Additive Manufacturing of an Electric Machine Stator with reduced eddy current losses

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Design to enable 3D flux paths

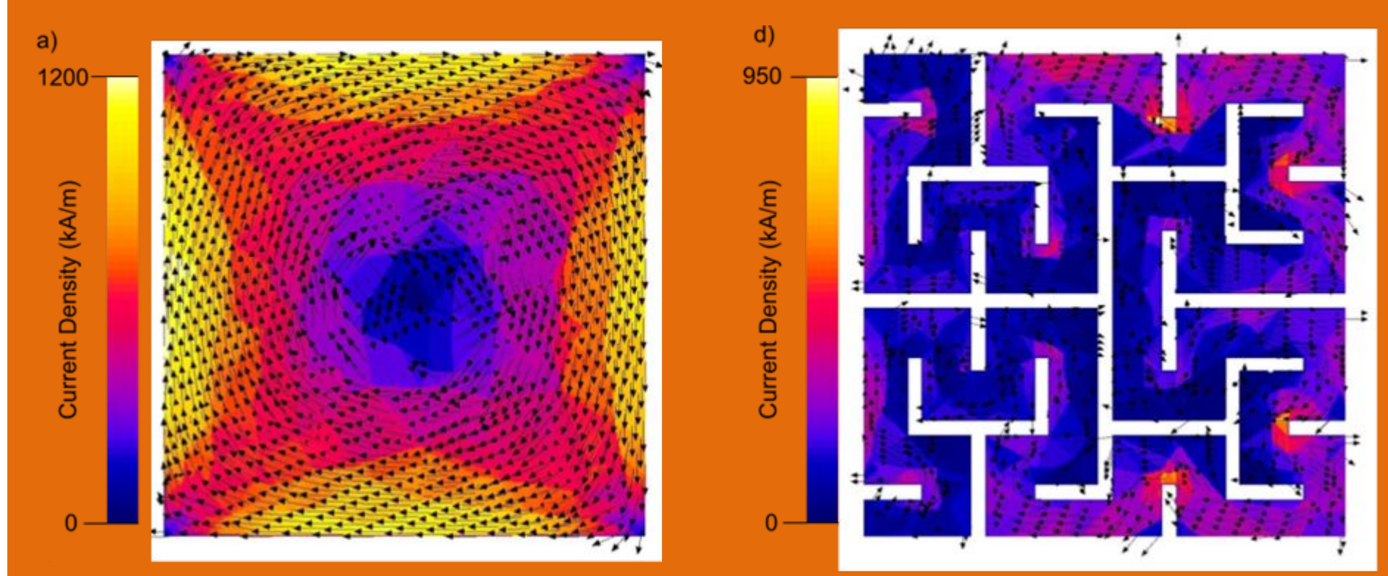

Figure 1 -Bulk section (left) results in large eddy currents and losses of 11.9W/kg, whereas the hilbert space filling curve decreases the thickness of the material, resulting in losses of only 2.26W/kg.

Traditional electric motor stators are built using electric steel laminations. These laminations are limited to 2D shapes and hence limit the design freedom of electrical engineers. Additive manufacturing can provide geometrical freedom, but for soft-magnetic materials it is necessary to manage the eddy currents and avoid large cross-sections. The hilbert space filling curve is used here to break the cross-section into smaller areas, reducing the simulated losses from 11.9W/kg (50Hz@1T) for a 5mm solid cross-section, to only 2.26W/kg, resulting over a 500% reduction in eddy current losses. These cross-sections can run in three dimensions, allowing for complex 3D magnetic flux paths in motor components.

Eddy Currents - What are they and why we don't want them

Whenever a magnetic flux (B) is carried in a soft-magnetic material, an electric current (I) called an eddy current forms in a plane perpendicular to the magnetic field. These currents cause the material to heat up and lose energy. To reduce these losses, we can either increase the resistivity of the material, or split the area into smaller sections to decrease the induced current. These eddy currents have no useful impact in electric motors, hence reducing them as much as possible is a large advantage.

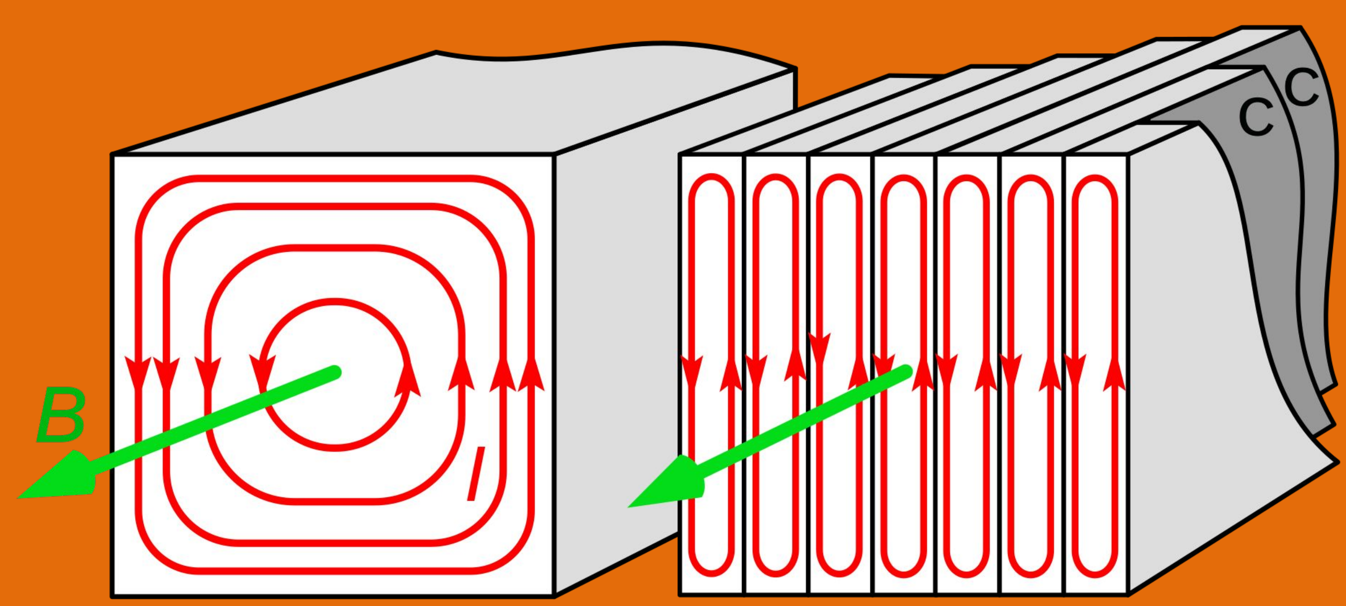

Figure 2 -Using Bulk sections (left) allows large eddy currents to circulate, whereas splitting the section into smaller areas (right) yields lower currents and hence losses.
Image Credit: https://en.wikipedia.org/wiki/Eddy_current

Motor Application

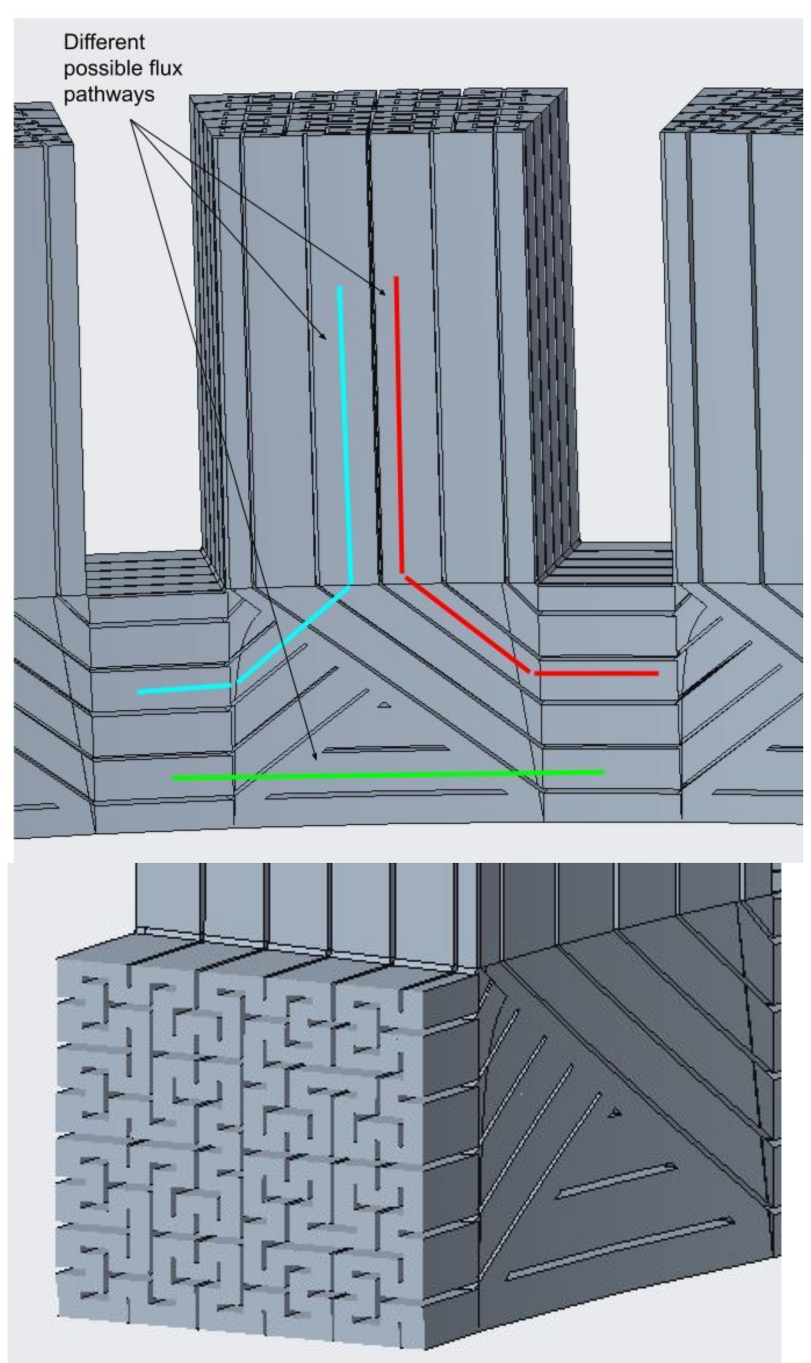

Figure 3 -Using the hilbert space filling curve, the cross-section is broken into smaller wall thicknesses, running in the three possible directions of magnetic flux for this motor

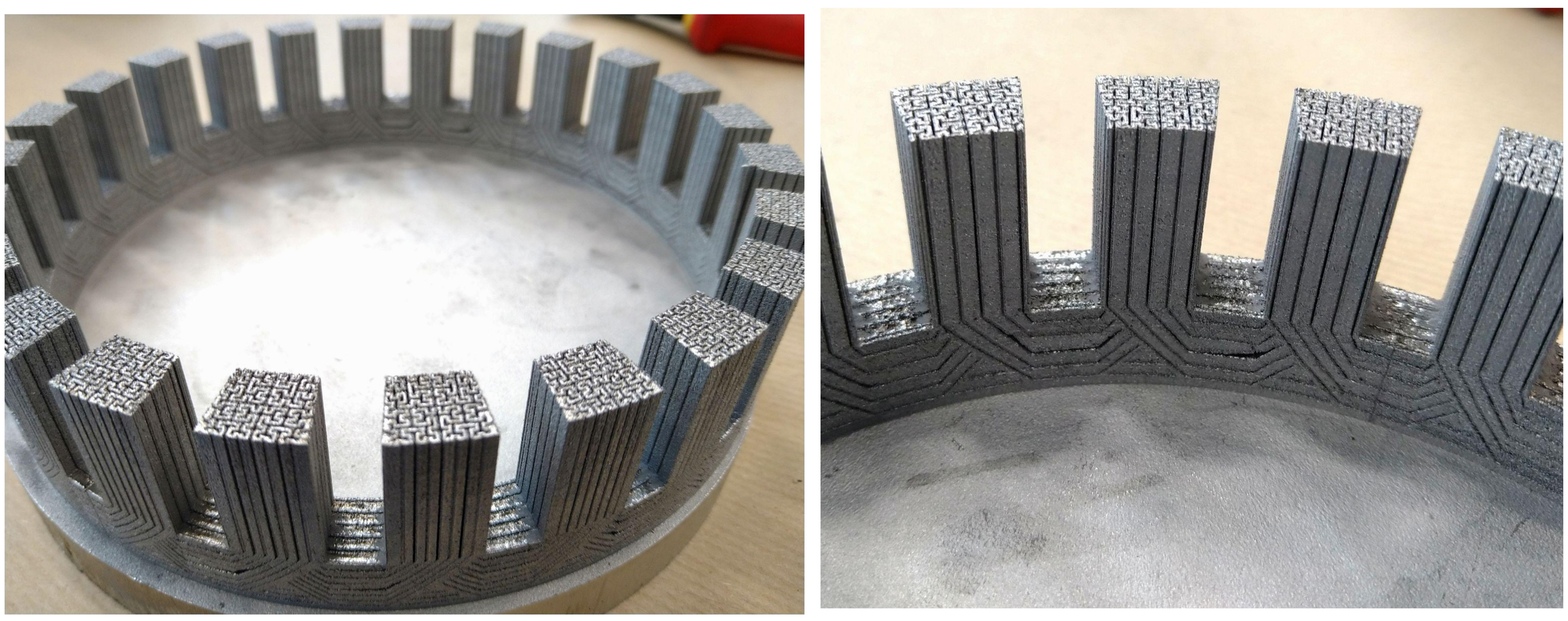

Figure 4 - This design was manufactured using laser powder bed fusion, ensuring that the eddy currents in this electric machine stator are managed, yielding a large reduction in losses over a solid cross-section whilst allowing the magnetic flux to run in three dimensions.

There are many challenges for additive manufacturing in this part, including unsupported horizontal surfaces, thin walls of less than 1mm thickness and being built using a traditionally brittle material, Fe-6.5%Si. However we were successfully able to manufacture this part, which is now being characterized at the University of Wisconsin by the WEMPEC research group. Full information on the behaviour of this part will be published in due course.