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Effect of β/α Strength Ratio on the Stress-Strain Curve of Beta Titanium Alloy by Finite Element Modelling

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Abstract - A systematic study was undertaken to determine the effect of the β/α strength ratio on the stress-strain behavior of near beta titanium alloy by the finite element method where the volume percent of the second phase was constant at 16 vol.%. The β/α strength ratio of the harder β phase to the softer α phase was varied from approximately 4 to 5 where the α phase strength (0.2% YS) was kept constant at 296 MPa. It was found that the flow stress did not vary linearly with the strength ratio. Stress gradients were found in both α and β phases and the nature of the stress gradient was found to depend on α particle shape. In some locations higher stresses were found in near the interface. In β , the stresses were generally higher near the interfaces.

Key words - Finite element method; titanium alloy; stress-strain distributions.

I. INTRODUCTION

Many technologically important materials consist of two or more ductile phases among which titanium alloys are an important class. To improve the properties of titanium alloys, or to develop a material with improved properties it is necessary to understand the deformation behavior of the titanium alloys in terms of the volume fraction, morphology and strength of the component phases. There is a lack of understanding in this area. This is due to the fact that whenever a two-phase material is subjected to stress, the component phases deform differently resulting in inhomogeneous stress and strain distributions.

Many investigators studied the deformation behaviour and stress distributions of materials consisting two ductile phases. Poech et al. [1] studied the deformation of two phase materials by using strain compatibility model and obtained a good agreement with experiment results for two-phase microstructures consisting of WC and Co and of martensite and austenite. Ankem and Margolin [2-4] calculated the stress and strain distributions of two-phase materials where the strength ratio of the harder phase to the softer phase was 3. S. Neti et al. [3] investigated the effect of strength ratio and volume fraction of the secondary phase on the deformation behaviour of two-phase materials. Hai-feng Dong et al. [5] simulated the stress-strain curve of low Si-Mn-Nb dual-phase steel and based on the FE model, the author analyzed the micro stress and micro strains.

The aim of these investigations was to study the stress and strain distributions as a function of the strength difference between the phases. Both the longitudinal and the transverse stress distributions were studied.

II. FINITE ELEMENT MODELING

The ANSYS program which is based on the finite element method (FEM) [6] principles was used to calculate the stress-strain behaviour of near beta Ti alloy (Ti-10V-4.5Fe-3Al). In order to simulate the stress-strain curve, the stress-strain curves individual phases (Figure 1) are required. The stress-strain curve of β is obtained from the experimentation according to ASTM standards, where as the stress-strain curve is obtained from the literature [7].

Fig. 1: Stress-strain curves of individual phases (α & β)

Fig. 2 : Microstructure of beta phase.

The microstructure of full beta phase is obtained with the help of optical microscope and it is shown in the Figure 2. It consist of beta grains and it is solution treated at 1000 °C, soaked for 1 hour and then water quenched.

A. Effect strength ratio (β/α)

To study the effect of strength ratio on the stress-strain curve of near beta Ti alloy (α is constant at 16% volume fraction), the beta curve is changed and the alpha curve is kept constant at 296 MPa. In the Figure 1, the strength ratio is 4.52 and in this study it varied to 4 and 5. ANSYS software is used to develop the FEM model consist of 582 traingular elements which are connected by 1201 nodes. The Figure 3 shows the FEM model, green elements represents β phase and violet elements represents α phase. The volume fraction of α phase elements is 16%.

Fig. 3 : FE Model (α is constant at 16%)Table 1. Input parameters (β phase) for modeling.

	Strength Ratios		
	4	4.54	5
Strain	Stress (MPa)	Stress (MPa)	Stress (MPa)
0	0	0	0

0.015	1045	1187	1306
0.02	1089	1231	1350
0.05	1053	1195	1314
0.1	1039	1181	1300
0.15	1028	1170	1289
0.2	1014	1156	1275

Table 1. shows the data (Figure 4) which is used in modeling to get the strength ratio effect on the stress-strain curve.

Fig. 4 : Stress-strain curves of beta phase at different strength ratios.

To analyse the distributions at the interface and also to study the effect of α particle shape on the stress and strain distributions by using below FE Model (Figure 5). In this model the α is taken like single particle with varying shape. In this case also the volume fraction of α is 16%.

Fig. 5 : FE Model (all α is considered single particle)

III. RESULTS AND DISCUSSIONS

A. Effect strength ratio (β/α) on the stress strain curve

After simulating the results, the stress-strain curve is calculated at each strength ratio and compared. The Figure 6 shows the comparison between stress-strain curves at different strength ratios. It is observed that the yield strength increases with the increase in strength ratio and it is nonlinear. The stress-strain curve shifts upwards in the graph with the increase in the strength ratio. The reason behind this change is the beta phase is stronger than that of the α phase. Figure 6 shows the distribution of stress at displacement of 0.1 mm for different strength ratios.

(a)

(b)

(c)

Fig. 6 : Distribution of first principle stresses at a displacement of 0.1 mm load (a) at strength ratio of 4, (b) at strength ratio of 4.5 and (c) at strength ratio of 5

(a)

(b)

(c)

Fig. 7: Distribution of first principle total strains at a displacement of 0.1 mm load (a) at strength ratio of 4, (b) at strength ratio of 4.5 and (c) at strength ratio of 5

From the Figure 6 it is clearly observed that the stress increases with the increase of strength ratio in β phase and it is non uniform. It also observed that the stress is more in beta phase as compared with the stress in the α phase. Similarly the Figure 7 shows the distributions of total strain at a displacement of 0.1 mm. From the Figure 7 it is observed that the strain in α phase increases with the increase of strength ratio.

(a)

(b)

Fig. 8 : Distribution of stresses at a section A (top) (a) longitudinal stress (b) transverse stress.

(a)

(b)

Fig. 9 : Distribution of stresses at a section B (bottom)
(a) longitudinal stress (b) transverse stress.

Fig. 10 : Comparison of stress-strain curves at different strength ratios.

Figure 8 and 9 shows stress distribution at sections A and B respectively. It is observed that the stress in α is low as compared with that of stresses in the β phase. In β phase the stress is decreasing away from the interface, where as in some cases the stress is high in middle and some other cases the stress is high near the interface in α phase. The variation of stress is because of the change in shape of the α particle.

IV. CONCLUSIONS

From these investigations the following conclusions can be drawn:

1. The yield stress increases with the increase of strength ratio and it is nonlinear.
2. The distributions of stress in both the bases are non uniform and stress gradient exist in both the phases.
3. The stress increases with the increase of strength ratio in β phase, where as the strain increases with the increase of strength ratio in α phase.
4. The stresses in β are high as compared to the stresses in α phase and the strain is more in α phase as compared to the strain β phase.
5. In β phase the stress is decreasing away from the interface, where as in some cases the stress is high in middle and some other cases the stress is high near the interface in α phase.

REFERENCES

- [1] M. H. Poeh and H. F. Fischmeister, Deformation of two-phase materials: a model based on strain compatibility," *Acta metall, mater.* Vol. 40, No. 3, pp. 487-494, 1992.
- [2] Sreeramamurthy Ankem and Harold Margolin, "Finite Element Method (FEM) Calculations of Stress-Strain Behavior of Alpha-Beta Ti-Mn Alloys: Part I. Stress-Strain Relations," *Metallurgical Transactions A*, Volume 13a. April 1982 595-601.
- [3] S. Neti, M. N. Vijayshankar and S. Ankem, "Finite element method modeling of deformation behavior of two-phase materials part II: stress and strain distributions," *Materials Science and Engineering:A*, Volume 145, Issue 1, 25 September 1991, Pages 55-64.
- [4] J. Jinoch and S. Ankem, *Mater. Sci. Eng.*, 34, 1978, pp. 203.
- [5] Hai-feng Dong, Jing L, Yue Zhang, Joongkeun Park, and Qing-xiang Yang, "Numerical simulation on the microstress and microstrain of low Si-Mn-Nb dual-phase steel," *International Journal of Minerals, Metallurgy and Materials*, Volume 17, Number 2, April 2010, Page 173-178.
- [6] Y. Nakasone, S. Yoshimoto, and T. A. Stolarski, *Engineering Analysis With ANSYS Software*. Elsevier Butterworth, 2006.
- [7] ZHAO Xiqing, ZANG Xinliang, WANG Qingfeng, Park Joongkeun, and YANG Qingxiang, "Numerical simulation of the stress-strain curve and the stress and strain distributions of the titanium-duplex alloy", *Rare Metals*, Vol. 27, No. 5, Oct 2008, p. 463-467.