



JOINING
INNOVATION
AND EXPERTISE

TOD – Thermoplastics on Doors

10th EASN Virtual Conference

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Outline



- Project Background
- Project Objectives
- Consortium
- Project activities / Main findings
 - Process setup
 - Tool design and fabrication for process validation
 - Industrial Cost Evaluation
- Impact
- Next steps

- Weight reduction on going challenge for aircraft manufacturers to meet
 - International targets for emission reduction
 - Improve capacity and return on investment for customers
- Thermoplastic composites can save more weight compared to thermoset composites
- Thermoset composites have long curing cycles within large and expensive autoclaves
- Thermoplastics have shown improved mechanical performance and fast production cycles
 - They can be heated and reheated locally
 - They are offering potential for more automated manufacturing processes
 - Recyclable with different alternatives for their end of life handling



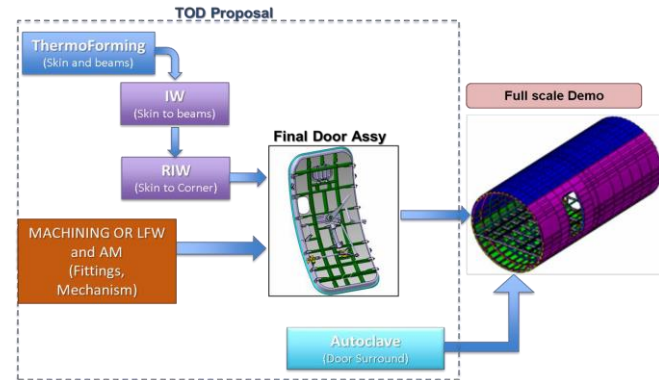
!!!Main objective of CS2JU

Reduction of carbon emission and environmental footprint

Project Objectives



- Demonstration of rapid manufacturability and validation of a full-scale thermoplastic composite door including:
 - Surrounding
 - Sub-structure for regional aircraft fuselage barrel
- Optimization and validation of component manufacturing using
 - Thermoforming
 - Induction Welding
- Thermoforming
 - Uses heat and pressure to transform a flat sheet into any shape
 - Good repeatability (for high production rate)
 - Mature technology
- Induction welding (IW)
 - Unique process to join composites that does not require contact with the heating element (induction coil)
 - No heat is produced outside the welding area



▪ TWI (Research and Technology Organization)

(<https://www.twi-global.com/>)

- Alternative process evaluation between Machining versus AM for fitting
- Non-Destructive Inspection on assembled parts
- Life Cycle and Cost Analysis based on ISO 14040:2006, ISO 14044

▪ DEMA (Aero structures World-Class Supplier)

(<https://www.demaspa.it/en/>)

- Process set up and validation at full size with special regards to process development and validation
- Parts fabrication for on-ground fuselage demonstrators
- Tools chain definition, design, manufacturing

▪ CETMA (Material and Structures Engineering Department)

(<http://www.cetma.it/en/index.aspx>)

- Setup of the Induction Welding technology for the assembly of the thermoplastic part of the door

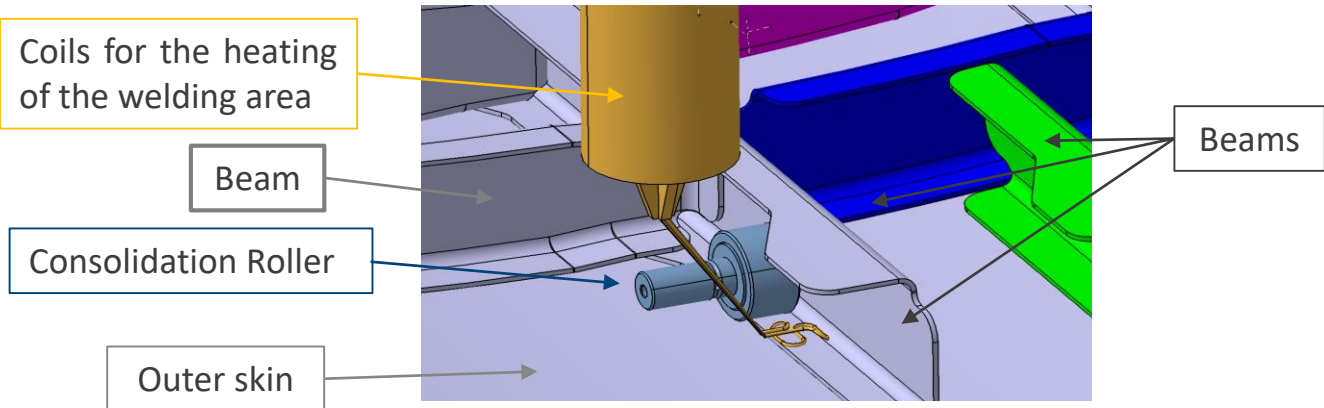
Process setup

- Thermoforming process (out-of-autoclave) used for the following thermoplastic parts:
 - Outer skin
 - Inner Skin
 - Horizontal Beam
 - Vertical Beam
- Autoclave process for thermoset parts
 - Door pan
 - Surrounding intercostals
- Induction Welding process
 - Use of induction welding can avoid the use of metallic fastener for assembling leading to time and weight saving
 - Establishment of the appropriate welding sequence is crucial in order to avoid any interference
 - Door configuration on the tool defined with the following strategy:
 - Welding of the door with the outer skin placed on the tool
 - Allows for good support under the welding interface to oppose the applied force

Process setup

■ Induction Welding process

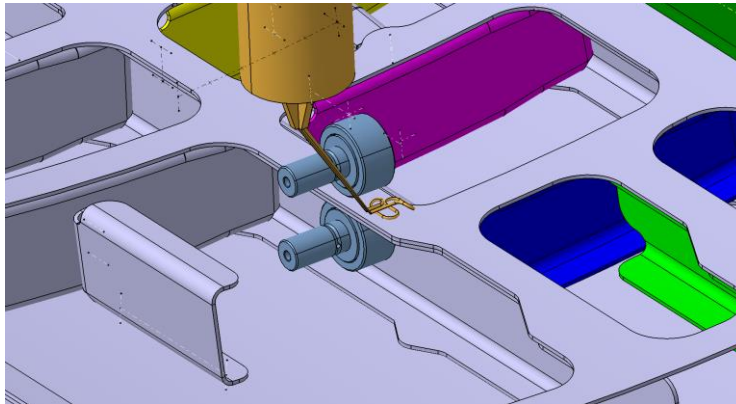
- Phase 1 (Joining of horizontal beams to the outer skin)
- Phase 2 (After horizontal beams are attached, welding of the other beams to the skin takes place)
 - Pressure will be applied with a cantilever roller
 - Outer skin is placed on the tool and roller applies pressure without deforming the beam



Concept design of head configuration for welding of beams to the outer skin

Process setup

- Induction Welding process
 - Phase 3 (Welding between the inner skin and the beam)
 - For the welding of the inner skin the pressure applied by the roller should be balanced
 - Stiffness of beams not sufficient to support the material during heating
 - Heated part of the beam should be supported to achieve good result in terms of the structure deformation
 - Support is realized with a second roller which applies local pressure to stabilize the welding area



Concept design of welding between the inner skin and the beam

Process setup

■ Additive manufacturing

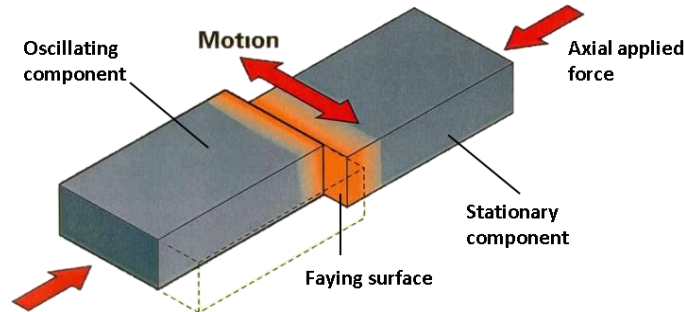
- Linear Friction Welding (LFW) and Laser Powder Bed (LPB)
 - Emerging technologies to manufacture titanium and aluminium alloy components
- LFW
 - Produces welded components of very high integrity within seconds but input material is not as close to shape as LPB
 - Three components to be manufactured using LFW
- LPB
 - Produces optimised components with a rate seldom adequate for commercial aero throughput
 - Three components to be manufactured using LPB
- LFW+LPB
 - Two components to be manufactured using the combination of those techniques
 - Combination of both techniques expected to improve production lead time
 - Reduction of waste material by 50%
 - Promotion of environmental sustainability
 - Less powder feedstock exposed to laser melting process
 - Efficient powder recycling

Process setup

■ Additive manufacturing

□ LFW

- Generation of frictional heat through rubbing of two surfaces in a reciprocating motion under normal applied force
- Rubbing surfaces are rapidly heated and softened
- Hot softened material constantly displaced and expelled from weld interface as flash
- After predefined trigger is reached, amplitude oscillation decays to zero and axial force consolidates the joint as it cools
- Depending on material, friction stage can take one to ten seconds



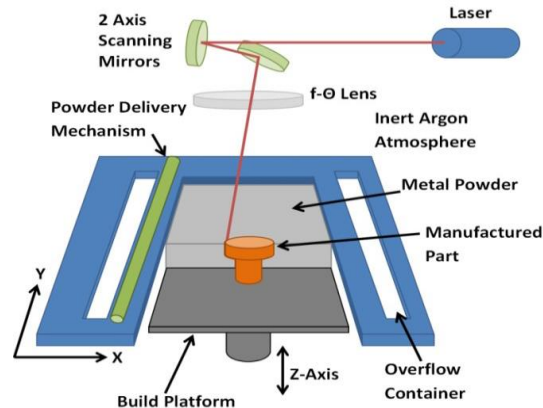
Description of working principle of Linear Friction Welding

Process setup

■ Additive manufacturing

□ LPB

- Powder is spread in a thin layer (25-60 μ m)
- Powder is selectively melted using a focused laser beam scanned across the bed in controlled manner
- Powder bed is incremented one layer down, a new powder layer spread across the bed and the next layer scanned fusing material to the previously fused material below
- Sequence repeated layer by layer until desired geometric part is produced



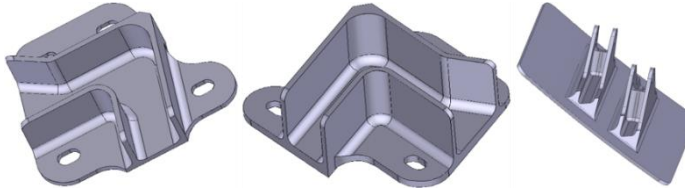
Description of working principle of Laser Powder Bed

Project Activities

Process setup

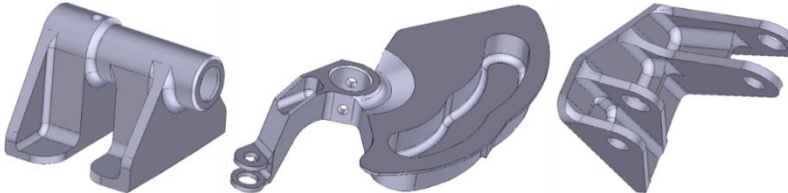
- Additive manufacturing

- LFW



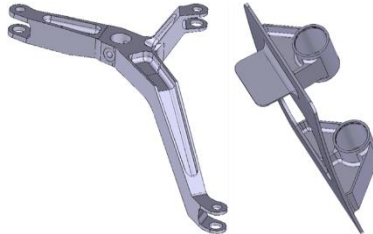
Track fittings surround, parallel link door fitting

- LPB



Short bolt door housing, door cam fitting, surround motion fitting

- LFW+LPB

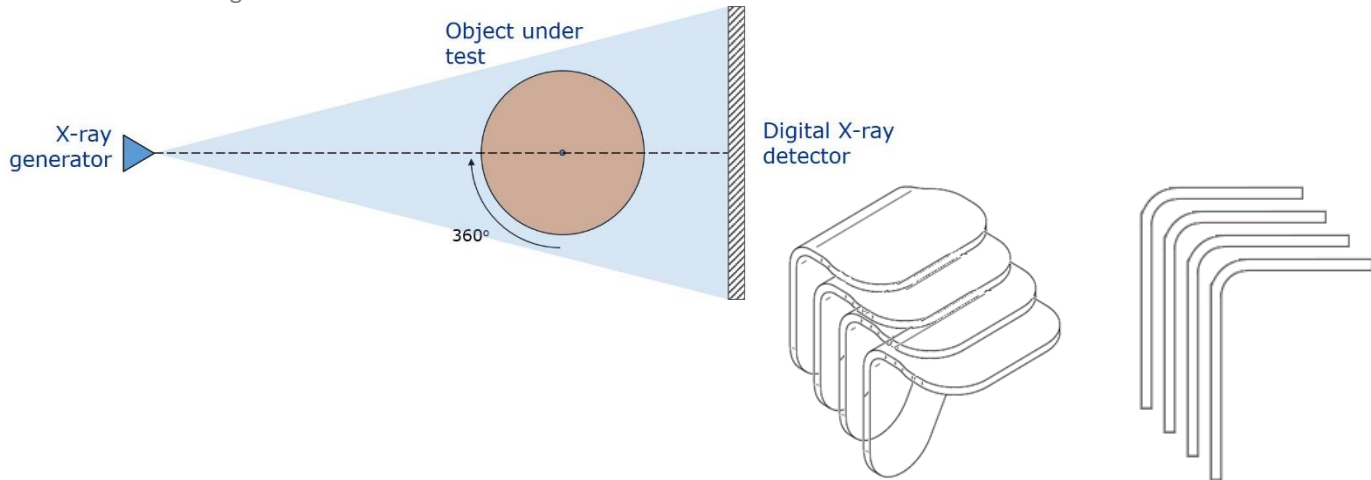


Door Lever external handle, Door Lift Shaft Mounting Fitting

Process setup

■ Non-destructive inspection

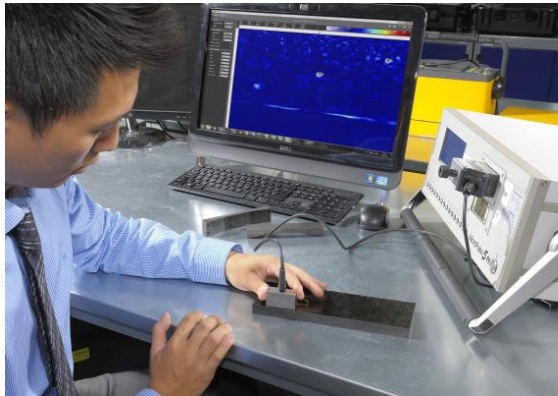
- Manufactured components will be inspected with the following techniques:
 - Computed Tomography (CT)
 - CT involves 2D radiographic image collection over a 360° rotation
 - Images are fed into the reconstruction software and representative to object volumetric data is generated



Process setup

■ Non-destructive inspection

- Manufactured components will be inspected with the following techniques:
 - Ultrasonic Inspection (UT)
 - Ultrasonic waves with frequencies between 100kHz and 10MHz applied on structure of interest
 - Components will be inspected and checked for defects such as delaminations (composites), porosity , inclusions



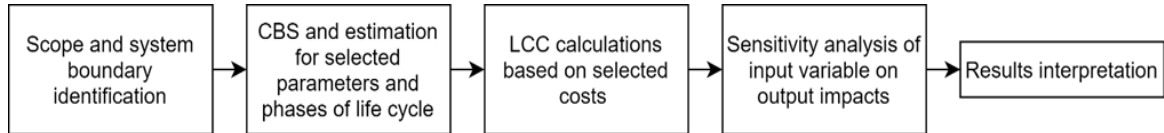
Left: Manual ultrasonic pulse-echo scanning, Right: Automated inspection system using industrial robots

Tool design and fabrication for process validation

- Analysis of CAD models provided by Leonardo to improve design and manufacturing process
- Parts were communalized with appropriate modifications for further reduction of tools
- Based on numerical simulation, tools were designed with appropriate silicone pad thickness and spring stiffness
 - Target was to avoid wrinkles on the heated material blank
- The metallic and thermoset parts to be manufactured based on the extensive experience of DEMA partner

Industrial cost evaluation

- Evaluation of economic performance of a thermoplastic door compared to equivalent conventional aluminium door using life cycle costing (LCC) analysis



- System boundary is cradle to grave
- Life cycle processed in three major phases : production, operating & maintenance and end of life
- Bottom up method selected to develop the cost estimation model
 - A cost breakdown structure is necessary
 - Total cost consists of production, operation & maintenance and end of life costs

- Use of thermoplastic materials in out-of-autoclave process
- 15% weight reduction on structural components (doors)
- Reduction of recurrent costs
 - Development of adaptive and smart manufacturing equipment to:
 - Increase production flexibility
 - Decrease the full line tools cost
- Reduction of waste and scrap by 10%
- Significant eco-impact reduction through the components' and aircraft's life-cycle



Welding capability of thermoplastic material, use of AM for complex mechanism parts and high rate production of thermoforming process are the best combination towards reduction of weight and manufacturing time

Next Steps



- Manufacturing of components with the defined techniques
- Non-destructive inspection
- Life Cycle Cost Analysis
- Assembly of parts
- Delivery of 4 doors to LEONARDO



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