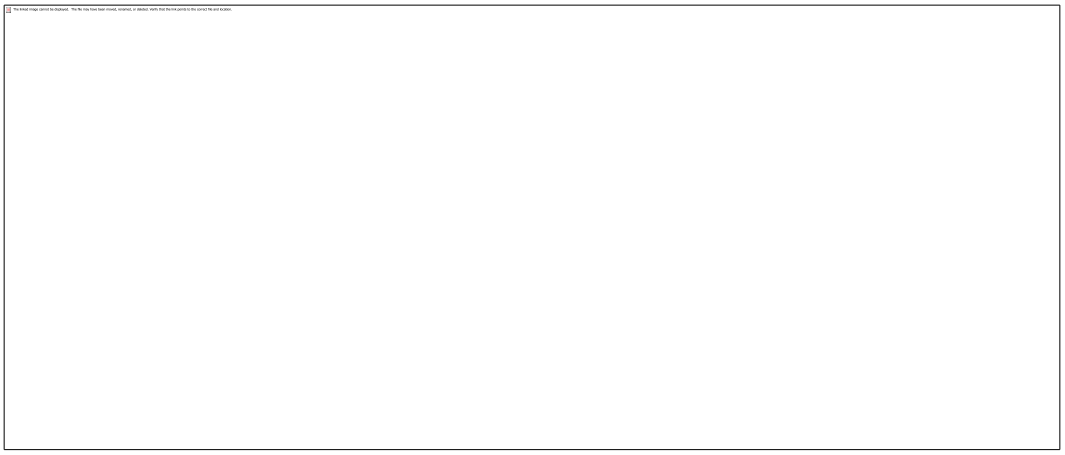

JTEC Panel Report on

Advanced Manufacturing Technology for Polymer Composite Structures in Japan

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EXECUTIVE SUMMARY

INTRODUCTION

The United States has invested a great deal of effort in developing polymer composite structures. Now, the government seeks expanded applications. Experts perceive that the barrier to expanded applications is the high cost of manufacturing. This is not only an American issue, but an international one. Consequently, the government asked this panel to evaluate the status and outlook for manufacturing, or fabrication, technology in the U.S. and Japan, with an eye toward finding or developing mechanisms of cooperation.

The title for this study, "Advanced Manufacturing Technology for Polymer Composite Structures," reflects the panel's emphasis on polymer composites, and the focus on manufacturing technology as the key to wider use of composites by lowering the cost of using them.

For the purpose of this study, we define a composite as a combination of two or more materials that enhances their properties. Composites are being used because of their superior capabilities in the following categories:

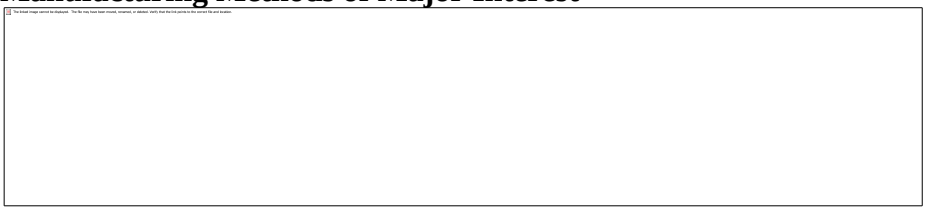
- Stiffness/weight
- Ability to tailor structural performance
- Ability to tailor thermal expansion
- Strength/weight
- Corrosion resistance
- Fatigue resistance

Familiar applications include boats, surf boards, fishing rods, racquets, skis, and tool handles. Many advanced applications of composites have been made in the aircraft industry:

- Commercial aircraft flaps, slats, elevators, tails
- Helicopter blades and bodies
- F-16 tail surfaces
- F-18 wings and tails
- AV-8B Harrier fuselage, wings, tails
- F-117
- B-2

The manufacturing methods of major interest for this study are shown in Table E.1.

Table E.1
Manufacturing Methods of Major Interest



APPROACH

The panel's approach was to develop a draft report summarizing the status and outlook for advanced manufacturing technology of polymer composite structures in the U.S. This report was given to the hosts in the approximately 20 Japanese organizations that the 10-person JTEC team visited over a 10-day period in December 1992.

Sponsors for this study were:

- NSF: Paul Herer
- Army Research Office: Dr. Andrew Crowson
- Air Force Office of Scientific Research: Dr. Charles Lee
- Department of Energy: Dr. Paul Maupin, Dr. George Jordy

The study was carried out under the auspices of the Japanese Technology Evaluation Center (JTEC) at Loyola College, funded by the above agencies through NSF's grant to JTEC. JTEC studies are carried out by the International Technology Research Institute (ITRI) at Loyola College; ITRI is directed by Dr. R.D. Shelton. Within ITRI, the JTEC Principal Investigator and Director is Dr. Michael J. DeHaemer and the JTEC/WTEC Staff Director and Series Editor is Geoff Holdridge.

As detailed in Appendix B, the panel had unique qualifications for this study:

Dick Wilkins (Chair), University of Delaware

- 17 years at General Dynamics, Fort Worth in composites development (Coordinator of F-16 Tail Certification)
- Five years as Director of UD Center for Composite Materials (two years as President of American Society for Composites)
- Two years as Director of Institute for Applied Composites Technology

Moto Ashizawa, Ashizawa and Associates Composites Engineering

- 15 years in composites design, analysis and development at Douglas
- 10 years in composites program management, certification, and manufacturing at Douglas
- One year in composites consulting in both the U.S. and Japan

Jon DeVault, Advanced Research Projects Agency (ARPA)

- 25 years experience in advanced materials industry with Hercules
- Former President of Hercules Advanced Materials & Structures Company
- Now starting a new position organizing composites initiatives at ARPA

Dee R. Gill, McDonnell Douglas

- 25 years in manufacturing methods development at Hercules
- Four years as Director of Production Operations and Director of Manufacturing in the New Aircraft Division of McDonnell Douglas

Vistasp Karbhari, Center for Composite Materials

- Scientist, Center for Composite Materials, U. of Delaware
- Research Assistant Professor in Civil Engineering, U. of Delaware

Joe McDermott, Composites Services Corp.

- 11 years as Director, Composites Institute of SPI
- 12 years in composites consulting in both the U.S. and Japan

During the visit to Japan, the panel was assisted by a number of highly qualified sponsor representatives:

Dr. Iqbal Ahmad, ARO

- Excellent background in materials science
- Army Representative in Japan

Dr. Alan Engel, ISTA, Inc.

- Several years in polymer and composites research at DuPont
- JTEC contractor for advance arrangements in Japan

Dana Granville, ARL

- Army Materials Directorate Coordinator for Composites

Dr. Bruce Kramer, NSF

- Program Director for Manufacturing & Materials Processing

Xavier Spiegel, JTEC

- Teaches materials at Loyola College

Our special thanks go to Dr. Tsuyoshi Hayashi, Professor Emeritus at the University of Tokyo, for his gracious help in organizing our study.

The mission of the study was to summarize the current status and future outlook of polymer composite structures in Japan and in the United States. It was motivated by the desire of the U.S. to move from invention to commercialization, which dictates advancements for low cost,

repeatable manufacturing. The hope was expressed to the Japanese hosts that the U.S. and Japan could cooperate so as to expand the market for composites.

Available literature was used to summarize the U.S. status in a document for the Japanese hosts to see the scope being sought. Available literature and key Japan site visits were also used to summarize the Japanese status. Summary findings were presented at a Workshop in Washington, D.C. on February 18, 1993. This report was then developed.

OVERALL FINDINGS

It is overwhelmingly clear that individual organizations in both Japan and the United States practice the same basic manufacturing technologies. But Japanese companies practice them with a much greater respect for detail. This respect for detail leads directly to the high quality evident in their operations and parts.

The Japanese hosts expressed great confidence in the training and skills of their work force. At the same time, factory workers help develop the fabrication methods to achieve the best chance of success.

Many of the processes observed were relentlessly developed to remove chances for errors and reduce cost. This persistence was striking.

The panel observed impressive efforts to reduce composite detail part count. One derivative is the high level of excellence achieved in co-curing. Another is the observed emphasis on dry-fiber preforming.

There were a number of interesting areas showing strong potential for success. These included:

- Co-cured Omega stringer panels
- 3-D and 2.5-D weaving
- Curved pultrusion
- Super composite bolt
- Continuous forming of thin-walled pipes

DETAILED FINDINGS

The JTEC panel's qualitative comparisons between the United States and Japan in advanced manufacturing technology for polymer composite structures are shown in Table E.2. The remainder of the report addresses each of the topics listed in the table in some detail. Conclusions in each of these topics are also summarized below.

Aerospace

The aerospace sector is focused on commercial applications of aerospace technology. Japanese technology was introduced through alliances with U.S. and European companies, from which the Japanese companies have transferred both good and bad habits.

Automotive and Industrial

While the U.S. seems to still have opportunities in automotive applications, Japan appears to be stymied by recycling concerns.

Japan is quite aggressive in this industrial field. Many cost-driven applications are being tried.

Civil Engineering

In contrast to the U.S., where the construction industry is fragmented, the Japanese opportunities in civil engineering applications are many and varied.

Materials

There is still a large effort to introduce pitch carbon fiber into applications. The economics are still mysterious, however.

Emphasis on thermoplastics was evident, in spite of the reduction in emphasis in the U.S. Similarly, high temperature resins are getting much attention.

Table E.2
Japan Compared to U.S. in Advanced Manufacturing Technology for Polymer Composite

Structures

Manufacturing/Processing Science

In contrast to the U.S. approach of developing computational models to understand processes better, Japanese manufacturing science appears to reside in experienced workers who develop understanding of the processes over long periods of time.

Product and Process Development Methods

Japanese product and process development methods use concurrent engineering by definition. Japanese teams have developed the human factors issues far beyond those in the West.

POLICY CONSIDERATIONS

Advantages in Japan

- The Japanese appear to be able to accomplish more with less.
- They drive to low cost from a life cycle viewpoint.
- Manufacturing people have high status.

- While the U.S. is better at university-industry links and university education, Japan is better at *keiretsu*, consortia, and industry-government links. A good example is the 3-D Composites Research Corporation that was formed by a number of Japanese organizations for a fixed number of years to advance the technology of preforming.
- The Japanese will derive a cost advantage from government projects in standards and data bases.
- The Japanese appear to be better at a number of aspects of composites manufacturing. They focus more on long-range strategy, and invest more up front to ensure success. These up-front investments are frequently justified by careful cost trade-offs. The other critical investment is in the training of the entire work force to achieve a unified approach throughout the company. The high-quality people assigned to production management maintain a high priority on manufacturing. They enforce high standards and goals in development and execution of fabrication processes. The above-mentioned attention to detail is a direct result.

IMPRESSIONS

Japan and the U.S. have much to gain from each other. Each country has different strengths to bring to composites manufacturing. Many of our hosts expressed the belief that they must develop ways to cooperate with the U.S. In perspective, producers in both countries can reduce costs by obtaining a deeper understanding of basic processes. Companies in both countries must also develop a unified basis for understanding what it takes to make repeatable composite structures so that new markets may be opened with more confidence and reliability. It is also clear that the process advancements made by the Japanese can be transferred to the U.S. only by also transferring the spirit of cooperation that exists within Japanese companies.

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