Recycling permanent magnets in one go

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Electric motors or wind turbines are driven by powerful permanent magnets. The most powerful ones are based on the rare earth elements neodymium and dysprosium. In future, a new process route realized by Fraunhofer researchers will enable the fast and cost-effective recycling of these crucial materials.

The rotors whir in the wind and provide the networks with electricity. In order to ensure that the plants run as fault-free as possible and achieve a high energy yield, the latest generation is increasingly being equipped with strong, multi-ton permanent magnets instead of a gearbox. These magnets do a good job in cars, too: They enable the numerous electric actuators, which drive the windscreen wipers, for instance, to be of a smaller and lighter design. Electric actuators or servomotors are located in many positions inside a car, wherever things need to be specifically moved and positioned, whether for the side windows or for the seat adjustment. The most powerful magnets are based on neodymium, iron and boron. Dysprosium is also frequently contained. The problem: While iron and boron are readily available, the supply of neodymium and dysprosium is critical. Because these rare earth elements are only gained under difficult conditions and with a great deal of energy input. They are therefore quite expensive in comparison and their procurement leaves an ecological footprint behind. Furthermore, more than 90 percent of these elements come from China. Almost half of the worldwide reserves are situated there.

Turning old into new

Therefore, scientists are trying to recycle magnets. Up until now, this means: You extract the rare earth elements from the magnets again. This is, however, extremely laborious and expensive. The scientists of the Fraunhofer Project Group for Materials Recycling and Resource Strategies IWKS in Alzenau and Hanau of the Fraunhofer Institute for Silicate Research ISC are now pursuing a different approach. "Instead of trying to regain each individual type of rare earth, we focus on recycling the entire material, meaning the complete magnet – and this in only a few steps", Oliver Diehl, scientist in the Project Group IWKS explains. "This process is much easier and more efficient, because the composition of the material is already almost as it should be."

For recycling, the scientists rely on the melt spinning process – a method already tried and tested for other alloys, also known as "rapid solidification". The name reveals the method: The researchers liquefy the magnet in a melting pot. The liquefied material, heated to more than 1000 degrees Celsius, is directed via a nozzle onto a water-cooled copper wheel that rotates at a speed of 10 to 35 meters per second. As soon as the melted droplet comes into contact with the copper, it transfers its heat to the metal within fractions of a second and solidifies. The scientists call the emerging material formations "flakes". The special feature is the structure formed inside the flakes. If the melted material were allowed to solidify in the normal way, the atoms would "line up in rows" in a crystal lattice. In the melt spinning procedure however, crystallization is avoided: Either an amorphous structure is formed, in which the atoms are completely irregularly arranged, or a nanocrystalline structure, in which the atoms arrange themselves in nanometer-sized grains to form a crystalline structure. The advantage: The grain sizes – meaning the areas with the same crystalline structure – can be specifically varied. They can be used to change the properties of the permanent magnet. In a further step, the researchers mill the flakes into a powder, which can then be further processed. "We press it into its final shape", Diehl says.

First magnet successfully recycled

The scientists have already set up a demonstration plant and have managed to recycle magnets there. "The demo system can process up to half a kilogram of molten material and is somewhere between a lab and a large-scale plant", Diehl goes on to specify. The researchers are now optimizing the properties of the recycled magnets by varying the melt spinning process – such as the speed of the copper wheel, for example, or the temperature of the melted material during the rapid solidification process. Both influence the cooling rate and consequentially also the crystalline structure of the solidified material.

In many cases, the magnets are extremely difficult to remove from the engines. The scientists are therefore developing potential ways of creating a collection cycle for used engines, and also of a design more suitable for disassembly: How could the engines be alternatively designed to make it easier to remove the magnets at a later date? What costs will be incurred is a question that is currently difficult to answer: "The anticipated financial advantage in recycling the magnets depends not only on the recycling process, but also on the price development for rare earth elements", Diehl says. "The higher the raw material prices for rare earths, the more it will pay off to recycle already existing materials."

Provided by Fraunhofer-Gesellschaft

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