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NONFERROUS ALLOYS

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	Mg
6	Zn
0.8	Zr

ZK61A

1. GENERAL
ZK61A is a magnesium sand-casting and investment-casting alloy, which has an outstanding combination of strength and ductility in the age-hardened condition. It was developed to provide castings with a very high strength-to-weight ratio for use in aerospace applications at temperatures up to about 350F (1). The achievement of this goal resulted in somewhat poorer foundry characteristics--fluidity, microporosity, hot-cracking tendency--than most of the other magnesium alloys. This alloy has excellent machinability but poor weldability. Its corrosion resistance is similar to that of most other magnesium alloys; for long-time exposures to marine or industrial environments, chemical treatment followed by painting is recommended.

1.01 Commercial Designation
ZK61A

1.02 Alternate Designations
ZK61

1.03 Specifications
AMS 4444A
ASTM B80-68, B403-67
Federal QQ-M-56b (1)
MIL-M-46062A
SAE 513

1.04 Composition
Table 1.04.

TABLE 1.04

Alloy	ZK61A			
Source	AMS 4444 A(2), ASTM B80-68, B403-67			
	Percent		Percent	
Element	Minimum	Maximum	Minimum	Maximum
Zinc	5.5	6.5	5.5	6.5
Zirconium (total)	0.6	1.0	0.6	1.0
Zirconium (soluble)*	0.6	-	-	-
Copper	-	0.10	-	0.10
Nickel	-	0.01	-	0.01
Others (total)	-	0.30	-	0.30
Magnesium	Remainder		Remainder	

* Soluble zirconium is that portion of the zirconium that is soluble in 1:4 hydrochloric acid held below its boiling point.

1.05 Heat Treatment
Table 1.05.

TABLE 1.05

Alloy	ZK61A				
Source	(3) (4) (5)				
	Solution			Age	
Treatment	Temp F	Time hr	Cool	Temp F	Time hr
T4 Solution(a)	930	5	a.b. (b)		
T5 Artificial Age				300	48
T6 As Cast + Solution(a) + Artificial Age	930	5	a.b. (b)	265	48

(a) Alternate solution: 900F, 10 hr.
(b) a.b. - air blast

1.051 Effects of variations in heat-treating conditions (solution time, cooling method, and aging time) on the tensile properties of chilled casting, Figure 1.051.

1.052 ZK61A - F (as cast) also age hardens at room temperature, 10 months' aging resulting in properties equivalent to those produced by the T5 heat treatment (6).

1.06 Hardness

1.061 Hardness of sand castings in different heat-treated conditions, Table 1.061.

TABLE 1.061

Alloy	ZK61A	
Form	Sand Cast	
Source	(1)	
Condition	BHN	RE
F*	58-65	65-70
T5	65-70	75-80
T6	65-75	75-82

* As-cast

1.062 Effect of temperature on hardness, Figure 1.062.

1.07 Forms and Conditions Available
Produced primarily as sand castings; has been used to a small extent as investment castings; used in the T4 (solution-treated), T5 (artificially aged), and T6 (solution-treated and artificially aged) conditions.

1.08 Melting and Casting Practice (7)(8)(9)
ZK61A is melted in gas-fired or oil-fired crucible-type furnaces. The same steel container should be used for both melting and pouring because of the excessive losses of zirconium if the molten metal is transferred from a melting crucible to a casting crucible. Since losses of zirconium are greater when pre-alloyed ingots are melted, most foundries start with primary magnesium and add zinc and zirconium at about 1450F by plunging them below the surface of the melt. Zinc is added as pure metal and zirconium as a magnesium-zirconium master alloy containing 30-50 percent zirconium or as zirconium tetrachloride salt. Zinc losses are negligible, but zirconium recovery is only about 10-50 percent, depending upon the foundry conditions. About 3 pounds of crucible flux per 100 pounds of metal is used to prevent burning and to trap impurities. This flux is a mixture of magnesium chloride with various other chlorides and fluorides. Since zirconium is an extremely effective grain refiner, no further grain refining treatments are necessary. For pouring, the flux is skimmed from the melt, and a mixture of sulfur and boric acid is dusted onto the surface to prevent burning. The normal pouring temperature is about 1425F. When the molten metal is held below 1400F, zirconium settles out as an insoluble material; above 1500F, however, the alloy tends to absorb iron, which is a detrimental impurity, from the crucible. During melting, therefore, the metal should be brought to 1400F as quickly as possible and held between 1425 and 1475F until poured.

1.09 Special Considerations

1.091 The attainment of fine grain size and associated optimum strength is highly dependent upon the amount of soluble zirconium in the alloy as illustrated in Figure 1.091. This type of zirconium is in solid solution in the alloy rather than distributed in metallic-particle form. The maximum attainable soluble zirconium content is 0.85 percent and the minimum for acceptable properties is about 0.60 percent (1). Good melting practice and temperature control as discussed in Section 1.08 are essential for the production of the proper soluble zirconium content.

1.092 It is essential in producing this alloy that all equipment and scrap metal be controlled to prevent contamination with aluminum, iron, manganese, and silicon. These elements remove zirconium from the melt.

2. PHYSICAL AND CHEMICAL PROPERTIES

2.01 Thermal Properties

2.011 Melting range. 985-1175F (8).

2.012 Phase changes. In the as-cast (F) condition, massive magnesium-zinc compounds occur at the grain

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boundaries, and smaller magnesium-zinc and zirconium-zinc compounds form within the alpha magnesium grains. During solution treatment, most of the compounds go into solution in the alpha magnesium, and they reprecipitate in finely dispersed form during aging (11). If heat-treated ZK61A is held at 250F and above for extended periods, over-aging occurs, during which the precipitates coagulate and grow causing a deterioration of mechanical properties.

2.0121 Time-temperature-transformation diagrams.

2.013 Thermal conductivity. Table 2.013.

TABLE 2.013

Alloy	ZK61A	
Form	Castings	
Source	(8) (12)	
Condition	Temperature, F	Thermal Conductivity Btu ft per (ft^2 hr F)
T6	68	63
All	212-570	51

2.014 Thermal expansion. 14.5 x 10^{-6} per F from 68 to 212F (8).

2.015 Specific heat. 0.25 Btu per (lb F) (approximate) at 78F (13).

2.016 Thermal diffusivity.

2.02 Other Physical Properties

2.021 Density. 0.066 lb per in^3 (8).

2.022 Electrical properties.

2.0221 Electrical conductivity. T6 condition: 27 percent IACS conductivity.

2.0222 Electrical resistivity. T6 condition: 2.52 microhm - inch at 68F (8).

2.023 Magnetic properties.

2.024 Emittance.

2.025 Damping capacity.

2.03 Chemical Properties

ZK61A, like other magnesium alloys, corrodes in industrial, marine, and moist environments. For long-time applications under these conditions, therefore, suitable surface coating is recommended to protect the metal and to insulate contact surfaces from galvanic corrosion. Coated parts are suitable for exposure to all natural environments except continuous immersion in water (14)(15). For a discussion of galvanic corrosion, see Code 3601, Section 2.0312.

2.031 Safety precautions should be directed to the prevention of fires, burns, and explosions. (see HZ32A, Code 3408, Section 2.032)

2.04 Nuclear Properties

3. MECHANICAL PROPERTIES

3.01 Specified Mechanical Properties

Table 3.01.

TABLE 3.01

Alloy	ZK61A					
Form	Castings					
Specification	Type Casting	Cond	Specimen	F_{tu} min ksi	F_{ty} min ksi	e min (2 in)
AMS 4444 A (2)	Sand	T5	Separate cast (single)	39	26	5
			Cut from casting (average 4 or more)	34	24	3
			Cut from casting (single)	30	21	2
ASTM B80-68	Sand	T6	Separate Cast(single)	39	26	5
ASTM B403-67	Invest-ment	T6	Separate cast (single)	40	25	5

3.02 Mechanical Properties at Room Temperature

3.021 Tension.

3.0211 Stress-strain diagrams, Figure 3.0211.

3.0212 Typical tensile properties, Table 3.0212.

TABLE 3.0212

Alloy	ZK61A				
Form	Castings				
Source	(6)(16)(17)				
Type Castings	Condition	Specimen	F_{tu} ksi	F_{ty} ksi	e (2 in)
Sand	F	Separate cast	40	21	11
	T5	Separate cast	41.5	28.5	6.5
	T6	Separate cast	46	30	10
	T6	Cut from castings	41	29	5
Investment	T6	Separate cast	44	29	10

3.0213 Effect of section thickness on tensile properties, Figure 3.0213.

3.0214 Effect of end chill on tensile properties of cast plates of two thicknesses, Figure 3.0214.

3.022 Compression

3.0221 Stress-strain diagrams.

3.0222 Compressive yield strength of castings in different heat-treated conditions, Table 3.0222.

TABLE 3.0222

Alloy	ZK61A	
Form	Sand Cast	
Source	(1)	
Condition	Specimen	F_{cy}-ksi
F	Separate cast	18
T5		25.1
T6		29.2

3.023 Impact.

3.0231 Impact strength of castings in different heat-treated conditions, Table 3.0231.

TABLE 3.0231

Alloy	ZK61A		
Form	Sand Cast		
Source	(1)		
		Charpy Impact, ft lb	
Condition	Specimen	V notch	No notch
F	Separate cast	3.5	20
T5		2.5	14
T6		3.5	18

3.024 Bending.

3.025 Torsion and shear.

3.0251 Shear strength for separate sand-cast test specimens (1).

F condition: F_{su} = 24.5 ksi
T5 condition: F_{su} = 24.8 ksi
T6 condition: F_{su} = 26.5 ksi

3.026 Bearing.

3.027 Stress concentration.

3.0271 Notch properties.

3.0272 Fracture toughness.

3.028 Combined properties.

3.03 Mechanical Properties at Various Temperatures

3.031 Tension.

3.0311 Stress-strain diagrams.

3.0312 Effect of temperature on tensile properties, Figure 3.0312.

3.032 Compression.

3.0321 Stress-strain diagrams.

3.033 Impact.

3.034 Bending.

3.035 Torsion and shear.

3.036 Bearing.

3.037 Stress concentration.

3.0371 Notch properties.

3.0372 Fracture toughness.

3.038 Combined properties.

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3.04 Creep and Creep Rupture Properties

3.041 Effect of temperature on stresses to cause 0.2 percent and 0.5 percent creep in 100 hours, Figure 3.041.

3.05 Fatigue Properties

3.051 Rotating beam fatigue strength of notched and smooth specimens, Figure 3.051.

3.06 Elastic Properties

3.061 Poisson's ratio.

3.062 Modulus of elasticity. All conditions: 6500 ksi (14).

3.063 Modulus of rigidity.

4. FABRICATION

4.01 Formability

4.02 Machining and Grinding

4.021 This alloy, like other magnesium alloys, has exceptionally good machinability, which enables it to be machined at high speeds and feeds (8)(14)(19)(see also HZ32A, Code 3408, Section 4.021).

4.03 Welding

ZK61A has poor weldability in comparison with most other magnesium alloys and is not recommended for use in applications requiring appreciable welding. When welding is required, helium-or argon-gas shielded arc techniques with tungsten or consumable electrode and EZ33A filler metal should be used. A Stress-relieving treatment of 500F for 5 hours is recommended after welding (8)(13)(14)(20).

4.04 Surface Treatment

(see AM100A, Code 3509, Section 4.041 through 4.044)

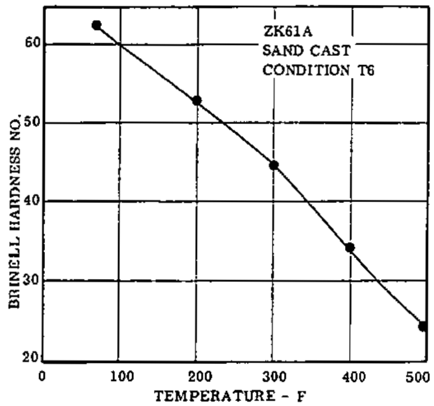

FIG. 1.062 EFFECT OF TEMPERATURE ON HARDNESS. (18)

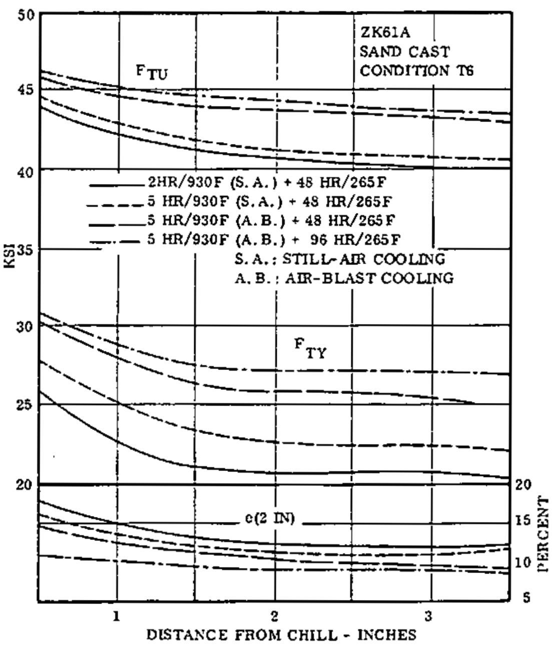

FIG. 1.051 EFFECT OF VARIATIONS IN HEAT TREATING CONDITIONS (SOLUTION TIME, COOLING METHOD, AND AGING TIME) ON THE TENSILE PROPERTIES OF CHILLED CASTING. (4)

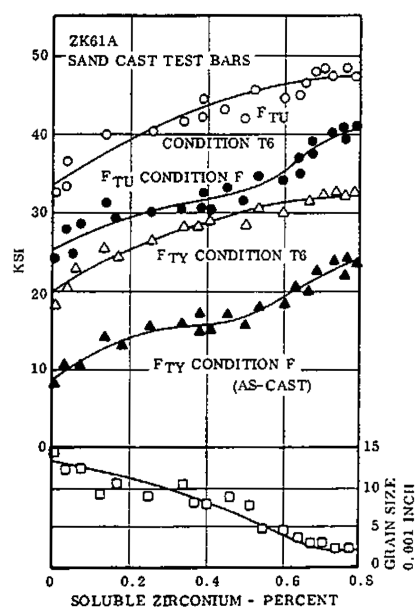

FIG. 1.091 EFFECT OF SOLUBLE ZIRCONIUM CONTENT ON TENSILE STRENGTH AND GRAIN SIZE. (1)(6)(10)

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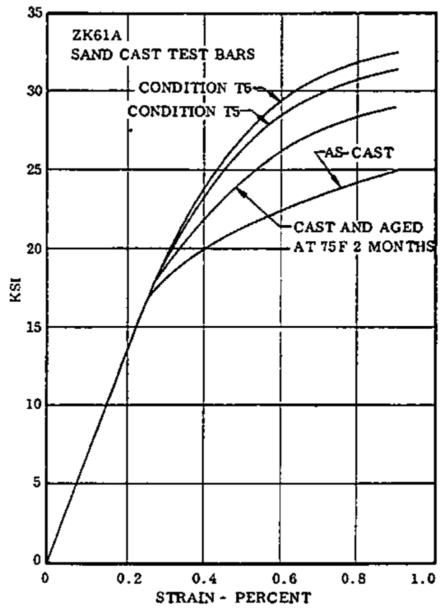

FIG. 3.0211 STRESS-STRAIN DIAGRAMS. (6)

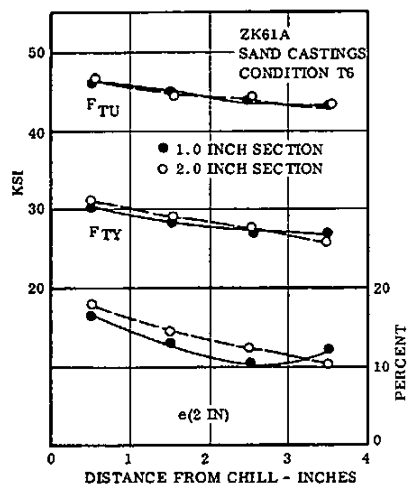

FIG. 3.0214 EFFECT OF END CHILL ON TENSILE PROPERTIES OF CAST PLATES OF TWO THICKNESSES. (4)

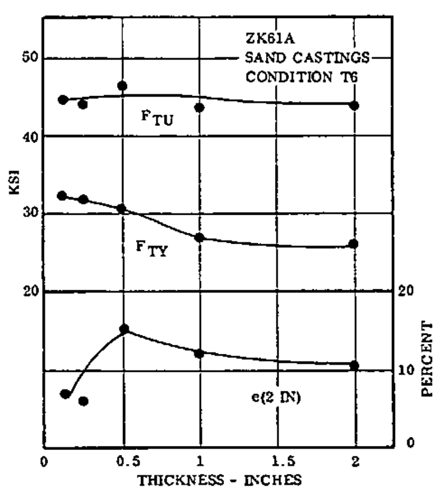

FIG. 3.0213 EFFECT OF SECTION THICKNESS ON TENSILE PROPERTIES. (4)

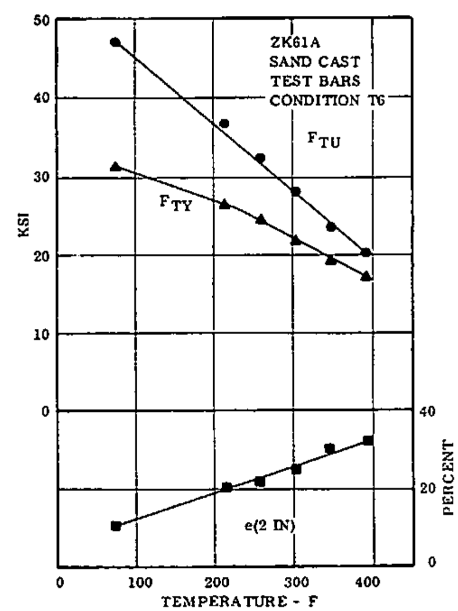

FIG. 3.0312 EFFECT OF TEMPERATURE ON TENSILE PROPERTIES. (1)

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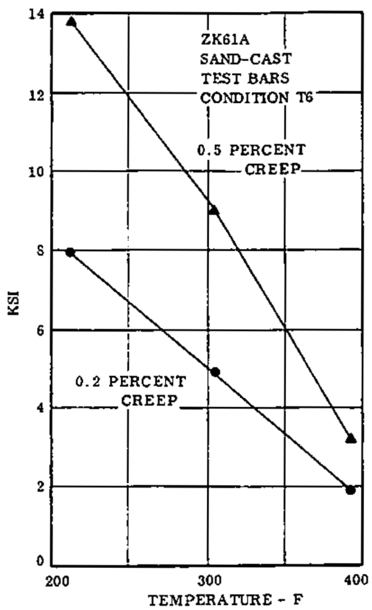

FIG. 3.041 EFFECT OF TEMPERATURE ON STRESSES TO CAUSE 0.2 PERCENT AND 0.5 PERCENT CREEP IN 100 HOURS. (1)

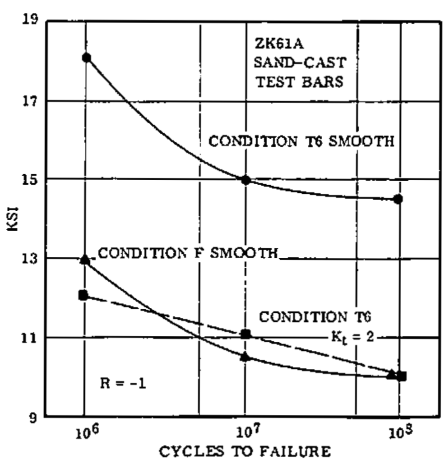

FIG. 3.051 ROTATING BEAM FATIGUE STRENGTH OF NOTCHED AND SMOOTH SPECIMENS. (1)

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