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Application of UHMWPE Fiber Based Composite Material

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Abstract- Ultra High Molecular Weight Polyethylene fiber composite are presently the best fiber composite. It consist highest specific strength clubbed with resistance to aircraft fluids such as lubricating oils, aircraft turbine fuel, hydraulic oil, battery asset etc. As per the global status this fiber composites have replaced the other high performance fiber including Carbon, Kevlar, & glass based composite in the armor and personnel protective gears for military and Para-military forces all around the globe.
So many attempts have also been made for constructing Radome from this material to reduce attenuation of electromagnetic signals. However the composites made out of presently available perplex suffer from low flexural strength and thermal stability. Never the less these composites are suitable for subsonic aircraft where the temperature rise due to air friction of flying aircraft on its outer skin is limited to 80^0c.
This paper gives the detail work carried out to enhance the flexural strength by developing hybrid composite using glass fiber and epoxy resin matrix. The paper outlets increase of surface energy for arriving at an energized surface for ensuring its compatibility with fiber stroke epoxy composites. An optimization has been arrived for the hybrid composite between lowering the weight and desired strength for aircraft application involving its use as Radome, fairings, under carriage door, wings tip, and Vertical Stabilizer tip, fuel tank etc. which have the potential of reducing the structural weight of aircraft there by increasing aircraft payload significantly. This paper also prescribes the thermal and chemical characteristic of composite by the authors.

Keywords- Radome1, Uhmwpe2, Epoxy Resin Matrix3, Chromitization4, Flexural Strength5.

1. INTRODUCTION- In light of good performance of UHMWPE fiber has been widely used, especially in the fields of normal and low temperature. Since its advent, it has been applied to military and aerospace market. At present, UHMWPE fiber is widely used in aero-space, bulletproof and scrape-resistant safeguard articles, marine engineering cables and composite reinforced materials and so on, which is irreplaceable. Rest of the paper comprises as: Section 2 describes as oxidation process of UHMWPE. Section 3 describes as flexural strength test conducted on it. Section 4 describes as application of UHMWPE in various field of defence. Section V describes as the concluded the properties

2. Material properties of UHMWPE- UHMWPE contains repeating unit of polyethylene.

$$-(CH_2\text{-}CH_2)_n-$$

The molecular chain of UHMWPE can be visualized as a tangled string of wires and it's not a static but function of a temperature. When temperature of UHMWPE chain is lower than the melting temperature then it will tends to rotate along the C-C bonds.
Experimental data are shown below-

Relative molecular mass	2 to 6
Melting temperature (^{o}c)	125 to 138
Poisson ratio	0.46
Specific gravity	0.932- 0.945
Tensile modulus of elasticity(GPa)	0.8 to 1.6
Tensile yield strength	21 to 28
Tensile ultimate strength	39 to 48
Tensile ultimate elongation	350 to 525
Degree of crystalinity	39 o 75

2.1 ETCHING (OXIDATION) PROCESS OF UHMWPE LAMINATES II

The etching (oxidation) of UHMWPE is well known method of surface modification that changes both surface chemistry and roughness. The surface characterization of UHMWPE laminate was performed with energy dispersive spectroscopy (EDX) method [1].
The processes used for fabrication of UHMWPE laminates, UHMWPE prepregs are used. These layers are kept one above the other after which it is placed

into compression molding machine, then laminate is allowed to post cure at a temperature of 50^o-80^o C. But surface energy of UHMWPE laminate is very low; therefore it is not compatible to epoxy resin and shows very poor adhesion property.

The surface energy of UHMWPE laminate was increased using chromitization process. The chromic acid solution was prepared by mixing potassium dichromate ($K_2Cr_2O_7$), sulphuric acid (H_2SO_4) and Distilled water in a 7:150:12 mass ratios. The UHMWPE laminate was immersed in the chromic acid solution at room temperature for 30 minute. After that the UHMWPE laminate was washed by hydrochloric acid (HCl), distilled water and rinse with acetone respectively. Finally it was dried in vacuum oven at the room temperature for 12 hour and stored in N_2 gas

2.1.2. *Mould Preparation*

- Clean all surfaces, which come in contact with resin using zero emery paper.
- In second stage clean surfaces with cotton dipped in acetone.
- Apply two coats of release agent and buff with clean cotton cloth.
- Fix extraction on the base plate of male

2.2 Layup procedure for Hybrid of UHMWPE/Glass fibers

For radome fabrication process composite material system uses UHMWPE prepregs and glass fiber for hybrid construction, epoxy resin LY 556 (Manufactured by HUNTSMAN Pvt. Ltd.), hardener HY 951 (Manufactured by HUNTSMAN Pvt. Ltd). We used hybrid construction because of low stiffness of UHMWPE laminate. The procedure of layup are-

- Resin mixing with hardener (Resin LY-556 and Hardener HY-951 in 10:1 by weight ratio).
- Stir the mixture properly at room temperature.
- Mix the required amount of acetone as a solvent.
- Apply a uniform coat of resin over glass fabric and an etching laminate of UHMWPE using brush.
- Leave it for ten minutes for the evaporation of solvent at room temperature.
- Lay up three layers of glass fiber one over the other without any wrinkles.
- Placed all layers in between Teflon sheets and put all in compression molding machine at 30 kg/cm^2 pressure for 24 hour at room temperature.

3. FLEXURAL STRENGTH TEST

In view of high margins of safety obtained in the analysis of TDF Radome structure design, the structural strength test is required to be carried out. Flexural properties, such as flexural strength and flexural modulus are determined by ASTM-D790 test method. Flexural strength [2,3] is the maximum stress developed when a rectangular shape test piece, acting as a simple beam, is subjected to a bending force perpendicular to the bar. Composite beam specimen of rectangular cross section is loaded in three point bending mode. The Flexural test result of UHMWPE laminate, UHMWPE/Glass hybrid laminate and Glass laminate are summarized in the table 1and 2 respectively.

The formulas followed by the ASTM-D790 test method are as follows;
Specimen length = 20*thickness of specimen (mm)
Specimen width = 12.5 (mm)
Span length = L= 16* thickness of specimen (mm)

Speed of Flexural load = $(Z*L^2/6*d)$ mm/min.

Flexural extension or depth = $(r*L^2/6*d)$ mm

Flexural strength = $(3*P*L/2*b*d^2)$ N/mm^2

Where,
Z = 0.01 = constant, r = 0.05 = constant
b = breadth of specimen, d = thickness or depth

Table 1: Flexural test results of UHMWPE laminate

Sl. No.	Maximum Flexural Load (N)	Flexural Strength (MPa)	Modulus (MPa)	Flexural Strain
1.	8.83	5.07	270.83	5.00218
2.	9.27	5.33	377.45	5.00431
3.	8.77	5.04	331.54	5.00059
4.	10.91	6.27	297.78	5.00057
5.	12.77	7.34	355.02	5.00056
Avg.	**10.11**	**5.81**	**346.52**	**5.00164**

From the table 1, it is clear that the maximum flexural load capacity of UHMWPE is 10.11 N, and flexural

strength 5.81 MPa, at maximum flexural load with modulus 346.52 MPa. For the glass epoxy the maximum flexural load capacity is 631.36 N, and flexural strength 611.27 MPa, at maximum flexural load with modulus 31587.64 MPa. The data shows that the flexural strength of UHMWPE is low as compared to glass epoxy. Therefore to maintain the desirable stiffness and flexural strength using hybrid of UHMWPE/glass epoxy. The flexural load v/s flexural extension curve for the five samples of UHMWPE laminate are as under.

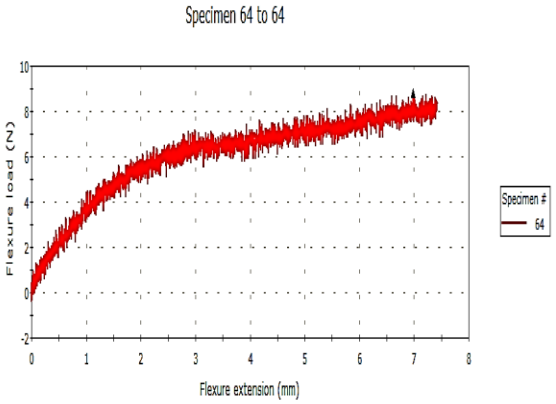

Figure 2: Flexural load v/s Flexural extension curve (UHMWPE laminate)

Table 2: Flexural test results of UHMWPE/Glass hybrid laminate

Sl. No.	**Maximum Flexural Load (N)**	**Flexural Strength (MPa)**	**Modulus (MPa)**	**Flexural Strain**
1.	22.95	8.71	335.48	5.00270
2.	25.16	9.75	369.50	5.00176
Avg.	**24.055**	**9.23**	**352.49**	**5.0223**

From the table 2, it is clear that the maximum flexural load capacity of UHMWPE/glass hybrid laminate is 2.4 times, and flexural strength 1.6 times greater than UHMWPE laminate, at maximum flexural load with modulus 352.5MPa.

4. APPLICATIONS

With wide application, UHMWPE fiber is mainly used in following fields:

4.1. Safeguard articles- In the field of safeguard articles, UHMWPE fiber reflects excellent properties including high impact toughness. It absorb impact energy is the highest among advanced composites and 2.6, 3 and1.8 times higher than aramid fiber, carbon fiber and E glass fiber composite materials. Due to its high impact resistance and bulletproof property, it can be made into bulletproof vest, helmet and armor, etc.

UHMWPE fiber composite armor's bulletproof property is 2.5 times higher than aramid fiber, so it can be made into the lightest but strongest armor. Its U/P is 10 and over 2 times greater than steel and glass and aramid fiber respectively, so it can be used for soft bulletproof vest and bulletproof steel plate, as well as armor and impact resistance plate for racers and alpinists.

Therefore, it can be said UHMWPE fiber has great potential in life protection. Besides bulletproof vest and helmet, it can be made into bulletproof armor, banknote carrier, armored car, bulletproof car and armed helicopter as well as anti-explosion liner, all of which should attribute to its light weight property. Because of good textile processing performance, it can be made from stab-resistant and scrape-resistant fabrics.

4.2. Aerospace material [4] **-** Due to light weight, high strength and high impact resistance, composites made by UHMWPE fiber can be widely used for wingtip structure, inner wall structure, landing system and salvage and recovery system of aero-space instrument. The shell materials of gunship and battle plane are bulletproof, too. Today, UHMWPE fiber plates have been compulsorily used in civil plane cabins by USA as well as Europe.

4.3. Cable products- Cable products include those widely used in ship, marine engineering, land and other fields. Because of its high strength, high modulus, wear resistance, corrosion resistance and age resistance, UHMWPE fiber is universally suitable for all kinds of cables and ropes. Compared with aramid fiber, cables made by UHMWPE fiber is 12% thinner in diameter, 52% lighter in weight but 10% stronger in strength. The breaking length of UHMWPE fiber cable is larger than aramid one and steel one. Because its specific gravity is less than 1 and its breaking length is unlimited in water, it's especially fit for cables of marine engineering, including super tanker, offshore oil platform and light tower. In aerospace industry, it's widely used in reducing parachute,

suspended cable of airplane and based materials and slings of high-altitude balloon.

4.4. Fishing net- Today, synthetic fiber becomes the most popular material for fishing net. In China, net material is nylon and polythene, whose consumption amount is 6,000 tons and 20,000 to 30,000 tons per year respectively. Under same mesh strength, the fishing net made by UHMWPE fiber is 50% lighter than that made by polythene fiber. When weight is the same, specification of the former is larger, which can increase catching amount and reduce net weight and water resistance so as to enhance trawling speed and decrease energy consumption. Now, offshore fishing industry has become a new trend, so the consumption of UHMWPE [5] fiber will increase considerably.

4.5. Biomaterial- UHMWPE fiber reinforced composite material can be applied to denture, medical transplant and plastic suture. Characteristics like good biocompatibility and durability, high stability, no allergic and biological rejection, have been demonstrated in the clinical trials. Besides, it can be used in cut-protective gloves and other medical instruments.

5. CONCLUSION

By these experiments it can be seen that the Ultra High Molecular Weight Polyeurethane has a low density, high specific strength and modulus. so it will be suitable for making different variety of product with wide range of applications. The surface of the material is very smooth as compare to other material. Thus it provides good flexural rigidity.

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