COMPASS

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FINAL PUBLISHABLE SUMMARY REPORT

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TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF ACRONYMS

UD	Unidirectional
CFRP	Carbon Fiber Reinforced Plastic
NDT	Non destructive technique
CCC	Conditioning in Climatic Chamber
IHW	Immersion in Hot Water
STL	Sound Transmission Loss
CAP	CEM Acoustic Prepreg
ILSS	Interlaminar Shear Strength
RT	Room Temperature
ATL	Automatic Tape Layup
FP	Fiber Placement
WP	Work Package
TL	Transmission Loss

4.1 Final publishable summary report

4.1.1 Executive summary

COMPASS Project, which full title is "Functional Laminates Development. Components compatibility and feasibility assessment. Industrialization." is a FP7 project of 27 months, which began on October 2010, the 8^{th} and ended on January 2013, the 8^{th}. The project is related to the CfP of Clean Sky: SP1-JTI-CS-2010-01. It has been developed in the frame of the Green Regional Aircraft programme and its activity code is: JTI-CS-2010-1-GRA-01-031. COMPASS consortium is composed of 2 partners: FIDAMC as coordinator and INTA. Both Research Institutes are located in Spain.

In the pursuit of weight reduction, future structures will have to be multifunctional in the sense that a single component fulfils various objectives and was not necessary to develop independent structures for each of the functions required by the aircraft (acoustic and vibration attenuation, mechanical properties, electrical conductivity, etc.). Therefore multifunctional materials need to be developed and compared with current structural solutions to quantify the improvement offered by these new hybrid configurations over traditional composite architectures.

Within the scope of this project, the main goal that should be combined into a multifunctional laminate is acoustics and vibration isolation capabilities. In this frame, multifunctional CFRP laminates with insertion of vibro-acoustic damping materials have been investigated in COMPASS project. Mechanical properties of the proposed solutions have been also evaluated to ensure that they are similar (and do not suffer a considerable reduction) with respect to the properties of the baseline configuration of the laminate before the multifunctional elements are added to it. Moreover, other characteristics like erosion, lightning protection (and electrical conductivity) and moisture ingress have been assessed to check the laminate behaviour compared with traditional composite laminates. Once an optimum set of possible multifunctional laminate concepts has been developed and its properties tested, the research ensured that the performance is kept when the size of the part is scaled up to full scale for the future industrial application.

The main role of FIDAMC in this project is the selection of several materials and different manufacturing techniques with the aim of minimizing noise and vibration propagation. INTA is in charge of the acoustic and vibrational evaluation while erosion assessment, moisture ingress, lightning strike and mechanical testing have been performed by FIDAMC. Finally, various demonstrators of the full scale components were built to study manufacturability issues and properties on the real size part. In parallel with this last stage of the project, an industrialization strategy has been proposed.

4.1.2 Summary description of project context and objectives

The recent use of layered composites in aircraft fuselage structural components offers the opportunity to embed interleaved layers of different materials in the skin laminates so that additional performances may be added while maintaining the structural efficiency. The presence of layers of damping materials inside the composite laminate normally results in an important reduction of mechanical properties. The goal is to design composite laminates with integrated acoustic insulation without compromising the mechanical performance of the composite structure. For this purpose different alternatives have been studied in terms of:

- Vibro-acoustic damping performance of the materials to be integrated in the laminate.

- Vibro-acoustic and mechanical behavior of the hybrid laminates depending on the position of the protector material in the composite structure. The mechanical properties of the proposed solutions will have to be evaluated to ensure that they do not suffer a considerable reduction compared against the baseline laminate, without the integration of the vibro-acoustic damping material.

This integration of acoustic damping function in a single material system will permit enhancing the structural behavior and diminish overall structural weight by reducing redundancies between subsystems and functions.

To meet the objectives of the project, work has been split up into work packages that intend to investigate the different kind of acoustic damping materials as well as different techniques for integrating them into a composite structure with the intention of optimizing the acoustic damping/weight ratio of the multifunctional structure.

The aim of WP1 is to propose, based on a review of the current state of the art and on the team's experience in previous works carried out in this field, the most promising candidate materials for multifunctional laminates development, mainly aiming at acoustic and vibrational damping. WP2 and WP3 are devoted to select the most appropriate integration techniques in order to introduce the damping material most efficiently into the composite structure.

The objective of WP4 is to evaluate the surface performance (anti-erosion characteristics for external application) of the selected materials using the optimum integration and manufacturing techniques explored in previous work packages. The test plan followed was according to aerospace norms. The aim was to reproduce as realistic as possible erosion/blast conditions. The goal WP5 is to evaluate the moisture ingress of the selected materials. A test plan was prepared according to aerospace norms. The aim was to reproduce as realistically as possible an aircraft's operating environment. In the frame of WP6 the lightning strike protection performance of the selected materials and their electrical conductivity was assessed. Lightning direct effects were tested at 1A and 2A zone levels. WP7 is devoted to evaluate the mechanical performance of the selected materials. Both monolithic and sandwich coupons will be mechanically tested. The objective WP8 is to evaluate the acoustic/vibrational performance of the selected materials. Those properties correspond to acoustic transmission coefficients and mechanical modes.

Finally, the objective of last WP is to carry out trials to address the difficulties involving automatic processing. Flat panels will be manufactured, but also curved panels will be processed using FIDAMC's fibre placement machine. Reliability of manufactured specimens will be probed through non destructive inspection. Additionally, proposals for efficient industrialization will be presented.

4.1.3 Description of the main S&T results/foregrounds

4.1.3.1 Material pre-selection

On the basis of a comprehensive material evaluation, five acoustic damping materials were preselected due to (according to information provided by the suppliers) their good to fair compromise between specific performance, low impact on mechanical performances, processability and commercial availability. The concerned materials are listed below and a brief explanation of their characteristics provided by suppliers is given as well.

- SMACWRAP® EX & ST from SMAC Group, MontBlanc Technologies.
- CEM Acoustic prepreg (CAP) from Cytec Engineered Materials
- Non-vulcanized rubber (K180) from Kraiburg Group
- Hexweb® Acusti-core ® from Hexcel Composites

Both SMACWRAP ST and EX consist in 0.1mm thick ribbons of viscoelastic rubbers. Two alternatives are offered for different temperature ranges, ST compound is optimized for ambient temperatures while EX product is designed for working at low temperatures. These materials are dedicated to direct integration in composite panels and especially with honeycomb. According to the supplier, a layer of SMACWRAP® embedded in the core of a fuselage composite skin laminate should be able to bring a high amount of damping. Figure 1 shows SMACWRAP samples.

Figure 1a) SMACWRAP® ST 65 mm width bobbin; 1b) SMACWRAP® ST 600mm width sample; 1c) SMACWRAP® EX 600mm width sample

CEM acoustic prepreg from Cytec is an acoustic veil embedded in an epoxy resin layer with a thickness of 0.15mm which makes the material easy to integrate in a composite laminate since it can be handled like conventional carbon fibre prepregs. According to supplier, an acoustic interleaf laid up at the mid plane of an eight layer carbon laminate shows a significant improvement in acoustic damping properties if compared to a reference laminate without CEM material insertion.

KRAIBURG non-vulcanized rubber is a 0.5mm thick calendered raw rubber compound bondeable directly to prepregs. It is conceived to vulcanize at the temperature at which the prepreg resin cures, giving good bonding properties to the laminate layers. According to the supplier, this calendered raw rubber can be processed like conventional prepregs. It can be doubled it up and it is freely drapeable. Many features as colour, flowability, hardness, dampening and terms of vulcanization time may be modified on request. Therefore, a non-vulcanized rubber could be developed to properly vulcanize in a standard CFRP laminate curing cycle. In this sense, non-vulcanized rubbers from Kraiburg are a very flexible alternative for acoustic damping improvement in composite laminates.

Finally, Hexweb Acousti-core is a 15mm thick honeycomb filled with sound-absorbing fiberglass and provided by Hexcel Composites S.L. This material provides a broadband of sound-reducing capability honeycomb cores. They are manufactured from Hexcel´s standard honeycomb products whose cells are uniformly filled with sound-absorbing fibreglass bating resulting in a minimal weight increase with unchanged mechanical properties. Figure 2 presents a sketch of the geometry of the Hexweb acoustic-core and Figure 3 shows a sample of this acoustic damping material.

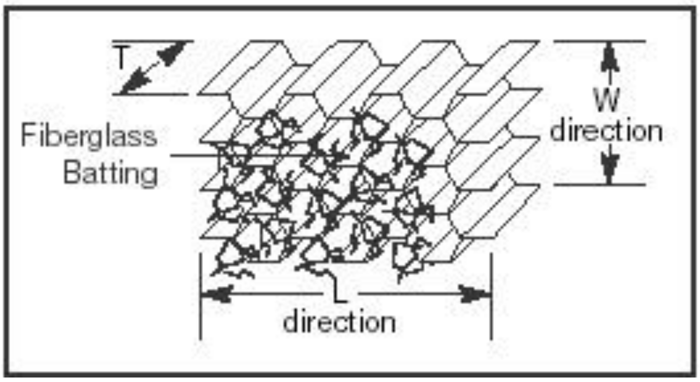

Figure 2. Geometry of the Hexweb® acousti-core®;

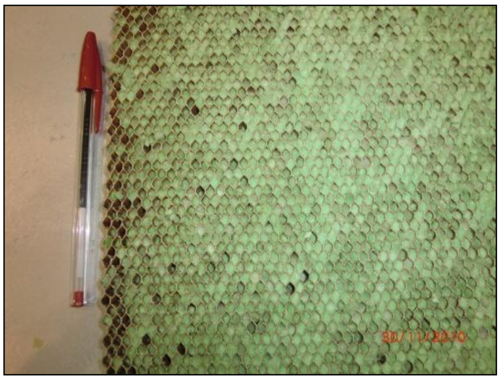

Figure 3. Acousti-core® sample

4.1.3.2 Manufacturability and integration strategies

After selecting acoustic materials candidates, the work was focused to select the most appropriate integration techniques in order to introduce the acoustic damping material most efficiently into the composite structure without reducing relevant mechanical properties. In order to determine the acceptability/unacceptability of these multifunctional composite laminates and to select the best configuration acoustic-material/laminate among the candidates analyzed, several manufacturing and mechanical tests were performed.

As an example, Figure 4 schematizes some of the alternatives considered along COMPASS project in order to integrate acoustic materials in sandwich configurations. Alternative a) consists in a co-cured double sandwich with a layer of acoustic-damping material between the panels. Figure 4b) presents the integration of the acoustic layer as interleave in one skin of the sandwich panel. Design c) suggests the insertion of the acoustic material between the honeycomb and one skin of the sandwich. In this case the structural resistance can be affected since the acoustic material is directly bonded to the honeycomb. However, it involves a weight saving, necessary when lightness is mandatory. Finally, the scheme 4d) makes reference to a sandwich panel already cured to which is bonded an acoustic damping material layer plus a CFRP layer.

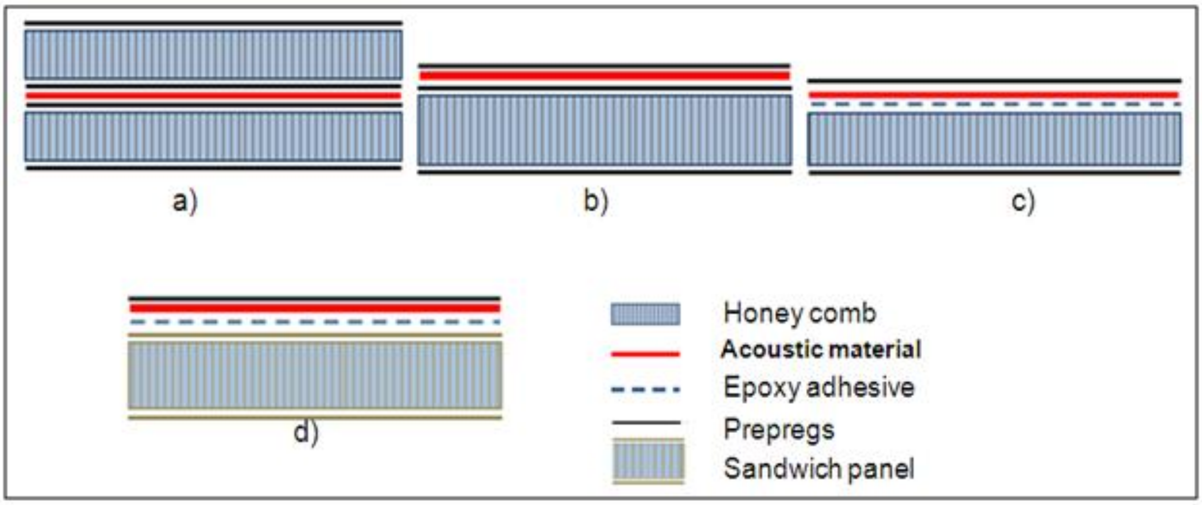

Figure 4. Different ways to integrate acoustic materials in sandwich panels

In view of monolithic configurations, Figure 5 shows a sketch of the architecture alternatives for hybrid composite laminates. Acoustic-damping material centered in the mid plane of the laminate is represented in sketch C while non symmetric configurations with the multifunctional material placed externally or under few CFRP plies are schematized in B and A respectively.

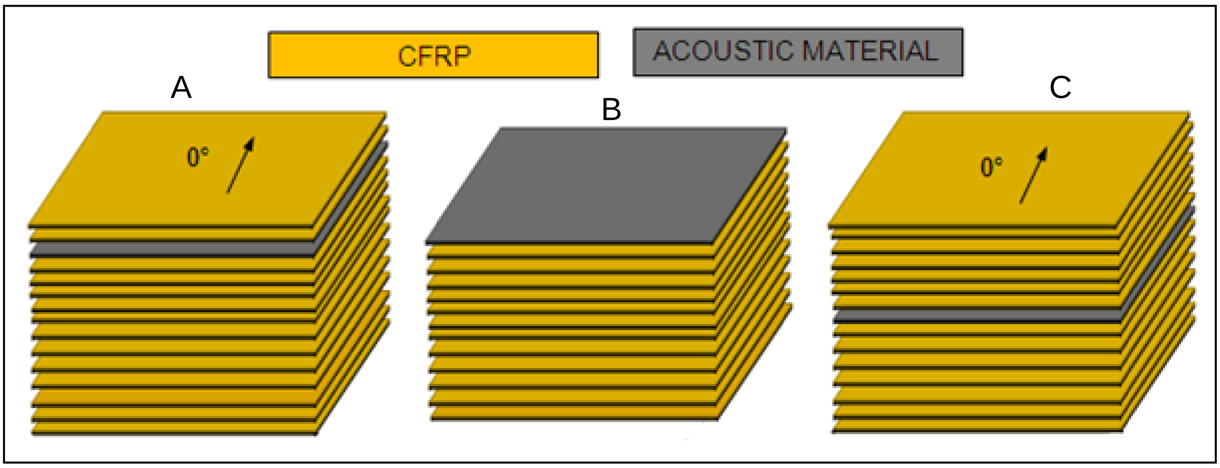

Figure 5. Architecture alternatives for monolithic laminates

Once acoustic material insertion strategies were selected, several manufacturing tests were carried out. Next figures present manufacturing trials performed with both SMAC EX and ST, K180 and CAP materials. Dimensions of the concerned panels were 500mmx500mmx2mm approximately.

The acoustic layers were positioned directly in contact with the carbon epoxy UD tape in all cases, without using any kind of adhesive films. In order to favor the adhesion between the uncured carbon epoxy UD tape and the acoustic material, a debulking bag was implemented immediately after placing the acoustic layers.

Regarding to tackiness, CAP material showed the best tacking to the uncured fiber epoxy UD Cytec tape due to its compatible preimpregnated resin. The rest of acoustic materials presented low tacking but after performing a debulking bag they did not make difficult the manufacturing process.

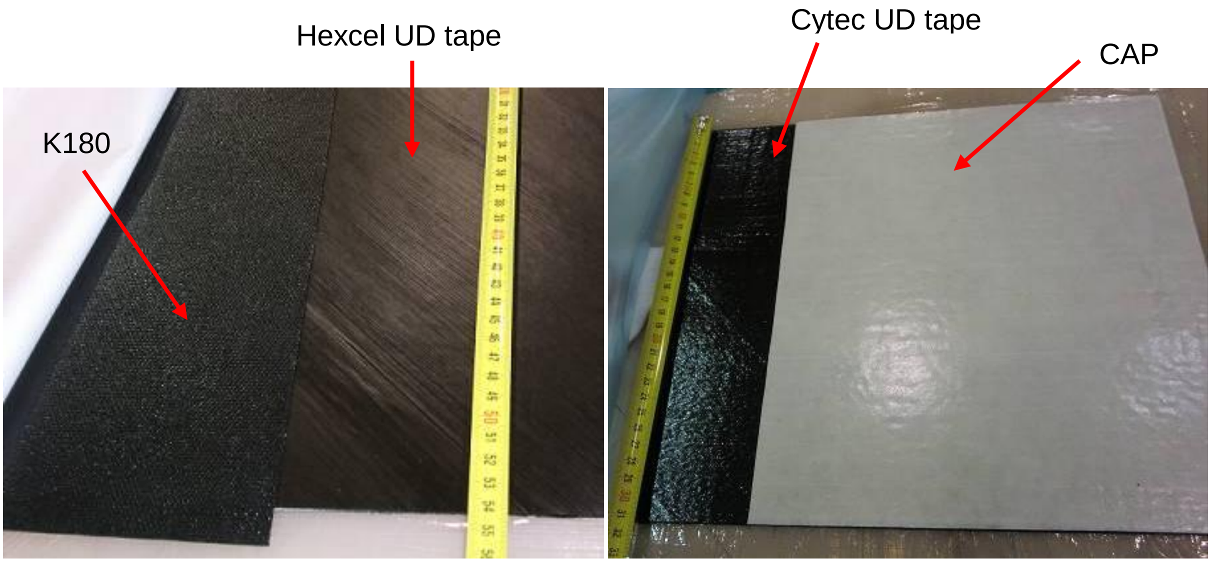

Figure 6. Manufacturing trials with K180 (left) and CAP (right) in monolithic configurations

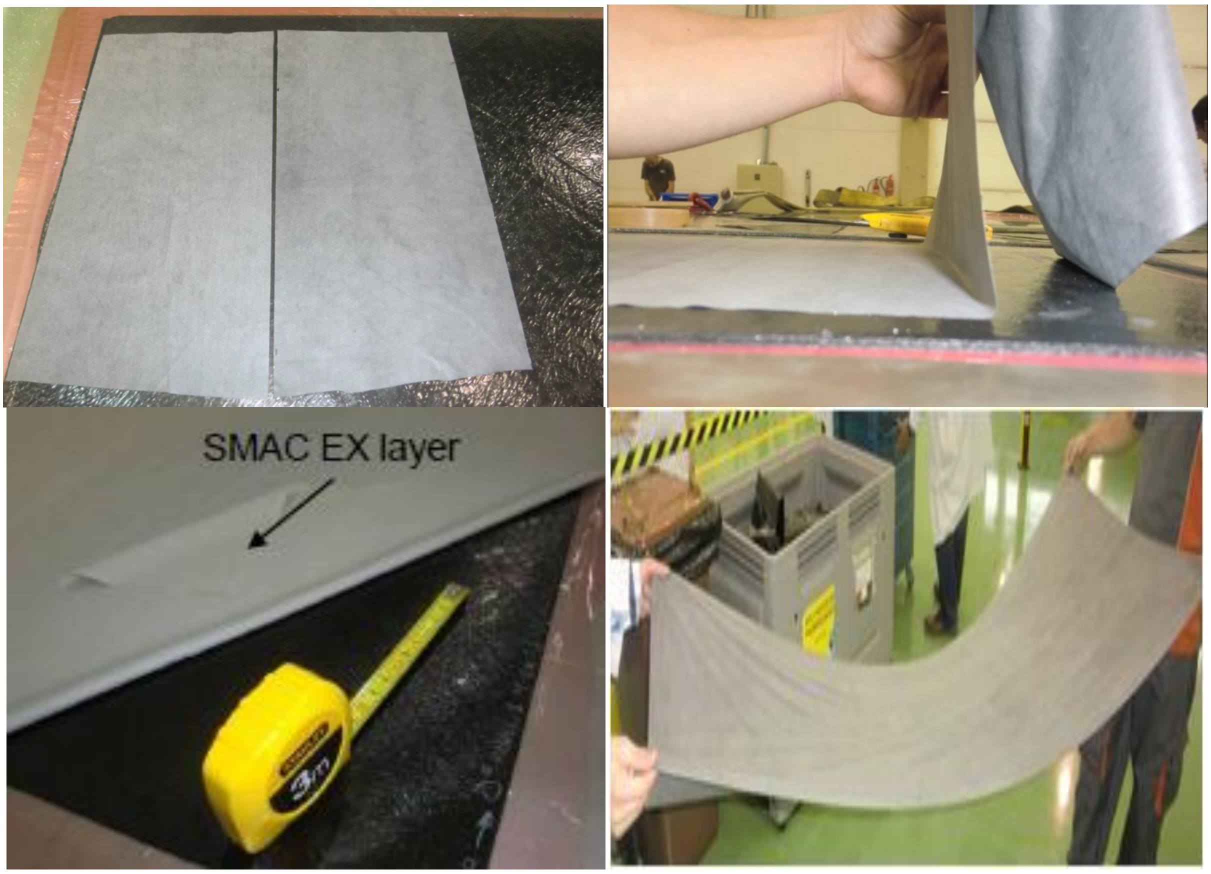

Figure 7. Manufacturing trials with SMACWRAP® products in monolithic configurations

The placement of the acoustic layers on the uncured prepreg material did not present problems: no bubbles or wrinkles appeared, acoustic layers kept their position in the panel when a carbon epoxy UD ply was placed on it. In general terms, SMAC, K180 and CAP materials showed a relatively fast and easy adaptation to the composite laminate. Acoustic materials were not damaged during the autoclave curing cycle. Hybrid panels were fairly well consolidated to the laminates without presenting cracks or insufficient adhesion to the carbon fiber.

The cutting of the acoustic materials is easier in the case of CAP and K180 due to its support paper that facilitates a tight cutting. Cutting of SMAC materials is more complex due to the elastomeric nature of the material and the absence of a protector paper. These materials offered easy handling during the manufacturing of the hybrid laminates. Trimming and machining after curing did not cause discontinuities between the acoustic interleaves and carbon epoxy UD tapes.

Summarizing, SMAC ST, SMAC EX, K180 and CAP material have shown an easy handling during the manufacturing of hybrid panels. It can be concluded that they seem not to influence significantly the manufacturing process. The disadvantage of SMAC materials is the cleaning requirement which increases the process time and introduces a factor that may increase the variability of results depending on the cleaning process. The main advantage of CAP material is its excellent tacking to the uncured prepreg tape. However, the fact that the acoustic material is preimpregnated involves resin compatibility issues; which decreases its versatility in comparison with other acoustic materials explored in this project. Its more decisive drawback is the impediment that offers to ultrasound inspection.

Concerning sandwich constructions, Figure 8 shows the manufacturing of a sandwich panel with Hexweb® acousti-core®. No relevant problems arose during the manufacturing process. This material behaves as a regular honeycomb from manufacturability point of view. However, a delicate handling and machining of the acoustic core is needed in order to avoid acoustic filling losses.

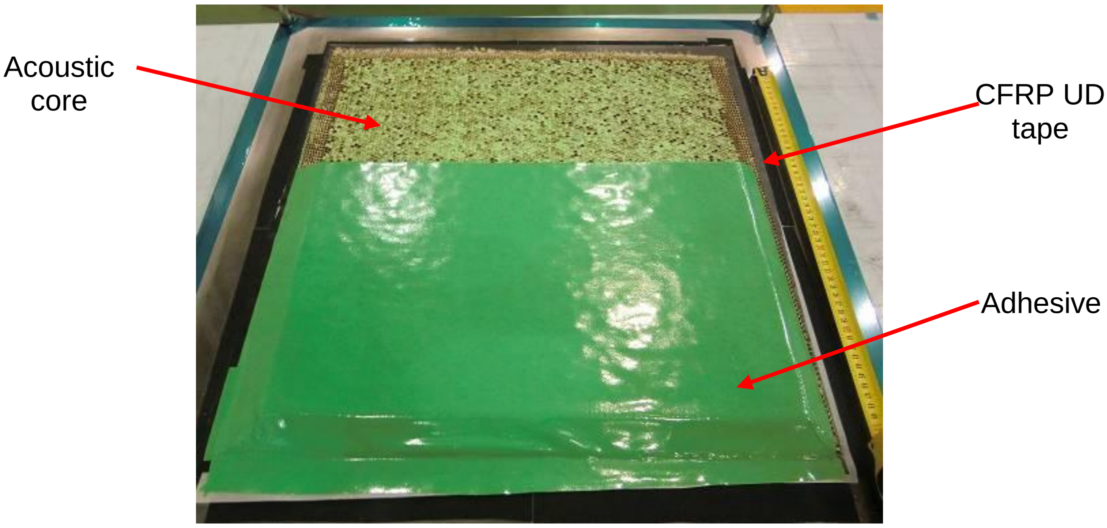

Figure 8. Manufacturing of sandwich panel with Hexweb® acousti-core®

Additionally, SMAC EX was also inserted in sandwich configurations with a regular honeycomb core.

From the point of view of inspectability, all the panels manufactured with exception of those with insertion of CAP material, were successfully assessed by means of standard NDT (pulso echo for monolithic constructions and transmission for sandwich configurations).

4.1.3.3 Mechanical assessment

A mechanical test campaign was performed in order to assess the mechanical behavior of the hybrid laminates and approximately quantify the effect of the insertion of these acoustic materials on the mechanical properties of the laminates. ILSS, compression, G_{IC} and flatwise tensile tests according to standards EN2563, EN2850, AITM1-0005 and I+D-E-246 respectively were performed among others. Most relevant conclusions from mechanical tests are summarized in next paragraphs. Results were compared with typical values for monolithic laminates without acoustic insert.

ILSS tests on monolithic coupons with SMAC EX registered quite acceptable values. SMAC EX-carbon epoxy UD tape interface seemed to be unaltered neither because of the applied load nor because of the temperature (see Figure 9 left). On the other hand, monolithic constructions with SMAC ST showed values lower than those obtained from SMAC EX coupons and additionally, a separation of the acoustic layer from its substrate was observed in some coupons (see Figure 9 right).

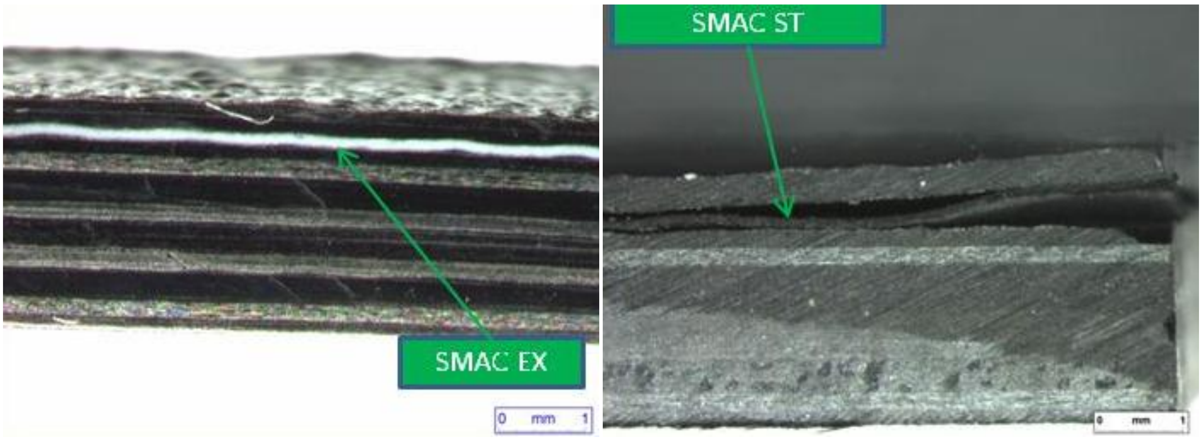

Figure 9. Left) ILSS coupon with SMAC EX tested at RT and right) ILSS coupon with SMAC ST tested at 90°C

Kraiburg material involved higher diminution of the ILSS values.

CAP coupons presented an excellent load transmission at -55 C but the interlaminar shear strength diminished dramatically at high temperature. Figure 10 shows coupons with insertion of CAP and K180 acoustic material already tested.

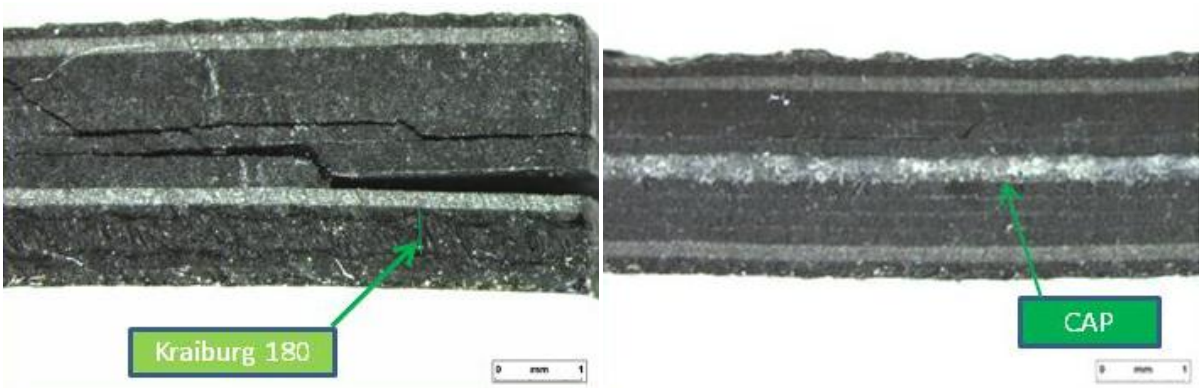

Figure 10. Left) ILSS coupon with K180 tested at -55°C and right) ILSS coupon with CAP tested at 90°C

Next figures present G_{IC} coupons with insertion of CAP and K180 acoustic materials. As it can be observed in the photographs, all CAP coupons tested present 100% cohesive failure while K180 coupons show 100% adhesive failure. In Figure 11 B white lines signalize the end of the test. In these specimens, the black side corresponds to the elastomeric material, completely fixed to one semi-coupon while the less dark side corresponds to the Hexcel UD tape, totally clean of acoustic material. On the other hand in Figure 11 a high homogeneity in the surface crack propagation is observed due to the cohesive breakage of the Cytec acoustic prepreg. Figure 11 C and D presents the propagation crack detail during testing of CAP and K180 coupons respectively.

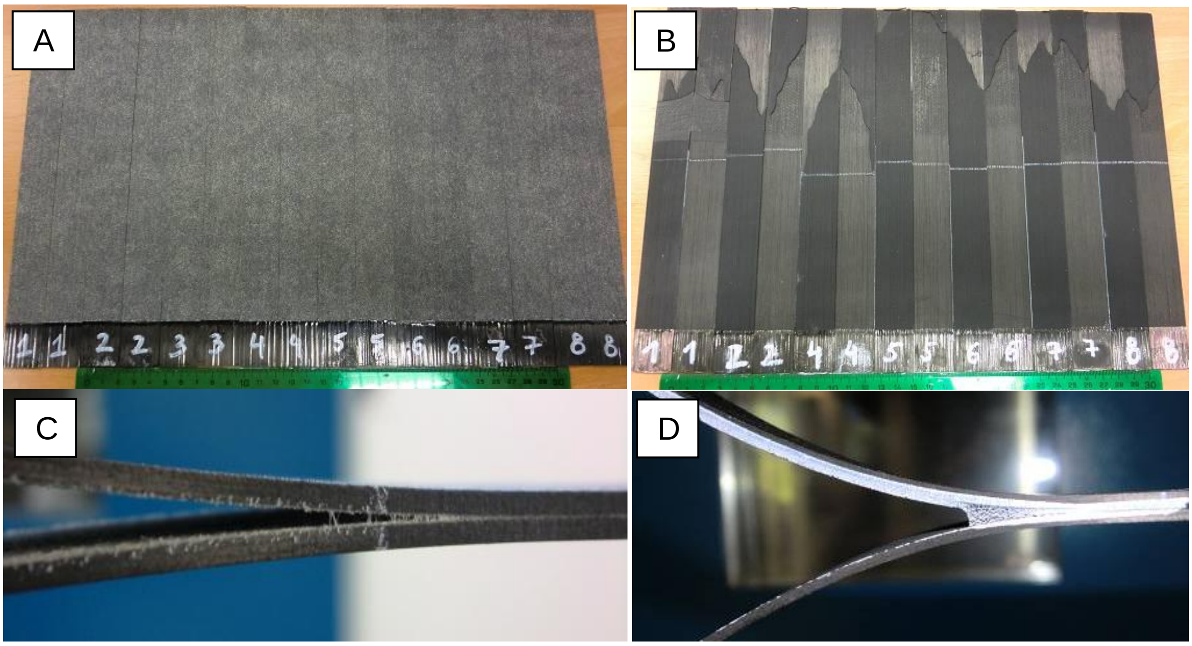

Figure 11. A) CAP G_{IC} coupons tested (cohesive failure); B) K180 G_{IC} coupons tested (adhesive failure); C) propagation crack detail on CAP coupon during G_{IC} test; D) propagation crack detail on K180 coupon during G_{IC} test

Regarding to compression strength tests, it is important to highlight that Kraiburg and specially, CAP coupons, presented polymer squeeze-out during load application at 90°C. Compression strength obtained in Kraiburg coupons was clearly lower at high temperature. Alternatively, results from tests done on CAP coupons suggest that the temperature does not affect significantly the compression strength of the hybrid laminate in spite of the acoustic material overflowing experimented at 90°C (see Figure 12).

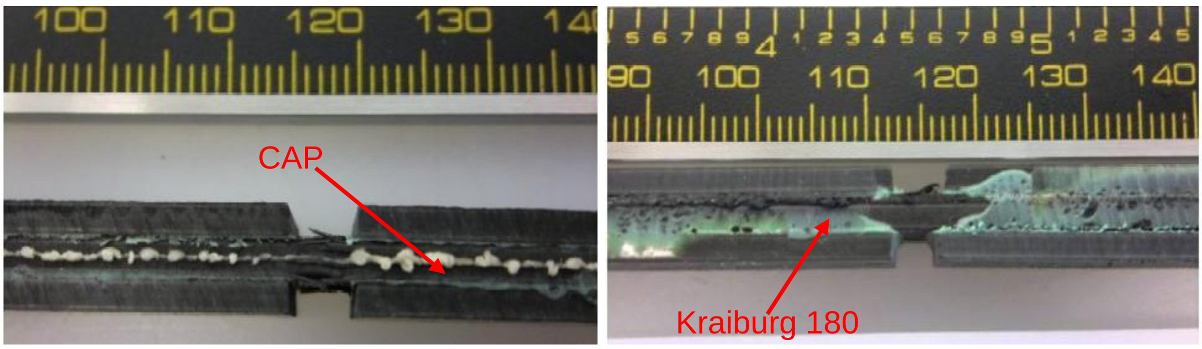

Figure 12. left) CAP compression strength at 90°C and right) K180 compression strength at 90°C - failure details

Concluding, among monolithic constructions with carbon epoxy UD tape from Hexcel, the rubber from Kraiburg showed the highest drop in mechanical properties, probably due to its thickness significantly coarser than SMACs materials, which is its biggest drawback. Concerning to Cytec construction, CAP material seems to influence in great measure ILSS and compression strength values but it behaves acceptably in terms of G_{IC}.

Concerning to sandwich constructions, Hexweb® acousti-core® seems not to make influence on the flatwise tensile strength compared to results from reference panels manufactured and tested in this research project.

From the point of view of mechanical behavior, it was concluded that SMAC EX placed externally under a few CFRP plies is the configuration with the best mechanical behavior among alternatives explored in this project. Most of the work done and presented hereafter is related to tests performed on coupons with this configuration.

4.1.3.4 Erosion assessment

With the intention to assess the behavior against erosion of some of the materials pre-selected in previous work packages, several erosion tests were carried out in a blasting equipment (see Figure 13 and Figure 14) according to test procedure based on standard AIMS 04-12-000. The goal was to establish a material ranking for erosion protection as well as to check that the insertion of these acoustic materials does not negatively affect the behavior against erosion of the hybrid laminates when compared to reference coupons.

Figure 13. Blasting equipment

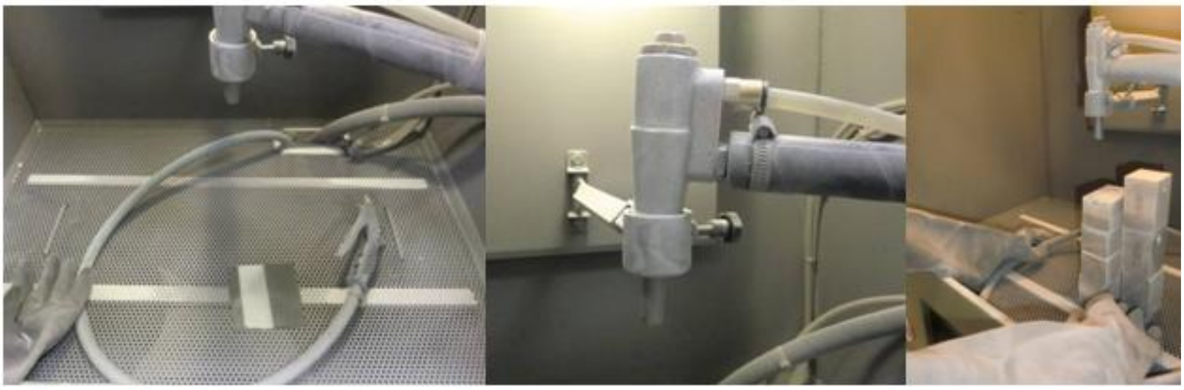

Figure 14a) Interior of blasting cabin; 14b) Detail of the nozzle; 14c) test set-up

Several coupons of dimensions 100mmx100mm were exposed to different erosion times. Coupons with SMACs and Kraiburg materials placed on surface and under CFRP plies of the base laminate were tested. Some of the coupons with the acoustic material placed between CFRP plies were painted with an erosion resistant paint scheme of 120μm of thickness. Results were compared against CFRP and metallic (AL 2024 T3) coupons.

Some of the most interesting results are presented in next figures. Coupon with SMAC EX on surface exposed 15 seconds to the media blasting showed a “wrinkled bubble” in the acoustic material layer (Figure 15 A). On the other hand, SMAC ST is entirely broken in the damaged area with some carbon/epoxy layers affected by the erosion in a coupon tested during 60 seconds (see Figure 15 B). Alternatively, after 10 minutes of blasting only slight changes in color and roughness were observed in coupon with Kraiburg material (Figure 15 C). Figure 15 D shows a coupon with SMAC ST inserted between CFRP plies tested during 1 and 2 minutes. In both cases the damage was almost a circular area.

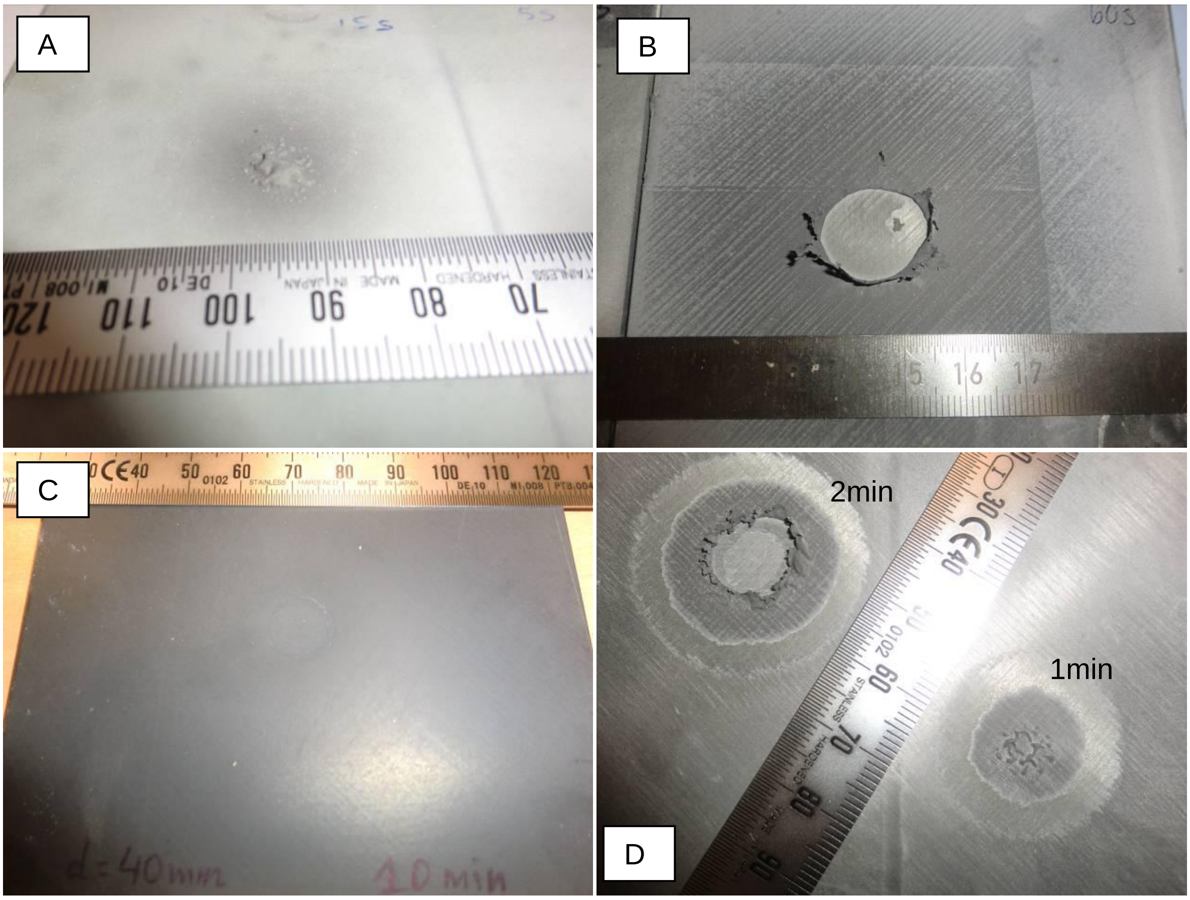

Figure 15. A) coupon with SMAC EX on surface tested during 15 seconds; B) coupon with SMAC ST on surface tested during 60 seconds; C) coupon with K180 on surface tested during 10 minutes and D) coupon with SMAC ST inserted between CFRP plies tested during 2 and 1 minutes

As an example of coupons prepared with an erosion resistant paint scheme, Figure 16 shows a coupon with insertion of K180 acoustic material under CFRP plies with erosion resistant paint on surface. The coupon was exposed to 11 and 12 minutes to the blasting media and only an area with maximum dimensions of 10mmx9mm with the paint chipped can be observed. On the right side of the image, aluminum coupon with same erosion resistant paint scheme and tested during 2 and 7 minutes shows paint removal areas with maximum dimensions of 20mmx12mm and 25mmx25mm respectively.

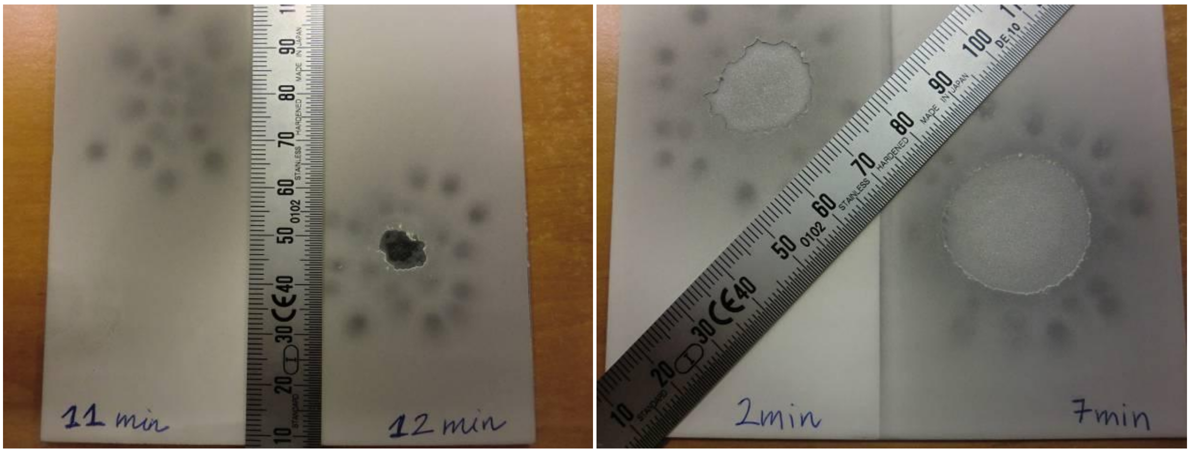

Figure 16. Painted coupons. Left) coupon with K180 under CFRP plies exposed during 11 and 12 minutes; right) Al 2024 T3 coupon tested during 2 and 7 minutes

Concluding, Kraiburg 180 compound seems to significantly improve the erosion protection of the laminate in both configurations explored (placed on the surface and inserted between CFRP plies), being even better than the erosion resistant paint scheme typically used in aircrafts. On the other hand, SMACs materials do not cause decreasing of erosion protection when they are placed on the surface of the composite laminate. However, further tests are envisaged in order to ensure that SMACs materials do not negatively affect the erosion protection of the laminates when they are inserted within the CFRP laminate.

4.1.3.5 Moisture ingress assessment

The purpose of these tests is to quantify the water amount absorbed by a hybrid laminate with insertion of SMAC EX in comparison with a reference configuration without acoustic insert. With the aim of reproducing as realistically as possible an aircraft's operating environment, this tests campaign allows us to discard that the insertion of SMAC EX negatively affects the behavior of the hybrid laminate in terms of moisture ingress.

Two different tests were performed in the frame of moisture ingress assessment: Conditioning in Climatic Chamber (CCC) and Immersion in Hot Water (IHW). Figure 17 shows coupons corresponding to both tests in the interior of the climatic chamber.

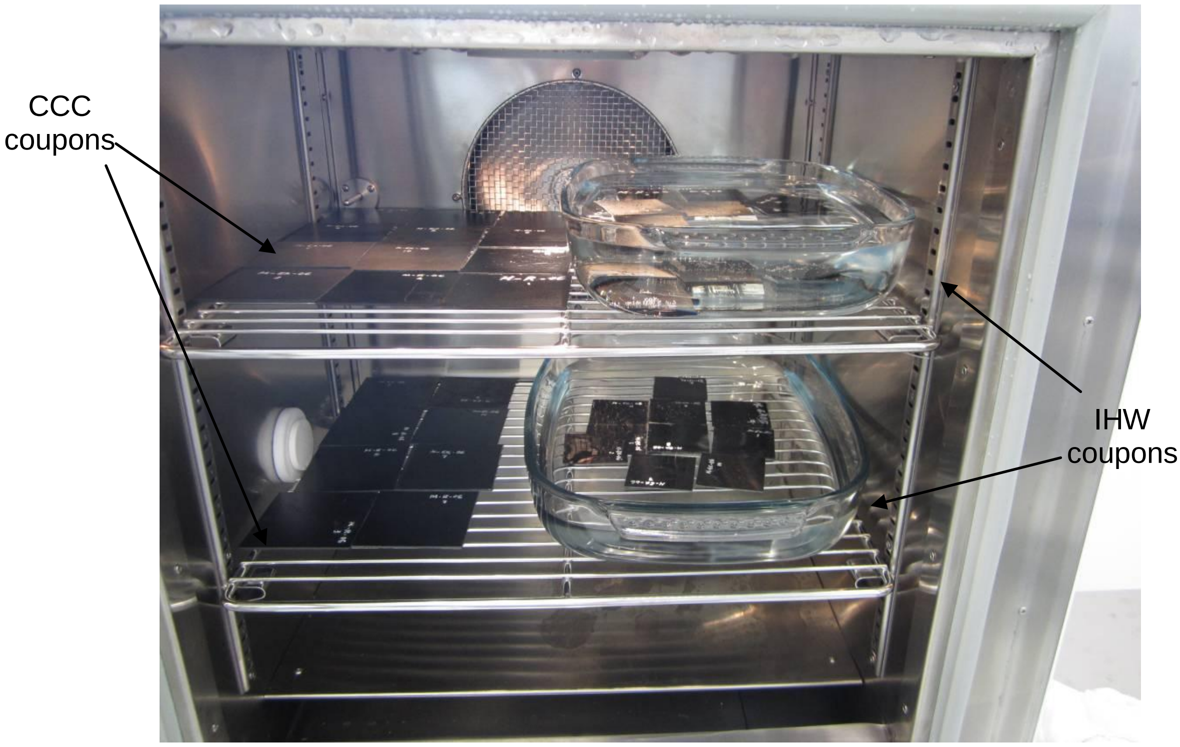

Figure 17. Interior of climatic chamber with CCC and IHW coupons

Main conclusions extracted from these tests are exposed below:

Coupons with SMAC EX absorb approximately 10% less water than reference coupons in CCC and IHW tests. SMAC EX material seems to act as a barrier for the water and moisture. Once the external CFRP plies have absorbed water, the acoustic material seems to block the water to advance through the laminate and therefore, the hybrid laminate can only absorb water through the bag face, which decreases the water absorption rate.

Concluding, SMAC EX insert seems to improve the moisture ingress of a composite laminate, not only in terms of percentage of water absorption but also in terms of absorption rate, being the absorption rate of coupons with SMAC EX insertion 25% slower than the rate measured for reference coupons.

4.1.3.6 Lightning strike protection assessment

In order to assess the behavior against lightning strike of a laminate with insertion of SMAC EX, lightning strike tests were performed on hybrid and reference laminate. Both specimens were painted with a conventional aircraft paint scheme. Test samples were subjected to simulated lightning tests at different levels: I, II and III with current peak amplitude of 200KA, 100KA and 60KA respectively.

Temperature measurements during the simulated lightning test were carried out with a thermal camera. Figure 18 shows the maximum temperature reached during tests at level I for both the multifunctional and reference laminate.

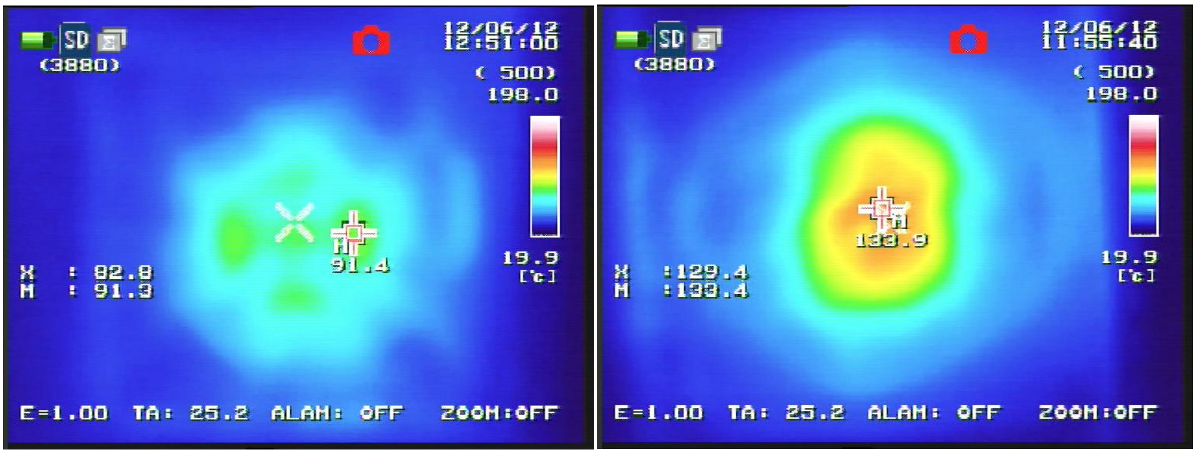

Figure 18. Maximum temperature reached in lightning test at Level 1: left) multifunctional coupon; right) reference coupon

Once the specimens were tested they were inspected by NDT in order to quantify the damage caused by the lightning impacts. For same impact levels, sample with SMAC EX showed less damage depth than the reference specimen with very scarce delaminations below the acoustic layer. Furthermore, in the case of impact corresponding to zone 2A, no damage was found below acoustic layer during ultrasonic assessment, being the damage caused restricted to outer carbon/epoxy plies. Figure 19 presents both multifunctional and reference coupons already tested.

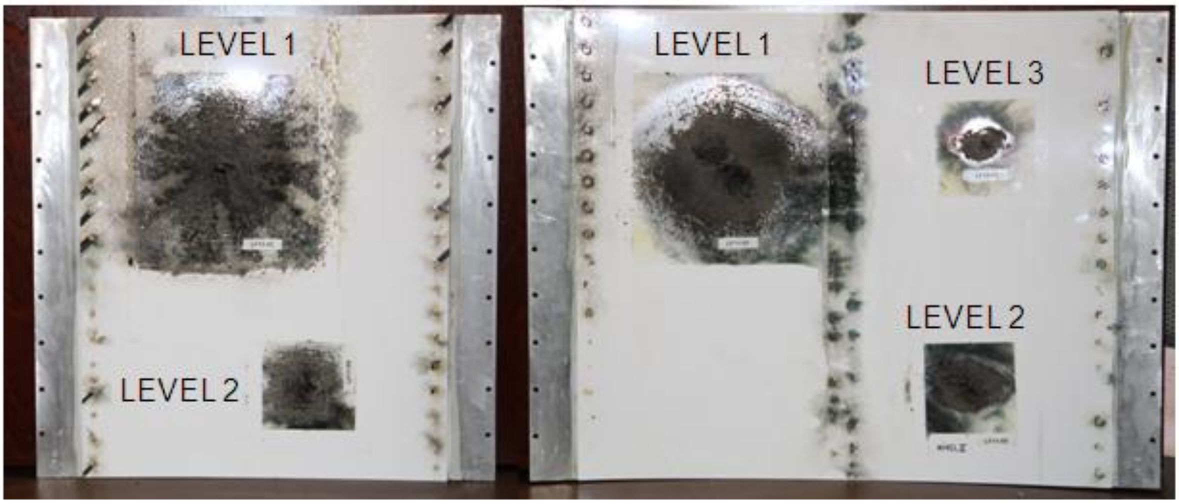

Figure 19. Multifunctional coupon (left) and reference coupon (right) tested

Damage produced in laminate with SMAC EX is extended in the outer carbon/epoxy plies, reaching the rivets which make the connection between the sample and the metallic plates for connecting the specimen to the test rig. Compared to the reference specimen, the damage is bigger in area extension but the hybrid laminate is significantly less affected through the thickness than the reference sample.

It seems that SMAC EX behaves as an electric and thermal insulator acting as a barrier for the electrical current. It can be concluded that the SMAC EX inserted between carbon/epoxy plies does not negatively affect the lightning protection of the hybrid laminate but it improves the behavior of the laminate against lightning strike.

4.1.3.7 Acoustic-vibration damping assessment

Regarding acoustic behavior, the performance of the multifunctional configuration was explored through acoustic and vibration tests from which sound transmission loss factor (TL) and modal damping were measured respectively. Next paragraphs compile most relevant test results extracted from three specimens: multifunctional configuration (SMAC EX placed under CFRP plies), CFRP reference and aluminum (Al 2024 T3) reference. Dimensions of the test specimens were 1650mmx600mm.

Acoustic tests were performed in a double partition room according to ISO 140-3 standard. TL factor was measured at diffuse incidence. Figure 20 shows the test set-up.

Figure 20. Left) Aluminum test specimen mounted in the wall of the double partition room; (right) detail of the installation of the test specimen

Figure 21 presents the TL versus frequency for the three test specimens (multifunctional, CFRP reference and aluminum reference).

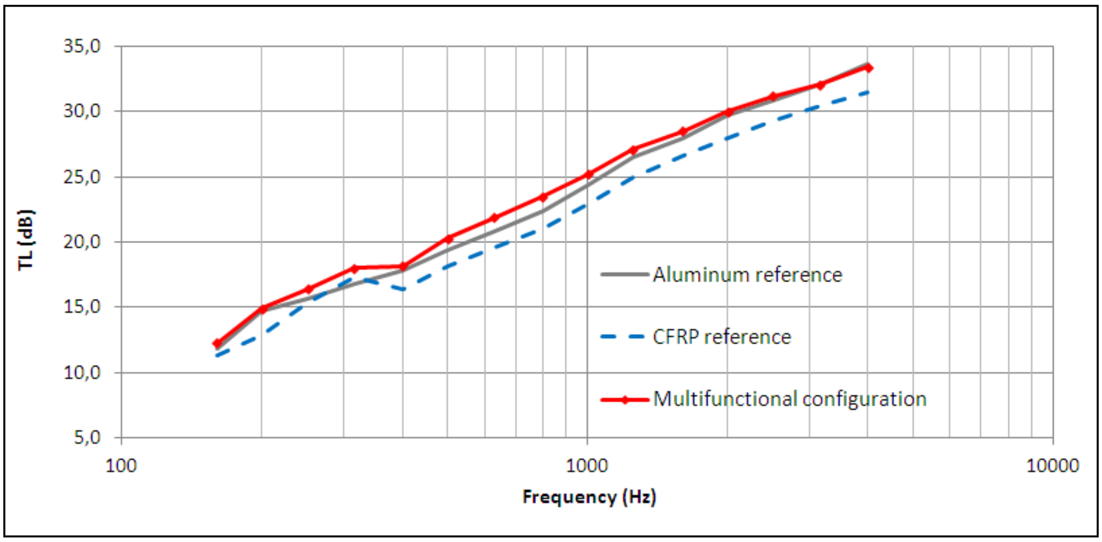

Figure 21. TL factor versus frequency for multifunctional, CFRP reference and aluminum reference configurations

From the graph presented above, it seems that the multifunctional configuration does not noticeably differ either from the CFRP reference or from the metallic reference.

On the other hand, modal damping obtained from vibration tests shows an improvement of the hybrid laminate with SMAC EX compared to the CFRP and aluminum references. The acoustic material SMAC EX improves the modal damping of the hybrid laminate, being the damping of the multifunctional configuration 1.84 and 1.48 higher than the CFRP and metal references respectively.

4.1.3.8 Manufacturing at large scale and industrialization works

The manufacturability of hybrid laminates with insertion of SMACWRAP materials has been explored through several manufacturing trials along COMPASS project. Hybrid laminates have been manufactured by means of hand layup, ATL and FP lay-up (automatic lay-up of CFRP UD tape over SMACWRAP materials). Regarding geometry, flat (1650x600mm^2) and curved (300x150mm^2) panels with insertion of SMACWRAP materials were successfully manufactured.

Figure 22 shows a stiffened laminate with hybrid configuration in the skin (SMAC EX placed between CFRP) plies. The stiffened panel was co-cured in autoclave and aluminum ribs were subsequently riveted. The panel was successfully manufactured. Neither during manufacturing nor in the assembly process did problems arise from the insertion of the acoustic material.

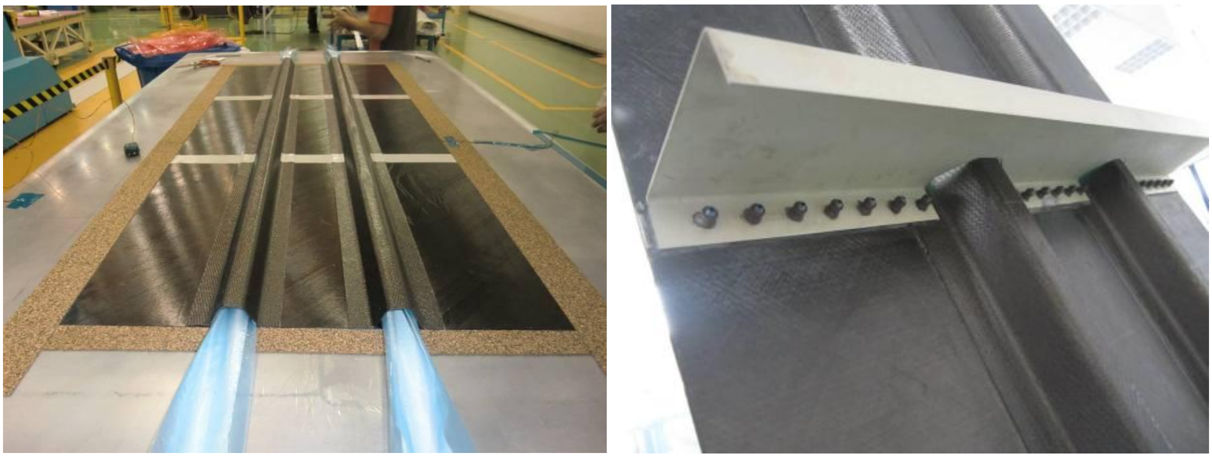

Figure 22. Stiffened panel with multifunctional configuration: Ω stringers co-cured and metallic ribs riveted. Left) Uncured multifunctional stiffened panel; right) detail of the aluminum rib riveted to the multifunctional panel

Figure 23 shows some details of the manufacturing process with ATL. Regarding automatic cutting process with the Panex device integrated in the ATL head machine, uncured hybrid laminates were successfully cut. Panex device is basically a sonotrode consisting of a blade activated by ultrasounds that allows the cutting of uncured laminates. Figure 23A shows a detail of the blade of the Panex device while Figure 23B presents the Panex cutting process of a hybrid laminate with insertion of acoustic material. Figure 23C shows the ATL head machine working above acoustic material. A detail of the gap left by the ATL during the placement of UD prepreg tape can be observed in Figure 23D.

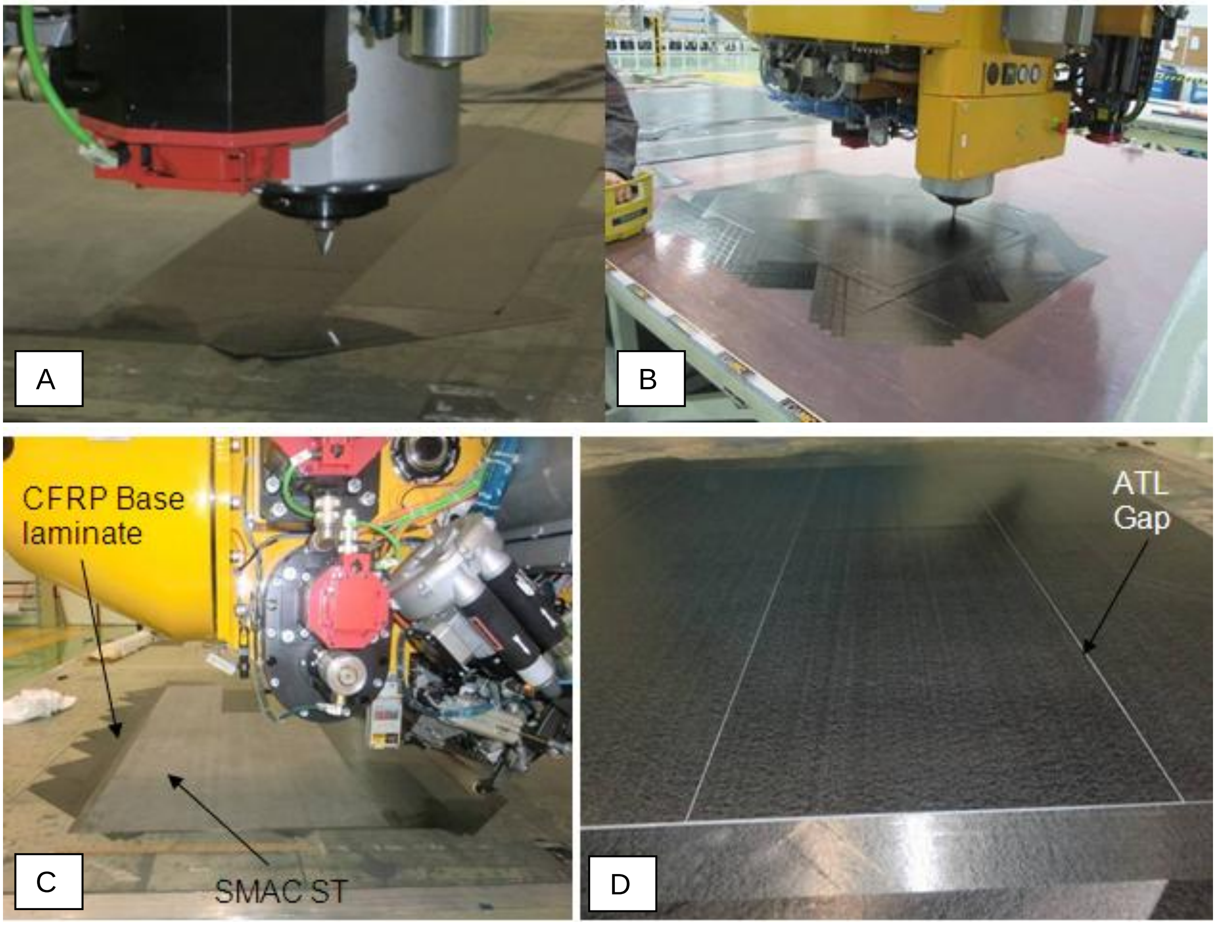

Figure 23. Manufacturing tests with ATL machine. A) sonotrode detail, B) panex cutting, C) automatic tape layup over SMAC layer and D) ATL gap detail over SMAC material

Manufacturing tests with FP machine were also carried out. Hybrid curved panel of dimensions 300x150mm^2 was manufactured. Figure 24 (left) shows the acoustic material over the CFRP slit tape already laid up by the FP. A detail of the slit tape laid up over the acoustic material can be noticed in the right side of Figure 24.

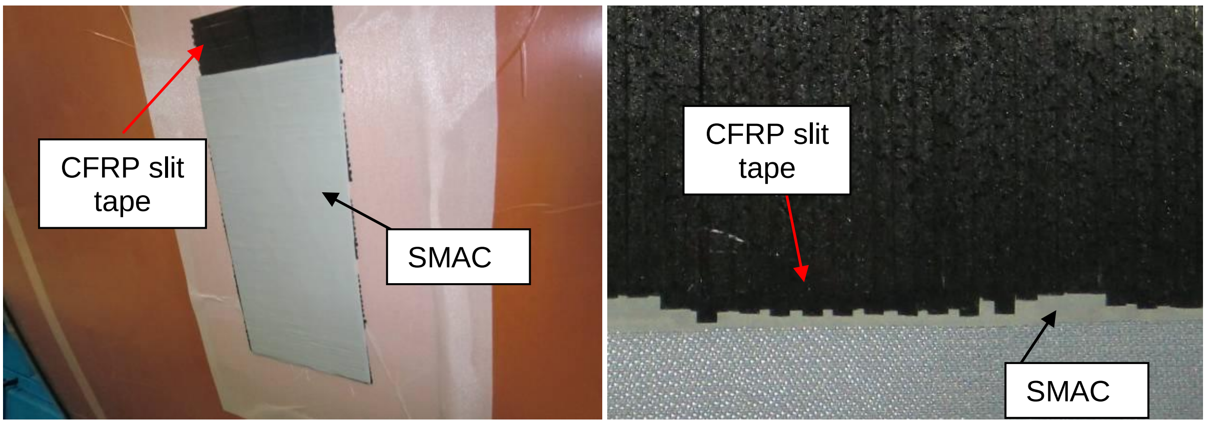

Figure 24. Manufacturing tests with FP machine. Left) acoustic material placed over slit tape ; right : slit tape placed over acoustic material

No relevant issues need to be reported regarding the lay up of the slit tape over the acoustic layer. However, further manufacturing trials are foreseen (in the frame of HYBRIA project) in order to check that the manufacturability is kept when the size of the part is scaled up to full or at least element scale.

Finally, Figure 25 shows the automatic inspection (pulso-echo technique) of a panel with multifunctional configuration.

Figure 25. Automatic NDT of multifunctional configuration

4.1.4 Potential impact and the main dissemination activities and exploitation of results

Regarding acoustics, future aircraft generation has highly demanding requirements to produce designs that will be increasingly more attractive for airlines and comfortable for passengers. The fact that next generation fuselages will have an important amount of composite materials offers the opportunity to reduce engine and aerodynamic noise, as well as vibration transmission to the interior of the aircraft using acoustic multifunctional lay up.

The most common method to minimize noise and vibration propagation to the interior of the cabin in current aircraft is the use of add-on parts that contribute to partially reduce noise and vibration levels. However, many add-on parts are required and this leads to high material costs, high labour costs and increased weight of the aircraft.

Developing multifunctional structures based on an efficient combination of materials, integration techniques, manufacturing process and industrialization proposals would prove a strong stepping stone in the area of acoustic damping in the aircraft cabin as well as their corresponding weight saving due to the multifunctional integrated architectures.

Spread of use of multifunctional materials in aircraft fuselages will result in:

- Increase of passenger comfort by aerodynamic and engines noise reduction in the aircraft cabin.
- Enhancement of structural behaviour by means of reduction of vibration transmission to the interior of the aircraft.
- Optimization of the production process by reduction of assembly steps.
- Labour costs saving related to these assembly steps
- Production of lighter structures due to a reduction of use of bolts and rivets.
- Fuel consumption saving due to diminution of aircraft parts weight and reduction of industrial production steps (less energy required as less parts produced separately).

Globally, impacts on society will be:

- Diminution of production costs and costs of use of aircraft vehicles: anyone will benefit of the limitations of the costs that airline companies will operate.
- Improvement of time production.
- Progress in green transportation: lower carbon emission, which is in line with European policy objectives in the frame of Clean Sky programme.
- EU technical leadership with new architectural CFRP concepts.

4.1.5 Relevant contact details

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