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Short communication

Influence of defects on strength of industrial aluminum alloy Al–Si 319

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Abstract

The effect of cooling rate, chemical composition, and type of heat treatment and microstructural architecture of cast Al–Si 319 industrial alloy has been quantified using the cumulative Weibull distribution. This allows a particular figure to quantify the spread of the data with the Weibull modulus. Modulus was found to vary from 12.47 to 68.64, and characteristic life was found to vary from 201.48 to 347.89 MPa depending on processing conditions of material.

Fractographic examination of the castings showed tangled networks of oxide films, which are actually cracks in the casting. Oxide films are normally observed in the fracture surfaces of the specimens. The mechanical properties depends primarily of defects population instead other factors.

Keywords: Oxide film; Cooling rate; Weibull; Heat treatment; Mechanical properties; Industrial aluminum alloy

1. Introduction

Many liquid metals has a lot of solid phases floating in the liquid this behavior not corresponding to any simple liquid unless solid–liquid mixture whose viscosity properties are very different. The knowledge of internal structure of liquid metal with solid phases has grown in the last years in agreement the detection techniques are improve. In the aluminum alloys has concentrated the most effort. It's reasonable to propose that many mechanical and fatigue properties values can be explained considered that the liquid metal it's the source of solidification structure contain a lot of aluminum oxides films impurities. The classic mechanic metallurgy and the solidification theory that are considered this alloys like pure metal, another way are homogenous materials, isotropic and continuous [1,2], actually there are unable to explain certainly experimental remark in the foundry alloys. This phenomenon can explain better if considerer that defects may form since liquid metal. The foundry aluminum alloy forms a self protecting film when their surfaces it exposes at the atmosphere that contain oxygen behold here oxides films [3].

Recently research confirm the effect of casting defects over mechanical properties specially in aluminum foundry [3–7] G.E. Byczynski y J [8]. Campbell asserts that casting defect like oxide film act like crack and reduces the strength in tension specimens. N.R Green & J. Campbell [4] using Weibull distribution to quantified the effect of filling design and they found that strength distribution is controlled by the runner system design. Use of runner system that promoted the formation of large amounts of defects produced casting with Weibull modulus in the range 11–22. The use of runner system designed to minimize surface turbulence produced castings with Weibull modulus in the range 38–54. Campbell [4] concludes that porosity beginning and decreased of mechanical properties are caused by a lot of amounts of casting defects and principally by bi-films, (entrapped oxides film) cause by turbulent filling. Another research carried by Emany and col. [9] to study the effect over the performance of filling design in the UTS (ultimate tensile strength) conclude that improve the filling design the Weibull modulus grow until value of 50. Fracture surface analysis of specimens with new design filling rarely

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show presence of oxides films, moreover the specimens with traditionally filling systems show a lot of quantities of oxides films in combination with the typical porosity. L.W. Huang and col. [10] have maintain during casting of 356.2 alloy in permanent molds has possibility to break the surface and trap oxides films.

Naturally the presence of defects has a measure scatter of mechanical properties. For this reason many statistical techniques has been using to analyze the data distribution. The data distributions more apply are: Normal, Log Normal, Extreme Value, Exponential, Beta, Uniformed, Rayleigh, Poisson and Weibull. Also can use mathematical equations to describe the distribution data in a specific property, though they intend to correlated those techniques with real fracture mechanic, the majority of them are empirical relations of a brief data description.

In general the failure on metals properties are described by Weibull distributions. There are many reasons to this. Although the original formula was due to Weibull in 1951, originally was a purely mathematical description scatter, later improved by Khalili and Kromp [11] it was Jayatilaka and Trustrum in 1977 who explained that the formulation arose from properties of flaw size distribution randomly inclined cracks. The strength distribution was accounted for by the probability of brittle fracture from the most severe defect, taking account of size and orientation. It was a sophisticated development of the "weakest link concept".

In materials research, Weibull analysis was originally used almost exclusively for ceramics and glasses. The work by Green and Campbell (1993 and 1994 [4]) illustrated the usefulness of this approach to casting.

The slopes of the Weibull plots are a measure of the reproducibility of the data and are known as the Weibull modulus m. This parameter more important than the position parameter (or average strength σ).

The dispersion of mechanical properties values was a consequence of presence of defects [12]. For this reason many statistics techniques has been using to analyze the data distribution, but it's the Weibull distribution whom came in the most widely use function. The two-parameter is the more simple form of Weibull equation:

$$P_f = 1 - \exp\left[-\left(\frac{\sigma_f}{\sigma_c}\right)^m\right], \quad (1)$$

where P_f statically fraction of specimens that failed at given stress or lower; σ_f ultimate tension stress UTS ; σ_c average fracture tress when 63.2% of specimens have failed;m shape parameter or Weibull modulus.

For other way to began of analysis over aluminum casting, it's necessary to affirm that this found full of defects oxides films principally originated from liquid metal. When analysis the oxides film phenomenon into aluminum melt, it is important emphasize that the size of the film which was originally in contact with the melt will continue to be well wetted, i.e. it will be in perfect atomic contact with the liquid. As such it will adhere well, and be an unfavorable nucleation site for volume defects such as cracks, gas bubbles or shrinkage cavities. When the metal solidifies the metal–oxide bond will be expected to continue to be strong, as in the perfect example of the oxide on the surface of all solid aluminum products like SAP (sintered aluminum powder) and especially noticeable in the case of anodized aluminum. Nevertheless, in contrast the side of film that originally has in contact to the air will have a gas superficial layer. Firstly, the oxides are usually wetted with the metals with certainly strength. Second, the microscopic superficial wrinkled of oxide film help to additional gas retention in their cavities. Thirdly, if the film is bended dry side to another dry side, probably air entrapped between two sides. This is the air film (another gas) associated with the oxide it is very detrimental. The layer gas it's a discontinuity, another words, and acts as a crack [13] Table 1.

Table 1
Types of inclusions in Al alloys [13]

Types of inclusions in Al alloys		
Inclusion type		Possible origin
Carbides	Al_4C_3	Pot cells from Al smelters
Boro-carbides	Al_4B_4C	Boron treatment
Titanium boride	TiB_2	Grain refinement
Graphite	C	Fluxing tubes, rotor wear, entrained film
Chlorides	NaCl, KCl, $MgCl_2$, etc.	Chlorine of fluxing treatment
α Alumina	α-Al_2O_3	Entrainment after high-temperature melting
γ Alumina	γ-Al_2O_3	Entrainment during pouring
Magnesium oxide	MgO	Higher Mg containing alloys
Spinel	MgO–Al_2O_3	Medium Mg containing alloys

2. Experimental

The chemical composition of the industrial alloy 319 used to produce engine blocks show in Table 2. Fig. 1 show

Table 2
Show the chemical composition of alloy used in this experimentation

Alloy 319 Elements	% wt
Si	8.5–8.8
Cu	3.8
Fe	máx 0.50
Mn	máx 0.30
Cr	máx 0.05
Mg	máx 0.36
Ni	0.023
Zn	0.55–0.56
Pb	0.015
Sr	120 ppm
P	0.0025–0.0027
Sn	0.012
Ti	0.127
Al	Balance