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CarE-Service

Circular Economy Business Models for innovative hybrid and electric mobility through advanced reuse and remanufacturing technologies and services

Editorial

2021 means we have entered the last year of our project and we are looking forward to presenting you with the promising results we're obtaining up to this point. In this edition you'll find our proposal for *batteries re-design* in order to overcome the present criticalities that prevent the re-using and recycling of batteries. We also share the recycling processes developed for techno-polymers, and the novelties on mobility services. An overview of the operation of disassembly Smart Mobile Module (SMM), and their connection to the ICT Platform will give you an idea of the possibilities of this solution. Finally, you can read the outcomes of our successful 1st Exploitation Webinar, held last December.

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Re-design of Li-ion Batteries for H&HEV in a circular economy perspective

The design of an automotive Lithium-ion Battery (LIB) pack is a complex and highly specific task due to the different OEMs requirements, since it depends on the power requirements and therefore, to a great extent, on the components it has to accommodate. The proposal of a new battery design concept facilitating the disassembly, testing and reuse cannot be mandatory for each LIB pack producer, but should highlight some suggestions to be integrated in the existing battery packs design.

The objective of the re-design is to facilitate: i) the testing of modules in order to understand if it's worth disassemble them, ii) the removal of the external module framework to liberate the cells to further reuse them for secondary applications, and iii) the setting of cells electrical connection to avoid destructive techniques during their removal and to encourage their reusability during the re-manufacturing stage. To this purpose, within the CarE-Service Project, we focused on a preliminary re-design concept of a Li-ion battery module finalized to an easy disassembly and reuse.

The innovation of the re-designed LIB module starts from an in-depth analysis of current automotive E&HEVs components in order to identify the major criticalities during the disassembly procedure and the worst practices in terms of cell/modules connections, geometrical features and components' assembly. LIB modules coming from different E&HEVs have been manually disassembled to have a full comprehension of their structures, with the aim to collect several criticalities and to define a more generalized re-design concept.

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The major criticalities are represented by i) the module assembly, since in many cases the poles are placed in positions not guaranteeing the accessibility of equipment for a preliminary test on module State of the Health (SoH) and significantly increasing the safety risks for the operator related to the presence of residual voltage; ii) the electrical and mechanical connections existing between two modules and/or cells, determining the operating disassembly time, the proper procedure according to precedence constraints and the reusability of each component; iii) the presence of mechanical joints, such as rivets, snap-fits, adhesive and glue, soldering and welding, affecting dramatically the disassembly time also compromising the reuse of the disassembled parts, since they require a destructive approach.

In order to overcome the described criticalities, reduce the disassembly time and the risk associated with this operation, and allow the reusability of disassembled components, a preliminary re-design concept of a LIB module structure has been proposed, integrating specific features on the cells' frame and connection, external housing joints, bus-bar element connection, and labeling.

LIB Module prototype rendering (left) and 3-D printed module prototype (right).

In order to contribute to the generation of practical industrial knowledge on the disassembly battery process and on the suitability of battery re-design for circular economy, the JRC organized a workshop at the premises of EcarACCU company. The objective of the workshop was to disassemble selected battery pack models to increase the learning opportunities and identify the most relevant messages and recommendations in view of reusing and repurposing EV battery packs. The Battery packs were selected based on the experience of the company in such a way, that the "difficult cases" were taken. The dismantling was performed manually, with the support of tools that are potentially applicable in automated or semi-automated systems.

The key messages resulting from the visit in view of identifying suitable parameters for assessing easiness of dismantling and for easy-to-dismantle design were:

- Scrap rate of the dismantling operation.
- Dismantled components should be reusable and the scrap rate should be minimum.
- Easy and ubiquitous access to all the modules and electric/electronic components.
- Easy access to the cells inside the modules.
- Improved information and marking (e.g. type of screws, HV components, sequence and steps to follow).
- Time duration of dismantling operations might not be a suitable parameter, as it may depend on the operator's skills and level of automation.
- The battery auxiliary systems (e.g. cooling system, low voltage hardware, cabling, feedthroughs) should not hinder the dismantling operations.
- Ease of dismantling should not compromise the safety, e.g.:
    - gas tightness,
    - location of the pressure release valve,
    - location and easy access to the main HV disconnection plug,
    - structural strength and integrity of the battery pack.

Disassembling of the battery pack at the EcarACCU company

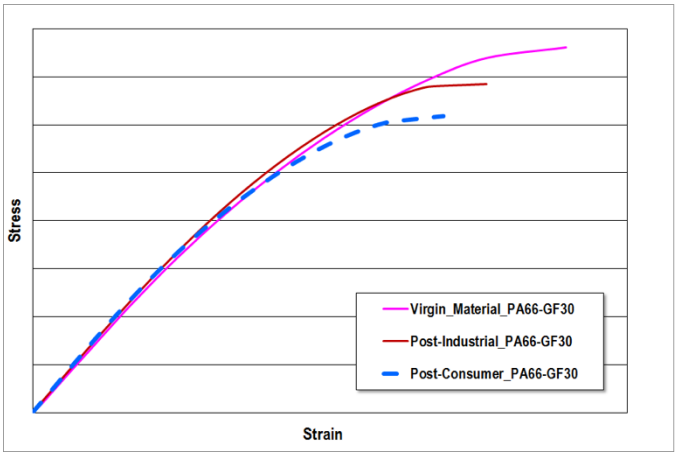
Post-consumer recycled materials

In CarE-Service, the mechanical recycling process of techno-polymers is perfomed in the "High-performance Polymer plant" of RadiciGroup. Thermal and mechanical energies are used to melt and mix the perfectly required raw materials to produce the final granulated products with calibrated performances.

The production of recycled materials aims at preserving the material's performance and limiting their variability. Thus, in order to meet target requirements, new formulations of materials were carefully tuned before industrial production, as in the case of the post-consumer polyamide 6.6 (PA6.6) compounds. Automotive airbags, wheel covers and rear wipers were chosen as selected poct-consumer parts to be recycled. In the case of airbags, due to the excessive accumulation of silicon in the ground airbags, a right mix of additives to reduce the impurities during the recycling process was assumed. However, this recycling activity did not involve any chemical processes of solvent usage.

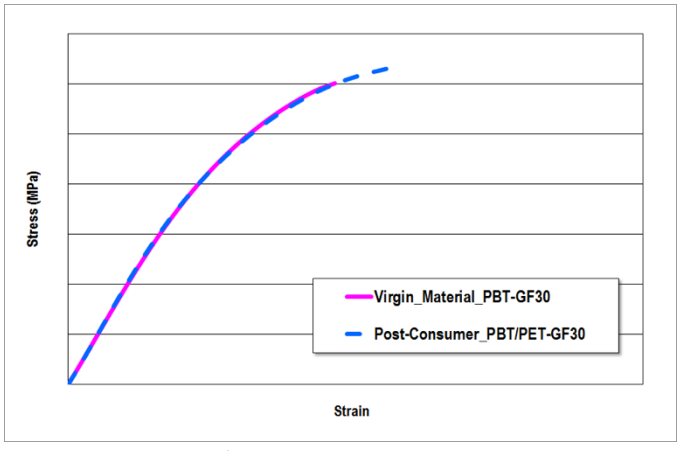
RadiciGroup produced five prototypes of the post-consumer recycled materials. Within this newsletter issue, some examples of the recycled materials developed in the class of PA6.6 are presented. The first one is the PA6.6 with 30% glass fibers, thermal stabilizer, and black color produced with 50% of the recycled content. The upper figure in the right column shows the tensile test comparison between the post-consumer recycled material (blue dashed line), the post-industrial reference material (brown curve), and virgin material (pink line). As it can be noticed, the breaking stress-point of the post-consumer material is comparable with the others, showing that the recycled material has mechanical characteristics similar to the virgin and post-industrial one.

For the electric and electronic sector, or in the e-mobility market, flame retardant properties, and electric insulation are the main requirements. To meet these properties, another recycled material, PA6.6 with 25% glass fibers, flame retardant, and laser marking properties has been formulated. It contains 40% of the airbag material.



PA6.6GF30 post-consumer material tensile curves comparison

Another post-consumer material produced was the PA6.6 with 20% glass fibers, 7% mineral filler, and black color produced using 54% of wheel cover. It is suitable for applications where the mechanical and aesthetic properties are at the lower importance. The validation studies obtained from the polyesters family analysis, besides all the prototyped materials indicated remarkable results.
Finally, PBT-PET base polymers reinforced with 30% glass fibers were produced using 50% of rear-wiper content. The figure below shows that obtained mechanical performances are significant, since the break-point of the recycled material (blue dashed line) is a little bit higher than the reference point (pink curve).



PBT/PET GF30 for validation

Smart Mobile Modules (SMMs) for on-site dismantling

In the CarE-Service project, two “Smart Mobile Modules” (SMMs) are being realised in order to bring to dismantlers’ site the technologies and capabilities to safely and efficiently dismantle battery packs, as well as to perform on-site tests of several disassembled parts of vehicles to decide their optimal End of Life (EoL) route.

The dismantling module, which is under the responsibility of the partner CIA, is focused on the dismantling of battery packs that are the most valuable element in the E&HEV vehicles.

To enable this operation a transportable module composed by a high-cube container will be delivered to the dismantlers. The technologies that are requested for the dismantling of a battery pack in a semi-automatic way.

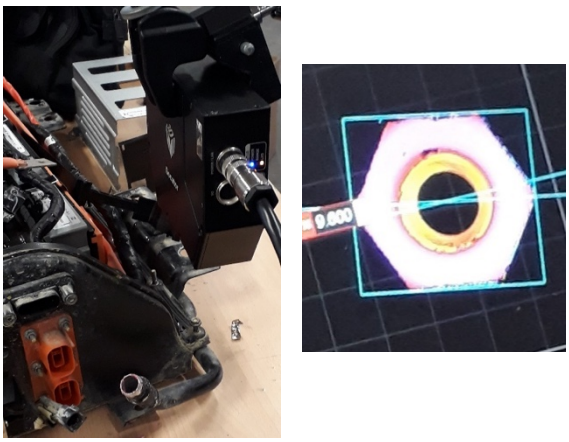
Linked to the ICT platform and the logistic module of the service, the dismantling module will receive all the information about the packs that are ready to be dismantled and with the aid of an operator these pack will be loaded into the module. After the preliminary phase of checking safety some operations are automatized with the use of a Robot and a rotary table for handling the pack.

The robot can perform operations such as unscrewing, cutting and grasping elements inside the pack.

A 3D vision system will match the 3D model of the pack with the current status and adjust the position of the robot using the results of this comparison. This feature increases the number of operations that the robot can perform autonomously and is crucial for this application: treating EoL components means that some mechanical properties change.

Results of the vision test are represented with the real object and the reconstructed, as can be observed in the figures.

The robot can change many tools autonomously to enable all the operation required for dismantling, selecting the right one depending on the dismantling phase that is running in a certain moment.

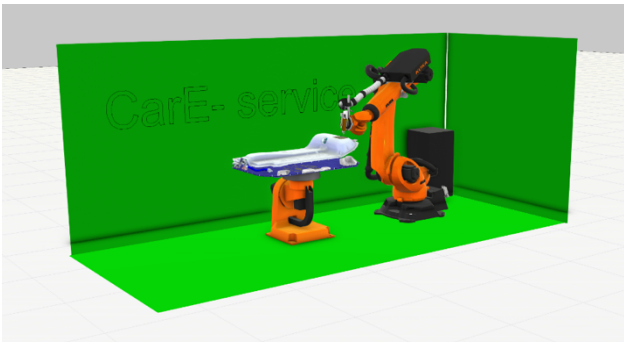


Angle detection

Surface detection

For example, as represented in the figure below, the robot selects the unscrewer tool and then the right nut for the screws that are used in the battery pack.

The goal of the dismantling module is to remove the modules from the battery pack and based on their status decide how to route them for the optimal use of the component.



Side view of module. Robot perform unscrewing

Voltage and visual inspection tests are executed after the removal of modules from the pack. Subsequent charge-discharge tests of modules and cells are expected to be carried out at stationary facilities of remanufacturers, since they require expensive and large equipment.

Exploitation Webinar: CarE-Service Community

As project exploitation leader of CarE-Service, FCA organized the first CarE-Service exploitation event on December 9th, 2020, in collaboration with the project coordinator National Research Council of Italy (CNR). It consisted of a webinar to present the scope and the preliminary results of the project to potential exploiters from industry and interested professionals dealing with the environmental and business challenges of the automotive electric transition.

The event took place successfully with a high number of almost 200 registrations and more than 110 participants from companies, universities and research centres located in various European and extra-European Countries.

It was a fruitful webinar to share the project outcomes regarding the various investigated topics: battery disassembly, remanufacturing and recycling methods presented by Envirobat; recycling of post-consumer techno-polymers by RadiciGroup; remanufacturing of EOL car metal sheets by Fraunhofer_IWU; the innovative CarE-ServicePlatform and Market Place by C-ECO and Prodigentia; new integrated sharing mobility services by E-VAI.

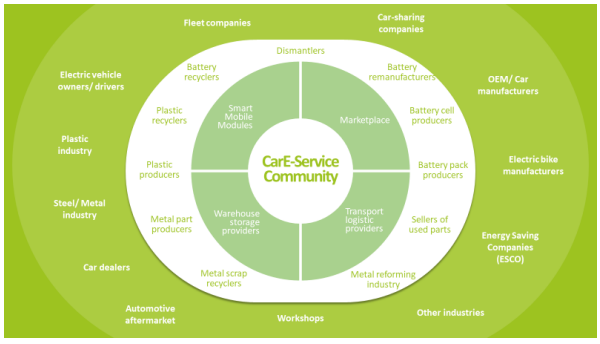
During the webinar, we introduced the CarE-Service Community. A new ecosystem is going to be developed around the end-of-life of electric vehicles with many different stakeholders such as manufacturers and industrial partners, service providers, users of sharing companies, car owners, part traders, workshop, etc. currently, an ecosystem like this is already existing for conventional vehicles, but it's not yet existing for electric vehicles with all the possible cross-sectorial relations. The existing ecosystem for conventional vehicles is based on traditional supporting tools and media, already existing for many years. Nowadays, as the first electric cars sold 10 or 15 years ago come to the end of their life, it is time to start creating this kind of ecosystems as we are just in the beginning of this challenge.

CarE-Service ecosystem will be based upon the CarE-Service Platform. It will integrate all the stakeholders of the E&HEVs EoL (dismantlers, remanufacturers, recyclers, logistics providers, OEMs, components producers, users of recycled/remanufactured parts in other sectors, etc.) in order to match demand and offering of certified parts, thus creating critical mass and reducing the uncertainty which is typical of EoL businesses.

The Platform will be integrated with the operations of the SMMs which will offer high added-value services to dismantlers in order to enable the circular economy of parts that are currently not re-used, remanufactured or recycled on the one hand, and that will guarantee that parts that enter the marketplace have tested quality.

The CarE-Service Community will have a strong impact on diverse European Industries and Sectors besides automotive (such as renewable energy, plastics, metal, furniture, etc.), since it aims at making EOL electric vehicles parts and materials available also to other sectors.

All the presentations are now accessible through the CarE-Service website on Document Section part. Moreover, if you are interested into the project upcoming webinar, workshops on demonstration results, as well as start experiencing the functionality of the CarE-Service Platform in the project environment, please register into our Community for receiving our periodic news and event invitations.



CarE-Service Community integration

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