DESIGN STRESS CONSIDERATIONS FOR ZA ALLOYS

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When designing with new materials, it is customary to evaluate tensile properties to determine ultimate design. This procedure is usually adequate for most alloys. However, when zinc alloy designs are under evaluation and are expected to perform under constant tensile load conditions or at elevated temperatures, the creep strength of zinc alloys will be the determining factor for the design. This brochure is intended to assist designers to properly apply the new ZA (zinc-aluminum) alloys in applications where creep properties should be considered.

What Is Creep?

The phenomenon of creep is a process in which plastic flow or deformation occurs when a constant stress is applied to a material for an extended period of time. Creep deformation is a function of temperature, increasing as temperature rises. Creep normally is considered by engineers and designers when a material is used in the temperature range of 0.4 to 0.7 times the melting point (in absolute temperature ^{o}K or ^{o}R). At these elevated temperatures most alloys are in their plastic range and start to elongate slowly at stresses well below their room temperature yield strengths.

The low melting temperatures of zinc alloys which make them attractive, energy-saving casting alloys also makes them sensitive to creep. In comparison to other metals, zinc alloys at room temperature are at a temperature which is within their hot working (plastic) range.

Most designers are aware of the creep limitations of conventional zinc die casting alloys. However, the new ZA (zinc-aluminum) casting alloys offer improved creep strengths for higher strength designs

Design Stress Criterion

To properly apply zinc alloys to both new applications and as substitutes for other alloys in existing designs, a method to compare mechanical properties is required. The ASME Boiler Code allows such a comparison by using a design stress criterion which includes creep performance considerations. The Boiler Code is normally used for design, construction and inspection of boilers and pressure vessels.

At temperatures at which creep is a factor, the Boiler Code design stress is based upon creep rate or stress to rupture at the specified temperature. Thus, the design stress permits a convenient method to compare different alloys which may not be readily compared due to differences in how limiting stresses are determined.

Creep resistance data of the ZA alloys are being determined at three temperatures (20, 100 and 150°C). Examples of results of ongoing creep tests for ZA-27 in the sand cast condition are shown on the back page (Figure 1). These plots of inverse creep rate show the linear relationship between the logarithm of the inverse creep rate and logarithm of stress. By extrapolating this linear relationship to the allowable Boiler Code creep rate, permissible design stresses are determined.

Table I presents zinc alloy design stress data developed from these creep tests. The design stress values are based upon creep strength, specifically the stress which results in a creep rate of 0.01% per 1,000 hours or an inverse creep rate of 100,000 hours per %. This represents the allowable creep rate according to the ASME Boiler Code.

Table II includes design stress data for competitive alloys which have been extracted from the ASME Boiler Code. As can be noted, ZA alloys at room temperature possess design stresses up to three times higher than standard zinc die casting alloy and equivalent to or higher than standard brass, aluminum or cast iron alloys. However, the maximum design stress in tension for the ZA alloys decreases with temperature.

It should be remembered that many applications do not impose constant stress at elevated temperatures and creep may not be the limiting design factor. Design stress does allow another type of comparison between the mechanical properties of casting alloys and should be used in conjunction with good part design practice and a complete knowledge or part application.

TABLE I: MAXIMUM ALLOWABLE DESIGN STRESS IN TENSION FOR ZINC AND ZA ALLOYS ACCORDING TO THE ASME BOILER CODE

ALLOY	Design Stress MPa (lb in $^{-2}$)* Secondary Creep Rate of 0.01% in 1,000 h		
	20°C (68°F)	100°C (212°F)	150°C (302°F)
ZA-8 (permanent mold)	>70 (10,000)	U.R.*****	≃4 (600)
ZA-8 (pressure die cast)	>70 (10,000)	≃7 (1,000)	—
ZA-12 (sand cast)	>70 (10,000)	≃9 (1,300)	≃3.5 (500)
ZA-12 (permanent mold)**	>70 (10,000)	—	—
ZA-12 (pressure die cast)	>70 (10,000)	—	—
ZA-27 (sand cast)	>70 (10,000)	≃10 (1,500)	≃5 (750)
ZA-27 (sand cast & homogenized)***	>95 (14,000)	≃12 (1,700)	≃5.5 (800)
ZA-27 (sand cast & stabilized)****	>90 (13,000) —	—	U.R.***** —
ZA-27 (pressure die cast)	>70 (10,000)	≃7 (1,000)	—
Die Cast Alloy #3	≃20 (3,000)	NIL	NIL

* Most results are estimates based on extrapolated data which must be supported by further experimentation.

** Two tests conducted at room temperature with permanent mould test pieces gave similar creep rates to the sand cast test pieces.

*** Homogenized for 3 h at 320°C (608^{0}F), followed by furnace cooling.

**** Stablized for 12 h at 250°C (482^{0}F), followed by furnace cooling

***** Under review.

— Data not available.

TABLE II: MAXIMUM ALLOWABLE DESIGN STRESS IN TENSION FOR COMPETITIVE FOUNDRY ALLOYS ACCORDING TO THE ASME BOILER CODE

ALLOY	Design Stress MPa (lb in $^{-2}$)
Brass Alloy 85-5-5-5 (CDA-836)	52 (7,500) at temp. not exceeding 120°C (250°F) 47 (6,800) at temp. not exceeding 230°C (445°F)
Aluminum Alloy 356-T6	52 (7,500) at temp. not exceeding 85°C (185°F) 43 (6,300) up to 120°C (250°F)
Cast Iron Grade 30	21 (3,000) at temp. not exceeding 250°C (480°F)

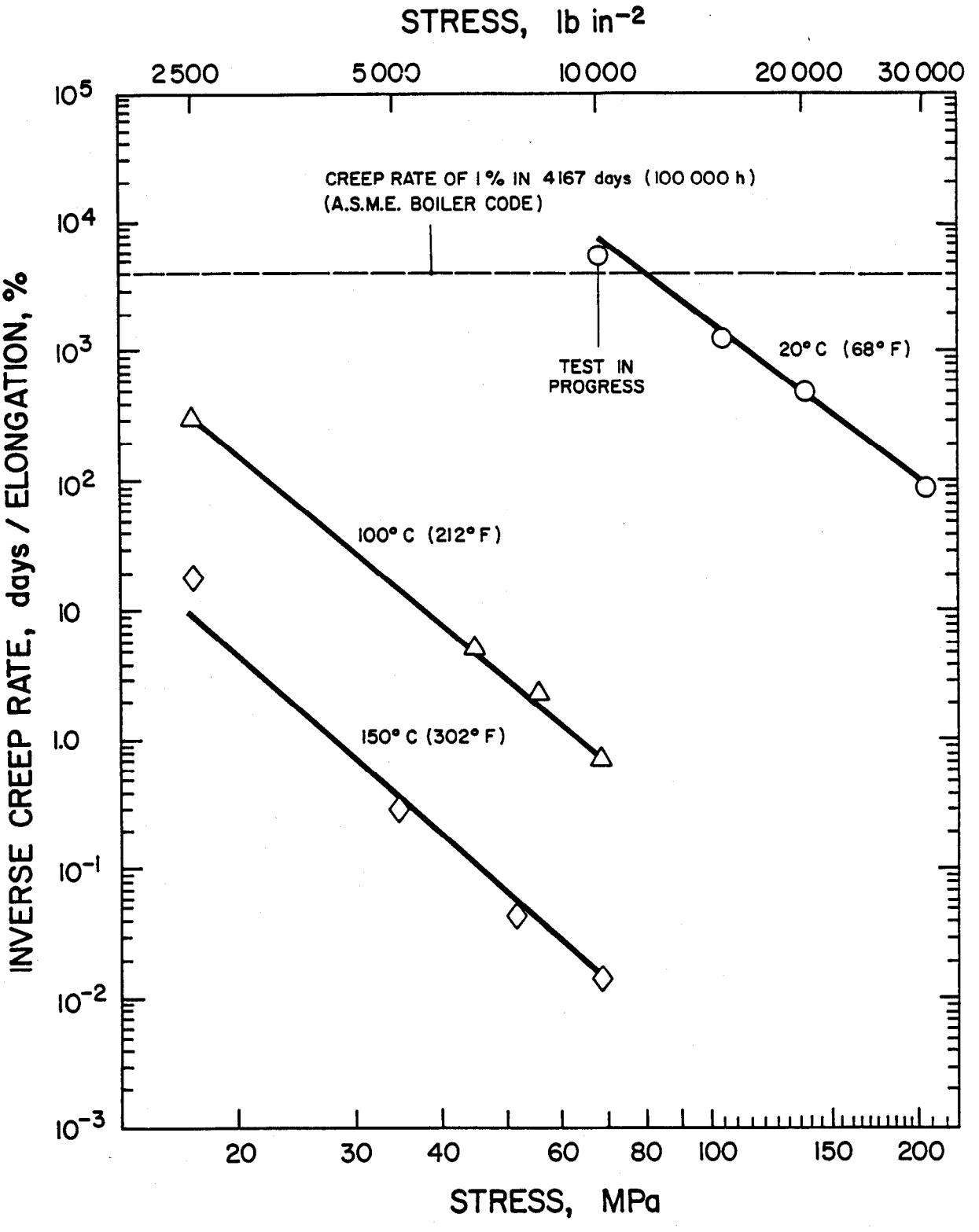

Figure 1 - Secondary creep rate of the sand-cast ZA-27 alloy as a function of load and temperature.

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