NICKEL BASE
SINGLE CRYSTAL
SUPERALLOY

TMS-138

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

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TMS-138

A 4th generation nickel-base single crystal superalloy with superior high temperature creep strengths and the stability of γ/γ' two phases. An alloy TMS-138 with a multi chemical composition, having 5 wt.% Re, 2 wt% Ru, etc. The creep tests showed that the alloy has a good balance of creep strength over this temperature range; typical rupture lives at 900 deg C-392 MPa and 1100 deg C-137 MPa being 986.9 h and 412.3 h, respectively. Also, TMS-138 alloy has very good hot corrosion resistance as well.

Chemical composition, wt%

Element	Co	Cr	Mo	W	Al	Ta	Hf	Re	Ru
	5.8	3.2	2.8	5.9	5.9	5.6	0.1	5.0	2.0

Heat Treatment Condition (Typical)

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

*Gas Fan Cooling (GFC), ** Air Cooling (AC)

Solidus Temperature : 1390℃(2534°F)
Solvus Temperature : 1300℃(2372°F)
Heat Window for Solution Treatment : 44℃(111°F)

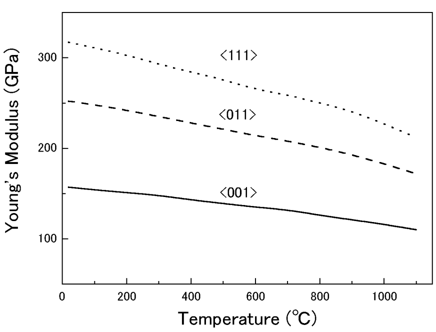
Physical Constants and Thermal Properties

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

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

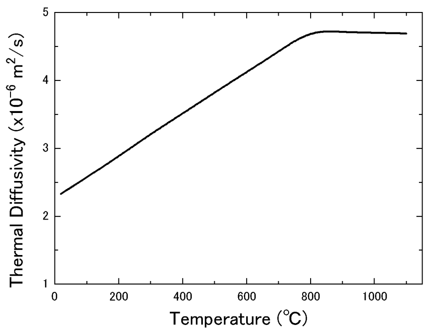
Young's Modulus

Rectangular parallelepiped resonance



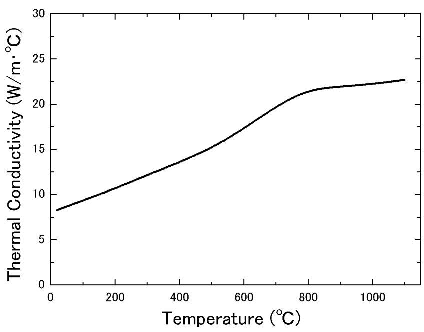
Thermal Diffusivity

Laser-Flush Method



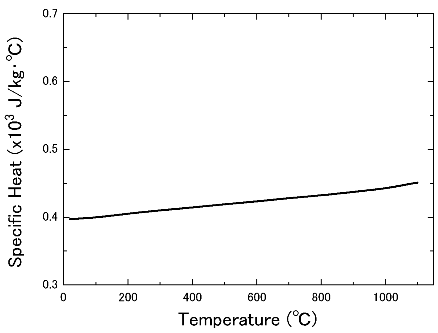
Thermal Conductivity

Laser-Flush Method



Specific Heat

Adiabatic calorimeter (Nernst method)

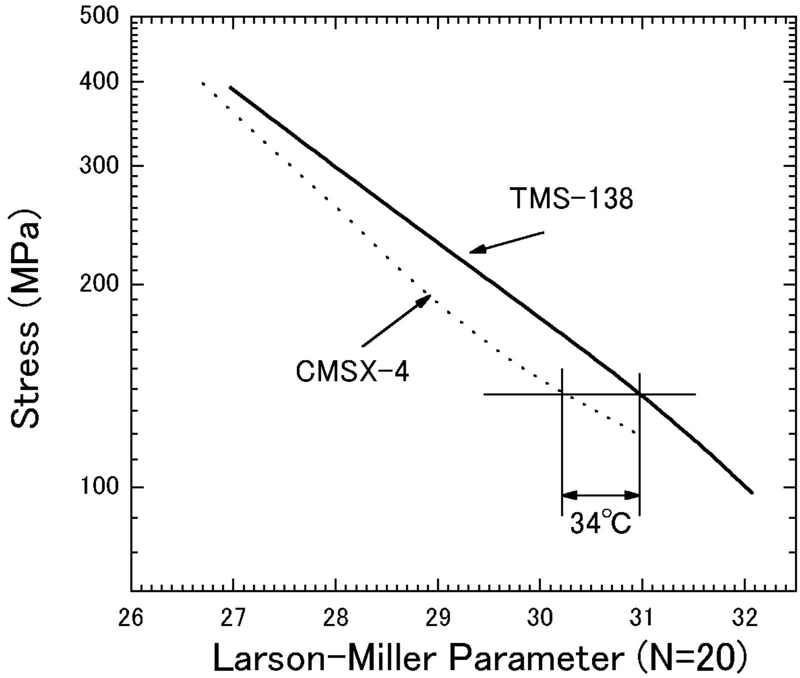


Typical Mechanical Properties

Creep Rupture Strength

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

Larson-Miller Plot (= T(20+log(τ))

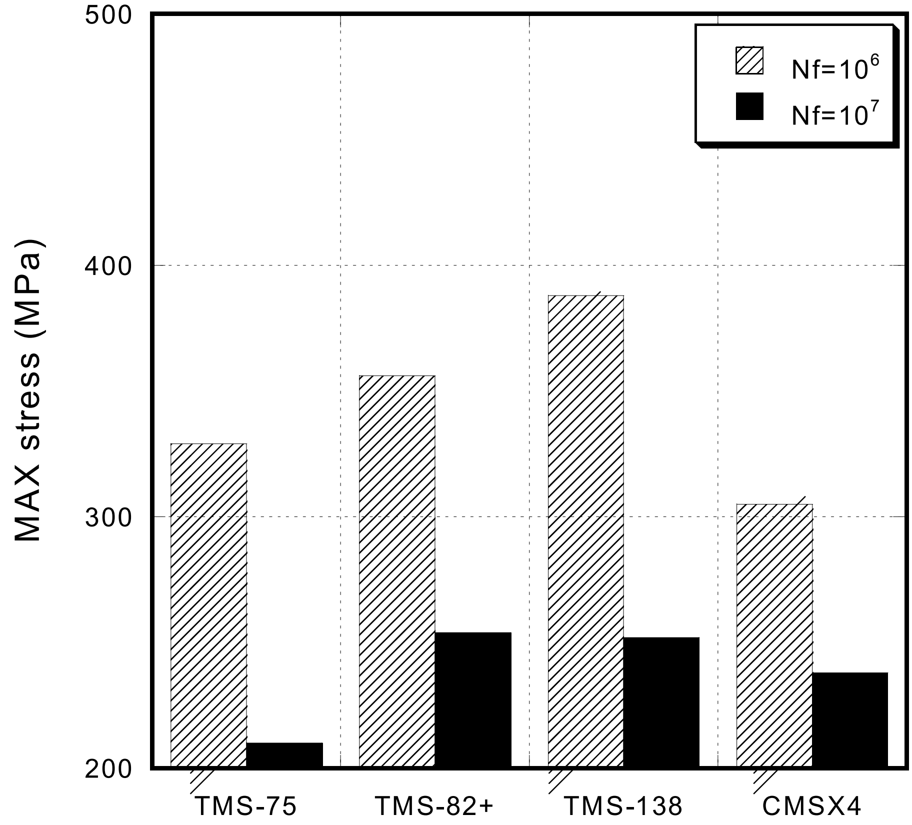


Tensile Strength

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

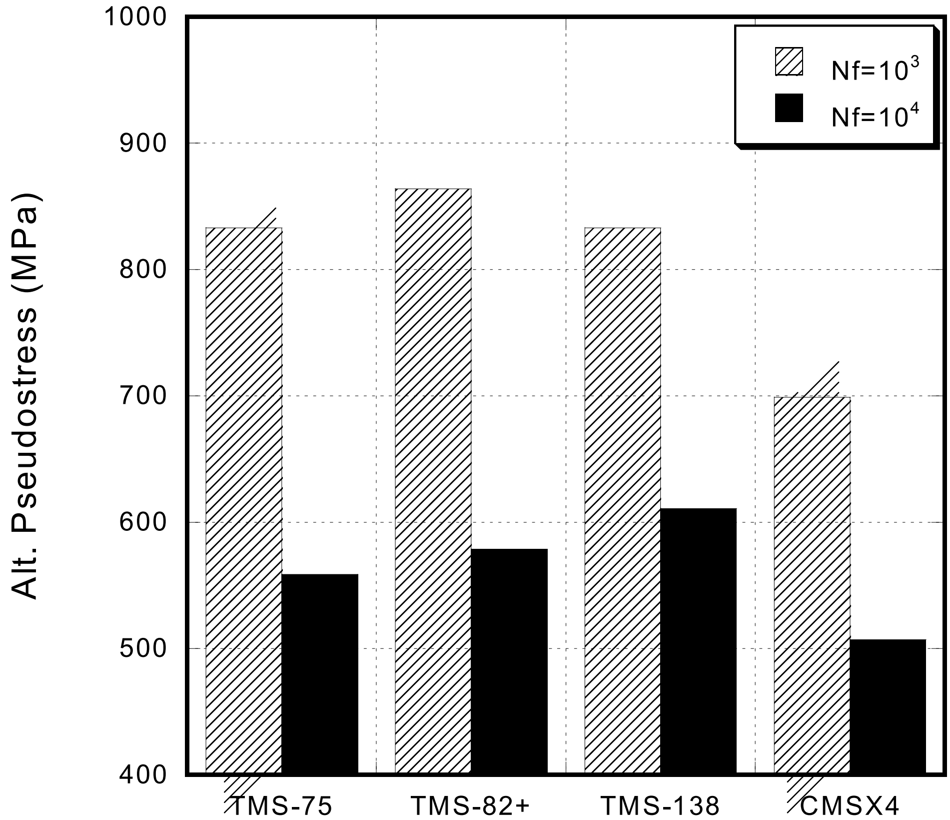
High Cycle Fatigue

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



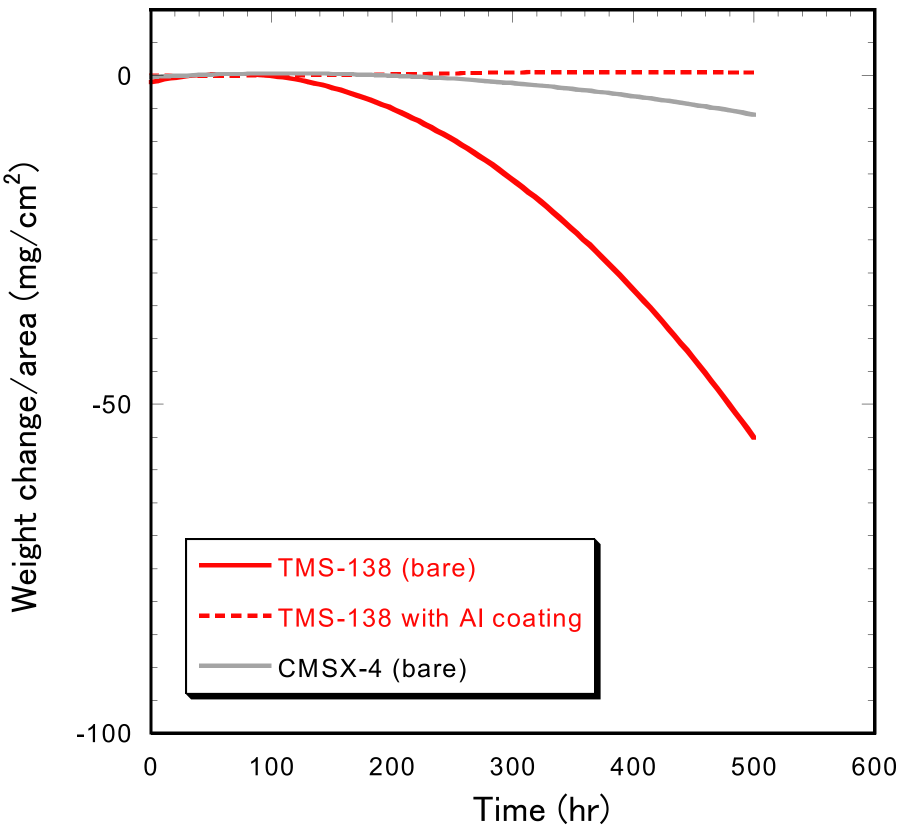
Low Cycle Fatigue (Strain : Constant)

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



Oxidation Properties

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).

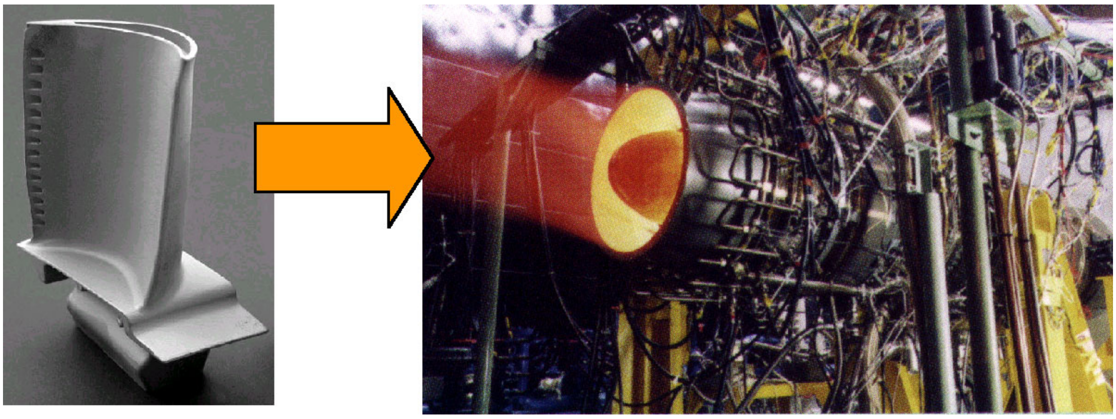
8) J.X.Zhang, T.Murakumo, Y.Koizumi, T.Kobayashi and H.Harada; Advanced Materials and Processes for Gas Turbines; Copper Mountain, CO, USA, 169-175 (2003).

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℃