NICKEL BASE
SINGLE CRYSTAL
SUPERALLOY

TMS-75

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TMS-75

A 3rd generation nickel-base single crystal superalloy with balanced intermediate and high temperature creep strengths. An alloy TMS-75 with a multi chemical composition, having 3 wt.% Cr, 5 wt.% Re, 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 1040 deg C-137 MPa being 961 h and 1526 h, respectively. Also, TMS-75 alloy has very good hot corrosion resistance as well.

Chemical composition, wt%

Element	Co	Cr	Mo	W	Al	Ta	Hf	Re
	12	3	2	6	6	6.0	0.1	5

Heat Treatment Condition (Typical)

Solution; 1300℃/1h+1320℃/5h→R.T. *, Aging; 1150℃/4h→R.T. +870℃/20h→R.T.*

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

Solidus Temperature : 1399℃(2530°F)
Solvus Temperature : 1283℃(2359°F)
Heat Window for Solution Treatment : 61℃(116°F)

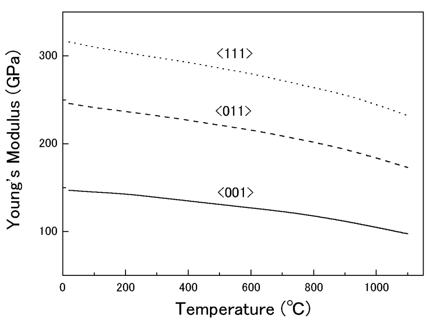
Physical Constants and Thermal Properties

Density………..………..………..………..……… at R.T...………..8.894 g/cc

Coefficient of Expansion………..………..…20 – 200℃………..11.7 $\times 10^{-6}$

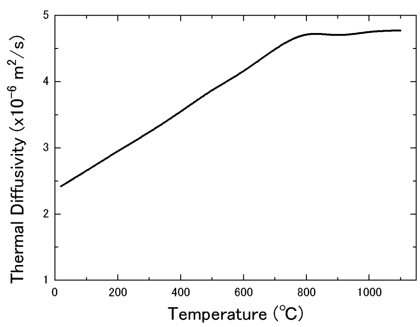
Young's Modulus

Rectangular parallelepiped resonance



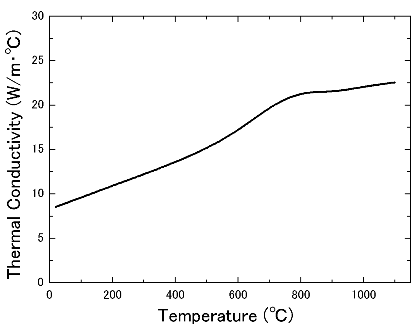
Thermal Diffusivity

Laser-Flush Method



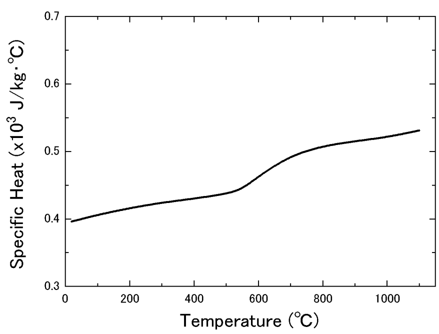
Thermal Conductivity

Laser-Flush Method



Specific Heat

Adiabatic calorimeter (Nernst method)

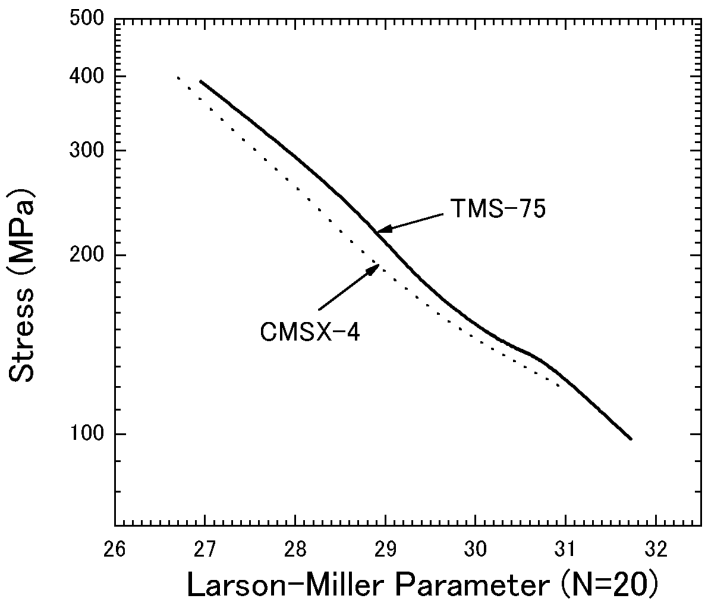


Typical Mechanical Properties

Creep Rupture Strength

Conditions		Rupture life τ	Elongation	Reduction of Area
Temperature, ℃(K)	Stress, MPa	h	%	%
900 (1173)	392	961	23.0	30.3
1000 (1273)	245	329	27.9	34.0
1000 (1273)	176	1264	25.3	34.8
1040 (1313)	137.2	1526	30.2	32.4
1100 (1373)	137.2	227	14.0	26.2
1150 (1423)	98	196	11.9	39.1

Larson-Miller Plot (= T(20+log(τ))



Tensile Strength

Temperature ℃(K)	0.2% Proof Stress MPa	Tensile Stress MPa	Elongation %	Reduction of Area %
R.T.	854	898	7.0	14
550 (823)	805	863	6.5	11
750(1023)	972	1287	7.7	9
850(1123)	893	1179	14	18
950(1223)	564	932	20	24
1050(1323)	513	717	16	41
1150(1423)	266	417	-	-

High Cycle Fatigue (Stress : Constant)

Test Number	Temperature ℃(K)	Stress MPa	Strain Rate %/sec.	Cycles to Failure N_f x10^5
1	1100 (1373)	450		2
2	1100 (1373)	350		7
3	1100 (1373)	300		10
4	1100 (1373)	250		40

Low Cycle Fatigue (Strain : Constant)

Test Number	Temperature ℃(K)	Strain Rate %/sec.	Total Strain $\Delta\varepsilon_t$, %	Stress (Initial) $\Delta\sigma_{Range}$, MPa	Cycles to Failure N_f x10^3
1	900 (1173)	0.1	0.7	784	103.7
2	900 (1173)	0.1	1.0	1120	8.82
3	900 (1173)	0.1	1.2	1344	1.75
4	950 (1223)	0.1	1.0	1090	27.19
5	950 (1223)	0.1	1.2	1308	4.65
6	1000 (1273)	0.1	1.0	1050	3.05
7	1000 (1273)	0.1	1.2	1260	1.65

Low Cycle Fatigue (Stress : Constant)

Test Number	Temperature ℃(K)	Stress MPa	Strain Rate %/sec.	Cycles to Failure N_f x10^3
1	800 (1073)	600		7
2	800 (1073)	450		40
3	800 (1073)	300		350
4	1100 (1373)	400		1
5	1100 (1373)	300		3.5
4	1100 (1373)	200		20

Oxidation Properties

Cyclic Oxidation in Air (Condition: 20h/Cycle in Air)

Cycles / Temp. ℃(K)	Weight Loss, mg/cm^2		
	10Cycles	20 Cycles	30 Cycles
1100 (1373)	23.3	52.6	79.8
1100 (1373)	0*	5.1*	13.8*

* With Al-packed

Related Articles

Alloy Development

1) H.Harada; Materials Design Approaches and Experiences as held during the TMS Fall Meeting; Indianapolis, IN, USA, 29-39 (2001).
2) H.Harada; Kogyo Zairyo (Engineering Materials). **47**, 1, 72-73 (1999).
3) T.Kobayashi, Y.Koizumi, S.Nakazawa, T.Yamagata and Harada, H; Advances in Turbine Materials, Design and Manufacturing; Newcastle upon Tyne, UK, 766-773 (1997).

Creep Behaviors

4) M.Maldini, H.Harada, Y.Koizumi, T.Kobayashi and V.Lupinc; Scripta Materialia. **43**, 7, 637-644 (2000).

Thermal Fatigue

5) H.Zhou, H.Harada, Y.Ro, T.Kobayashi and Y.Koizumi; Mat. Sci. Tech. **19**, 7, 847-852 (2003).
6) H.Zhou, H.Harada, Y.Ro, Y.Koizumi and T.Kobayashi; Fatigue: A David L. Davidson Symposium at the 2002 TMS Annual Meeting; Seattle, WA, USA, 203-215 (2002).

Microstractural Analysis

7) J.X.Zhang, T.Murakumo, Y.Koizumi and H.Harada; Journal of Materials Science, **38**, 24, 4883-4888, (2003).
8) J.X.Zhang, T.Murakumo, Y.Koizumi, T.Kobayashi and H.Harada; Metallurgical and Materials Transactions A, **33A**, 12, 3741-3746A (2002).
9) T.Yokokawa, M.Osawa, K.Nishida, Y.Koizumi, T.Kobayashi and H.Harada; Journal of the Japan Institute of Metals, **66**, 9, 873-876 (2002).
10) T. Yokokawa, M. Osawa, H. Murakami, T. Kobayashi, Y. Koizumi, T. Yamagata, H. Harada; 6th Liege conf. "Materials for Advanced Power Engineering 1998" 1121-1128 (1998).

Coating System

11) F.Wu, H.Murakami and H.Harada; Materials Transactions, **44**, 9, 1675-1678 (2003).
12) F.Wu, H.Murakami and A.Suzuki; Surface and Coatings Technology, **168**, 1, 62-69 (2003).
13) P.Kuppusami, H.Murakami and T.Ohmura; Surface Engineering: in Materials Science II at the 2003 TMS Annual Meeting; San Diego, CA, USA, 309-318 (2003).

Application Examples

At Toshiba co. ltd., real machine tests were successfully completed using a generator gas turbine employing the first stage blade made of TMS-75 single crystal superalloy.

A 15MW-class turbine rotor installed TMS-75 blades.

Inlet gas turbine temperature : 1300℃

Rotating speed : 3000 rpm

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--2008. 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).