C^{3}HARME

Next Generation Ceramic Composites for Combustion Harsh Environments and Space

NOVEMBER 2019

EDITORIAL

C^{3}HARME is a research project funded under the EU's Horizon 2020 Framework Programme for Research and Innovation. Its main purpose is the design, testing and manufacturing of a new class of ceramic matrix composites based on ultra-high temperature ceramics.
The new UHTCMC materials should be suitable to operate in severe aerospace environments, with applications in rocket nozzles and vehicles for hypersonic re-entry. The 8M€ project, started in June 2016, will run for 4 years and involves 12 partners from 6 European countries. Every 6 months, our newsletter shares relevant news and a summary of our achievements. If you wish to be updated with C^{3}HARME's progresses, sign up on our website (www.c3harme.eu). In the meantime, enjoy reading!

Diletta Sciti
Project Coordinator

NEWSLETTER #3

FUTURE EXHIBITIONS

As we are approaching the end of the project, we now have large demostrator ready to be showcased at events. The first exhibition is at the **New Space Economy European Expoforum** (Rome, Dec 10-12) where the CNR team will be there with a project poster and a booth. Organized in collaboration with Space Foundation, NSE Expo Forum will create an opportunity to meet and exchange views among existing and new industrial players, small and medium innovative companies, investors, venturers, startuppers, research centers, space agencies and institutions with interests in space.

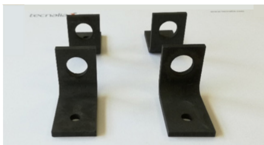
In 2020 we will join another international events, the **Paris Space Week** (Paris, Feb 25-26). PSW gathers the World's Space Tech Ecosystem under one roof for 2 Days. Besides our booth, we will also give a 15-minute intervention at the PSW's Center of the Arena. Hope to see you there!

PARTNERS

ISTEC-CNR
UNIVERSITY OF NAPLES
UNIVERSITY OF BIRMINGHAM
AIRBUS
ARIANE GROUP
AVIO S.P.A
CRANN
DLR
HPS-PT
IN SRL
NANOKER RESEARCH
TECNALIA R&D

THIS PROJECT HAS RECEIVED FUNDING FROM THE EUROPEAN UNION'S HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME UNDER THE GRANT AGREEMENT N° 685594.

GROUND TESTING OF PROTOTYPE TPSs



Thermal protection systems (TPSs) using CMC materials have quite a history already. Three examples can be cited in which a TPS based on CMC materials was used as an essential element of the spacecraft in flight and not just as an experiment: the U.S. Space Shuttle, the Intermediate Experimental Vehicle (IXV) from ESA and the experimental flight vehicles SHEFEX I and SHEFEX II, flown in 2005 and 2012 by DLR.

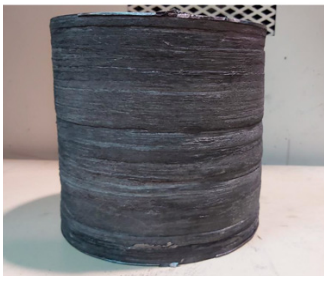
The TPS configuration used in SHEFEX was selected as reference for the design of the TPS to be manufactured and tested within C3HARME. In SHEFEX, TPS's tiles were made of flat C/C-SiC panels, attached to the vehicle via fixation elements, screws and nuts, made of the same CMC material. This solution allows to use the fixation components also in areas where the high temperatures exceed the capabilities of metals. Following a similar approach in C3HARME, the TPS tile and all relevant fixation elements will be now be manufactured following the most UHTCMC material configurations developed inside the project.

Flat ceramic discs produced so far have reached a diameter of 40 cm with thicknesses between 5 -7 mm. These dense pieces are manufactured with UHTCMCs reinforced with either short or long carbon fibers by using the Spark Plasma Sintering as densifying technique. Large tiles of 190 x 240 mm in size have already been successfully machined out of these large pieces. The standoffs have also been developed following a similar processing route. C3HARME's Consortium is also working on the upscaling of novel UHTCMCs by non-sintering techniques like Reactive Metal Infiltration (RMI) and radio-frequency chemical vapor infiltration (RF-CVI).

The tests on these TPS tiles prototypes will be carried out in the arc-heated wind tunnel L3K of DLR in Cologne. This facility creates an environment that is very close to real flight at hypersonic speeds (Mach numbers between 4 and 10). Very high temperatures can be reached, and the flow chemistry is quite close to the one of a high-speed flight in the atmosphere. An incremental verification procedure is now under development with first stagnation tests on 50 mm diameter samples (heat flux rates of more than 12 MW/m2 can be achieved) and subsequent tests on a larger full TPS assembly to demonstrate the targeted TRL level of 5.

LARGER NOZZLE PROTOTYPES

Nozzles are the subcomponents of space propulsion rockets devoted to the conversion of thermal energy into kinetic energy of combustion gas. C3HARME is focussing on a common type of nozzle, known as "De Laval", in which an internal convergent-divergent profile is responsible for a pressure unbalance: the passage area for the gas is decreasing up to a minimum value and increasing downstream the throat area, leading to a transition from subsonic to supersonic flow. Therefore, materials used in the throat region shall withstand extreme environment and very high thermal and mechanical gradients.



	Before Sintering	After Sintering
Weight (g)	11952	11645
Diameter (mm)	169.0	167.5
Thickness (mm)	270.0	157.8
Volume (cm³)	6057	3477
Density (g/cm³)	1.97	3.35

Typical classes of materials used for this application are refractory metals and metallic alloys, composite materials and ceramic materials. C3HARME is testing prototypes of complete subscale nozzles or of the throat insert made of UHTCMCs based on short carbon fibers (in collaboration with TECNALIA) or long carbon fibers (in collaboration with CNR-ISTEC).

The up scaling of manufacturing of the nozzle prototypes is done by the Spanish SME Nanoker, by Spark Plasma Sintering (SPS) as densifying technique. As a first approximation to laboratory scale, trials were performed in a small SPS facility at TECNALIA. The overall dimensions were then increased in a stepwise manner, starting with a diameter of 40 mm and thickness of few mm.

The latest challenge was to obtain the piece that has a diameter of ~170 mm and thickness of ~158 mm, for the manufacturing of a large nozzle insert. This larger piece has now been handled for machining and it is going to be tested in a solid rocket engine experimental facility available at our partner AVIO for validation at TRL6.