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ARTICLE

A New Study on the Superplasticity of TiAl Alloys

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ABSTRACT

The superplasticity of Ti-46.7Al-2.2Cr(at.%) alloy was studied by mathematical induction. It is found that Zener Hollomon relative formula and there are serious deflections. According to the true superplastic stress and true strain curves, the deflection values of n=-7.46 and B=1439MPa are obtained, indicating that the limit of n>0 has been exceeded, which needs to be characterized by a negative sign. This shows that it conforms to the principle that the smaller n is, the better superplasticity is, but the problem that it has become a negative number needs to attract the attention of peers meantime B is a better match.

1. Introduction

Superplasticity is a significant phenomenon in TiAl. The n and B is usually determined with Zener Hollomon formula. [1] 0<n<1 is the scope of n. But it can not be represented according to formula. So in this paper it is investigated that the n and B in terms of Boyun Huang et al [2] experiment on TiAl superplasticity behavior. It is calculated that n and B is from the modeling which is adopted with their experimental data. n and B will become small when the superplasticity is taken according to new finding [3]. But n is small and B is normal which is acquired in this paper. So n is fitting to finding. Because the n and B is important in superplasticity research due to its true stress and true strain relationship. Not only from experimental value but also from parameters can we control and utilize it. So that these parameters feature need to be found for us to use them practically. Only this can we finally solve our difficulties to wield superplasticity function to meet our high elongation needs. For instance to aircraft it will be applied from one hand. On the other hand to spacecraft it will be applied too due to its excellent property. It is hoped that this study satisfies to search parameters of superplasticity on Ti-33Al-3Cr(wt.%) in this paper.

2. Modeling

According to

$$\sigma = K\varepsilon^n \quad (1)$$

takes (1) to natrural logarithm

$$LN\sigma = LNK + nLN\varepsilon \quad (2)$$

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takes random two points coordinate

$$LN\sigma_1 = LNK + nLN\varepsilon_1 \quad (3)$$

and $LN\sigma_2 = LNK + nLN\varepsilon_2$ (4)

From above two formula it is gained

$$n = \frac{LN\left(\frac{\sigma_1}{\sigma_2}\right)}{LN\left(\frac{\varepsilon_1}{\varepsilon_2}\right)} \quad (5)$$

And

$$K = EXP\left[LN\sigma_2 - \frac{LN\left(\frac{\sigma_1}{\sigma_2}\right)}{LN\left(\frac{\varepsilon_1}{\varepsilon_2}\right)}LN\varepsilon_2\right] \quad (6)$$

Here B=K is strength coefficient; n is work hardening exponent. Two points were measured through the curve in reference that is the true stress and strain curve causing the super plastic behavior in TiAl allloys. We supposed that these two points coordinates are 1 and 2 as above.

3. Discussion and Conclusions

The Zener Hollomon formula and the relative formula are the series formulas. [1] the feature values of n=-7.46 and B=1439MPa are obtained by taking points from the experiment [2] and calculating the above model, indicating that the limit of n>0 has been exceeded, which needs to be characterized by a negative sign. This shows that it conforms to the principle that the smaller n is, the better superplasticity is, but the problem that it has become a negative number needs to attract the attention of the material research colleagues. Here 0<n<1 is the normal value, and the negative value of n indicates that it has exceeded the calculation limit and is a negative partial value. What that means is that when n goes down to zero and then goes down to minus 7 that's the superplasticity value. It indicates that the superplasticity has exceeded the limit capacity, and only the negative value is its choice, and the greater the negative value indicates that the greater the superplasticity value and the better the superplasticity. Here the strain is selected as 1.85, while the stress is 29MPa. This is n at this fracture value. B is 1439 which is a little bit larger. It is not clear why B value is too high, but B value is reasonable.It is found that B value is inferior to n value in superplastic deformation. According to Boyun Huang et al., the temperature was 1025 ℃ and the strain rate was 2×10^{-4} / s. The fine grain diameter of the experimental structure was 2-3μm and the composition was Ti-46.7%Al-2.2%Cr (atomic fraction). As shown in Table 1 the parameters is listed for instance σ_1、ε_1 and σ_2、ε_2 to calculate the parameters n and K according to Modeling above. Although it has little value when the plasticity becomes big according to the reference research it may be had some reason. For example if superplasicity happens it may follow its intrinsic feature as for these two parameters. As for B according to other reference there is some normal value in the same to superplasticity in Ti_3Al alloys which directional tensile strain reaches about 300%. So it is supposed that the phenomenon of normal B is affected by its intrinsic substance. It shall be further researched to investigate in detail. If B behavior is investigated detail the intrinsic feature will be cleared and clarified in the end.

Table 1. The parameters n and K with σ_1、ε_1 and σ_2、ε_2 in TiAl

Items	ε_1	ε_2	σ_1	σ_2	n	K/MPa
value	1.85	1.47	29	77	-7.46	1439

Now we take a way to calculate the atomic fraction as mentioned above on mass fraction of Ti-33Al-3Cr. It is Supposed that:

Ti-XAl-YCr is in atomic fraction. X is Al and Y is Cr atomic fraction respectively. So Ti fraction is 100-X-Y. Accordin to atomic fraction equivalence it has:

$$\frac{33/27}{64/48} = \frac{X}{100 - X - Y} \quad (7)$$

and

$$\frac{3/52}{33/27} = \frac{X}{Y} \quad (8)$$

From (8) it is gained that

$$Y\text{=}0.047X \quad (9)$$

To substitute (9) into (7), it gains

$$X\text{=}46.7 \quad (10)$$

To replace (7) or (8) with (10), we gain

$$Y\text{=}2.2. \quad (11)$$

So the final content of this alloy is Ti-46.7Al-2.2Cr(at.%).

Here atomic weight Ti=48, Al=27, Cr=52.

4. Conclusions

In the superplasticity experiment, when the fracture strain

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is 1.85 and fracture stress is 29MPa, n is -7.36, and the negative value indicates that n is the inverse value, that is, the minimum value. The superplasticity has exceeded the limit capacity, and the great negative value indicates that the greate superplasticity value. B is a relatively normal value of 1439MPa, which is a certain high value for Ti-33Al-3Cr(wt.%) alloys. It is supposed that B is normal generally and affected by its intrinsic substance.

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