EVALUATION OF FATIGUE LIMIT FOR ALUMINIUM ALLOYS BY ULTRASONIC MEASURING

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Abstract : *The evaluation of fatigue limit -* σ_{-1} *for* AlSi7Mg, AlCu6Mn *aluminum alloys is frequently encounter in material testing. In this method there is necessity of manufacture of test-tube from tested material or detail and made tension test.. There is destructive method. For many details there is not acceptable. Calculated in the usual ways fatigue limit appear only their statistical averaging between a number of structural factors indicating the influence. In material testing there is interest to non-destructive evaluation of fatigue limit* σ_{-1} *for the specimens and details. In this paper is lock at possibility for non-destructive evaluation of fatigue limit* σ_{-1} *by means measure velocities of propagation of longitudinal and transversal ultrasonic waves -* V_L *and* V_T *in tested materials and details.*

KEY WORDS: NON-DESTRUCTIVE EVALUATION OF FATIGUE LIMIT, ALLUMINIUM ALLOYS, VELOCITIES OF PROPAGATION OF ULTRASINIC WAVES

1.Introduction

Destruction of fatigue in aluminum alloys can occur in an area of elastic deformation. Even adding modifiers and higher plastic limit leads to destruction without structural changes and a clear boundary-σ_{-1}. Under the action of cyclic stresses brittle fracture occurs. Fatigue of material, ratio is dependent on the dimensions of the dendrites (Solid solution of Si in Al).

2. Structure of aluminum castings alloys and ultrasound

Aluminum alloys AlSi7Mg, AlCu6Mn have a structure shown in Figure 1. There are α-matrices and Si eutectic in the form of fiber in inter dendritic field. Phases of Gine-Preston after heat treatment of Mg_2 Si, θ-Al_2Cu. By the relationship (1) are defined: Grain size-$\overline{D_{Al}}$: about AlSi7MgSr [Popov] .It was receive (24 ÷ 35) µm and silicon eutectic - (1,2 ÷ 4,0) µm. . It is AlCu6Mn alloy, the grain size $\overline{D_{Cu}}$ is in the range (29,03÷132,86)µm. The relationship between $\overline{D_{Al}}$ and acoustic characteristics $(V_L;V_T;\alpha_L)$ is [1]

(1) $$W(V_L;V_T).f^4.\left(\overline{D_{Al}}\right)^3-\alpha_L=0$$

where $W(V_L;V_T)=\dfrac{4.\pi^2}{1125}\dfrac{V_T^4}{V_L^3}\left(\dfrac{2}{V_L^5}+\dfrac{3}{V_T^5}\right)$ and $(V_L;V_T;\alpha_L)$ is respectively longitudinal and transversal velocity and attenuation in ultrasonic wave propagation ASTM E 494: 2010.

3.Empirical correlations

The materials science used to dependence. [2]

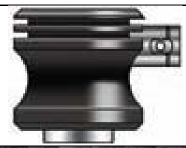
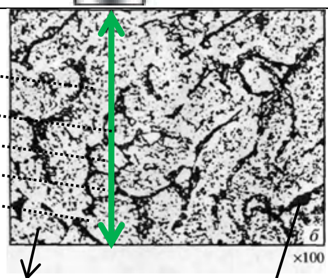
US sensor	
K=1 K=2 K=3 K=4 K=5 $\overline{D_{Al}}=\frac{1}{5}\sum_{k=1}^{5}D_K$ $\overline{D_{Al}}$ - average value of dendrites	 α 's dendrites - (Al solid phase). Eutectic at grain boundaries-$(Al+Si)$ Microstructure of AlSi7Mg, AlCu6

Fig.1.

(2) $$\sigma_{-1}\approx 0.19HB$$

where: *HB* is Brinell's hardness.

This article consider the microstructure's factors as to destruction of fatigue. The fatigue of the grain size-D_{Al} of the Al- phase. In literature [3] is given depending $\sigma_{-1}\left(\overline{D}\right)$. It is shown explicitly.

(3) $$\sigma_R=\sigma_{iR}+K_R.\left(\overline{D}\right)^{-1/2};\ R=-1$$

where $\sigma_{iR};K_R$ - material constants. To obtain explicit constants in (3) for cast aluminum alloys AlSi7MgSr, AlCu6Mn considering the relationship:
a) Hol-Petch's relstionship [4]

(4) $$\sigma_S=\sigma_0+K_y^{(Al)}\left(\overline{D}\right)^{-1/2}$$

where: $\sigma_0^{(Al)}$ =50MPa $K_y^{(Al)}$ =8.5 MPa.mm$^{1/2}$.

b) From Solution of Businesq's problem [5]

(5) $\tau_{\max} \approx \varphi(\nu)HB$

where $\nu = \dfrac{0.5-(V_T/V_L)^2}{1-(V_T/V_L)^2}$;

$$\varphi(\nu)=\left\{\frac{1}{2}(1-2.\nu)+\frac{2}{9}(1+\nu).[2.(1+\nu)]^{1/2}\right\}$$

c) Tresca's condition for plasticity [2]

(6) $\tau_{\max} = \sigma_S/2$

Therefore there is relstionship

(7) $\sigma_S \approx \varphi(\nu)HB$

4. Derivate ot relationship $\sigma_{-1}\left(\overline{D_{Al}}\right)$

From equations (2) and (7) follows $\dfrac{\sigma_{-1}}{\sigma_S} = \dfrac{0.19HB}{\varphi(\nu)HB} = 0.19\varphi^{-1}(\nu)$ and therefore

(8) $\sigma_S = \dfrac{\sigma_{-1}}{0.19\varphi^{-1}(\nu)}$

After substitution (8) in (4) it was obtained

$\dfrac{\sigma_{-1}}{0.19\varphi^{-1}(\nu)} = \sigma_0^{(Al)} + K_y^{(Al)}\left(\overline{D_{Al}}\right)^{-1/2}$ and

(9) $\sigma_{-1} = \tilde{\sigma}_0^{(Al)} + \tilde{K}_y^{(Al)}\left(\overline{D_{Al}}\right)^{-1/2}$

where $\tilde{\sigma}_0^{(Al)} = \dfrac{0.19\sigma_0^{(Al)}}{\varphi(\nu)}$; $\tilde{K}_y^{(Al)} = \dfrac{0.19K_y^{(Al)}}{\varphi(\nu)}$

5.Conclusion

In this paper the relationships (7) $\sigma_S \approx \varphi(\nu)HB$ and (9) $\sigma_{-1}\left(\overline{D_{Al}}\right)$ are obtain.

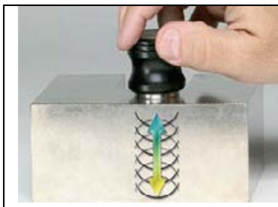
The material constants in (9) are $\sigma_{iR} \equiv \tilde{\sigma}_0^{(Al)}$ and $K_R \equiv \tilde{K}_y^{(Al)}$. Because there is $\nu = \nu(V_L;V_T)$ then coefficients are

$\tilde{\sigma}_0^{(Al)} = \tilde{\sigma}_0^{(Al)}(V_L;V_T)$; $\tilde{K}_y^{(Al)} = \tilde{K}_y^{(Al)}(V_L;V_T)$.

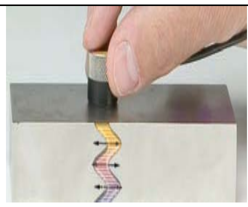
It is non-destructive evaluation of material constants. σ_{iR}; K_R.

6.Измерване на V_L и V_T

За измерване на величините V_L и V_T се използват ултразвукови осезатели с пиезопластини (ПП) X - срез и фиг.2., Y- срез, фиг.3. на ф-ма PANAMETRICS – САЩ



Фиг.2.



Фиг.3.

За измерване на величините $t_{L,T}, \mu s$ се използва ултразвуково устройство US Key (ф-ма LECOEUR ELECTRONIQUE, Франция). Точността на измерване на времето на $t_{L,T}, \mu s$ е 0.01 μs .

Фиг.4.

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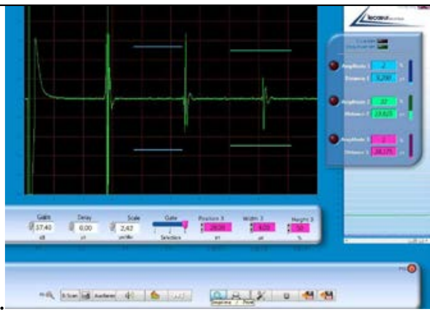

Фиг.5.

Микрометър Digimatic Micrometer (MITUTOYO, Япония). Обхват 0-30 mm. Този микрометър, единствен в света, измерва с точност на отчета 0.0001 mm и точност на измерването $\Delta S \pm 0.5\mu m$.

Величините V_L и V_T се изчисляват от зависимостите, съгласно ASTM E 494-2010

(10) $$V_{L,T} = \frac{2.l, mm}{\left(t_{L,T}\right), \mu s}$$

където l, mm - делелина на измервания образец, $t_{L,T}, \mu s$ - сътветно времена на разпространение на надлъжни и напречни ултразвукщови вълни. Използвя се доверителен интервал за $V_{L,T}$ е [3]

(11) $$\overline{V_{L,T}} \pm \left(\frac{1}{n}\right)^{1/2} T(n;\alpha) S_{V_{L,T}}$$

Използва се толерантнен интервал за $V_{L,T}$ е [3]

(12) $$\overline{V_{L,T}} \pm \left(1 + \frac{1}{n}\right)^{1/2} T(n;\alpha) S_{V_{L,T}}$$

Където $\overline{V_{L,T}}$ и $S_{V_{L,T}}$ са съответно средна стойност и стандартно отклонение за измерената скорост, n – брой на измерванията, $T(n;\alpha)$ - разпределение на Стюдънт при вероятност $\Pr = 1 - \alpha$.

7.Literature

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