Claims

What is claimed is:

1. A method of producing a high elastic modulus shaft from an alloy, the method comprising:

providing a single crystal cylinder of the alloy, the single crystal cylinder having a longitudinal axis, the single crystal cylinder being seeded so that a high modulus <111> direction is at least substantially parallel to the longitudinal axis;

hot working the cylinder to achieve a desired size of the cylinder;

heat treating the cylinder at a temperature below a recrystallization temperature of the alloy.

2. The method of claim 1 wherein the alloy is a nickel based alloy.

3. The method of claim 1 wherein the alloy is an iron based alloy.

4. The method of claim 1 wherein the alloy is steel.

5. The method of claim 1 wherein the hot working comprises axisymmetrically hot working the cylinder.

6. The method of claim 1 wherein the heat treating is direct age heat treating.

7. The method of claim 1 wherein a Young's modulus in the <111> direction is greater than about 37 Mpsi (255 GPa).

8. The method of claim 1 wherein a Young's modulus in the <111> direction ranges from about 37 to about 45 Mpsi (from about 255 to about 310 GPa).

9. The method of claim 1 wherein the cylinder is solid.

10. The method of claim 1 wherein the cylinder is hollow.

11. A method of producing a high elastic modulus shaft from an alloy, the method comprising:

casting a single crystal cylinder from the alloy, the single crystal cylinder having a longitudinal axis, the single crystal cylinder being seeded so that a high modulus <111> direction is at least substantially parallel to the longitudinal axis of the cylinder;

axisymmetrically hot working the cylinder to achieve a desired size of the cylinder at a temperature below a recrystallization temperature of the alloy;

heat treating the cylinder at a temperature below the recrystallization temperature of the alloy.

12. The method of claim 11 wherein the alloy is a nickel based alloy.

13. The method of claim 11 wherein the alloy is an iron based alloy.

14. The method of claim 11 wherein the alloy is steel.

15. The method of claim 11 wherein the heat treating is direct age heat treating.

16. The method of claim 11 wherein a Young's modulus in the <111> direction is greater than about 37 Mpsi (255 GPa).

17. The method of claim 1 wherein a Young's modulus in the <111> direction ranges from about 37 to about 45 Mpsi (from about 255 to about 310 GPa).

18. A high modulus shaft comprising:

the shaft having a longitudinal axis;

the shaft comprising a hot worked, limited recrystallized single crystal of an alloy having a high modulus <111> direction that is at least substantially parallel to the longitudinal axis of the shaft.

19. The shaft of claim 18 wherein a Young's modulus of the shaft in the <111> direction is greater than about 37 Mpsi (255 GPa).

20. The shaft of claim 18 wherein a Young's modulus of the shaft in the <111> direction ranges from about 37 to about 44 Mpsi (from about 255 to about 310 GPa).

21. A method of producing a high strength and or high torque resistant shaft from an alloy, the method comprising:

providing a single crystal cylinder of the alloy, the single crystal cylinder having a longitudinal axis, the single crystal cylinder being seeded so that a high modulus <111> direction is at least substantially parallel to the longitudinal axis;

hot working the cylinder to achieve a desired size of the cylinder;

heat treating the cylinder at a temperature below or above a recrystallization temperature of the alloy to maximize the strength.

22. The method of claim 21 wherein the alloy is an iron based alloy.

23. The method of claim 21 wherein the alloy is steel. Such steel may be ferritic, austenitic , martensitic or strengthened by precipitation and commonly used for all wrought and cast structural applications.

24. The method of claim 21 wherein the hot working comprises axisymmetrically hot working the cylinder.

Claims:

1. A method of producing a high elastic modulus shaft (19,20) from a nickel based or iron based alloy, the method comprising:

providing a single crystal cylinder (30) of the alloy, the single crystal cylinder (30) having a longitudinal axis, the single crystal cylinder (30) being seeded so that a high modulus <111> direction is at least substantially parallel to the longitudinal axis;

hot working the cylinder (30) to achieve a desired size of the cylinder; and

heat treating the cylinder (30) at a temperature below a recrystallization temperature of the alloy.

2. The method of claim 1 wherein the alloy is steel.

3. The method of claim 1 or 2 wherein the hot working comprises axisymmetrically hot working the cylinder (30).

4. The method of any preceding claim wherein the heat treating is direct age heat treating.

5. The method of any preceding claim wherein a Young's modulus in the <111> direction is greater than 37 Mpsi (255 GPa).

6. The method of any of claims 1 to 4 wherein a Young's modulus in the <111> direction ranges from 37 to 45 Mpsi (from 255 to 310 GPa).

7. The method of any preceding claim wherein the cylinder (30) is solid.

8. The method of any of claims 1 to 6 wherein the cylinder (30) is hollow.

9. The method of any preceding claim, wherein said providing comprises:

casting a single crystal cylinder (30) from the alloy;

and wherein said hot working comprises:

axisymmetrically hot working the cylinder (30) to achieve a desired size of the cylinder (30) at a temperature below a recrystallization temperature of the alloy.

10. A high modulus shaft (19,20) comprising:

the shaft (19,20) having a longitudinal axis;

the shaft comprising a hot worked, limited recrystallized single crystal of a nickel based or iron based alloy having a high modulus <111> direction that is at least substantially parallel to the longitudinal axis of the shaft (19,20).

11. The shaft of claim 10 wherein a Young's modulus of the shaft (19,20) in the <111> direction is greater than 37 Mpsi (255 GPa).

12. The shaft of claim 10 wherein a Young's modulus of the shaft (19,20) in the <111> direction ranges from 37 to 44 Mpsi (from 255 to 310 GPa).

13. A method of producing a high strength and or high torque resistant shaft (19,20) from a nickel based or iron based alloy, the method comprising:

providing a single crystal cylinder (30) of the alloy, the single crystal cylinder (30) having a longitudinal axis, the single crystal cylinder (30)

being seeded so that a high modulus <111> direction is at least substantially parallel to the longitudinal axis;

hot working the cylinder (30) to achieve a desired size of the cylinder (30); and

heat treating the cylinder (30) at a temperature below or above a recrystallization temperature of the alloy to maximize the strength.

14. The method claim 13, wherein the alloy is steel.

15. The method of claim 13 or 14, wherein the hot working comprises axisymmetrically hot working the cylinder (30).