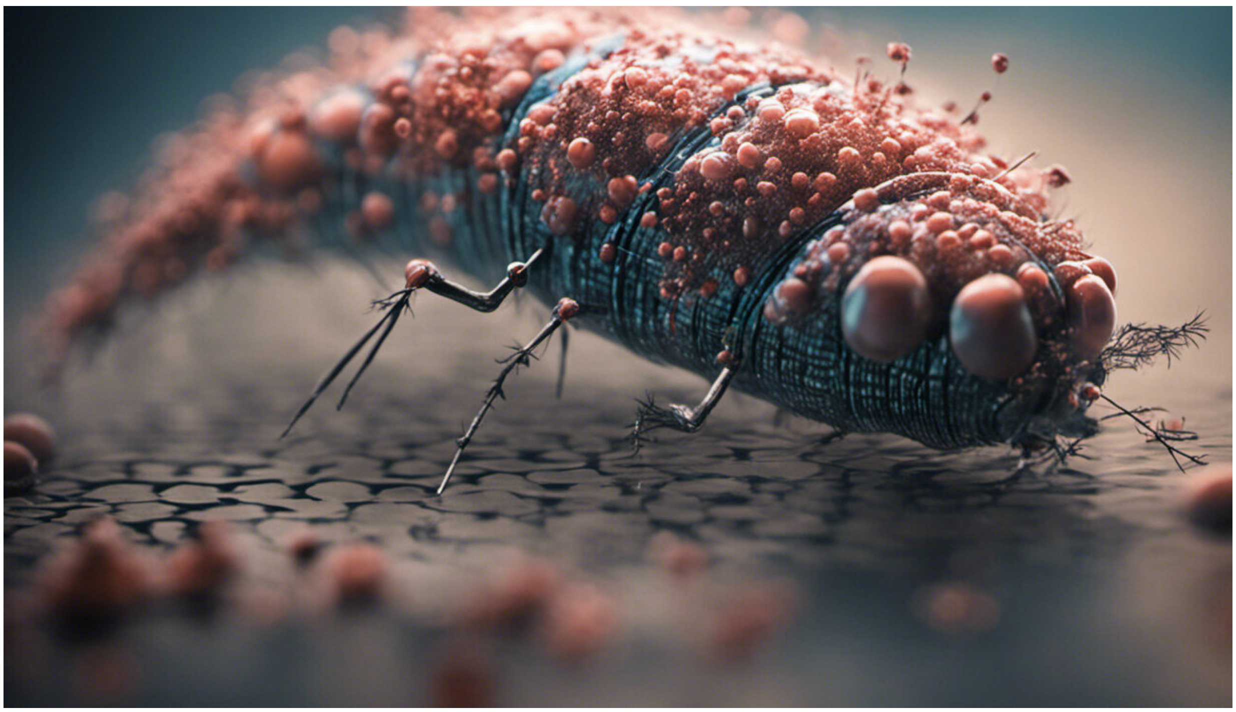
New vibration-proof 'metamaterial' that could save premature babies' lives

January 20 2017, by Andy Alderson And Fabrizio Scarpa



Credit: AI-generated image (disclaimer)

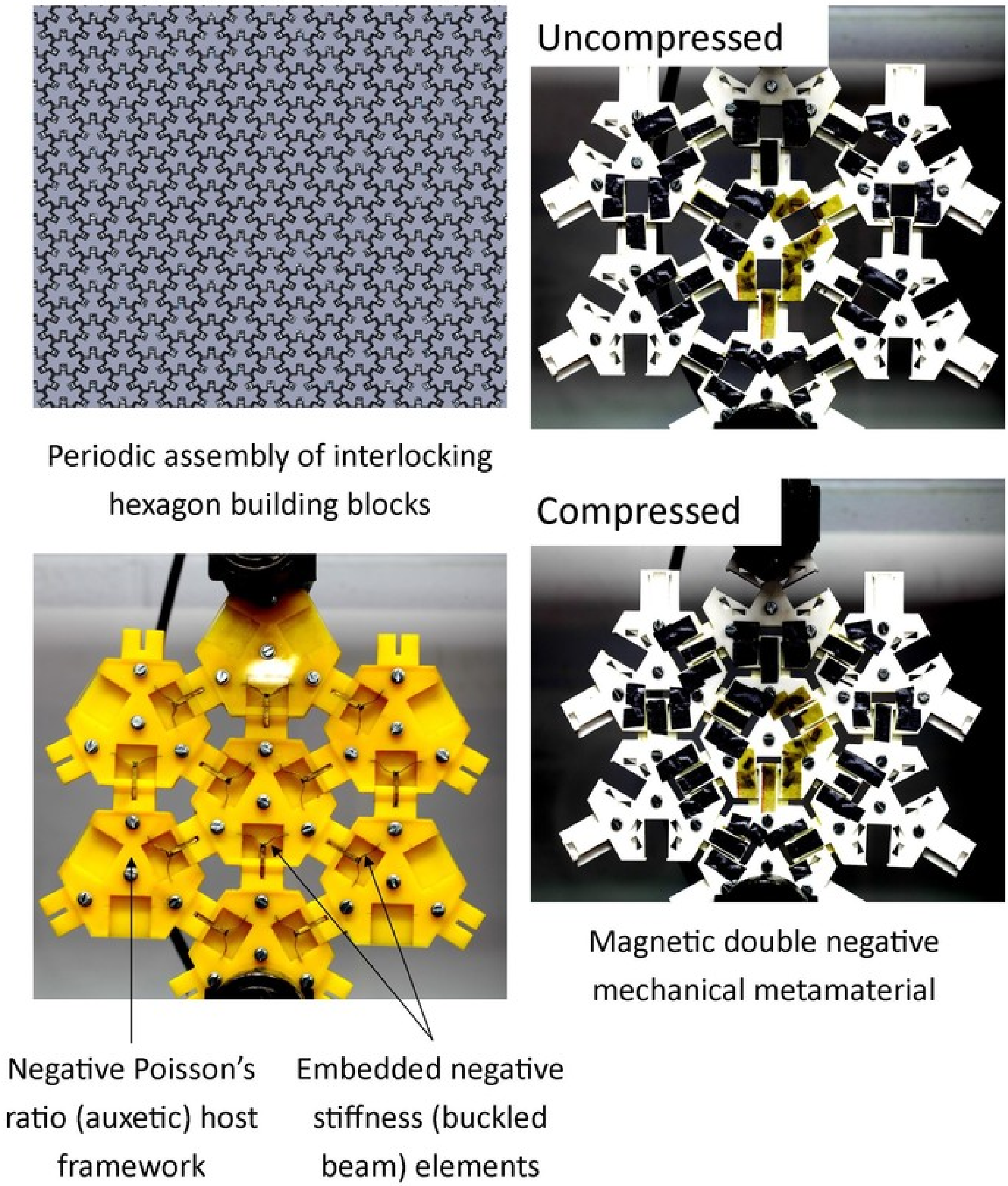
There are 16,000 transfers of premature babies to medical facilities each year in the UK alone. The babies are often transported over large distances from rural to city locations over significant periods of time, in some cases two hours or more. The ambulances, helicopters or aircraft used are miniaturised intensive care units, containing all the equipment required to keep the baby alive.

But mechanical vibrations and noise from the equipment and transfer vehicle can provide significant, even life-threatening stress to the most vulnerable and delicate human lives. As we discovered when speaking to clinicians, transfers are sometimes aborted as a result of the stress that develops in the baby. These vehicles need materials and structures to reduce the noise and vibrations to tolerable levels.

Our team has recently developed a special "metamaterial" inspired by a nuclear reactor design that offers a double whammy of protection by combining two unusual properties known to dampen vibrations to a much greater degree than existing materials. Once we've tested and adapted the material, it could be used to help make safer neonatal transfer vehicles. And it could even be used in much bigger structures, for example to help prevent earthquake damage in buildings.

Auxetic materials can dampen vibrations. They have what's called a negative Poisson's ratio, which means that they become thicker when stretched along their length, unlike an elastic band, which becomes thinner. Imagine stretching a crumpled or folded sheet of paper. The unfolding of the paper as it is stretched causes the sheet to become both longer and wider. This is the auxetic effect.

There are also other unusual materials that contract (rather than stretch) along their length when pulled lengthwise (negative stiffness), which also have dramatic vibration damping properties when used as part of a composite material.



How it works. Andy Alderson/Sheffield Hallam University, Author provided

If you stand a ruler on its end and push it down from the top it will bend into a C shape. If you then push sideways against the mid-point of the outer edge of the C, initially the ruler will offer resistance to the sideways push. That's positive stiffness. But keep increasing the force and the bend in the ruler snaps through to the other side, creating an inverted C shape. During the snap-through period, the ruler is working with the force, not resisting it. So in this transition phase it displays what is called negative stiffness.

One way of achieving such unusual properties is to develop mechanical metamaterials. These are made from a particular geometric arrangement of smaller building blocks that give the materials their special mechanical properties. We have developed "double negative" mechanical metamaterials that combine both negative Poisson's ratio and negative stiffness properties simultaneously.

Our metamaterials comprise interlocking hexagon building blocks that move together in all directions when compressed, by sliding along the interlocks that connect adjacent hexagons. This creates an auxetic effect.

These were in part inspired by the graphite core interlocking structures of some nuclear reactors designed and built in the 1950s and 1960s, which are auxetic and were specifically designed to withstand seismic vibrations during earthquakes. We have also added three negative stiffness elements – foam inserts, buckled beam inserts and an arrangement of magnets – between the interlocking blocks.

Stopping bad vibes

We expect the combination of both auxetic and negative stiffness properties in the bulk metamaterial will give it better vibration damping ability than if it just had one of these properties. And through careful design, we expect it to be able to dampen vibrations at many different frequencies.

Because the technology can be scaled up or down – and once we have determined exactly how good it is at dampening vibrations – it could be used in lots of different applications, from ambulances to buildings.

We also think the principle of combining these two properties could be used in other materials. For example, you could use collapsible auxetic truss structures as rapidly deployable tents and shelters in military and disaster-relief situations. Building negative stiffness into such structures would enable them to provide protection from severe vibrations, such as earthquakes.

We still need to turn the prototype technology into designed and manufactured products, but this metamaterial could have a vibrant future ahead of it.

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