CLAIMS

1. A method of refining alpha-phase grain size in an alpha-beta titanium alloy, the method comprising:

working an alpha-beta titanium alloy at a first working temperature within a first temperature range, wherein the first temperature range is from a temperature 300℉ below a beta transus temperature of the alpha-beta titanium alloy to a temperature 30℉ below the beta transus temperature;

slow cooling the alpha-beta titanium alloy from the first working temperature, wherein on completion of working at the first working temperature and the slow cooling from the first working temperature, the alpha-beta titanium alloy comprises a primary globularized alpha-phase particle microstructure;

wherein the slow cooling occurs prior to any further working of the alpha-beta titanium alloy and comprises cooling the workpiece at a cooling rate no greater than 5ºF per minute;

working the alpha-beta titanium alloy at a second working temperature within a second temperature range, wherein the second temperature range is from a temperature 600℉ below the beta transus temperatur e to a temperature 350℉ below the beta transus temperature; and

working the alpha-beta titanium alloy at a third working temperature in a third temperature range, wherein the third working temperature is lower than the second working temperature, wherein the third temperature range is 1000℉ to 1400℉, and wherein after working at the third working temperature, the alpha-beta titanium alloy comprises a desired refined alpha-phase grain size.

2. The method according to claim 1, wherein the alpha-beta titanium alloy is selected from Ti-6Al-4V alloy (UNS R56400), Ti-6Al-4V ELI alloy (UNS R56401), a Ti-6Al-2Sn-4Zr-2Mo alloy (UNS R54620), a Ti-6Al-2Sn-4Zr-6Mo alloy (UNS R56260), and a Ti-4Al-2.5V-1.5Fe alloy (UNS 54250).

3. The method according to claim 1, wherein the alpha-beta titanium alloy is selected from Ti-6Al-4V alloy (UNS R56400) and Ti-6Al-4V ELI alloy (UNS R56401).

4. The method according to claim 1, wherein the alpha-beta titanium alloy is a Ti-4Al-2.5V-1.5Fe alloy (UNS 54250).

5. The method according to claim 1, wherein the slow cooling comprises furnace cooling.

6. The method according to claim 1, wherein the slow cooling comprises transferring the alpha-beta titanium alloy from a furnace chamber at the first working temperature to a furnace chamber at the second working temperature.

7. The method according to claim 1, further comprising, before the slow cooling the alpha-beta titanium alloy from the first working temperature:

heat treating the alpha-beta titanium alloy at a heat treating temperature in a heat treating temperature range that is from a temperature 300℉ below a beta transus temperature of the alpha-beta titanium alloy up to a temperature 30℉ below the beta transus temperature of the alpha-beta titanium alloy; and

holding the alpha-beta titanium alloy at the heat treating temperature.

8. The method according to claim 7, wherein holding the alpha-beta titanium alloy at the heat treating temperature comprises holding the alpha-beta titanium alloy at the heat treating temperature for 1 hour to 48 hours.

9. The method according to claim 1, further comprising, after working the alpha-beta titanium alloy at the second working temperature, annealing the alpha-beta titanium alloy.

10. The method according to claim 9, wherein annealing the alpha-beta titanium alloy comprises heating the alpha-beta titanium alloy at a temperature in an annealing

temperature range of 500℉ below the beta transus t emperature to 250℉ below the beta transus temperature for 30 minutes to 12 hours.

11. The method according to claim 1, wherein at least one of working the alpha-beta titanium alloy at the first temperature, working the alpha-beta titanium alloy at the second temperature, and working the alpha-beta titanium alloy at the third temperature comprises open die press forging.

12. The method according to claim 1, wherein at least one of working the alpha-beta titanium alloy at the first working temperature, working the alpha-beta titanium alloy at the second working temperature, and working the alpha-beta titanium alloy at the third working temperature comprises a plurality of open die press forgings, the method further comprising reheating the alpha-beta titanium alloy intermediate two successive press forgings.

13. The method according to claim 12, wherein reheating the alpha-beta titanium alloy comprises heating the alpha-beta titanium alloy to a previous working temperature and holding the alpha-beta titanium alloy at the previous working temperature for 30 minutes to 12 hours.

14. The method according to claim 11, wherein each of the open die press forgings comprises upset forging.

15. The method according to claim 11, wherein each of the open die press forgings comprises draw forging.

16. The method according to claim 11, wherein each of the open die press forgings comprises at least one of upset forging and draw forging.

17. The method according to claim 16, wherein working the alpha-beta titanium alloy at the third working temperature comprises radial forging the alpha-beta titanium alloy.

18. The method according to claim 1, further comprising:

beta heat treating the alpha-beta titanium alloy at a beta heat treating temperature prior to working the alpha-beta titanium alloy at the first working temperature;

wherein the beta heat treating temperature is within a temperature range from a beta transus temperature of the alpha-beta titanium alloy to a temperature 300℉ greater than the beta transus tem perature of the alpha-beta titanium alloy; and

quenching the alpha-beta titanium alloy.

19. The method according to claim 18, wherein beta heat treating the alpha-beta titanium alloy further comprises working the alpha-beta titanium alloy at the beta heat treating temperature.

20. The method according to claim 19, wherein working the alpha-beta titanium alloy at the beta heat treating temperature comprises one or more of roll forging, swaging, cogging, open-die forging, impression-die forging, press forging, automatic hot forging, radial forging, upset forging, draw forging, and multiaxis forging.