Physicists learn how to make bearings more stable

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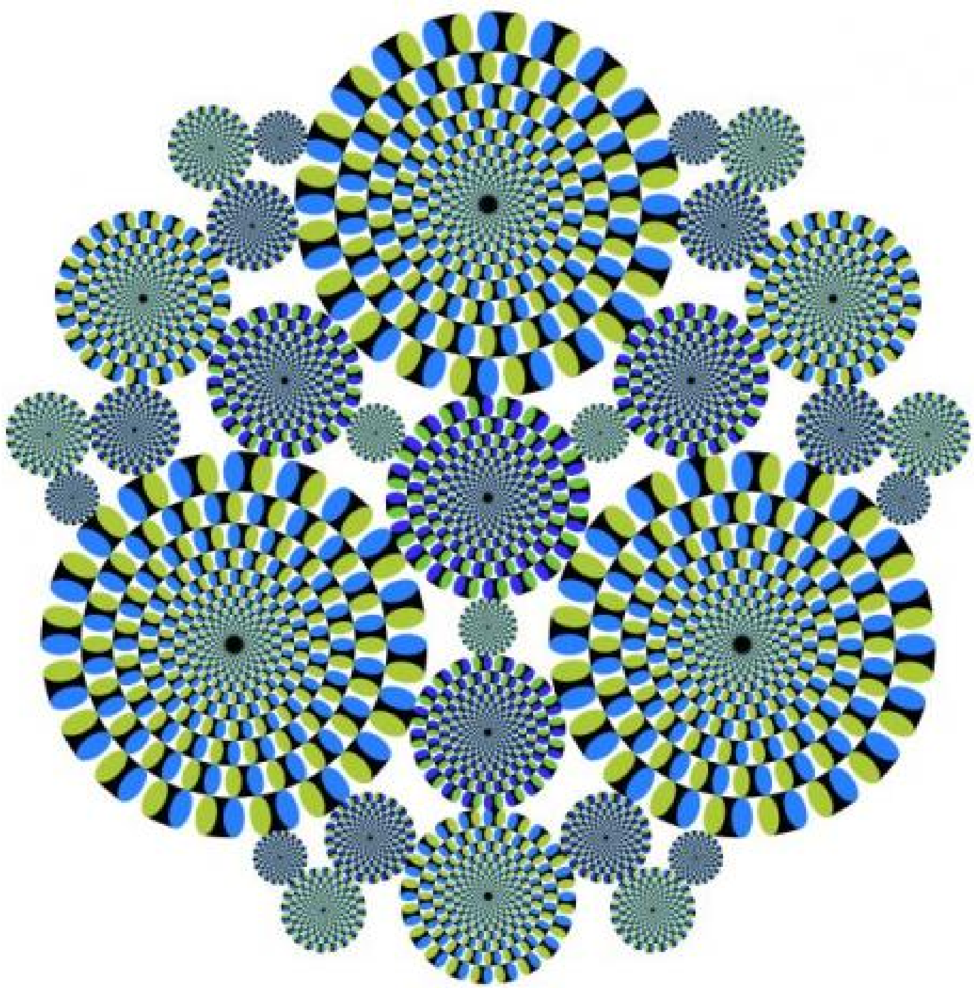

Two-dimensional space- lling bearing con guration with 31 rotor disks. In order to suppress gliding friction, disks rotate either clockwise or anticlockwise, all with the same tangential velocity, and loops of touching disks always have an even number of disks. This static illusory-motion image is an adaptation from the peripheral drift illusion "Rotating Snakes". Note that every two touching disks always have opposite senses of rotation. Credit: arxiv.org/abs/1301.4188

(Phys.org)—A team of physicists, led by Nuno Araujo of the Swiss Federal Institute of Technology (ETH) in Zurich, has found a way to optimize the stability of systems of rotating bearings. The team discovered that it is easiest for such systems to recover from disturbances when the masses of the bearings are proportional to their radii.

Araujo and his colleagues developed a mathematical model for a system of rotating two dimensional bearings in which successively smaller rotating disks fill spaces between larger ones. They prevented slippage by ensuring that each disc was in contact only with discs rotating in the opposite direction and that all of the disks had the same tangential velocity.

The researchers found that the system acted as a network of synchronized oscillators. They were able to make the system as stable as possible by ensuring that the mass of each disc was directly proportional to its radius.

Their study confirmed earlier predictions that a synchronized system will be most stable when its interaction strength is inversely proportional to the number of contacts of each oscillator. In the team's model, although the larger discs had more contacts, they had weaker interactions, because they had more inertia.

By counterbalancing the number of contacts and the inertia of the constituent discs, the physicists dissipated energy evenly between the discs and maximized the average participation of each disc.

Previous studies have already shown that scale-free topologies, such as the one used in this model, enhance synchronization. Scientists think topologies that allow small bearings to fill spaces between larger ones could explain the existence of seismic gaps, regions between tectonic plates that have not experienced earthquake activity for a long time. Small fragments within the gaps could act as bearings, which reduce friction.

In the future, engineers and physicists could use the findings from this study to increase the efficiency of any mechanical system that uses bearings to decrease friction. Another member of the team, Hans Herrmann, also of ETH, says that increasing stability by adjusting the relationship between the masses and the radii of bearings would decrease the likelihood that a synchronized system would fail because of perturbation or because of wear and tear on individual parts.

The team believes that their work could have implications for other, more complex synchronized systems, such as neural networks and technical infrastructures. Herrmann suggest that the model could be an analogy for the Internet.

More information: Optimal Synchronizability of Bearings, *Phys. Rev. Lett.* 110, 064106 (2013) link.aps.org/doi/10.1103/PhysRevLett.110.064106 . Available on Arxiv: arxiv.org/abs/1301.4188

Abstract
Bearings are mechanical dissipative systems that, when perturbed, relax toward a synchronized (bearing) state. Here we find that bearings can be perceived as physical realizations of complex networks of oscillators with asymmetrically weighted couplings. Accordingly, these networks can exhibit optimal synchronization properties through fine-tuning of the local interaction strength as a function of node degree [Motter, Zhou,

and Kurths, Phys. Rev. E 71 016116 (2005)]. We show that, in analogy, the synchronizability of bearings can be maximized by counterbalancing the number of contacts and the inertia of their constituting rotor disks through the mass-radius relation, m∼rα, with an optimal exponent α=α× which converges to unity for a large number of rotors. Under this condition, and regardless of the presence of a long-tailed distribution of disk radii composing the mechanical system, the average participation per disk is maximized and the energy dissipation rate is homogeneously distributed among elementary rotors.