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DESIGNING A COOLING SYSTEM FOR AN ELECTRIC MOTOR THAT IS USED IN THE AUTOMOTIVE INDUSTRY

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Abstract: *The paper presents the design of a cooling system that is used for an induction electric motor used in the automotive industry in hybrid cars. The purpose of this project was to build a cheap and with a long-life span cooling system. The material chosen for this cooling system is aluminum because this material is widely used for cooling systems. Also, with the help of the 3D printer for the test part, a cooling system mock-up was built. The design of the cooling system was done using the Catia program and the Ansys program was used to analyze the flow regime.*

Key words: *cooling system, electric motor, hybrid vehicles, 3D printer, pump, sensor.*

1. INTRODUCTION

Because an electric motor is composed of some elements that can be affected by rising temperature due to electric currents which can generate significant heat loss in the windings there is a need to design a cooling system. In electric motors industry numerous cooling systems can be found, and for simplicity most systems use air, water or oil for as the thermal coolant. In automotive industry, the motors are very compact and usually here is used oil and water for coolant system [1]. For a few decades people have been made huge efforts on exploiting sustainable and clean energy to mitigate the global crisis of fossil energy and deterioration of environment. With high interests are investigated systems powered by new and clean energy. Electric and hybrid vehicles are the crucial solutions to the issue. These vehicles rely fully or partly on electricity, which can be transformed from clean energy such solar, wind and renewable. [2]. For these vehicles the motor requires efficient cooling, having different cooling modes depending on the operating fluid, such as: liquid-cooled, air-cooled and oil-cooled. To be able to choose between the different cooling systems we must look at capacity and mounting environment of the motor [3]. Inside an electric motor car, the noise is lower compared to the interior of an internal combustion engine car [4].

2. THE COOLING SYSTEM OF AN ELECTRIC MOTOR

The overall performance of an electric vehicle is directly affected by the performance of the electric motor. When operated under extreme load the electric motor windings heats up, reducing the efficiency of the vehicle. Because of this the electric vehicle propulsion system requires cooling systems in order to ensure efficient operation and maximizing the electric components and vehicle lifetime [5].

2.1 Electric motor cooling system concept

Hoping that an electric motor used in a hybrid vehicle will respect the lifespan the manufacturer has said it will achieve, it must be provided with normal operating parameters. Otherwise, the electric motor may overheat and burn. For an electric motor, it is not complicated to reach its maximum power and torque, but it is extremely complicated for it to provide that power and torque in a constant way. This constant delivery of power or torque makes an electric motor warm up extremely quickly. It heats up very quickly due to the very high revs that the engine rotor reach. The engines that are used in full electric cars can reach speeds up to 18,000 rpm, which greatly heats the rotor and makes it almost impossible to use the engine for long periods of time. Electric motors use energy that is sustainable and also environmentally friendly, that is why it is encourages the use of electric motors in cases like: transport of people, or anything that needs transport or transfer. In order for an electric motor to perform at its normal parameters, it needs a rotor and stator cooling system, as well as the inverter cooling solution. The inverter converts the direct current into alternating current. Since the batteries store direct current and the inductive electric motor works with AC, this current needs to be transformed. This is where this inverter comes into use without which the inductive electric motor would not work. This cooling system works with a pump that supplies a flow of 450 l / h, which is enough for the electric motor to operate in normal conditions[6]. We realize that 450 liters per hour is enough flow for the electric motor to be cooled from the heat transfer ratio.

2.2 Electrical actuated cooling system

In order for this cooling system to work in normal parameters, and for the heat transfer to occur, it is necessary for a pump to move the liquid. Also, in order to avoid increased flow and speed, noise in the system, possible cavitation conditions (premature wear of the pump), overload for the electric motor, it is necessary to dimension a pump. This pump dispenses 450 liters per hour. This means that it offers 7.5 liters of water per minute, just enough for the electric motor to remain cool in normal or intensive operating conditions. We realize this by calculating the heat transfer rate. For obvious reasons, the heat transfer rate changes from one season to the next. In the winter, this cooling system does not have to work as intensively as during the summer. Because of this, a temperature sensor will be the one that controls the flow of the pump. In winter, this cooling system stagnates in most of the time. There is a risk that the water in this system will freeze during the winter even if the system is isolated from the environment. But also, for obvious reasons in such cases the engine will not need cooling. If the engine still needs cooling, it will be the one that acts as a de-icing system for this system. He will be able to bring the liquid from the solid state to the liquid state and in that moment the pump starts off.

3. THE DESIGN PROCESS OF A COOLING SYSTEM FOR AN ELECTRIC MOTOR

The purpose of this project is to model, design and produce a cooling system that is suitable to ensure the operation of an induction motor, used in a hybrid car, in normal parameters.
In order to achieve the purpose of the project it is necessary to:

- obtaining a 3D model of the cooling system that respects the space it has at its disposal, and also it has to respect all dimensions so that the electric motor fits perfectly into the cooling system;
- in order for this system to be able to make the heat transfer at a higher rate, the materials from which it is produced must be chosen as such, we will have to look for a material that is easy to process, cheap enough for our product to be competitive in the market and also the material used to make the system has to have high strength;
- in order to realize the strength and durability of our final product, we will need to make a finite element analysis;
- also, that we can figure out the flow regime that will be inside the cooling system we will need to perform a very detailed analysis, which will include: the inlet and outlet temperature of the coolant, the determination of the speed of the cooling fluid displacement, as well as the density of the liquid inside the system, the inlet and outlet pressure of the coolant, and so on;
- in order for this cooling system to be meticulously designed it needs a

simulation demonstrating that the fluid inside the system has a laminar flow regime and also the material from which the cooling system is made is quite resistant;

- also, to watch real-time performance and behavior of the cooling system a prototype will be produced.

3D modeling has been designed using the Catia software (figure 1). This software meets all our needs regarding the modeling of this cooling system. Also, its interface is intuitive, but at the same time this software is extremely powerful. In it can be made extremely complex projects and works. The materials are very well chosen, they must be suitable for this cooling system. That's why we chose the aluminum, because it allows the heat transfer rate to be quite high. The analysis of the finite element is done with the help of the Catia software. This analysis will determine the strength of the final product. It must be durable in time. Because it is not a moving piece or a piece to be subjected to a high load, the final product should not be good only in terms of its corrosion resistance and it must support the weight of the electric motor, this cooling system is its support. The simulation we managed to complete in the Ansys program, is a crucial one in the good functioning of this project, because it shows us if the designed part of this work is right to be put into production.

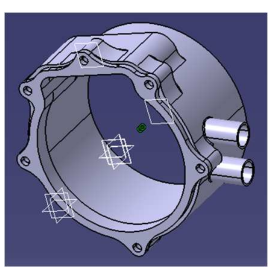

Fig. 1 Cooling system CAD model

As working plan this project can be divided into four major steps that we had to follow in order for this project to be done in an appropriate way, as follow:

- the first step was to analyze and propose solutions to solve the problem for this project;
- the next step is about 3D modeling where a proposal has been thought and generated so that it is as close as possible to solving the problem that has been raised;
- this step is very important because in this step we test and analyze whether the solution and system we think is reliable and sufficiently pragmatic for it to be put into production;
- in the last step we can see in the most clear way the final result.

For construction of the cooling system we chose the aluminum material. This material has one-third of the steel density of 2,700 kg / m3, which makes it very easy. This is just one of the reasons that makes aluminum replace materials in so many industries. Aluminum alloys have strengths between 70 and 700 MPa. It differs from many materials and its resistance increases at low temperatures. This material is also an excellent thermal conductor and is therefore very used in heating and cooling applications. Also, aluminum does not rust, making it the main favorite in producing this cooling system. It is quite important to have the basics of Material Science to make the right choice when certain features are required from a material. To begin designing the cooling system, we had to know the majority of the engine characteristics in order that the system will be suitable for it. The design of the cooling system has started from the diameter of the electric engine and from the thermal power that has to deal with. After these steps we used the Catia program to be able to model the cooling system. We started from the engine diameter, more precisely from the area where this system had to cool it. Also, Catia software has helped us determine the strength of this system in our given situation. With Ansys software (figure 2) we have tested the flow inside the cooling system. This software has been able to test the flow inside the cooling system, which has attested that this cooling system has managed to provide a lamellar flow regime for the system. We also realized, thanks to this analysis, that the design system manages to cool the electric motor used in a hybrid machine. We had also able to observe several aspects of this cooling system. About the calculations made for this cooling system, it was first necessary to calculate the heat transfer rate between the two environments so that we can realize if this system will be able to cool the engine, so it remains in the normal operating parameters. It was also necessary to calculate the flow rate that this cooling system can obtain. So, we figure out why we need the pump. It is important to know these things from the design stage due to financial factors.

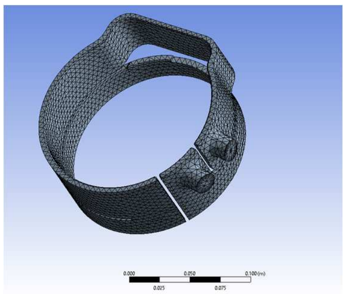

Fig. 2 Ansys mesh development

With the aid of the 3D printer, we also physically created this cooling system (figure 3). With the aid of the 3D printer, different products can be built at low prices like Head-Mounted Display (HMD), which represents an eye wear device that has been designed to be compatible with different types of mobiles phone [7]. With the 3D printer a cooling system for the plastic injection mold was also created [8].
Plastic parts resulted from 3D printing process can improve for obtaining a better roughness through combining the unconventional technology to achieve layer by layer of plastics parts with conventional milling technology [9].
The fact that we physically produced this cooling system we designed, helped us and confirmed that everything we tested in Ansys and we designed in Catia meets our expectations.

Fig. 3 Creating the cooling system

4. CHOOSING THE TYPE OF COOLANT AND TESTING THE COOLING SYSTEM

Everything we tested for this cooling system to function as desired was with the help of some accurate software. Catia is an excellent software that lets us design and model a lot of pieces, and not only that, it's a complicated software but once we learn it, can make projects or works that we could not do with other software's. We also used quite a lot of the section that Catia offers to be able to design this cooling system. This option offered by Catia was helpful when we design a route that does not change its section.
One of the most important decisions for the design of a cooling system is the choice of the cooling fluid. As coolants we can use air and water, which are both widely used as coolants and were considered possible choices. After we made a comparison between the two, water has been chosen as coolant because the heat transfer rate is superior to air heat transfer rate.
In figure 4 we can see the section where the water is guided to be 4.1 mm because this section is enough in order for the thermal transfer to occur and the engine can stand at a normal operating temperature.

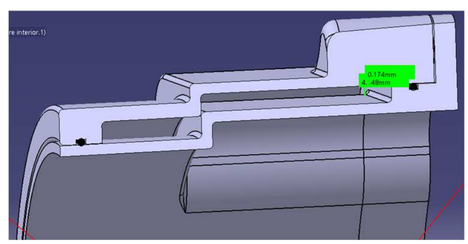

Fig. 4 Section cut through cooling system

The wall thickness between the engine and the water greatly influences the performance of the cooling system. The smaller or thinner the separator is, better the transfer rate will become, and we can say that the cooling system have increased performance. But this wall thickness is also very important because of its mechanical strength. This cooling system will support a part of the weight of the electric motor so it must be able to do so in more difficult contexts, but at the same time this cooling system have to be light weight in order to the performance of the car does not decrease because of it.

4.1 Choosing the water pump and the temperature sensor

In our case, the electrical assembly that drives the fluid inside the cooling system is an electric pump. Depending on the heat transfer rate, this pump will be sized. Depending on the heat transfer rate, we can figure out what flow rate we need. After choosing a nominal flow, a pump was selected. The pump should be chosen so that the performance required to cool the electric motor is exceeded by the pump performance by approximately 30%. The pump has a flow of 450 liters per hour.
The cooling system needs a temperature sensor (figure 5) for coolant control.

Fig. 5 Temperature sensor [10]

The sensor works after some preset parameters. If the engine is at its normal operating temperature, this sensor will command the pump to reduce the flow. Pump flow is variable and proportional to engine temperature. The temperature varies greatly depending on global positioning, but also because of the season. In this case of extreme temperatures where is no need for cooling, the pump will provide a smaller flow rate, but there are also cases where the pump will have to work continuously for example in summer, or in desert areas.

4.2 Testing the Cooling System

To design this cooling system, a series of tests were needed to pass both the mechanical part of the system and also the flow of the liquid. The liquid test portion was made in Ansys Fluid Flow (Fluent) (figure 6).

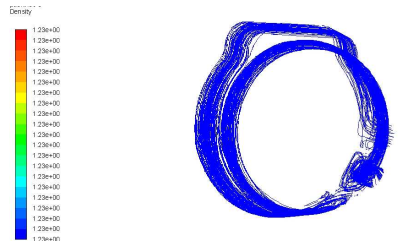

Fig. 6 Density shown by pathlines

In this program we did a CFD analysis that shows and demonstrates that the fluid flowing inside the cooling system has a lamellar flow rather than a turbulent flow, and it also manages to cool the engine. If this analysis did not succeed in removing the desired results, in this case it was necessary to modify the geometry of the cooling system, where the local resistances appeared or, worse, a cavitation phenomenon appeared. In figure 7 we can see the total fluid pressure inside the system.

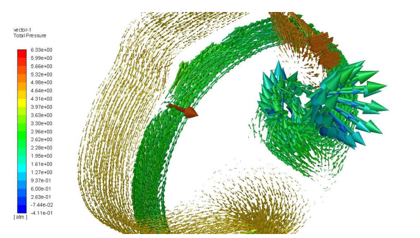

Fig. 7 Total Pressure shown by vectors

5. CONCLUSION

This paper has been presented how a cooling system for an induction motor for hybrid cars has been designed. After designing the 3D model, we chose the material from which the cooling system will be built, after which tests were carried out in the Ansi program for an analysis of the flow regime for the liquid used for cooling. For testing, a mock-up was built using the 3D printer. A pump was attached to this model through which coolant was pumped. Since the cooling system uses water as a cooling fluid this system will be cheaper to implement and automatically it will be more competitive on the market.

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PROIECTAREA UNUI SISTEM DE RĂCIRE PENTRU UN MOTOR ELECTRIC UTILIZAT ÎN INDUSTRIA AUTOMOTIVĂ

Rezumat: Lucrarea prezintă proiectarea unui sistem de răcire care este folosit pentru un motor electric cu inductie folosit în industria auto la masinile hibride. Scopul acestui proiect a fost de-a construi un sistem de răcire ieftin și cu o durata lungă de viată. Materialul ales pentru acest sistem de răcire este aluminiul deoarece acest material este folosit pe scară largă la sistemele de răcire. De asemenea cu ajutorul imprimantei 3D pentru partea de testare s-a construit o machetă pentru sistemului de răcire. Proiectarea sistemului de răcire s-a făcut cu ajutorul programului Catia iar pentru analiza regimului de curgere s-a folosit programul Ansys.

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