Advanced Cryo-Tanks Research in CHATT

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An EU-funded study called CHATT (Cryogenic Hypersonic Advanced Tank Technologies) has been initiated early 2012. One of its core objectives is to investigate Carbon Fiber Reinforced Plastic (CFRP) cryogenic pressure tanks. The focus of the paper is on the technology development tasks of the study and its major obtained results.

1. Introduction

In future aviation and particularly in hypersonic systems new propellants will be used, such as liquid hydrogen, liquid methane and possibly liquid oxygen. Some studies in Europe investigate advanced vehicles with these fuels for passenger transport. The question of cryogenic propellant storage inside an airliner – although of critical importance but by far not yet mastered – has not been addressed up to now in comparable detail. Another well-known application of cryogenic propellant tanks is for launch vehicles. Thus, the investigated technologies will also support future ELV and RLV.

The project CHATT is part of the European Commission's Seventh Framework Programme and run on behalf of the Commission by DLR-SART in a multinational collaboration. One of the core objectives is to investigate Carbon Fiber Reinforced Plastic (CFRP) cryogenic pressure tanks. Four different subscale CFRP-tanks are planned to be designed, manufactured, and tested. The total budget is exceeding 4.2 M€. [1]

2. Research activities

The proposed research in CHATT will increase the knowledge within Europe to a practical cryogenic tank demonstrator level for future aerospace reusable lightweight composite cryogenic structures. The advantages and disadvantages of using liner/linerless tank designs will be investigated as well as issues related to the realisation of more complex geometrical tank shapes. The project is broken down into three main technical activities (Workpackages WP2 to WP4), which have a close interaction as shown in Figure 1.

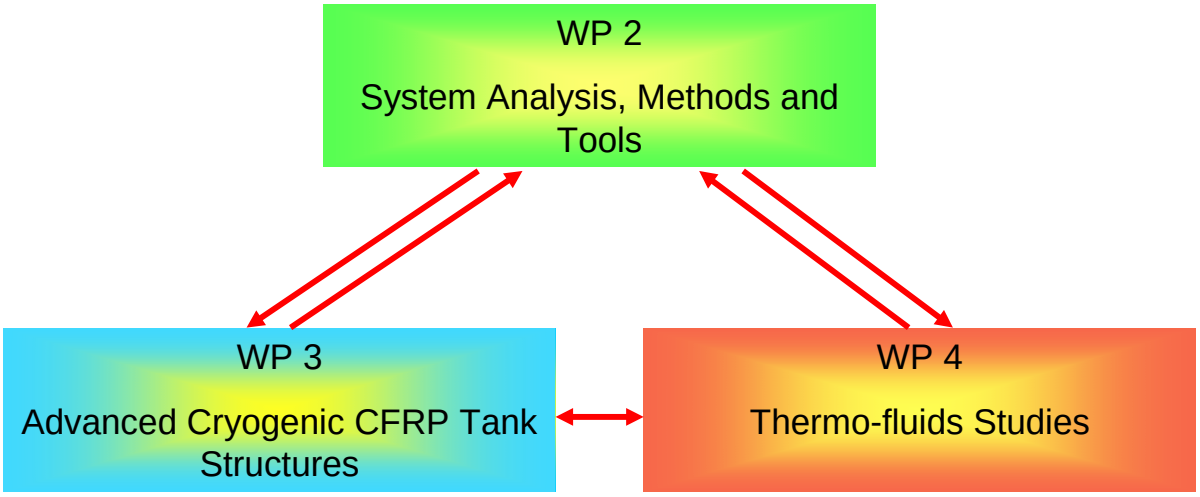

Figure 1: Interaction of different workpackages in CHATT study [1]

A central, steering role is applied to WP2 focusing on system requirements of advanced passenger airplanes, the development, test and implementation of engineering methods and tools. The two remaining workpackages WP3 and WP4 are dedicated to fundamental research with special focus on manufacturing and testing of fully integrated subscale hardware samples. Both WPs are serving as modules supporting the vehicle design and the verification of fast engineering methods.

Four different subscale CFRP-tanks are planned to be designed, manufactured, and tested under mechanical and thermal loads within the scope of the CHATT project. At DLR-Braunschweig three different tank design variants have been in the discussion and have been analysed in pre-production runs (Figure 2).

Figure 2: Tank with bandage in test production run at DLR [2]

The challenge in developing a cryogenic CFRP tank is finding a solution for the problems caused by differences in thermal expansion coefficients (CTE) on a microscopic scale. If a liner is required, there is also the challenge to overcome the differences in CTE of the liner with respect to the structural shell.

Propellant management is imperative to achieve reliable and efficient vehicle operation. It is therefore the third pillar of the CHATT study and covers tank pressurization, fuel location/retention, and sloshing in horizontal tanks. Apart from thermal aspects, sloshing of cryogenic fluids within the tanks can have a significant impact on flight operation as the liquid excited through vehicle movements may travel distances of considerable lengths compared to the overall size of the aircraft. The vehicle may consequently experience a noticeable shift in its centre of gravity and hence its controllability is put into question.

Counter-measures such as anti-sloshing devices and tank design are susceptible to reduce these effects but will come at the cost of increased mass and production effort. The CHATT study will focus on establishing engineering models for sloshing in large horizontal tanks verified by numerical calculations and experiments. These models will then be applied to flight control simulations of the reference vehicle concepts allowing an evaluation of their overall feasibility.

Heat-exchangers are one of the most essential elements of a tank pressurization system. Two different types of ceramic heat-exchangers will therefore be looked at in CHATT. C/SiC ceramic matrix composites (CMC) with high silicon content allow achieving air-tight materials with negligible porosity, high heat conductivity and low coefficients of thermal expansion (CTE). Such materials would therefore be highly attractive for heat-exchanger designs. The CDR of the test heat-exchanger designs will be held early 2013.

The paper outlines the study logic of CHATT, gives a detailed presentation of the technology development tasks, and summarizes major research results already available.

3. References

1. NN: Grant agreement for: Collaborative project, Annex I - "Description of Work", Project acronym: CHATT, Project full title: "Cryogenic Hypersonic Advanced Tank Technologies", Grant agreement no: 285117, Version date: 2011-07-11, PART B
2. Sippel, M.; Kopp, A.; Sinko, K.; Mattsson, D.: Advanced Hypersonic Cryo-Tanks Research in CHATT, AIAA-5945, 18th AIAA International Space Planes and Hypersonic Systems and Technologies Conference, Tours, September 2012