New nanomaterial introduced into electrical machines

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Lappeenranta University of Technology in Finland has constructed the world's first prototype electrical motor using carbon nanotube yarn in the motor windings. The new technology may significantly enhance the performance.

Engineers of LUT have constructed the world's first electrical motor applying a textile material; carbon nanotube yarn. The presently most electrically conductive carbon nanotube yarn replaces usual copper wires in the windings. The motor prototype is built by the LUT Electrical Engineering group as a start towards lightweight, efficient electric drives.

The test motor output power is 40 W, it rotates at 15000 rpm, and has almost a 70 % efficiency. In the near future, carbon nanotube fibers have potential to significantly enhance the performance and energy efficiency of electrical machines. The new technology may revolutionize the whole industry.

Researchers are constantly searching for opportunities to upgrade the performance of electrical machines; to this end, one of the objectives is to find higher-conductivity wires for the windings. The best carbon nanotubes (CNTs) have demonstrated conductivities far beyond those of the best metals. Thus, future windings made of CNTs may have a double conductivity compared with the present-day copper windings. In order to make CNTs easy to manipulate, they are spun to form multifiber yarn.

"If we keep the electrical machine design parameters unchanged and only replace copper with future carbon nanotube wires, it is possible to reduce the Joule losses in the windings to half of the present-day machine losses. Carbon nanotube wires are significantly lighter than copper and also environmentally friendlier. Therefore, replacing copper with nanotube wires should significantly reduce the CO2 emissions related to the manufacturing and operating of electrical machines. Furthermore, the machine dimensions and masses could be reduced. The motors could also be operated in significantly higher temperatures than the present ones," says Professor Juha Pyrhönen, who has led the design of the prototype at LUT.

No definite upper limit for the conductivity

Traditionally, the windings in electrical machines are made of copper, which has the second best conductivity of metals at room temperature. Despite the high conductivity of copper, a large proportion of the electrical machine losses occur in the copper windings. For this reason, the Joule losses are often referred to as copper losses. The carbon nanotube yarn does not have a definite upper limit for conductivity (e.g. values of 100 MS/m have already been measured).

According to Pyrhönen, the electrical machines are so ubiquitous in everyday life that we often forget about their presence. In a single-family house alone there can be tens of electrical machines in various household appliances such as refrigerators, washing machines, hair dryers, and ventilators.

"In the industry, the number of electrical motors is enormous: there can be up to tens of thousands of motors in a single process industry unit. All these use copper in the windings. Consequently, finding a more efficient material to replace the copper conductors would lead to major changes in the industry," tells Professor Pyrhönen.

Important innovation for the industry

The prototype motor uses carbon nanotube yarns spun and converted into an isolated tape by a Japanese-Dutch company Teijin Aramid, which has developed the spinning technology in collaboration with Rice University, the USA. The industrial applications of the new material are still in their infancy; scaling up the production capacity together with improving the yarn performance will facilitate major steps in the future, believes Business Development Manager Dr. Marcin Otto from Teijin Aramid, agreeing with Professor Pyrhönen.

"There is a significant improvement potential in the electrical machines, but we are now facing the limits of material physics set by traditional winding materials. Superconductivity appears not to develop to such a level that it could, in general, be applied to electrical machines. Carbonic materials, however, seem to have a pole position: We expect that in the future, the conductivity of carbon nanotube yarns could be even three times the practical conductivity of copper in electrical machines. In addition, carbon is abundant while copper needs to be mined or recycled by heavy industrial processes."

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