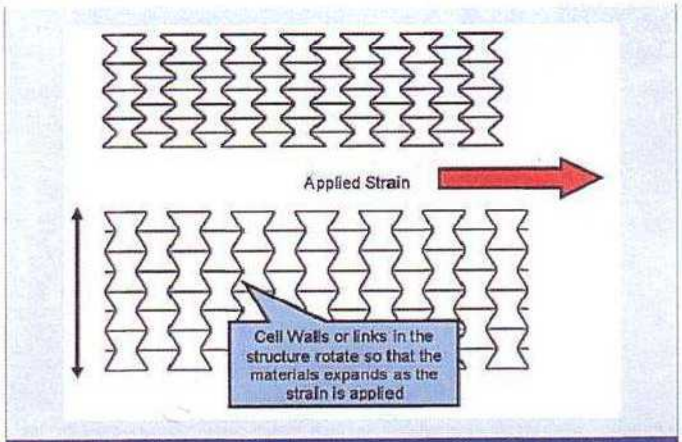

Fig. 2: The classic example of an auxetic honeycomb which expands as a strain is applied.

In the example shown in the diagram, it can easily be seen that the oblique walls of the cells rotate as horizontal strain is applied, creating the effect that the honeycomb sheet is expanding.

Auxetic honeycombs have been known for some time and have potential in a range of applications. The increase in cell (pore) size in response to stretching means that they could be used for self-cleaning filters in nuclear plants, for example. A great advantage of an auxetic honeycomb is that it drapes well, since it does not suffer the anticlastic bending that constrains the use of single pieces of honeycomb core bent around complex shapes or tight curves such as aircraft engine cowlings. It is thought that auxetic honeycomb would be superior to existing grades of Flexcore.

While the honeycomb format is one that is easy to explain, other auxetics can be formed from rotating plates and molecular networks, for example, demonstrating that the auxetic effect can be achieved from the macro to molecular scale.

While auxetic properties are thought to be rare in nature, notable examples include crystalline silica (--cristobalite and --quartz) and 69% of cubic elemental metals (with potential as electrodes in piezoelectric devices), at the molecular level, and biomaterials (e.g. certain forms of skin), at the microscale.

Main features ...

Auxetic materials display extraordinary properties - they expand when they are stretched. Researchers worldwide are discovering ways to apply these properties to composite materials. Auxetic Technologies Ltd, based at the Bolton University, in the UK, is a leader in this field and is developing these materials to create advanced composites that display significantly improved performance, including reduced weight, improved strength, improved impact resistance and energy absorbing properties.

Auxetic fibres, composites and films

Scientists at the University of Bolton (fig. 3) have been extending the auxetic principle to polymeric films and fibres that display these peculiar properties, and they have patented a route to manufacturing auxetic monofilaments. Auxetic multifilament yarns have also been produced in research performed at the University of Exeter.

Continuous auxetic fibres have many potential applications, including in composites. For example, research at the University of Bolton shows that auxetic fibres display excellent pullout properties, requiring three times as much energy to cause pullout of the fibre from a surrounding matrix compared to the non-

Fig. 3: Melt extruder for producing auxetic fibres at the University of Bolton, these are currently being converted for use in auxetic composites.

More information ...

Auxetic Technologies is a company that specialises only in auxetic materials. They are leading participants in AuxetNet, which is a network of academics and commercial companies with serious interest in this area. www.auxetictechnologies.com

Product Technik is a technology consultancy specialising in automotive and aerospace production. Product Technik has a track record varying from spacecraft component production to volume production of high-performance automobiles. www.product-technik.co.uk

auxetic counterpart. In essence, the harder they are pulled, the more tightly they expand to grip the material from which they are being extracted.

Auxetic composite laminates, made from commercially available prepreg using commercial fabrication processes, are already being tested and show significant improvements in impact resistance.

Even more extraordinary is the property of holes in auxetic films to get smaller when the film is subject to a strain - a kind of self-healing structure.

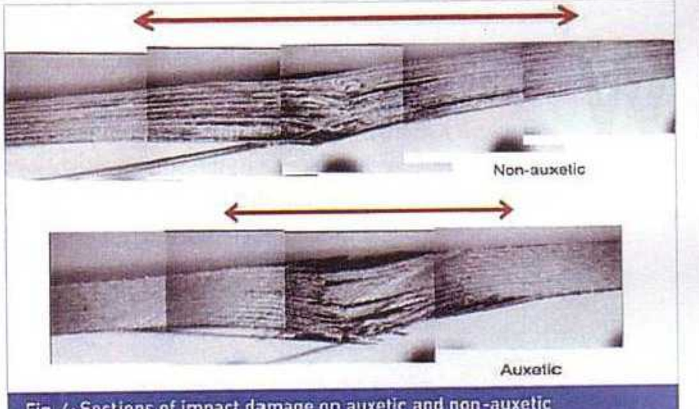

Fig. 4: Sections of impact damage on auxetic and non-auxetic carbon-fibre-reinforced epoxy composite laminates.

Many potential applications

The properties of auxetic fibres, composites and films are likely to be adopted in composite body armour (fig. 4). Other potential applications are many and include rawl plugs, dampers and brakes. In composites, there is the potential for easily removable lay-up mandrels and intensifiers made from auxetic foams that do not require the high temperatures for silicone rubber intensifiers.

Auxetics is a science in its early stages that is set to revolutionise advanced composites during the next ten years. ■

More information: www.auxetictechnologies.com