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i-HeCoBatt: Intelligent Heating and Cooling solution for enhanced range EV Battery packs

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Abstract

The envisaged European CO2 fleet emission limits for 2025-2030 require a massive market introduction of electric-vehicles (EVs), but their high cost, slow charging, limited range or perceived lack of added value hinder the user acceptance. In order to contribute to solve the technical issues, the H2020 project "i-HeCoBatt" aims at achieving a smart, cost bursting industrial battery heating and cooling system to minimize the impact on EVs range in extreme conditions. The project will develop an innovative heat exchanger to enhance the efficiency, as well as an advanced instrumentation system to feed the battery management system and a cloud-based monitoring system. Finally, the solution will be industrialised to enhance the cost reduction and to introduce the product in OEMs value chain in a maximum period of 2 years after the closure of the project. This paper presents i-HeCoBatt project and the main contributions expected from it.

Keywords: e-mobility, lithium batteries, heating and cooling system, product design, manufacturing, vehicle industry.

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1. Introduction

During the recent years, a major concern has raised to electrify the transportation sector. The envisaged European CO2 fleet emission limits for 2025-2030 already require a massive market introduction of EVs, so the European automotive sector is redefining its strategy to introduce new models in the market. However, there are still some obstacles for user acceptance of EVs. The major drawbacks are high cost, slow charging, limited range, perceived lack of added value and concerns of limited mobility.

In this context, a consortium of seven industrial & research organizations will jointly develop innovative solutions for the EV sector in the i-HeCoBatt project, funded by the Horizon 2020 programme of the European Commission. i-HeCoBatt stands for Intelligent Heating and Cooling solution for enhanced range EV Battery packs. Its aim is to achieve a smart, cost bursting industrial battery heat exchanger to minimize the impact on full electric vehicle range in extreme conditions.

The proposed solution will remove the currently used expensive and heavy gap filler between the heat exchanger and the battery pack (BP) and will replace the interface plate in contact with the BP with an advanced material product. This design enhances the efficiency of the heating and cooling system that will be supported by a heating actuator in direct contact to the BP. Customized printed sensors will be embedded to the heat exchanger to monitor relevant parameters and will feed the battery management control unit as well as an external early diagnostic and safety system connected to the cloud. Different interfaces will be created to access these data according to user profiles: designers, testers, maintenance teams or driver. Finally, the industrialization of the patented innovative heat exchanger concept will contribute to the cost reduction of the heating and cooling system and the EV.

The consortium gathers know-how from a multidisciplinary group of research centres, SME and industrial partners, including an automotive OEM, with expertise in BP and thermal systems design, testing and manufacturing for automotive applications. Partners behind the intelligent heat exchanger concept are European TIERs that intend to position with an unbeatable environmental compliant product that will be introduced in OEMs value chain in a maximum period of 2 years after the closure of the project.

1.1. Objectives of i-HeCoBatt

The aim of i-HeCoBatt is to achieve a smart, cost bursting industrial battery heat exchanger to minimize the impact on full electric vehicle range in extreme conditions. Smart, because new sensing functionalities will be embedded to the thermal system in order to monitor the behaviour of the whole BP thermal system. Cost bursting, because expensive components of current SoA products will be replaced by cost efficient components as well as the number of parts minimized. Industrial, because mass production means will be used to manufacture the heat exchanger. More specifically, the pursued objectives of i-HeCoBatt are:

- To increase the e-powertrain overall efficiency up to 5%, compared to a state of the art EV, through the implementation of a novel BP heating and cooling system.
- To prove a minimum of 20% cost reduction in mass production of the thermal system by the introduction of an innovative heat exchanger.
- To integrate new components and functionalities leading to higher user friendliness, reduction of range anxiety and temperature impact on degradation of the BP.
- To achieve automotive class quality.
- To demonstrate the developed solutions in several Audi BEV prototypes.

1.2. Concept to be developed in i-HeCoBatt

One of the main targets of iHeCoBatt is to increase the e-powertrain overall efficiency by introducing an innovative heat exchanger that will optimize the thermal conductivity of the thermal system and will reduce its weight. Linked to that, the heat exchanger design and manufacturing process will reduce the cost of the thermal system in mass production.

This heat exchanger will include new functionalities provided by advanced sensors, whose data will be shared with the thermal management system (TMS) and an external cloud and tablet. All the activity will be developed under automotive quality guidance and demonstrated in 3 Audi BEV prototypes.

As first step, the boundaries of the extreme condition scenarios are defined. Then the current BP, equipped with the standard thermal management system is tested in order to get the thermal map in standard thermal operation and extreme conditions. This will be the initial input for the design of the innovative heat exchanger and, later on in the project, these results will be used as reference for evaluating it. This experimental data will feed different ongoing models of the BP, the heat exchanger and the whole thermal system.

Hence, in parallel with the testing activity the heat exchanger and the sensors & heating actuator are designed. The heat exchanger surface is where the sensors will be placed, so this process will be guided by the design and manufacturing steps of the heat exchanger. The heat exchanger will be modelled using CFD tools taking as reference the tested thermal map of the BP.

The first step before addressing the design of the sensors is to precisely define the phenomena to be measured: temperature, pressure, humidity, cracks, etc. There are several physical principles (piezoresistivity, thermoresistivity, piezoelectricity, etc.) that could give answer to each request. Once the measuring parameter is defined, the next step will be to select and customize the technology which is manufacturable in an industrial process and provides the right technical features.

To conclude with the sensing set-up, it is necessary to implement the electronics that will share the data with the thermal management system and the external tablet computer, which will be linked to the cloud based data storage system. The purpose of this data is the early diagnostic and friendly access feasibility for the user. Suitable HW and SW will be implemented considering that the final device will be integrated in an EV and used by different profiles (tablet). The diagnostic system that will be developed will store all actions performed in the cloud, with the identification of the device from which the operations have been done, as well as the ID of the user. This information will be stored in the cloud in the form of traceability. This database will make debugging of the responsibilities easier in case any issue should arise.

Moreover, as a general rule during the decision making process of every activity, there is a criterion that will be always considered, regardless of the technical result, which is the environmental compatibility and cost of the selected option. This criterion will be based on the corresponding LCA and LCC analysis.

As a result of the development of the heat exchanger and the sensing devices, two generations will be created. After individual tests by the developers, an A-sample heat exchanger will be manufactured and tested together with the BP at lab level set-up. The results of this test will feed the redesign of the sensors and the heat exchanger. A full system model will be set up, developing an optimized TMS control loop according to expected temperature profiles and parts characteristics. This system behaviour will be fitted with the experimental data so that it could be then used to define the expected characteristics of the idustrialisation concept that will be designed, the B-sample of the heat exchanger. Hence the loop will be closed, A-sample redesigned and B-sample manufactured and tested. When this B-sample is ready, it will be integrated in another car, so that the comparison between the standard heat exchanger and the two generations of the innovative solution will be completed.

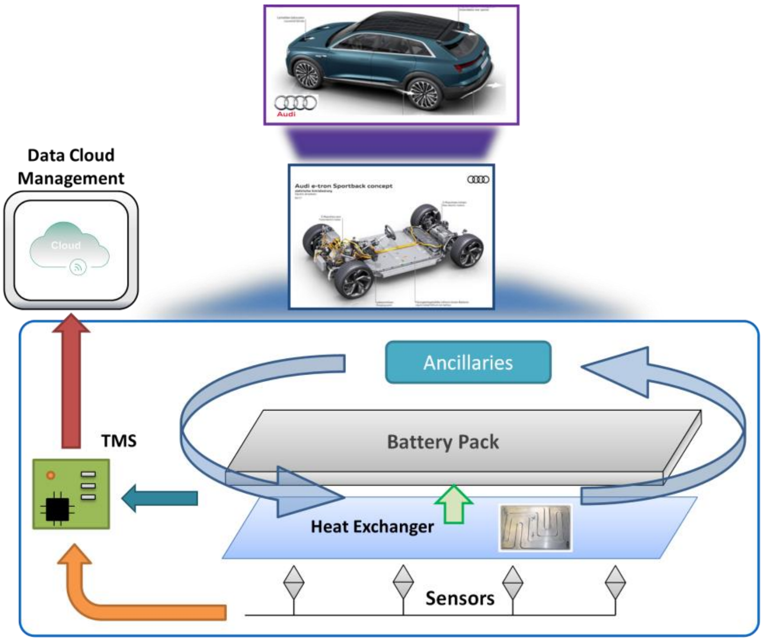

Fig. 1 Concept to be developed in the project.

1.3. Impact of i-HeCoBatt results

The i-HeCoBatt project will bring advancements on battery heating and cooling systems, improving the overall e-powertrain efficiency and reducing the need of raw materials. The BP will be benefitted from the novel heating and cooling system: the new implemented sensors and associated software together with the improved adaptive thermal management system performance, thanks to the novel heat exchanger will provide with a greater thermal control. It will allow operating in a more stable operational window and managing in a secure way extreme conditions due to, among others: overheating during fast-charging, extreme hot / cold weather, highly demanding driving cycles, etc.

As a consequence, BP operation and service life will be enhanced with increased reliability and safety. In addition, the reduction of weight of the heat exchanger has as a direct impact as less energy consumption due to the reduced overall EV weight.

2. Methodology of the project

In order to fulfil each of the objectives and to obtain the expected results, the project has been structured in nine work packages. Seven technical WPs have been created, apart from another WP comprising management and coordination tasks and another one for dissemination and communication activities. On the following, the methodology to carry out the technical work is explained:

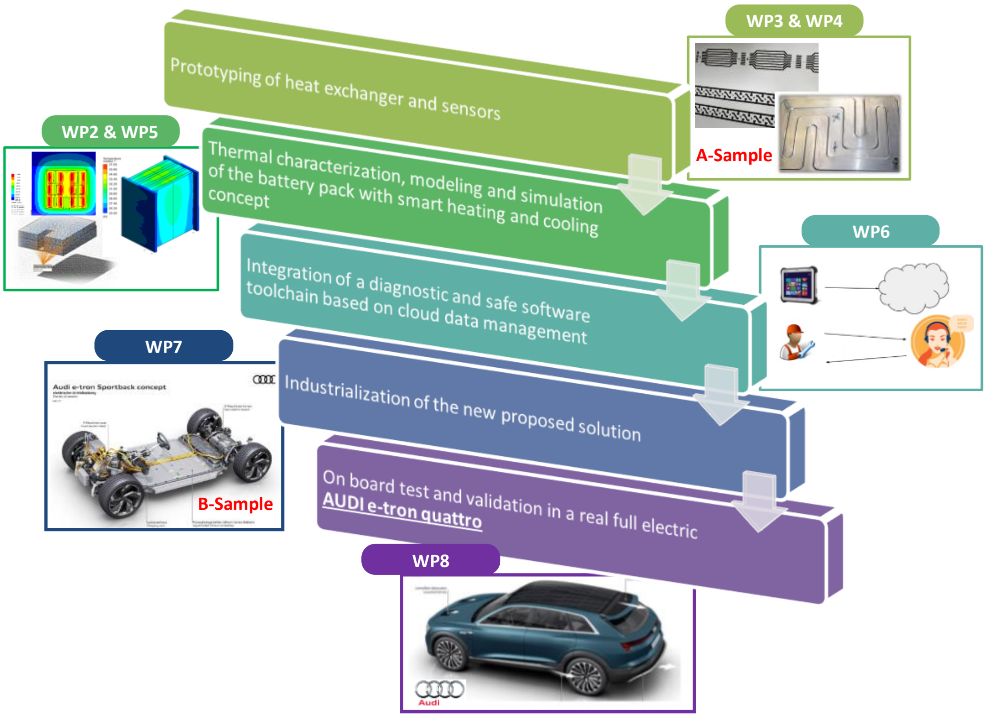

Fig. 2 Methodology of i-HeCoBatt, distributed in different technical work packages.

2.1. Thermal characterisation of battery pack in extreme conditions

The main objective of this WP is to define the thermal framework of the BP and check the behaviour and improvement achieved with the proposed heat exchanger. The activity is focused on different thermal testing scenarios set-up and execution: only BP, BP with a SoA cooling system and BP with the innovative heat exchanger. These tasks will be fundamental to check & adjust thermal simulations of other WPs as well as to experimentally demonstrate the overall system efficiency improvement.

2.2. Preliminary prototyping of heat exchanger

The heat exchanger will be developed and a preliminary prototype manufactured. Based on a new concept and the BP thermal needs resulting from the testing activity in 2.1, a customized design is launched and then simulated. Once the simulation-redesign loop is successfully closed, the focus will change towards the manufacturing of the prototype and the integration of sensing functionalities. This approach will be tested to match the launched simulations and to follow the optimization cycle towards a semi-industrial prototype.

2.3. Sensorization of the heat exchanger

The goal is to define the best technology for each sensing case, build prototypes and test them. Some physical phenomena as temperature and humidity are fundamental to cover the thermal system's early diagnostic and safety goals. Additional sensing capacity will be proposed and checked if they result in a competitive advantage for the product. The necessary HW for emitting and receiving the measured data will be developed too.

2.4. Thermal strategy to reduce impact on vehicle range

The entire thermal system is simulated and the thermal management strategy to optimize the overall thermal behavior is developed. In order to set up the system, different models are necessary. BP thermal model will be achieved, the system ancillary elements (pump, chiller, etc) will be modelled and the heat exchanger model developed in WP3 will be implemented. BP model will be matched with experimental data of 2.1 and it will feed the heat exchanger design modelling activity in 2.2.

2.5. SW tool for external diagnosis & safety and secure data-cloud management

The goal of this WP is to make accessible the data from sensors to different users: designer, manufacturer, tester, maintenance workstation or driver. The work is focused on the definition of the interface and the data shared between the sensorized heat exchanger and an external device by allocating the data in the cloud.

2.6. Industrialisation of the proposed heating and cooling solution

This phase will accomplish the industrialization of the products developed in previous stages. The innovative heat exchanger will jump to industrialisation, so that industrial tooling and means will be applied. Sensors will be integrated in that industrial manufacturing workflow in order to get as close as possible to a market product. Besides, the core of the eco-design, LCA and LCC approach will be applied to every solution. In this sense, all the procedures, parameters and roadmaps regarding a suitable approach will be defined.

2.7. In-car integration of the proposed heating and cooling solution

Once the intelligent heat exchanger has been manufactured, it will be integrated into the vehicle and connected to the ancillary devices and rest of the system on board. During the process the sensors and corresponding HW and SW will be implemented on board. Once all the system is ready it will be tested in a roller test bench and then on track. Data is acquired and analysed.

Results

The project has effectively started in February 2019 and it is in the first phase of the development. Therefore, by the time of this submission, no valuable results are available yet, so this paper only presents the general concepts to be developed in the project. However, given that the conference will be held in April 2020, the results of first testing, modelling and simulation activities obtained during the first year of activity will be available.

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