MATERION

Tech Brief

Metal Matrix Composites

SupremEX® Composites Heat Treating

SupremEX products are a family of high-performance aluminum-silicon-carbide (AlSiC) metal matrix composites (MMCs). SupremEX MMCs combine an ultra-fine silicon carbide reinforcement with aerospace aluminum alloys. Materion offers several grades of SupremEX with different metal-to-reinforcement ratios and a range of physical and mechanical properties in order to meet specific application requirements. All SupremEX materials respond to conventional solution heat treatment and quench and age treatments to achieve high strength and fatigue performance.

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SupremEX 2- series composites are based on a 2124 or 2009 precipitation-hardened aluminum alloy and are reinforced with various quantities and sizes of silicon carbide particles. However, certain heat treatment conditions are modified as a result of the powder metallurgy manufacturing route and the presence of the fine particle reinforcement.

The SupremEX 6- series composites are based on a 6061 precipitation-hardened aluminum alloy. These show that low quench rate sensitivity and high strengths can be achieved with lower cooling rates by using hot water or polymer quench; or by direct cooling from HIP, forging or extrusion processes.

SupremEX Composite	Al Alloy Matrix	SiC Particle Loading	SiC Particle Size
215XK	2009	15	5 µm
225XE/CA	2124	25	3 µm
225XF	2124	25	0.7 µm
620XF	6061	20	0.7 µm
640XA	6061	40	3 µm

SOLUTION HEAT TREATMENT

Solution heat treatment for SupremEX composites is performed at 505°C for the SupremEX 2- series and 535°C for the SupremEX 6- series. The minimum time is one hour at temperature for up to 25 mm of section thickness. To avoid formation of intermetallic phases, the solidus at 545°C for the SupremEX 2- series and 570°C for the SupremEX 6- series should not be exceeded during heat treatment or fabrication processes.

Preferred tolerance for furnace control for SupremEX products is +/-5°C. Significant reduction in solution heat treat temperature and time will result in incomplete solid solution of alloy elements and the presence of intermetallic phases in the final microstructure. Such phases will reduce strength because a lower fraction of strengthening precipitate will be formed, and this can also reduce fatigue strength.

Cross sections over 25 mm will be difficult to quench fast enough to achieve peak strength. If the design requires a thicker cross section, add an additional hour at temperature for each additional 25 mm of section thickness.

QUENCH PROCESSES

The quench medium and conditions may be selected to balance strength and residual stress. Section thickness will affect the choice of quench medium, with thicker sections requiring faster quench rates to maximize strength. Section thickness should be less than 25 mm (1") during quenching to achieve target properties.

Maximum quench rate will result in the highest strength and fatigue performance, with a trade off in higher residual stress that may cause distortion for complex parts and/or for close tolerance machining processes. For general guidance: to maximize quench rate, transfer time from furnace to quench medium should be minimized, especially for thin section parts.

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Techniques employed to minimize distortion on 2024, 2009 and 6061 can be applied to SupremEX products such as modifications to the quench media and temperature. In addition, suitable racking, fixturing and quench orientation should be selected for the specific component geometry. Like most aluminum alloys there is more risk for distortion in non-symmetrical parts or parts with extended, thin features. In many applications rough machining can be performed before the solution anneal, quench and age followed by finish machining processes. This practice improves the quench rate due to reduced cross section thickness and provides options to improve dimensional stability.

AGING TEMPERATURE - SUPREMEX 2- SERIES

SupremEX 2- composites will age at room temperature and reach peak strength T4 temper after >100 hours. Artificial aging SupremEX 2- composites at 150°C for an hour will achieve the T6 temper. This may sacrifice some strength but can increase ductility and reduce residual stress. Preferred tolerance for furnace control is +/-5°C.

Please note: data is for informational purposes only, it does not constitute a guarantee. CWQ refers to Cold Water Quench and PGQ refers to Poly-Glycol Quench.

T1 mechanical properties are highly variable because of the variation in cooling from elevated temperature forming processes.

Table 1: SupremEX 225XE, 225CA and 215XK - Heat Treatment Designation and Practice

Temper	Solution Anneal	Heat Treatment	Comments
T1	Air-cooled from elevated temperature forming process		Suitable for low-stress parts, those subject to high temperature soak in operation, or as a supply condition for material that will be further processed.
T4 CWQ	505°C for one hour minimum, plus one hour for each additional 25 mm over 25 mm (as described above)	Aging complete after 100 hours at room temperature	Suitable for thin section and/or symmetrical parts. Peak properties, but some risk of distortion during quench or during subsequent machining.
T4 PGQ (20-25%)			Poly-glycol quench reduces the risk of distortion on complex or thick section components. Lower quench rate causes some reduction in fatigue properties, depending on section.
T6 CWQ		Age at 150°C for 1 hour minimum	Suitable for thin section and/or symmetrical parts. Some risk of distortion during quench or during subsequent machining. For engine components there is an option to age at 190°C.
T6 PGQ (20-25%)			Poly-glycol quench reduces the risk of distortion on complex or thick section components. Lower quench rate causes some reduction in fatigue properties, depending on section.

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Table 2: Effect of Heat Treatment on SupremEX 225XE - Typical Measured Values

	HIP'd Billet			Forged Plate			Extrusions*	
Heat Treatment	T1	T4 CWQ	T6 PGQ	T1	T4 CWQ	T6 PGQ	T1	T6 PGQ
Yield Strength MPa (kpsi)	260-310 (38-45)	470 (68.2)	400 (58.0)	270-310 (39-45)	440 (63.8)	400 (58.0)	270-310 (39-45)	400 (58.0)
Tensile Strength MPa (kpsi)	370-410 (54-59)	570 (82.7)	535 (77.6)	390-450 (57-65)	610 (88.5)	570 (82.7)	410-460 (59-67)	600 (87.0)
Elongation to Failure %	2-4	1.8	2.0	5.2	3-4	3-4	4-8	4-5

*30:1 reduction ratio.

Table 3: Effect of Heat Treatment on SupremEX 215XK T4 - Typical Measured Values

	HIP'd Billet	HIP'd Billet	Forged Plate
Heat Treatment	T1	T4 CWQ	T4 CWQ
Yield Strength MPa (kpsi)	180-230 (26-33.5)	410 (59.5)	380 (55.1)
Tensile Strength MPa (kpsi)	290-340 (42-49.5)	540 (78.3)	550 (79.8)
Elongation to Failure %	6-10	5	8

AGING SUPREMEX 6- SERIES COMPOSITES

SupremEX 6- composites must be aged at 175°C to achieve T6 temper. Aging SupremEX 6- composites at 175°C for at least one hour will achieve the T6 temper which sacrifices some strength but increases ductility. Preferred tolerance for furnace control is +/-5°C.

Please note: data is for informational purposes only, it does not constitute a guarantee. T1 mechanical properties are highly variable because of the variation in cooling from elevated temperature processing. CWQ refers to Cold Water Quench and PGQ refers to Poly-Glycol Quench.

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Table 4: SupremEX 620XF, 640XA - Heat Treatment Designation and Practice

Temper	Solution Anneal	Heat Treatment	Comments
T1	Air-cooled from elevated temperature forming process		Suitable for low-stress parts and those subject to high temperature soak in operation; or as a supply condition for material that will be further processed.
T5	Cooled from an elevated temperature forming process and artificially aged.		
T6 CWQ	535°C for 1 hour minimum, plus 1 hour for each additional 25 mm over 25 mm (as described above)	Age at 175°C for 1 hour minimum	Peak properties but involves the most distortion.
T6 PGQ (25%)		Age at 175°C for 1 hour minimum	Near peak properties with reduced distortion risk.
T7 PGQ (25%)		Over-aged hotter than 175°C	Used when peak strength is not as important as other material characteristics.

Table 5: Effect of Heat Treatment on SupremEX 620XF - Typical Measured Values

	HIP'd Billet		Forged Plate		Extrusions		
Heat Treatment	T1	T6 CWQ	T1	T6 CWQ	T1	T5	T6 CWQ
Yield Strength MPa (kpsi)	250-300 (36-43)	430 (62.4)	260-300 (38-43)	410 (59.4)	270-310 (39-45)	240 (34.8)	380 (55.1)
Tensile Strength MPa (kpsi)	320-360 (46-52)	500 (72.5)	340-380 (49-55)	490 (71.1)	350-400 (51-58)	360 (52.2)	470 (68.2)
Elongation to Failure %	1-4	4	7-10	7	5-17	8	7

continued

Table 6: Effect of Heat Treatment on SupremEX 640XA - Typical Measured Values

	HIP'd Billet			Forged Plate		
Heat Treatment	T1	T6 CWQ	T6 PGQ	T1	T6 PGQ	T7
Yield Strength MPa (kpsi)	320-360 (46-53)	490 (71)	450 (65)	350-390 (51-56)	400 (58)	350 (51)
Tensile Strength MPa (kpsi)	410-450 (59-65)	560 (81)	540 (78)	440-500 (64-73)	530 (77)	470 (68)
Elongation to Failure %	1.0	1.0	1.3	2.0	2.0	2.0

OXIDATION DURING HEAT TREATMENT

The oxidation of the SupremEX composites is very similar to the oxidation characteristics of the matrix aluminum alloys. The silicon carbide particles are stable up to and beyond the solidus temperature for the matrix alloys.

STRESS RELIEF CYCLES

When performing stress relief cycles on SupremEX, the material temper and future heat treating must be considered. Stress relief cycles performed on SupremEX in the T1 condition may be performed at temperatures approaching 500°C, provided the parts will be solution annealed later in the process. Care must be taken so part features do not sag due to creep. Stress relief after heat treatment to a T4, T6 or T7 condition must be performed below the defined aging temperature.

SupremEX 2- series composites are insensitive to over-aging at temperatures below 150°C. However, aging at more than 200°C results in precipitate coarsening leading to lower retained strength. At temperatures of more than 300°C, the retained room temperature strength is reduced to a base "T1" temper with 0.2% yield strength of 280 to 300 MPa.

SupremEX 6- series composites in the T6 condition are artificially aged at 175°C. Exceeding this temperature with a stress relief cycle will reduce material properties. Depending on the temperature, T7-like properties may be obtained and can be beneficial in situations where T7 properties meet design requirements.

We recommend following the machining guidelines found in our Tech Brief, Machining Recommendations for SupremEX Metal Matrix Composites, to improve dimensional stability through heat treat and stress relief cycles.

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