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A Brief Review on Carbon-Carbon Composites Their Properties and Their Future Aspects

Gopal Sahu[1], Prof. Brijesh patel[2]
[1]Student,M.Tech. Turbomachinery.MATS University,Raipur
[2]Coordinator,M.Tech. Turbomachinery.MATS University,Raipur

Abstract

Carbon-Carbon Composites plays a vital role in or day to day life. Its explicit strength and outstanding mechanical properties makes it even more important to human society welfare. Research has been going on a large scale to know more about the compound and enhance its properties as required by us. This paper throws light on the existing Carbon-Carbon Composites and its mechanical properties. It also enlightens the future aspects of Carbon-Carbon Composites.

Keywords

Carbon-Carbon Composites; CCs; Future; Carbon Composites; CNTs

I. INTRODUCTION

Carbon-carbon composites are a new class of engineering materials that are ceramic in naturebut exhibit brittle to pseudo plastic behaviotir. Carbon-carbon is a unique all-carbon composite with carbon fiber embedded in carbon matrix and is known as an inverse composite. Due to their excellentthermo-structural properties, carbon-carbon composites are used in specialized application like re-entry nose-tips, leading edges, rocket nozzles, and aircraft brake discs apart from several industrial and biomedical applications. The multidirectional carbon-carbon product technology is versatile and offers design flexibility.

Carbon is a unique element that can exhibit differentproperties in different forms. Sollle forms of carbon areextremely hard, like diamond, while some forms areextremely soft and ductile. Thus, in addition to its well-defined .Isotropic forms (diamond and graphite) ,carbon can take any number of quasi-crystalline formsranging from amorphous or glassy carbon to highly crystalline graphite. The latest form of carbon (C60),discovered recently, is called Fullerene, named after Buck-Minister Fuller, the renowned American architectand philosopher. Fullerene is the roundest of all roundmolecules, more like a soccer ball, and has propertieslike. high strength, ferromagnetic properties, Superconductivity and is an excellent semiconductor .Full knowledge of its properties is still not acquired. The advent of carbon-carbon (CC)composites changed the scene drastically.[1]

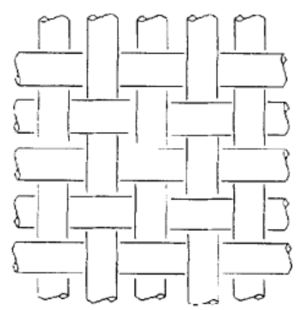

Fig 1- Bi directional woven fibers

II. CARBON-CARBON COMPOSITES(CC)

Carbon-carbon composites are a family of advanced composite materials. They are the most advanced form of carbon and consist of a fiber based on carbon precursors embedded in a carbon matrix. This unique composition

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gives them such properties as low density, high thermal conductivity and shock resistance, low thermal expansion and high modulus.

Carbon-carbon is mostly used in aerospace applications, mainly for aircraft disc brakes, rocket re-entry nose tips and for parts of rocket nozzles. The unique features and an advanced manufacturing technology which leads to a cheaper production process make this material more and more available for industrial applications.

For impregnating carbon fibres with a matrix in the form of gas Chemical Vapour Infiltration (CVI, or also called Chemical Vapour Deposition, CVD) is used. At 700-2000°C hydrocarbon gas is impregnated into the preforms, which can be prepregs (carbonized and graphitized fibres) or dry wound fibres. Three CVI methods are available:

1. Isothermal: the gas and sample kept at uniform temperature; several cycles are necessary and the surface is skinned in-between cycles

2. Temperature gradient: use of induction furnace, deposition of carbon first inside the sample; process is limited to one single sample per operation

3. Pressure gradient: a hydrocarbon gas impinges on the inside surface of the sample, the gas pressure inside the sample is higher than outside; also limited to single sample and not widely used.

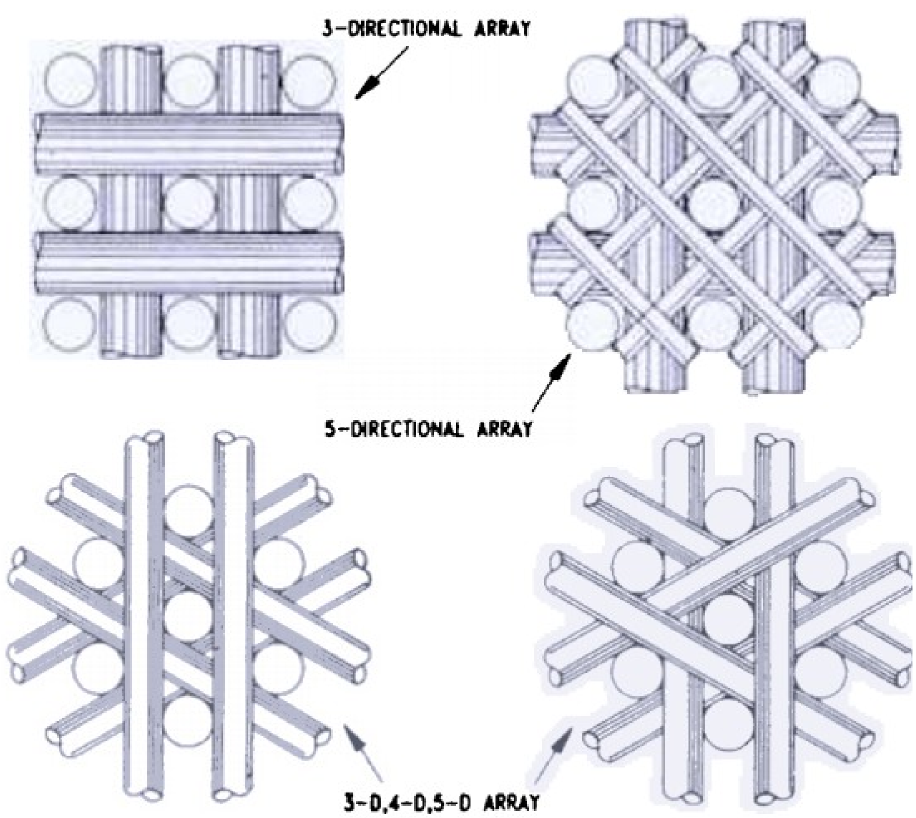

Fig 2- Arrangements Of Carbon-Carbon Composites

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III. ATTRIBUTES OF CARBON-CARBON COMPOSITES(CCs)

The properties or attributes of CCs are very much dependent on manufacturing processes used, on the raw materials and on additional treatments such as fibre surface modification or inclusion of oxidation protection. Considerable changes inproperties can be achieved by varying these parameters.[2][3]The properties are shown in Figure[4] below:

Property	Unit	Carbon-carbon	Ferritic steel	Titanium alloys
Compressive strength	MPa	100–150	240–400	130–1400
Density	g cm^{-3}	1.3–2.5	7.5–7.7	4.38–4.82
Tensile strength	MPa	up to 900	500–800	241–1280
Thermal expansion	K^{-1}	-2–2×10^{-6}	12–15×10^{-6}	7.9–9.8×10^{-6}
Thermal conductivity	W m^{-1} K^{-1}	20–150	23–27	4–21.9
Thermal shock resistance	W mm^{-1}	150–170	5.5	N/A
Young's modulus	GPa	up to 300	200–205	95–125

Fig 3- Attributes/properties of CCs

Carbon-carbon composites with high thermal conductivity are important for first wall components for nuclear fusion reactors, hypersonic aircraft, missiles and spacecraft, thermal radiator panels and electronic heat sinks. The thermal conductivity at > 1000°C increases with the heat treatment temperature, particularly above 28OO"C, as more graphitic carbon is associated with a higher thermal conductivity.

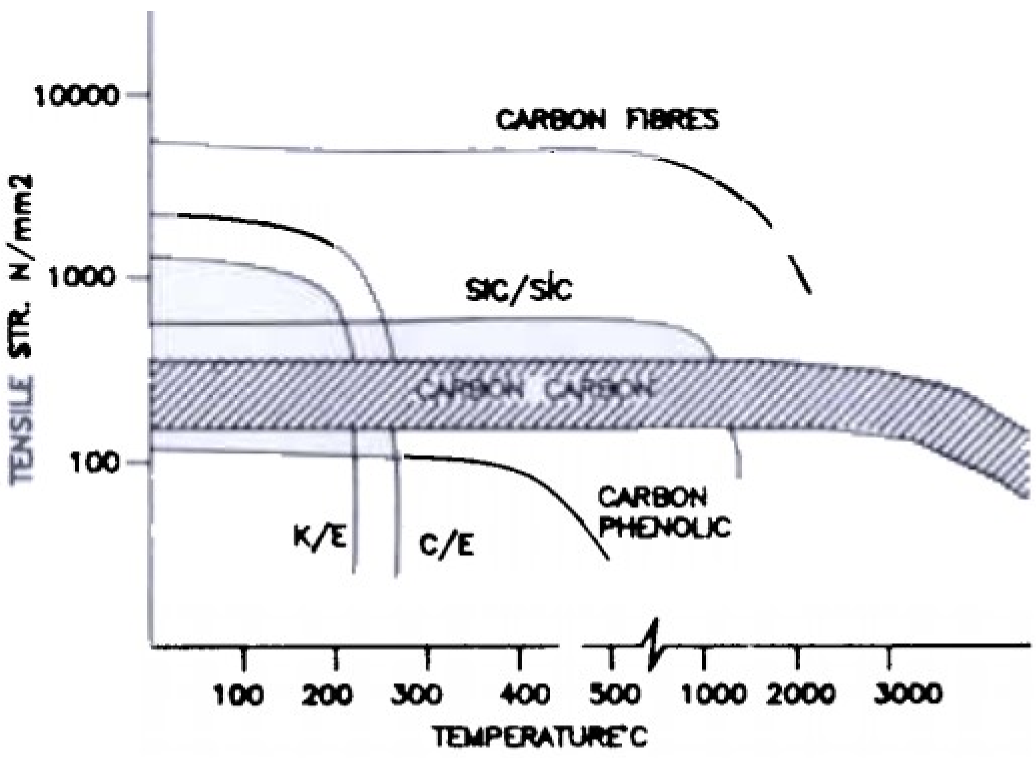

Fig 4- Plot of Temperature versus Tensile strength of different CCs.

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IV. FUTURE OF CCs AND ITS APPLICATIONS

Although specific strength and thermal properties of carbon-carbon make it the ideal material for high temperature applications, its use has been restricted by two major factors: the high costs and the susceptibility to oxidation. With more than 60% by volume, aircraft disc brakes are the main application. Compared to a steel brake, carbon-carbon has a 2.5 higher heat capacity, reduces the weight by 40% and doubles the service life. Other main applications are re-entry heat shields for space vehicles and missiles and rocket nozzles. Since the first use of carbon-carbon in aircraft brakes in 1974, major research programmes have led to new applications, of which some are:

1. Racing car brakes and clutches
2. Hot glass transfer elements
3. Protective shielding
4. Vacuum/inert gas furnace insulation
5. Hot pressing moulds
6. Metal sintering trays
7. Electronic circuit board thermal planes
8. Semiconductor manufacturing components.

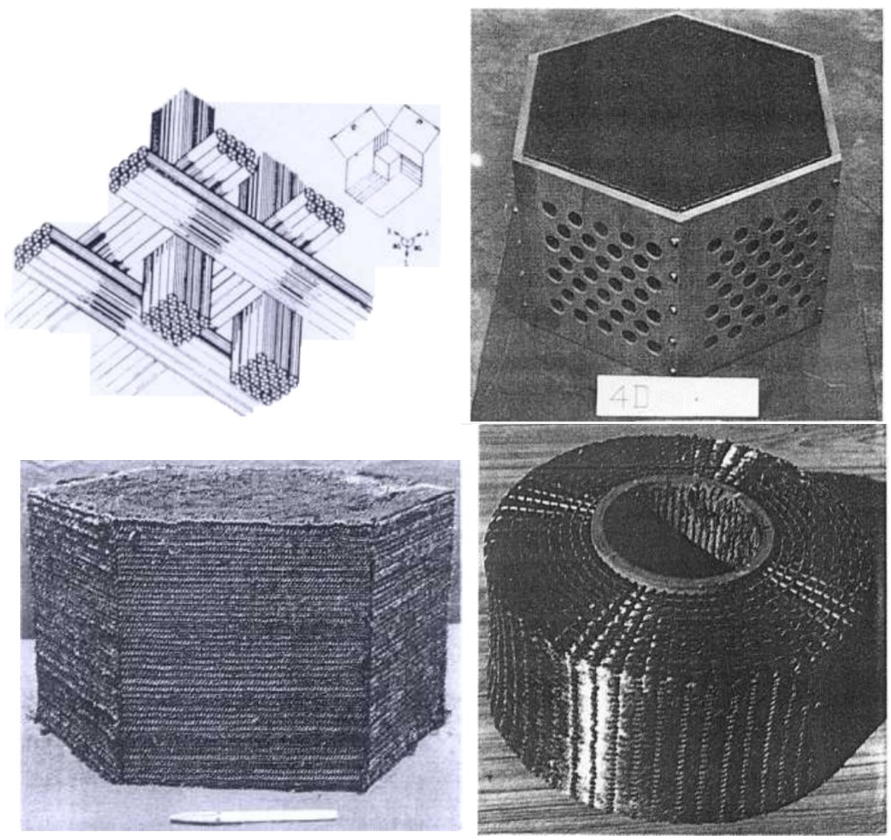

Fig 5- Different Carbon-Carbon Composites in their 3-D view.[5]

Although the load bearing ability of carbon-carbon at room temperature is not as high as that of metals, it is superior at high temperatures. This makes it the first choice for high temperature mechanical fasteners, where this material also saves weight. In braking applications it is not the frictional behavior that is of major interest but the ability to absorb and conduct large quantities of heat in a very short period of time without damaging the brake assembly. For biomedical devices carbon-carbon is used for prosthetic implants such as hip joint replacements and it has been tested in artificial hearts for animals. It is considered to be 'bio-active', as it is compatible with blood, bones and soft tissue and properties can be tailored to be close to those of bones. Other future applications where this material can be considered are protective shielding against Xray and laser, and parts in gas turbine engines such as flaps, seals, liners, vanes and tail cones. Its high purity and its resistance to heat and ionizing radiation make it a possible material for the nuclear industry, it is already being used in the JET (Joint European Torus) fusion reactor. Due to the secrecy and price of carbon-carbon composites, applications have been mainly restricted to military and aerospace use. This is about to change as improved manufacturing facilities and the increased amount of applications reduce the price permanently. The price varies significantly with the manufacturing methods and precursor materials and can be considered currently at around &300 per kg for a medium priced material. Most manufacturers who exclusively served the military market are now expanding their knowledge into the civilian market.

V. CONCLUSIONS

Carbon-Carbon composites are advance composites with superior thermal properties. It is currently the ultimate material for brakes and other high performance applications. The manufacturing process is very cost intensive as high temperatures and high pressures are required. The main factors influencing the quality are:

1. The quality of polymer matrix composite from which carbon-carbon is made
2. The choice of pitch as it affects carbon yield the use of resin
3. The choice of carbon fibre
4. The microstructure of mesophase (pitch-based)
5. The weave pattern of carbon fabric
6. Fibre matrix bond strength
7. Carbonization method/medium
8. Surface treatment of carbon fibre

Thus, Carbon-Carbon composites are an important aspect of human society and hence are the most researched compound in the present era. Its mechanical properties and thermal properties make it superior than any compound present on earth. Hence it is getting a wide range of use in aircraft design and scientific research.

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