UNCURED CFRP RECYCLING

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"This activity is under the lead and request of Airbus"

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Abstract

Last decade has seen a startling development of technologies for carbon-fibre reinforced polymers (CFRP), but the full potential for reusing the waste as other applications has not been yet accomplished.

Finding an industrial solution to reuse the waste inherent to CFRP manufacturing processes is a goal that Airbus and FIDAMC are trying to address.

This document collects information about the effort done to re-use manufacturing scrap prepreg as by-product material. This project aims to continue the effort addressed to find an available solution to recover value from something that today is an economic loss.

So far, two areas have been conducted;

Studies focused on the manufacturing and characterization of panels made of reused chopped prepreg residue. These trials involve material cutting tests by means of a press machine and the manufacturing and testing of several panels with several length dimensions. Tensile and CAI tests have being carried out. These studies have been complemented by physic-chemical tests such as glass transition temperature, cured degree measurements, fiber volume content or micrographs.

On the other hand, feasibility process trials have been also conducted by the manufacturing of several demonstrator parts.

1. Introduction

Carbon fibre composites (CFRP) have accomplished considerable attention thought the marketing efforts of aircraft companies, resulting in an increase of fibre composites production. If fibres used in these composites were recycled or reused in the market, their lifetime could be extended e.g. for utilizing fibres and prevent shortages for future applications [1].

Manufacturing and machining of composite parts outcomes in a substantial amount of CFRP residue. The buy to fly ratio is about 1.4:1, depending on the operation and the demonstrator to be manufactured, this 40% of material is lost in processes such as cutting, patterns contour, errors... Most of the scrap produced (about 60- 70%) is uncured prepreg which entails a significant cost for its disposal due to be considered as special waste with environmental penalties. Besides, waste treatment policy in the European Union aims to limit the impacts of waste on the environment and creating resource efficiency by promoting the use of waste.

This project is focused on reusing fresh thermoset pre-impregnated material, prior to the curing cycle. The intention is recycling raw fresh scrap material waste from the manufacturing of aircraft parts. This

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new raw material will be proposed as raw material for BMC processes without mixing with other material.

1.2 Classification of uncured waste

Composite components that have to meet demanding structural requirements are usually manufactured from continuous fibre reinforcement (tow, tape or fabric). During the manufacturing of the parts with continuous fibre a percentage of prepreg waste is discarded.

Scrap: ATL discards scrap out of the part to prepare the next cut in order to adapt the shape to the final contour of the pattern course. Scrap can be mono or multilayer and unidirectional (UD) or multidirectional.

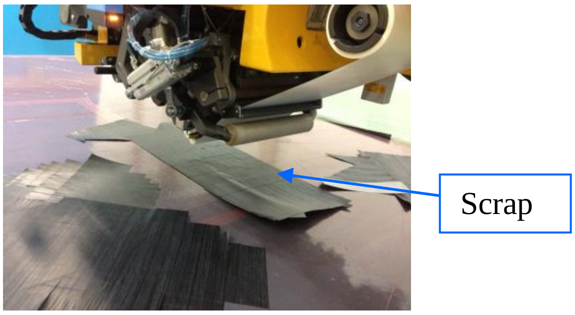


Figure 1: Scrap waste material

Trimming off-cuts: this waste is the extra material to be cut in size following the final contour part, usually is multilayer and with different orientations. This type of waste can be generated by the ALT processes or the trimming machines.

On both types of waste material the orientation of the plies don’t follow any equilibrated formula, the orientation 90,0,45º -45º is random.

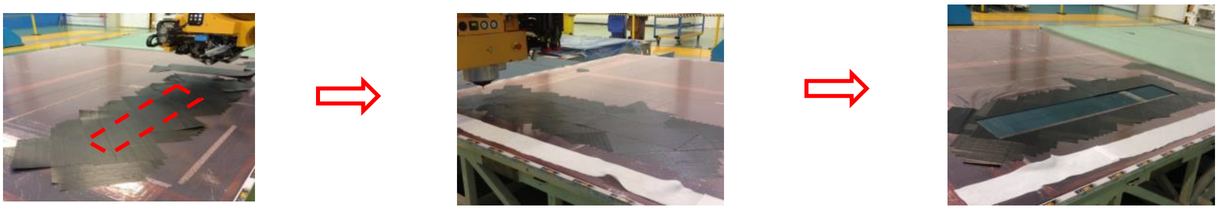
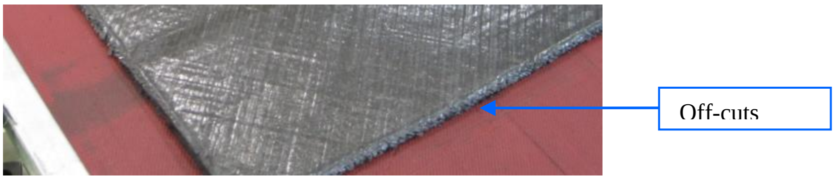


Figure 2: Off-cuts waste material

FP also generates leftover to adapt the contour to the final size part.



Ends of rolls (ATL and FP), raw material manufacturing defects

Expired rolls: out of date material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2. Results

2.1 Technologies definition

Depending of the fibre length and the classification of the waste material above mentioned, two kinds of recycled waste materials are proposed. SMC and BMC waste materials schematically described in Figure 3 are the final classification.

BMC (Bulk Moulding Compound) and SMC (Sheet Moulding Compound) are made from randomly oriented chopped prepreg. Both technologies consist in manufacturing of parts using chopped scrap material as raw material for moulding press compound processes. SMC has longer fibres than BMC and is therefore stronger.

BMC is divided into two different technologies. The first named as bulk moulding composite (BMC) and the second one defines as Hybrid bulk moulding technology (HBMC). The Hybrid bulk moulding technology (HBMC) main difference consisted in an additional second step where one ply is placed over and beneath the part or the panel, so final appearance is similar to a prepreg composite laminate (see Figure 4).

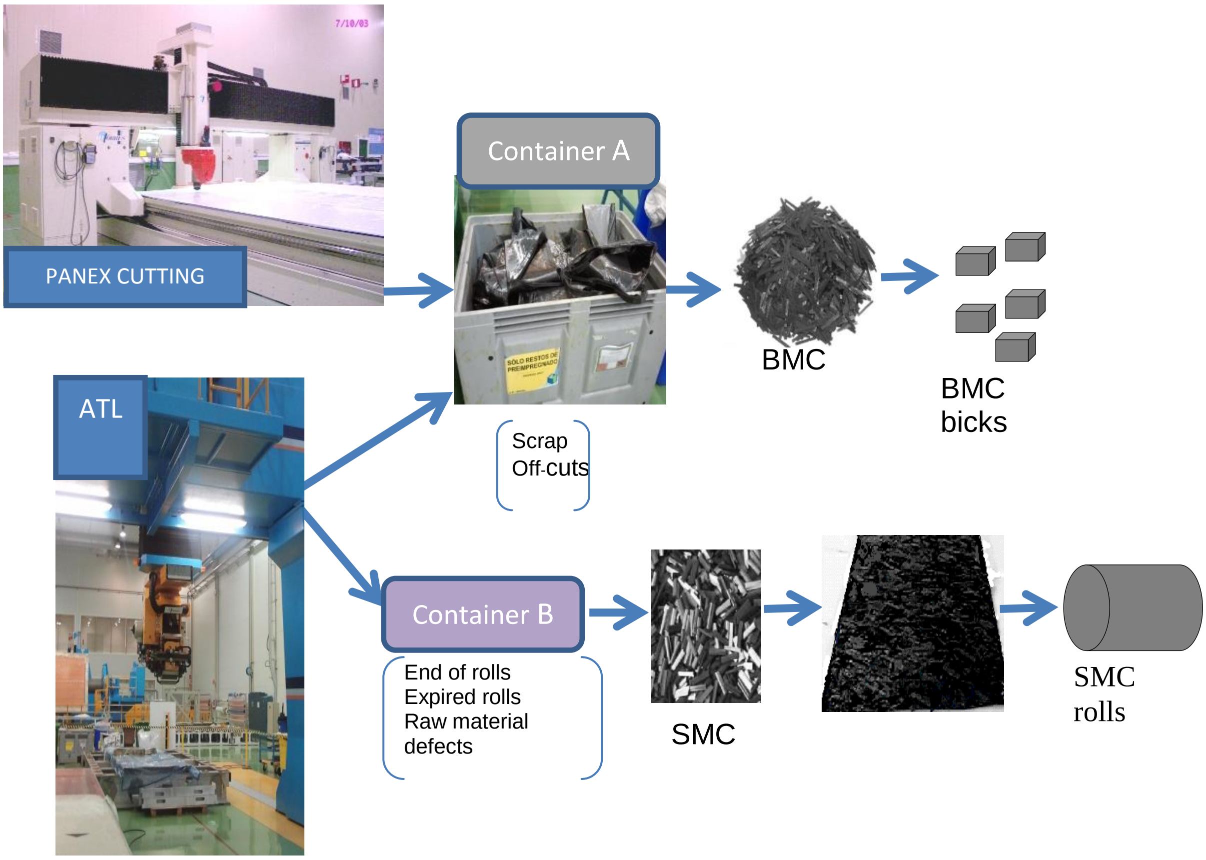

Figure 3: Fresh waste recycled chain

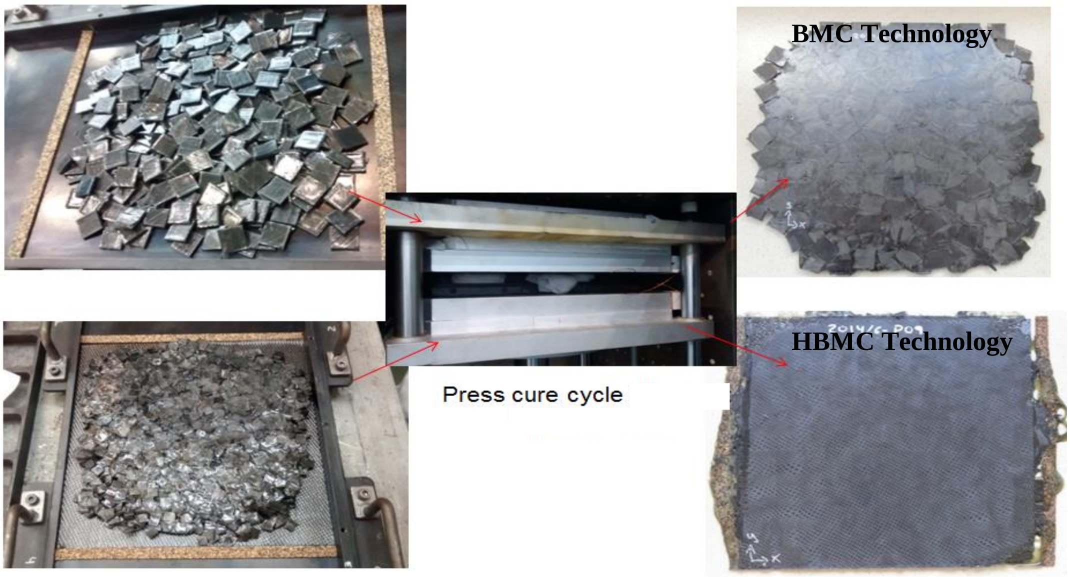

Figure 4: Process manufacturing of panels with BMC and HBMC technologies

2.1 Manufacturing process

2.1.1 Cutting process

Chopped materials have been prepared by two processes:

- A die cutting press process for laminates
- A cutting machine specially designed to cut end of rolls

2.1.2 Press process

Several press processes are conducted to optimize the curing cycle. The cycle selected consists in:
- Pre-curing cycle: a pre-cured step of 10 minutes, 120 bar at 190ºC in a hot plates press. The intention is keeping the press temperature at 125ºC constantly between different processes; saving time and energy when several curing cycles are planned.
- Post-curing cycle: step in oven during 1h at 180ºC. This cycle can be used to cure several parts or panels at the same time.

Here below are shown some pictures of the chopped material panels, in particular monolayer chopped panel, multilayer chopped panel and SMC panel (Figure 5).

In addition to the previous studies, different aged materials and contaminated waste (mainly with glass fibre or bronze mesh) have been also chopped and studied resulting in grades of material with different qualities, prices and possible applications.

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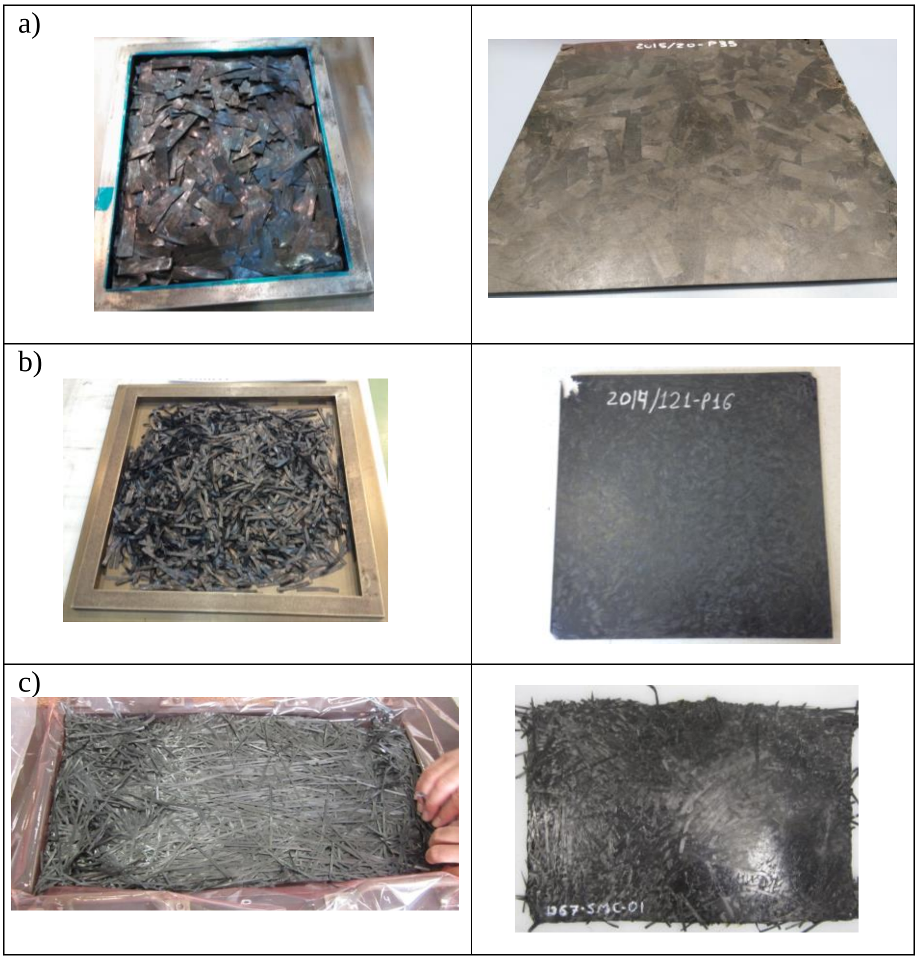

Figure 5: a) 50x12.5mm monolayer chopped material panel, b) 50x5 multilayer chopped material panel and c) 135x3,2 SMC Monolayer chopped material panel

3. Results

3.1 Panels characterization results

Panels are cut to perform tensile and CAI tests. Extend of cure and glass transition temperature (Tg) are measurement by DSC, morphology observed by microscopy and void content obtained by acid digestion. The press processes provide semi-cured composites with 80-90% of extent of cure and 90ºC-210ºC in Tg. After post-cured cycles in oven, panels develop an extent of cure of 100% and Tg in concordance with the relevant material specification.

Some of the mechanical results are shows in the following figures for BMC and HBMC panels with different fiber length.

Tensile mechanical results under EN2561 show that the higher fiber length the higher strength and modulus results. Nevertheless, it is important to remark how the presence of a ply above and below the chopped panel (HBMC) approach the tensile values to those obtained for longer fiber length. The highest tensile values are obtained for the monolayer chopped material panel manufactured with longest and widest chopped dimensions.

CAI results are promising since some panels show values close or higher to those reached by HexMC impacted to 30J.

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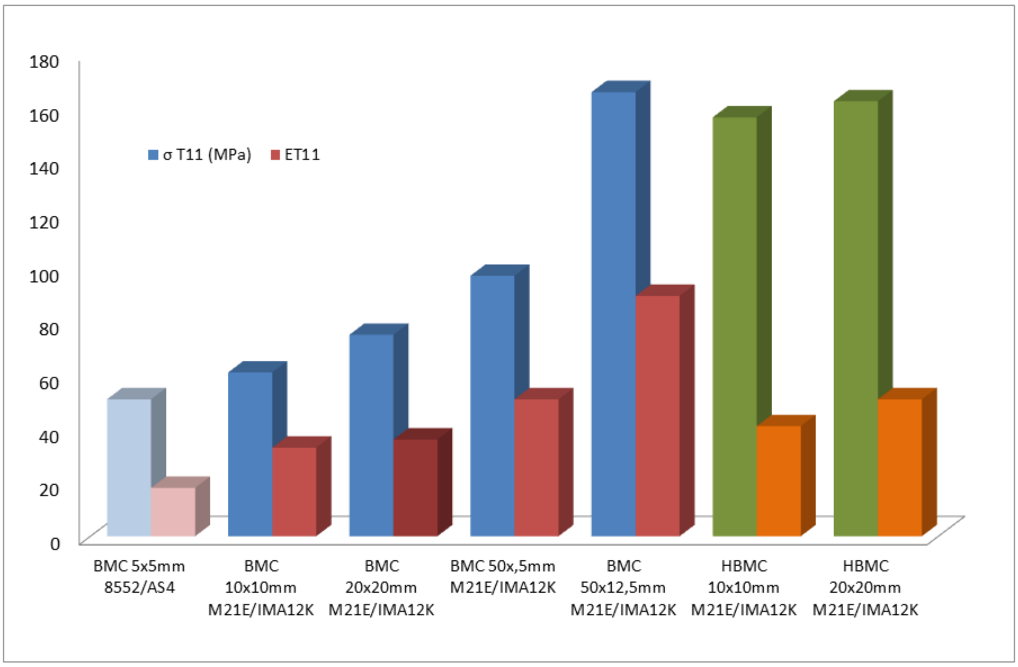

Figure 6: Tensile results for monolayer and multilayer chopped material BMC panels with different chopped size, and HBMC panels with multilayer chopped material

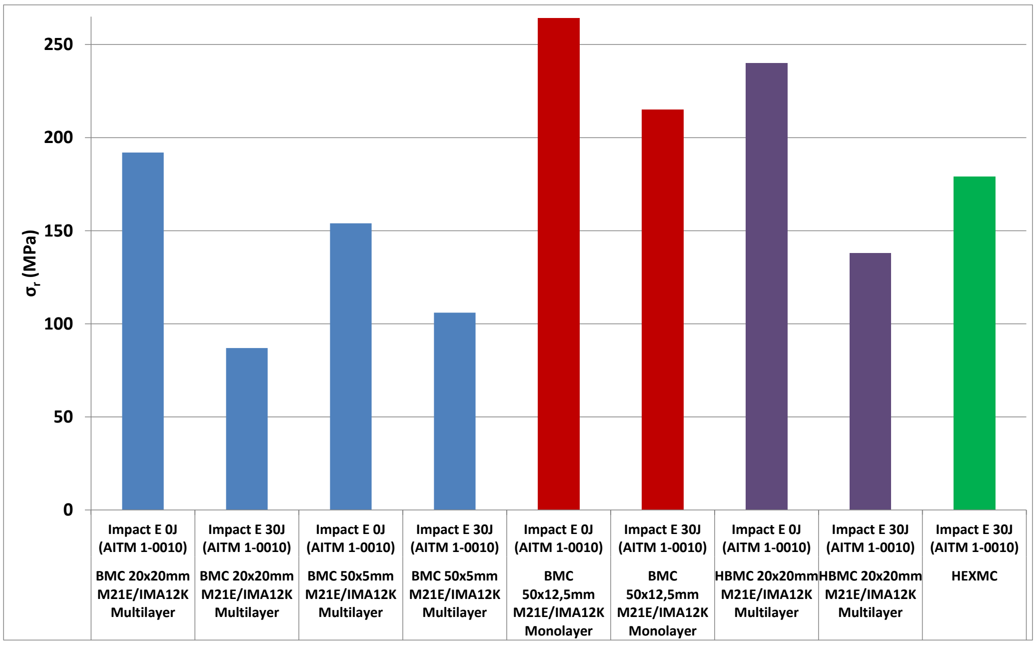

Figure 7: CAI results for monolayer and multilayer chopped material BMC panels with different chopped size, HBMC and HEXMC (not impacted values not available)

3.2 Demonstrators results

Several demonstrators have been manufactured by press process with special tooling designed to this purpose. The intention is to value the process manufacturing feasibility with the chopped material.

Results obtained with this demonstrators point out this material to be considered as material to manufacture drilling templates, support templates or even to be valued as material to manufacturing of tooling. Beside the curved part demonstrators shows that the chopped material is able to adapt to the geometry and size of the different complex parts. A corner bracket is also manufactured in order to consider this material to perform systems supports. The results show that the material copy the mould proving its suitability for such application, the manufacturing challenge would be solved.

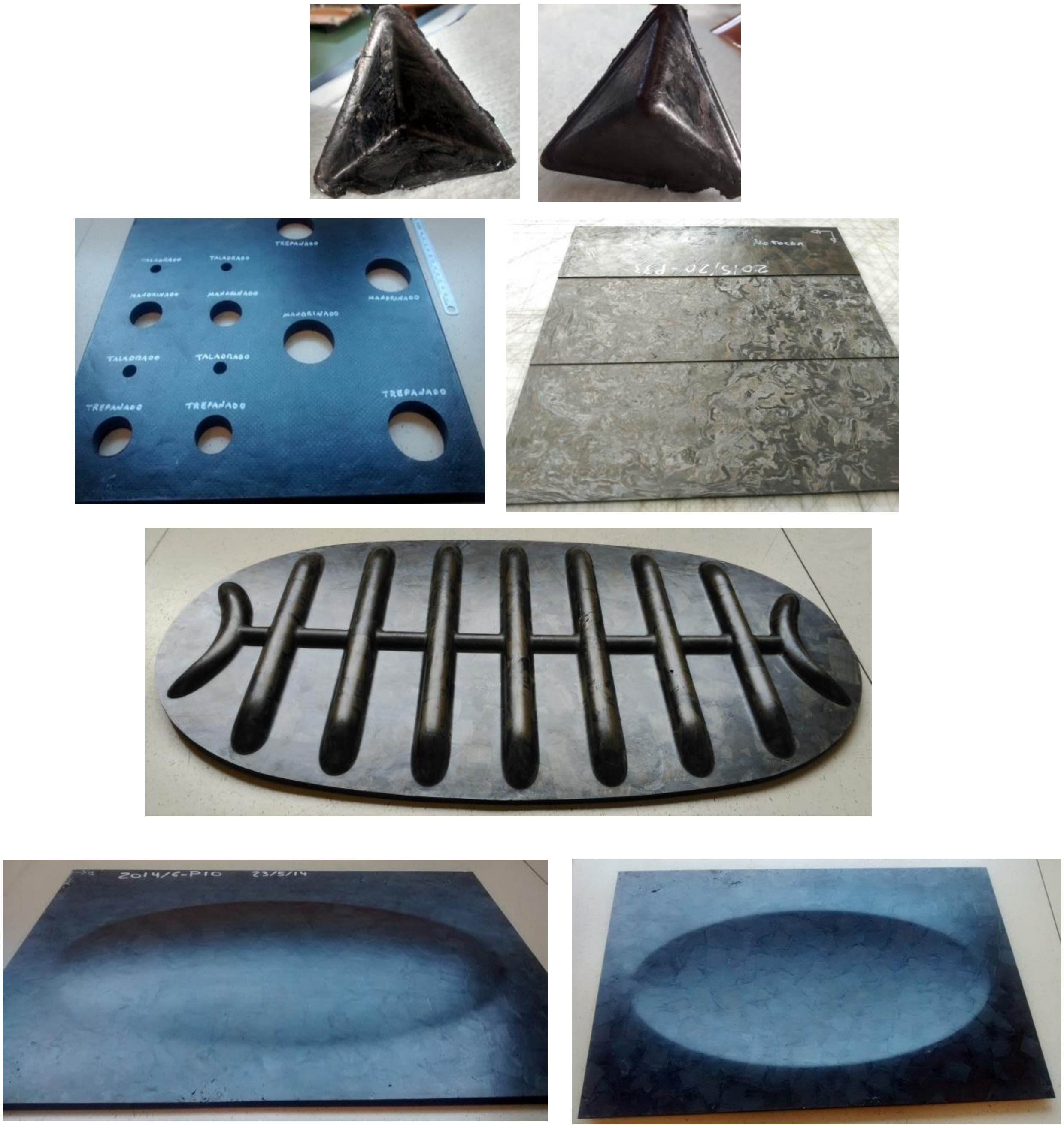

Figure 8: Recycled Chopped material Demonstrators

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4. Conclusions

The target of this study is to transform uncured waste prepreg produced during the manufacturing of the CFRP composites into recycled raw material by cutting the prepreg into chopped material. This brings the opportunity to reuse a material which up to now is discarded, with the expenses and environmental troubles that it entails. This chopped material is reprocessed by a sheet or bulk moulding compound technology to become a by-product material.

Main activities has helped to define the processes parameters, cutting processes options, demonstrators manufacturing feasibility and mechanical and physic-chemical characterization of different chopped material. Different technologies have been settled and named as bulk moulding compound (BMC), hybrid bulk moulding compound (HBMC) and sheet moulding compound (SMC). Both technologies consisted in manufacturing of parts using chopped scrap being the main difference the additional weave ply placed over and beneath from HBMC panels technology. Chopped dimension studies vary from 5x5mm to 20x20mm, 50x5mm, 135x3.2mm...

The activities include the curing cycle selection to reduce press times without loss of properties. Physic-chemical characterization includes glass transition temperature, extent of cure, void, resin and fiber content and microscopy inspection of the panels. Tensile and CAI tests complete the process characterization.

An improvement of mechanical properties is pursued during the project progress. One methodology followed to achieve this goal is increasing the size of the chopped material looking for an enlargement of the mechanical properties at expenses of a lower workability. HBMC (Hybrid BMC technology) technology which incorporates fabric plies to the chopped preform improves substantially final mechanical properties. That improvement can reach up to 3 times tensile properties with regards to the lower BMC trials properties. CAI properties show that the drop of properties when HBMC coupons are impacted is 60% lower than those results for BMC coupons. Nevertheless, HBMC technology is less appropriate when final part has a complex geometry

Besides, some mechanical results can be compared to those reached by other chopped materials already commercially available as Hextool or HexMC.

It is clear that the degree of gridding, monolayer or multilayer format of the prepreg and the presence or not of a ply of continues fibre on top and below the panels will determinate the possible applications. An interesting application for this new material would be the use of this chopped material for the manufacturing of low cost & weight tooling (drilling, support, manufacturing tooling, engine mount for maintenance operations, ground equipment) or system support (brackets with complex geometries, low mechanical requirements..) beside other non-aeronautic applications such as sewer or drain, dashboards, cases… It should be noted that this product can be customized as a function of a specific application.

Currently, there is a prototype cutting machine available to industrialize the end of rolls cutting process. The intention is to find an industrial process able to manufacture chopped material at industrial scale. New trials are being conducted to characterize panels with the new process in order to find a specific aeronautical application.

References

[1] Eylem et all, Journal of Composites Material 48 (5), 593, 2014.

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