Facts

Challenge

Design and production of a function-integrated cooling water jacket, that dissipates heat directly at the electric motor creating it.

Solution

Additive Manufacturing of different test components from polyamide as well as of the final component with integrated cooling channels using the EOS M 290.

Results

- Functional: Integration of cooling and transmission/ wheel mounts in a single component
- Lightweight: 16% weight reduction improves performance
- Effective: Increase in cooling performance by 37% compared to the previous season's car

Victorious: The cooling jackets for the electric motors were produced with Additive Manufacturing and played a key role in ensuring that the race car performed well enough in the long-distance tests to secure the GreenTeam 2nd place in the overall ranking for the Formula Student Germany (courtesy of GreenTeam, Stuttgart University).

Leading the Pack – Race Car with Water-Cooled Electric Motors Brings Students a Place on the Podium

Improved Cooling Thanks to Aluminum Jacket with Internal Helix-Structure Produced with Additive Manufacturing

Short profile

The GreenTeam is a registered association and one of two Formula Student teams at the University of Stuttgart. It was formed in 2009 and is made up of students from the universities of Stuttgart and Hohenheim, Stuttgart Media University and the FOM Hochschule.

Further Information

www.greenteam-stuttgart.de

"Rallying has confirmed my presumption that a car with just two-wheel drive is nothing more than an emergency solution." These words of racing legend Walter Röhrl also reflect the belief of the GreenTeam, one of two Formula Student teams at the University of Stuttgart. For their racing car for the 2013/2014 season the young engineers chose a four-wheel drive design with electric motors positioned close to each of the wheels. There are 52 students that make up the team, which applies innovative technology not only to powering the vehicle, but also to its manufacture. Central components of the cooling system were produced using Additive Manufacturing, supported by EOS.

The Challenge

While the aims of the student racing series Formula Student Electric (FSE) are broadly educational, success is ultimately measured in lap times and victories. Electric engines provide extremely high torque and thereby offer a very interesting drive option. An additional advantage is that they are relatively small in size. Because of the high power density of electric motors, the selection and design of the cooling concept has a big influence on the performance and efficiency of the engine. Optimal cooling can lead to a significant improvement in the long-term performance of an electric motor. This allows motors to be smaller, leading to important weight savings.

Thanks to this complex aluminum component, cooling performance was increased by 37%. This achievement was the result of optimized coolant flow and improved heat dissipation (courtesy of EOS GmbH).

Alongside the benefits of transferable engine power, contemporary vehicle electronics allow each wheel to be configured individually, ensuring the best respective traction. Such a design, however, also has its disadvantages. One of these is the limited possibility of heat dissipation due to relatively little available space. In addition, the motors release heat in close proximity to the braking system. In short, the temperature build-up and the limited solutions to the problem represent a significant challenge wherein the basic choice is still between air and water cooling. During the 2012/2013 season the GreenTeam opted for water cooling and the concept proved to be highly promising.

Nonetheless, the previous year's car had to battle with heat build-up. "The water cooling didn't function perfectly," says Dominik Schäfer, a member of the team working on the power train. "It became clear that we had to take a closer look at the engine cooling concept." What they found was that the high temperatures were predominantly caused by heat transfer and convection. "The reason for this lay in the geometry of the water channels. Hotspots had formed in areas with low water flow velocity," continues Schäfer. The design options were nonetheless limited – on the one hand because of the lack of space, and on the other, as a result of the limitations of the manufacturing process itself.

Solution

Once again it was Additive Manufacturing that pointed the way toward a solution. One reason for this is the high degree of flexibility offered in the construction of any geometric form. Another is the ability to produce small series of components

both quickly and economically. The process made it possible for the GreenTeam to produce three different forms for the cooling unit and to not only test them in simulation, but actually manufacture them from the polyamide PA2200. The aim was to achieve sufficient cooling at a minimum water pump throughput rate. A larger pump could, of course, increase the pressure and flow velocity of the water, thereby improving cooling. However, this would in turn require more energy and a corresponding increase in the weight of the battery or of the pump itself. The best way to overcome this trade-off was through perfecting the geometry of the cooling channels.

Schäfer tested different variations in the form of the cooling jacket using software for what is known as Computational Fluid Dynamics (CFD). The final component looked like a cup. The integrated cooling coils are channels on the interior wall, comparable to a coarse thread. This becomes a watertight cooling pipe when the electrical motor is slid into the cup in the form of a cylinder. It is not a simple task to construct such a complex component with the necessary precision and such limited production quantities (only one is required for each wheel). Thankfully EOS were on hand to help.

"Production turned out to be both fast and simple," explains Schäfer. "The transfer of the design data also took place without any problems." The EOS M 290 was used to build the component, layer by layer, from a fine metal powder by means of a high precision laser. The metal used, the EOS Aluminum AlSi10Mg, is particularly well suited to the task at hand because it unites high mechanical and thermal durability with light weight, making it ideal for applications on the race track. In very little time the racing team was able to benefit from the advantages of the helix geometry, conceived by Schäfer, which had proved its worth over other honeycomb and meander structures.

Results

In addition to built-in cooling channels, the finished component had the further advantage that the cooling jacket was integrated with both the transmission flange and the wheel mounts. Besides the advantages of part consolidation, the total weight was reduced and the final assembly was less complicated due to fewer individual parts. Brackets for the intake and draining of water were also built in to the design. The result was that the young engineers were able to reduce the weight by 16% compared to the previous year – a decisive factor in achieving greater speed and in the endurance tests that are such a key part of the FSE. The final weight was just 370 g. Even more important was the improvement in the cooling: performance rose by 37% over the 2012/2013 season.

Nikolai Zaepernick is responsible for Strategy and Business Development at EOS. Alongside the direct advantages brought by the technology he also has an eye on its future potential. "Experts predict a big future for electromobility. Wheel-hub electric motors in road vehicles bring similar challenges to those faced in this racing series. It is good to know that intelligent minds have already been successfully working around the issues that arise in this area."

Back on the track, the advantages are there for all to see. The GreenTeam broke the world record in a drag racing competition for the Formula Student Germany (FSG)! The race car covered the 75 m distance in just 3.36 sec. Walter Röhrl once summed up the acceleration of his Audi Quattro S1 as follows: "It's like someone crashing into the back of you at thirty when you're at a red light." Perhaps the young engineers shared the racing legend's thoughts as they set a new world record on the track.

"In the 2013/2014 season our team achieved outstanding results, including 2nd place in the overall standings for the Formula Student Germany and 1st place at the Formula Student China. Our car simply performed extremely well. The four-wheel drive with wheel-hub motors proved the right choice in terms of performance, and the cooling water jacket produced through Additive Manufacturing was shown to be the ideal way of attaining the required heat dissipation. We were successful in reducing the build-up of heat compared to last year and EOS technology made a great contribution to this achievement."

Dominik Schäfer, Member of the power train working group with GreenTeam, Stuttgart University

EOS GmbH
Electro Optical Systems
Corporate Headquarters
Robert-Stirling-Ring 1
D-82152 Krailling/Munich
Germany
Phone +49 89 893 36-0
Fax +49 89 893 36-285

Further EOS Offices

EOS France
Phone +33 437 49 76 76

EOS Greater China
Phone + 86 21 602307 00

EOS India
Phone +91 44 39 64 80 00

EOS Italy
Phone +39 02 33 40 16 59

EOS Japan
Phone +81 4567 00250

EOS Korea
Phone +82 2 6330 5800

EOS Nordic & Baltic
Phone +46 31 760 46 40

EOS of North America
Phone +1 248 306 01 43

EOS Singapore
Phone +65 6430 0463

EOS UK
Phone +44 1926 67 51 10

www.eos.info • info@eos.info

Think the impossible. You can get it.