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ALBATROSS

Carbon neutrality and zero-emission vehicles with smart battery cells

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Abstract

ALBATROSS is a European Funded project by the European Commission that addresses the needs of European Electric and Hybrid-Electric passenger vehicle market by overcoming driver concerns relating to battery range and anxiety, cost, long-term reliability, and excessive charging times. ALBATROSS will develop an integrated approach based on smart batteries combined with lightweight designs. Using innovative cooling technologies, we will achieve pack temperature range 5-40°C, with <3°C variation between battery cells and optimal operating temperature 20-23°C. The light weighting solutions, based on modular multi-material systems for battery modules and trays, will be fabricated and joined using cutting edge, fast and cost-effective processes, with disassembly, recycling and reuse designed in as a part of an eco-design approach. The modular approach provides solutions for BEVs and PHEVs.

Keywords: Electric Propulsion; Electric Vehicle; Smart Batteries; Temperature Control; Battery Management Systems

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1. Introduction

ALBATROSS aims to develop a commercially and technically viable “Smart battery cell” approach using very rapid, accurate individual cell temperature measurements coupled with very high efficiency heating and cooling technologies. The system must be able to overcome the inherent physical conditions of time-lag for accurate temperature measurements as well as fast and reliable heating/cooling of cells. Therefore, these approaches are coupled with highly advanced and fast BMSs coupled with cloud-based AI capabilities for learning and optimisation.

Using a BMW i3 passenger vehicle to base the developments on, ALBATROSS will achieve a Peak Energy Density >200Wh/kg, increase driving range to 480km and reduce charging times by 25%. Advanced sensing and control, as a part of a flexible advanced Battery Management System, will be utilised on-vehicle and using the cloud to conduct remote maintenance and troubleshooting ensuring safety even at these high energy densities. Using advanced analytics will enable the State of Health and State of Safety to be continuously and accurately measured. The system will be validated on-vehicle under real world, extreme environmental conditions.

Table 1. Comparison between ALBATROSS solution and others available on market.

ODEM/Model	Storage (*kWh*)	Total Weight (*Kg*)	Battery Weight (*Kg*)	Peak Energy Density (*Wh/Kg*)	Range (EPA or WLTP) (*Km*)	Charging Time @ 150 kW (*min.*)
Tesla Model 3 Long Range	75	460	385	163	496	27
BMW i3	42	278	204	152	285	40
ALBATROSS	Up to 55	222	164	>200	480	30

2. Approach

The overall ALBATROSS concept is built a unique approach that will combine a “Smart battery cells” approach with a lightweight, crash resistant battery system (trays and modules) within a sustainable and reliable manufacturing eco-system based advanced joining technology know-how to design and manufacture. It will, then, be necessary to understand and achieve several targets to achieve this main goal, such as:

- High density module designs based on selection of high energy density cylindrical cells.
- High efficiency and rapid cooling and heating based on two-phase dielectric immersion thermal management zero-emission, bioethanol catalytic heating and direct differential heating of the cells using printed heaters.
- Improved thermal management for increased heat transfer of battery pack components through direct laser based micro texturing of metallic parts, whose microstructures act as large-scale surface heat exchangers.
- Temperature measurements of individual cells using ALGO’s Algoshield technology with a speed of 1kHz combined with direct (highly accurate) measurements using PST’s printed sensors with accuracy <±0,1°C).
- Thermal management and BMSs for accurate measurement and control of the electrical and thermal properties of individual cells (FEV, ALGO) combined with a cloud-based system for continuous measurement and optimization of the SOH/SOS, significantly reducing battery degradation and increasing battery lifetimes. Battery cell safety will be ensured using ALGO’s unique approach to predict thermal runaway in advance enabling trigger control of cooling or electronic parameters to prevent this.
- Lightweight, crash resistant battery system to achieve design flexibility, safety, and crashworthiness battery packs through using dissimilar materials, each of which has respective benefits. To combine composites with aluminium and join different aluminium alloys; advanced techniques such as laser welding, laser texturing, friction stir welding will be used. The aluminium-composite elements will reduce the weight of battery pack while smart use of heat treatable cast and extruded crash alloys will increase safety and thermal efficiency. The mechanical design of battery packaging will not only consider a design approach to use advanced joining, material technologies, but also lays out an architectural baseline for novel thermal management technologies, BMS and enhanced safety.

A detailed and organized workplan, divided into several work packages (WP) with different roles, activities, and responsibilities within the ALBATROSS project, has allowed for its continuous progress. The latest results portray month 16 (M16) of the project.

3. Results and Discussion

3.1. Battery Modules and packaging

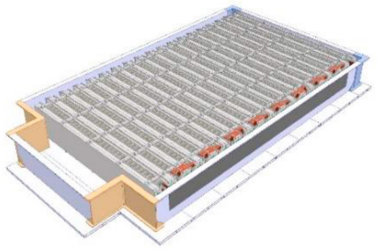

Figure 1. Battery Module Design

For the next generation of electric vehicles, it is crucial to reconsider the concept to which battery modules are designed, and how they are cooled. The main objectives for this are to achieve maximal energy density and allow for optimal thermal performance. To simultaneously achieve an increased energy density and improved thermal efficiency, WP2 of the ALBATROSS project has been cooperating extensively with other work packages to achieve a completely novel battery module, that integrates thermal management, structural support, and battery cell connections into one part. The reasoning behind this is that by combining the functions of multiple parts into one part, the number of needed parts and total weight can be reduced, helping to simplify production and increase the energy density of the complete battery pack.

3.2. Battery trays

Mechanical design of battery tray is under constant development with different versions that are shaped according to welding process requirements of WP3 partners. The geometries are being adapted for the best outcome of welding processes, and of course safety. In this direction, in order to possible distortions as a result of the welding process, the interlocking/clinching structure is applied to related geometries. In addition, geometry changes that can be resulted from integration studies are expected. The integration studies are conducted under WP1 activities and include WP2 – Battery Modules, and WP4 – Battery & Thermal Management Systems, as well.

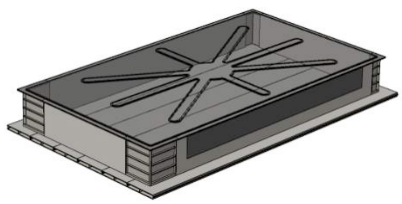

Figure 2. Battery Tray Design

3.3. Battery Management System, Thermal Management and Sensing

The Battery Management System will be responsible for safe and reliable operation of ALBATROSS battery pack. During the first year of project, architecture of both Hardware and Software were created, and requirements were defined by FEV. A System on Chip concept was selected as the Battery Master Unit processor. SOx algorithms are being developed using selected methodologies. The concept of Cloud operations and a control unit for CAN operations, cloud computing, data storage, etc. were designed.

Different film printed sensor/heater positions and wiring layouts of sensing/heating system for different cell configurations were examined by PST Sensors. Different approaches to find an optimum solution to produce working sensors are being investigated by Centre for Process Innovation Limited.

In the scope of thermal management system development, studies of benchmarking, investigation of cooling methods and concept generation have been conducted by University Of Nottingham. A partial immersion cooling concept was selected as part of a scalable cell-to-pack design that can be utilised with either single-phase fluid or partial two-phase boiling in future experimental development. Qualitative conjugate heat transfer analysis was undertaken. The results were utilised as part of a formal concept selection process with priority given to thermal power, pack energy density ratio and practicality.

IWS investigated the improvement potential of heat transfer between busbar and cooling fluid by increasing the surface area and roughness using laser texturing. IWS also uses laser structuring on busbars to improve weldability and to reduce thermal resistance between cell tab and busbar.

Thermal simulations of candidate cell types and cooling methods were conducted to support cell selection process by European Thermodynamics. A fluid-thermal analytical model has been developed to capture the various heat

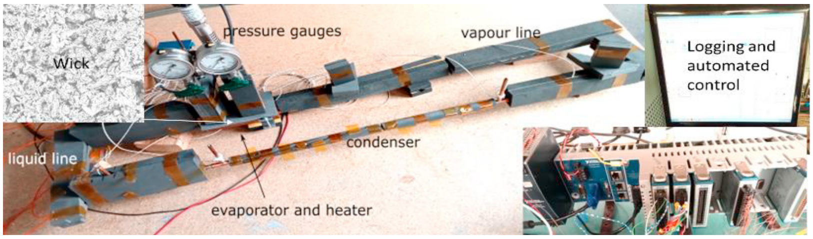

Figure 3. Test Rig.

transfer limitations and to better understand the key variables of heat pipes. A test rig (Figure 3) has been built and experimental testing is in progress to validate and refine the theoretical models.

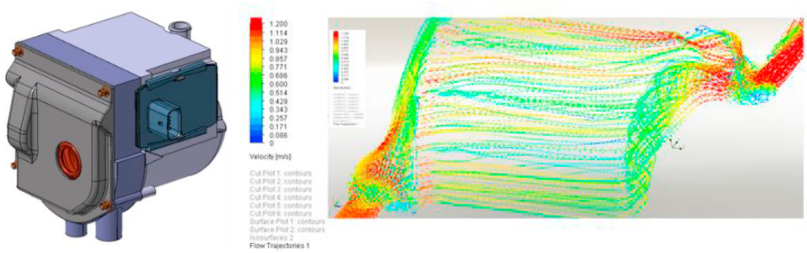

Figure 4. Heater device and simulation study.

Algolion prepared the concept of Early Warning Battery Failure Detection Software, and it is ready to be integrated. The software continually monitors the pack to detect precursors to faults while battery is still operating safely. It takes snapshots of data (few seconds, several times) and alerts up to a week prior to threshold to thermal runaway.

The heating part of the thermal management system consists of the Zemission heater, an intermediate heat exchanger and heating circuits. During the study, the design was optimized to take full advantage of radiative heat transfer, resulting in reduced heat exchanger size weight. Communication between the heater, BMS and vehicle systems was also defined.

Detailed procedures for cell characterization have been prepared and tests have been conducted in Spain and Turkey. Obtained data is being used for both SOx algorithms and electro-thermal cell modelling. A customized cell model of the selected cell has been generated on MATLAB/Simulink environment and detailed user guide has been prepared.

3.4. Dismantling, second life, re-use and recycle – Design and implementation

Battery lifecycle mapping has started. This process considers reuse in primary applications as well as 2nd life and eventually recycling.

Regarding the development of tools for data gathering, EV model on MATLAB was developed to translate speed profiles into BMS data and synthetic BMS data based on real data and Monte Carlo analysis.

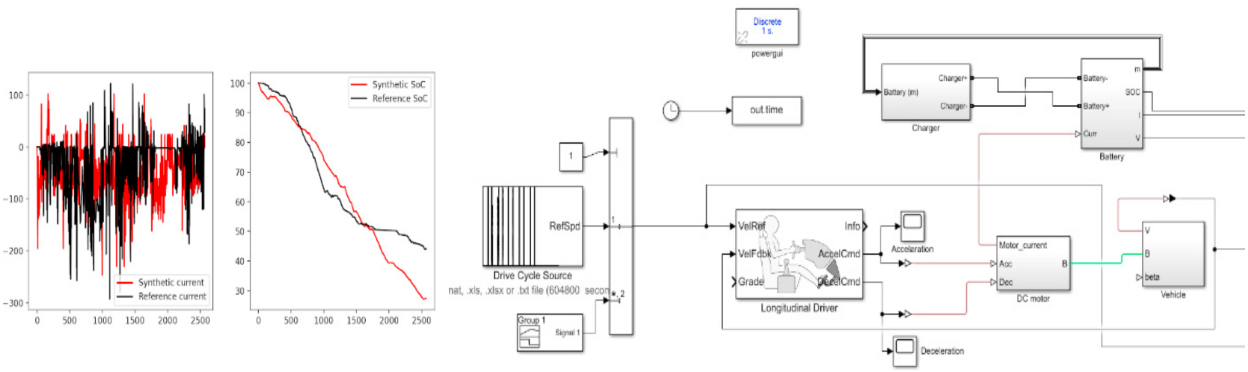

Figure 5. Model on MATLAB to translate speed profiles into BMS data and synthetic BMS data based on real data and Monte Carlo analysis.

Considering a variety of 2nd life applications and how the batteries would be used in those scenarios, this includes consideration for the impacts of degradation on the extent of usage.

In current technology, there are still challenges that need improvement, such as:

- Li lost (as slag) needs further processing: selective leaching of Li prior other metals extraction.
- Process effective only for certain battery composition: development of omnivore process.
- Many separation and purification steps to produce the precursor: direct synthesis of cathode from leachate.
- Impurities in Li salts: exploring other methods for Li separation-purification (SX) and crystallization.
- Graphite recyclability: flotation prior to leaching.
- Organic electrolyte and fluoride recovery/removal.

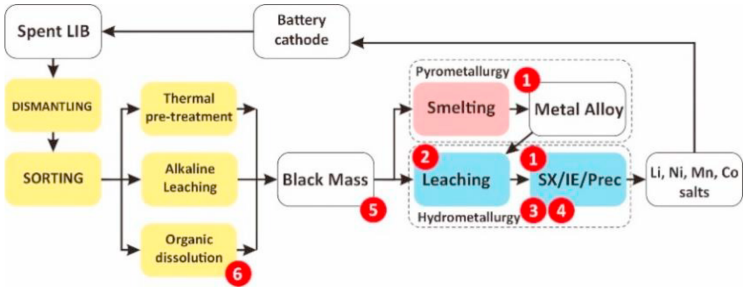

Figure 6. Outline of the challenges that need improvement.

3.5. Life Cycle Analysis and Sustainability

The first version of the ALBATROSS database to capture the information about battery design layout, simulation results, test configuration, results from the post-processing phases of cell electrical processing results of thermal analyses was defined. It has systematically reviewed scientific papers on electric vehicle battery and battery pack design and thermal analysis and started populating the database with data available in the literature. The work package has developed the Software Requirements Specification (SRS) and System Analysis and Design (SAD) documents of the KBE system that will automate the eco-design of battery cells, battery packs, etc., using the relevant knowledge-based engineering methodologies and technology stack.

As defined in the SRS document and further analysed in the SAD document, the KBE system will:

- Support the creation of battery pack specification.
- Support the definition of test configuration for the electrical test for different types of cells.
- Perform first analytical thermal analysis based on rules and data provided in the knowledge base.
- Create pack layout configuration.
- Maintain an optimal balance between thermal management of the battery pack and environmental impact.
- Support automatic battery design via the use of a knowledge base and rules.
- Develop mechanical eco-design of the battery carrier system.
- Develop the following two data integration schemes: Import data from the database to integrate into the knowledge base and export data from the knowledge base to integrate into the database.
- Support interfacing with CAx software systems to run simulations such as FEA to simulate the physical phenomenon of designed components and CFD simulations for thermal analysis of battery cell and battery pack with required inputs and import simulation results to the knowledge base.
- Provide data exchange of XML and JSON formatted data.

- Make APIs available for authorized CRUD operations.

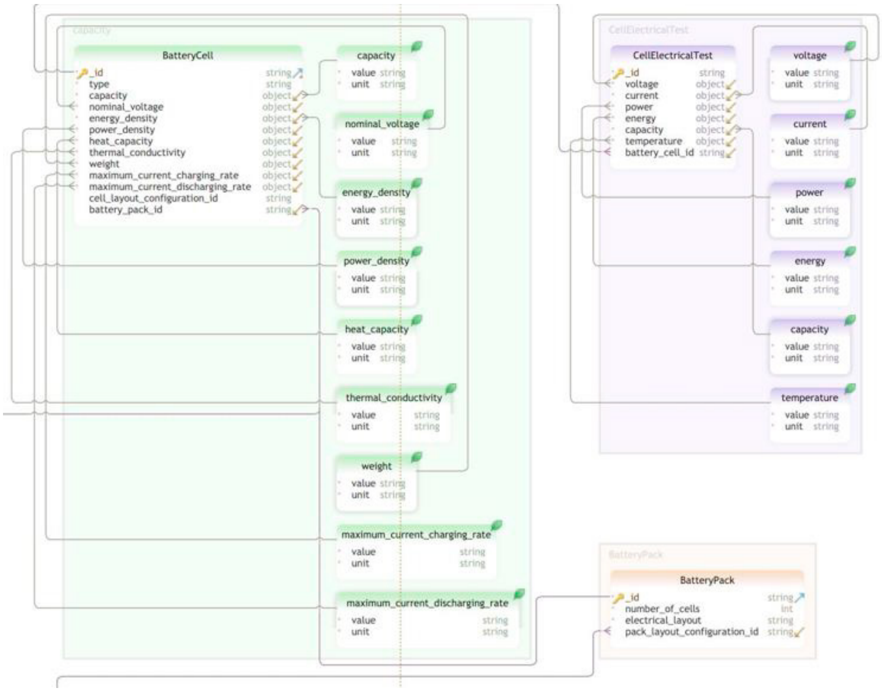

Figure 7. Partial view of the first version of the ALBATROSS database schema showing the battery cell, battery pack and cell electrical test tables and relationships between them.

The KBE system is not self-contained and does not belong to any larger system as a component. It depends on the ALBATROSS database for test models of battery cells and geometrical layout models of battery packs, a CAD tool, and test and analysis tools. The system will analyse and optimize thermal management of battery cells and battery packs to reduce environmental impact and enable battery eco-design.

The KBE system includes the support for creating battery pack specifications with user-provided inputs such as the height and diameter of battery cells, height and radius of cell terminals, depth and height of serial connecters, and height and width of parallel connectors. For thermal analysis of battery pack, the KBE system allows the creation of a mesh of the battery pack, provides different inputs, including initial temperate, capacity and rate of charge, and runs a solver. An API is developed using the Comsol Java library to run the meshing process, set input parameters and start the process of thermal analysis. This is an important step towards achieving advanced automation in battery design. An example battery pack is designed with twelve cylindrical battery cells and analysed to assess thermal properties during a charging and discharging phase. The solver was executed multiple times with some variations in the input parameters. In each run, the result was in agreement with calculated values. The number of cells in the pack and the materials used in cells and connectors are predefined in the current version. These parameters will be made configurable in future work.

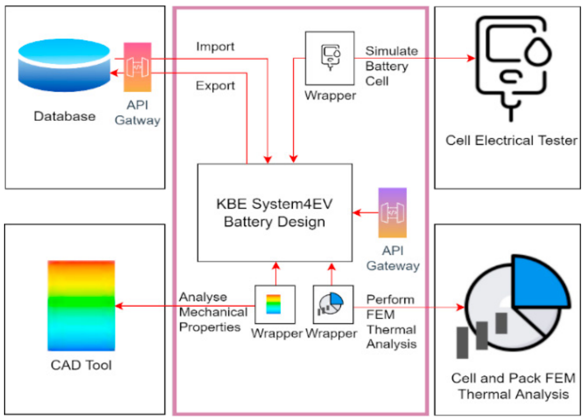

Figure 8. Top level architecture of the KBE system depicting internal components and relationships with the database, CAD tool, cell electrical tester and thermal analysis components.

3.6. Exploitation and Dissemination

3.6.1. Initial Data Management Plan, including stakeholder database

The Data Management Plan (DMP) must cover several topics established by the European Commission and it describes the Data Management life cycle for all data sets that will be collected, processed, or generated by the research project. The DMP will identify the different items that are relevant to the correct identification and management of the data produced during the project. This means that all the data produced in the ALBATROSS project will have to be identified according to the following items: Data identification, Data Set Description, Data standards and metadata, Data sharing and archiving and preservation (including storage and backup).

The results and outcomes of the project cannot be kept solely for the consortium or partners. The real impact of ALBATROSS' innovations on the European industry will need to be ascertained. To manage the organizations' interest in the project goals the contact details must be maintained accurate and reliable; A stakeholder database is a tool to reach relevant parties for ALBATROSS and is currently being developed to register the technical and commercial interests of these companies.

3.6.2. Communication materials pack including multimedia content

The ALBATROSS logo will be used in all dissemination material for project events and dissemination activities (e.g., presentations, publications, leaflets, brochures) and in the project website. An initial PowerPoint presentation has been produced at the beginning of the project, to be used by the ALBATROSS partners and the European Commission.

There is a project website and various social media (SM) platforms for dissemination of results and project related success stories. These platforms are a tool to disseminate the project results and news. This guarantees the success and survival of social platforms linked to the ALBATROSS project and will attract the interest of the industry and allow the connection with stakeholders' pages and accounts in SM: The LinkedIn profile enables a more professional/scientific engagement with relevant users to disseminate the project results; The Facebook page addresses an engagement with the general public; The Instagram is a dissemination more based in pictures and videos; The YouTube is a dissemination more based in pictures and videos.

Now a digital flyer and 2 videos were developed as dissemination materials. In the ALBATROSS YouTube page are available both teasers. The first one presents the project to the general public with the main goals and objectives of the project. The second teaser focus on the challenges and solutions that the project entails. A third video is being developed to present the ALBATROSS consortium.

Communication and Dissemination activities represent a very important part of the ALBATROSS project. The communication strategy has been designed to ensure that the commercial impact of the project is not endangered.

Table 2. ALBATROSS Social Media Links.

ALBATROSS SM	Link
Website	www.albatross-h2020.eu.
LinkedIn	https://www.linkedin.com/showcase/h2020-albatross-project/?trk=affiliated-pages_result-card_full-click
Facebook	https://www.facebook.com/Albatross-Project-H2020-100745362097521
Instagram	https://www.instagram.com/albatrossproject_h2020/
YouTube	https://www.youtube.com/channel/UCbjk3OirCf0mNaPmxiCXChg

3.6.3. Clustering and liaising with other relevant initiatives – COLLABAT

COLLABAT is a cluster liaising between LC-BAT-10 projects under H2020 call. This establishes the links on collaboration and the conduction of joint dissemination activities which are of interest to all stakeholders of the project's activities. The projects involved in COLLABAT are ALBATROSS, LIBERTY, MARBEL and HELIOS.

During the cluster meetings, were identified topics that could bring benefits to the development of the projects involved if discussed in a more centralized way. With this in mind, three subclusters were created: Subcluster A for Sustainability; Subcluster B for Testing and Validation; Subcluster C for Battery Management System (BMS).

4. Conclusions and Future Work

ALBATROSS represents a pan-European EU consortium of world leading organizations that are looking to commercialize these technologies of European origin.

There is still a long way to go in terms of the expected results of this project, mainly because the project is still on M16, but very valuable and viable impacts are expected. These being:

- Considerably improved performance of the EV through reduced battery system weight by 20% at constant electric vehicle range for mid-size battery electric car. Through ALBATROSS, the battery system weight for a BMW i3 will be reduced by 20% to 222 kg.
- Overcome the uncertainty of range by achieving 25% shorter recharging time with a 150kW charger compared to the best-in-class electric car available on the market in 2018. The demonstrator must have the same battery capacity as the reference car and meet the useful battery life mentioned below. ALBATROSS will develop innovative thermal management designs and a BMS that achieves a battery recharging time 25% shorter (from 40 minutes to 30 minutes) with a 150kW charger for the BMW i3.
- Improved attractiveness of the EV through achieving extended useful battery life to 300 000 km in real driving referring to a mid-size passenger car using improved battery management, balancing and thermal management during high-power charging/discharging.
- ALBATROSS will demonstrate an approach to improved battery management, balancing and thermal management during high power charging/discharging, thereby extending the useful life of a battery in a mid-sized passenger car to at least 300 000 km.
- Contribution to Circular Economy goals through a minimum 20% Life Cycle Analysis improvement compared to existing products. The ALBATROSS pack will contribute to the EU Circular Economy goal through an improvement to Life Cycle Analysis (LCA) of 20% compared to current EV products.
- Considerably improved knowledge on module and pack sensitization and thermal management. Innovative sensors and an advanced BMS will be combined with cloud-based AI techniques to come to a much greater understanding of pack sensitization and thermal management.

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References

ALBATROSS Grant Agreement; ALBATROSS Website; Deliverable 9.3 – "Communication materials pack including multimedia content"