

What if your refrigerator cooled your food by twisting wires?

Enlarge / Thermal images show how stretching twisted rubber causes its temperature to change.

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Although some manufacturers have attempted to spice up refrigerators with an Internet-of-Things capacity, few of us have found automatic egg-inventory-tracking notifications a compelling upgrade. So are any real technological revolutions possible for this humble home appliance?

A team of researchers led by Nankai University's Run Wang and the University of Texas at Dallas' Shaoli Fang certainly thinks so. They're not thinking about the front of the fridge, though—for them, the party is in the back. They're looking to replace compressed gas coolants with a twisted solid.

It's solid

Refrigerators have long run on a vapor-compressor design that uses circulating coolant to pump heat energy out of the fridge and into your kitchen. At this point, we've pretty much maxed out the potential energy efficiency of that design, which isn't ideal. Also not ideal is the fact that the coolants used are not without problems if they leak—problems range from

health hazards to a history of ozone depletion to their behavior as greenhouse gases.

There is, in theory, at least one way to pump heat more efficiently, and that's to manipulate the entropy of solid materials. You may actually have experienced this in a chemistry class, stretching or relaxing a rubber band and quickly holding it to your skin to feel it warm or cool. The polymer fibers within a rubber band are oriented randomly, but when you stretch the band, the fibers are pulled into a more consistent—and therefore ordered—orientation. That's a decrease of entropy. Relax the band and it reverts to disordered chaos (higher entropy). This causes the band to absorb or release heat energy.

The researchers' idea was to—quite literally—put their own twist on that phenomenon. By twisting strands of similar materials, they hoped to amplify the temperature change and make this much more practical for a physical device. Traditional vapor compression devices can reach about 60% of theoretical cooling efficiency, but this “elastocaloric” process (or this new “twistocaloric” take on it) has the potential to hit about 84% efficiency.

The team tested this with various configurations of strands of rubber, fishing line, and the unique nickel-titanium alloy sometimes called “memory wire.” With a thermal camera, they measured the temperature change as they twisted, coiled, stretched, and relaxed the fibers to see what could generate the largest temperature swings.

Rubber bands and fishing line

Simply stretching and relaxing some rubber, for example, only changed the temperature by about 2.5°C. Twisting it into a spring-like shape raised that to 6.5°C and required less stretching distance. Twisting it even more until the coils themselves began to coil up on each other—giving it a knobby

appearance—added another degree or so.

Simply twisting and untwisting the rubber worked even better, with an average temperature change of about 12°C. Adding a little bit of stretch won a couple more degrees. Compared to the roughly 60% efficiency of traditional refrigeration, twisting the rubber hit about 63%, and twisting plus stretching hit 67%.

The tests with fishing line included an interesting configuration: twisting the line one direction into a coil and then wrapping that coil around a post in the opposite direction. Stretching this setup actually untwists the line instead of twisting it tighter, reversing the warming/cooling cycle. In some cases, it even increased the temperature swing.

The nickel-titanium “memory wire,” though, may hold the most promise. It’s particularly elastic for a metal and has the remarkable party-trick ability to return to an initially set shape, regardless of how much it has been bent, just by changing the temperature. Memory wire can do that because the crystalline organization of its atoms can switch between a couple different geometries that are stable at different temperatures. Change the temperature enough, and the atoms will jump into the other geometry.

Enlarge / Nickel-titanium wire coated with a dye that responds to temperature change shows how the wire heats and cools with twisting and untwisting.

Wang et al./Science

Party trick aside, these properties are pretty handy for twist cooling. Untwisting a single 0.7 millimeter wide wire causes a 14°C temperature drop. Twisting four wires together led to an 18°C drop. This was run through 1,000 cycles without any measured drop in performance.

As a sort of proof of concept, the team put one of these wires in a thin tube with an inlet and outlet and pumped a trickle of water through it. The researchers only ran it through one cooling cycle, simply untwisting the wire, but they measured an almost 8°C cooling of the water through the tube.

Of course, to approach a functioning refrigerator, this design would have to be cycled endlessly, with all the heat absorbed

by the wire deposited outside the device. But twist cooling may be the innovation that is needed to take this from a chemistry-class demo to a plausible practical mechanism. Someday, your fridge could be whirring with the twisting and untwisting of little wires instead of the grumbling sounds you're accustomed to as you ponder that midnight snack.

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