United States Patent [19]

Malone et al.

[11] **3,844,778**

[45] **Oct. 29, 1974**

[54] **METHOD FOR PRODUCING GROOVED ALLOY STRUCTURES**

[75] Inventors: **Raymond F. Malone**, Beaver, Pa.; **Linus M. Raring**, Glastonbury, Conn.

[73] Assignee: **Crucible Inc.**, Pittsburgh, Pa.

[22] Filed: **Apr. 12, 1973**

[21] Appl. No.: **350,423**

[52] **U.S. Cl.** ..... **75/208 R**, 75/214, 75/226, 29/182.3

[51] **Int. Cl.** **B22f 1/00**

[58] **Field of Search** 29/182.3; 75/208, 214, 75/226, 200

[56] **References Cited**

UNITED STATES PATENTS

2,783,504	3/1957	Hamjian et al.	75/214
2,847,708	8/1958	Hamjian et al.	75/214
3,166,836	1/1965	Bigler	29/182.3
3,361,562	1/1968	Ulrich et al.	75/208 R
3,394,446	7/1968	Valyi	29/182.3

Primary Examiner—Benjamin R. Padgett
Assistant Examiner—B. Hunt

[57] **ABSTRACT**

A method for producing an alloy structure having deep surface grooves therein by bonding of alloy powder to a fully dense member, such as a plate having on surfaces thereof nondeformable ceramic mandrels defining the grooves desired. After compacting to fully densify the alloy powder and bond it to the fully dense alloy plate member the ceramic mandrels are removed to expose the grooves. An air-tight, evacuated assembly constituting the powder, plate and nondeformable ceramic mandrels is provided for unitary hot isostatic compacting.

13 Claims, 3 Drawing Figures

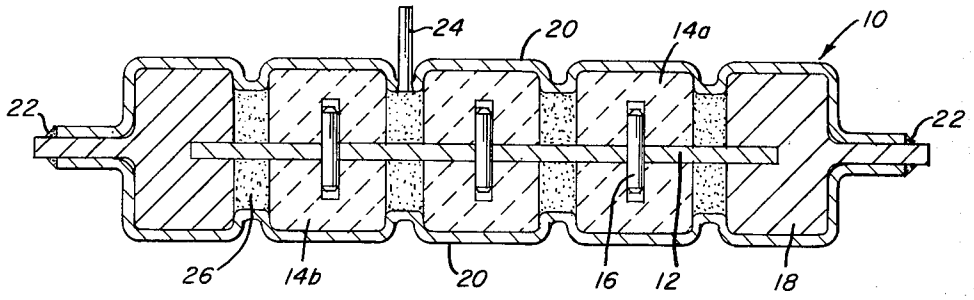


FIG. 1

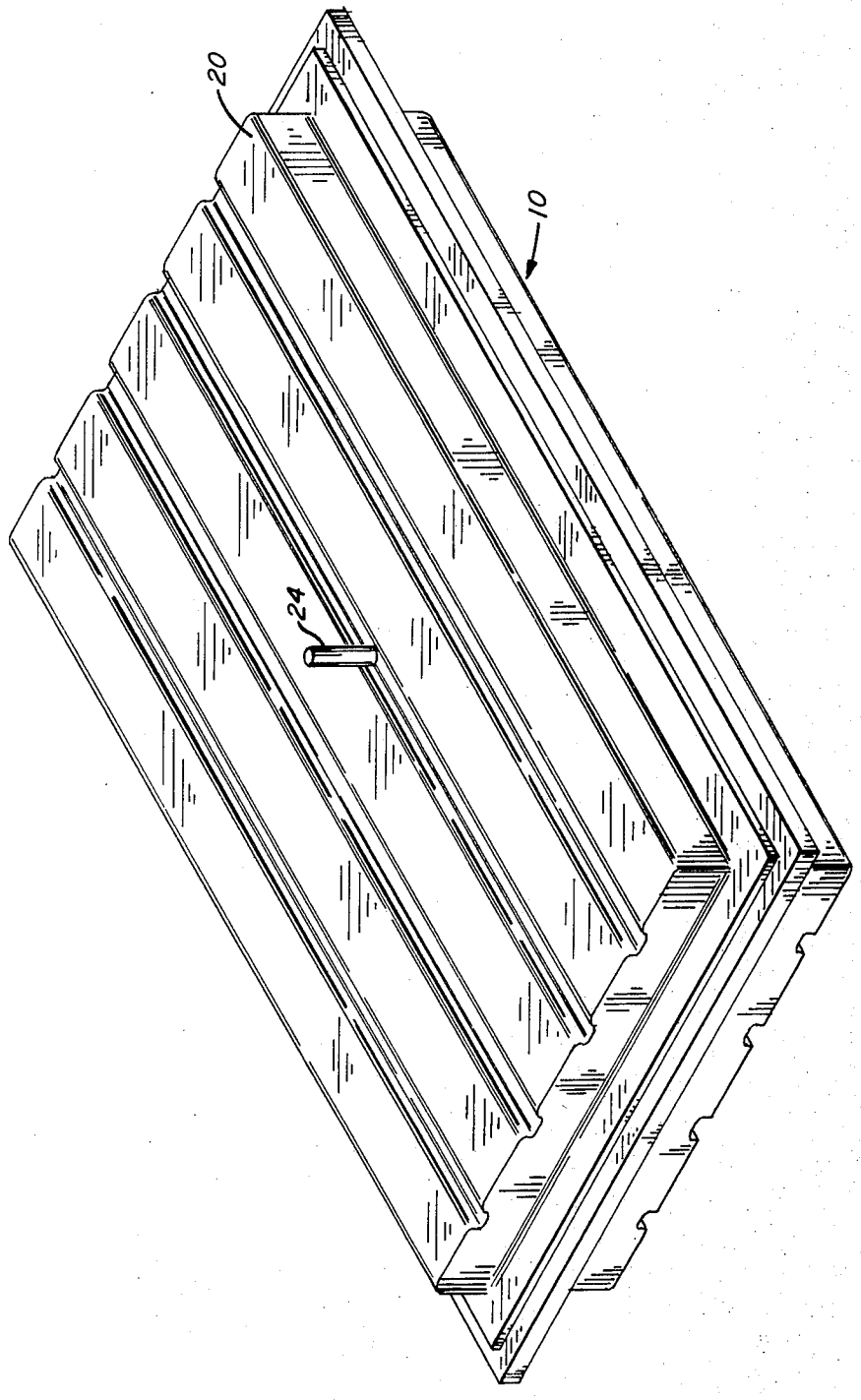


FIG. 2

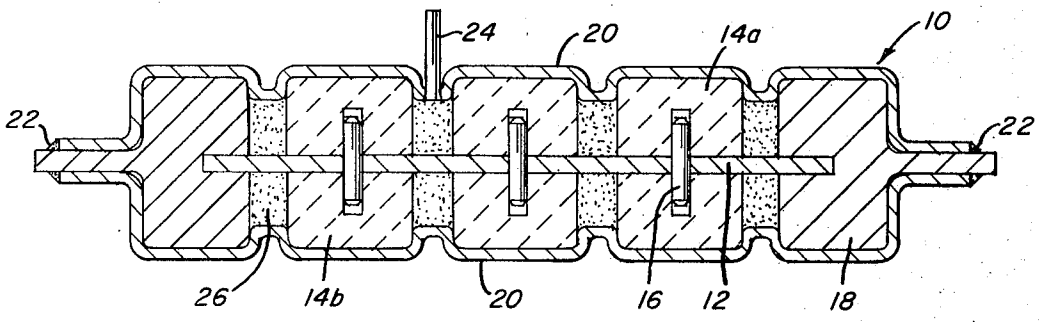
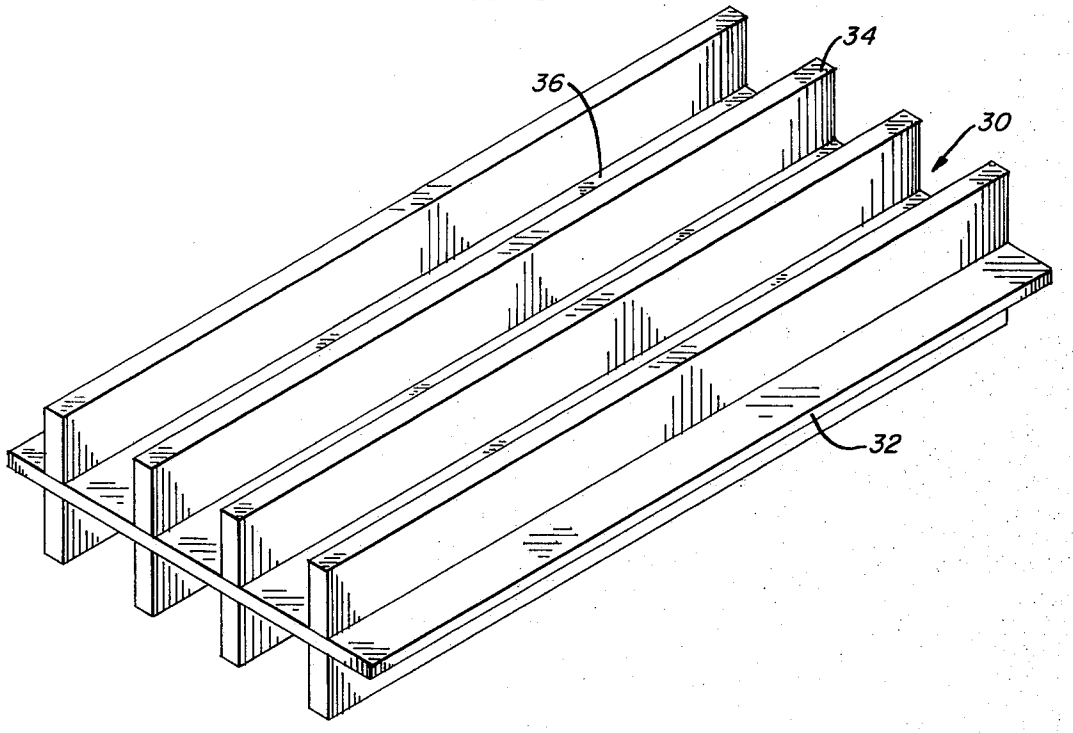


FIG. 3



METHOD FOR PRODUCING GROOVED ALLOY STRUCTURES

In many applications it is desired to have deep-pocketed structural members having grooves, ribs and the like in somewhat intricate configuration. Particularly in the aircraft industry alloy air frame components, such as bulkheads, ribs, spars and the like, are characterized by this structure. Conventionally these components were made from aluminum alloys. The deep-pocketed structural members of aluminum alloys were produced by machining of aluminum forgings. With newer aircraft wherein more stringent strength-to-weight ratio requires the use of titanium alloys as a substitute for aluminum alloys for air-frame components, it is no longer economically feasible to form such components by machining of forgings because of the relatively high cost of titanium alloys in comparison with the aluminum alloys conventionally used for the purpose.

It is, therefore, a primary object of the present invention to provide a method for producing alloy structures, particularly from titanium-base alloys, by a hot-isostatic compacting technique wherein the machining required to form ribs, grooves or the like is substantially eliminated.

This and other objects of the invention as well as a complete understanding thereof may be obtained from the following description, specific examples and drawings, in which:

FIG. **1** is a perspective view of an assembly suitable for compacting to form deep-pocketed structural members in accordance with the method of the invention;

FIG. **2** is a transverse section of the assembly of FIG. **1**; and

FIG. **3** is a perspective view of the deep-pocketed alloy structure resulting from the use of the method of the invention with the assembly of FIGS. **1** and **2.**

Broadly in the practice of the invention alloy structures, particularly of titanium-base alloys, having deep-surface grooves are produced by bonding alloy powder to a fully dense alloy member, such as a plate, with the alloy powder constituting the ribs or other projections defining the deep-surface grooves. For this purpose nondeformable mandrels, preferably of a ceramic material, are placed on the fully dense alloy member, which may be a plate, with the mandrels having a configuration and orientation with respect to the plate conforming to the desired configuration and orientation of the deep-surface grooves desired on the final structure. The plate with the associated mandrels is placed in an envelope that may be sealed against the atmosphere and the interior of the same is filled with alloy powder generally of the same composition as the alloy of the fully dense plate member. The envelope should be of a deformable material such as mild steel. The envelope is evacuated for removal of impurities, particularly oxygen, and heated to an elevated temperature suitable for compacting, which may be within the range of 1,500° to 1,950° F with a preferred range of 1,650° to 1,850° F for titanium-base alloys for which the method of the invention is particularly adapted. Upon reaching elevated temperature the assembly, which is sealed against the atmosphere, is transferred to a pressure vessel for hot isostatic compacting to final density. Generally for this purpose when using autoclaves with gas as the pressure medium pressures on the order of 12,000 to 20,000 p.s.i. are sufficient. After compacting during which the alloy powder is compacted to substantially full density and metallurgically bonded to the fully dense member the assembly is cooled and the ceramic mandrels are removed to expose the desired grooves or pockets in the final structure. The envelope providing the gas-tight enclosure for the assembly is likewise removed as by machining, acid pickling or a combination thereof. The ceramic mandrel may generally be removed by a mild grit-blasting operation. To facilitate removal it is preferred that the nondeformable ceramic mandrel by constructed from about 95 percent alumina with the balance being a binding agent such as colloidal silica. However, any refractory oxide or a combination thereof, such as zirconia, alumina and silica, may be used in combination with a suitable binding agent. It is necessary that the ceramic material of the mandrel be nondeformable under the existing pressure and temperature conditions during hot isostatic compacting so that the projections and grooves formed on the surface of the fully dense plate by welding and compacting of the powder relative to the plate will be of the desired configuration as governed by the configuration of the mandrels. For this purpose refractory oxides are preferred materials for construction of the mandrels in that they will not deteriorate or lose significant strength at the high temperatures and pressures required for hot isostatic compacting and, consequently, the term "refractory" as used herein means that the material remains nondeformable under the high-temperature and pressure conditions incident to the hot isostatic compacting operation. Although from the commercial standpoint prealloyed powder would generally be employed in the practice of the invention in special applications elemental powder could be used. Therefore, the term "alloy" as used herein also includes metals in unalloyed or elemental form. To prevent contamination of the structure it is customary to subject the assembly to conventional "outgassing" prior to compacting. In the well-known manner the assembly would be heated to an intermediate temperature at which the gassification products would be withdrawn and the evacuated assembly would then be sealed against the atmosphere prior to hot isostatic compacting.

With reference to the drawings there is shown in FIGS. **1** and **2** an assembly, designated generally as **10,** suitable for use in the practice of the invention. The assembly **10** consists of a fully dense alloy plate **12** of generally rectangular configuration. Attached to the two major surfaces of the plate **12** in opposed relation are nondeformable ceramic mandrels **14***a* and **14***b*. There are, as shown in FIG. **2,** three opposed pairs of mandrels with each pair secured to the plate **12** by pins **16.** The periphery of the plate **12** is positioned and secured within a rectangular enclosure **18** which may be of mild steel. Identical top and bottom covers **20,** which are contoured to mate with the mandrels **14,** are secured to the enclosure **18** and are in sealing engagement therewith, as by welding at **22.** A stem **24** is provided for connection to a suitable vacuum pump for evacuating the interior of the assembly **10** during outgassing. Although only a single stem **24** is shown in the drawing, a plurality could in practice be employed for effective outgassing. The interior of the assembly, as best shown in FIG. **2,** is filled with alloy powder **26.** The alloy powder **26** is in contact with the plate **12** and is confined

by the mandrels **14**. The assembly **10**, as shown in FIG. **1**, is placed in any suitable furnace (not shown) for heating to compacting temperature and is thereafter transferred to an autoclave for hot isostatic compacting. If desired, heating to compacting temperature may take place in the autoclave. Upon compacting the alloy powder **26** is compressed to substantially full density and simultaneously welded at the areas of contact to the plate **12**. Since the mandrels **14** do not deform during the compacting operation the configuration of the final compacted structure will be substantially as defined by the configuration and orientation of the mandrels relative to the plate and alloy powder. With the assembly as best shown in FIG. **2** after compacting and removal of the mandrels **14**, pins **16**, enclosure **18** and covers **20**, the deep surface grooved alloy structure as shown in FIG. **3** is produced. This structure, identified generally as **30** in FIG. **3**, has a web portion **32** constituting the plate **12** of assembly **10** prior to the compacting operation, and ribs **34** defining grooves **36**, which ribs are comprised of the alloy particles **26** of the assembly **10** compacted to full density and metallurgically bonded to the web. The grooves **36** therebetween are defined by the mandrels **14** of assembly **10**.

As an alternate embodiment of the invention, a fully dense alloy member or members may be substituted for a portion of the alloy particles **26** and positioned between the mandrels **14** of the assembly shown in FIG. **2**; these fully dense members would be spaced apart from plate **12** with particles **26** being placed therebetween. With this embodiment, upon hot isostatic compacting these members would be bonded to the particles **26** as is the plate **12**.

Another embodiment would comprise substituting fully dense alloy members that are positioned between the mandrels **14** for the particles **26**; accordingly, the plate **12** would be replaced by alloy particles.

In applications involving product structure with strict tolerance requirements the structure of the type shown in FIG. **3** after compacting may be subjected to a further final sizing operation. This sizing operation may comprise hot-coining by the use of heated dies which are machined to the required tolerances.

In accordance with the following which may be considered as a specific example of a typical practice of the invention, an assembly similar to that shown in FIGS. **1** and **2** would be constructed.

The assembly would include a fully dense plate or web member of a titanium-base alloy of the approximate alloy composition of 6 percent by weight aluminum, 4 percent by weight vanadium and the balance titanium. The plate dimensions are 24 × 12 × ⅛ in. The alloy particles are −60 mesh U.S. Standard and of substantially identical alloy composition as that of the plate. The mandrels are constructed from zirconia. The assembly is heated to a temperature of about 1,650° F and then hot isostatically compacted while being maintained at substantially this temperature at a pressure of approximately 15,000 p.s.i. by the use of nitrogen gas. After compacting, cooling and disassembly the resulting alloy structure, which is similar to that of FIG. **3**, would have a density of substantially 100 percent of theoretical and an integral bond formed between the ribs, which are of the compacted alloy particles, and the plate.

We claim:

1. A method for producing an alloy structure having a deep surface groove formed by the bonding of alloy powder to at least one fully dense alloy member, said method comprising placing adjacent said fully dense member at least one nondeformable mandrel having a configuration and orientation conforming to said deep surface groove desired on said structure, placing said alloy powder adjacent said mandrel and adjacent said fully dense member, sealing said fully dense member, said mandrel and said alloy powder in a deformable envelope to form an assembly that is sealed against the atmosphere, heating said assembly to an elevated temperature, hot isostatically compacting said assembly by the application of fluid pressure sufficient to deform said envelope and compress said alloy powder against said nondeformable mandrel and said fully dense member to compact said alloy powder to substantially full density and produce a metallurgical bond between said fully dense powder and said fully dense member without deforming said mandrel and upon completion of said compacting removing said nondeformable mandrel from said assembly to expose said surface groove on the resulting alloy structure.

2. The method of claim **1** wherein said fully dense alloy member and said alloy powder are of substantially identical alloy composition.

3. The method of claim **1** wherein said nondeformable mandrel is constructed from a ceramic material.

4. The method of claim **1** wherein said fully dense alloy member has two substantially parallel, coextensive surfaces each of which has adjacent thereto at least one said nondeformable mandrel and said alloy powder.

5. The method of claim **1** wherein said assembly comprises a fully dense alloy plate having two substantially parallel, coextensive major surfaces, at least one nondeformable ceramic mandrel on each of said major surfaces, with said mandrels being removably secured to said surfaces within said deformable envelope.

6. The method of claim **5** wherein said ceramic mandrels are secured to said surfaces in substantially opposed relation.

7. The method of claim **5** wherein the interior of said envelope is evacuated prior to said hot isostatic compacting.

8. The method of claim **5** wherein said plate and said powder are of substantially different alloy compositions.

9. A method for producing an alloy structure having deep surface grooves formed by the bonding of alloy powder to opposite surfaces of a fully dense alloy plate of substantially the same alloy composition as said alloy powder, said method comprising removably securing on each of said opposite plate surfaces at least one nondeformable ceramic mandrel having a configuration and orientation conforming to the deep surface grooves desired on said alloy structure, placing said plate and mandrels in a deformable envelope substantially filled with said alloy powder to form an assembly, evacuating said assembly, sealing said assembly against the atmosphere, heating said assembly to an elevated temperature, hot isostatically compacting said assembly by the application of fluid pressure sufficient to deform said envelope and compress said alloy powder against said nondeformable mandrel and said plate to compact said alloy powder to substantially full density and produce a metallurgical bond between said fully dense powder

and said fully dense plate without deforming said mandrel and upon completion of said compacting removing said nondeformable mandrel from said assembly to expose said surface groove on the resulting alloy structure.

10. The method of claim **9** wherein said fully dense alloy plate and said alloy powder are of substantially the same titanium-base alloy composition.

11. The method of claim **9** wherein said nondeformable ceramic mandrels are constructed from an admixture comprising refractory oxide particles from at least one of the group of refractory oxides consisting of zircon, alumina and silica, and a binding agent.

12. The method of claim **11** wherein said binding agent is colloidal silica.

13. A method for producing an alloy structure having deep surface grooves formed by the bonding of alloy powder to a surface of a fully dense alloy plate, said method comprising removably securing to said plate surface at least one nondeformable ceramic mandrel having a configuration and orientation conforming to a deep surface groove desired on said alloy structure, placing a fully dense alloy member contiguous to said mandrel and in spaced apart relation to said plate surface, placing said plate, alloy member and mandrel in a deformable envelope substantially filled with said alloy powder to form an assembly, evacuating said assembly, sealing said assembly against the atmosphere, heating said assembly to elevated temperature, hot isostatically compacting said assembly by the application of fluid pressure sufficient to deform said envelope and compress said alloy powder against said nondeformable mandrel, said alloy member and said plate to compact said alloy powder to substantially full density and produce a metallurgical bond between said fully dense powder, said alloy member and said plate without deforming said mandrel and upon completion of said compacting removing said nondeformable mandrel from said assembly to expose said surface groove on the resulting alloy structure.

* * * * *