Available online at www.sciencedirect.com
ScienceDirect
RARE METALS
RARE METALS, Vol. 27, No. 5, Oct 2008, p. 463

Numerical simulation of the stress-strain curve and the stress and strain distributions of the titanium-duplex alloy

ZHAO Xiqing[a], ZANG Xinliang[a], WANG Qingfeng[a], Park Joongkeun[b], and YANG Qingxiang[a]

[a] *Key Laboratory of Metastable Materials Science & Technology, Yanshan University, Qinhuangdao 066004, China*
[b] *Department of Materials Science and Engineering, Korea Advanced Institute of Science and Technology, Taejon 305-701, South Korea*

Received 10 October 2007; received in revised form 6 December 2007; accepted 10 December 2007

Abstract

The stress-strain curve of an α-β Ti-8Mn alloy was measured and then it was calculated with finite element method (FEM) based on the stress-strain curves of the single α and β phase alloys. By comparing the calculated stress-strain curve with the measured one, it can be seen that they fit each other very well. Thus, the FE model built in this work is effective. According to the above mentioned model, the distributions of stress and strain in the α and β phases were simulated. The results show that the stress gradients exist in both α and β phases, and the distributions of stress are inhomogeneous. The stress inside the phase is generally higher than that near the interface. Meanwhile, the stress in the α phase is lower than that in the β phase, whereas the strain in the α phase is higher than that in the β phase.

Keywords: titanium alloy; stress-strain curve; numerical simulation; finite element method

1. Introduction

The titanium alloy has been considered as an important material because of its high strength, low density, and good corrosion-resisting properties. It can be heat treated and hot or cold deformed [1-2] and has gained more and more applications in many fields [3-7].

The characteristics of the industrial α-β titanium alloy, which has α and β phases with different percentages, are in stabilized state, and it has good comprehensive properties in wide temperature range, especially, good plasticity [8]. With different percentages of α and β phases, several metastable microstructures can be formed. Thus, it is formed with integration of several physical properties, functional performances, and processing properties [9]. Many researches have been carried out on the mechanical property of the duplex alloy [10]. However, because of different percentages of α and β phases, a lot of funds and time will be wasted by experiments. Furthermore, because the distribution of stress and strain in different phases and even in different grains is inhomogeneous, it is hard to express the distribution of stress and strain in the titanium alloy clearly. According to Ref. [11] and based on the stress-strain curves of single α and β phase alloys, the stress-strain curve of the duplex alloy was simulated using finite element method (FEM). The simulated result was compared with the measured one and then, the distributions of stress and strain of the α-β Ti-8Mn duplex alloy were analyzed in this work.

Corresponding author: YANG Qingxiang **E-mail:** qxyang@ysu.edu.cn

2. Experimental materials and methods

2.1. Experimental materials

The specimen was taken from a Ti-8Mn duplex alloy, whose chemical composition is listed in Table 1. The single α and β phase alloys, whose compositions were similar to α and β phases in the Ti-8Mn alloy, were designed for calculating the stress-strain curve of the Ti-8Mn duplex alloy and their compositions are listed in Table 1 too.

2.2. Stress-strain curve of the Ti-8Mn alloy

The stress-strain curves of the single α, β phases and duplex α-β specimens with the dimension of 8 mm × 50 mm were measured using a hydraulic servo universal test machine. The results are shown in Fig. 1.

2.3. Finite element model

The microstructures of single α, β phase alloys and the Ti-8Mn duplex alloy are shown in Fig. 2. From Fig. 2(c), the matrix of titanium alloy microstructure is the β phase, whereas the α phase is distributed on the β phase ho-

Table 1. Chemical compositions of the Ti-8Mn duplex alloy and designed single phase alloys

Elements	f_α / %	Content / wt.%						
		Mn	C	O	N	H	Other total	Ti
α + β	17	6.50-9.00	<0.20	<0.20	<0.07	<0.015	0.60	Remain
α	100	0.50-0.70	<0.20	<0.20	<0.07	<0.015	0.60	Remain
β	2	7.50-10.50	<0.20	<0.20	<0.07	<0.015	0.60	Remain

Note: * f_α is the volume fraction of α phase.

mogeneously. The model built based on the real microstructure of the titanium alloy is too complex, and it varies with simplifications of the calculation. A 2D model was built by using FEM. The element division is shown in Fig. 3. The model is divided into 392 triangular elements including 225 nodes in total. The violet parts are the α phase, whereas the green ones are the β phase. The proportion of the two phases in the simulation model is the same as that in the morphology of the Ti-8Mn alloy, namely, the fraction of α phase is 17%, whereas that of the β phase is 83%. The load is given in the vertical direction gradually, based on the stress-strain curve of the Ti-8Mn alloy (Fig. 2(c)). The loads are 276, 414, 552, 690, 827, and 965 MPa respectively.

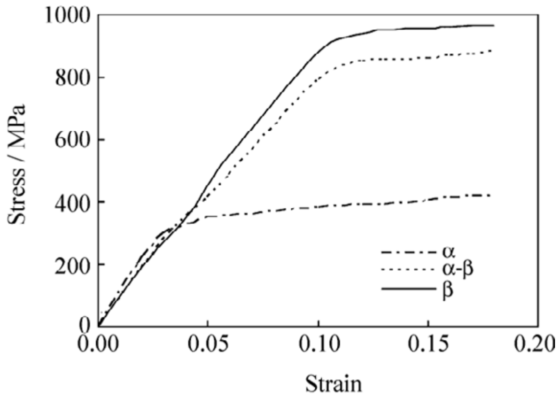

Fig. 1. Stress-strain curves of the single α, β phase alloys and the duplex α-β alloy.

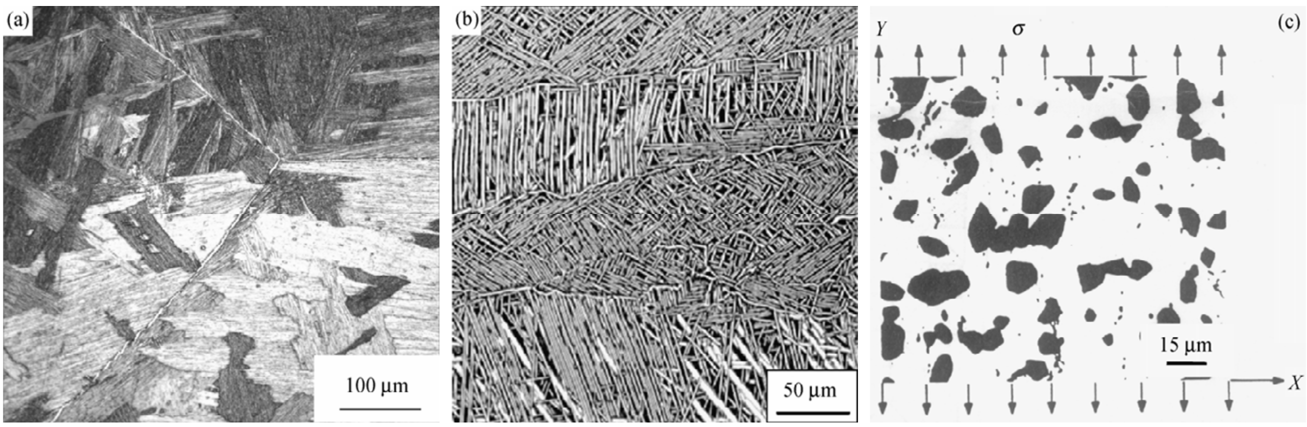

Fig. 2. Microstructures of the single α (a), β (b) phase alloys and the Ti-8Mn duplex alloy (c).

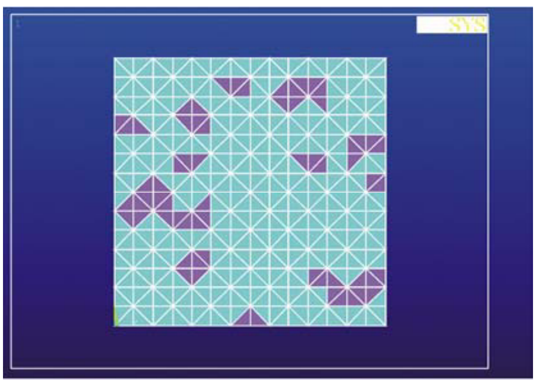

Fig. 3. Modeling and meshing.

The Young's modulus of the single α and β phase alloys are 1500 and 1300 MPa respectively, and Poisson's ratio is 0.3. The measured parameters of stress and strain are shown in Table 2.

Table 2. Parameters of stress and strain for simulation

No.	Single phase α alloy		Single phase β alloy	
	Strain	Stress / MPa	Strain	Stress / MPa
1	0.027	276	0.090	827
2	0.032	297	0.100	896
3	0.035	331	0.110	945
4	0.061	345	0.120	965
5	0.200	359	0.200	986