## CLAIMS

1. A forge lubrication process comprising:

positioning a solid graphite sheet between a workpiece and a die in a forging apparatus, the workpiece comprising titanium, a titanium alloy, zirconium, or a zirconium alloy; and

applying force to the workpiece to plastically deform the workpiece with the die,

wherein the workpiece is at a temperature greater than 1000°F during deformation, and a shear factor between the die and the workpiece during deformation is less than 0.50.

2. The process of claim 1, wherein the workpiece is at a temperature in the range of 1000°F to 1600°F during deformation, and the shear factor between the die and the workpiece during deformation is in the range of 0.09 to 0.20.

3. The process of claim 1, wherein positioning a solid graphite sheet between a workpiece and a die in a forging apparatus comprises:

positioning the solid graphite sheet onto an upper surface of a lower die; and

positioning the workpiece onto the solid graphite sheet,

wherein the solid graphite sheet is positioned between a bottom surface of the workpiece and an upper surface of the lower die in the forging apparatus.

4. The process of claim 3, further comprising positioning an additional solid graphite sheet onto a top surface of the workpiece.

5. The process of claim 1, further comprising heating the die before the solid graphite sheet is positioned between the workpiece and the die in the forging apparatus.

6. The process of claim 1, wherein the workpiece is plastically deformed in a forging operation selected from the group consisting of open-die forging, closed-die forging, forward extrusion, backward extrusion, radial forging, upset forging, and draw forging.

7. The process of claim 1, wherein the workpiece is plastically deformed in one of a near-net-shape forging process and a net-shape forging process.

8. The process of claim 1, further comprising removing residual solid graphite from the workpiece after the workpiece is plastically deformed.

9. The process of claim 1, wherein the solid graphite sheet prevents die locking of the workpiece to the die.

10. The process of claim 1, wherein the forging apparatus comprises in a closed-die forging apparatus, and wherein the solid graphite sheet comprises a pre-formed shape that matches a contour of at least a region of the die.

11. The process of claim 10, wherein positioning a solid graphite sheet between a workpiece and a die in a closed-die forging apparatus comprises:

inserting the solid graphite sheet into a die cavity in the die, wherein the pre-formed shape of the solid graphite sheet matches a contour of at least a region of the die in the die cavity; and

inserting the workpiece into the die cavity and onto the solid graphite sheet;

wherein the solid graphite sheet is positioned between a bottom surface of the workpiece and an upper surface of the die in the die cavity.

12. The process of claim 10, wherein positioning a solid graphite sheet between a workpiece and a die in a closed-die forging apparatus comprises:

inserting a first solid graphite sheet into a die cavity in the closed-die forging apparatus, wherein the first solid graphite sheet comprises a pre-formed shape that matches a contour of at least a region of a lower die in the die cavity;

inserting the workpiece into the die cavity and onto the first solid graphite sheet; and

positioning a second solid graphite sheet between a top surface of the workpiece and a lower surface of an upper die in the closed-die forging apparatus.

13. A forge lubrication process comprising:

positioning a solid lubricant sheet between a workpiece and a die in a forging apparatus; and

applying force to the workpiece with the die to plastically deform the workpiece;

wherein a shear factor between the die and the workpiece during deformation is less than 0.50.

14. The process of claim 13, wherein the solid lubricant sheet comprises a solid-state lubricant material selected from the group consisting of graphite, molybdenum disulfide, tungsten disulfide, and boron nitride.

15. The process of claim 13, wherein the solid lubricant sheet is a solid graphite sheet.

16. The process of claim 13, wherein positioning a solid lubricant sheet between a workpiece and a die in a forging apparatus comprises:

positioning the solid lubricant sheet onto an upper surface of a lower die; and

positioning the workpiece onto the solid lubricant sheet,

wherein the solid lubricant sheet is positioned between a bottom surface of the workpiece and an upper surface of the lower die in the forging apparatus.

17. The process of claim 16, further comprising positioning an additional solid lubricant sheet onto a top surface of the workpiece.

18. The process of claim 13, further comprising heating the die before the solid lubricant sheet is positioned between the workpiece and the die in the forging apparatus.

19. The process of claim 13, wherein the workpiece is at a temperature in the range of 1000°F to 2000°F during deformation, and the shear factor between the die and the workpiece during deformation is in the range of 0.05 to 0.50.

20. The process of claim 13, wherein the workpiece is at a temperature in the range of 1000°F to 1600°F during deformation, and the shear friction factor between the die and the workpiece during deformation is in the range of 0.09 to 0.20.

21. The process of claim 13, wherein the workpiece is plastically deformed in a forging operation selected from the group consisting of open-die forging, closed-die forging, forward extrusion, backward extrusion, radial forging, upset forging, and draw forging.

22. The process of claim 13, wherein the workpiece is plastically deformed in one of a near-net-shape forging process and a net-shape forging process.

23. The process of claim 13, wherein the workpiece comprises a titanium alloy.

24. The process of claim 13, wherein the workpiece comprises a zirconium alloy.

25. The process of claim 13, further comprising removing residual solid lubricant from the workpiece after the workpiece is plastically deformed.

26. The process of claim 13, wherein the solid lubricant sheet prevents die locking of the workpiece to the die.

27. The process of claim 13, wherein the forging apparatus comprises in a closed-die forging apparatus, and wherein the solid lubricant sheet comprises a pre-formed shape that matches a contour of at least a region of the die.

28. The process of claim 27, wherein the workpiece is plastically deformed in one of a near-net-shape forging process and a net-shape forging process.

29. The process of claim 27, wherein positioning a solid lubricant sheet between a workpiece and a die in a closed-die forging apparatus comprises:

inserting the solid lubricant sheet into a die cavity in the die, wherein the pre-formed shape of the solid lubricant sheet matches a contour of at least a region of the die in the die cavity; and

inserting the workpiece into the die cavity and onto the solid lubricant sheet;

wherein the solid lubricant sheet is positioned between a bottom surface of the workpiece and an upper surface of the die in the die cavity.

30. The process of claim 27, wherein positioning a solid lubricant sheet between a workpiece and a die in a closed-die forging apparatus comprises:

inserting a first solid lubricant sheet into a die cavity in the closed-die forging apparatus, wherein the first solid lubricant sheet comprises a pre-formed shape that matches a contour of at least a region of a lower die in the die cavity;

inserting the workpiece into the die cavity and onto the first solid lubricant sheet; and

positioning a second solid lubricant sheet between a top surface of the workpiece and a lower surface of an upper die in the closed-die forging apparatus.

CLAIMS

1. A forge lubrication process comprising:
positioning a solid graphite sheet between a workpiece and a die in a forging apparatus, the workpiece comprising titanium, a titanium alloy, zirconium, or a zirconium alloy; and
applying force to the workpiece to plastically deform the workpiece with the die, wherein the workpiece is at a temperature greater than 1000°F during deformation.

2. The process of claim 1, wherein the workpiece is at a temperature in the range of 1000°F to 1600°F during deformation, and a shear factor between the die and the workpiece during deformation is less than 0.50.

3. The process of claim 1, wherein positioning a solid graphite sheet between a workpiece and a die in a forging apparatus comprises:
positioning the solid graphite sheet onto an upper surface of a lower die; and
positioning the workpiece onto the solid graphite sheet,
wherein the solid graphite sheet is positioned between a bottom surface of the workpiece and an upper surface of the lower die in the forging apparatus.

4. The process of claim 3, further comprising positioning an additional solid graphite sheet onto a top surface of the workpiece.

5. The process of claim 1, further comprising heating the die before the solid graphite sheet is positioned between the workpiece and the die in the forging apparatus.

6. The process of claim 1, wherein the workpiece is plastically deformed in a forging operation selected from the group consisting of open-die forging, closed-die forging, forward extrusion, backward extrusion, radial forging, upset forging, and draw forging.

7. The process of claim 1, wherein the workpiece is plastically deformed in one of a near-net-shape forging process and a net-shape forging process.

8. The process of claim 1, further comprising removing residual solid graphite from the workpiece after the workpiece is plastically deformed.

9. The process of claim 1, wherein the solid graphite sheet prevents die locking of the workpiece to the die.

10. The process of claim 1, wherein the forging apparatus comprises a closed-die forging apparatus, and wherein the solid graphite sheet comprises a pre-formed shape that matches a contour of at least a region of the die.

11. The process of claim 10, wherein positioning a solid graphite sheet between a workpiece and a die in a closed-die forging apparatus comprises:
inserting the solid graphite sheet into a die cavity in the die, wherein the pre-formed shape of the solid graphite sheet matches a contour of at least a region of the die in the die cavity; and
inserting the workpiece into the die cavity and onto the solid graphite sheet;
wherein the solid graphite sheet is positioned between a bottom surface of the workpiece and an upper surface of the die in the die cavity.

12. The process of claim 10, wherein positioning a solid graphite sheet between a workpiece and a die in a closed-die forging apparatus comprises:
inserting a first solid graphite sheet into a die cavity in the closed-die forging apparatus, wherein the first solid graphite sheet comprises a pre-formed shape that matches a contour of at least a region of a lower die in the die cavity;
inserting the workpiece into the die cavity and onto the first solid graphite sheet; and
positioning a second solid graphite sheet between a top surface of the workpiece and a lower surface of an upper die in the closed-die forging apparatus.

13. A forge lubrication process comprising:
positioning a solid lubricant sheet between a workpiece and a die in a forging apparatus, wherein the solid lubricant sheet comprises at least one solid-state lubricant material selected from graphite, molybdenum disulfide, tungsten disulfide, and boron nitride; and
applying force to the workpiece with the die to plastically deform the workpiece.

14. The process of claim 13, wherein the solid lubricant sheet is a solid graphite sheet.

15. The process of claim 13, wherein positioning a solid lubricant sheet between a workpiece and a die in a forging apparatus comprises:
positioning the solid lubricant sheet onto an upper surface of a lower die; and
positioning the workpiece onto the solid lubricant sheet,
wherein the solid lubricant sheet is positioned between a bottom surface of the workpiece and an upper surface of the lower die in the forging apparatus.

16. The process of claim 15, further comprising positioning an additional solid lubricant sheet onto a top surface of the workpiece.

17. The process of claim 13, further comprising heating the die before the solid lubricant sheet is positioned between the workpiece and the die in the forging apparatus.

18. The process of claim 13, wherein the workpiece is at a temperature in the range of 1000°F to 2000°F during deformation, and the shear factor between the die and the workpiece during deformation is in the range of 0.05 to 0.50.

19. The process of claim 13, wherein the workpiece is at a temperature in the range of 1000°F to 1600°F during deformation, and the shear friction factor between the die and the workpiece during deformation is in the range of 0.09 to 0.20.

20. The process of claim 13, wherein the workpiece is plastically deformed in a forging operation selected from the group consisting of open-die forging, closed-die forging, forward extrusion, backward extrusion, radial forging, upset forging, and draw forging.

21. The process of claim 13, wherein the workpiece is plastically deformed in one of a near-net-shape forging process and a net-shape forging process.

22. The process of claim 13, wherein the workpiece comprises a titanium alloy.

23. The process of claim 13, wherein the workpiece comprises a zirconium alloy.

24. The process of claim 13, further comprising removing residual solid lubricant from the workpiece after the workpiece is plastically deformed.

25. The process of claim 13, wherein the solid lubricant sheet prevents die locking of the workpiece to the die.

26. The process of claim 13, wherein the forging apparatus comprises a closed-die forging apparatus, and wherein the solid lubricant sheet comprises a pre-formed shape that matches a contour of at least a region of the die.

27. The process of claim 26, wherein the workpiece is plastically deformed in one of a near-net-shape forging process and a net-shape forging process.

28. The process of claim 26, wherein positioning a solid lubricant sheet between a workpiece and a die in a closed-die forging apparatus comprises:
inserting the solid lubricant sheet into a die cavity in the die, wherein the pre-formed shape of the solid lubricant sheet matches a contour of at least a region of the die in the die cavity; and
inserting the workpiece into the die cavity and onto the solid lubricant

sheet;

wherein the solid lubricant sheet is positioned between a bottom surface of the workpiece and an upper surface of the die in the die cavity.

29. The process of claim 26, wherein positioning a solid lubricant sheet between a workpiece and a die in a closed-die forging apparatus comprises:
inserting a first solid lubricant sheet into a die cavity in the closed-die forging apparatus, wherein the first solid lubricant sheet comprises a pre-formed shape that matches a contour of at least a region of a lower die in the die cavity;
inserting the workpiece into the die cavity and onto the first solid lubricant sheet; and
positioning a second solid lubricant sheet between a top surface of the workpiece and a lower surface of an upper die in the closed-die forging apparatus.