FOURTH GENERATION NICKEL BASE SINGLE CRYSTAL SUPERALLOY

TMS-138 / 138A

(Developed by the collaboration of NIMS[1] and IHI[2])

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TMS-138 / 138A

These are the 4th generation nickel-base single crystal superalloys containg ruthenium additions. Both TMS-138 and TMS-138A possess excellent high temperature creep strengths, microstructural stability and hot corrosion resistance.

Chemical composition, wt%

Alloys	Co	Cr	Mo	W	Al	Ta	Hf	Re	Ru
TMS-138	5.8	3.2	2.8	5.9	5.9	5.6	0.1	5.0	2.0
TMS-138A	5.8	3.2	2.8	5.6	5.7	5.6	0.1	5.8	3.6

Heat Treatment Condition (Typical)

Solution; 1300℃/1h+1340℃/5h→R.T. *, Aging; 1100℃/4h→R.T. +870℃/20h→R.T.*

*Gas Fan Cooling (GFC)

	TMS-138 / TMS-138A
Solidus Temperature	: 1390℃ / 1390℃
Solvus Temperature	: 1300℃ / 1290℃
Heat Window for Solution Treatment	: 44℃ / 50℃

Physical Constants and Thermal Properties

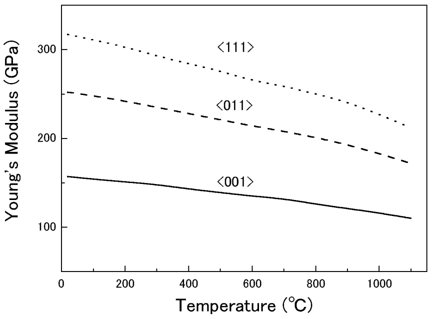
TMS-138 / TMS-138A

Density……………………………………………… at R.T..…………8.95 / 9.02 g/cc

Coefficient of Expansion………………………20 – 200℃………11.2 / 10.7 x10^{-6}

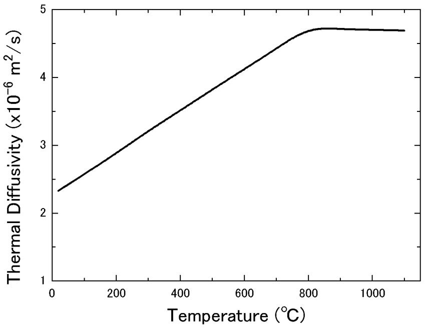
Young's Modulus (TMS-138)

Resonance method



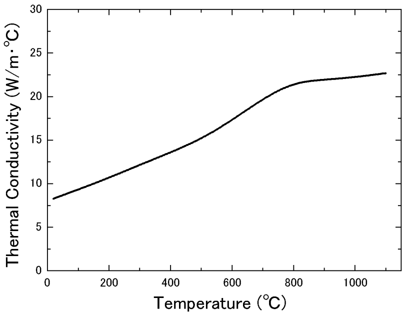
Thermal Diffusivity (TMS-138)

Laser-Flush Method



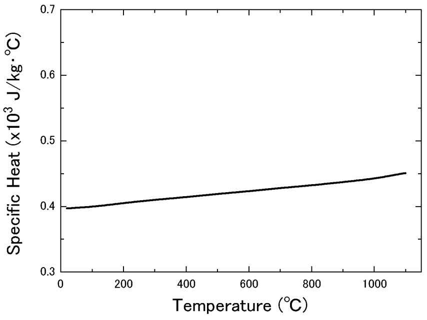
Thermal Conductivity (TMS-138)

Laser-Flush Method



Specific Heat (TMS-138)

Adiabatic calorimeter

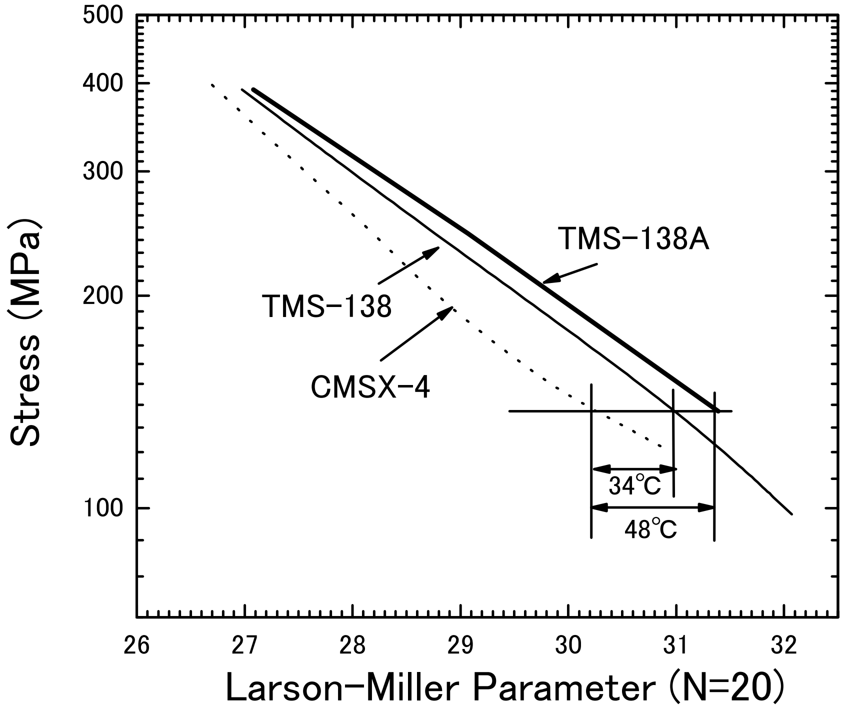


Typical Mechanical Properties

Creep Rupture Strength (TMS-138 / TMS-138A)

Conditions		Rupture life τ	Elongation	Reduction of Area
Temperature	Stress, MPa	h	%	%
900℃(1173K)	392.0	986.9 / 1223.8	20.8 / 31.8	31.2 / 35.5
1000℃(1273 K)	245.0	380.5 / 688.2	28.1 / 17.0	31.5 / 32.7
1100℃(1373 K)	137.2	412.3 / 722.4	7.6 / 8.7	32.1 / 35.7
1150℃(1423 K)	98.0	343.3 /-	9.9 /-	35.0 /-
1150℃(1423 K)	137.2	81.5 /-	12.6 /-	33.9 /-

Larson-Miller Plot (= T(20+log(τ))

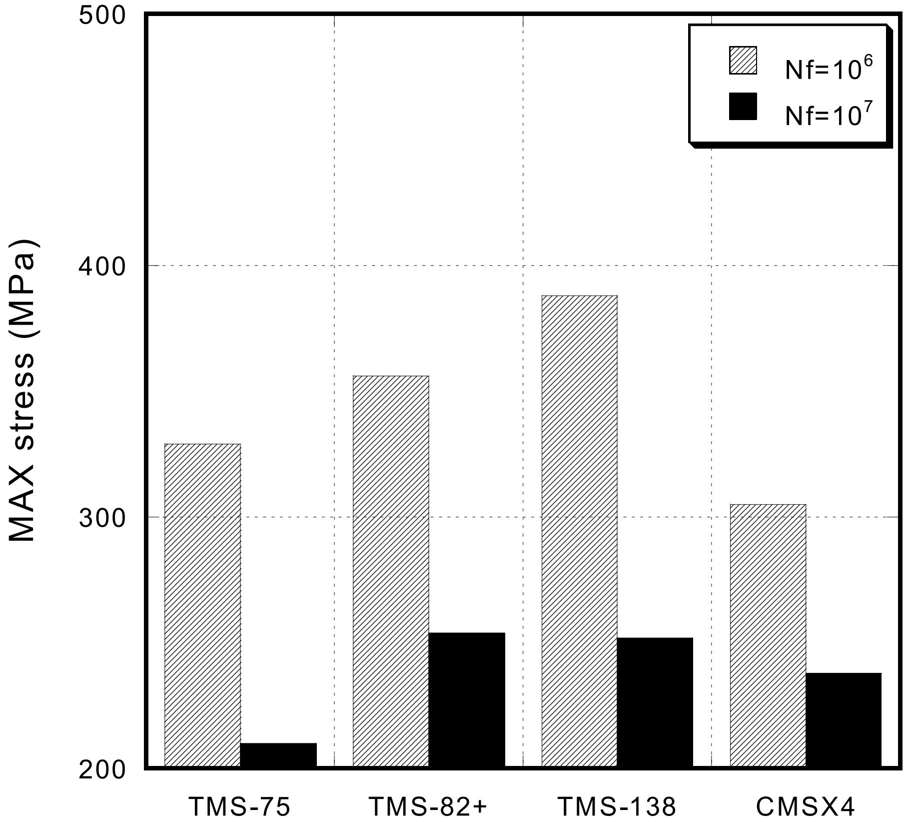


Tensile Strength (TMS-138)

Temperature ℃(K)	0.2% Proof Stress MPa	UTS MPa	Elongation %	Reduction of Area %
500 (773)	804	958	8.8	9.2
800 (1073)	869	1208	12.5	12.1

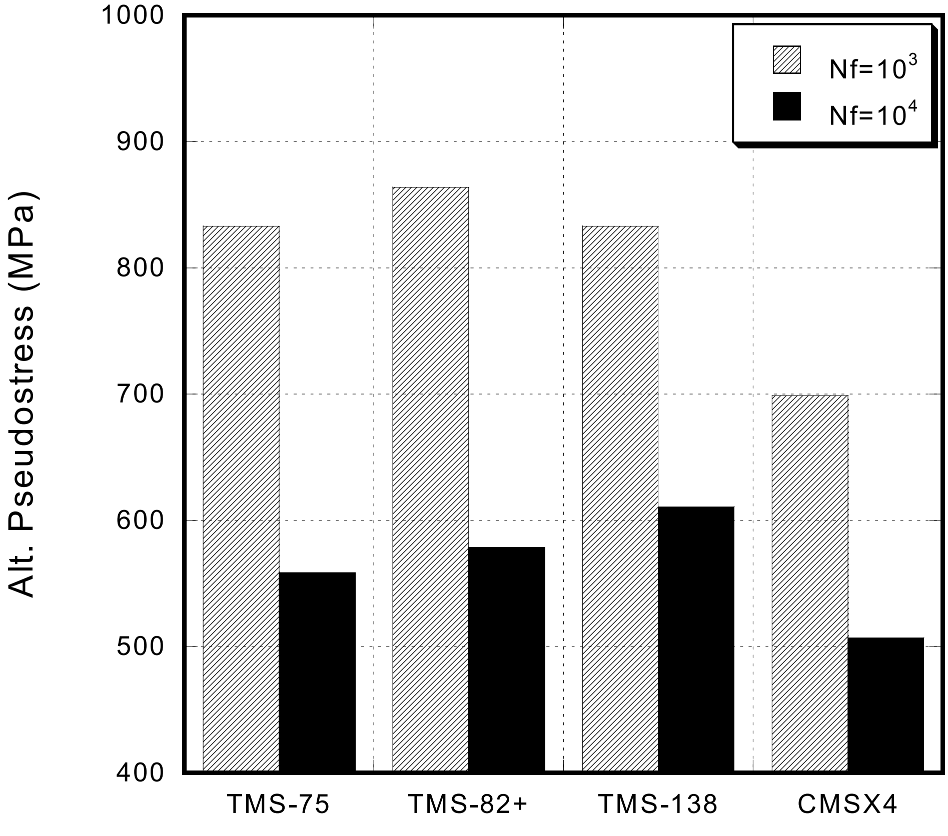
High Cycle Fatigue (TMS-138)

HCF failure stress ratio of TMS alloys and CMSX-4 at 1373K; R ratio: 1.0



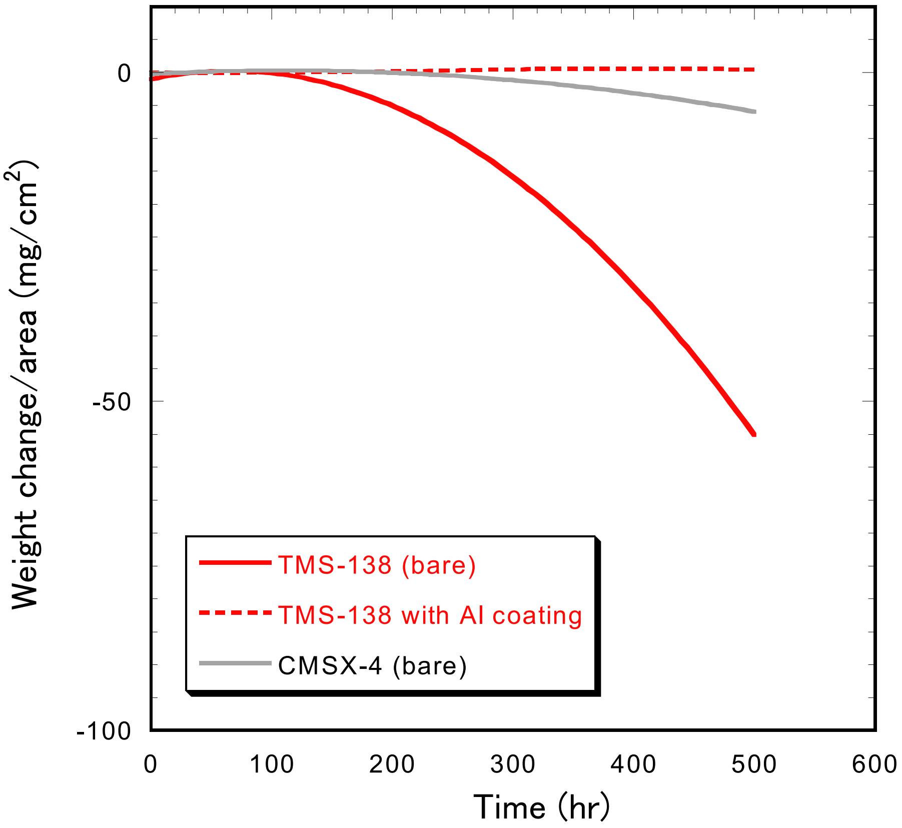
Low Cycle Fatigue (Strain: Constant)

LCF failure stress ratio of TMS alloys and CMSX-4 at 1073K; R ratio: 1.0.



Oxidation Properties (TMS-138)

Static oxidation tests of both bare alloys and Al coated TMS-138 alloy at 1373K in air.



Related Articles

Alloy Development

1) Y.Koizumi, J,X.Zhang, T.Kobayashi, T.Yokokawa, H.Harada, Y.Aoki and M.Arai; Journal of the Japan Institute of Metals, **67**, 9, 468-471 (2003) (in Japanese).
2) H.Harada; Materials Design Approaches and Experiences as held during the TMS Fall Meeting; Indianapolis, IN, USA, 29-39 (2001).
3) Y.Aoki, M.Arai, K.Chikugo, Y.Koizumi and H.Harada; Proceedings of the International Gas Turbine Congress; Tokyo, Japan, TS-118 (2003)

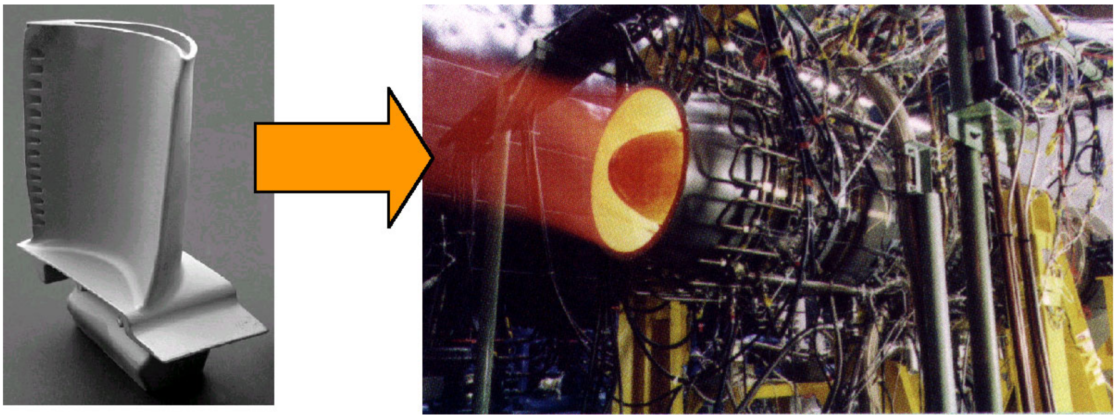
Microstractural Analysis

3) J.X.Zhang, Y.Koizumi, T.Kobayashi, T.Murakumo and H.Harada; Metallurgical and Materials Transactions A **35A**, 6, 1911-1914A (2004).
4) T.Yokokawa, M.Osawa, K.Nishida, T.Kobayashi, Y.Koizumi and H.Harada; Journal of the Japan Institute of Metals **68**, 2, 138 - 141 (2004) (in Japanese)
5) .J.X.Zhang, T.Murakumo, Y.Koizumi, and H.Harada; Journal of Materials Science, **38**, 24, 4883-4888 (2003).
6) J.X.Zhang, T.Murakumo, Y.Koizumi, T.Kobayashi and H.Harada; Acta Materialia, **51**, 17, 5073-5081 (2003).
7) T.Yokokawa, M.Osawa, K.Nishida, T.Kobayashi, Y.Koizumi and H.Harada; Scripta Materialia, **49**,1041-1046 (2003).
8) J.X.Zhang, T.Murakumo, Y.Koizumi, T.Kobayashi and H.Harada; Advanced Materials and Processes for Gas Turbines; Copper Mountain, CO, USA, 169-175 (2003).
9) J.X.Zhang, T.Murakumo, Y.Koizumi, T.Kobayashi, H.Harada and S.J.Masaki; Metallurgical and Materials Transactions A, **33A**, 12, 3741-3746A (2002).

Application Examples

At ESPR project*, endurance test of HTCE (High Temperature Core Engine constructed employing TMS-138 superalloy) was successfully conducted at 1650°C turbine inlet temperature that is the highest level in the world.

*ESPR project : Research and Development of Environmentally Compatible Propulsion System for Next-generation Supersonic Transport (organized by New Energy Development Organization in Japan).



Out view of test bench installed TMS-138 blades.

Turbine inlet gas temperature : 1650℃

High Temperature Materials 21 Project

On June 1, 1999, ex-NRIM (now NIMS) launched an R&D project, "High Temperature Materials 21 (HTM 21)" Project, (1999. 6--2010. 3). In this Project we develop high temperature materials for 1700℃ ultra-efficient gas turbines in power generations, small but efficient gas turbines for local power systems, next generation jet engines, high performance space rockets, and so on. These materials include Ni-base single crystal superalloys up to 5th generation alloys with new coating systems, as well as alloys with new concepts, e.g., platinum group metals (PGMs)-base refractory superalloys, Cr-base alloys, and so on. Materials design of empirical and theoretical approaches and microstructure analysis to support the alloy design and developments are also conducted with a major importance. We have world wide collaborations to enhance the high temperature materials researches mentioned above (Director; Hiroshi Harada).