CARBON-CARBON COMPOSITES

Carbon-Carbon Composites are composite materials consisting of a carbon matrix reinforced by carbon fibers.

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Structure of Carbon-Carbon Composites

Carbon-Carbon (C/C) Composites may be manufactured with different orientation of the reinforcing phase (carbon fibers): unidirectional structure, bi-directional structure (cloth made of multiple carbon fiber yarns), multi-directional structure (3D, 4D, 5D, etc.). Multi-directional reinforcement provides maximum level of mechanical properties in the directions of the woven structure.
The simplest multi-directional reinforcement consists of 3D orthogonal structure woven of straight carbon fiber yarns.

Fabrication of Carbon-Carbon Composites by Liquid Phase Infiltration process

- Preparation of carbon/Graphite fiber preform of the desired structure and shape.
- Infiltration of the preform with a liquid precursor: petroleum pitch/phenolic resin/coal tar.
- Pyrolysis/carbonization (chemical decomposition by heat in the absence of Oxygen) of the polymer precursor at 1000-1830ºF (538-1000ºC) under normal or high pressure.
- Infiltration – pyrolysis cycle is repeated several (3-10) times until the desired density is achieved.
- Graphitization heat treatment. At this stage amorphous carbon is transformed into crystalline graphite. The temperature of the treatment may vary within the range 2700-5400°F (1500-3000°C). Typical graphitization temperature is 4530°F (2500°C). Graphitization of carbon-carbon composites results in increase of Modulus of Elasticity and strength of the composite.

Fabrication of Carbon-Carbon Composites by Chemical Vapor Deposition process

- Preparation of carbon/Graphite fiber preform of the desired structure and shape.
- Densification of the composite by Chemical Vapor Deposition (CVD) technique. The CVD process involves infiltration of the preform with a pressurized hydrocarbon gas (propane, methane, propylene, acetylene, benzene) at 1800-2200ºF (982-1204ºC). The gas is pyrolyzed forming carbon deposition on the fiber surface. The process duration is determined by the thickness of the preform, through which the gas diffuses.
- Graphitization heat treatment. At this stage amorphous carbon is transformed into crystalline graphite. The temperature of the treatment may vary within the range 2700-5400°F (1500-3000°C). Typical graphitization temperature is 4530°F (2500°C). Graphitization of carbon-carbon composites results in increase of Modulus of Elasticity and strength of the composite.

Fabrication of Carbon-Carbon Composites by Chemical Vapor Deposition process results in higher (as compared to Liquid Phase Infiltration technique) Modulus of Elasticity and mechanical strength.

Properties of Carbon-Carbon Composites

- Excellent thermal shock resistance;
- Low Coefficient of Thermal Expansion;
- High Modulus of Elasticity (up to 29000 ksi / 200 GPa);
- High Thermal Conductivity (about 700 BTU*in/(hr*ft²*ºF) / 101 W/m*K;
- Low density (about 114 lb/ft³ / 1.83*10³kg/m³);
- High strength;
- Low coefficient of friction (in the fiber direction);
- Excellent heat resistance in non-oxidizing atmosphere. C/C Composites retain their mechanical properties up to 5432ºF (3000ºC).
- High abrasion resistance;
- High electrical conductivity;
- Non-brittle failure.

Oxidation protection of Carbon-Carbon Composites

The main disadvantage of Carbon-Carbon Composites is their low oxidation resistance. Carbon materials react with Oxygen at temperatures above 900ºF (482ºC).

The following methods are used for oxidation protection of Carbon-Carbon Composites:

- Protection coatings. The ceramic coatings (commonly multi-layer) of carbides, nitrides and oxides. Protection coatings may be deposited by Chemical Vapor Deposition (CVD) (including pack cementation), Physical Vapor Deposition (PVD) or Plasma spraying method.
- Impregnation of oxidation inhibitors: inorganic salts, borate and silicate glasses, phosphates, boron oxides, polysiloxanes, halogen compounds.
- Replacement of the matrix material from carbon to SiC. C-SiC composites possess excellent oxidation resistance.

Applications of Carbon-Carbon Composites

- High performance braking systems (eg. brake discs for high speed aircrafts);
- Refractory material (eg. protection tubes and grids);
- Hot-pressed dies;
- Heating elements;
- Turbojet engine components (eg. rocket nozzles).

Source : http://www.substech.com/dokuwiki/doku.php?id=carbon-carbon_composites