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HPGT

Melt Growth Composites for Ultra High Efficiency Gas Turbine Components

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Background & Motivation

❑ Single Crystal Eutectic Composites

ex. $Al_2O_3/Y_3Al_5O_{12}$(YAG), $Al_2O_3/GdAlO_3$(GAP), $Al_2O_3/Er_3Al_5O_{12}$(EAG)

❑ Advantages

- Three-dimensional network structure
- High strength up to melting point temperature
- High creep and oxidation resistances
- Good machinability and productivity to fabricate complex shape components

❑ Disadvantages

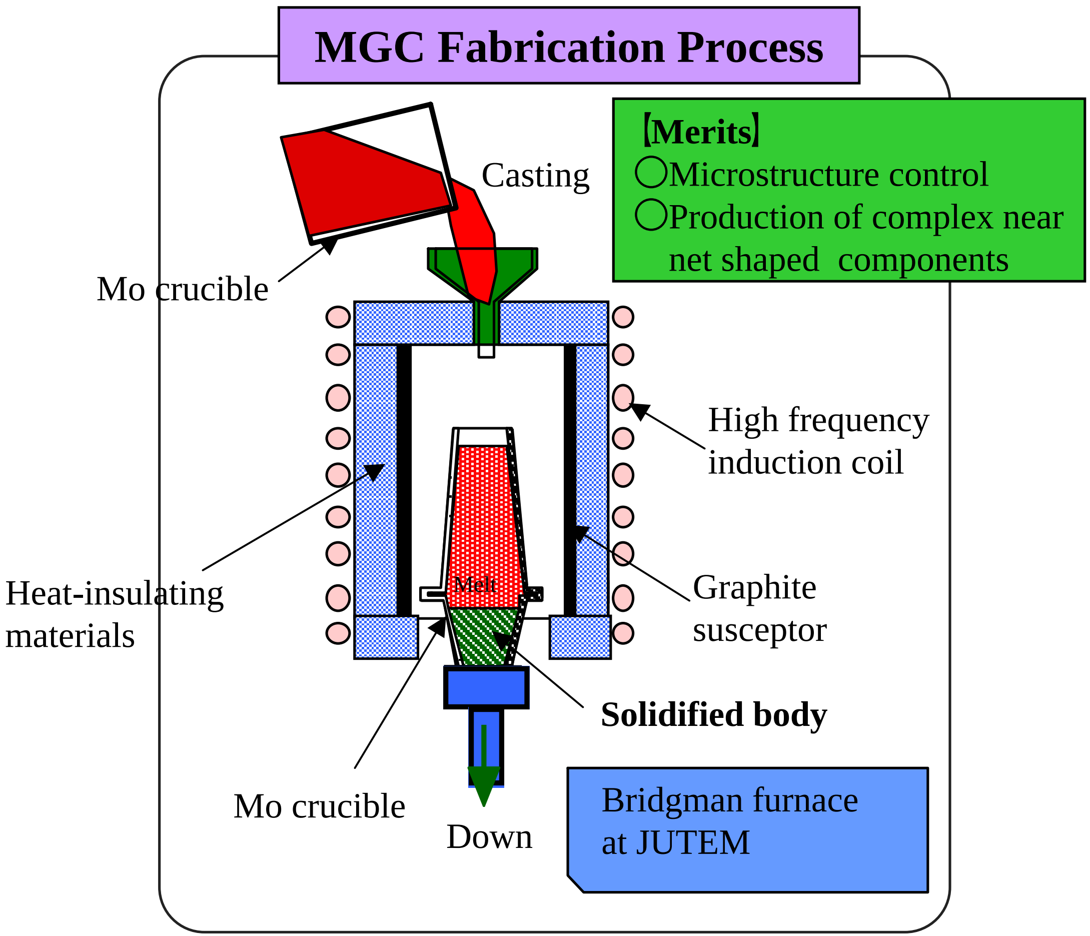
- Low fracture toughness and low thermal shock resistance

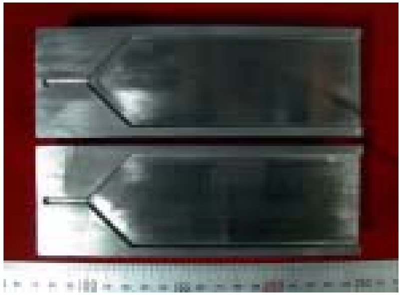
New eutectic composites ↓ ***Improving design methodology***

Ultra-high temperature structural components for gas turbine

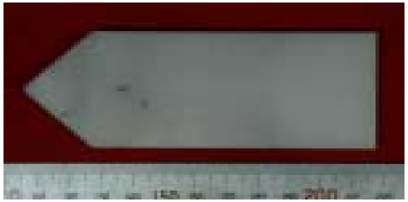
Combustor liner, Turbine nozzle & Blade

MGC Fabrication Process





Molybdenum divided mold

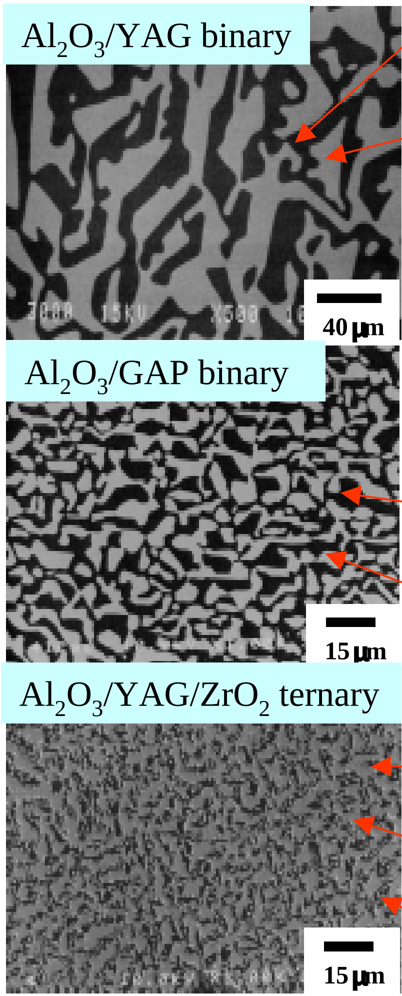


Al_2O_3/YAG plate

Al_2O_3/GAP ϕ53 mm rod

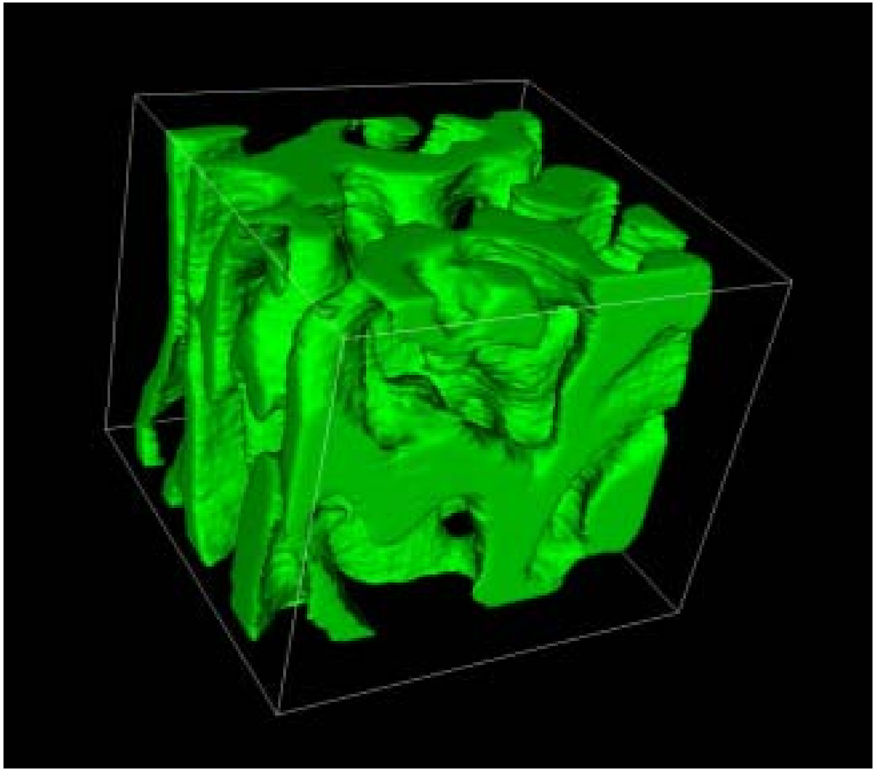
Microstructure and Three- Dimensional Network of MGCs

Microstructure of MGCs



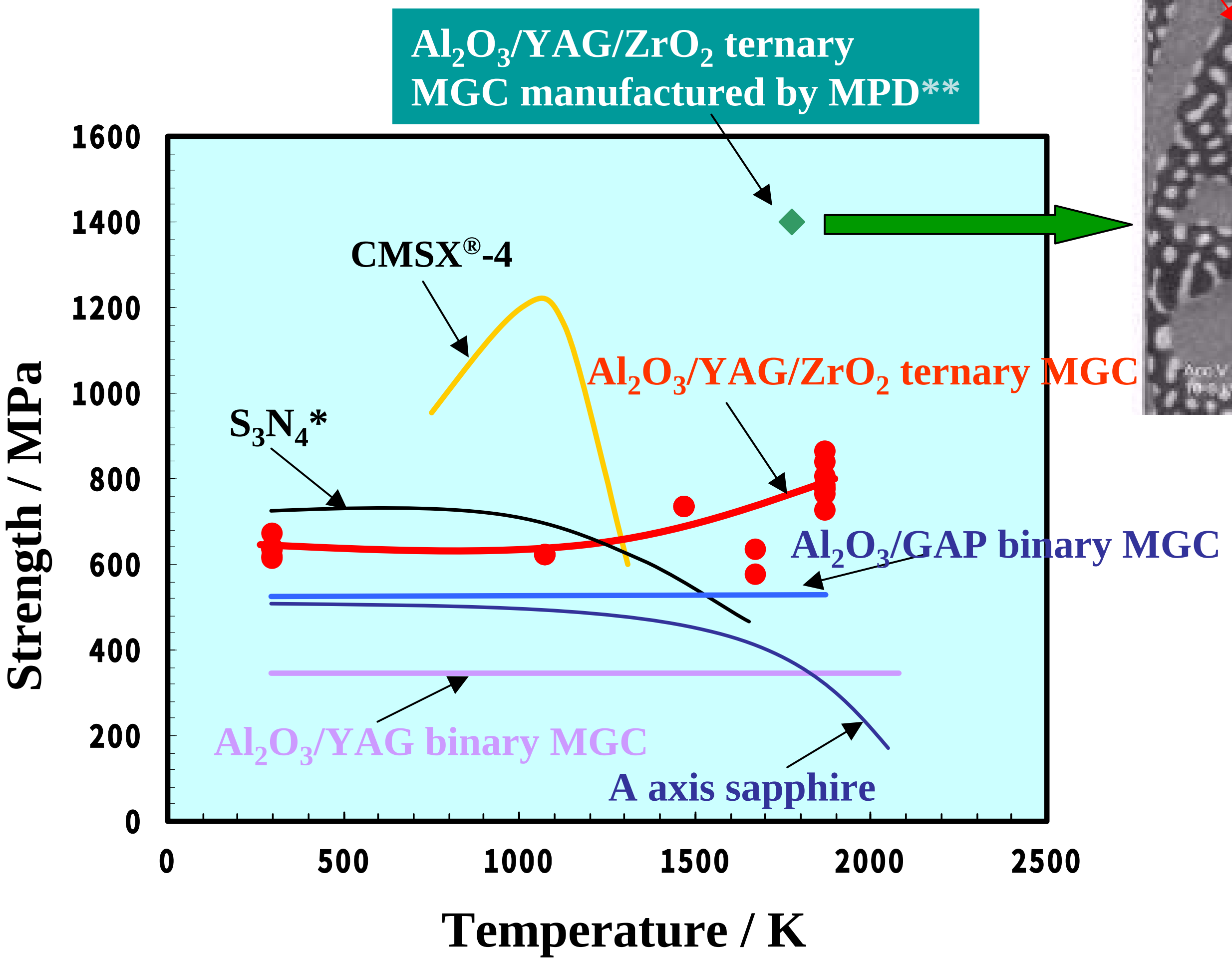
Al_2O_3 removal

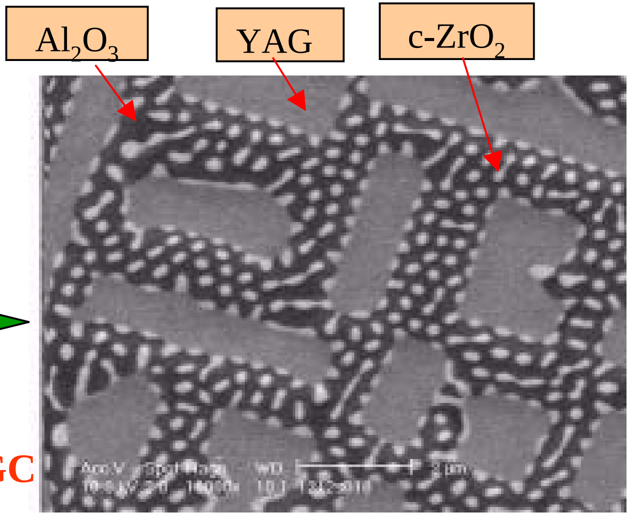
Three-dimensional connected porous structure of irregular shape



A 3D image showing the network structure of the Al_2O_3/YAG system MGC obtained from X-ray computerized tomography (micro X-ray CT).

Temperature Dependence of Strength





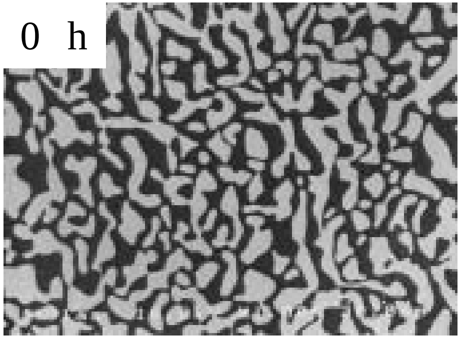
CMSX®-4:
Tensile strength
Al$_2$O$_3$/YAG/ZrO$_2$(MPD):
Compressive strength
Others:
Flexural strength

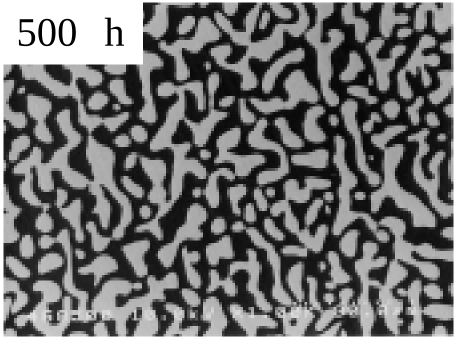
* Yoshida et al (1998)

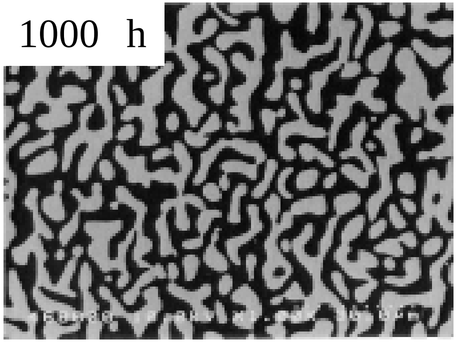
** Professor T. Fukuda of Tohoku University

Thermal Stability of the microstructures

- The grain growth was slightly observed after 1000 hours. However, the present MGC were shown to be comparatively stable without void formation during lengthy exposure at 1973 K in an air.
- The MGC components have excellent oxidation resistance with no change in dimensions ,weight and surface roughness after 1000 hour at 1973 K in an air.







SEM images of the microstructures of cross-section perpendicular to the solidification direction of the Al_2O_3/GAP binary MGCs after 1000 hours of heat treatment at 1973 K in an air.

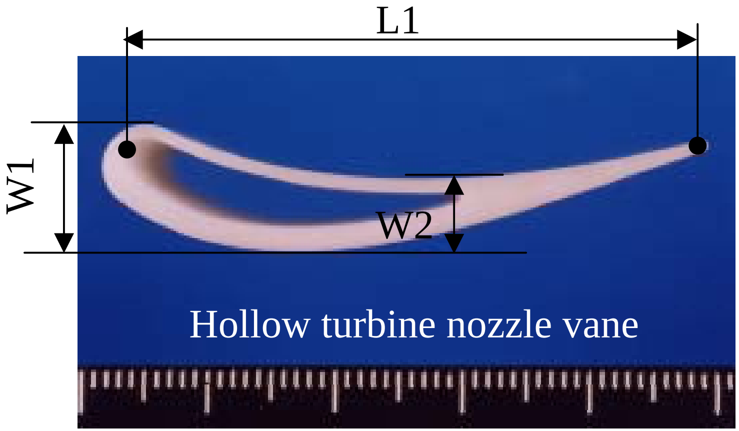


Table.1 Difference of the MGC nozzle vane after exposure test for 1000 hours at 1973 K in an air atmosphere.

Length	0 h	500 h	1000 h	Dimensional change
L1 (mm)	43.971	43.977	44.000	0.029
W1 (mm)	10.614	10.614	10.598	−0.022
W2 (mm)	5.389	5.385	5.371	−0.019
Weight (g)	26.194	26.232	26.227	−0.019
Roughness (Ra/μm)	0.46	0.78	0.75	0.29

Organization of NEDO Project

Project term
FY2001-2005

Total budget (5 years)
3,000 million yen

Ministry of Economy, Trade and Industry (METI)

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New Energy and Industrial Technology Development Organization (NEDO)

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Engineering Research Association for High Performance Gas Turbine (HPGT)

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- **Ube Industries, LTD.**
- **Ishikawajima-Harima Heavy Industries, LTD.**
- **Kawasaki Heavy Industries, LTD.**

National Project in Japan

A NEDO project on MGC application technology to ultra high efficiency gas turbine system (FY2001-05)

Materials & Process Technology: UBE

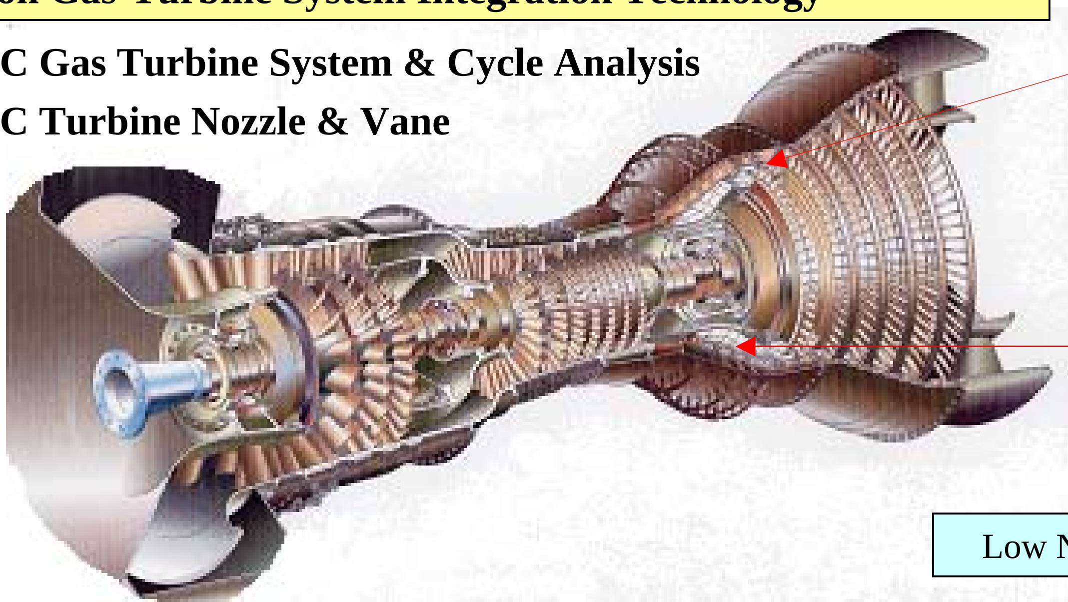
R&D on Innovative Process & Manufacturing Technology

- **Near-Net Shape Casting of Complex Shape Components**
- **Improvements of Materials Reliability & Long-term Durability under Severe Environments (highly water vapor pressurized at ultra-high temperatures)**

System Integration Technology: IHI & KHI

R&D on Gas-Turbine System Integration Technology

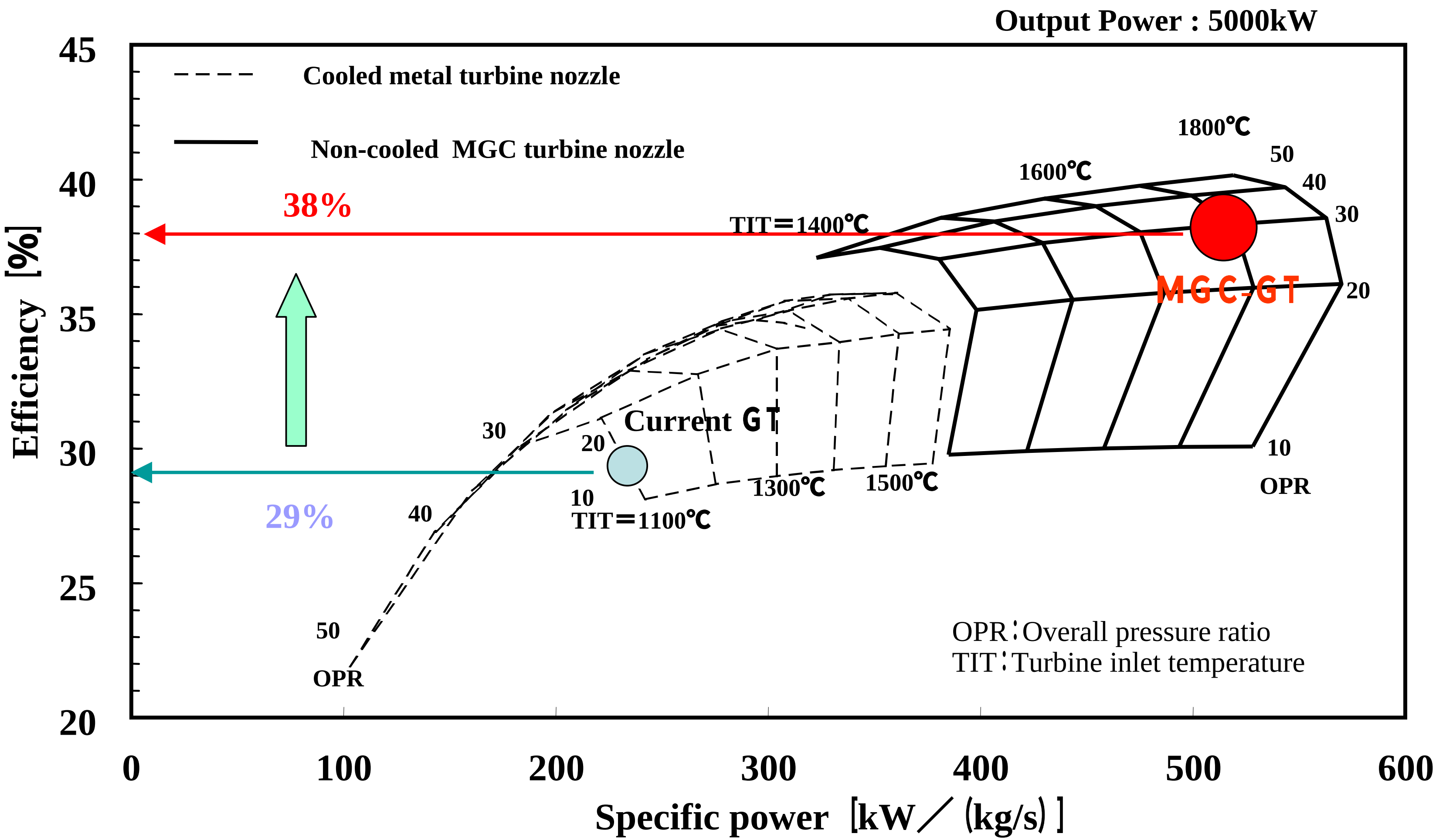
- **MGC Gas Turbine System & Cycle Analysis**
- **MGC Turbine Nozzle & Vane**



MGC Bowed Stacking Nozzle

Low NOx Combustor with MGC panels

Cycle Analysis - Efficiency Improvements -

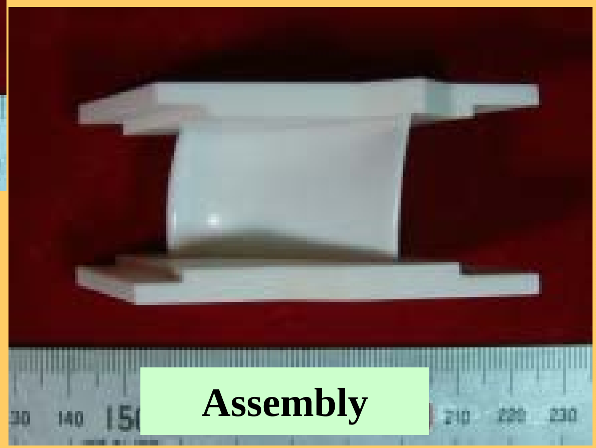


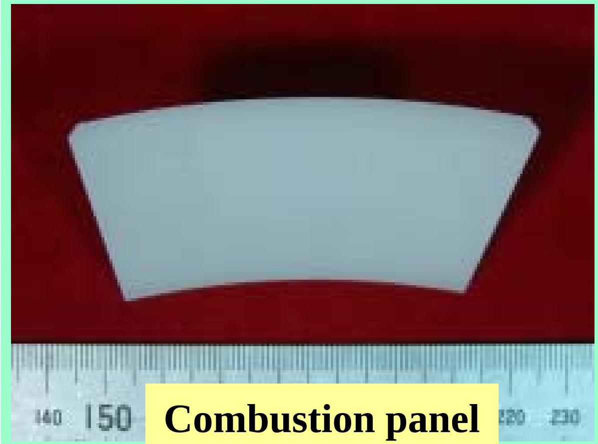
Performance estimation of MGC gas turbine

MGC Components of High Efficiency Gas Turbine

Nozzle

Liner





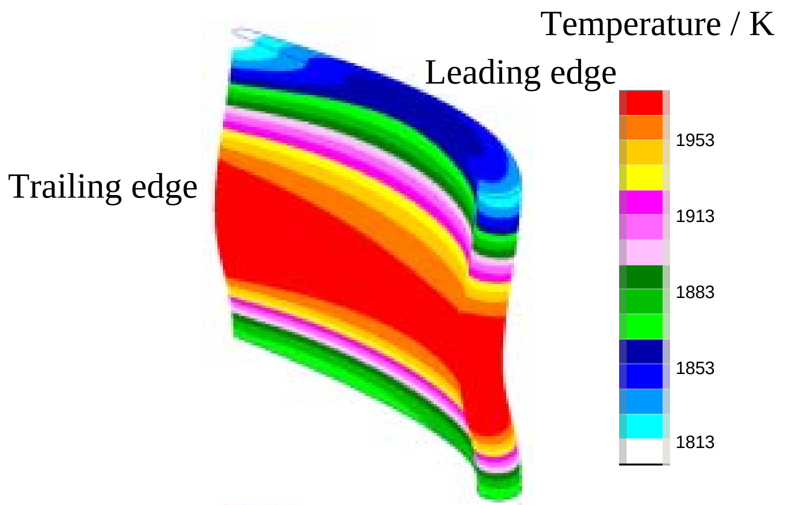
*The bowed stacking nozzle, the outer band and the inner band were manufactured from the Al_2O_3/GAP binary MGC that has high temperature strength superior to that of Al2O3/YAG binary MGC.

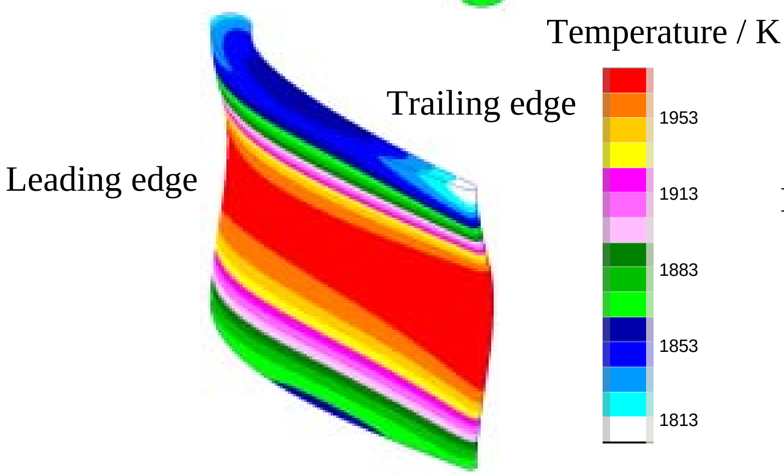
*The combustion panel was manufactured from the Al_2O_3/YAG binary MGC that is relatively easy to fabricate a larger component.

*All components were manufactured from MGC ingots by machining with a diamond wheel.

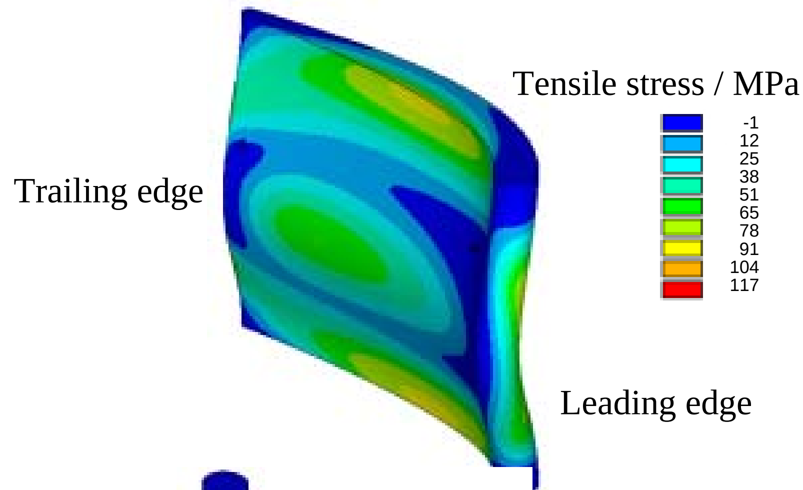
Steady State Temperature and Thermal Stress Distribution at TIT of 1973 K

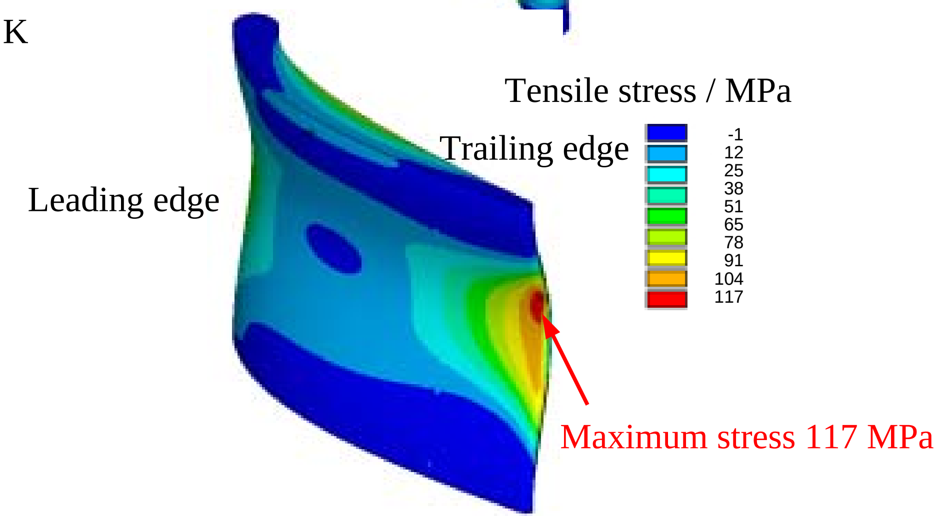
Temperature distribution





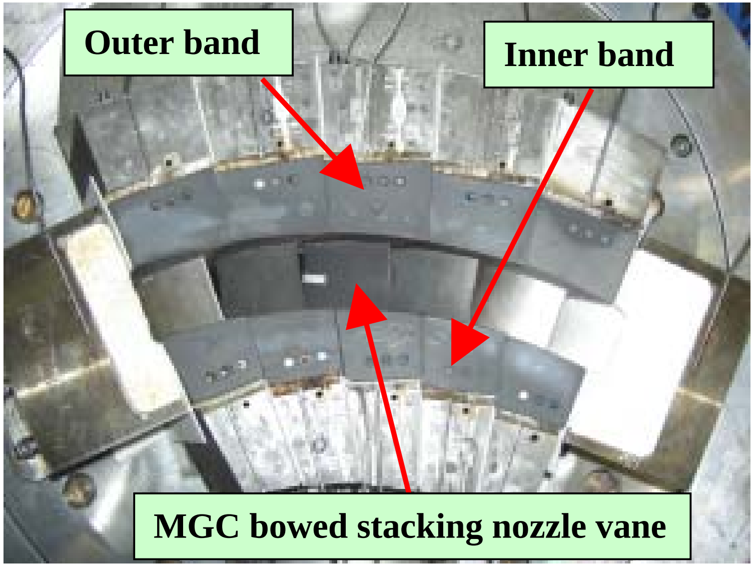
Thermal stress distribution

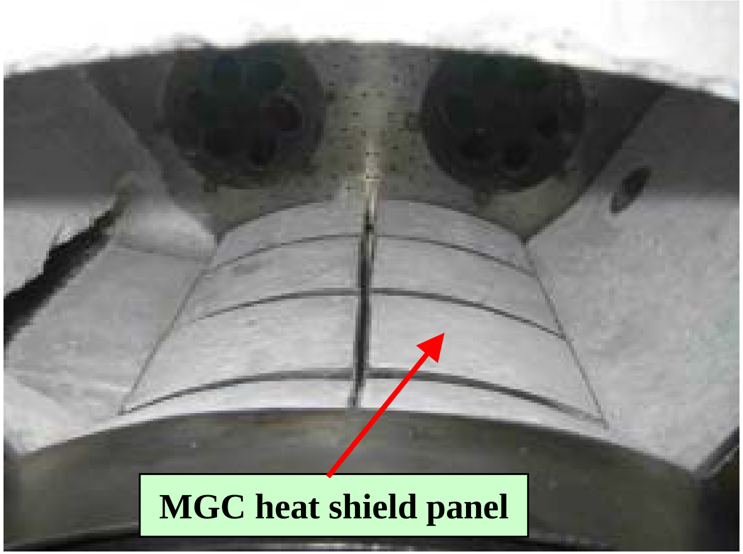




High Temperature Test Rig at 1973 K

The structural integrity of MGC turbine nozzles and heat shield panels was verified under the steady-state and trip conditions at 1773K.





- The high temperature test rig (maximum temperature ~1973 K) have been improved to measure continuous temperature distribution on the nozzle surface by using an infrared camera.
- We are now planning the test rig at an inlet gas temperature level of 1973 K in order to ensure the structural integrity of the MGC bowed stacking nozzle and heat shield panel under the steady-state and thermal cycle conditions.

Concluding Remarks

- **MGCs have the unique microstructure consisting of three-dimensionally continuous and complexly entangled single-crystal Al_2O_3 and single-crystal compounds.**
- **MGCs (melt growth composites) have many advantages over other ultra-high temperature structural materials.**
- **The NEDO project on MGCs Gas Turbine System was briefly introduced.**
- **The structural integrity of MGC turbine nozzles and heat shield panels was verified under the steady-state and trip conditions at 1773K.**