What are ceramic matrix composites?

Ceramic matrix composites (CMCs) are a special type of composite material in which both the reinforcement (refractory fibers) and matrix material are ceramics. In some cases, the same kind of ceramic is used for both parts of the structure, and additional secondary fibers may also be included. Because of this, CMCs are considered a subgroup of both composite materials and ceramics. Ceramic matrix composites (CMC) are generally made from ceramic fibres or whiskers embedded in a ceramic matrix. These ceramics cover a varied range of inorganic materials that are usually non-metallic and commonly used at high temperatures. Ceramics can be classified into two classes:

- Traditional or conventional ceramics – which usually are in monolithic form. They include tiles, bricks, pottery, and a wide range of art materials.

- Advanced or high-performance ceramics – which often undergo chemical processing to be derived. These include nitrides, oxides, and carbides of aluminium, silicon, zirconium, and titanium.

CMC reinforcing materials

Typical reinforcing fiber materials include the following:

- Carbon, C
- Silicon Carbide, SiC
- Alumina, Al_2O_3
- Mullite or Alumina Silica, Al_2O_3-SiO_2

The refractory fibre can be in the form of whiskers, particles, long or short fibres, and nanofibres. These fibres have a polycrystalline structure similar to that of conventional ceramics. The fibers can take many different forms, including the more traditional continuous fiber as well as short fibers, particles, whiskers, and nanofibers. These fibers all have a polycrystalline structure like traditional ceramics possess.
Continuous or long fibres provide better toughness as they can support a load even after the ceramic matrix undergoes cracking, thus slowing down the crack's propagation. Short fibres and whiskers, on the other hand, give improved resistance to crack growth. This makes composites less sensitive to flaws, yet once a crack begins to propagate, failure could be disastrous [2].

CMC matrix materials

The matrix materials used are the same as the reinforcements stated above, with the addition of non-oxide, ultra-high-temperature (UHT) ceramics used for special applications. The advanced ceramics are commonly used in the production of ceramic matrix composites to overcome the main disadvantage of traditional ceramics; namely, their brittleness. The most commonly used CMCs are non-oxide CMCs, such as carbon/silicon carbide (C/SiC), carbon/carbon (C/C), and silicon carbide/silicon carbide (SiC/SiC). Generally, their names follow the *fibre material type/matrix material type* structure .

Synthesis of CMC

Ceramic matrix composites are made using ceramic fibers of 3 to 20 micrometres in thickness. The main processes for synthesizing CMCs include chemical vapor or liquid phase infiltration, polymer infiltration and pyrolysis (PIP), and hot press sintering techniques. However, the most common method is PIP. In PIP, the ceramic matrix is formed from a fluid that is infiltrated into the fiber reinforcement.

Ceramic matrix composites reinforced with continuous fibers are commonly fabricated by infiltration methods, in which a ceramic matrix is formed by a fluid infiltrating the fibrous structure. The conversion of fluid into ceramics varies according to the type of fluid used and the processes involved. Some infiltration techniques are as follows:

- Liquid silicon infiltration (LSI)
- Polymer infiltration and pyrolysis (PIP)
- Ceramic slurry infiltration (CSI)
- Chemical vapour infiltration (CVI)
- Reactive melt infiltration (RMI)

Properties of ceramic matrix composites

Common properties of ceramic matrix composites are:

- High thermal shock and creep resistance
- High temperature resistance
- Excellent resistance to corrosion and wear
- Inertness to aggressive chemicals
- High tensile and compressive strength, thus no sudden failure as compared to conventional ceramics
- Increased fracture toughness due to reinforcement
- Lightweight due to reduced density
- High strength retention at elevated temperatures

Applications of ceramic matrix composites - Common applications of ceramic matrix composites are

- **Heat exchangers and burner components**
- **Gas turbine components** – these include turbine blades, combustion chambers, stator vanes and turbine engines, where coated silicon carbide fibres are embedded in a ceramic matrix to impart temperature resistance, toughness, and low density.
- **Aerospace industry** – including body flaps, shrouds and space shuttle shielding, where coated ceramic tiles provide protection from extreme heat.
- **Engine exhaust systems** – including ceramic exhaust nozzles for commercial aircraft to increase component life and reduce weight and engine noise.

- **Hypersonic vehicles** – these utilise structural materials such as ultra-high-temperature ceramics, which make good candidates for high heat flux areas.

- **Nuclear power industry** – including internal reactor structures made from MAX phase composites that can withstand high temperatures and have high mechanical damage tolerance and good chemical compatibility with coolants such as sodium and molten lead.

CARBON/SILICON CARBIDE

Carbon fiber reinforced silicon carbide is a very strong composite made of a silicon carbide matrix with carbon fiber reinforcement. The material is very suitable for oil quenching processes in metal hardening due to its low porosity. Furthermore, by its low weight it fits perfectly to your automation idea for your hardening process.

Typical properties of the material -

Light (perfect for automation in heat treatment)
Low open porosity (perfect for oil quenching)
High strength
Fracture resistant
Thermal shock resistant

Applications

- Combustion and turbine section components of aero-propulsion and land-based gas turbine engines
- Heat exchangers, reformers, reactors, and filters for the chemical industry
- Preheaters, recuperators, and radiant tubes for the heat transfer industry
- Thermal protection systems, thruster nozzles, reusable rocket nozzles, and turbopump components for space vehicles
- Furnace components
- Nuclear fission and fusion reactors as fuel cladding and radiation blankets