Supplementary Material

Improved Strength-Ductility of Ti-6Al-4V Casting Alloys with Trace Addition of TiC-TiB₂ Nanoparticles

Yunlong Zhu 1,2, Qinglong Zhao 1,2,* , Xiao Liu 1,2, Run Geng 1,2, Bao Wang 1,2 and Qichuan Jiang 1,2,*

1 State Key Laboratory of Automotive Simulation and Control, Jilin University, Changchun 130025, China; yunlong18@mails.jlu.edu.cn (Y.Z.); xiaoliu19@mails.jlu.edu.cn (X.L.); gengrun18@mails.jlu.edu.cn (R.G.); wangbao18@mails.jlu.edu.cn (B.W.)
2 Key Laboratory of Automobile Materials, Ministry of Education and School of Materials Science and Engineering, Jilin University, No. 5988 Renmin Street, Changchun 130025, China
* Correspondence: zhaoqinglong@jlu.edu.cn (Q.Z.); jqc@jlu.edu.cn (Q.J.)

Figure S1. The FESEM images of TiC-TiB₂ particles (a–b) and the statistical results of the diameter of the TiC and TiB₂ (c–b).

The TiC and TiB₂ particles were obtained by extracting from the TiC-TiB₂/Al master alloys. The extractant was 90% hydrochloric acid. The size of spherical TiC particles is small. TiB₂ particles are regular hexagon or rectangle and large in size. The areal number density of TiC is more than that of TiB₂.
Figure S2. TEM images of TiC and TiB$_2$ particles in TiC-TiB$_2$/Ti64 (a,b); FESEM patterns of TiC-TiB$_2$/Ti64 (c,d).

Figure S2 shows that TiC and TiB$_2$ particles are located at the border of $\alpha$-Ti and $\beta$-Ti. Those particles may suppress the movement of the boundaries of $\alpha$-Ti/$\beta$-Ti.

Figure S3. TEM and FESEM images of TiC and TiB$_2$ in TiC-TiB$_2$/Ti64. a, b: the location of TiB$_2$ particles; c-f: the locations of TiC particles.

Figure S3 shows that some TiC, TiB$_2$ particles are inside the $\alpha$ laths, which may act as the nucleation site of $\alpha$-Ti.
The data for the Ti64 and TiC-TiB₂/Ti64 after heat treatment tested in this study indicate good repeatability.

Table S1. Details of the tensile tests performed on the cast Ti64 and TiC-TiB₂/Ti64 after heat treatment.

| Samples | \( \sigma_{0.2} \) (MPa) | \( \sigma_{UTS} \) (MPa) | UE (%) |
|---------|----------------|----------------|-------|
| TiC-TiB₂/Ti64 Sample 1 | 926.2 | 992.6 | 11.2 |
| TiC-TiB₂/Ti64 Sample 2 | 937.2 | 996.0 | 8.9 |
| TiC-TiB₂/Ti64 Sample 3 | 925.2 | 990.7 | 7.8 |
| Ti64 Sample 1 | 796.6 | 857.9 | 10.0 |
| Ti64 Sample 2 | 794.1 | 859.0 | 7.4 |
| Ti64 Sample 3 | 789.2 | 856.7 | 6.8 |

Figure S5. (a) The content changes of Al and V element in β-Ti during solidification. (b) The content changes of Al and V element in β-Ti when the temperature is below the phase transform point.

Figure S5 was calculated by JMatPro v10 (Sente Software Ltd.; 2001). Scheil calculations suggest that the element V accumulates at dendritic regions while Al is concentrated in the dendrite center of β-Ti (Figure S5a). The content of V element of β-Ti rises sharply, as the temperature decreases below the phase transition point, and the content of Al element of β-Ti is slightly reduced (Figure S5b).
Figure S6. The statistical results of the size of α-Ti colony.

The mean size of α-Ti colony in Ti64 is 109 μm. The mean size of α-Ti colony in TiC-TiB2/Ti64 is 43 μm. Ten metallographies are counted for each value.

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