Dry Process for Making Polyimide/Carbon-and-Boron-Fiber Tape

The tape has superior properties and can be used in automated tape placement.

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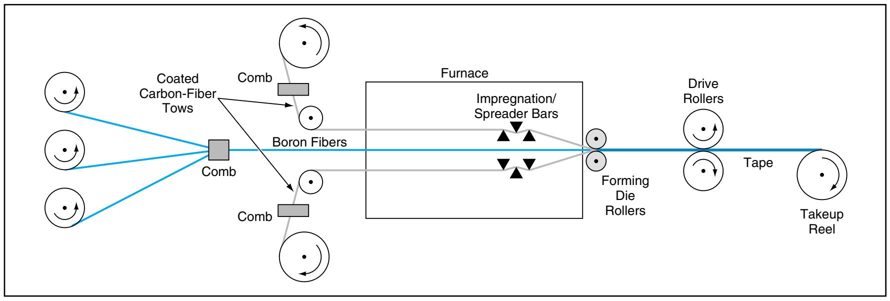
A dry process has been invented as an improved means of manufacturing composite prepreg tapes that consist of high-temperature thermoplastic polyimide resin matrices reinforced with carbon and boron fibers. Such tapes are used (especially in the aircraft industry) to fabricate strong, lightweight composite-material structural components. The inclusion of boron fibers results in compression strengths greater than can be achieved by use of carbon fibers alone.

Until now, polyimide/carbon-and-boron-fiber tapes have been made in a wet process: Boron fibers are calendered onto a wet prepreg tape comprising carbon fibers coated with a polyimide resin in solution. In the calendering step, the boron fibers, which typically have relatively large diameters, are pushed only part way into the wet prepreg. As a result, the boron fibers are not fully encapsulated with resin. In addition, the presence of solvent in the prepreg contributes significantly to the cost of the finished product in two ways: (1) the tackiness and other handling qualities are such that the prepreg tape must be laid up in a labor-intensive process and (2) the solvent must be removed and recovered before and/or during the final cure of the polyimide.

The present dry process is intended to enable the manufacture of prepreg tapes (1) that contain little or no solvent; (2) that have the desired dimensions, fiber areal weight, and resin content; and (3) in which all of the fibers are adequately wetted by resin and the boron fibers are fully encapsulated and evenly dispersed. Prepreg tapes must have these properties to be useable in the manufacture of high-quality composites by automated tape placement. The elimination of solvent and the use of automated tape placement would reduce the overall costs of manufacturing.



A **Layer of Boron Fibers** is formed between two layers of resin-coated carbon-fiber tows. The fibers in each layer are spaced apart in the direction perpendicular to the page. The layers are heated and pressed together to form a composite tape.

In this process, a layer of parallel boron fibers is formed and sandwiched between two layers of parallel carbon-fiber tows coated with a powdered polyimide resin. The layers are then heated and pressed together to form a composite tape. As shown in the figure, the boron fibers and the powder-coated carbon-fiber tows are pulled off reels and through combs that form the groups of fibers into the various layers with the lateral spacings consistent with the desired areal densities of carbon and boron fibers. The three layers are pulled through a furnace and maintained parallel until they reach a position where each layer of coated carbon-fiber tows slides against a set of impregnation/spreader bars. The temperature zones in the furnace are set to provide enough heat to melt the polyimide before arrival at the bars. The bars are heated to promote the flow of the resin system while facilitating the spreading of the tows as they slide over and under the bars.

After passing the bars, the layers are brought out of the furnace and pressed together between two forming die rollers. The speed of pulling of the tape and its fiber constituents is controlled by means of a pair of drive rollers downstream of the forming die rollers. The speed is chosen such that the time at temperature is adequate for the required melt flow. After passing through the drive rollers, the finished tape is wound on a takeup reel.

This work was done by Harry L. Belvin, Roberto J. Cano, and Norman J. Johnston of **Langley Research Center** *and Joseph M. Marchello of Old Dominion University. Further information is contained in a TSP (see page 1).*

This invention has been patented by NASA (U.S. Patent No. 6,500,370). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to Barry Price, Technology Commercialization Program Office, Langley Research Center, MS 200, Hampton, VA 23861; E-mail: b.l.price@larc.nasa.gov. Refer to LAR-15470-1.

Relatively Inexpensive Rapid Prototyping of Small Parts

Paper drawings and the associated delays in fabrication are eliminated.

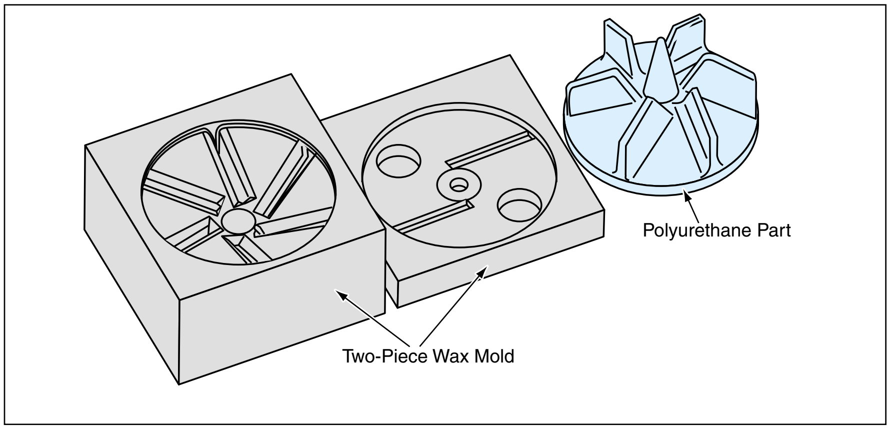
Lyndon B. Johnson Space Center, Houston, Texas

Parts with complex three-dimensional shapes and with dimensions up to 8 by 8 by 10 in. (20.3 by 20.3 by 25.4 cm) can be made as unitary pieces of a room-temperature-curing polymer, with relatively little investment in time and money, by a process now in use at Johnson Space Center. The process is one of a growing number of processes and techniques that are known collectively as the art of rapid prototyping. The main advantages of this process over other rapid-prototyping processes are greater speed and lower cost: There is no need to make paper drawings and take them to a shop for fabrication, and thus no need for the attendant paperwork and organizational delays. Instead, molds for desired parts are made automatically on a machine that is guided by data from a computer-aided design (CAD) system and can reside in an engineering office.

The process centers around the Actua 2100 (or equivalent) office-compatible rapid-prototyping machine. This machine is essentially a three dimensional printer that builds a part directly from a CAD data that specify a solid mathematical model, in the same manner as that of a rapid-prototyping machine of the stereolithographic or fused-deposition-modeling type. A CAD operator merely builds a plot file and submits it to the machine (this submission takes approximately one minute per part), then the machine builds the part. The time that it takes to build the part could be a few hours or as much as 30 hours, depending on the size of the part.

The machine builds parts with extremely fine detail but with two severe drawbacks. One of the drawbacks is that it makes parts of a wax that lacks toughness and strength. The other drawback is that any surfaces that are facing down with respect to the machine are covered with supports. These supports can easily be cleaned off by a light manual brushing, but the resulting surfaces are not smooth.

The present rapid-prototyping process overcomes these drawbacks. The steps of the process are the following:



A **Two-Piece Mold** is used to make a complex three-dimensional part.

1. The CAD system is used to design the desired part.
2. Taking advantage of a solid-modeling subtraction capability, the CAD system is used to design a mold that contains a cavity of the size and shape of the desired part.
3. The CAD model of the mold is sliced into appropriate pieces to eliminate any downward-facing surfaces (to prevent the production of supports on surfaces of the molded part).
4. Filling ports and vents are added to the CAD model to complete the mold design.
5. The data from the CAD model of the mold pieces are submitted as a print job to the rapid-prototyping machine, then the machine builds the mold pieces.
6. The mold pieces are taped together and filled with a room-temperature-curing polymer. The polymer used by the developer of this method is a durable polyurethane that becomes cured sufficiently for removal from the mold in about 1/2 hour.
7. The mold is removed and, after removal of any minor flashing, the part is ready for use.

One advantage of using a wax as the mold material is that mold can be removed from the part by melting, if necessary (the melting temperature of the wax is less than that of the polyurethane). Of course, if the mold is melted and it is desired to produce more copies of the part, then more copies of the mold must be built from the CAD files.

This work was done by Scott A. Swan of **Johnson Space Center**. *Further information is contained in a TSP (see page 1). MSC-23035*