Magnaweave and Carbon-Carbon Composite Shapes

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Introduction

The MAGNASWIRL process, the circular counterpart to MAGNAWEAVE, fabricates "woven" multidimensional shaped axisymmetric preforms for composites. Both MAGNASWIRL and MAGNAWEAVE are proprietary to The CUMAGNA Corporation, under United States Patent(1)

The potential value of MAGNASWIRL for the fabrication of high performance exit cones and other carbon-carbon composites shapes has been recognized for the past five years. Naval Surface Weapons Center contract has been awarded to Atlantic Research Corporation (a CUMAGNA licensee) and Fiber Materials, Inc. for the fabrication of MAGNASWIRL preforms and densification of subscale exit cones.(2,3) Hercules Aerospace Division considered the construction for MX third stage exit cones(70 inch diameter); both Vought Corporation and DARPA have pursued the use of the technology for Cruise Missile turbine wheels.(4,5)

THE MAGNASWIRL Process

Historical

The current continuous, automated, and computer-controlled manufacturing technology evolved from initial andsimultanious studies by Bluck, of P and PDA, and FLorentine and associates at GE's RESD.(6,7) The concept of a "three-dimensional braid" was generated to meet the requirements for advanced missile heat shields, which should be survivors in a nuclear defense. As it evolved, MAGNAWEAVE (originally named "OMNIWEAVE' at Ge by the senior author) had the flexibility to orient fibers over a wide range, to meet structural requirements, the delicate treatment of the frangible and brittle fibers then available, and had the capability to assemble complex preforms directly, and without delamination as apossible failure mode(8).

These original concepts were manipulated manually, whihc precluded commercial exploitation. In 1973, Florentine conceived of the automation processeswhich resulted in the patent of reference(1), and allowed the technology to assume commercial importance. In its current mode, the process does have the flexibility of fiber orientation, has employed every fiber in existence, and does produce net shape preforms of complex nature. In addition, weaving speeds that produe shapes at linear rates of 50 to 100 yards/hour have been achieved, and are currently being employed in the aircraft and construction markets.

Details of The MAGNASWIRL Process. The MAGNASWIRL process, the circular counterpart of the MAGNAWEAVE process, consists of concentric rings, slotted to hold elements on which are fixed fiber supplies(spools, tubes) in a verticla position. The slots correspnd to the number of fibers required to produce the circumference of the shape of interest. The slots are arranged such that the slots in succeeding rings form spokes, issuing radially from theinnermost fixed ring.

The outer ring is fixed, as well, while the intervening rings can move. Their motion is clockwise and counterclockwise, each alternate ring moving in the same direction. The elements in the rings can be movedradially, inward or outward. In operation, alternate spokes are moved toward the center, the others toward the periphery.

In operation, the rings are loaded with fiber spools, and each fiber is collected and held above the loom base, which sits on a base plate at ground level. The rings are moved, simultaniously clockwise and counterclockwise, followed by the opposing spoke motion. These motions result in the intertwining of the fibers. A "weave" is formed at the level where the fibers had been gathered, and succeeding motions make the weave grow. A mandrel positioned along the axis of the loom forms the inner surface of the part. Details of the process can be found in several papers presented earlier by the author(s) (9,10,11).

Characteristics of The Process.

The earlier objectievs have been exceeded, and fresh objectievs have been met. Not only does the process, in its current state of development, meet the earlier requirements of weave flexibility and control, but the machine capability has been vastly extended to permit introduction of axial or transverse stiffener fibers in the weave itself; parts can be fabricated, automatically, whose cross sections may vary, gradually, or suddenly; both these thickness and width variations can be done reversibly.

Briefly stated, the process has the following characteristics:

1. Extreme fiber orientation
2. THrough-the-thickness properties
3. Low fabrication costs
4. Excellent complex shape capability
5. Integral shapes fabrication

MAGNASWIRL and Simple Shapes

MAGNASWIRL shapes are produced by assembling a loom with the required number of fiber elements to produce the desired dimension andshape and wall thickness. A mandrell is used for the internal surface contour, and the rest of the shape evolves by the weaving process. The shapes produced by the MAGNASWIRL includes the above mentioned exit cones, rocket nozzles, missile skins, road wheels for tanks, piston rings and rods for cars, "sucker rods" for oil well drilling, pipe for oil and gas exploration, as well as oil and gas pipe lines.

MAGNASWIRL and Complex Shapes

MAGNASWIRL has an appeal for the designer of complex shapes. (1) The shapes are often impossible to make other than with MAGNASWIRL; (2)MAGNASWIRL produces net shape preforms, making for simple densification(metals as well as carbon);(3) probably most important, MAGNASWIRLwill integrally weave a complex preform as asingle part that requires no attachments, and must be minimal in weight. This last simplifies assembly, insures survivalagainst stresses that strain joints, and promotes the long-range effects of fiber continuity.

Among those complex shapes, already fabricated, or in development, are (1) four-bladed marine propellers;(2) Cruise Missile turbine wheels;(3) piston connectors(4) jet engine fan blades;(5) heat exchangers for nuclear reactors;(6) engine components;(7) artificial vascular prostheses for by-pass operations;(8) bone replacements-hip sockets, jaws, etc.

Carbon-Carbon MAGNASWIRL Properties

Vought Corporation performed minimal testing on some limited carbon-carbon MAGNASWIRL composite weave geoemtries. Their results are tabulated in Table I. (Also included are the predicted values for hoop and radial mechanical properties for this composition.

Analyzing this data shows that the performance observed with organic composites is borne out with the Carbon matrix. The tensile properties increase as a function of weave orientation, the values exceed the normal composites(laminates), and the moduli are as expected. With these axial properties, the hoop and radial properties far exceed the values seen for normal carbon composites, where only the matrix material provides the strengths.

Table I

Carbon-Carbon MAGNAWEAVE

Mechanical Properties

Weave	Tensile Strength	Tensile Modulus	Shear Strength	Hoop and Radial St.
1x1x1	28×10^3psi	15×10^6	3.1×10^3	28×10^3
1x1x3	54	20	2.9	20

Fiber Interaction and MAGNAWEAVE Properties

The properties listed above are impressive. They were measured on coupons cut from a wide panel. No fiber path extended more than 2" in any of the pieces. It has been the author's contention that such short range fiber lengths produced properties less than those observed in panelsthemselves.

To confirm this hypothesis, graphite fiber/epoxy resin composites were measured in axial tension, one set cut from panels similar to these, the second set being woven to test piece width as well as thickness. The results showed an ihcrease of 100% in tensile strength(85ksi to 190ksi), an increase of 30%(13×10^6 to 17×10^6) in modulus. Were that long range fiber interaction effect on properties(in the woven to width, all the fibers extended from one end of the piece to the other, at least 12") be reflected in the Carbon-Carbon system, then we have a material capable of tensile strengths of 100Ksi in axial direction.

Conclusions

The MAGNASWIRL process constitutes a major breakthrough in fabrication technology for carbon-carbon composites. The ease of fabrication of the preform, its inexpensive price, all suggest that future applications of carbon-carbon composites may be greatly expanded beyond current levels.

References

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