LUNAR PREFORM MANUFACTURING

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Abstract

A design for a machine to produce hollow, continuous fiber-reinforced composite rods of lunar glass and a liquid crystalline matrix using the pultrusion process will be presented. The glass fiber will be produced from the lunar surface, with the machine and matrix being transported to the moon. The process is adaptable to the low gravity and near-vacuum environment of the moon through the use of a thermoplastic matrix in fiber form as it enters the pultrusion process.

With a power consumption of 5kW, the proposed machine will run unmanned continuously in fourteen-day cycles, matching the length of lunar days. A number of dies could be included that would allow the machine to produce rods of varying diameter, I-beams, angles, and other structural members. These members could then be used for construction on the lunar surface or transported for use in orbit.

The benefits of this proposal are in the savings in weight of the cargo each lunar mission would carry. The supply of glass on the moon is effectively endless, so enough rods would have to be produced to justify its transportation, operation, and capital cost. This should not be difficult as weight on lunar mission is at a premium.

Introduction

Purpose

The purpose of this project was to design a process to form long lengths of hollow glass filament-reinforced composite rods on the moon. It is believed that glass can be produced from compounds present in lunar regolith. By producing the glass in a vacuum, it is possible to achieve high tensile strength and a better fatigue life due to a lack of flaws in the fiber and to less crystallization of fibers after creation. Production of the materials on the lunar surface will also present transportation savings.

Possible Uses for Rod

These rods would be used as reinforcing beams in platforms, antennas, tethers, and solar reflectors. Another possibility for the use of the rods is to transport them from the lunar surface to future Space Stations to be used as construction materials.

Constraints

The project was limited as follows: all processing will be done on the moon; all materials, other than glass fiber, would be transported to the moon; weight must be kept to a minimum; five kilowatts of power will be available for the entire process; and the process must be able to produce rods that vary in inner diameter from 1 cm to 10 cm.

Process

Manufacturing Methods

Many different methods for manufacturing fiberglass composite rods were considered for use on the moon. Because of the limiting factors of the lunar environment, machine simplicity took precedence over optimal rod properties. Through the use of a design matrix, it became clear that the pultrusion option was the best for optimizing rod properties while simplifying design. Figure 2 is a representation of the lunar pultrusion process as we envision it.

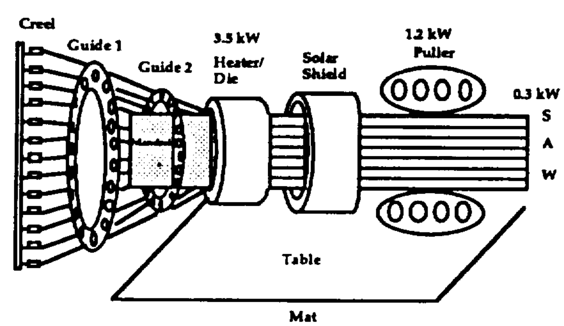

Fig. 2 Conceptualization of lunar pultrusion machine

Pultrusion Machine

Machine Components

Creel. To hold the packages for a 336-hour run, a V-creel of aluminum 6061-T6 would be required with the two halves being 10 m long and 2 m wide.

Guides. Two guides, one 92 cm in diameter and one 84 cm in diameter, are used to guide the 100 strings of glass fiber and matrix from the creel to the heater/die. Each are cast out of 6061-T6 aluminum. The guides are then welded to a stand which enables them to be moved as needed for the various sizes of rods being manufactured.

Mandrel. The mandrel is a 3.5 m hollow tube that will impart both shape and support to the pultruded rod. Both it and the mandrel stand will be cast of 6061-T6 aluminum. It will be necessary to have a set of mandrels of varying diameters in order to produce rods between 1 and 10 cm inner diameter.

Heat Die. Through the use of a thermoplastic matrix, the rate control of the process is simply the melting of the matrix. After extensive research of materials, it was decided that the heat die would be made of silver with a nichrome element and a plated black chrome insulation coating. From this design the power consumption of the die for a composite tube with an inside diameter of 10 cm, a thickness of 1 cm, a die length of 75 cm with a puller velocity of 0.001875 m/s, is 3386.1 Watts.

Solar Shield. Once the composite tube leaves the heat die, it enters a very thin cylindrical tube. In this tube of anodized aluminum with a white zinc oxide paint, the rod is cooled to hardening. For the case of a 10-cm inside diameter and 1-cm thickness composite tube traveling at .001875 m/s the length of the shield is calculated to be 2.25 m.

Puller. Friction calculations prove that 1.2 kW is more than enough to power a motor to pull the required load. To solve the problem of lubrication, molybdenum disulfide-based lubricants would be used, primarily Vac Kote. Also, the bearing chosen was ceramic, silicon nitride. These components, along with a variable gearbox with a vitron fluorestomer pulley system, would combine to form a very reliable system.

Cutoff Saw. The cutoff saw is the last stage of the pultrusion process. The purpose is to saw the rods periodically into 10 m lengths. A timer/controller such as a mercury switch will be used to turn the saw on and off and to load the saw down to the rod. The saw will be allowed a maximum 300 W.

Scray. Constructed of 6061-T6 aluminum, the scray is designed to hold half of the 720 rods of 12-cm outer diameter the machine could produce in one lunar day. Therefore, replacement of the full scray with an empty one would be required. The scray was designed with a folded lip on each side to allow for this.

Rails and Tables. The 6061-T6 aluminum tables will allow the components mobility for adjustments for different size rods.

Dust Protection. Because of the rough terrain of the lunar surface and the potential for dust, a 15 m x 15 m area should be cleared. A mat constructed of a thin aluminum sheet with a neoprene foam on the underside will be laid out under the machine prior to the installation of the pultrusion unit.

Operating Cycle. The pultrusion machine is set up to run for the 14 days of daylight during the lunar day and then to be shut down for the 14 days of darkness of the lunar night.

Composite Rod

Glass Fibers

The glass used for the composite rods will be produced using the process designed by researchers at Clemson University. In short, the lunar surface (containing an abundance of silicon dioxide) will be used as the source of the glass. Since the production will be in the vacuum of space, the glass will be of a quality not attainable here on Earth.

Matrix

The selection of the matrix for this process and composite was extremely complex. The extreme environment of the lunar surface made processing and end-use characteristics of the resin chosen very important. With all of the processing problems in mind, the liquid crystalline polymer Vectra was selected. Having a high radiation resistance and a high strength made it the perfect choice. In addition, Vectra is also available in fibrous form under the name Vectran. This would allow the pultrusion process to be done with both matrix and reinforcement in fibrous form.

Composite Properties

The actual end uses of the pultruded rods were quite vague, so in determining the rod properties, spreadsheets were set up to allow the designer to vary volume fraction, inner diameter, outer diameter, and length of the rods and to be able to calculate the critical tensile and compressive loads of the chosen rod.

Tension Analysis

Tensile calculations allow creation of a graph of composite area versus fiber volume fraction for given loads as shown in Figure 3.

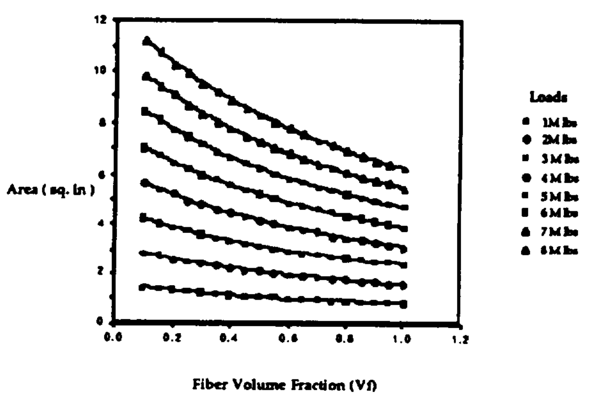

Fig. 3 Area vs. fiber volume fraction for tensile loads

Compression analysis

Considering first mode buckling as the limiting factor for critical load, a similar graph can be generated for the ultimate compressive loads of various rod designs. This has been done in Figure 4 for our composite rod of length = 10 ft and inner radius = 2 in (5cm).

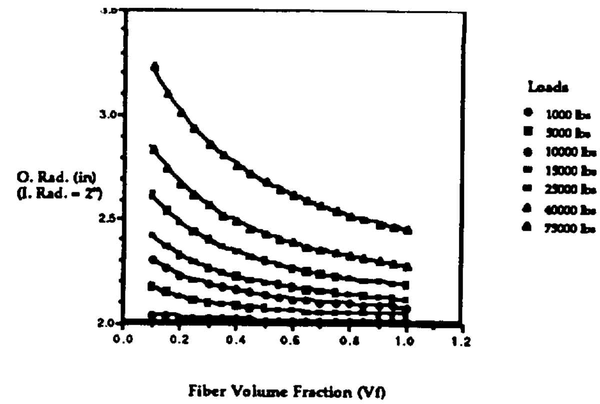

Fig. 4 Outer diameter vs. fiber volume fraction for compressive loads

From the previous graphs and the probable difficulty in pultuding a part with a fibrous matrix, we believe that 60% fiber volume fraction would be the optimum setting for the machine. Based on this assumption, the 3-m rod with an inner diameter of 10 cm and an outer diameter of 12 cm would have the capacity to carry approximately 5 Msi in tension and 35 ksi in compression.

Cost Analysis

Based on the calculations for the 3 m rods with a 10 cm inner diameter and 12 cm outer diameter, the relative weight savings is 3,799.1 kg. This calculation shows that to take identical rods to the moon would require a cargo 3799.1 kg larger than that of the materials necessary to make the rods on the lunar surface. Based on the figure of $100,000/lb of cargo, this translates to a savings of $835.8M. With a cycle start-up labor cost of $500,000, it seems obvious that even with a lengthy initial start-up, this design is easily justifiable for one cycle, and the savings will only increase as more rods are produced.

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VARIABLE SPEED CONTROLLER

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Abstract

This report details a new design for a variable speed controller which can be used to operate lunar machinery without the astronaut using his or her upper body. In order to demonstrate the design, a treadle for an industrial sewing machine was redesigned to be used by a standing operator. Since the invention of an electrically powered sewing machine, the operator has been seated. Today, companies are switching from sit down to stand up operation involving modular stations. The old treadle worked well with a sitting operator, but problems have been found when trying to use the same treadle with a standing operator. Emphasis is placed on the ease of use by the operator along with the ergonomics involved. Included with the design analysis are suggestions for possible uses for the speed controller in other applications.

Problem Statement

The development of a variable speed controller that will enable a standing operator to control the rate per minute on an industrial sewing machine is needed.

The controller must:

-be hands free
-be no longer than 3 feet wide
-be no longer than 2 feet deep
-be no higher than 2 inches high
-be mobile so that it can be placed in the best possible position for each operator

The controller will have:

-a potentiometer
-110 volts AC input
-4-20 milliamperes output
-an automatic shutoff
-a pad surrounding the device
-no more than 15 pounds weight
-a pad with a nonslip contact area
-a compression-type spring for pedal return