AUBERT&DUVAL

MLX17™

X1CrNiMoAlTi12-11-2

A very high strength stainless steel

CONTINUOUS
METALLURGICAL
INNOVATION

SPECIAL STEELS

DEVELOPMENT

RESEARCH

SERVICE

Enhancing your performance

MLX17

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THE INDUSTRIAL ENVIRONMENT

Numerous applications require the use of stainless steel solutions. The ban of Cr and Cd plating has shifted the need towards higher strength stainless steels.

Aubert & Duval has therefore adapted its high strength steel offering with the development of **MLX17**, a high corrosion resistant grade capable of 1700 MPa (247 Ksi) with high fracture toughness and excellent corrosion resistance.

The Aubert & Duval stainless steels family and **MLX17** show:

- High resistance
- High stress corrosion resistance
- Good fatigue behavior.

The Aubert & Duval high strength family offers a replacement for low carbon steels from AISI 4340 to 35NiCrMo16.

DEVELOPMENT OF THE GRADE MLX17

The following criteria have been taken into account for the development of this grade:

- Capable of 1700 MPa (247 Ksi) with a minimum dispersion: Al and Ti are used for hardening,
- High ductility, fracture toughness and stress corrosion resistance. The Ni content is pushed to its optimum,
- Capable of very large parts with the possibility to refine the grain size of die forged parts during heat treatment: a low solutionning temperature is preferred,
- Weldable and easily machined: a PH grade.

UNS: S11100
AMS 5937

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APPLICATIONS

- Structural parts for the aerospace industry (landing gears, actuators, flaps, rod ends, …)
- Medical devices
- Fasteners
- Marine applications: landing grids, …
- Defense

CHEMICAL COMPOSITION

	C	Si	Mn	Cr	Mo	Ni	Al	Ti
min.	--	--	--	11.00	1.75	10.25	1.35	0.20
max.	0.02	0.25	0.25	12.50	2.25	11.25	1.75	0.50

SPECIFICATIONS

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PHYSICAL PROPERTIES

Density

Temperature		Aged 510 °C / 950 °F		Aged 540 °C / 1000 °F	
°C	°F	g/cm³	lb/in³	g/cm³	lb/in³
20	68	7.67	0.2769	7.67	0.2769
100	212	7.66	0.2765	7.66	0.2765
150	302	7.65	0.2762	7.64	0.2758
200	392	7.63	0.2755	7.63	0.2755
250	482	7.62	0.2751	7.62	0.2751
300	572	7.60	0.2744	7.60	0.2744
350	662	7.59	0.2740	7.59	0.2740
400	752	7.58	0.2736	7.58	0.2736
430	806	7.57	0.2733	7.57	0.2733

Mean coefficient of thermal expansion

Temperature range		Aged 510 °C / 950 °F		Aged 540 °C / 1000 °F	
°C	°F	10^{-6}/m/m/°C	10^{-6}/in/in/°F	10^{-6}/m/m/°C	10^{-6}/in/in/°F
25/100	77/212	10.32	5.73	10.38	5.77
25/150	77/302	10.70	5.94	10.79	5.99
25/200	77/392	11.05	6.14	11.14	6.19
25/250	77/482	11.26	6.26	11.36	6.31
25/300	77/572	11.40	6.33	11.51	6.39
25/350	77/662	11.52	6.40	11.63	6.46
25/400	77/752	11.61	6.45	11.75	6.53
25/430	77/806	11.68	6.49	11.83	6.57

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Thermal conductivity

Temperature		Aged 510 °C / 950 °F		Aged 540 °C / 1000 °F	
°C	°F	W.m/m².°C	Btu.in/hr.ft².°F	W.m/m².°C	Btu.in/hr.ft².°F
20	68	17.3	119.5	15.9	110.2
100	212	18.0	124.7	17.5	120.9
150	302	18.8	130.2	18.6	128.9
200	392	18.9	130.9	19.5	134.8
250	482	19.8	137.2	20.3	140.7
300	572	20.1	139.2	20.5	142.1
350	662	21.0	145.5	21.1	145.9
400	752	21.7	150.0	22.1	152.8
430	806	23.0	159.3	22.7	157.0

Specific heat

Temperature range		Aged 510 °C / 950 °F		Aged 540 °C / 1000 °F	
°C	°F	J/kg.°C	Btu/lb/°F	J/kg.°C	Btu/lb/°F
20	68	481	0.12	489	0.12
100	212	510	0.12	508	0.12
150	302	522	0.13	524	0.13
200	392	536	0.13	539	0.13
250	482	556	0.13	557	0.13
300	572	568	0.14	569	0.14
350	662	592	0.14	593	0.14
400	752	616	0.15	621	0.15
430	806	658	0.16	650	0.16

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TRANSFORMATION POINTS

Ms	133 °C / 271 °F
Mf	23 °C / 73 °F

MACROSTRUCTURE

The segregation observed on the ingots is well within the limits of aerospace industry requirements:

Class	Type	Severity
1	Freckles	A
2	White spots	A
3	Radial segregation	A
4	Ring pattern	B

Macrostructure according to ASTM A 604

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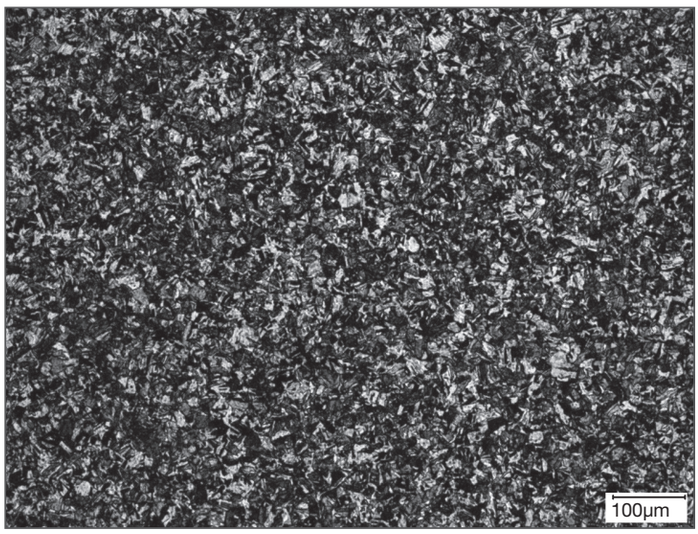
MICROGRAPHIC CHARACTERIZATION

Aged Condition

The structure is very fine.

Typical aspect of the structure



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MECHANICAL CHARACTERISTICS (DESIGN VALUES)

The grade is included in the MMPDS handbook.

MECHANICAL CHARACTERISTICS (TYPICAL)

Heat Treatment:

- 840 °C / 1544 °F – 2 hrs – Oil or Water quench
- Deep Freezing below -80 °C / -112 °F – 8 hrs
- Aging

In the solution treated state the hardness is approximately 33 HRC.

The graphs on the following page shows the typical properties.

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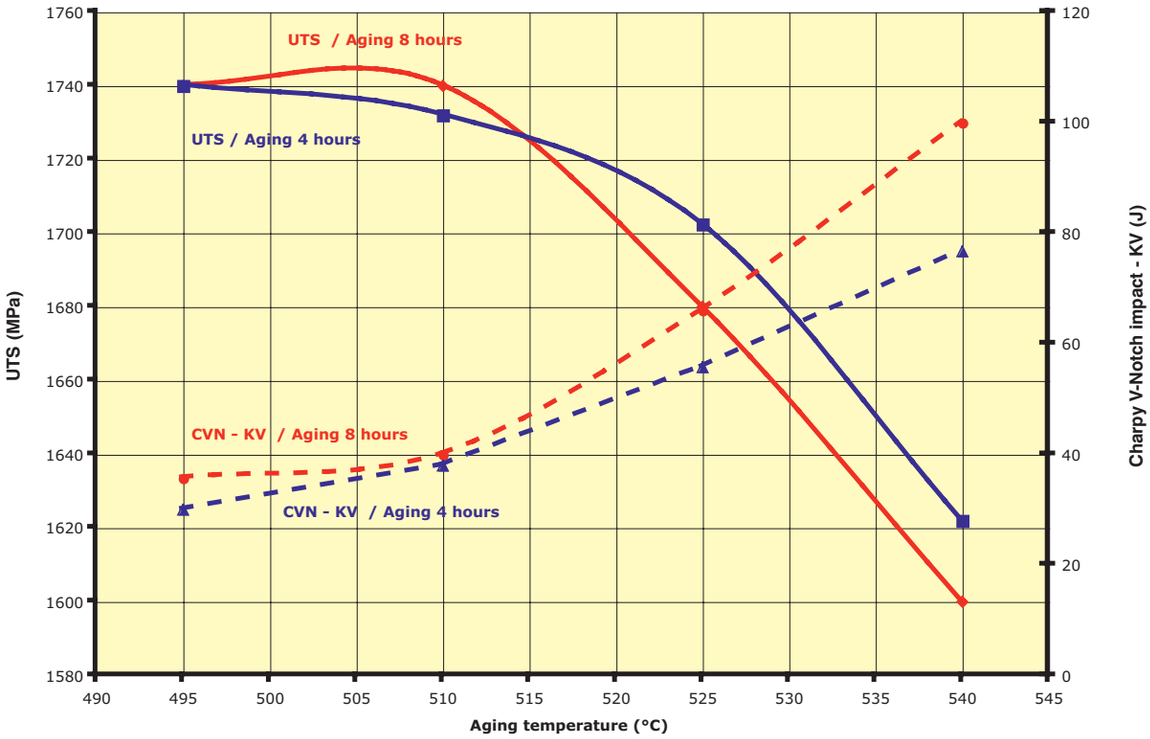

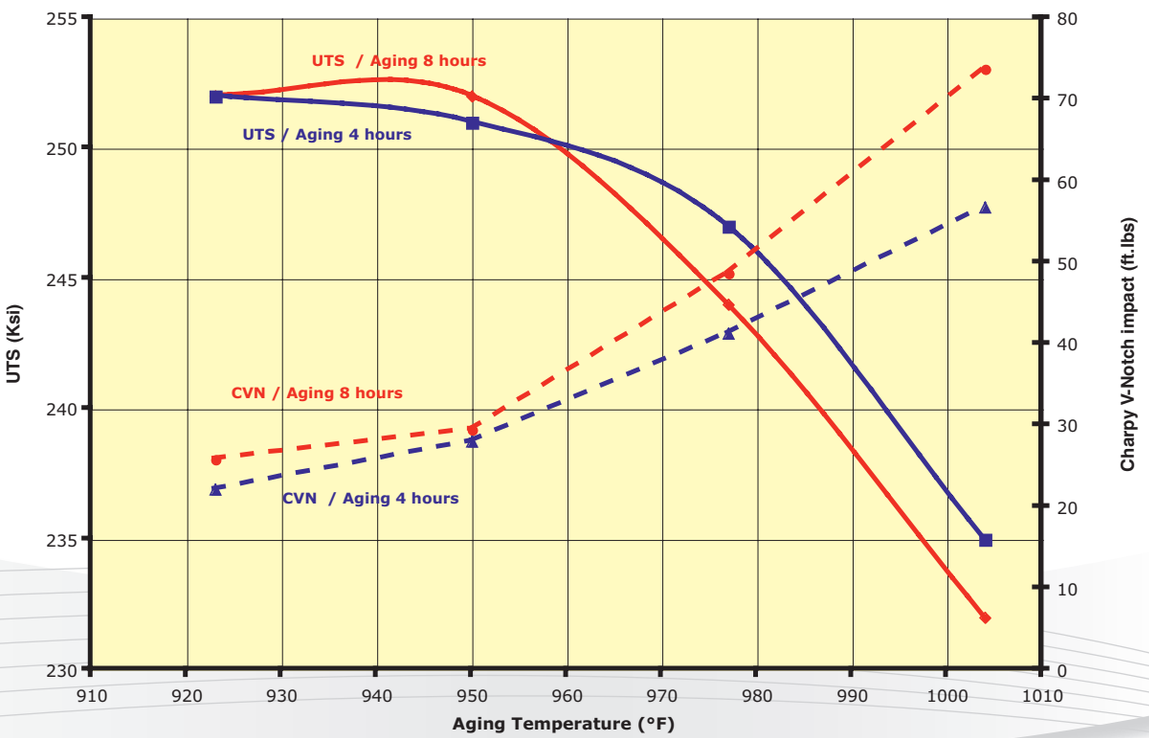

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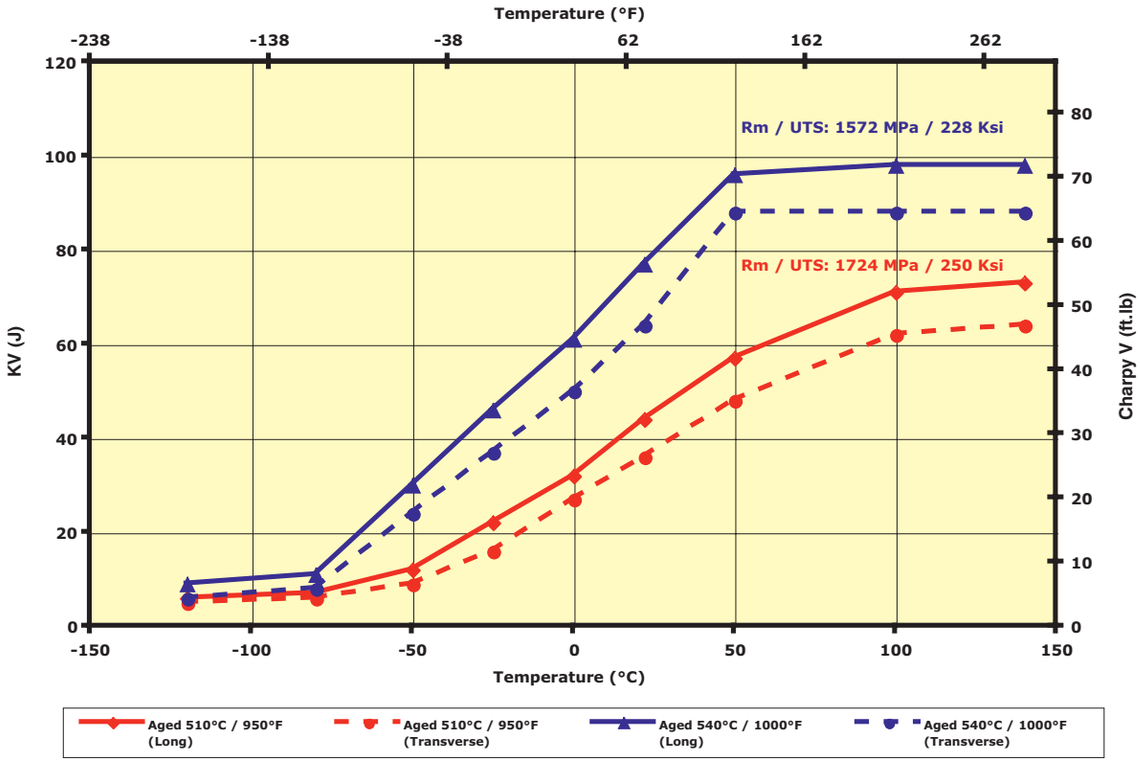
Transition curves



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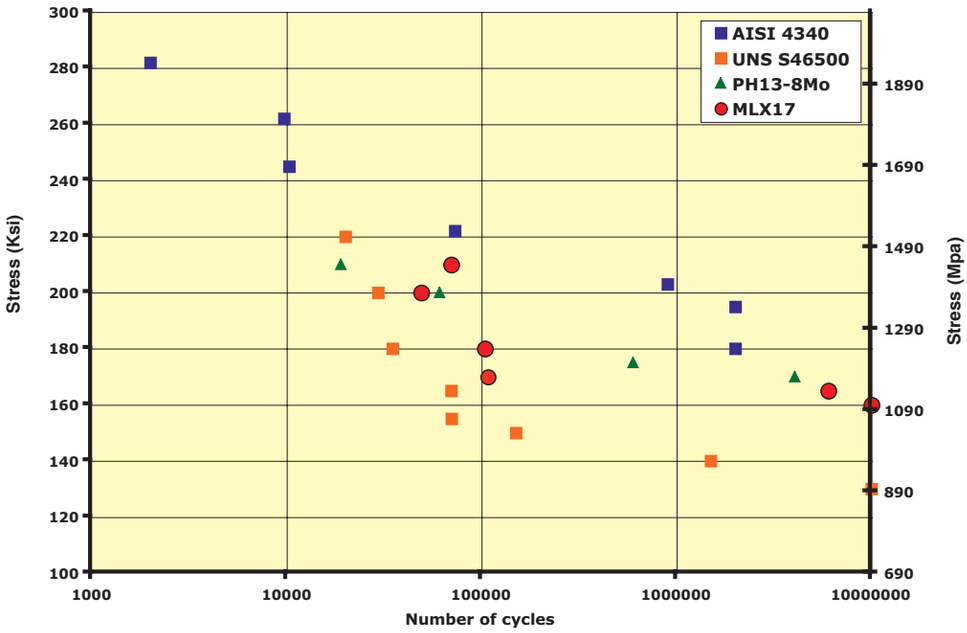
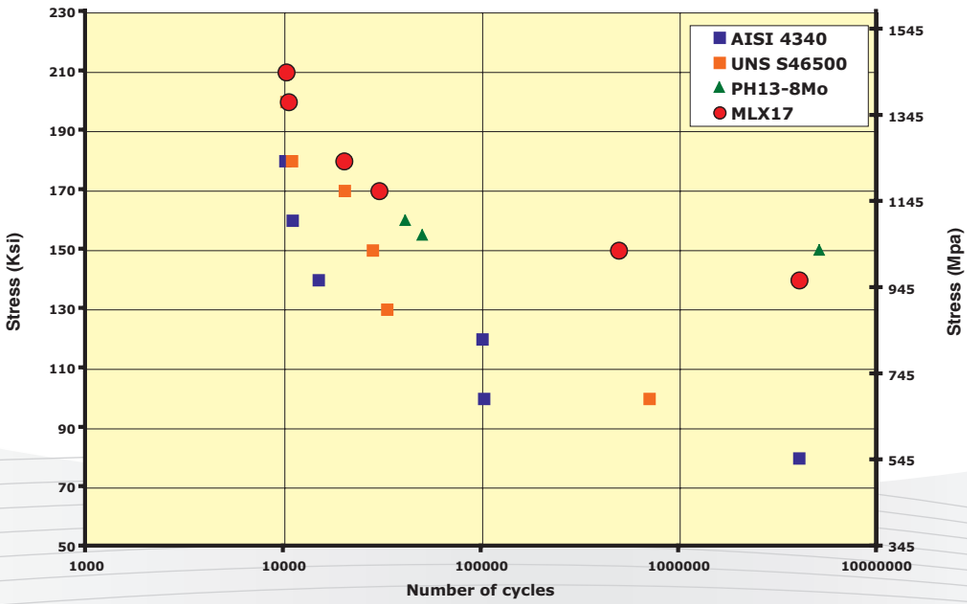
Fatigue curves

MLX17 Aged 510 °C / 950 °F (H950)

Tensile fatigue – R = 0.1 – Kt = 1.035 (Medium = Air)



Tensile fatigue – R = 0.1 – Kt = 1.035 (Medium = NaCl solution)



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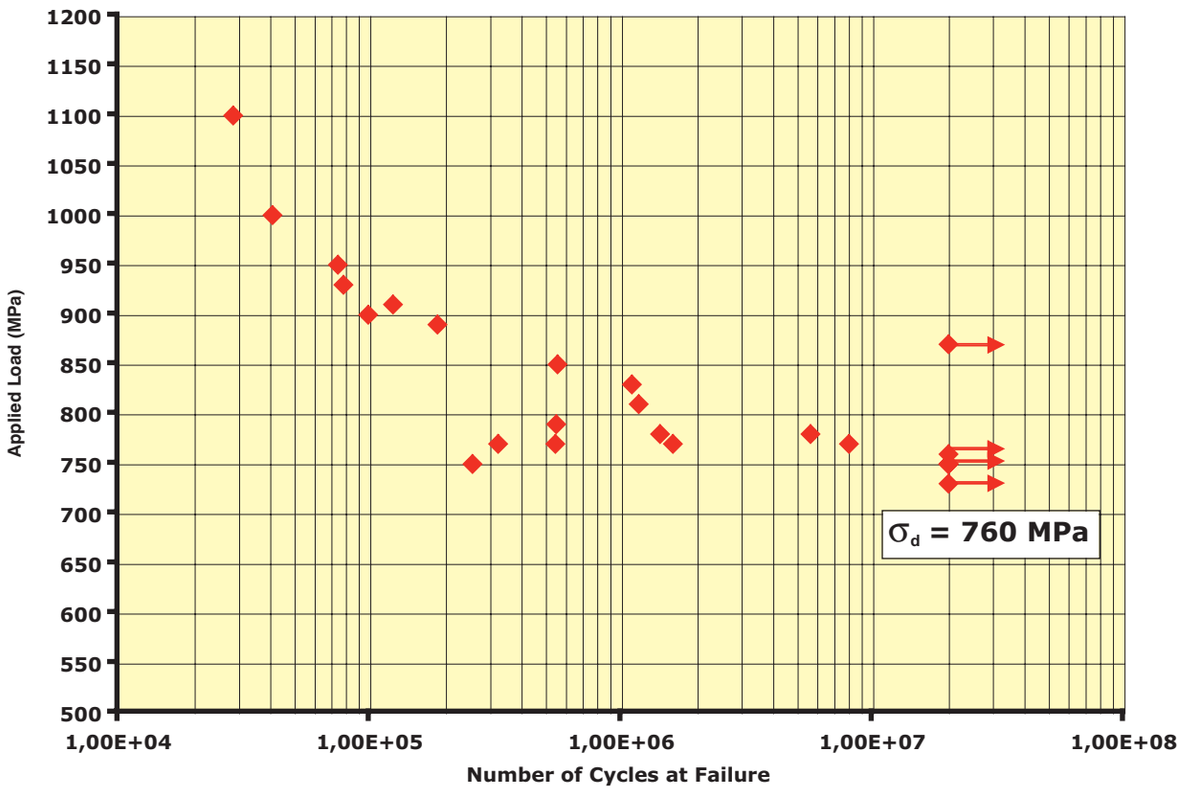
AUBERT & DUVAL fatigue tests – rotative bending (r = -1), kt = 1.035

MLX17 Aged 510 °C / 950 °F (H950)



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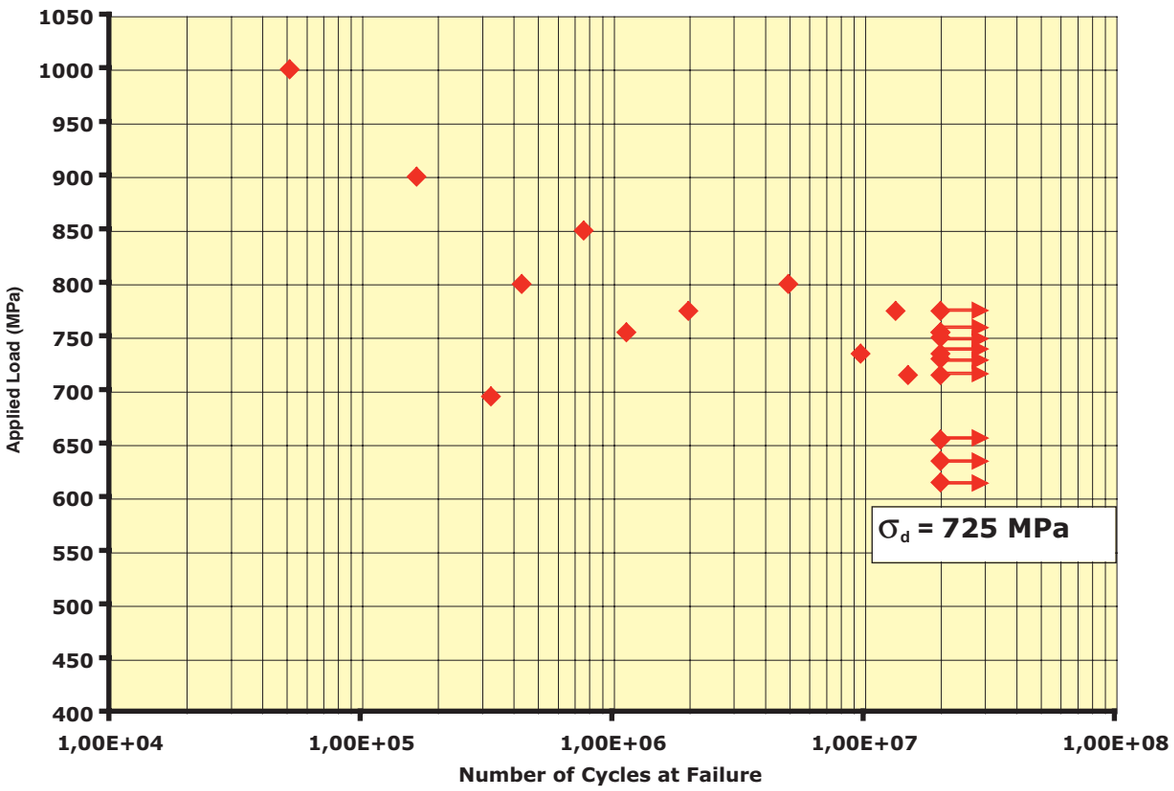
MLX17 Aged 540 °C / 1000 °F (H950)



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CORROSION RESISTANCE

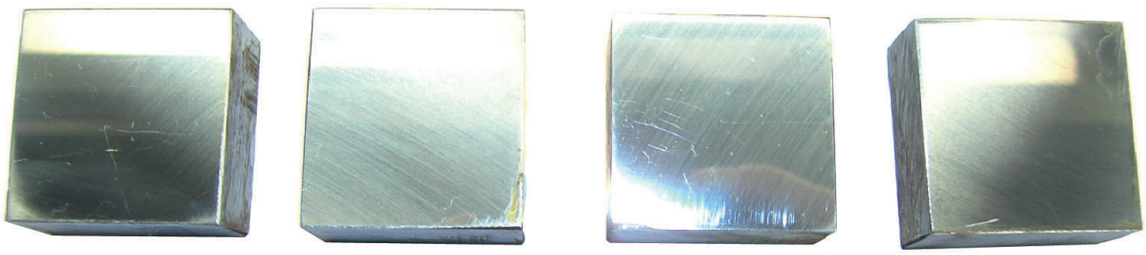
General corrosion resistance

The corrosion resistance of **MLX17** is similar to AISI 304 stainless.

Salt-spray tests (NF X 41-002) have not shown any sign of corrosion on:

- Aged + machined samples after 700 hrs
- Aged + passivated samples after 4000 hrs.

Example of results



Passivated samples – 673 hours

Stress corrosion resistance

Like the Aubert & Duval high strength stainless steel family, this grade has been developed to show excellent stress corrosion resistance.

Different tests have been carried out as no standard test exists to measure stress corrosion resistance.

Examples of results are given in the following tables extracted from US NAVY report NAWCADPAX/TR-2009/12

	PH13-8Mo **Aged 538 °C / 1000 °F**	**UNS: S46500** **Aged 510 °C / 950 °F**	**MLX17** **Aged 510 °C / 950 °F**
UTS (MPa / Ksi)	1480 / 215	1740 / 252	1710 / 248
Elongation (%)	14	13	14
HRC	44	48	48
K1c (MPa√m / Ksi√in)	97 / 88.3	90 / 82	80 / 72.9
K1scc (MPa√m / Ksi√in)	70 / 63.8	>53 / 48.3	68 / 61.9

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NOTES:

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Design: affinity makhesis group

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