SOCIETY FOR THE ADVANCEMENT OF
MATERIAL AND PROCESS ENGINEERING

ADVANCED MATERIALS & PROCESSES PREPARING FOR THE NEW MILLENNIUM

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PREFACE

At the approach of this new millennium we have seen technology soar into realms which were only dreams decades ago. Technology advances in electronics, computer technology, medicine and aerospace easily catch our attention and we are astounded. Technological innovation in advanced materials and processes are equally astounding, but sometimes less obvious. Advanced materials are the building blocks by which much of the technology that is in the public eye today is made possible.

The collection of papers included in these proceedings reflect some of those advances in the materials arena which work towards *"Preparing for the New Millennium."* The challenges of the next millennium will drive the use and enhancement of advanced materials. Advanced materials, as represented in these proceedings, are mainly those composed of fibers and matrix materials, or composites. The behavior of these fibers and matrix materials as they act together and separately are addressed herein.

Many materials have been developed which offer superior fire protection and are conducive to a variety of curing techniques. Advances in engineering design and analysis of these materials allow for better understanding of them and their application to marketable structures. Of considerable importance to the field of composites are manufacturing methods used to produce these structures. Within this book the methods of filament winding, transfer molding and pultrusion, among others, are highlighted as low cost, high volume methods of fabrication. Keys to making these processes work for structural applications are emphasized. Of course, no collection of papers on advanced materials would be complete without the inclusion of state-of-the-art test methods for materials and structures alike.

Finally, the application of advanced materials to the world of useful structures and components are critical to the success of these materials. The aerospace, industrial, commercial and infrastructure industries are using advanced materials more commonly today than they ever have in the past. Specific applications in all of these industries are focused upon.

Advanced materials and the processes used to fabricate components and structures using them are important to our future and will help to "Prepare Us for the New Millennium."

John Green
Composite Machines, Inc.
Vice Chairman

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BETTER ROBOTICS USING COMPOSITES

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ABSTRACT

Demanding applications and performance characteristics for robotic and automation systems are pushing the limits of traditional materials. Steel and aluminum have been the staple material used in robotic structures. Robotic arms made from these materials can be heavy, requiring a bulky structure just to limit member deflection due to its own weight, and the weight of the object being acted upon. A byproduct of a heavy, bulky robot is limited speed, large servo motors, and high power consumption. Composites offer an alternative which can reduce weight, limit deflection, require smaller motors and less power. Several applications of composites to robotics will be examined and the benefits explained.

KEY WORDS: Robotics, Composites

1. INTRODUCTION

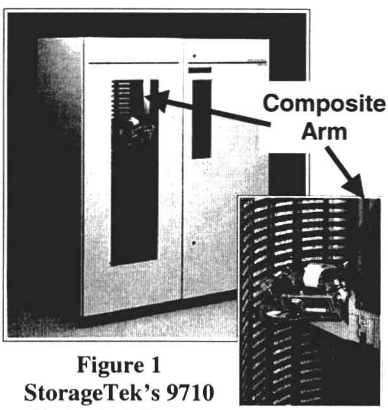

Figure 1
StorageTek's 9710
Robotic Library

For many years the application of composites to the robotics and automation industries has been a long sought after prize. Composite material prices continue to decrease, especially with the advent of large filament count fibers and improved methods of producing prepreg tow and uni-directional tape. Material price reduction along with more refined manufacturing processes has helped to lower the cost of composite structures, approaching automation industry accepted values. This helps to open up more markets in the automation arena. This paper will highlight the advantages composites can offer the automation industry and will showcase several applications (Figure 1) of composites being volume produced in the industry today.

2. ROBOTICS CAN BENEFIT FROM COMPOSITES

Composites offer quite a few benefits for robotic applications, when compared to traditional metallics. Many of the basic characteristics of composite materials apply:

- **Light Weight**: Lighter weight translates into less energy consumption and has a cascading effect which could reduce weight, wear, cost etc. of other components in a system. The reduced weight means reduced accelerated inertia and the ability of the robot to carry a heavier payload. Composites can be five times lighter than steel and 2 times lighter than aluminum.
- **High Stiffness:** High stiffness helps to limit how much a structure will deflect or deform under a load. Robotic members can be made longer than metallic members, yet maintain the same or even less deflection. Composites can be as much as 4 times stiffer than steel.
- **High Strength:** High strength allows a composite structure to handle high loads before breaking. Composites can be as much as 4 times stronger than steel.
- **Part Consolidation:** Reducing part count can lead to lower cost and reduces stresses in the structure due to fewer joints.
- **Extended Life Cycle:** Composites do not fatigue like metals, they do not corrode or dent, they have excellent impact resistance.
- **Special Needs**: Dimensional stability under changing temperatures, improved vibrational dampening, electronic transparency, electrical conductivity or insulation.
- **Design Flexibility:** Unlike metals, composites can be specifically tailored to give exacting performance characteristics.

Of particular interest for robotics is the high stiffness (E), high strength (σ) and light weight (low density, ρ) of composites. These three benefits of composites can be represented in terms of specific stiffness (stiffness/density,)

$$E_{specific} = E/\rho$$

Equation 1
Specific Modulus

and specific strength (strength/density,)

$$\sigma_{specific} = \sigma/\rho$$

Equation 2
Specific Strength

These parameters offer a representation of how much stiffness and strength can be obtained per unit weight of material. Figures 2 and 3 illustrate how various 60% fiber volume, uni-directional composites (Ultra-high modulus carbon, standard modulus carbon, Kevlar™ and S2-fiberglass) compare to steel and aluminum. Composites have a distinct advantage by as much as 8 to 10 times better than aluminum or steel.

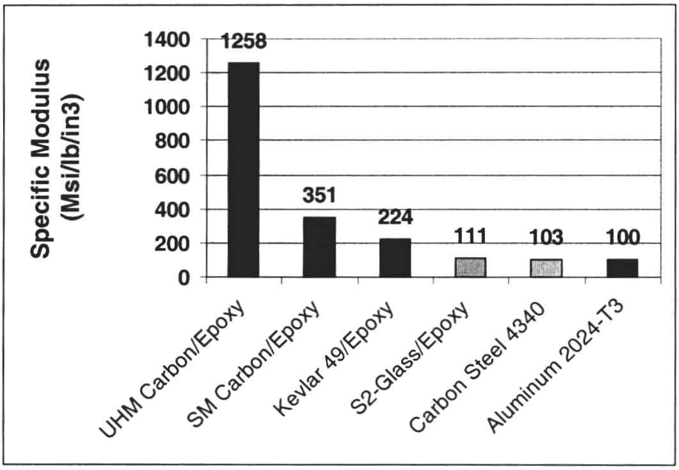

Figure 2
Specific Modulus Comparisons

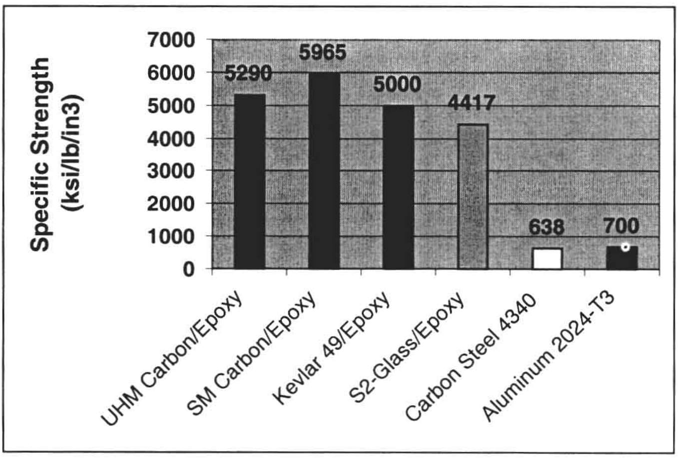

Figure 3
Specific Strength Comparisons