

1

3,489,617

METHOD FOR REFINING THE BETA GRAIN SIZE OF ALPHA AND ALPHA-BETA TITANIUM BASE ALLOYS

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No Drawing. Filed Apr. 11, 1967, Ser. No. 630,125

Int. Cl. C21d 7/14

U.S. Cl. 148—11.5

13 Claims

ABSTRACT OF THE DISCLOSURE

A method for processing bodies of alpha and alpha-beta type titanium base alloys consisting of working a body of the alloy from an initial temperature above the beta transus of the alloy to effect a substantial reduction in cross sectional area above the beta transus to impart strain energy to the metal and recrystallizing the beta grains. The recrystallization may be effected either simultaneously with working or by a separate anneal at a temperature at least as high as the initial working temperature.

This invention relates to refining the beta grain size of alpha and alpha-beta type titanium base alloys and more particularly to refining the beta grain size of such alloys during processing of ingots to billets for forging stock.

Excessive surface cracking is often encountered when forging certain types of titanium alloys, and this cracking is believed to result from coarse beta grain size in the ingot or billet. Tests have demonstrated that susceptibility to surface cracking is related to beta grain size, and that material having a fine beta grain size exhibits substantially less surface cracking than material with a coarse beta grain size when both materials are forged from the same temperature.

Processing of alpha and alpha-beta titanium base alloy ingots to produce forging stock involves forging the cast ingot to a suitable size billet for subsequent forging. Forging temperatures have heretofore largely been determined in accordance with the lowest temperature at which the required plastic deformation can be obtained for the particular alloy being processed. Although higher forging temperatures than the minimum necessary for plastic deformation result in greater plasticity and thereby reduce the amount of work required to effect a predetermined reduction in cross sectional area, the use of higher forging temperatures requires additional expense for furnace heating and increases surface oxide and scale. Additionally, it has heretofore been believed that higher forging temperatures caused undesirable grain growth.

Efforts have been made to refine the beta grain size of alpha and alpha-beta type titanium base alloys by extensive working in the alpha-beta field in conjunction with various annealing procedures. While this type of processing has been successful, it requires a long period of time and often results in low metal yield as extensive working in the alpha-beta field causes surface cracking requiring grinding between successive forging steps.

My invention provides a novel method for refining the beta grain size of an alloy selected from the group consisting of alpha and alpha-beta type titanium base alloys which comprises working the alloy to an extent providing substantial plastic deformation at a temperature above the beta transus to introduce strain energy into the metal and effecting recrystallization of the beta grains at a temperature above the beta transus. Plastic deformation and recrystallization may be carried out separately or may be combined in a single step. The temperature at which working is initiated and the amount of reduction of

2

the metal body will determine whether an independent anneal is required to effect recrystallization and the working temperature will vary with the type of alloy being processed.

The alpha and alpha-beta type titanium base alloys may be advantageously treated by the method of this invention. An alloy containing 5% aluminum, 2.5% tin, balance titanium is typical of the class of alpha type alloys in its characteristics, properties and susceptibility to beta grain refinement in accordance with my method. An alloy comprising 6% aluminum, 4% vanadium, balance titanium is typical of the alpha-beta type alloys in its characteristics, properties and susceptibility to beta grain refinement by my method. The alloys which may be processed by my invention include alloys sometimes classified as alpha-lean beta, which contain alpha and beta stabilizing elements, but in which the beta stabilizing elements are present in relatively smaller amounts than in the alpha-beta type alloys. Due to the fact that the beta stabilizer content is small, these alloys in their characteristics, properties and susceptibility to beta grain refinements are similar to the alpha titanium base alloys and are considered as being in the same category as the alpha type alloys for the purpose of my invention. An alloy comprising 8% aluminum, 1% vanadium, 1% molybdenum, balance titanium is typical of the alpha-lean beta type titanium base alloys.

Working of the ingot at a temperature above its beta transus is carried out so as to effect substantial deformation of the metal in the beta field to impart strain energy to the metal. For the purpose of my invention, initial working temperature must be above the beta transus of the alloy being processed and preferably will be between about 100° F. and about 500° F. above the beta transus of the alloy. It will be appreciated that lower temperatures within this range will involve lower heating cost and less scaling and surface contamination of an article so processed; while temperatures higher in the range will provide increased plasticity resulting in easier deformation. It is pointed out that at the higher temperatures recrystallization will occur simultaneously with working and will, therefore, take place throughout a large part of the working cycle; whereas at the lower temperatures, an anneal at a temperature at or above the initial working temperature is required to effect recrystallization. The plastic deformation will preferably be no less than about a 30% reduction in the cross sectional area of the metal body, and reductions up to about 90% may be employed with better grain size effects being obtained with increased plastic deformation.

Preferably, the recrystallization anneal will be between about 2100° F. and about 2400° F. but must be at least as high as the initial working temperature. The duration of the anneal must be sufficient to bring the metal body into the beta field throughout its extent. This will be accomplished in a period of about one hour at 2300° F., although the time at temperature will vary between about one hour and about four hours with the higher temperatures being employed with the shorter time periods and the lower temperatures being combined with longer time periods.

More precise temperature ranges for initiating working and for annealing may be defined for the particular types of alloys which may be processed according to my invention of the anneal being determined by the temperature. working will preferably begin at a temperature between about 1900° F. and about 2050° F. After sufficient working has been accomplished, the alloy will preferably be annealed between about 2100° F. and about 2400° F. for a period of about one hour to four hours; the duration of the anneal being determined by the temperature. When the alloy to be processed according to my inven-

tion is of the alpha or alpha-lean beta type, working will preferably be started at a temperature in the range of about 1950° F. to 2150° F. The temperature and duration of the subsequent anneal for this group of alloys is the same as for the alpha-beta type, that is, between about 2100° F. and about 2400° F. for a period of about one hour to four hours. The temperature is selected to be higher than the initial working temperature, and the higher temperatures are employed with the shorter times and vice versa as in treating the alpha-beta type alloys.

In carrying out my novel process in a single step combining recrystallization with working, the working must be initiated at a temperature substantially above the beta transus of the alloy and about 2200° F. is the minimum for both the alpha and alpha-beta type alloys. At temperatures below about 2200° F., it is not possible to reduce the metal sufficiently to impart enough strain to the metal to permit recrystallization during working. The preferred temperature range for effecting simultaneous recrystallization and plastic deformation is from about 2200° F. to about 2400° F.

As stated heretofore, the plastic deformation accomplished during working must result in a substantial reduction of the cross sectional area of the metal body which will preferably be at least about 30%. A minimum of about 30% reduction in cross sectional area is necessary to introduce sufficient strain energy into the metal for nucleation to promote the fine beta structure. As stated heretofore, reductions of substantially more than 30% may be employed, and improved overall results are obtained with up to about 90% reduction. It will be appreciated that the amount of reduction will depend upon the temperature employed and the dimension limits of articles being produced during various stages of conversion of ingots to mill products. Therefore, a range of reduction between about 30% and about 90% will provide adequate working and at the same time may be incorporated into the forging sequence when producing a majority of titanium alloy mill products.

After recrystallization of the beta grain structure is obtained, the metal body must be worked in the alpha-beta field in order to break up the alpha network which precipitates on the recrystallized beta grain boundaries as the metal cools through the beta transus. It is necessary to break up the alpha network to impart ductility and strength to the metal. Working in the alpha-beta field does not affect the fine beta grain size obtained by processing the metal in accordance with my invention and is not not considered to be a part of the invention. The metal may be worked from a temperature in the beta field, but it is essential that the major portion of the reduction occur in the alpha-beta field to break up the alpha network.

The following non-limiting examples shows the practice of an embodiment of my method on representative alloys.

EXAMPLE A

A Ti-6Al-4V bar was forged from a 6 inch by 4 inch billet to a 3 inch square which is a reduction in cross sectional area of 62%. The forging was initiated at 2000° F. Following the forging, the 3 inch square was annealed for one hour at 2300° F. Extremely advantageous grain refinement was achieved by processing in accordance with my invention.

EXAMPLE B

The typical as-cast coarse structure of an ingot of Ti-5Al-2.5Sn which is a representative alpha type alloy is a result of precipitation of alpha along the original large beta grain outlines. The beta transus of this alloy is approximately 1900° F. A Ti-5Al-2.5Sn alloy was forged from a 6 inch square to a 5 inch square to effect a 30% reduction. The forging was initiated at 2050° F. and no recrystallization was apparent. A section of the

square was heat treated at 1950° F., which is slightly above the beta transus for the alloy but below the initial forging temperature and no recrystallization occurred. However, a section taken from the same bar was annealed for two hours at 2300° F., well above the initial forging temperature, and complete recrystallization is observable.

Simultaneous recrystallization with working for representative alloys is shown by the following non-limiting examples.

Example I

A 28-inch diameter ingot of Ti-8Al-1Mo-1V alloy having a beta transus of about 1900° F. was processed to an 8-inch round as follows:

Upset 35% from 2200° F.
Reheat to 2200° F. and forge to 24" square
Reheat to 2200° F. and upset 35%
Reheat to 2200° F. and forge to 24" square
Reheat to 2200° F. and forge to 16" square
Reheat to 1950° F. and forge to 12" square
Reheat to 1900° F. and forge to 8" square
Reheat to 1875° F. and forge to 8" round

The 8-inch round billet resulting from this processing had a fine beta grain size indicating that recrystallization occurred simultaneously with working during the high temperature reductions. Additionally, no cracking occurred during the various reduction steps; and, hence, it was not necessary to grind between reductions.

Example II

A 28-inch diameter ingot of Ti-5Al-2.5 Sn alloy having a beta transus of about 1900° F. was processed to a 12 inch round as follows:

Upset 35% from 2200° F.
Reheat to 2200° F. and forge to 24" square
Reheat to 2200° F. and forge to 16" square
Reheat to 1950° F. and forge to 12" square
Reheat to 1900° F. and forge to 12" round

The resulting billet had a fine beta grain size indicating simultaneous recrystallization with working during the high temperature reductions and no significant cracking occurred during forging.

Example III

A 6-inch cube of Ti-6Al-4V alloy having a beta transus of approximately 1825° F. was processed to a 2.25-inch round in the following sequence:

Upset 55% from 2200° F.
Reheat to 2200° F. and reforge to 6" square
Reheat to 2200° F. and forge to 4.25" square
Reheat to 1900° F. and forge to 3.25" square
Reheat to 1800° F. and forge to 2.25" round

Observation of a section from the billet indicated that recrystallization occurred. The fine beta grain size was clearly observable.

It should be understood that the recrystallization temperature of the alloys will vary with the amount of strain energy imparted to the metal during working; and, therefore, it will be necessary to effect greater reductions at higher temperatures to obtain the desired strain in the metal. Additionally, the starting grain size will affect the recrystallization temperature. The length of time at temperature during annealing will also have an effect on the temperature necessary to effect recrystallization with shorter anneals requiring higher temperatures.

My invention is important in that it permits ingots of alpha and alpha-beta type titanium base alloys to be forged to billet stock from higher temperatures than those used heretofore while permitting obtention of fine beta grain size which is advantageous for subsequent forging of products from the billet. Due to the use of higher forging temperatures than those used heretofore,

5

the ingot may be reduced to a billet of the desired size in a minimum time and surface cracking during reduction is substantially eliminated. The avoidance of surface cracking during reduction is substantially eliminated. The avoidance of surface cracking is extremely important as it eliminates grinding the billet and the consequent expense and metal loss.

While I have described preferred embodiments of my invention, it may be otherwise embodied within the scope of the appended claims.

I claim:

1. A method for refining the beta grain size of an alloy selected from the group consisting of alpha and alpha-beta type titanium base alloys comprising heating a body of said alloy to an initial temperature above the beta transus of said alloy, working said body of said alloy from said initial temperature above its beta transus to effect substantial plastic deformation of said body while said body is above said beta transus and annealing said body at a temperature at least as high as said initial working temperature for a period of time sufficient to effect substantially complete recrystallization of the beta grains of said body.

2. A method as set forth in claim 1 wherein said plastic deformation is at least about a 30% reduction in cross sectional area of said body.

3. A method as set forth in claim 1 wherein said plastic deformation is between about a 30% and about a 90% reduction in cross sectional area of said body.

4. A method as set forth in claim 1 wherein annealing said body is carried out for a period of from about one hour to about four hours.

5. A method as set forth in claim 4 wherein said annealing is at about 2300° F. for a period of about one hour.

6. A method as set forth in claim 1 wherein said initial working temperature is at least about 100° F. above the beta transus of said alloy.

7. A method as set forth in claim 1 wherein said alloy is the alpha-beta type and said initial working temperature is between about 1900° F. and 2050° F. and said annealing is at a temperature between about 2100° F. and 2400° F.

6

8. A method as set forth in claim 1 wherein said alloy is the alpha type and said initial working temperature is between about 1950° F. and 2150° F. and said annealing is at a temperature between about 2100° F. and 2400° F.

9. A method for refining the beta grain size of an alloy selected from the group consisting of alpha and alpha-beta type titanium base alloys comprising heating a body of said alloy to an initial temperature substantially above the beta transus of said alloy, working said body of said alloy from said initial temperature to effect substantial plastic deformation of said body above the beta transus of said alloy, said plastic deformation imparting sufficient strain energy to said alloy to permit substantial recrystallization of the beta grains of said body during working.

10. A method as set forth in claim 9 wherein said initial temperature is at least about 2200° F.

11. A method as set forth in claim 9 wherein said initial working temperature is between about 2200° F. and 2400° F.

12. A method as set forth in claim 9 wherein said working effects a reduction in cross sectional area of said body of at least about 30%.

13. A method for refining the beta grain size of an alloy selected from the group consisting of alpha and alpha-beta type titanium base alloys comprising heating a body of said alloy to a temperature of at least about 100° F. above the beta transus of said alloy, working said body to effect a reduction in cross sectional area of at least about 30% and recrystallizing the beta grains of said body.

References Cited

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L. DEWAYNE RUTLEDGE, Primary Examiner

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U.S. Cl. X.R.

148—12.7

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,489,617 Dated January 13, 1970

Inventor(s) WALTER W. WUERFEL

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In Column 2, Line 29, "substantial deformation" should read "substantial plastic deformation", Column 2 Line 54, delete "duration", Column 2 Line 65, after "tion" delete "of the anneal being determined by the temperature", Column 2 Line 66, before "working" insert "For titanium base alloys of the alpha-be type," Column 3, Line 49, delete "not", Column 4, Line 6, "is" should read "was", Column 5, Line 3, delete "The avoidance of surface cracking during reduction is substantially eliminated."

Signed and sealed this 16th day of June 1970.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
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