Increasing current capacity of machine windings using hollow conductors

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***Abstract*—The torque capabilities of electrical machines are today limited by magnetic saturation and the ability to transfer thermal loads away from the machine. Using hollow conductors the cooling capabilities are drastically increased allowing for a significant increase in current densities. Results show continuous current density capabilities well in excess of 30 A/mm^2.**

I. Introduction

THE torque capability of an electrical machine is highly dependent on the maximum allowed current through its windings. This maximum current is in turn limited by the heat generated as the current flows through the copper conductors inside the machine. As the copper is heated the insulation between the conductors deteriorates and eventually fails, short circuiting the windings. Modern electrical machines uses water-cooled jackets around the outside of the machine to allow higher currents and thus higher torque. A problem with this method is that the cooling takes place on the outside and not where the heat is generated thus relying heavily on good thermal connection to the inside the machine. A solution to this problem widely used in larger electrical machines is found in the use of a hollow conductors where a cooling fluid passes through interior channels. This cooling method allows for direct cooling of the heat source with a significant increase in current capabilities. The work done as part of this master thesis attempts therefore to predict the cooling performance of hollow conductors intended for use in a smaller electrical machine.

II. Components examined

Four different components have been examined using compressed air as cooling fluid. The two leftmost components shown in 1 represents the simplest possible case and was used to gain a good understanding of the general physics. Once this was achieved a progression towards a components similar to an actual electrical machine winding were used, shown in the middle column.

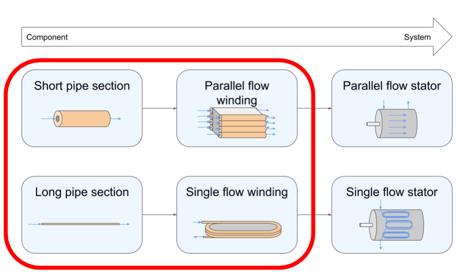

Fig. 1. The examined components and their intended implementation

By measuring the current flowing through the copper and the inlet pressure of the airflow a relationship between the power needed to cool the machine and the maximum possible current density is obtained. These results can then be used to assess which method is the best and what levels of current density can be achieved.

III. Results

The measured current capabilities from experiments made on the parallel flow winding, see figure 1, is shown below. As a general reference the uncooled hollow conductor will overheat at a current density of 12-15A/mm^2, with temperatures rising above 180°C.

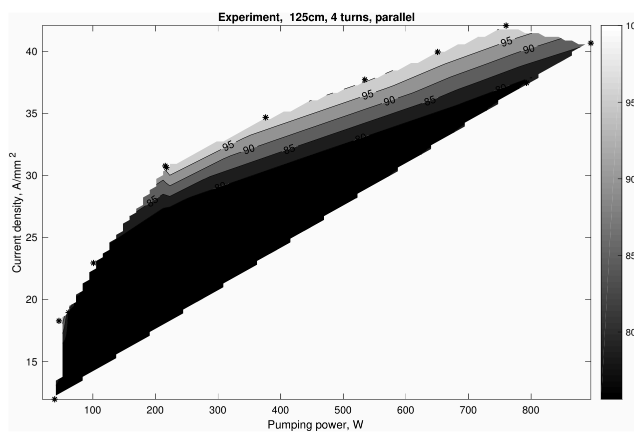

Fig. 2. Current capabilities of the air-cooled parallel flow winding, the top

By flowing compressed air through the parallel flow winding it is possible to more than triple the current flowing through it while still keeping a maximum temperature below 100°C. This is achieved using a theoretical pumping power of approximately 100W per cooling channel. The results also show that a significant increase in current capabilities can be achieved already at 10W per cooling channel if a higher maximum temperature is allowed.

IV. Conclusion

Experiments using compressed air show great potential for direct cooled windings: the use of hollow conductors allows for a significant increase in current capabilities, thereby opening up possibilities for a new generation of electrical machine cooling.