ALPHABUS CENTRAL TUBE.

DEVELOPMENT AND MANUFACTURING OF THE BREAD BOARD MODEL

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OVERVIEW

In the frame of the Development of AlphaBus Satellite platform, EADS CASA Espacio has the responsibility to Develop, Qualify and Manufacture the Central Tube. The phase C/D has started in February 2006, as a continuation of the Pre-Development phase. Thales Alenia Space is the responsible of the complete Structure for AlphaBus.

After an exhaustive trade-off, EADS CASA Espacio proposed to manufacture a full scale Bread Board (BB), in advance to the Qualification Model (QM) and as early as possible. The aim of this BB is to identify all the critical areas that later could impact in the overall planning of the QM and 1st Flight Model, and to apply the corrective actions in advance, if needed. In order to mitigate the cost impact, it was decided to use the same lay-up tooling as for the QM, but slightly over dimensioned to cover the likely design changes that could be necessary to implement in the following months, until the design is totally frozen. In this way, the same tooling will be refurbished and used for QM and FM models.

AlphaBus Central Tube is a co-cured cylinder sandwich shell with 3 m in height and a diameter of 1,6 m. It is made using Fiber Placement technology with High Modulus CFRP skins and 10mm aluminium honeycomb.

The paper present the @bus central tube design, Bread Board definition, manufacturing and lessons learned.

Materials, manufacturing and inspection processes used for the @Bus Central Tube Bread Board production and verification have been confirmed to be valid and ready for use in the production of the @Bus Central Tube QM

The exploitation of the dimensional control measures of the BB curing mould and BB internal surface will permit a more accurate dimensioning of the QM curing mould.

1. BREAD BOARD DESIGN DESCRIPTION

The BB shell configuration design is presented in FIG. 2. The BB shell is axial-symmetric. The BB includes all the basic laminates and general layers drop-off expected in the QM. In addition, the BB includes three propellant tank inserts (PT) type, FIG.4, three of single flanged type and eight of double flanged type, FIG. 3. All the materials and key shell design solutions used are the same or fully representative of the ones foreseen at PDR close out. In particular:

- Materials
- Skin configuration and drop-offs.
- Core mapping and joints (foam lines)
- Inserts definition

The BB is a cylinder produced using a dedicated Aluminium Alloy mould, FIG. 5. Mould diameter is some millimetres bigger than the expected for the QM. In such a way that the BB mould could be used for QM after refurbishment (re-machining of the mould curing surface).

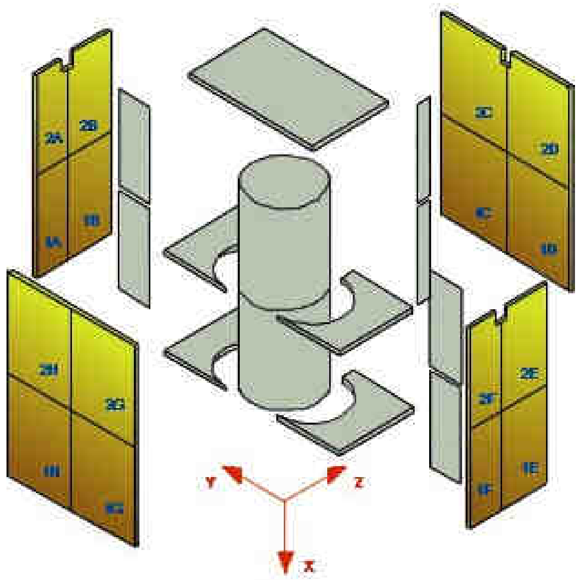

FIG. 1 Central Tube in a typical satellite structure.

1.1. Materials

Skin material is the epoxy system Hexcel M18 reinforced with high modulus fiber Toray M55J, in slit tape format to be used at Fiber Placement machine. A low density 5056-3.1-1/8-07P–10 mm aluminium honeycomb is used for core and joined to skins with Redux 319L adhesive film. Core to core joint are made using adhesive foam Cytec FM410-1.

1.2. Configuration and drop-offs

The neutral line of the shell is kept straight from top to bottom by means of including all the inner skin thickness changes housed in the curing mould surface, FIG 5.

There are two current areas of thin (GF) and thick (GG) skins. Three areas reinforced with additional plies are presented: one at the lower end (LJF) for interface with the launcher frame, and the two areas for propellant tank inserts assembly (LPT and UPT), FIG2.

Skin thickness transitions (drop off) areas are the same as expected for QM. Skin thickness transitions are defined with very low slope. All the drop-off are embedded in the laminate, and the external layer cover the full length of the cylinder. This drop-off configuration has been proven not to reduce the shell strength by means of development tests.

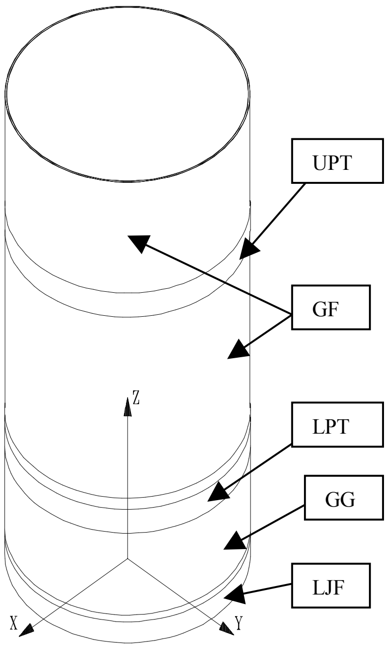

FIG. 2 Central Tube shell: current skins and reinforced areas

1.3. Core mapping and joints (foam lines)

The core map has 8 identical slides to fit 1.5 m (“L”) x ¼ of the circumference (≈1.3 m). The slides are arranged in two levels, four slides per level. Two vertical core/core joint are not in the same line. Foam adhesive are used in all core/core joints lines.

1.4. Inserts definition

Definition of Inserts are presented in FIG. 3 and 4. Single and double flanged insert are made of aluminium alloy and installed with potting injection at the surrounding honeycomb. The propellant tank insert type, has two aluminium alloy flanges and a central titanium alloy adjustable bushing. Eight titanium alloy bolts also joint flanges and composite skins.

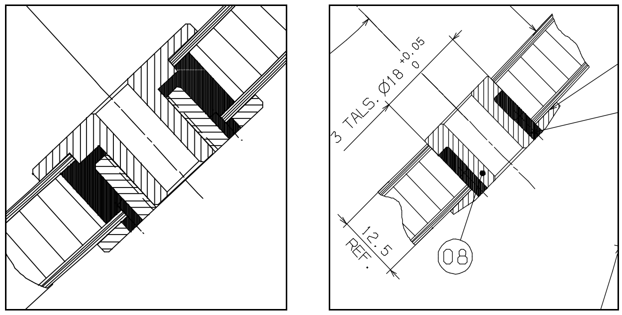

FIG. 3 Double flanged (left) and single flanged insert design.

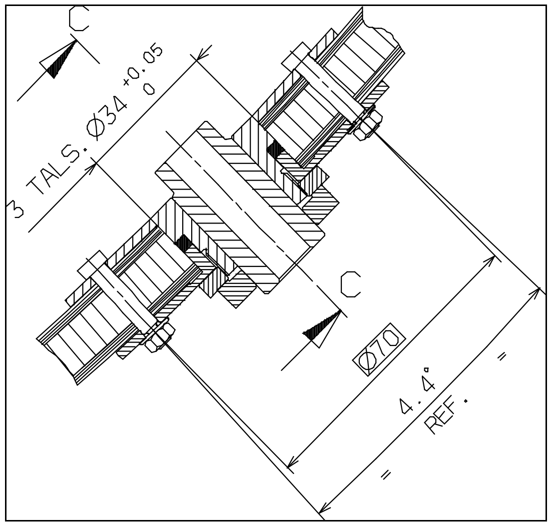

FIG. 4 Propellant Tank insert design.

1.5. BB and QM shell design differences

The differences between the composites shell of BB and QM (CDR design) are only related with local reinforcements (TAB 1).

Current skin configurations are the same in BB and QM at:

- LJF: 3.0 mm, 24 plies skin thickness.
- Thick current skin, GG: 1.9 mm, 15 plies.
- Thin current skin, GF: 1.0 mm, 8 plies.
- Core at current areas: 5056-3.1-1/8-07P-10 mm

Item	BB	QM
Upper and Lower PT skin reinforcements	2 layers: (+/-45)	4 layers: (+/-45)s
FFF skin renforcements	None	2 layers: (+/-45)
Windows skin reinforcements	None	10 layers: (0x3, +/-45)s
Web skin reinforcements	None	2 layers: (0x2)
Shell neutral axial diameter	1648 mm	1638 mm
Core reinforcement at PT areas	None	5056-6.1-1/8-15P-10 mm

TAB 1. BB and QM shell differences.

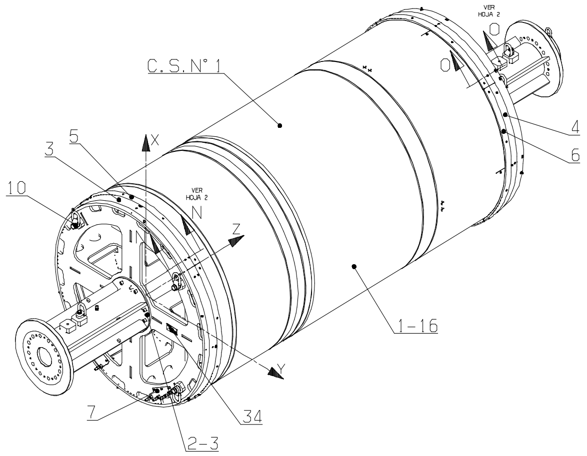

FIG. 5 Mould drawing

2. BB DESIGN DESCRIPTION

2.1. Composite shell

The lay up process of the BB was the same as expected for QM. The skin layers was laid by Fiber Placement (FP) process using Cincinnati Viper machine. The same mould is used for lay-up and curing.

The layers of the inner skin are laid up using the Fiber Placement machine FIG. 6. A layer of adhesive film is placed on top of the inner skin lay up. Then honeycomb slides are assembled on top of the adhesive layer and adhesive foam is placed at core to core joint lines. Additional adhesive layer is put on top of the honeycomb. Then, the layers of the outer skin are laid up using the Fiber Placement machine FIG. 7.

Together with the shell lay-up it is also laid up the manufacturing witness sandwich sample using the same machine, material and process. The FP machine has two working stations, in one it was placed the BB mould and at the other a flat mould for panels. The head of the machine can move to put material on a mould or on the other at any time.

The BB mould was placed on an auxiliary supporting tool for BB curing in autoclave FIG. 8. This support locate the axis of the mould aligned with the axis of the autoclave.

After curing, the BB and mould was released form the support and rotated to let the BB and mould in vertical position. An auxiliary tool (cage) was installed around the BB for handling and protection of BB during demoulding and transport. The BB was released from the mould by lifting the cage and BB in vertical position FIG. 9. After release, the cage and BB were rotated to horizontal position and installed on the fixation frame in the transport container FIG. 10.

FIG. 6 Lay up of the first ply on the mould at the fibre Placement Machine.

FIG. 7 Lay up of the first ply of the outer skin (over the core+adhesive) at the fibre Placement Machine.

FIG. 8 Central tube on the mould after curing.

FIG. 9 Release of the central tube shell

FIG. 10 Central tube shell at the transport container

3. SHELL MACHINING

The definition of the machining process of the BB was the same as expected for QM. The first step was to drill the holes for hoisting inserts and install these inserts. The BB was placed on a dedicated supporting tool for machining FIG. 11. The tool fixes the BB from the inside and the machine drill and mill from outside the BB.

At the machining centre, the lower and upper ends of the BB were cut to final edge by milling. The holes for inserts installation were produced by orbital drilling machining process. In figures 12 and 13 is shown an insert hole from the inner and from the outer BB faces.

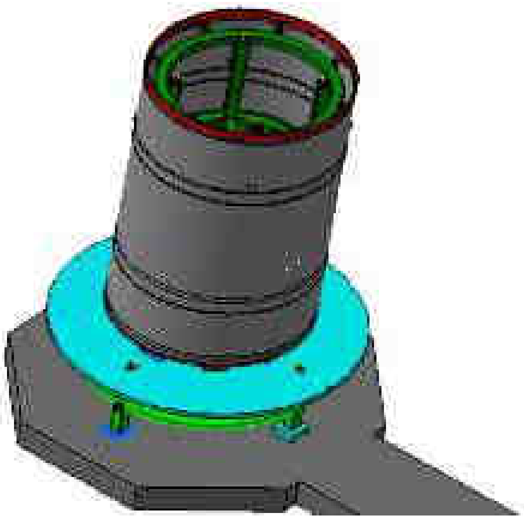

FIG. 11 Skect of the Central Tube at the machining tool.

FIG. 12 Machined hole for insert assembly (inner view)

FIG. 13 Machined hole for insert assembly (outer view)

4. ASSEMBLED INSERTS

The definition of the insert installation process of the BB was the same as expected for QM. Inserts installed on BB are shown in figure 14.

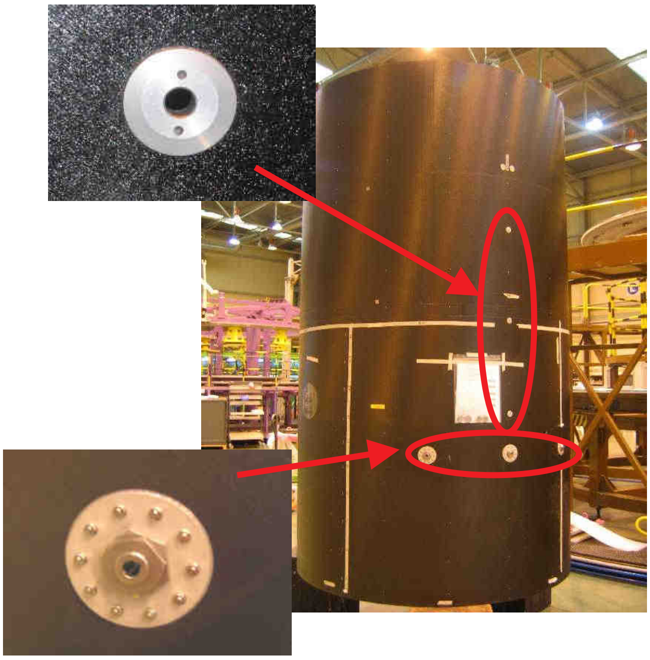

FIG. 14 Inserts installed in Central Tube.

5. BB VERIFICATIONS

Verifications on the BB have been performed at different steps throughout the manufacturing steps. The definition of the inspection processes of the BB was the same as expected for QM. All the inspections were successfully passed. The more relevant verifications performed to BB are:

- Cure cycle verification, the records of the cure cycle parameters were reviewed.
- Visual inspection.
- Ultrasonic inspection, FIG. 15, was performed to the 100% of the surface of the composite shell. It was used an automatic system by transmission.
- X-ray inspection to the 100% of the foam lines (core to core joints).
- Tests on samples from witness sandwich panel.
  - Skins Interlaminar Shear Strength (ILSS),
  - Flatwise Tensile Test
  - Volume fraction and porosity
  - Glass Transition Temperature
  - Cured Ply Thinness
  - Degree of cure

FIG. 15 Central Tube Shell automatic ultrasonic inspection.

6. DIMENSIONAL CONTROLS

The position of points at the inner and outer surface of the BB has been measured with Laser Tracker system.

Points measured on each surface at 18 vertical levels, 16 points per diameter (each 22.5º), 576 points in total.

Vertical levels (mm from tube lower end):

- LJF: 30, 130;
- GG: 300, 500, 700, 960
- LPT: 850, 900
- GF: 1220, 1420, 1620, 1820, 2430, 2570, 2850
- UPT: 2240, 2320

Same best-fit cylinder axis used for all vertical levels.

In the same way, also measured with Laser Tracker system, the curing mould was measured before starting the BB lay-up. The mould machining deviation is very low, the deviation is lower than 0.16 mm pick to pick in radius.

The measures of the BB surfaces has been compared with respect to the predicted ones. The analysis of this information are split in two topics: average diameters and circularity.

The maximun average deviation of diameters from prediction to measures is 0.4mm. BB Internal surface circularity +/-0.5 mm (>93% of points); External surface circularity +/-0.4 mm (>97% of points);

The information of the average deviation of diameters will be used to better estimate the correction factor Mould/QM for the dimensioning of the QM curing mould. The measured circularity gives a first estimation of the expected circularity of the QM. The requirement of QM circularity is +/-1 mm, which is confirmed to be feasible from the BB results.

The minimum difference in radius between the mould and the BB internal surface is 1.7 mm. This gap confirms the validity of the process to cope with local reinforcements up to 10 layers per skin without jeopardizing the mould release.

7. CONCLUSIONS

- Materials, manufacturing and inspection processes used for the @Bus Central Tube Bread Board production and verification have been confirmed to be valid and ready for use in the production of the @Bus Central Tube QM and FMs

- The exploitation of the dimensional control measures of the BB curing mould and BB internal surface will permit a more accurate dimensioning of the QM curing mould.