Characteristics of Re-Inforced Carbon-Carbon

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Abstract- ***The*** **Reinforced Carbon-Carbon (RCC) is gaining significant position among the materials of modern period. The light weight and high strength composite is finding its way in various applications of Bio, Medical, Space and Defence fields. The growing use of Carbon Fiber Reinforced Carbon (CFRC) composites as high performing material in aerospace and defence industries has prompted studies in developing technology for machining of these composites in recent years. This paper emphasizes the characteristics and importance of this unique material. The varied and wide applications of CFRC with case studies were discussed in this paper.**

Key Words- Carbon-Carbon composites; RCC; CFRC; Prosthetics; MBT ARJUN.

I. INTRODUCTION

A literature review has been under taken on the details of most advanced and promising engineering material carbon fiber reinforced carbon (CFRC). CFRC is a light weight and high strength composite material capable of withstanding temperatures in many environments. In the general field of materials, CFRC composite materials ,which consist of carbon fibres having various textile structures and a carbonaceous matrix based on coke, polymeric resins, pitch or pyrolitic carbon occupy a special place. CFRC matrix composites or the so called carbon-carbon or carbon/carbon composites, which can be treated as an important subclass of ceramic matrix composites have lower density values, much lower than the metals and ceramics and hence make lower component weight, which is an important consideration for aero vehicles and bio materials. Reinforcing fibres are more anisotropic in structure and properties than the carbon matrix. Carbon-carbon prosthetic devices have been shown to be compatible with the human body. The unique properties of this composite are determined by the properties and textile structure of the reinforcing carbon fibres and the carbon matrix. The purpose of this paper is to summarize the characteristics and applications of the unique reinforced carbon-carbon (RCC) material. Efforts have taken to present the details, however it is difficult to cover completely all these aspects in this paper.

II. PROCESSING

Carbon/Carbon composites may be manufactured with different orientation of reinforcing phase.i.e unidirectional structure, bidirectional structure and multidirectional structure. Various fabrication methods for production of carbon/carbon composites are based on the required properties are available. But the major and main methods are discussed. Carbon fibre preforms, which is woven is impregnated under heat and pressure with pitch. This is followed by pyrolysis of the pitch to obtain a carbonaceous matrix. .This cycle may be repeated to obtain the desired densification. This is also obtained by another method known as chemical vapour deposition from a gaseous phase [1]. A schematic of carbon-carbon composite manufacturing process is shown in Figure 1

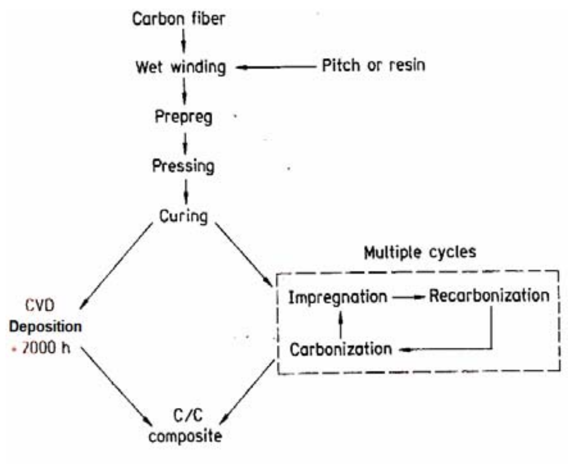

Figure 1 Carbon – carbon manufacturing process

III. PROPERTIES

The unique properties of RCC are determined by the properties of the reinforcing carbon fibres and the carbon matrix. Multidirectional reinforcement provides maximum level of mechanical properties in the direction of woven structure of composites. Chen et.al [2] have observed different values of flexural strength and density from six carbon/carbon

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components, which were fabricated by using three different production techniques. They have excellent thermal shock resistance, low coefficient of thermal expansion, high modulus of elasticity and low coefficient of friction. The low density and high strength reduces weight of the material. Other important properties are creep resistance, excellent abrasion resistance and high electrical conductivity. The thermal conductivity values of C-C are 5-10W/m^{o}C when fibres are in perpendicular direction and 50-60W/ m^{o}C, when fibres are oriented in parallel direction. They have densities in the range 1.6-2.0 gm/cm3, much lower than those of monolithic metals and ceramics. Chen and co-workers [2] have compared the tribological behaviour of carbon/carbon brakes under a high speed condition. RCC is an intensely hard material. The characteristics of these materials under neutron radiation have been extensively studied. These materials degrade when subjected to in core radiation levels and this radiation damage are reversed by treatment at temperatures near 2000^{o}C. The strength and fracture of Carbon/Carbon composites are governed by the Cook-Gorden theory for strengthening of brittle solids, which states that if the ratio of the adhesive strength of the interface to the cohesive strength of the solid is in the right, a large increase in strength and toughness of otherwise brittle material is achieved[9,10]. Carbon/carbon composites exhibit low coefficient of friction μ in the fibre direction (0.3-0.5) and in the perpendicular direction (0.5-0.8).Wear rates also follow similar trends (0.05-0.1and0.1-0.3mm). Carbon-carbon composites are bio compatible and can be made with directional properties. John and Matt of Boeing Company have tried to understand the complex interaction between the carbon brakes and the environment in which it must operate.

IV. APPLICATIONS

Major applications involve high performance braking systems, refractory materials using at high temperatures. Most notable applications are Heat shields for re entry vehicles, aircraft brakes, hot pressing dies, nozzles, and nose cones of intercontinental ballistic missiles and leading edges of the space shuttles. Carbon/Carbon brakes are used in subsonic aircrafts; Concorde supersonic aircrafts and racing cars. The brakes of some high end super cars like Bugatti Veyron were made off with C/C material. Many advanced fighters, such as the US F-14, F-15,F-16 and French Mirage 2000, as well as commercial aircrafts such as the Boeing-747, airbus, Canadair Challenger and Gulfstream III etc.,

Forsberg et.al [3] have proposed the advanced nuclear reactors, that are built entirely from carbon-carbon materials, which use salts as the heat transfer medium between the reactor and power generation equipment and/or heat rejection systems to create reactor systems with very high power-to-mass ratios. Carbon/Carbon composites have been developed for the fusion and fission applications. Printed – circuit heat exchangers are currently manufactured from carbon-carbon composites [13,14]. Agni missile, a reentry structure has used this advanced material in its manufacturing. Nizam orthopedic centre has used carbon/carbon calipers instead of heavy metallic calipers.

Carbon-Carbon prosthetic devices have been shown compatible with the human body. The replacement of knee and hip joints with metallic prosthetic devices has provided mobility to many elderly patients suffering from bone diseases [4]. Failure of the bond requires a second replacement. Fibre reinforced composites can be constructed to provide strength and stiffness in the necessary directions. Satisfactory fatigue strength and low density made this as an ideal material for prosthetic devices. The biological applications of the composite have been demonstrated and have permitted the use of carbon in the body for a non loading bearing applications.

Programmes are currently underway for development of ultra-high performance internal combustion engines with carbon/carbon composite pistons and cylinders[6,7,8]. Many turbine components have been built of c/c composite materials. Carbon-carbon composites have widened the scope of application of carbon based materials in wear related applications from bearing seals and electrical brushes to brake pads for heavy duty vehicles such as military trucks. Carbon/carbon composites have great potential in energy sectors as polar plates for fuel cells, in storage batteries etc. As the technology becomes more economical a viable, more and more applications get evolved [11, 12].

V. MACHINING OF CARBON-CARBON COMPOSITES

Very little has been found in the literature concerning machining of CFRC Composites. Since these composites are difficult to machine, a detailed study of their machinability features is essential. J.R.Ferreira et.al have carried out in rocket nozzle throats to study the performance of different tool materials. They also have carried out to observe the influence of cutting speed and feed rate on cemented carbide tool wear [5].

VI. BRAKE DISKS FOR MBT ARJUN

The case of the development of main battle tank Arjun brake discs by DRDO and CVRDE will give more idea and inputs about the application and importance of carbon-carbon composite materials. Defence Research and development organization (DRDO), with Combat Vehicle Research and Development Establishment (CVRDE) as the main laboratory, was tasked with the development of MBT ARJUN. Weighing 58.5 tons, the arjun tank is significantly heavier than the soviet legacy tanks used presently by Indian army. The Combat Vehicles Research and Development Establishment (CVRDE), Chennai has made outstanding contributions in the design, development, manufacturing prototypes and performance evaluation of Tracked Combat Vehicles and Specialist Tracked Vehicles. The tracked vehicle developed is shown in the Figure 2. The laboratory has successfully carried out the Transfer of technology for MBT Arjun. The first regiment of MBT Arjun was inducted into the Indian Army after successful completion of Accelerated Usage cum Reliability Trials (AUCRT).

CVRDE has developed high performance Carbon fibre reinforced carbon Brake discs for Main Brake assembly of MBT Arjun .Figures 3,4,5 show the assembly of brakeshoes,rotor and stator. The weights of brakes were compared with that of monolithic steel material, generally used for manufacturing brake discs and found a saving of weight by 75%.

The various performance characteristics requirements of c/c brakes were found as following.

1. Maximum torque: 18000 N-m
2. Maximum Inertia: 324Kg.m^2
3. Maximum Energy: 11MJ
4. Stop time: 6-9 secs
5. Wear : 3mm/side/5000km

Figure 2 Tracked vehicle

The weight savings of carbon-carbon brake discs over conventional steel discs are given in Table 1.

TABLE I COMPARISON OF WEIGHT OF STEEL AND C/C DISCS

S.No.	***Brake Parts***	***Weight Of Steel Brakes In Kg.***	***Weight Carbon-Carbon Brakes In Kg.***	***Weight Saving Per Brake Assembly In Kg.***	***Weight Saving Per Brake Assembly In %***
1.	Rotor	31	10.76	20.24	65
2.	Stator	10	1.8	8.2	82
3	Brake shoes	16	3.2	12.8	80
Total weight of Assembly		57	15.76	41.24	75

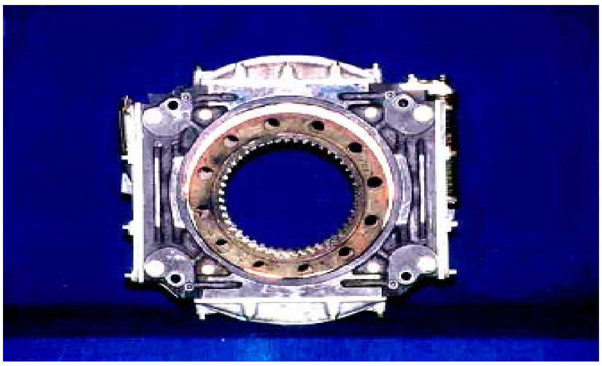

Figure 3 Double disc dry type hydraulic actuated 32 brake shoes/assembly

Figure 4 Carbon/Carbon rotor

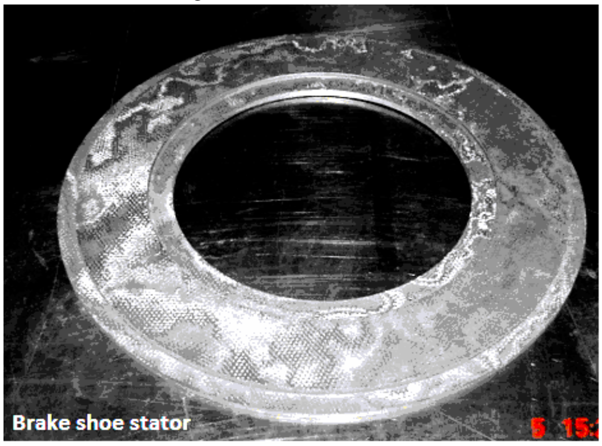

Figure 5 Carbon/Carbon stator

VII. CONCLUSION

Despite the major advantages of c/c composites, lack of oxidation resistance and impact resistance are the major problems and the oxidation problem can be overcome by silicon carbide coating. Impact resistance can be overcome by using Kevlar material coatings. As a braking material, carbon/carbon composites are superior to high strength than bulk graphite and the hot pressing molds can withstand higher pressures and offer a longer use life than polycrystalline graphite. Development of very low permeability carbon-carbon materials for operation at extreme temperatures for very long periods may be a major challenge. Weight saving is the major advantage of these unique materials. However, major research will be required to determine the real potential of this unique material. Then it will provide high performance material for application in a number of sectors.

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