Project no.: ***SP1-JTI-CS-2010-01-270573-GRA-01-029***

Project acronym: ***EXPECT***

Project title: ***Examination of Practical Aspects of Innovative Bonded Composite Repair Techniques***

Instrument: ***Cleansky JTI***

Publishable Summary

Start date of project: ***01 January 2011*** Duration: ***24 Months***
Report Lead Partner: **GMI**
Contributions made by: **NTUA**
Topic Manager: **Fraunhofer IFAM**

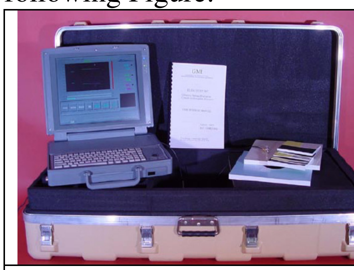
Revision [Draft, **final**]

Dissemination Level		
PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

The main steps which need to be followed for the performance of a "typical" repair to a composite structure generally include:

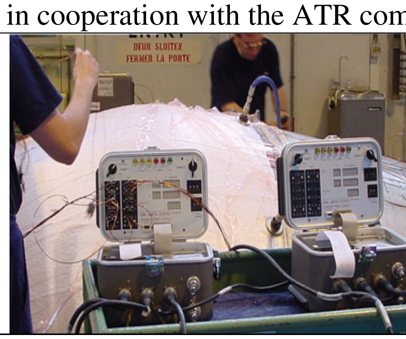
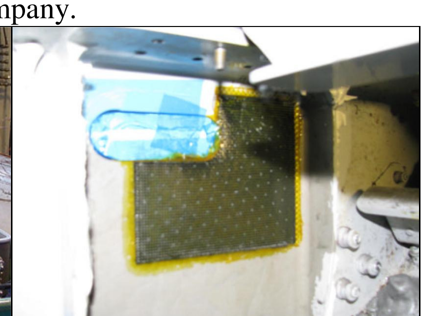
- **a.** Initial Non Destructive Testing (NDT) of the damaged area, in order to define in detail the external borders of the damage.
- **b.** Removal of the damaged composite material by cutting, drilling and milling, in order to get a scarfed or stepped configuration.
- **c.** Composite patch preparation (lay-up) / application (preparation of vacuum bagging and application of heat)
- **d.** Final NDT of the repair, to identify potential debondings, delaminations, moisture, foreign inclusions or other anomalies.

In order to enable the performance of these repair steps in situ, a series of special **portable** equipment has been developed, fulfilling the repair specifications requirements and overcoming the numerous constraints of repair performance within hangars or repair workshops. For example, a series of such composite repair equipment used by many airlines and MROs, which have been specially developed and continuously upgraded by GMI during the last thirty years, is shown in the following Figure.

			
Portable ultrasonic equipment for NDT of the repair area ***(Steps a,d)***	Portable surface preparation tooling for scarfed – stepped repairs ***(Step b)***	Portable closed-loop hot bonding console ***(Step c)***	Collection of heating blankets of various sizes ***(Step c)***

Representative portable composite repair equipment for in situ performance developed by GMI

Using this kind of portable equipment developed by GMI, the application of an extensive variety of composite repairs can be supported, as presented in the following Figure. These repairs range from typical small or large composite to composite repairs, up to composite to metal repairs, as, for example, the recent repair of an ATR-72 aluminium floor beam using a bonded carbon patch, performed in situ by GMI Aero, in cooperation with the ATR company.

		
Typical (small) composite to composite repair	Extensive composite to composite repair	Composite to metal repair on ATR 72 primary structure.

Example of repair range covered with portable tooling and equipment.

The **main concept** driving the EXPECT project is to perform the whole chain of required steps for the performance of typical composite repairs, as listed above, using the same equipment existing in repair workshops of airline companies and MROs, and applying the same conditions / constraints (environmental, personnel training level etc.) usually existing in typical workshops, with the following **main objectives**:

a. To **evaluate** the performance of bonding strength and examine practical application aspects of bonded composite repairs using innovative materials and, potentially, modified surface preparation processes as developed within the JTI-GRA WPs, along the whole range of repair application procedures (surface preparation of composite substrate (stepped / scarfed), lay-up of the repair patch, curing of the patch and the adhesive at elevated temperature (~120 °C) and NDI.

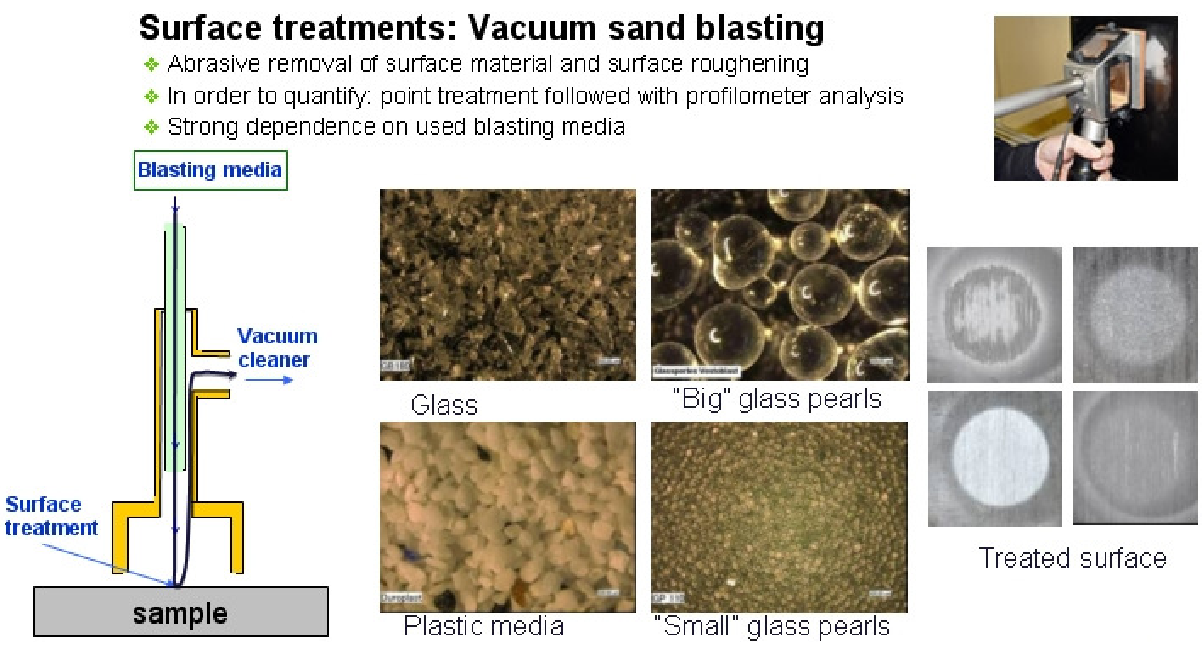
b. To **identify** areas of potential contradiction of new processes to existing repair practices and procedures.

c. To **propose** alternative solutions (changes of procedures, development of special equipment etc.) in order to overcome such potential contradictions / constraints

By applying these steps, the **main objective** of the project will be fulfilled, which is **to guarantee that the technological solutions developed within JTI-GRA ITD corresponding WPs will not only work under conditions of academic research, but will also work reliably if applied in commercial aircraft maintenance.** The practical applicability of the new methodology will also be demonstrated, by performing repairs to larger panels, within the frame of WP1.3.7 of the GRA ITD. More specifically, EXPECT focused on estimating the potential of vacuum sand blasting as a surface pre-treatment method in composite aircraft repair. Vacuum sand blasting is an abrasive method like grinding, but it may be that it will provide better process reliability than a manual grinding process. Compared to conventional sand blasting, it takes care that the blasted material will not pollute the surroundings.

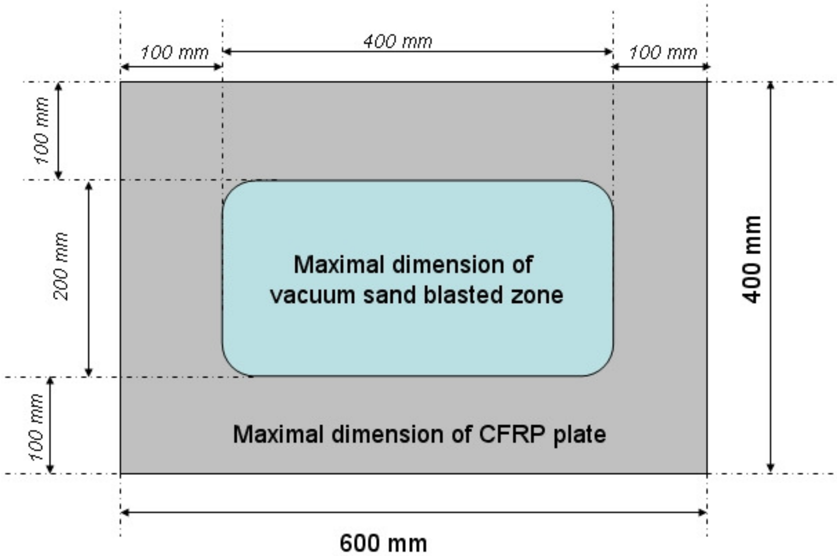
- Vacuum sand blasting methodology description

The main features of the vacuum sand blasting technique are presented in the following Figure:



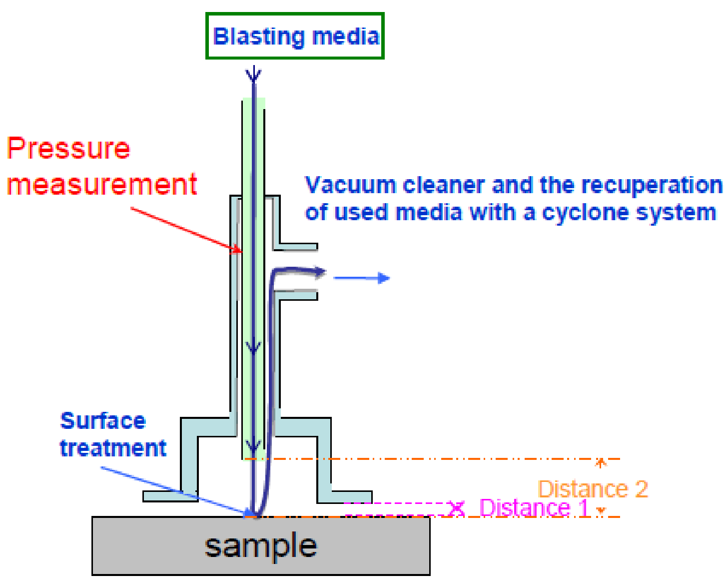
A surface pre-treatment with a vacuum sand blasting permits to replace the conventional manual grinding, improves bonding strength and permits to remove the eventual surface contamination. Its big advantage in respect to conventional sand blasting methods is the possibility to perform the treatments without the need for any special protective equipment. Thanks to the system design, blasting dust cannot escape even in case of leaks or other defects. The attractiveness to use it in repair process is based on a possibility of solvent and water-free treatment that could be done automatically, without hand contact with a repair zone.

As far as the methodology application constraints are concerned, the proposed maximum sand blasted area dimensions, according to currently available by the Topic Manager equipment, are presented in the following diagram:



Within the project, the main design parameters and repair process constraints that were taken into consideration concerning the examination of practical aspects of the vacuum sand blasting technique for the application on bonded composite repairs have been identified, in order to be taken into consideration within project.

<u>- Experimental configuration</u>
The configuration of the vacuum sand blasting equipment used in the campaign is presented in the following Figure.



Vacuum sand blasting equipment configuration and main parameters to be monitored (Distance 1 – Distance 2).

In order to evaluate in detail the innovative features compatibility with standard repair elements, certain composite parts, representative of most commonly encountered repair cases, were prepared by GMI, in order to be sand blasted by Fraunhofer IFAM team. According to that, GMI has used two sandwich panels made of composite materials (portions of landing gear doors of an Airbus A320 aircraft) for the preparation of areas usually encountered in repairs, as has already been described. Processing included both techniques commonly applied in surface preparation of composite materials (i.e. scarfing and stepping). Moreover, in certain cases a hole was opened and the honeycomb core material was removed. A close view of the vacuum sand blasting equipment during processing of the repair areas can be seen in the following Figure.

Close view of the vacuum sand blasting equipment during processing of the repair areas.

Within EXPECT, the following two VGB application methods were conceived:

<u>- Accurate VGB application method (AVGB).</u>

For the accurate application of Vacuum Grit Blasting, special equipment will need to be developed, together with the appropriate templates to be positioned on the composite part to be repaired. The application methodology together with the required equipment and templates will be based on the GMI Leslie surface treatment series of equipment operating principle. More specifically, the operating principle will be based on the controlled (in terms of location and distance from the part) dragging of the VGB orifice above the area to be repaired.

<u>b. Gross VGB application method (GVGB)</u>

Given that, according to experimental measurements, the material removal rate (i.e. reduction of thickness per "passage") is an order of magnitude less than the typical stepping height a less accurate but simpler application methodology could be alternatively proposed. Such method would be based on the standard sand blasting application method and would be manually applied by means of a pressure gun. Consequently, the need for development of new equipment would be significantly limited, while increasing the method application range, suffering a penalty on the quality of the achieved results, however.

<u>Conclusions</u>

Within EXPECT an extensive study was performed, in order to trace the optimum way to treat the non compatibilities of innovative repair processes against standard repair practices, and a sensitivity analysis was performed, in order to evaluate the effect of several parameters in the process implementation efficiency and justify the selection of appropriate solutions and change proposals to be implemented within following steps of the project. Further to the experience gained during the performance of Vacuum Grit Blasting (VGB) operations by Fraunhofer IFAM, in combination with the execution of actual composite repair applications by GMI and NTUA within the frame of JTI projects, and taking into consideration practical applicability issues (time, equipment, cost, precision, etc…), the final assessment of practicability issues related to VGB together with the advantages and disadvantages of each proposed application method is presented below:

a. Accurate VGB application method (AVGB).

For the accurate application of Vacuum Grit Blasting, special equipment will need to be developed, together with the appropriate templates to be positioned on the composite part to be repaired. The application methodology together with the required equipment and templates will be based on the GMI Leslie surface treatment series of equipment operating principle. The advantages and disadvantages of the AVGB application methodology could be summarized as follows:

- AVGB Advantages:

- Rather accurate method, achieving homogeneous surface preparation.
- High quality of surface prepared area.
- Reliable method, in terms of application and achieved results.
- Repeatable results.
- Non-operator dependent results.

- AVGB Disadvantages:

- High cost of developed equipment.
- Relatively low speed of application.
- Application limited to stepped repair profiles
- Difficulties in application to curved structures
- Relatively complicated method

b. Gross VGB application method (GVGB)

Given that, according to experimental measurements, the material removal rate (i.e. reduction of thickness per "passage") is an order of magnitude less than the typical stepping height a less accurate but simpler application methodology could be alternatively proposed. Such method would be based on the standard sand blasting application method and would be manually applied by means of a pressure gun. Consequently, the need for development of new equipment would be significantly limited, while increasing the method application range, suffering a penalty on the quality of the achieved results, however. The advantages and disadvantages of the GVGB application methodology could be summarized as follows

- GVGB Advantages:

- Low cost of developed equipment.
- High speed of application.
- Applicable to both stepped and scarfed repair profiles
- Applicable to curved structures
- Relatively simple method

- GVGB Disadvantages:

- Less accurate method, in term of homogeneous surface preparation.
- Low quality of surface prepared area.
- Non-reliable method, in terms of application and achieved results.
- Non -repeatable results.
- Operator dependent results.