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## Reutilización de CFRP proveniente de la fabricación de aviones. Aplicación industrial y solución logística inversa.

### RESUMEN

#### Historia del artículo:

Recibido 5 de Mayo 2017

En la versión revisada 5 de Mayo 2017

Aceptado 31 de Mayo 2017

Accesible online 21 de Junio 2017

#### Palabras clave:

Reciclado y reuso de CFRP

Fabricación

Avión

Material desechado / desperdiciado

Preimpregnado

El nuevo avión Airbus A350XWB contiene el mayor porcentaje de materiales compuestos en elementos considerados como estructura primaria. Por lo tanto, ha sido un gran reto para las Plantas de fabricación de piezas de fibra de carbono de matriz polimérica (termoplásticos), la gestión de miles de toneladas de prepreg al año, y consecuentemente, variadas iniciativas para reducir su consumo, reusar y reciclar los desperdicios asociados, han sido desarrollados durante los últimos años

La Planta de Airbus de Illescas está introduciendo nuevos procesos para reusar y reciclar fibra de carbono sin curar proveniente de la fabricación de las partes del fuselaje y ala. Dos iniciativas principales están siendo puestas en marcha en la Planta de fabricación.

Reusado de finales de bobinas y finales de rollos para la fabricación de rowing para larguerillos permite incrementar la compra de material in la Planta

## Reuse of CFRP material from Aircraft Manufacturing Parts. Industrial applications and inverse logistic solution.

### ABSTRACT

#### Keywords:

Recycle and reuse CFRP

Manufacturing

Aircraft

Scrap material

Prepreg

The new Airbus A350XWB has the largest % of an aircraft primary structure elements made of composites ever. Thus, it has been a huge challenge to manage thousands of CFRP Tons per year in the part manufacturing plants, and consequently, several initiatives to reduce, reuse and recycle scrap material has been developed during last few years.

Illescas Plant is introducing new processes to reuse and recycle CFRP material from wing covers and fuselage parts. Two initiatives are running these days:

Reusing of CFRP (prepreg) end of spools and end of rolls to manufacture rowing for stringers that allows to decrease the purchased material in the Plant.

## 1 Introduction

The brand new Airbus A350XWB, recently entered into service in 2015, has the largest % of aircraft primary structure elements made of composites ever (thermoset resin matrix reinforced with carbon fiber). Thus, it has been a huge challenge to this industry to manage thousands of CFRP Tons per year in the part manufacturing plants.

Consequently, an increase of use of this raw material involves a subsequent rise of CFRP waste to be handled.

Several initiatives to reduce, reuse and recycle scrap material have been investigated during last years in order to reduce the environmental impact and improve the industrial benefits of the business.

### 1.1 Manage scrap uncured prepreg into by-product specification

Uncured prepreg is one of the most relevant scrap sources that is generated due to the current manufacturing processes used to produce wing covers and fuselage parts of the A350 aircraft. Other scrap sources are also created but are not part of the current exhibition.

The above mentioned scrap source could be disposed into different formats and during divers steps across the manufacturing life cycle process. Wherever the scrap is generated and segregated from the manufacturing part, a special treatment should be applied to it if reusing/recycling applications are expected to be given.

Therefore, the CFRP part manufacturing industry is facing the problematic to manage segregated material (scrap) that was considered out of the process at the moment that was not going to be part of the structure.

Due to that, uncured scrap prepreg has been requested to be reconsidered again as usable material by applying some constraints in its future application and by enlarging the handling of it after being considered scrap. That situation has forced to redefine the scrap material requirements into a new by-product specification to be fulfilled.

The challenge then for the industry is how to recover a new material source that had been discarded until today (scrap yesterday, by-product nowadays), and has to be tracked and managed with additional requirements, not disturbing the established manufacturing processes that are running in parallel and have not to be penalized.

## 2 Industrial opportunities

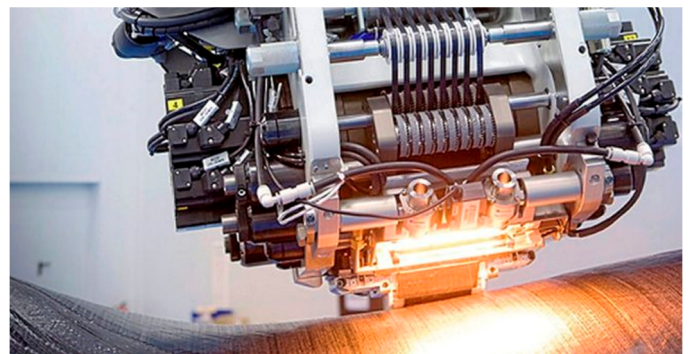
Most of the composites structures in the aviation industry are made by prepreg, and the advance manufacturing plants use, to produce them, automated lay-up machines.

Those automatic manufacturing processes need from cutting edge technology machines denominated as ATL's and AFP's (Automatic Tape Lay-up and Automated Fiber Placement machines, respectively). Consequently, prepreg manufacturers supply two main formats for its related raw material; Rolls and

Spools to be adapted into the mechanisms that will be able to lay up the prepreg material into specific tooling.

The mentioned prepreg formats and the associated machines used in the automatic manufacturing processes, generate some intrinsic scraps that are called End of Rolls and End of Spools (EoR and EoS from now on). That is the remaining material that could not be used by an ATL neither an AFP machine, because the related rolls and spools have less material that the needed for the subsequent manufacturing step, and have to be scrapped.

These by-products (EoS and EoR) are quite succulent to be reused within the same industrial environment as they are close to be considered as raw material in similar conditions as when they are delivered from the supplier.



**Figure 1.** Automated Fiber Placement 3D (AFP 3D) used to manufacture flat and curved panels (fuselage and wing structures)

Another potential scrap source which is significant because of the generated volume is the multiply uncured prepreg that is produced after the lay-up with the above described machines/processes, after the cutting operations. This scrap is made of several layers in different orientations and has a great variety of shapes, as it is extracted from the edges of the uncured laminate that has been cut by automated machines dedicated to this purpose.

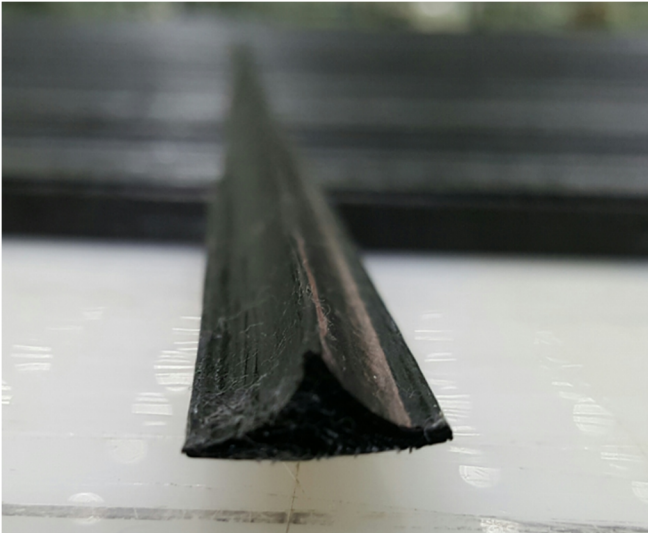
### 2.1 End of Spools and End of Rolls

As already highlighted, the EoS and EoR scrap sources have become one of the most interested by-products to be reused.

The possibility to find applications avoiding post-processing of the by-products allows to the Plants easier processes to be deployed.

One proposed industrial application is to manufacture rowing profiles (gusset filler strips used to cover the free space in stringers junctions; for instance between two L profiles that are assembled together to make a T-stringer shape). Thus, the associated amount of new material used to it, is reduced to zero as the EoS and EoR could feed the system to avoid purchasing virgin material.





**Figura 2.** Rowing profile used in T-stringers

The main difficulty faced with this scrapping source is the way to manage it as a by-product format that has a high volume/weight ration; that is, to recover, move and reuse spools and rolls with a few grams of prepreg. Due to that, productivity issues is the main pain for an industrial and valid application.

A potential solution for it, is to splice the different End of Spools and End of Rolls between them, to manufacture an intermediate by-products with a suitable format that is valid to be used in automatic machines.

## 2.2 Multiply uncured prepreg

The amount of tons generated as multiply uncured prepreg cut-outs are reduced, day to day, to the minimum by optimizing the numerical control programming of the ply sequence and by providing an intelligent distribution of the Engineering Edge of Part (EEoP) within the manufactured laminate part before cutting.

Nevertheless, these scrap edges generated after cutting the uncured laminate are not possible to be reduced to zero. Most of the stringer laminates are made by a set of them, and consequently, large and narrow strips of multiply uncured

## 3 Inverse logistic solution to manage by-product from different scrap sources

The main uncured prepreg scrap sources identified in the aircraft part manufacturing Plants, already described in section 2.1 and 2.2, have both of them, another important requirement to be meet. Traceability and by-product specification fulfilment.

In other words, to convert uncured prepreg scrap into a valid by-product, it should be demonstrated that the agreed properties and constraints in the material specification (by-product technical specification) are maintained and respected. To achieve that objective, several procedures and time-consuming tasks might be requested. That could be

multidirectional orientated prepreg are disposed into scrap containers after being released from the cutting tables.

This by-product needs from additional post-processing steps into external industries, out of the aircraft manufacturing Plants. Several initiatives have been launched to recover, reuse and recycle it.

Most challenging tasks are focused into managing the variety of shapes, thicknesses and aleatory material disposal into the scrap containers. Moreover, is being study how to process carbon fiber prepreg and other materials already included in the laminate like glass fiber preimpregnated films and ancillary not desirable materials (release films mostly).

Due to that, the subsequent process to be applied, aims to find proper material formats (BMC, SMC, etc), and a suitable, reasonable and efficiency procedure to provide an interesting by-product that could compete with virgin material.



**Figura 3.** Multiply uncured prepreg from cut-outs

transformed into a penalizing method when an industrial application of the by-product is aimed to be deployed.

This challenge has been studied and some inverse logistic solutions could be selected to reduce the bureaucracy and improve traceability to control and check the by-product requirements vs. collection and delivery conditions.

Consistency of the procedure is key to provide conformity to the uncured prepreg scrap. It is needed to validate the material original specification from which the scrap is extracted, provide evidences about the quantity of material disposed per recovering/reusing process and the most important constraint to be fulfilled, validate supplying conditions from clean room area (accumulated hours of the uncured material out of the freezer).





This last topic is a relevant restriction to be demonstrated and it represents a show-stopper to reuse or recycle the scrap sources.

By-product limits are defined based on the future application of the “reuse product”, so the original limitations of the raw material in terms of shop life (typical 30 days out of the freeze before expire date comes) could be relaxed to further limits, in accordance to the reality of the later post-processing method and based on the requirements of the subsequent application.

One solution established to better track and provide conformity to uncured material is the usage of RFID technology (Radio Frequency ID technology). This is based in an ID stickers that could include relevant information (“write mode”) and might be read in subsequent stages (“read mode”)

This tracking technology allows distinguishing between material sources, production batches, expire dates, relevant supplier prepreg information. It provides conformity to the by-product collection of material before being dispatched for being re-use in other applications. In addition, this is a productive and effective method to track and validate by-product batches.

Deployment of this traceability procedure within regular structural part manufacturing steps, avoid disturbing the regular production process (reducing the increase of workload due to the by-product conformity validation).

Moreover, RFID technology is able to be extended to whatever scrap sources formats, by establishing different procedures and stickers formats to be included into the EoS, EoR or logistics containers for the multiply uncured scrap.



**Figura 4.** Examples of RFID stickers used to track and validate by-products before being reused.

## 4 Conclusions

Reuse of uncured prepreg material is nowadays a reality in the manufacturing industry. Some scrap sources have more potential than others to be easily post-processed with simple procedures. EoR and EoS are monopoly by-products which could be reused avoiding auxiliary industry for potential applications like rowing manufacturing.

These opportunities on the prepreg manufacturing plants are essential today in order to decrease the level of raw material purchases that represents a big percentage of the total cost of the CFRP parts.

Additionally, conformity to the re-use process itself and validation of the generated by-product is mandatory. Inverse logistic solutions adapted to an already established manufacturing process are needed to not penalize regular production. There is a short margin on the benefits vs. associated cost originated to manage by-product conformity. RFID technology arises as a competitive option to be deployed on these industrial applications.



## Acknowledgments

I have to thanks to my Manufacturing Engineering colleagues that have helped me to develop the introduction of re-use techniques into Illescas Plant, as Pablo Avendaño and Georgina Galera.

Additionally, my gratitude to Eduardo López because of the encouragement he gave me to be part of the MATComp'17 program.

## References

- [1] N. Fanegas, Definition of short fibres prepreg manufacturing process, Reciclaje:short fibres prepreg, 2013/67-TR-01.
- [2] Management, Recycling and Reuse of Waste Composites, V Goodship, Elsevier, 18/12/2009
- [4] Requirements for waste material management, 2014/6-TR-1  
N.Fanegas
- [5] End of life, options for composites waste recycle, reuse or dispose?  
Dr Sue Halliwell. National Composites network best practice guide.
- [6] Hexply prepreg technology

