

## **MODERATE-STRENGTH ALUMINUM ALLOY ISOTHERMAL DIE FORGING PROCESS**

### **TECHNICAL FIELD**

5           The present invention relates to the field of forging technologies, and particularly to a moderate-strength aluminum alloy isothermal die forging process.

### **BACKGROUND**

10           Aluminum alloy has low density but high strength, which is close or superior to that of high-quality steel. It has good plasticity, which can be machined into various profiles, and has excellent electrical conductivity, thermal conductivity and corrosion resistance, which is the most widely used non-ferrous metal structural material in industry, and has been widely used in aviation, aerospace, automobiles, machinery manufacturing, ships, chemical, smart wear and other industries. During application of the aluminum alloy, it is often necessary to forge an aluminum alloy material into a  
15           required shape. The forging process takes advantage of the plasticity of the material, and the material is shaped and deformed by an external force.

            In a common aluminum alloy forging process, the aluminum alloy material is heated to a high temperature to improve the plasticity of the aluminum alloy material, and then the aluminum alloy material is forged into the required shape through free forging, die forging or rolled ring forging.  
20           However, the strength of the aluminum alloy material would also be greatly reduced after the forging process. Therefore, after the aluminum alloy material is forged, the workpiece is often subjected to a solid solution and an artificial aging heat treatment process to improve the strength of the workpiece. However, there is a tendency of intergranular corrosion in the solid solution plus the artificial aging treatment process, and intergranular corrosion will greatly reduce the mechanical strength of the  
25           aluminum alloy, seriously affecting the performance of the workpiece, thereby causing huge economic losses and serious safety hazards.

### **SUMMARY**

            The present invention aims to solve at least one of the technical problems in the prior art.  
30           Therefore, the present invention comprises a moderate-strength aluminum alloy isothermal die

forging process, so that the aluminum alloy material will always maintain a moderate strength in a forging process, thereby improving mechanical properties of an aluminum alloy workpiece, while improving forging efficiency, and at the same time, reducing forging costs.

5 The present invention describes various embodiment of a moderate-strength aluminum alloy isothermal die forging process comprising the following steps:

preparing aluminum alloy blanks;

performing a stress relief annealing heat treatment on the blanks, wherein a heating temperature is no higher than 250°C; and

performing isothermal die forging of the blanks.

10 The moderate-strength aluminum alloy isothermal die forging process described in the embodiments of the present invention has at least the following beneficial effects.

Stress relief annealing is adopted in a heat treatment process of the aluminum alloy blank, and the heating temperature of the blank is controlled to be no higher than 250°C, to enhance the plasticity of the blank, while the blank is maintained at a moderate strength. Therefore, the final forged  
15 workpiece will have a moderate strength, which means that a solid solution and an artificial aging treatment, used to enhance the strength of the workpiece, will not be needed any more, thereby reducing the total number of forging procedures, improving forging efficiency, and reducing forging costs.

According to the moderate-strength aluminum alloy isothermal die forging process in some  
20 embodiments of the present invention, performing the stress relief annealing heat treatment on the blanks comprises the following steps:

heating the blanks to 200°C to 250°C, and performing heat preservation for no less than 3 hours;

stopping heating in a furnace, and cooling the blanks subjected to the heat preservation, in the furnace to 150°C to 200°C; and

25 performing air cooling on the blanks cooled in the furnace.

According to the moderate-strength aluminum alloy isothermal die forging process in some embodiments of the present invention, the cooling time in the furnace lasts for no less than 5 hours.

According to the moderate-strength aluminum alloy isothermal die forging process in some  
30 embodiments of the present invention, performing the isothermal die forging of the blanks, comprises the following steps:

heating a forging die to 80°C to 300°C;

placing the blanks into the forging die; and  
assembling the forging die to forge the blanks.

According to the moderate-strength aluminum alloy isothermal die forging process in some embodiments of the present invention, the isothermal die forging is performed at 80°C to 300°C.

5 According to the moderate-strength aluminum alloy isothermal die forging process in some embodiments of the present invention, preparing the aluminum alloy blanks, comprises the following steps:

sawing or stamping an aluminum alloy material into a blank required for forging; and  
performing a surface treatment on the blank.

10 According to the moderate-strength aluminum alloy isothermal die forging process in some embodiments of the present invention, the surface treatment is a surface grinding treatment to increase a surface roughness.

The moderate-strength aluminum alloy isothermal die forging process in some embodiments of the present invention further comprises the following step:

15 performing a surface lubrication treatment on the blanks before the isothermal die forging.

According to the moderate-strength aluminum alloy isothermal die forging process in some embodiments of the present invention, the surface lubrication treatment is a surface saponification lubrication treatment.

20 Additional aspects and advantages of the present invention will be given in part in the following description, which will become apparent from the following description or be understood through practice of the present invention.

## **DETAILED DESCRIPTION**

25 Embodiments of the present invention are described below in detail, and examples of the embodiments are shown in the drawings, wherein identical or similar reference numerals denote identical or similar elements or elements having the same or similar functions. The embodiments described hereinafter with reference to the drawings are exemplary, are only intended to explain the present invention, and cannot be understood as limiting the present invention.

30 In the description of the present invention, it should be understood that the orientation or position relation related to the orientation description, such as the orientation or position relation indicated by

the terms “upper”, “lower”, “left”, “right”, “front”, “rear”, and the like, is based on the orientation or position relation shown in the drawings, which is only used for the convenience of description of the present invention and simplification of description instead of indicating or implying that the indicated device or element must have a specific orientation, and be constructed and operated in a specific orientation, and thus should not be understood as a limitation to the present invention.

In the description of the present invention, if there are descriptions of first and second, it is only for the purpose of distinguishing between technical features, and shall not be understood as indicating or implying relative importance or implying the number of indicated technical features or implying the order of indicated technical features.

In the description of the present invention, unless otherwise explicitly defined, the terms “setting”, “mounting” and “connecting” should be understood in a broad sense, and those of ordinary skills in the art can reasonably determine the specific meanings of the above terms in the present invention in combination with the specific contents of the technical solution.

A moderate-strength aluminum alloy isothermal die forging process in the embodiment of the present invention comprises the following steps:

preparing aluminum alloy blanks;

performing a stress relief annealing heat treatment on the blanks, wherein a heating temperature is no higher than 250°C; and

performing isothermal die forging on the blanks.

Stress relief annealing is adopted in a heat treatment process, and the heating temperature of the blank is controlled to be no higher than 250°C, to enhance the plasticity of the blank, while the blank is maintained at the moderate strength. Therefore, the final forged workpiece will have a moderate strength, which means that the solid solution and artificial aging treatment are not needed any more, thereby reducing the total number of forging procedures, improving the forging efficiency, and reducing the forging costs.

It is understood that, annealing is a metal heat treatment process, and refers to that a metal is slowly heated to a certain temperature, holding the temperature for a certain period of time, and then cooled at an appropriate speed. The purpose is to reduce hardness, eliminate residual stress, stabilize dimension, and reduce deformation and cracking tendencies. Common annealing methods in the aluminum alloy heat treatment specification comprise homogenization annealing, complete annealing and rapid annealing. In the homogenization annealing, the aluminum alloy is heated to 480°C to 495°C; in the complete annealing, the aluminum alloy is heated to 390°C to 430°C; and in the rapid

annealing, the aluminum alloy is heated to 350°C to 370°C. The common aluminum alloy annealing methods all have a very high heating temperature, which greatly reduces the strength of a heated aluminum alloy. Therefore, the strength of an aluminum alloy workpiece subjected to forging after conventional heat treatment cannot meet the requirements for usage. However, in the embodiment of the present invention, the heating temperature during annealing is controlled to be no higher than 250°C, so that a strength of the annealed aluminum alloy material is kept at a moderate strength, and mechanical properties of the forged aluminum alloy workpiece are not affected. The forging workpiece does not need the solid solution plus the artificial aging treatment, so that manufacturing costs are significantly reduced; and meanwhile, a tendency of intergranular corrosion after the solid solution and the artificial aging treatment is avoided, and mechanical properties of the workpiece are more stable and reliable.

It is understood that, performing the stress relief annealing heat treatment on the blanks, comprises the following steps:

- heating the blanks to 200°C to 250°C, and performing heat preservation for no less than 3 hours;
- stopping heating in a furnace, and cooling the blanks subjected to the heat preservation in the furnace to 150°C to 200°C; and
- performing air cooling on the blanks cooled in the furnace.

It is understood that, the heat preservation performed after heating the aluminum alloy material to 200°C to 250°C can reduce hardness of the aluminum alloy material. The annealing makes the microstructure of the aluminum alloy material more uniform and reduces the strength, which is beneficial for subsequent forging treatment.

It is understood that, the cooling in the furnace lasts for no less than 5 hours. Specifically, through the cooling in the furnace for 5 hours, the aluminum alloy material is cooled slowly, which can avoid shrinkage caused by a fast cooling speed and a low temperature at an edge and a wave form caused by a slow cooling speed and a high temperature at a center, thereby generating new stress and deformation.

It is understood that, performing the isothermal die forging of the lubricated blanks, comprises the following steps:

- heating a forging die to 80°C to 300°C;
- placing the blanks into the forging die; and
- assembling the forging die to forge the blanks.

It is understood that, the isothermal die forging is performed at 80°C to 300°C.

It is understood that, the forging die is preheated to 80°C to 300°C, so that a temperature of the forging die is higher than a normal temperature and lower than a recrystallization temperature of the aluminum alloy (the recrystallization temperature of conventional aluminum alloy is 350°C to 370°C). At the moment, the die forging in the embodiment belongs to a warm forging process. The warm forging process can improve accuracy and quality of a forged piece to obtain a precision forged piece with low costs. Moreover, the forging die is preheated to 80°C to 300°C, so that the temperature of the aluminum alloy material in the forging die can be increased through heat conduction, which is beneficial for forming the forged piece.

It is understood that, preparing the aluminum alloy blanks, comprises the following steps:  
sawing or stamping an aluminum alloy material into a blank required for forging; and  
performing a surface treatment on the blank.

It is understood that, the surface treatment in the embodiment is a surface grinding treatment to grind a surface of the blank, thereby increasing the surface roughness. Specifically, the surface treatment process may also be shot blasting, sand blasting and other processes.

It is understood that, the moderate-strength aluminum alloy isothermal die forging process in the embodiment further comprises the following step:

performing a surface lubrication treatment on the blanks before the isothermal die forging.

It is understood that, the surface lubrication treatment in the embodiment is a surface saponification lubrication treatment.

In a workpiece forging process, after the blank is pressed, the pressure in a die cavity is very large, so that if the lubrication of the blank is not ideal, the blank may directly exert a force on the die cavity and the force cannot be dispersed, and the strong pressure may eventually reduce a service life or cause direct rupture of the die. Therefore, it is necessary to remove a part of pressure acting on the die cavity and lubricate the surface of the blank, so as to reduce the friction between the blank and the die, and reduce wear of the surface of the blank at the same time, thereby prolonging service lives of the die and the workpiece.

Taking a 6063-T6 sheet as an example, an embodiment of the moderate-strength aluminum alloy isothermal die forging process of the present invention is introduced as follows.

A 6063-T6-state aluminum alloy sheet (with a thickness of 0.825 mm) was stamped into a blank dimension required for forging. The surface grinding treatment was performed on the blank to

increase the surface roughness. The stress relief annealing treatment was performed on the blank after the surface grinding treatment, wherein the stress relief annealing process comprises: heating at 240°C for 1 hour; performing heat preservation at 240°C for 2 hours, cooling in the furnace slowly for 5 hours to 200°C and then cooling in air; performing the surface saponification and lubrication treatment on the annealed blank; and performing the isothermal die forging on the lubricated blank, wherein the die was preheated at  $120\pm 10^{\circ}\text{C}$ , and the die forging was performed at  $120\pm 10^{\circ}\text{C}$ . In the embodiment, the workpiece manufactured by the isothermal die forging process has an average wall thickness of 0.5 mm, wherein a thickness deviation is  $\pm 0.05$  mm and the wall thickness is relatively uniform, and has good flatness and dimensional accuracy, and low energy consumption, safety and environmental protection, and stability and high efficiency in manufacturing. The workpiece manufactured by the isothermal die forging in the embodiment has a yield strength greater than or equal to 190 MPa and a tensile strength greater than or equal to 210 MPa. The yield strength is relatively high, which can still meet a yield strength requirement in a standard for a 6063-T6 state, and the tensile strength is slightly reduced, but it still remains in a high strength range. (A raw material in the 6063-T6 state has a yield strength greater than or equal to 190 MPa and a tensile strength greater than or equal to 240 MPa.)

Taking a 6063-T6 sheet as an example, another embodiment of the moderate-strength aluminum alloy isothermal die forging process of the present invention is introduced as follows.

A 6063-T6-state aluminum alloy sheet (with a thickness of 0.825 mm) was stamped into a blank dimension required for forging. The surface grinding treatment was performed on the blank to increase the surface roughness. The stress relief annealing treatment was performed on the blank after the surface grinding treatment, wherein the stress relief annealing process comprises: heating at 230°C for 1 hour; performing heat preservation at 230°C for 2 hours, cooling in the furnace slowly for 5 hours to 200°C and then cooling in air; performing the surface saponification and lubrication treatment on the annealed blank; and performing the isothermal die forging on the lubricated blank, wherein the die was preheated at  $150\pm 10^{\circ}\text{C}$ , and the die forging was performed at  $150\pm 10^{\circ}\text{C}$ . The workpiece manufactured by the isothermal die forging process has an average wall thickness of 0.3mm, wherein a thickness deviation is  $\pm 0.05$  mm and the wall thickness is relatively uniform, and has good flatness and dimensional accuracy, and low energy consumption, safety and environmental protection, and stability and high efficiency in manufacturing. The workpiece manufactured by the isothermal die forging in the embodiment has a yield strength greater than or equal to 190 MPa and a tensile strength greater than or equal to 210 MPa. The yield strength is relatively high, which can still meet a yield strength requirement in a standard for a 6063-T6 state, and the tensile strength is slightly reduced, but it still remains in a high strength range. (A raw material in the 6063-T6 state has

a yield strength greater than or equal to 190 MPa and a tensile strength greater than or equal to 240 MPa.)

Taking a 6063-T6 sheet as an example, another embodiment of the moderate-strength aluminum alloy isothermal die forging process of the present invention is introduced as follows.

5 A 6063-T6-state aluminum alloy sheet (with a thickness of 0.825 mm) was stamped into a blank dimension required for forging. The surface grinding treatment was performed on the blank to increase the surface roughness. The stress relief annealing treatment was performed on the blank after the surface grinding treatment, wherein the stress relief annealing process comprises: heating at 250°C for 1 hour; performing heat preservation at 250°C for 2 hours, cooling in the furnace slowly for 5  
10 hours to 200°C and then cooling in air; performing the surface saponification and lubrication treatment on the annealed blank; and performing the isothermal die forging on the lubricated blank, wherein the die was preheated at  $80\pm 10^{\circ}\text{C}$ , and the die forging was performed at  $90\pm 10^{\circ}\text{C}$ . In the embodiment, the workpiece manufactured by the isothermal die forging process has an average wall thickness of 0.5 mm, wherein a thickness deviation is  $\pm 0.05$  mm and the wall thickness is relatively  
15 uniform, and has good flatness and dimensional accuracy, and low energy consumption, safety and environmental protection, and stability and high efficiency in manufacturing. The workpiece manufactured by the isothermal die forging in the embodiment has a yield strength greater than or equal to 200 MPa, and a tensile strength greater than or equal to 210 MPa. The yield strength is relatively high, which can still meet a yield strength requirement in a standard for a 6063-T6 state,  
20 and the tensile strength is slightly reduced, but it still remains in a high strength range. (A raw material in the 6063-T6 state has a yield strength greater than or equal to 190 MPa and a tensile strength greater than or equal to 240 MPa.)

The workpieces manufactured by the isothermal die forging in the three embodiments above have a high strength, which can meet a moderate strength requirement of a certain product, and do  
25 not need the solid solution plus the artificial aging treatment, so that manufacturing costs are significantly reduced; and meanwhile, a tendency of intergranular corrosion after the solid solution and the artificial aging treatment is avoided, and mechanical properties of the workpiece are more stable and reliable.

Although the embodiments of the present invention have been shown and described, those of  
30 ordinary skills in the art may understand that various changes, modifications, substitutions and variations may be made to these embodiments without departing from the principle and purpose of the present invention, and the scope of the present invention is defined by the claims and their equivalents.

## CLAIMS

1. A moderate-strength aluminum alloy isothermal die forging process, comprising the following steps:

preparing aluminum alloy blanks;

5 performing a stress relief annealing heat treatment on the blanks, wherein a heating temperature is no higher than 250°C; and

performing isothermal die forging of the blanks.

2. The moderate-strength aluminum alloy isothermal die forging process according to claim 1, wherein performing the stress relief annealing heat treatment on the blanks, comprises the following steps:

heating the blanks to 200°C to 250°C, and performing heat preservation for no less than 3 hours;

stopping heating in a furnace, and cooling the blanks subjected to the heat preservation in the furnace to 150°C to 200°C; and

15 performing air cooling on the blanks cooled in the furnace.

3. The moderate-strength aluminum alloy isothermal die forging process according to claim 2, wherein the cooling in the furnace lasts for no less than 5 hours.

4. The moderate-strength aluminum alloy isothermal die forging process according to claim 1, wherein performing the isothermal die forging of the blanks, comprises the following steps:

20 heating a forging die to 80°C to 300°C;

placing the blanks into the forging die; and

assembling the forging die to forge the blanks.

5. The moderate-strength aluminum alloy isothermal die forging process according to claim 4, wherein the isothermal die forging is performed at 80°C to 300°C.

25 6. The moderate-strength aluminum alloy isothermal die forging process according to any one of claims 1 to 5, wherein preparing the aluminum alloy blanks, comprises the following steps:

sawing or stamping an aluminum alloy material into a blank required for forging; and

performing a surface treatment on the blank.

7. The moderate-strength aluminum alloy isothermal die forging process according to claim

6, wherein the surface treatment is a surface grinding treatment to increase a surface roughness.

8. The moderate-strength aluminum alloy isothermal die forging process according to any one of claims 1 to 5, further comprising the following step:

performing a surface lubrication treatment on the blanks before the isothermal die forging.

5        9. The moderate-strength aluminum alloy isothermal die forging process according to claim 8, wherein the surface lubrication treatment is a surface saponification lubrication treatment.