Japanese Fine Ceramics Effort - Archived 3/2005

Orientation

Description. The overall scope of this effort involves basic and advanced research in ceramics as well as ceramics technology, and the fabrication and machining of ceramic components. The program has drawn in many diverse firms, and has generated technology usable (and used) in many industry sectors, including utility/industrial power generation machines, automotive engines, and other heat engines.

The material in this report will not focus on the major Japanese activities in the Ceramic Gas Turbine (CGT) Engine Program for machines of 100-300 kW (please refer to Forecast International's separate report "Automotive/Vehicular/Rail Design, Preproduction and Inactive Programs").

Note: *This report does not cover engines/machines that are in series production.*

Sponsor. The overall sponsor is the Government of Japan, Ministry of Economy, Trade and Industry (METI, formerly MITI); Tokyo, Japan. Numerous Japanese government industrial research institutes, national laboratories, and universities have participated in the effort. Many research projects are jointly managed by industry and/or national laboratories and universities.

Work is currently conducted under the auspices of the Japanese Fine Ceramics Center (JFCC); Nagoya, Japan.

Status. Work on "Fine Ceramics" has taken place in Japan since 1983 in a number of programs and efforts. Work is continuing under the auspices of the JFCC.

Total Produced. Owing to the R&D nature of this effort, complete engines are *not* expected to be fabricated. However, ceramic and ceramic-based components for vehicular and industrial power generation gas turbine engines of a wide range of power outputs are fabricated and tested.

Application. This effort is aimed at technology and components for all fixed and rotating components of all forms of combustion engines. Considerable emphasis has been placed on automobile engines.

Price Range. Owing to the R&D nature of this effort, a price range is inapplicable.

Competition. The work being done in Japan under the auspices of the JFCC is not construed as being in competition with similar work being done in other countries, most notably France, Germany, the Russian Federation, Sweden, the U.K., and the USA. Rather, it is seen as an overall technology-generating effort that will be shared with others when applicable. The overall JFCC effort includes projects and input from the international community.

Contractors. Because of the broad scope of this ongoing effort, no single contractor can be singled out as having been the prime contractor or manufacturer, or as the current prime contractor or manufacturer.

Technical Data

Owing to the R&D nature of the Japanese Fine Ceramics work, the technology developed is applied to various engines/machines and their components. As such, the type of research and technical data generated depends on the firms involved and the respective areas of activity. Work done under the auspices of JFCC is *not* structured to result in the production of gas turbine engines or other combustion engines.

Variants/Upgrades

Work under the Japanese Fine Ceramics Program is being applied to several heat-engine programs and to other ceramics-related programs in various forms.

See **Program Review** section below for some of the more significant efforts and firms involved.

Program Review

Background. The government of Japan, through the Ministry of Economy, Trade and Industry (METI, formerly the Ministry of International Trade and Industry [MITI]), began the comprehensive study of advanced ceramic materials in 1977, and the Japanese Fine Ceramics Program was subsequently launched in 1983 as part of a totally new Industrial Technology Program (ITP). The program began as a 10-year effort with three distinct phases: a three-year effort with emphasis on materials development, identification, and evaluation; a second three-year effort with goals including the production and testing of simple ceramic material engine parts; and a four-year segment with emphasis on the design, production, and evaluation of complex shapes and components and their use in rotating combustion engines.

Japanese Fine Ceramic Center. The Japanese Fine Ceramic Center is engaged in an extensive range of research and development activities involving basic research as well as technological applications. The JFCC strives both to improve the quality of fine ceramic products by providing the technological infrastructure – the core of which is the development of a standardization test and evaluation system – and to promote the use of fine ceramics in industry and the community.

Ceramics and ceramics-related work done under the auspices of the JFCC includes:

Research and Development
1. Computational Design
2. Energy-Related Materials
3. High-Performance Functional Materials
4. Microstructure Analysis
5. Structural Property Evaluation
6. Processing and Chemical Analysis
7. Gas Separation Membranes

Construction of Techno-Infrastructure
1. Development of High-Temperature Material Evaluation Techniques
2. Creation of a Ceramics Database
3. Development of Material Design Techniques
4. Development of Reference Materials and the Open Materials System (OMS)

Projects for Small and Medium Enterprises
1. Technical Consultation
2. Fostering of Researchers and Engineers
3. Seminars/Lectures and Workshops

Public Relations and Promotional Activities
1. Fine Ceramics Fair
2. Fine Ceramics Workshop
3. Publications

International Cooperation
1. Personnel Exchange

Major Participants. In addition to the JFCC, the following are participants in the overall Japanese Fine Ceramics effort:

Government/National Labs; Organizations
The Ceramic Society of Japan
Japanese Institute of Metals
Japanese Ultra-High Temperature Materials Research Institute
The Japan Society of Applied Physics
Ministry of Economy, Trade and Industry (METI)
National Industrial Research Institute of Nagoya
National Institute for Materials Science
National Institute for Research in Inorganic Materials
National Institute of Advanced Industrial Science and Technology
Osaka National Research Institute
The Society of Materials Science of Japan
Synergy Ceramics Laboratory
Takasago R&D Center (of Mitsubishi Heavy Industries Limited)
Technology Research Institute of Osaka Prefecture
Toyota Central R&D Labs Incorporated

Colleges/Universities
Chiba University
Hachinohe Institute of Technology
Himeji Institute of Technology
Kagoshima Prefectural Institute of Industrial Technology
Kanazawa University
Kyoto Institute of Technology
Kyoto University
Kyushu University
Nagaoka University
Nagoya Institute of Technology
Okayama University
Sasebo National College of Technology
Shonan Institute of Technology
Takushoku University
Tohoku University
Tokai University
Tokyo Institute of Technology
Tokyo, University of
Tsukuba, University of
Yamaguchi University

Major Companies
Ebara Corporation
Furukawa Electric Company Limited
Hitachi Limited
Kawasaki Heavy Industries Limited

Kitawaga Industries Company Limited
Koyo Seiko Company Limited
Kyocera Corporation
Mitsubishi Motors Corporation
NGK Spark Plug Company Limited
Nippon Oil Company Limited
Nissan Motor Company Limited
NSK Limited
Sumitomo Corporation
Toshiba Corporation
Toyota Motor Corporation
Ube Industries Limited

Program Discussion. The JFCC's aim is to contribute to the economic growth and prosperity of Japan through the promotion of ceramics and related industries. It remains somewhat independent of the Agency of Industrial Science and Technology (AIST) effort devoted more specifically to ceramic components for automobile engines of about 100 kW in power output, and its parallel effort for engines of about 300 kW.

The JFCC has become renowned for its outstanding evaluation techniques in the field of fine ceramics. With well-organized, modern, high-performance equipment, it is able to take full advantage of the potential of fine ceramics. Its wide-ranging but integrated activities in basic and applied research support its expertise in manufacturing technology – from raw materials to final products.

Recent work on ceramics, including thermal properties of ceramics, has included:

- Molecular Dynamics Simulations of Grain Boundaries and Surfaces in Yttria-Stabilized Zirconia (YSZ)
- A Study of Interference of Electron Waves and Its Application to Visualize Electromagnetic Micro-fields
- Crystallographic Orientation Analysis Around Stable Cracks in MgO
- Study of the Effect of Processing Atmospheres on Creep Behavior of Dense Al_2O_3 Ceramics
- Interface Characterization of Phase Transformation in Si_3N_4 by Transmission Electron Microscopy
- Research into the Field of Sintering Mechanisms, Microstructure Control Processing, and Mechanical Properties for Nonoxide Structural Ceramic Materials such as Sialon, Si_3N_4 and SiC.
- An Integrated Approach to III-Nitride Crystal Growth and Wafering.

JFCC, Nagoya Agreement. In April 2004, the JFCC and the Nagoya Institute of Technology measurement analysis center agreed to cooperate on collaborative research into the next generation of advanced materials, for their mutual use and for the benefit of ceramics and materials researchers.

A prime research activity designated by both entities to be important is that of nanotechnology.

Funding

The Japanese Fine Ceramics R&D effort has received private funding and funding from the Japanese government. The program continues to have close ties with academic, industrial, and governmental entities not only in Japan but in the U.S. and other countries. The strategic commitment on the part of Japan's industries and government has been unwavering, and in some areas research has been accelerated. Commendably, industry has emphasized long-range potential payoffs over short-range benefits.

Recent Contracts

No major contracts specifically pertaining to the Japanese Fine Ceramics R&D effort have been identified.

Timetable

The Japanese Fine Ceramics Program was officially launched in 1983. It was initially structured as a 7-10-year effort, depending on the individual projects. However, many programs were rolled over into more advanced R&D efforts (e.g., New Sunshine Program). Some of the projects introduced under the seven-year Research & Development of Automotive Ceramic Gas Turbine Engine (CGT) Program, started in 1990, were melded into new programs.

The New Sunshine Program, as the combined effort between the (then) Ministry of International Trade and Industry (MITI) and Kawasaki Heavy Industries has been called, was completed by the end of Fiscal Year 1998. The

program was then extended through March 2000. In June 1999, Kawasaki introduced a 300-kW ceramic gas turbine, the CGT-302, at the annual ASME exhibition and congress in Indianapolis, Indiana (USA). The company has worked on developing a derivative model, the CGT303.

Some of the high-temperature R&D work on refractory ceramics able to be used at 1,500°C (2,732°F) and above will continue to be done under the project "High Temperature Materials 21," promoted since Fiscal (Japanese) 1999.

As for the JFCC itself, major program developments include the following:

Month	Year	Development
May	1985	MITI establishes the JFCC
Jun	1985	Approval received for test and research foundation
Apr	1987	JFCC begins construction of its facilities
Mid-Late	1988	JFCC facilities operational
JFY	1999	High Temperature Materials 21 program begun
	2000	Major ceramics conference held, attended by Russian Federation and China
Mar	2000	New Sunshine Program extended
Apr	2004	JFCC and Nagoya Institute of Technology agree to cooperate
Thru	2013	Ongoing ceramics work sponsored by JFCC projected to continue

Worldwide Distribution

Owing to the R&D nature of this program, *no* complete gas turbine engines or machines have been fabricated as part of the overall ceramics effort in Japan. Considerable technology has, however, been funneled into the gas turbine engine component programs of several Japanese engine manufacturers for automotive, aviation, turbocharger, marine, and utility/industrial power generation applications.

Forecast Rationale

Ceramics technology is moving closer to commercial applications of ultra-fine ceramic materials. The role of the JFCC, along with the other Japanese entities affiliated with the effort, has been to research, develop, and test for commercial use ceramic materials and components, and to explore their applications for various industries. While other countries have similar technological goals, Japan is considered the leader in the field of ceramics research.

It is premature to project where Japanese ceramics technology will primarily be used. We nonetheless look forward to much more use of ceramics in gas turbine and diesel engines and in turbochargers and ceramic ball bearings for all industries. They will also be widely used in the manufacture of cutting tools, and turbine seals and ring seals. Ceramic components offer superior hardness and resistance to heat – and they can replace elements (used in alloys) that are high in cost, often scarce, difficult to machine, and extensively located in politically unstable regions.

It takes a dedicated policy to have a laudable, nationally recognized and sponsored ceramics development program. Owing to the often-conflicting aims of the U.S. government and U.S. industry and academia, the U.S. does not have such a national program. In the U.S., ceramics work is done individually by a few major colleges and universities – among them North Carolina State University, Cornell, Alfred, Clemson, and the State University of New York at Stony Brook – and by some commercial concerns, often with little interface among the entities.

A viable candidate in the worldwide call for more fuel-efficient and less-polluting vehicles is a ceramic gas turbine engine, or one that is heavily ceramic-based, either as a fully dedicated propulsion/drive engine or in a hybrid combination with an efficient battery/electrical system. If a gas turbine/battery hybrid system enters production, we expect that the most efficient engines will utilize technology such as that pioneered by the JFCC. It is not inconceivable that such small gas turbines could find application in small distributed generation schemes.

It should be noted here that future ceramics-technology progress will not be made by leaps and bounds. Rather, progress will be slow, and in small steps. The new wave of ceramic materials that will be experimented with will likely contain even more exotic elements.

Ten-Year Outlook

At this time, it is too early to envision what the Japanese Fine Ceramics overall effort will entail in 2005 and beyond. We expect to see more attention being paid to fuel cells, especially solid oxide fuel cells, and to the concept of distributed generation.

The JFCC will continue to focus on such topics and products as advanced ceramics (to include ultra-high-temperature ceramics), advanced composites, High-Tc superconductors and perovskite materials and smart structures, and III-V nitrides and devices. A primary focus will be on novel materials processing, nanoscale characterization, structure-property correlations, device fabrication, and training of graduate and undergraduate students.

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