Self-primed Fabric in Self-reinforced UHMW-PE Composites: A Preliminary Study

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Statement of Purpose: Early studies in this laboratory on fiber self-reinforced UHMW-PE composites indicated their superior mechanical properties relative to unfilled UHMW-PE in terms of having higher flexural strength, higher impact strength, increased creep resistance, increased wear resistance, and higher modulus.[1,2] This was attributed to high levels of interfacing and adhesion between the fibers and matrix.[3,4] The desire to further maximize the level of interfacing and ability to form thick composites without compromising the orientation and hence, the strength of the reinforcing fibers prompted the pursuit of the study subject of this report which deals with applying the proprietary technology of self-priming the fibrous reinforcing component of the composites.[5]

Methods: Mesh Preparation: For mesh preparation, a multifilament, 650 denier yarn made of UHMW-PE comprising 120 filaments was used. The yarn was twisted to yield one twist per inch prior to warping and knitting, using a GE 203A warping unit and TR-6-E18 Rachel 6-bar knitting machine, respectively. The mesh was knit using a standard two-bar marquisette pattern with 21 courses per inch. To remove any fiber finishing additives, the meshes were sonicated in isopropyl alcohol for 5 minutes and dried prior to self-priming.

Self-Priming and Assembly of Composite Sheets: For self-priming, the warp-knitted mesh was dip-coated in a 6 percent solution of low density polyethylene dissolved in xylene at 110°C. The mesh was submerged for 15 seconds and removed with subsequent drying in a laminar flow hood until a constant weight was realized. A typical primer add-on was 10% by weight.

To prepare the UHMW-PE sheet components for use in assembling the self-reinforced composites, the polymer powder was compression-molded in a Carver Laboratory Press using a stainless steel mold. Molding conditions of 180°C and force of 133 kN for 30 minutes converted the UHMW-PE powder into uniform 10x10 cm sheets having a thickness of 1.3 mm.

Self-reinforced UHMW-PE composites were assembled into three patterns. In Pattern I, three sheets were stacked in an alternating manner with two meshes and three sheets. To determine the affect of self-priming, Pattern I was constructed from primed and unprimed mesh. A Carver Laboratory Press and a special mold to keep the mesh under tension (or strained) were used to form the self-reinforced composites following a three step process. To start, stacked components were heat soaked under moderate pressure. Next, pressure was increased to produce intimate contact between, and abridge, the UHMW-PE matrix with the self-primed UHMW-PE fibers. Finally, the stacked components were high-pressure annealed under reduced isothermal conditions.

Additionally, Pattern II and Pattern III were constructed in a like manner but utilized a two-stage assembly process without mesh constraint. In Pattern II and III, the compositions were stacked as follows: 3 sheets/mesh/sheet/mesh/sheet and 3 sheets/mesh/2 sheets/mesh/sheet, respectively.

Results: Data in Table I describe the affect on the mechanical bend properties of self-reinforced composites constructed from self-primed mesh. Self-priming increased both the maximum strength obtained and the composite stiffness characterized by the modulus.

Table II contains information on the bending maximum strength and modulus for varied constructions of the self-primed, self-reinforced composites. Data indicates that based upon the selective position of mesh and sheets within the composite stack, mechanical properties can be selectively modulated.

Table I: Comparative Properties of UHMW-PE Composites Using Unprimed and Self-primed Meshes[a]

Mesh			Mechanical Properties[b]	
Pattern	Self-Priming	Thickness (mm)	Max. Strength (MPa)	Modulus (MPa)
I	No	3.7	37	652
I	Yes	3.9	50	718

[a]First Stage: 140°C, 67 kN for 30 min.; Second Stage: 140°C, 133 kN for 60 min.; Third Stage: 110°C, 133 kN for 60 min.
[b]Using the 3-point bend method

Table II. Comparative Properties of Pattern II and III UHMW-PE Composites Using Self-primed Meshes[a]

Mesh			Mechanical Properties[b]	
Pattern	Self-Priming	Thickness (mm)	Max. Strength (MPa)	Modulus (MPa)
II	Yes	5.8	82	446
III	Yes	6.8	60	309

[a]First Stage: 145°C, 67 kN for 30 min.; Second Stage: 110°C, 67 kN for 30 min. [b]Using the 3-point bend method

Conclusions: Available results demonstrate the ability to increase the strength and stiffness of self-reinforced composites using a self-primed mesh to abridge the mesh/matrix interface. Additionally, strength and modulus properties have been shown to be varied based on construction for design-to-meet product specifications for various biomedical orthopedic applications. The properties of the new version of the fiber self-reinforced UHMW-PE composites signals their potential use as preferred alternative to UHMW-PE itself in orthopedic applications.

References:

1. Deng, M. et al., *Trans Soc Biomater*, 20, 218 (1997).
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