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Program Summary

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ADVANCED COMPOSITES IN JAPAN

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SUMMARY

The JTEC Panel on Advanced Composites surveyed the status and future directions of Japanese high-performance ceramic and carbon fibers and their composites in metal, intermetallic, ceramic, and carbon matrices.

Japan's ambitious space program includes development of a hypersonic civilian aircraft, to be completed by 2005. A major factor in the program is new materials, one of three areas selected by MITI for national development investment. The Japanese believe that technological superiority in space structures and launch systems could help them become dominant in the aerospace market.

Japanese industry and government are willing to forgo short-term gains to build for the future. The new MITI materials thrust initiated in 1989 (*High Performance Materials for Severe Environments*) was scheduled to continue for almost ten years, longer than would be possible in the U.S. The Japanese support parallel approaches to materials research and technology that often involve overlapping activities among several groups, sharing information at the precompetitive stage. By contrast, the U.S. seems to select one best approach initially, frequently finding later that other options are needed.

By attempting to find an immediate application for less-than-optimum materials, the Japanese gain the manufacturing experience to produce a lower-cost, more reliable product. For this reason, they tend to place less emphasis on basic science and more on manufacturing and large-scale pilot plants. Compared with the U.S., there seems to be more learning by doing and fewer analytical studies.

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Some previous MITI materials programs have led to new consumer markets and substantial returns on government investment. The Japanese formed technical teams within and across industries that remained intact for the long periods required to develop and exploit markets. The 1989 MITI initiative was different: although materials would be an enabling technology for a hypersonic transport vehicle, they might only be produced in small quantities. MITI also set very ambitious performance for its new program in 1989. The panel felt that these goals would be revised downward to achievable levels.

Because of a strong carbon and fiber industry, Japan is the leader in carbon fiber technology. Japan has initiated an oxidation-resistant carbon/carbon composite program. With its outstanding technical base in carbon technology, Japan should be able to match present technology in the U.S. and introduce lower-cost manufacturing methods. However, the panel did not see any innovative approaches to oxidation protection.

Ceramic and especially intermetallic matrix composites were not yet receiving much attention at the time of the panel's visit. There was a high level of monolithic ceramic R&D activity. High-temperature monolithic intermetallic research was just starting, but notable products in titanium aluminides had already appeared. Matrixless ceramic composites was one novel approach noted. Technologies for high-temperature composites fabrication existed, but large numbers of panels or parts had not been produced.

The Japanese have selected aerospace as an important future industry. Because materials are an enabling technology for a strong aerospace industry, Japan initiated an ambitious long-term program to develop high-temperature composites. Although the program was just starting, its progress should be closely monitored in the U.S.

Reinforcements

High-temperature/high-performance composites for aerospace applications depend on the availability of strong, lightweight fibers. Japan's commitment to several advanced aerospace efforts -- for example, Mach 4-6 hypersonic technology -- make its fiber accomplishments of particular interest. Japan has done well in developing a number of useful fibers, primarily through the polymer precursor approach. The Japanese are learning how to produce quality fibers in reasonable quantities and fabricate lower temperature composites with the fibers. They are developing insights into advanced composite fabrication and higher temperature composite durability, which would help them exploit improved fibers as they become available.

Ceramic Matrix Composites

Japanese researchers have focused on enhancing the toughness of the best already-available monolithic structural ceramics. Japan has been a prime supplier of

continuous high-performance, high-temperature fibers that have been used in the development of ceramic composites in the U.S.. The Japanese themselves have focused on the use of SiC and Si₃N₄ whiskers and particulates.

The Japanese are also devoting significant effort to processing hybrid ceramic/metal composite systems. They are developing sophisticated techniques for making functionally gradient materials (FGMs) whose properties change gradually from ceramic to metal. FGMs are designed to overcome the severe problems of thermal expansion mismatch in joining metal to ceramic parts in high-temperature engines. A separate processing effort is directed at making the high-temperature, high-performance composite materials into shapes needed for such engines. This effort involves combining self-propagating high-temperature synthesis with hot isostatic pressing to produce high-quality material in the desired complex shapes.

Metal and Intermetallic Matrix Composites

Japan entered the field of metal matrix composites about a decade later than the U.S. did. However, the Japanese have more than made up for lost time. At the time of the panel's visit, the Japanese had not developed widespread commercial applications for metal matrix composites; rather, the focus of activity was development of lower-cost production methods. The Japanese R&D programs also emphasize self-sufficiency in components. Some early successes have been achieved with intermetallic alloys that perform well in high-temperature turbines.

Carbon-Carbon Composites

The technology for fabrication of fiber-carbon matrix (C-C) composites has been funded by the U.S. government for almost twenty years. A mature domestic industry is manufacturing large, complex C-C shapes. In contrast, Japan has only recently begun to emphasize C-C components manufacturing. Although several Japanese companies possess the facilities and basic understanding to produce C-C components, the lack of applications and design experience has put Japan at a disadvantage.

C-C manufacturing innovation in Japan is driven in part by a concern with production costs and associated efforts to identify commercial nonaerospace applications for C-C composites. Japanese efforts to develop new low-cost fabrication methods have no parallel in the U.S. Clearly, even if new and significant industrial uses are not realized, the Japanese aerospace industry would very likely benefit from such improvements in C-C manufacturing methods.