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High temperature composite overview in France

Marc Montaudon
Eric Bouillon, Safran Ceramics, marc.montaudon@safrangroup.com

Eric Bouillon
Eric Bouillon, Safran Ceramics

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Ceramic Matrix Composites In France: 40 Years Of Innovations
—
Santa Fe, November 5th, 2017

Marc MONTAUDON, COO, Safran Ceramics
Chapter 1
The Tale of Carbon-Carbon
1) 1969-1979: acquire, taste and improve a processes toolbox

![Diagram showing processes]

1. Preform
2. Impregnation
3. Carbonization
4. Machining
5. Final Part

Vapor Route
- Preform
- CVI
- Machining
- Final Part

Liquid Route
- Resin
- Pitch
- Preform
- Impregnation
- Carbonization
- Machining
- Final Part

2) 1982: invent a technological/economical rupture, Novoltex® texture

- Automative process
- Various shapes (thin plates, parallelepipeds, blocks, cylinders, cones, etc.)
- Homogeneous pores network w/o bottlenecks
- Handlable & self-supporting w/o toolings

Perfectly adapted to any densification route, particularly CVI!
3) >1985: Develop a material range and extend the scope

Carbon-Carbon

Sepcarb®

Cost per kg: € 500 depending on volume and specifications

2016 Deliveries ~7500 parts + 1,100 tons of brakes

(1) Through our ArianeGroup subsidiary
(2) Through our Safran Landing Systems subsidiary

CFRC Nozzle: a World Monopoly based on a 40 Years Experience

Maximum diameter (mm)

Ground test Flight Extendible Nozzle

MAGE 2

RL10-B2

RL 10 B-2

HM7

Ariane 6 VINCI
Aircraft Brakes: Safran’s Carbon-Carbon Plants Spreading

Chapter 2
The Tale of Ceramic Matrix Composites
1977: First Ceramic Matrix Composite

- Densification of a carbon preform
- Chemical Vapor Infiltration from methyltrichlorosilane

1979: First Industrial Furnace

Laboratoire de Chimie du Solide (now LCTS) University of Bordeaux

Pr. Roger NASLAIN

SEP (now Safran), Bordeaux

The Process Toolbox

SiC Chemical Vapor Infiltration

Preform
- Novoltex ®
- 2D tows or fabrics
- 3D Weaving

Self Healing Matrix

Interphases deposit

Polymer Impregnation & Pyrolysis

Slurry Incorporation

Melt Infiltration of Silicon

Oxide sintering
2016 Deliveries ~5000 parts

French Fighter Rafale’s nozzles since 1990
also successfully ground (>11,000 TACs) and flight tested (>1,000h) on F-15, F-16

Hot Gas Valves Experience
Military serial application

80s 90s 00s

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ESA's IXV Atmospheric Re-Entry Demo: TRL6 for a re-usable CMC Nose and Thermal Protection System (Feb 2015)
Then came the Silicon Carbide Fibers…

Courtesy of Nippon Carbon K.K. (now NGS Advanced Fibers, K.K.)
Ceramic-Ceramic: towards Entries Into Service

Flight tests

Engine ground tests

Component tests

Scientific & Technological Challenges

BEHAVIOR JUSTIFICATION
- Fully understand and & the possible damages & failures
- Simulate and accelerate the ageing phenomena
- Adapt certification rules

AIM AT HIGHER PERFORMANCE
- 2700°F CMC
- Eutectic ceramics

COST, COST, COST!
- Fibers
- Recurring investments costs
- Number of process steps
- Automation

BROADEN THE APPLICATION FIELDS
- CMC-CMC and CMC-metal assembling
- CMC additive manufacturing