SECOND GENERATION SINGLE CRYSTAL SUPERALLOY

TMS-82+

(Developed under NIMS[1] / Toshiba[2] collaboration)

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TMS-82+

TMS-82+ is a high cost-performance 2nd generation Ni-based single crystal superalloy which provides creep strength 30ºC higher than CMSX-4 in temperature capability at a stress level of approximately 137.2MPa (19.9ksi). A large heat treatment window facilitates simple heat treatment. TMS-82+ alloy also has very good high temperature corrosion resistance. This alloy is suitable for turbine blades and vanes in industrial gas turbines and aero-engines.

Nominal chemical composition, wt%

Element	Ni	Co	Cr	Mo	W	Al	Ti	Ta	Hf	Re
	bal.	7.8	4.9	1.9	8.7	5.3	0.5	6.0	0.1	2.4

Heat treatment condition (Typical)

Solution; 1300°C/1h→1320℃/5h,GFC*, Aging; 1150°C/4h,GFC*, 870°C/20h,GFC*

*GFC : Gas Fan Cooling.

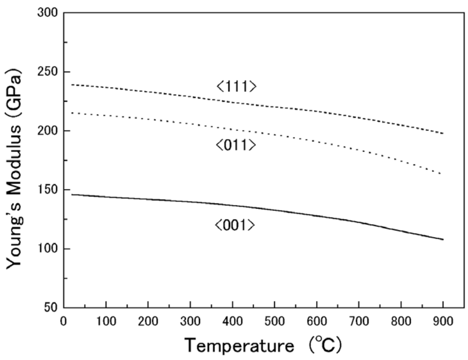
Incipient melting temperature : 1340°C(2444°F)
Solvus temperature : 1293°C(2359°F)
Heat window for solution treatment : 47°C(85°F)

Physical constants and thermal properties

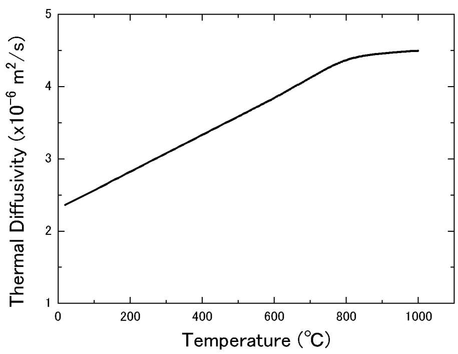
Alloy density………..………..………..……… at R.T...…….…….8.93 g/cc

Coefficient of expansion………..………..…20 –100°C………..11.6 x10^{-6} /°C

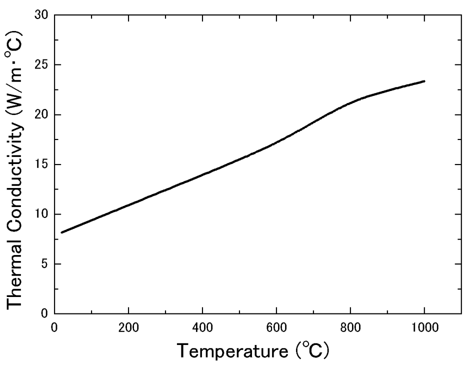
Young's modulus



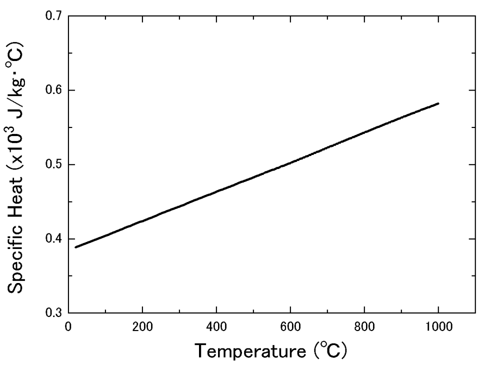
Thermal diffusivity



Thermal conductivity



Specific heat

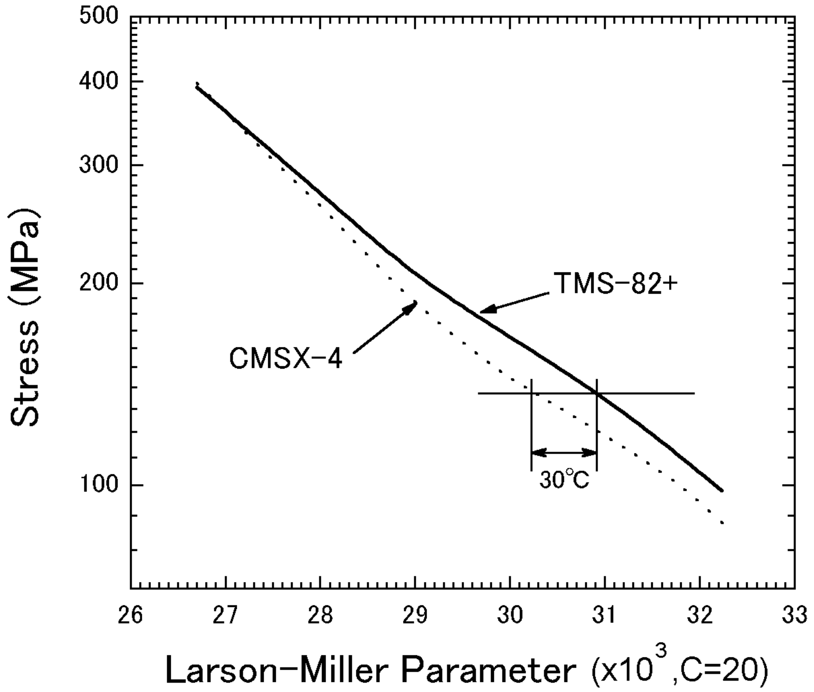


Typical mechanical properties

Creep rupture strength

Conditions		Rupture life τ	Elongation	Reduction of area
Temperature, °C(K)	Stress, MPa	h	%	%
900 (1173)	392	584.3	23.5	29.5
1000 (1273)	245	198.4	23.4	28.2
1000 (1273)	196	789.9	19.9	28.6
1100 (1373)	137.2	374.8	9.0	28.6
1100 (1373)	98	2987.2	9.1	30.6

Larson-Miller Plot [= T(C + log τ)]



Tensile strength

Temperature °C(K)	0.2% Proof stress MPa	Tensile stress MPa	Elongation %	Reduction of area %
R.T.	991.6	991.6	10.7	13.0
650 (923)	882.5	975.5	15.2	12.6
900 (1173)	809.6	824.0	18.6	31.9

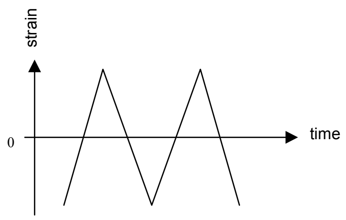
High cycle fatigue

Test Number	Temperature °C(K)	Revolution rpm	Stress MPa	Cycles to failure N_f x10^5
1	750 (1023)	3600	342	89.9
2	750 (1023)	3600	392	14.9
3	750 (1023)	3600	441	7.79

Low cycle fatigue (Triangular wave condition)

Test number	Temperature °C(K)	Strain rate %/sec.	Strain range at Nf/2, %		
			Total strain, $\Delta\varepsilon_t$	Elastic strain, $\Delta\varepsilon_e$	Plastic strain, $\Delta\varepsilon_p$
1	900 (1173)	0.1	0.79	0.77	0.02
2	900 (1173)	0.1	0.99	0.91	0.08
3	900 (1173)	0.1	1.49	1.23	0.26

Test number	Stress at Nf/2, MPa			Cycles to failure Nf
	Stress range, $\Delta\sigma$	Tensile stress, σ_{max}	Compression stress, σ_{min}	
1	747	381	-386	7035
2	905	444	-461	2315
3	1207	594	-613	290

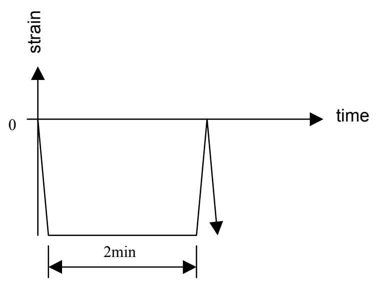


Waveform

Low cycle fatigue (Compression hold Condition)

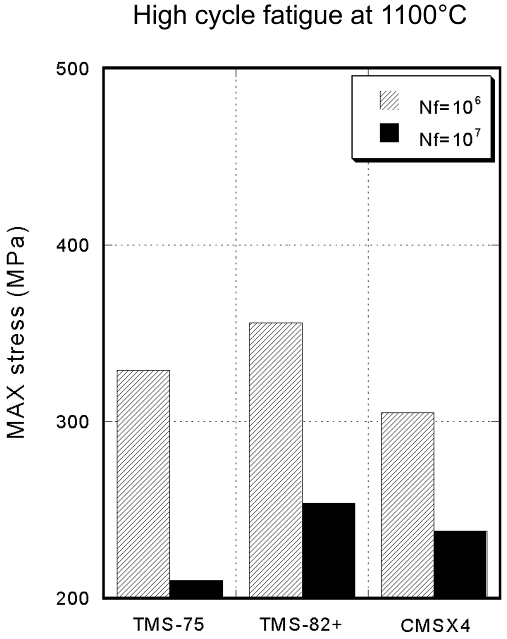
Test number	Temperature °C(K)	Strain range at Nf/2, %		
		Total strain, $\Delta\varepsilon_t$	Elastic strain, $\Delta\varepsilon_e$	Plastic strain, $\Delta\varepsilon_p$
1	900 (1173)	0.80	0.78	0.02
2	900 (1173)	1.00	0.94	0.06
3	900 (1173)	1.50	1.3	0.17

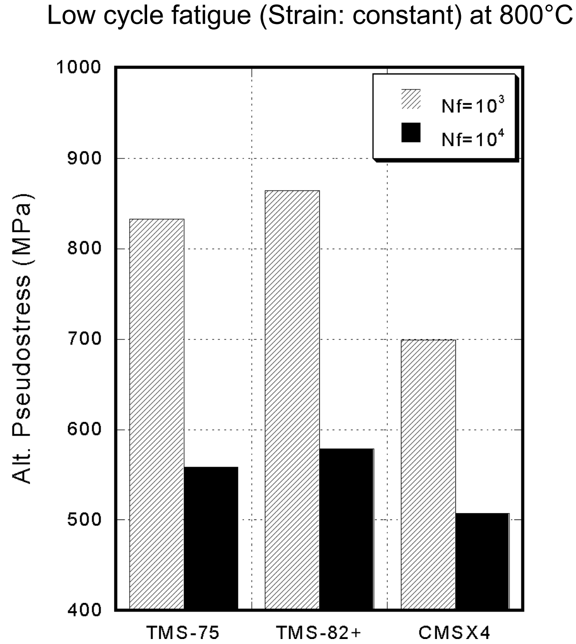
Test number	Stress at Nf/2, MPa			Cycles to failure Nf
	Stress range, $\Delta\sigma$	Tensile stress, σ_{max}	Compression stress, σ_{min}	
1	1423	1027	-396	8319
2	1004	709	-295	1887
3	4487	1027	-3460	233



Waveform

Failure stress ratio of TMS alloys and CMSX-4.





Oxidation properties

Isothermal oxidation in air

Temp. \ Time	Weight gain, mg/cm^2		
	300 h	600 h	1000 h
850 °C	0.98	1.10	1.18
950 °C	0.80	0.78	0.77

Cyclic oxidation in air (Based on JIS-Z2281)

Temp. \ Cycles	Weight gain, mg/cm^2	
	30Cycles	60 Cycles
950 °C	0.66	0.66

Patents

1) Y.Koizumi, T.Kobayashi, S.Nakazawa, H.Harada T.Hino, Y.Ishiwata and Y.Yoshioka; Nickel-base Single-Crystal Superalloys, Method of Manufacturing Same and Gas Turbine High Temperature Parts Made Therof, Japanese Patent Pending, Tokugan2001-256,449 (2000).
2) Y.Koizumi, T.Kobayashi, S.Nakazawa, H.Harada T.Hino, Y.Ishiwata and Y.Yoshioka; Nickel-base Single-Crystal Superalloys, Method of Manufacturing Same and Gas Turbine High Temperature Parts Made Therof, EPC Patent Pending, 01,120,897.2 (2001).
3) Y.Koizumi, T.Kobayashi, S.Nakazawa, H.Harada T.Hino, Y.Ishiwata and Y.Yoshioka; Nickel-base Single-Crystal Superalloys, Method of Manufacturing Same and Gas Turbine High Temperature Parts Made Therof, U.S. Patent US6,673,308 B2 (2004).

Related papers

1) T.Hino, T.Kobayashi, Y.Koizumi, H.Harada and T.Yamagata; 9^{th} International. Symposium on Superalloys 2000, Seven Springs,PA; USA, pp729-736 (2000).
2) H.Harada; Materials Design Approaches and Experiences as held during the TMS Fall Meeting, Indianapolis, IN, USA, pp29-39 (2001).
3) Y.Koizumi, T.Kobayashi, T.Yokokawa, T.Osawa, H.Harada, T.Hino and Y.Yoshioka; Journal of the Japan Institute of Metals, **67**, 4, pp 205-208 (2003).
4) Y.Ro, H.Zhou, Y.Koizumi, T.Yokokawa, T.Kobayashi, H.Harada and I.Okada; Mater. Trans., **45**, 2, pp 396-398 (2004).

Application examples

Actual machine tests were successfully completed at Toshiba Corporation using a power generation gas turbine with first stage blades made of TMS-82+ single crystal superalloy.

A 15MW turbine rotor installed TMS-82+ blades.

Turbine inlet gas turbine temperature : 1300℃