# Gear-based mechanical metamaterials allow for creation of configurable sheets

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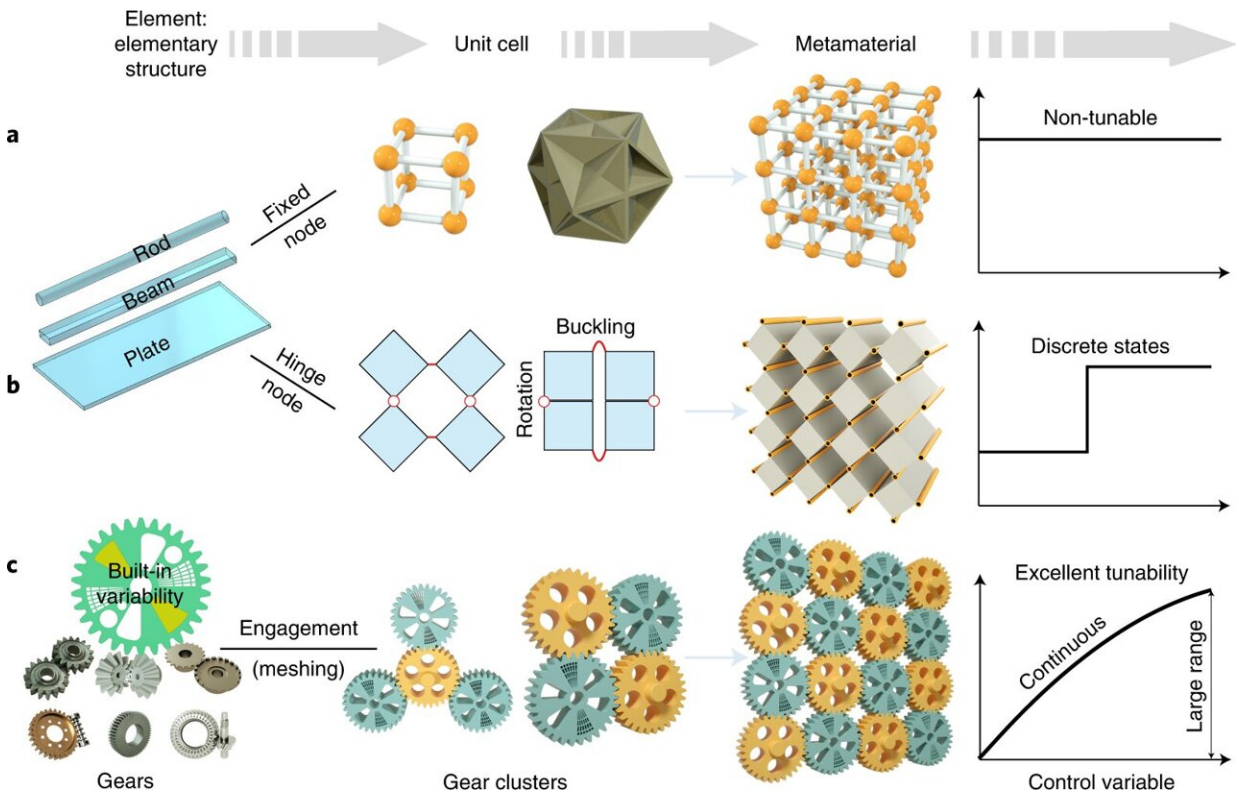


Design concepts of mechanical metamaterials. a,b, Classical paradigm: non-tunable metamaterial (a) and typical reconfigurable metamaterial (b). c, Gear-based metamaterials. Credit: Nature Materials (2022). DOI: 10.1038/s41563-022-01269-3

A team of researchers from the National University of Defense

Technology, Hong Kong Polytechnic University and Karlsruhe Institute of Technology has developed a host of gear-based mechanical metamaterials that allow for the creation of configurable sheets. In their paper published in the journal *Nature Materials*, the group describes how they developed their sheets and possible uses for them.

As the researchers note, sheets used for applications such as machine parts tend to be both inflexible and prone to breakage over time due to extended use and vibrations. They also are generally difficult to reconfigure if the need arises, especially on the fly. In this new effort, the researchers have developed a new kind of sheet that allows for on-the-fly configuration and that is also more elastic, which helps it to stand up to the stresses of commercial applications.

The new idea developed by the team involves the use of meshing gears affixed to a panel next to one another in the form of a matrix. In such a configuration, the gears move in unison. And as they do so, the researchers note, the flexibility of the sheet changes from either more bendable to less, or vice versa.

In their work, the researchers used both Taiji and planetary gears. The former are nearly two-dimensional and have a unique curvy center. They allowed for different orientations to be used when creating a sheet. Planetary gears are also nearly flat but have multi-holed centers. Their use allowed for compressive loading.

In their work, the researchers created a wide variety of sheets to test different configurations. In some, they used gears that were not all the same size; in others, they tried leaving out gears in patterns to see what sort of impact it might have on the flexibility of the sheet. They were able to create a host of sheets that had different degrees of elasticity, allowing for differing amounts of flexibility, stretching or bending. They also created sheets with gears that could be interlocked on demand,

allowing a sheet to become extremely stiff nearly instantly.

The researchers suggest that in addition to using their sheets as machine parts, they could also likely be used in robot appendages that constrict like muscle.

**More information:** Xin Fang et al, Programmable gear-based mechanical metamaterials, *Nature Materials* (2022). DOI: 10.1038/s41563-022-01269-3