Science Press

Trans. Nonferrous Met. Soc. China 17(2007) s490−s494

Transactions of Nonferrous Metals Society of China

www.csu.edu.cn/ysxb/

Influence of deformation parameters on microstructure and mechanical properties of TA15 titanium alloy

ZHU Jing-chuan(朱景川), WANG Yang(王　洋), LIU Yong(刘　勇), LAI Zhong-hong(来忠红), ZHAN Jia-jun(占家军)

School of Materials Science and Engineering, Harbin Institute of Technology, Harbin 150001, China

Received 15 July 2007; accepted 10 September 2007

Abstract: The influence of deformation parameters including deformation temperature, degree and speed on the microstructure and mechanical properties of TA15 titanium alloy was studied. The volume fraction, size and aspect ratio of primary α phase in deformed TA15 titanium alloy were quantitatively characterized. With increasing deformation temperature, the volume fraction and size of primary α phase decrease. The aspect ratio of primary α phase decreases with increasing deformation temperature. The tensile strength of TA15 alloy deformed at 0.1 mm/s is higher than that at 0.3 mm/s. After thermoforming at 960 ℃, 0.1 mm/s, the tensile strength is the highest up to 1 035 MPa and the elongation is 13.5%. When the thermoforming temperature is 1 050 ℃, the strength and elongation are both relative low, because the microstructure is Widmanstaten structure.

Key words: TA15 titanium alloy; deformation; microstructure; mechanical properties

1 Introduction

TA15 titanium alloy is an important titanium alloy extensively used in aircraft industry. It is a near alpha titanium alloy which was developed as BT20 titanium alloy by Russia in 1964[1−2]. TA15 alloy has been widely used because of its attractive properties such as high specific strength, thermal stability, weldability.

Extensive researches have been carried out on TA15 alloy. SHU et al[3] studied the hot deformation behavior of TA15 alloy. CAO et al[4] and ZHANG et al[5] investigated the microstructure and properties of TA15 alloy. WANHILL[6] studied beta treatment of titanium. These work focused on either deformation behavior or microstructure. With the development of the technology of precise formation, it is necessary to control the microstructure of materials during deformation. So it is important to understand the relationships between the processing variables, microstructure, and mechanical properties[7−8]. The objective of this study is mainly on the variation of microstructure and mechanical properties with the deformation conditions.

2 Experimental

The experimental material was commercial TA15 titanium alloy. The composition of the TA15 alloy is as follows(mass fraction, %): 5.5−7.5Al, 1.5−2.5Zr, 0.5−2.0 Mo, 0.8−1.8V and balance Ti. The beta transus of this alloy is about 980 ℃.

The samples used in the tests were rectangular solid of 40 mm×20 mm×20 mm. The sample was heated to the test temperature and hold for 40 min. Then it was compressed into specific shape by a die using press machine. The speeds of compression were 0.1 mm/s and 0.3 mm/s. The deformation temperatures were 850, 925, 960 and 1 050 ℃. The deformation degrees were 40%, 60% and 80%. The samples were cooled in air.

The microstructure of the TA15 alloy was observed and analysed by using Olympus optical microscope. The corrosive agent was 2%HF+3%HNO_3+95% distilled water. The volume fraction, size and aspect ratio of primary α phase of deformed TA15 titanium alloy were quantitatively characterized. The tensile strength of TA15 alloy deformed at different conditions were measured by Instron-1186 test machine. The tensile rate was 1 mm/min.

3 Results and discussion

Fig.1 shows the microstructures of TA15 titanium alloy deformed at different temperatures and speeds. The

Corresponding author: WANG Yang; Tel: +86-451-86413792; E-mail: wangyangmse@163.com

deformation degree is 80%. When the deformation temperature is 850 ℃, the microstructure consists of primary α phase and a little transformed β phase. The transformed β phase is composed of β phase and secondary α phase. With the deformation temperature increasing, because of the transformation of α phase to β phase, the volume fraction of primary α phase decreases, and the volume fraction of transformed β increases.

When the deformation temperature is 1 050 ℃, because the temperature is higher than the beta transus of TA15 alloy, the microstructure is Widmanstaten structure. From Fig.1, it can also be seen that the size of primary α phase decreases with the deformation temperature increasing. This is related to the transformation of α

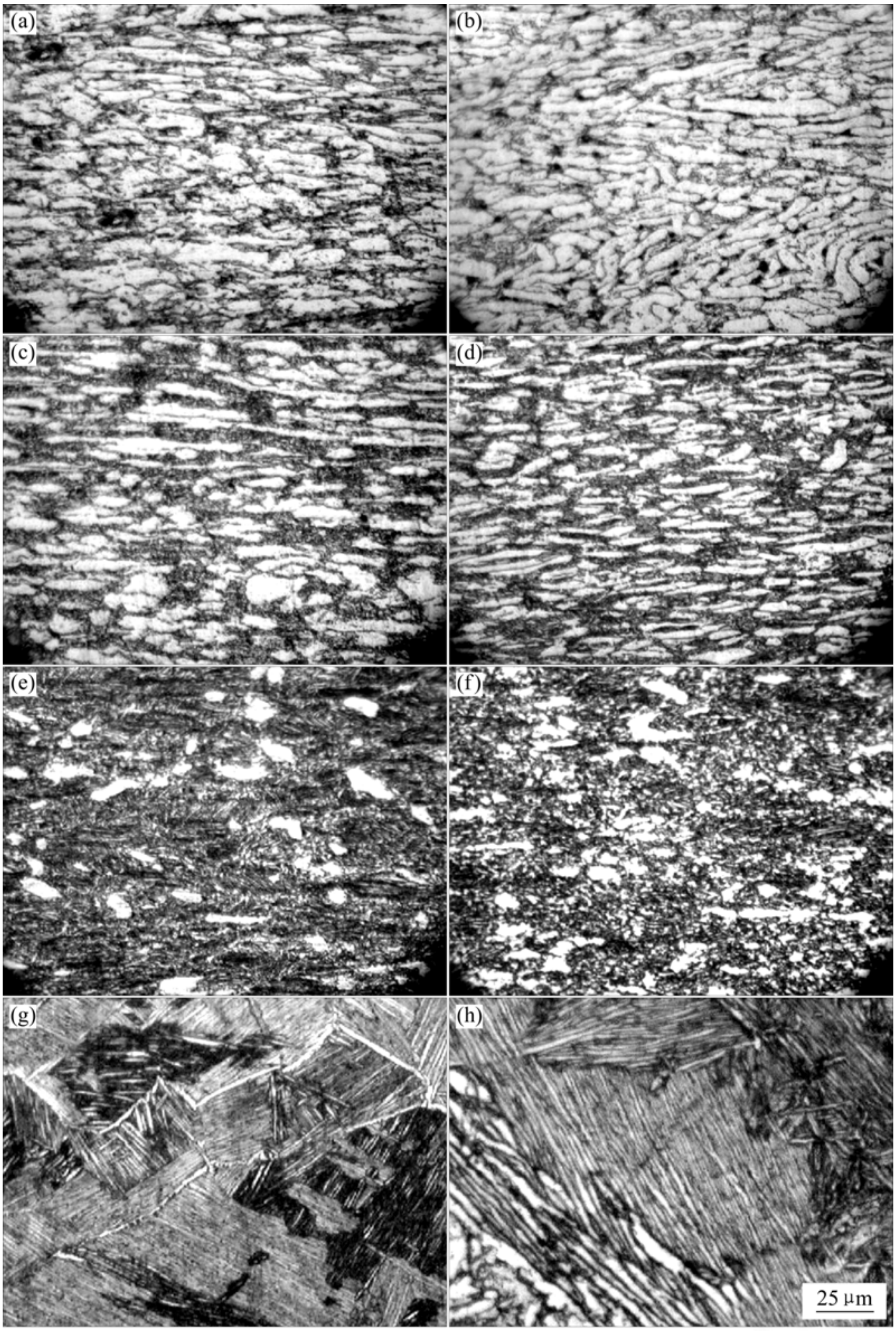

Fig.1 Microstructures of TA15 titanium alloy deformed at different conditions: (a) 850 ℃, 0.3 mm/s; (b) 850 ℃, 0.1 mm/s; (c) 925 ℃, 0.3 mm/s; (d) 925 ℃, 0.1 mm/s; (e) 960 ℃, 0.3 mm/s; (f) 960 ℃, 0.1 mm/s; (g) 1 050 ℃, 0.3 mm/s; (h) 1 050 ℃, 0.1 mm/s

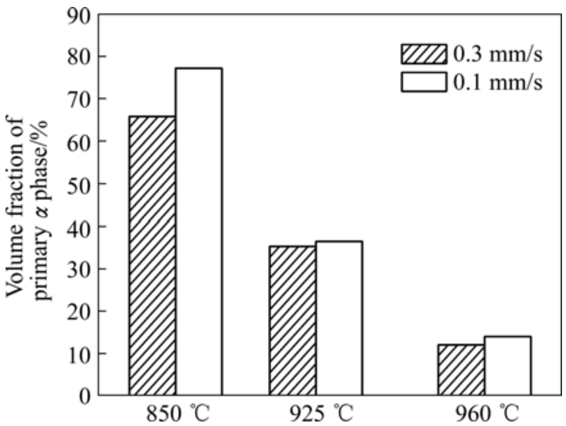

Fig.2 Effect of deformation temperature and speed on volume fraction of primary α phase

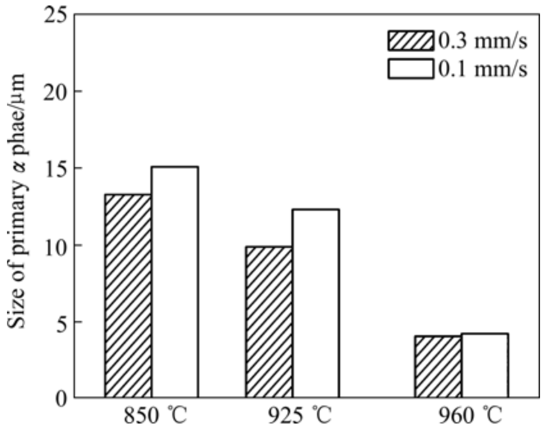

Fig.3 Effect of deformation temperature and speed on size of primary α phase

phase to β phase. The effects of deformation conditions on the volume fraction and size of primary α phase are shown in Figs.2 and 3.

With the variation of volume fraction and size, the aspect ratio of primary α phase changes too. Hot deformation can cause globularization of the microstructure through segmentation of the alpha lamellae by process such as boundary splitting and edge spheroidization[9−10]. The globularization is more apparent at higher temperature. So the aspect ratio of primary α phase decreases with the increase of deformation temperature. The effect of deformation temperature and deformation speed on the aspect ratio is shown in Fig.4. When the deformation speed is 0.1 mm/s, not only the primary α phase but also the secondary α phase is spheroidized (Fig.1(f)).

Fig.5 shows the microstructures of TA15 alloy deformed at different deformation degrees and temperatures. Because lager deformation degree can break a strip primary α phase into more pieces, it can be seen that the aspect ratio and size of primary α phase decrease slightly with the increase of deformation degree. While the volume fraction of primary α phase does not change greatly.

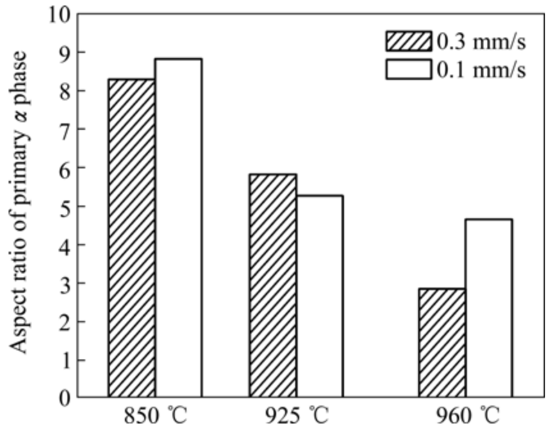

Fig.4 Effect of deformation temperature and speed on aspect ratio of primary α phase

The effects of deformation conditions on the tensile strength are shown in Figs.6 and 7. When the volume fraction of primary α phase is higher than 15%, the tensile strength does not change greatly with the volume fraction of primary α phase increasing[11]. At 960 ℃, the temperature is close to the beta transus, and the volume fraction of primary α phase in the microstructure of TA15 alloy is near 15%. The random distribution of secondary α phase help to increase the tensile strength. From Fig.6 it can be seen that the tensile strength of 960 ℃ is higher than that of 925 ℃. And the tensile strength of 0.1 mm/s is higher than that of 0.3 mm/s. The reason may be that the finer transformed β phase at 0.1 mm/s can strengthen titanium alloy. After thermal deformation at 960 ℃ and 0.1 mm/s, the strength is the highest up to 1 035 MPa. When the deformation temperature is 1 050 ℃, the tensile strength is lower than the strength in $\alpha+\beta$ zone. Though TA15 alloy has not much high strength after deformation at 1 050 ℃, but it has higher high temperature creep properties, higher impact toughness and higher fracture toughness. From Fig.7, it can be seen that the tensile strength doesn't change greatly with the variation of deformation degree.

The effects of deformation conditions on the elongation are shown in Figs.8 and 9. The tensile strength under deformation speed 0.1 mm/s is a little higher than that under 0.3 mm/s. This may be related to the spheroidized secondary α phase in the transformed β. It can be seen that the elongation is maximum up to 13.5% when the deformation temperature is 960 ℃ and the deformation speed is 0.1 mm/s. The elongation at 1 050 ℃ is relatively low because of Widmanstaten structure.

From above it can be concluded that when TA15 titanium alloy is deformed at 960 ℃ and 0.1 mm/s, the tensile strength and the elongation are both high.

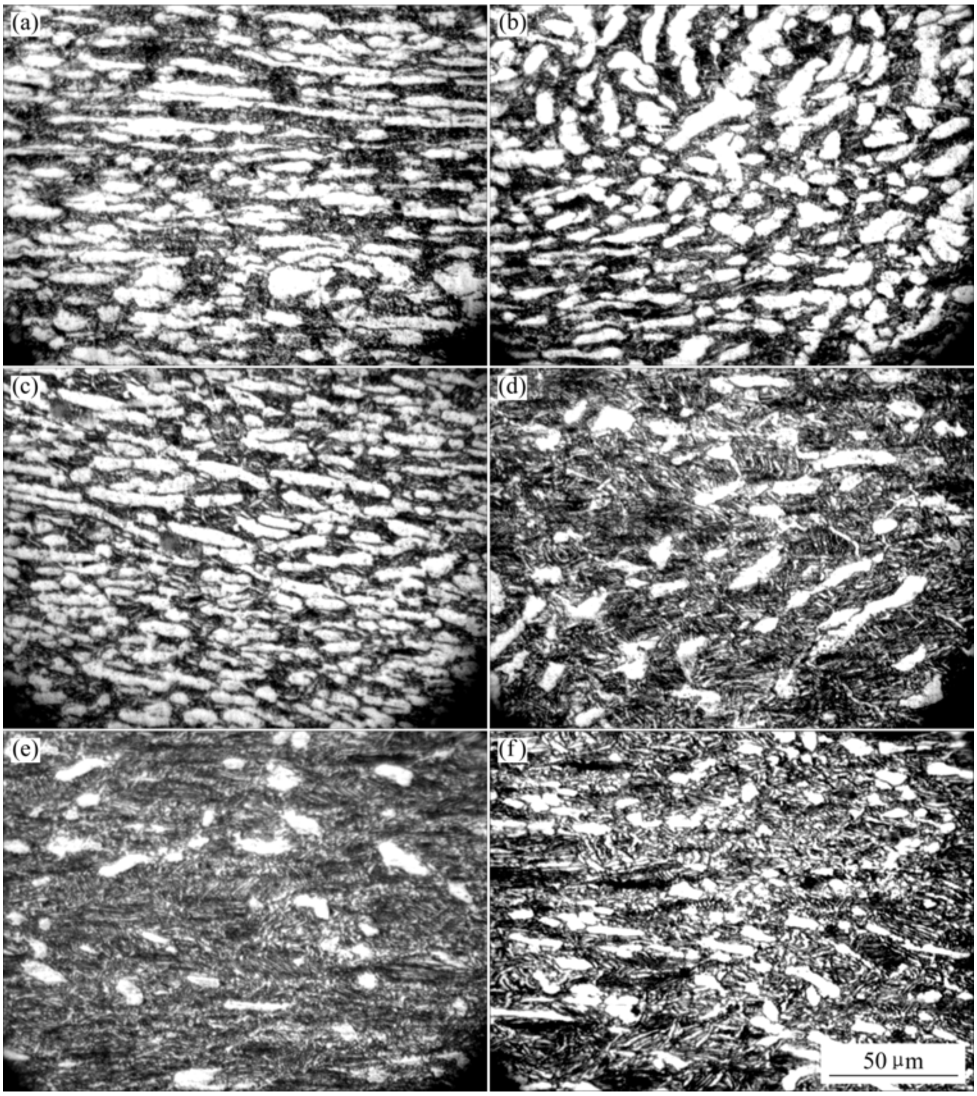

Fig.5 Microstructures of TA15 alloy deformed at different deformation degrees and temperatures: (a) 925 ℃, 40%; (b) 925 ℃, 60%; (c) 925 ℃, 80%; (d) 960 ℃, 40%; (e) 960 ℃, 60%; (f) 960 ℃, 80%

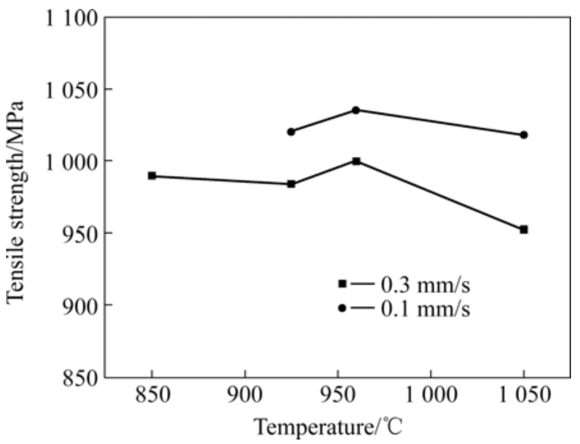

Fig.6 Effect of deformation temperature and speed on tensile strength of primary α phase

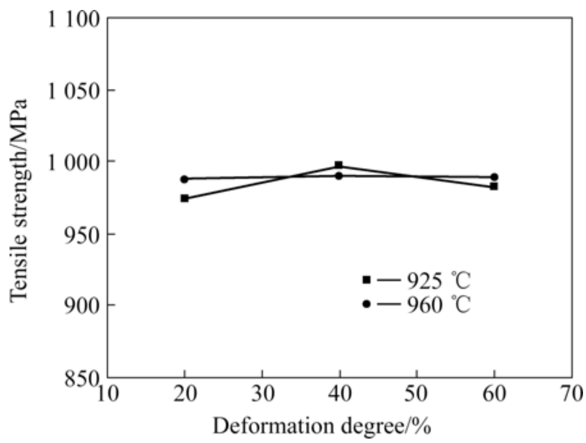

Fig.7 Effect of deformation degree and temperature on tensile strength of primary α phase

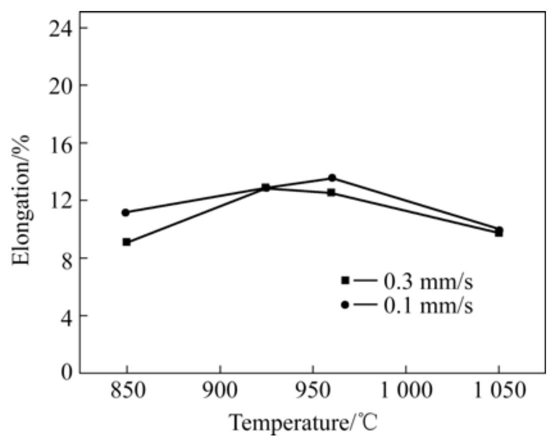

Fig.8 Effect of deformation temperature and speed on elongation of primary *α* phase

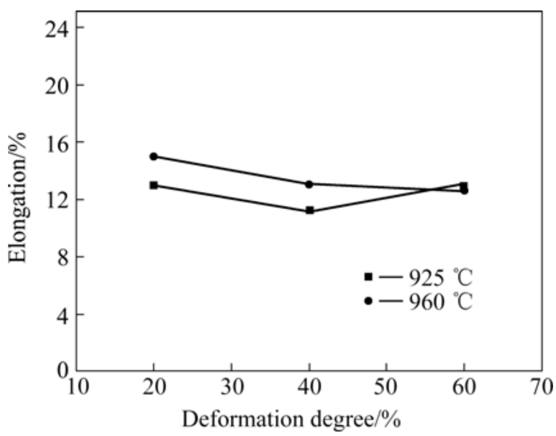

Fig.9 Effect of deformation degree and temperature on elongation percentage of primary *α* phase

4 Conclusions

1) With the increase of thermoforming temperature, the volume fraction and size of primary *α* phase decrease. The thermal deformation causes the strip primary *α* phase broken and spheroidized.

2) After thermoforming at 960 ℃, the tensile strength is higher than that at 850 ℃ and 925 ℃ because of the suitable volume fraction of primary *α* phase and random distribution of secondary *α* phase. The strength of TA15 alloy deformed at 0.1 mm/s is higher than that at 0.3 mm/s.

3) TA15 titanium alloy deformed at 960 ℃ and 0.1 mm/s, has high tensile strength and elongation. The tensile strength is the highest up to 1035MPa and the elongation is 13.5%.

References

[1] SHA Ai-xue, LI Xing-wu, CHU Jun-peng. Common annealing of TA15 alloy[J]. Chinese Journal of Rare Metals, 2003, 27(1): 213−215. (in Chinese)

[2] WANG Yong-lan, WANG Gui-sheng. Microstructure of BT20 titanium alloy[J]. Chinese Journal of Rare Metals, 1998, 22: 152−154. (in Chinese)

[3] SHU Ying, ZENG Wei-dong, ZHOU Jun, ZHOU Yi-gang, ZHOU Lian. A study of hot deformation behavior for BT20 alloy[J]. Materials Science and Technology, 2005, 13(1): 55−58. (in Chinese)

[4] CAO Jing-xia, FANG Bo, HUANG Xu, LI Zhen-xi. Effects of microstructure on properties of TA15 titanium alloy[J]. Chinese Journal of Rare Metals, 2004, 28(2): 362−364. (in Chinese)

[5] ZHANG Jing-yu, YANG Yan-qing, CHEN Yan, WEN Li, ZHOU Yi-gang. Effect of annealing on the structure and properties of TA15 titanium alloy[J]. Heat Treatment of Metals, 2003, 28(3): 46−48. (in Chinese)

[6] WANHILL R J H. Ambient temperature crack growth in titanium alloys and its significance for aircraft structures[J]. Aeronautical Journal, 1977, 81: 68−82.

[7] YAO Ze-kun, GUO Hong-zhen, SU Zu-wu. Effect of microstructure and recrystallization and mechanical properties of two phase (α+β) Ti alloy[J]. Rare Metal Materials and Engineering, 2000, 29: 340−343. (in Chinese)

[8] BRUN M, ANOSHKIN N, SHAKHANOVA G. Physical processes and regimes of thermomechanical processing controlling development of regulated structure in the alpha+beta titanium alloys[J]. Mater Sci Eng A, 1998, 243(1/2): 77−81.

[9] STEFANSSON N, SEMIATIN S L. Mechanisms of globularization of Ti-6Al-4V during static heat treatment[J]. Metall Mater Trans A, 2003, 34: 691−698.

[10] STEFANSSON N, SEMIATIN S L, EYLON D. The kinetics of static globularization of Ti-6Al-4V[J]. Metall Mater Trans A, 2002, 33A: 3527−3534.

[11] ZHOU Yi-gang, ZENG Wei-dong, YU Han-qing. The near β forging overthrows the conventional forging theory and develops a new tri-modal microstructure[J]. Engineering Science, 2001, 3(5): 61−66. (in Chinese)

(Edited by YUAN Sai-qian)