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[54] METHOD FOR PRODUCING ANNULAR FORGINGS

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[63] Continuation of Ser. No. 92,525, Nov. 24, 1970, abandoned.

[52] U.S. Cl. .... **148/11.5 R,** 75/175.5, 148/12.7, 148/11.5 F

[51] **Int. Cl.** **C21d**

[58] **Field of Search** .... 148/11.5 F, 12.7, 133, 148/131, 130; 75/175.5, 11.5 R

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[57] **ABSTRACT**

In the process of free forging an ingot made of titanium alloy with an $\alpha+\beta$ structure is subjected to multiple plastic deformation in its axial, radial, and tangential directions with an overall degree of deformation in each of these directions being not less than 60 percent of the total deformation, and with sucessive changing of the direction of the deforming force. On completion of deformation annealing is performed at a temperature somewhat below the temperature of phase transformation of the alloy from β to $\alpha+\beta$ structure.

4 Claims, No Drawings

METHOD FOR PRODUCING ANNULAR FORGINGS

This is a continuation, of application Ser. No. 92,525, filed Nov. 24, 1970, and now abandoned.

BACKGROUND OF THE INVENTION

The present invention relates to methods of making annular forgings intended to act under high mechanical loads, and can be used in the production of annular forgings for shroud rings of the rotors of powerful turbogenerators rated at 500 MW and more.

Known in the art is a method to make blanks for the rotor shroud rings by free forging, wherein the ingot is drawn, upset, pierced through, and expanded, the blank being then heat treated and strain-hardened.

Steel shroud rings made by this method, although possessing adequate mechanical properties in normal conditions of operation, may cause failure of turbogenerators under high mechanical loads in conditions of elevated temperature and increased moisture, thus requiring frequent examinations and replacement of the rings.

The well-known advantages of titanium alloys - their high strength and corrosion resistance - result in the development of these alloys in aircraft construction and other industries for producing heavy-duty components featuring high resistance to corrosion and elevated temperatures.

Known in the prior art are methods of producing blanks of components weighing up to 300 kg by free forging or swaging the ingots of titanium alloys with a single-phase or double-phase ($\alpha+\beta$) structure. Known for such components are conditions of hot plastic deformation and heat treatment, that provide for high strength and plasticity of titanium alloy forgings. In particular, for titanium alloys with a double -phase $\alpha+\beta$ structure hot plastic deformation is advised with these components being heated to temperatures corresponding to the $\alpha+\beta$ structure. Also known are more precise parameters of thermomechanical treatment of titanium alloys with an $\alpha+\beta$ double-phase structure, namely working of the ingot at temperatures 40°–90°C below the temperature point of transformation of β structure of the alloy into $\alpha+\beta$ structure, and to a degree of deformation equaling 40–70 percent.

The prior art conditions of hot plastic deformation in the production of titanium alloy articles do not secure uniform and equiaxial structure throughout the cross section of blanks of large size and weight, i.e. 500 kg and more, for example, of forgings of rotor shroud rings for powerful turbogenerators.

SUMMARY OF THE INVENTION

The object of the present invention is to choose such conditions of the working method to produce annular forgings by hot plastic deformation of an ingot of titanium-based alloys with a double-phase $\alpha+\beta$ structure with the amount of β phase being up to 30 percent; that will ensure the obtaining of a uniform and equiaxial structure throughout the cross section of the article.

The above and other objects are achieved according to the invention by multiple plastic deformation of the ingot in the axial, radial, and tangential directions with an overall degree of deformation in each of these directions being not less than 60 percent of the total deformation, and with successive changing of the direction

of the deforming force, the deformation in the last forging operation being not less than 40 percent. Also, the blank heating temperature is successively reduced from a temperature which exceeds by 50°–80°C the temperature point of the phase transformation of the alloy from β to $\alpha+\beta$ structure at the first forging operation, to a temperature 20°–30°C below said temperature point at the last forging operation, and on completion of plastic deformation the blank is annealed at temperatures below said temperature point.

The indicated solution provides for the action of forces of varying directions on all the layers of the forging in the most plastic condition of the ingot, working thereof being finished in the temperature zone of $\alpha+\beta$ state of the alloy structure, which makes it possible to obtain a uniform and equiaxial structure throughout the cross section of the forging.

To avoid cracks, the first of the forging operations preferably includes deforming the ingot in the radial direction.

In accordance with one of its embodiments the invention may provide for the following conditions and succession of plastic deformation realized in forging operations: ingot drawing with a lateral deformation of 30–50 percent at a temperature which exceeds by 50°–80°C the temperature point of phase transformation of the alloy from β to $\alpha+\beta$ structure; upsetting with a deformation of 50–70 percent and hole piercing at a temperature exceeding by 30°–50°C said temperature point; drawing the hollow blank with a deformation of 30–40 percent, expansion with deformation of 20–30 percent, and upsetting with deformation of 10–30 percent at a temperature which is 20°–30°C higher than said temperature point; after these operations the blank is drawn with a relative deformation of up to 30 percent, and expanded to deformation of 40–50 percent, at temperatures 20°–30°C below the said temperature point.

Advantageously, annealing of the obtained forgings should be performed in the following succession: heating the forging to 800°–900°C and keeping it at this temperature for not less than one hour, with subsequent complete air cooling, then second heating to a temperature of 550°–650°C with maintenance at this temperature for not less than 1 hour, and with subsequent complete cooling.

DETAILED DESCRIPTION OF THE INVENTION

Described below are exemplary embodiments of the method for producing an annular forging for the turbogenerator rotor shroud from a titanium-based alloy with a content of Al being 6%, Mo — 2.5%, Cr — 2%, and with the temperature of phase transformation from β into $\alpha+\beta$ structure being 980°C.

EXAMPLE 1

An ingot weighing 1300 kg is heated to a temperature of 1050°C and drawn under free forging to a deformation of 38% in its cross section. Next the thus obtained blank is heated to a temperature of 1000°C and upset to an axial deformation of 62 percent of the total deformation, and then pierced through. After the hollow blank is heated to 1000°C, it is placed on a mandrel and drawn with a deformation of 36 percent in the ring depth. The blank is again heated to 1000°C and expanded on a mandrel to a deformation of 26 percent in wall thickness. After heating to 1000°C the blank is upset with deformation of 29 percent in depth. Next, at a temperature of 1000°C the blank is drawn on a mandrel with deformation in the depth amounting to 25 percent. Then at a temperature of 950°C the blank is expanded to the required dimensions of the forging, the degree of deformation in wall thickness being 42 percent.

On completion of the forging operations the forging is air-cooled to room temperature. Annealing of the forging is performed as follows: heating to 800°C, keeping at this temperature for one hour, and air cooling.

EXAMPLE 2

The initial ingot with a weight of 2600 kg is heated to a temperature of 1040°C. At this temperature the ingot is upset by 52 percent in depth, and is pierced through. After that the hollow blank is heated to 1020°C and placed on a mandrel. At this temperature drawing is accomplished to a deformation in depth reaching 39 percent. After this operation and heating to 1000°C the blank is expanded with a deformation of 17 percent in the ring thickness.

Next the blank is heated to 980°C with subsequent upsetting to a deformation of 30 percent in depth. After this operation the blank is heated to 950°C, at which temperature it is drawn with deformation of 30 percent in depth. Final expansion is accomplished after heating to 950°C, the deformation in the ring thickness being 40 percent. After finishing the said operations the blank is air-cooled and heat treated in the followiong succession:

The forging is heated to 870°C, held at this temperature for 1 hour, and air-cooled. Then it is heated to a temperature of 650°C, and maintained at this temperature for 2 hours with subsequent air cooling.

The mechanical properties of forgings produced under the described conditions of the process, as obtained on specimens cut out tangentially at 20°C, are as follows:

ing by 50°–80°C the temperature of phase transformation from β to $\alpha + \beta$ structure; subjecting said ingot to successive multiple plastic deformations in the axial, radial, and tangential directions of the ingot with an overall degree of deformation being not less than 60 percent to form a blank; decreasing each heating step during said deformation from said first heating temperature to a temperature 20°–30°C below the temperature of said phase transformation before the last mentioned deformation, the temperature of each heating step being between 950° and 1050°C; and annealing the blank on completion of said plastic deformation, the annealing being performed at a temperature somewhat below said temperature of phase transformation whereby a large annular blank having solely a uniform equiaxial microstructure is produced.

2. The method as in claim **1**, wherein the first of the forging operations comprises deforming the ingot in the radial direction.

3. The method as in claim **1**, wherein plastic deformation is realized during the forging operations in the following succession and under the following conditions: ingot drawing with a lateral deformation amounting to 30–50 percent of the overall deformation at a temperature which exceeds by 50°–80°C the temperature of phase transformation of the alloy from β to $\alpha + \beta$ structure; upsetting with a deformation of 50–70 percent and hole piercing at a temperature exceeding by 30°–50°C said phase transformation temperature; drawing the hollow blank to a deformation of 30–40 percent, expanding with deformation of 20–30 percent, and upsetting with deformation of 10–30 percent at a temperature being 20°–30°C higher than said phase transformation temperature; then drawing the blank with a relative deformation of up to 30 percent and expanding with deformation of 40–50 percent at a temperature from 20°–30°C below said phase transformation temperature.

example	wall thickness mm	tensile strength kg/mm²	yield point kg/mm²	elongation δ%	relative reduction ψ%	impact ductility kg/cm²
1	120	104–109	97–102	12–15	28–42	3–4
2	160	101–106	93–101	9.5–14	28–35	4.–4.5

What is claimed is:

1. A method for producing large annular forgings of more than about 500 kg. by freely forging an ingot made of titanium-based alloys with a double-phase $\alpha + \beta$ structure, the amount of β phase being up to 30 percent, which comprises the steps of heating the ingot before successive forging steps, the first heating exceed-

4. The method as in claim **3**, wherein annealing is carried out by heating the blank to 800°–900°C and keeping it at this temperature for not less than 1 hour, with subsequent complete air cooling; then secondary heating to a temperature of 550°–650°C and maintaining at this temperature for not less than 1 hour; and finally completely cooling.

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