

May 5, 1953

E. F. LOSCO ET AL
PROCESS OF PRODUCING BOLTS

2,637,672

Filed Aug. 22, 1950

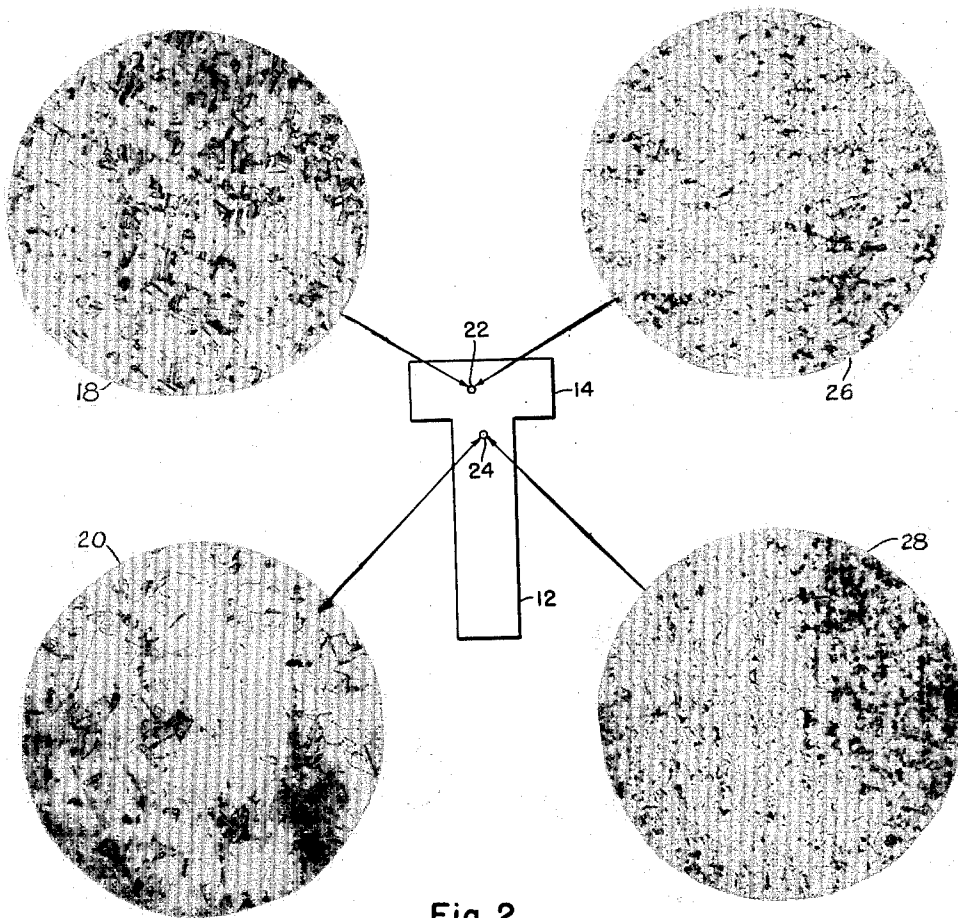
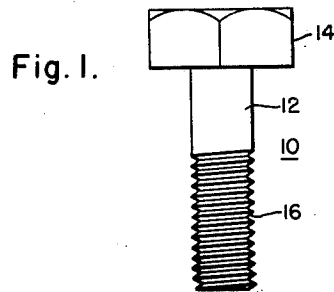


Fig. 2.

INVENTORS
Ezekiel F. Losco &
Frederick C. Hull

BY
James H. Ely
ATTORNEY

UNITED STATES PATENT OFFICE

2,637,672

PROCESS OF PRODUCING BOLTS

Ezekiel F. Losco and Frederick C. Hull, Pittsburgh, Pa., assignors to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

Application August 22, 1950, Serial No. 180,864

4 Claims. (Cl. 148—12.7)

1

This invention relates to the process of producing bolts having good mechanical characteristics at elevated temperatures from austenitic alloys.

Bolts have been widely used in gas turbines to hold the components thereof together. It has been quite difficult heretofore to produce bolts which will have adequate strength at the elevated temperatures encountered in use in the gas turbines. Heretofore, where the bolts have been made of heat resistant alloys, the bolts were produced by machining them from hexagonal or round bar stock of the alloy. Such methods of manufacture were costly and resulted in uneconomical utilization of the expensive and strategically important alloys because of the large percentage of the metal which was converted to turnings during the machining.

The heat resistant alloys which have been used as the bolting stock from which the bolts have been machined are of the austenitic type employing a precipitation hardening agent. Such alloys have been developed for use at elevated temperatures of 1000° F. to 1600° F. and respond to a precipitation hardening treatment. Such response is retained over a wide range of compositions where the austenitic alloys have chromium and at least one of the elements selected from the group consisting of nickel, iron and cobalt as the base metal thereof, when the precipitation hardening constituent is titanium. These alloys are not critical with respect to the content of the base metal so long as the matrix is a solid solution having only the face centered cubic crystal structure from room temperature up to at least 2200° F. Other elements and impurities including deoxidizers may be present in such austenitic alloys in nominal contents, and molybdenum and/or tungsten in effective amounts.

Other alloys of this class are precipitation hardened with molybdenum or molybdenum plus tungsten, and respond to a precipitation hardening heat treatment in the complete absence of titanium, for example, the alloys of U. S. Patent No. 2,403,128. In this case, however, the hardener content is contingent on the matrix composition in accordance with relations disclosed in that patent. Such alloys, nevertheless, react almost identically with the titanium alloys so far as the teachings of this invention are concerned.

Thus the alloy group from which the bolts are to be made can be broadly classified as austenitic alloys whose matrix is dominantly iron group elements and which has a face centered cubic crystal structure and which may be usefully hardened

2

for service at temperatures of 1000° F. to 1600° F. or higher by a combination of a solution treatment which dissolves the hardener and an ageing treatment which induces precipitation hardening.

In producing bolts from such alloys, it has been heretofore found to be practical to do so only by machining bar stock as referred to hereinbefore. Where attempts have been made to form the bolts by known heading processes after which the headed bolt was subjected to the solution and ageing treatment, it was found that the resulting bolt had a non-uniform grain size regardless of the size of the bolt, composition of the alloy or the heading temperature. In all cases the bolt so formed and so heat treated had coarse grained regions along the sides of the shank and below the head of the bolt, whereas the head of the bolt had a fine grain size with a coarse area near the top of the head in certain instances. Such mixed microstructures lead to inferior and non-reproducible properties in the resulting bolt.

Since the coarse grained region always appeared in the region very close to the junction between the head and the shank of the bolt, where the change of section provides a concentration of stress, the bolts headed from the austenitic alloys in accordance with known practice were always weak at this vital area of the bolt. This is because the coarse grained material has lower endurance strength and less ductility in creep at elevated temperatures producing the worst structural condition at this vital area of the bolt.

An object of this invention is to provide a process for producing bolts which will have improved mechanical properties at elevated temperatures from precipitation hardenable austenitic alloys.

Another object of this invention is to provide, in a process for producing bolts from precipitation hardenable austenitic alloys, for so conditioning the alloy that it can be headed, solution treated and aged to provide substantially uniform mechanical properties throughout the bolt and render it suitable for use at elevated temperatures.

Other objects of this invention will become apparent from the following description when taken in conjunction with the accompanying drawing, in which:

Figure 1 is a view in elevation of a bolt produced in accordance with this invention, and

Fig. 2 is a composite view showing photomicrographs of two different portions of bolts pro-

duced by a prior art process and by the process of this invention.

The alloys from which a bolt shown generally at 10 may be made in accordance with the process of this invention may generally be described as precipitation hardenable austenitic alloys having chromium and at least one of the elements nickel, iron and cobalt as the base metal thereof with a precipitation hardening constituent added thereto. Alloys of this type are disclosed and claimed in Patent No. 2,044,165, issued June 16, 1936, to G. P. Halliwell, and consist broadly of 20% to 70% nickel, 60% to 10% cobalt, 5% to 50% iron, 0.5% to 10% titanium, and chromium in amounts ranging from traces up to 20%. Another alloy of this type which has been employed for certain high temperature applications consists broadly of 32% to 42% nickel, 10% to 23% cobalt, 16% to 25% chromium, 3% to 19% iron, 2% to 4% titanium, molybdenum and/or tungsten in an amount to equal the equivalent weight of 2% to 5% molybdenum with minor impurities. Patent No. 2,475,642, issued July 12, 1949, to Scott and et al. also discloses an austenitic alloy of 15% to 35% nickel, 20% to 40% cobalt, 17% to 22% chromium, 3% to 15% molybdenum, 1% to 9% tungsten and the balance iron with minor impurities to which the process of this invention is applicable. Another austenitic alloy of this class is that disclosed in the Scott et al. application, Serial No. 41,467, filed July 30, 1948, now Patent No. 2,519,406 and comprises from 15% to 35% nickel, 7% to 20% chromium, molybdenum and/or tungsten in an amount to equal from 2% to 5% by weight, 1.3% to 1.9% titanium, not more than 0.4% aluminum and the balance iron with minor impurities. These alloys undergo no phase change between room temperature and the maximum feasible treatment temperature and therefore their grain size can not be refined by heat treatment alone, as is possible with low alloy and plain carbon steels.

While a number of alloys have been clearly identified it is to be understood that they have been so identified only by way of illustration of the alloys to which this invention may be applied and not as a limitation. This will be apparent for the process of this invention can be applied to other alloys having a matrix with a face centered cubic crystal structure and which are capable of being precipitation hardened. As examples of such alloys reference may be had to an alloy having a composition of 73% nickel, 15% chromium, 2.5% titanium, 7% iron, 1% columbium, 0.7% aluminum, 0.5% manganese, 0.4% silicon and .04% carbon and to the alloy having a composition of 73% nickel, 21% chromium, 2.2% titanium, 0.45% iron, 0.7% aluminum, 0.6% manganese, 0.6% silicon and 0.5% carbon.

In accordance with this invention, the ingot or billet of the austenitic precipitation hardenable alloy is so processed to a wire or bar form approaching the desired size of the shank 12 of the bolt 10 which is to be formed therefrom as to have a substantially uniform grain size at least as fine as No. 4 ASTM and preferably finer than No. 6 ASTM. A satisfactory method for accomplishing such results is to subject the billet to a number of cycles of cold drawing or cold rolling and annealing of the stock, the cold working applied effecting a reduction in area of between 25 and 50% between the annealing steps with the annealing being done at temperatures

in the range of 1750° F. to 2000° F. for a period of time of between one-half and two hours. Sufficient cycles are applied to reduce the bar to a predetermined size of from 10 to 25% over the size of the shank 12 of bolt 10 which is to be made therefrom while at the same time the recrystallization of the alloy is obtained to a uniform grain size of No. 4 ASTM or finer.

Instead of the alternate cold working and annealing of the bar to effect the reduction in size of the bar and the recrystallization of the alloy, other methods of effecting the refinement of the grain to a size at least as fine as No. 4 ASTM may be employed. Thus, for example, the alternate working and reheating cycles at elevated starting temperatures at which successive recrystallizations effect a substantial refinement of the grain size of the original coarse grained ingot or billet as disclosed in the copending application Serial No. 41,466, of Scott et al. filed July 30, 1948, now Patent No. 2,545,862, may be employed in forming the wrought bar having a uniform grain size of No. 4 ASTM or finer.

In order to control the final grain size of the bolt 10 to be formed, a controlled work hardening is applied to the bar having the grain size at least as fine as No. 4 ASTM without effecting recrystallization of the alloy. In practice the work hardening applied is sufficient to effect a reduction in area of the bar of from 10% to 25% and preferably from 15% to 20%. Such work hardening of the austenitic precipitation hardenable alloys may be performed at temperatures of up to 1650° F., the high end of the range being used if it is desired to reduce the resistance of the alloy to deformation. In most cases it is possible and more convenient to introduce the cold working by cold drawing the bar at room temperatures.

In applying the work hardening it is found that the reduction in area must not exceed 25% as further reductions introduce so much work hardening that it is impractical to cold head the bar with standard equipment and excessive wear of the cold heading dies occurs. On the other hand, if the cold working operation effects less than a 10% reduction in area it has been found that the shank 12 of the bolt 10 will have a coarser grain size than the head 14 of the bolt after solution treatment.

After the bar has been cold worked as described, it is cold headed by conventional methods to form the head 14 on one end of the bar. The cold heading may be accomplished at a temperature within the range of from room temperature up to 1650° F. without effecting appreciable recrystallization of the alloy prior to the heading operation. If the heading is accomplished at temperatures near the upper limit of 1650° F., the resistance of the alloy to plastic deformation is reduced. However, a satisfactory flow of the metal is obtained with the proper heading equipment even at room temperature to form even the extreme edges of the head 14 without accompanying cracking.

The bolt 10 headed in this manner is then subjected to a precipitation hardening treatment consisting of a solution treatment at a temperature between 1750° F. and 2300° F. for a period of time of ½ hour to 4 hours after which it is quenched, preferably in oil, and then aged at a temperature between 1200° F. and 1600° F. for from 20 to 100 hours. The solution treatment selected and time of soaking thereat is contingent on the alloy composition and the final grain size

desired. The ageing temperature and time of ageing are dependent upon the alloy composition and in particular upon the hardening agent. Thus if titanium is employed as the hardener then lower solution and ageing temperatures are to be preferred, whereas if molybdenum and/or tungsten are used as hardeners then higher solution and ageing temperatures are to be preferred.

In practice the bolt 10 may be threaded as at 16 either after the solution treatment or after the ageing treatment. It is preferred however to thread the bolt, either by machining or by rolling the threads, after the bolt has been subjected to the solution treatment and prior to the ageing treatment.

In order to illustrate the improvement obtained by practicing the process of this invention reference is had to Fig. 2 of the drawing in which 18 and 20 are photomicrographs at 100 diameters magnification at points 22 and 24, respectively, of the head 14 and shank 12 of a bolt 10 having a nominal composition of 42% nickel, 22% cobalt, 18% chromium, 0.7% manganese, 0.7% silicon, 0.2% aluminum, 2.2% titanium, 0.05% carbon and the balance iron, which was headed at 70° F. from a bar having a grain size at least as fine as No. 4 ASTM and annealed to relieve stresses and remove work hardening therefrom in accordance with accepted prior art practice previous to the heading operation and then solution treated for one hour at 1750° F., and 26 and 28 are photomicrographs at 100 diameters magnification of points 22 and 24, respectively, of the head 14 and shank 12 of a bolt 10 of the same composition but which was headed at 70° F. from a wrought bar having a grain size at least as fine as No. 4 ASTM and cold worked between 10 and 25% prior to the heading operation and then solution treated for one hour at 1750° F.

The photomicrographs 18 and 20 clearly demonstrate that the head 14 of the bolt 10 which was not cold worked 10 to 25% prior to the heading has recrystallized to a fine grain size whereas the shank 12 exhibits excessive grain growth in the area across the shank 12 adjacent to the head 14 of the bolt. Such excessive grain growth is also usually found in a thin surface layer extending toward the threaded end of the bolt. This is because the severe deformation of the cold heading operation had drastically work hardened the grains in the head portion but had little or no visible effect on the grains of the shank portion. Then when the solution treatment is applied to the bolt 10, the material of the head 14 recrystallizes to a fine grain size whereas the slightly deformed grains in the region of the shank just below the head recrystallize to a coarse grain size to give the worst structural condition in a vital area of the bolt. Such results are obtained in all heat treated bolts of austenitic alloy regardless of size, composition or heading temperature where either hot or cold heading is applied to a bar which has been annealed instead of cold worked an amount equivalent to a reduction in area of 10% to 25% prior to the cold heading operation.

As opposed to the results obtained by known prior art practices, photomicrographs 26 and 28 illustrate the substantially uniform fine grain size produced in all portions of the headed bolt when the bolt 10 is produced in accordance with this invention. The cold working, such as cold drawing or cold rolling, applied just prior to the heading operation places all of the material

of the bolt in a condition such that when solution treated after the heading operation a uniform fine grain size is obtained. Thus the cold working of 10% to 25% reduction in area of the bar prior to the heading operation introduces a minimum level of work hardening throughout the bar that is retained during the heading thereby eliminating any regions of critical strain so that upon solution treatment, the entire bolt 10 is recrystallized to a uniform grain size.

The bolts produced in accordance with this invention have superior mechanical characteristics at elevated temperatures over those obtained in bolts of austenitic alloy heretofore. The process may be closely controlled and makes possible the production of bolts having reproducible characteristics. There is no waste of expensive alloy in producing the bolts nor does the process require any special equipment as standard furnaces and headers may be employed. The resulting bolts of austenitic alloy are especially useful for high temperature applications such as in gas turbines or the like where good mechanical properties and creep resistance are required at temperatures between 1000° F. and 1600° F.

While this invention has been described with reference to the making of bolts, it is of course to be understood that the process is applicable also to the making of screws, rivets and other special parts which have somewhat similar form and which are to be produced with a headed section thereon. Where we have employed the term "cold heading" we mean the forcing of metal to flow cold into dies to form thicker sections and more or less intricate shapes and at temperatures up to the recrystallization temperature of the metal so headed.

We claim as our invention:

1. The process of producing a headed article from a wrought bar of an austenitic alloy having chromium and at least one of the elements selected from the group consisting of nickel, iron and cobalt as the base metal thereof and containing a precipitation hardening constituent, the wrought bar having a substantially uniform grain size at least as fine as No. 4 ASTM, the steps comprising, working the wrought bar at a temperature below the recrystallization temperature of the alloy to effect a reduction in area of from 10% to 25% and introduce work hardening therein, heading the bar at a temperature below 1650° F. to produce a head thereon, solution treating the headed bar at a temperature between 1750° F. and 2300° F. for a period of time between ½ and 4 hours to recrystallize the alloy whereby to remove work hardening therefrom and to produce a substantially uniform grain size throughout the head and the bar, quenching the headed bar, and ageing the quenched headed bar at a temperature between 1200° F. and 1600° F. for a period of time between 20 and 100 hours.

2. The process of producing a headed article from stock of an austenitic alloy having chromium and at least one of the elements selected from the group consisting of nickel, iron and cobalt as the base metal thereof and containing a precipitation hardening constituent, the steps comprising, working the stock to a bar having a predetermined size and being completely recrystallized to a substantially uniform grain size at least as fine as No. 4 ASTM, working the bar at a temperature below the recrystallization temperature of the alloy to effect a reduction in area of from 10% to 25% to introduce predetermined work hardening therein, cold heading the bar

at a temperature below 1650° F. to produce a head thereon, solution treating the headed bar at a temperature between 1750° F. and 2300° F. for a period of time between ½ and 4 hours to recrystallize the alloy whereby to remove work hardening therefrom and to produce a substantially uniform grain size throughout the head and the bar, quenching the headed bar, and ageing the quenched headed bar at a temperature between 1200° F. and 1600° F. for a period of time between 20 and 100 hours.

3. The process of producing a bolt from a wrought bar of an austenitic alloy having chromium and at least one of the elements selected from the group consisting of nickel, iron and cobalt as the base metal thereof and containing a precipitation hardening constituent, the wrought bar having a substantially uniform grain size at least as fine as No. 4 ASTM, the steps comprising, working the wrought bar at a temperature below the recrystallization temperature of the alloy to effect a reduction in area of from 10% to 25% and introduce work hardening therein, heading one end of the bar at a temperature below 1650° F. to produce a bolt head thereon, solution treating the headed bar at a temperature between 1750° F. and 2300° F. for a period of time between ½ and 4 hours to recrystallize the alloy whereby to remove work hardening therefrom and to produce a substantially uniform grain size throughout the head and the bar, quenching the headed bar, forming threads on the end of the solution treated bar opposite the headed end to structurally complete the bolt, and ageing the bolt at a temperature between 1200° F. and 1600° F. for a period of time between 20 and 100 hours.

4. The process of producing a bolt from stock of an austenitic alloy having chromium and at least one of the elements selected from the group

consisting of nickel, iron and cobalt as the base metal thereof and containing a precipitation hardening constituent, the steps comprising, working the stock to a bar having a predetermined size and being completely recrystallized to a substantially uniform grain size at least as fine as No. 4 ASTM, working the bar at a temperature below the recrystallization temperature of the alloy to effect a reduction in area from 10% to 25% to introduce predetermined work hardening therein, heading one end of the bar at a temperature below 1650° F. to produce a bolt head thereon, solution treating the headed bar at a temperature between 1750° F. and 2300° F. for a period of time between ½ and 4 hours to recrystallize the alloy whereby to remove work hardening therefrom and to produce a substantially uniform grain size throughout the head and the bar, quenching the headed bar, forming threads on the end of the solution treated bar opposite the headed end to structurally complete the bolt, and ageing the bolt at a temperature between 1200° F. and 1600° F. for a period of time between 20 and 100 hours.

EZEKIEL F. LOSCO.

FREDERICK C. HULL.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,173,092	Baker	Sept. 19, 1939
2,278,495	Schaufus	Apr. 7, 1942
2,423,738	Thielmann	July 8, 1947
2,519,406	Scott et al.	Aug. 22, 1950
2,545,862	Scott et al.	Mar. 20, 1951

FOREIGN PATENTS

Number	Country	Date
368,154	Great Britain	Mar. 3, 1932