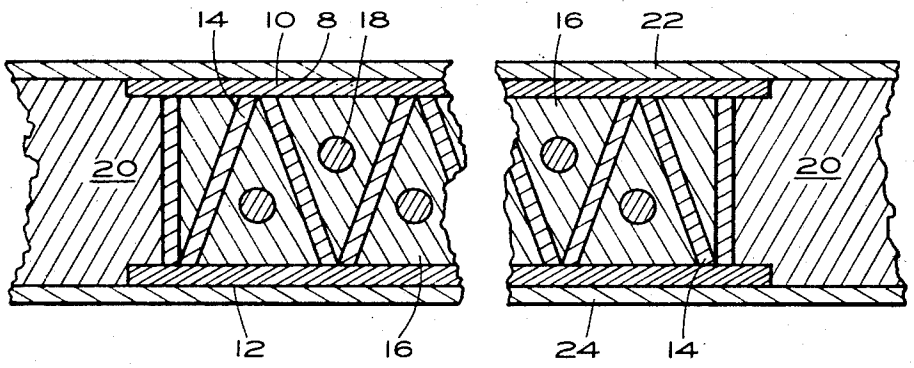
June 3, 1969 R. I. JAFFEE 3,447,231

METHOD OF PRODUCING RIBBED-METAL SANDWICH STRUCTURES

Filed June 21, 1967 Sheet 1 of 2

FIG. 1



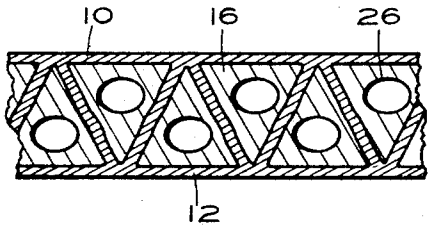
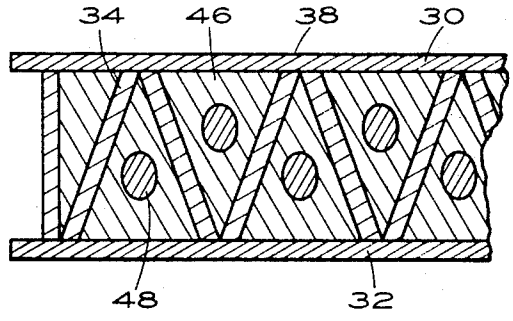


FIG. 2

FIG. 3



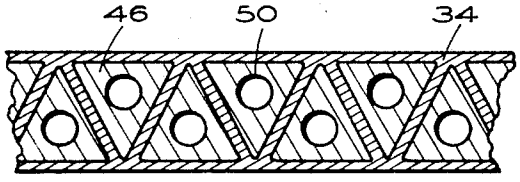


FIG. 3A

FIG. 4

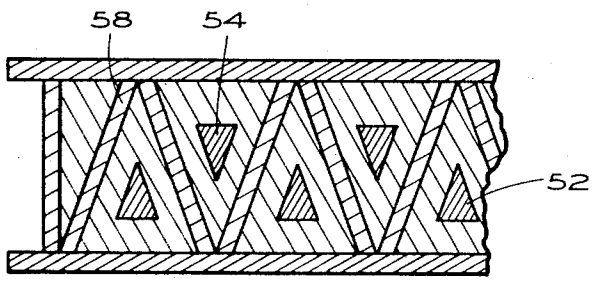


FIG. 4A

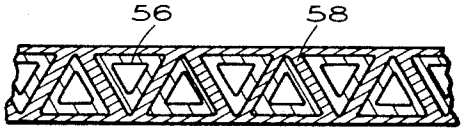


FIG. 5

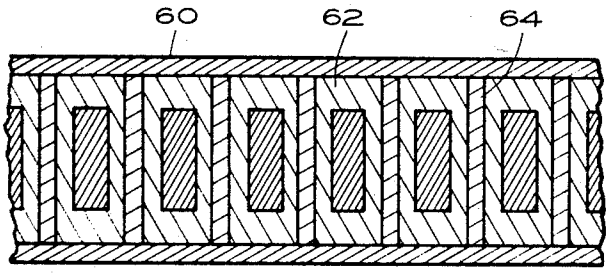
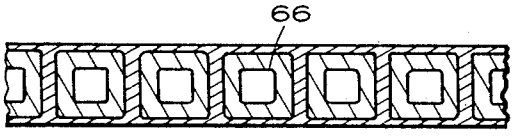


FIG. 5A



United States Patent Office

3,447,231

Patented June 3, 1969

3,447,231

METHOD OF PRODUCING RIBBED-METAL SANDWICH STRUCTURES

Robert I. Jaffee, Worthington, Ohio, assignor to The Battelle Development Corporation, Columbus, Ohio, a corporation of Delaware

Filed June 21, 1967, Ser. No. 647,752
Int. Cl. B23k *31/02;* B23p *17/00*
U.S. Cl. 29—423 9 Claims

ABSTRACT OF THE DISCLOSURE

A method for partially removing metal filler members from roll-bonded, ribbed-metal structures, which consists of providing bimetallic filler members formed with cores of a metal disposed for independent tensile elongation relative to their surrounding cases and separating these cores from their cases after roll bonding by exerting a tensile force on said cores so as to effect independent tensile elongation relative to the cases to effect a reduction in cross-sectional dimensions of the cores and cause them to separate from the fillers. The cores of said fillers may then be removed by mechanical means. The cross-sectional dimensions of the cores are preferably shaped with a high ratio of height-to-width so that after being elongated in a direction parallel to the direction of rolling, the ratio of height-to-width of the cores is approximately unity.

BACKGROUND

This invention relates to improvements in the manufacture of roll-bonded hollow-metal ribbed structures for structural use such as in the aerospace, marine, and transportation industries and relates in particular to the use of fillers that have mechanically removable cores which may be removed after roll bonding so as to remove at least a part of the filler and facilitate removal of the remainder by chemical leaching.

Lightweight panels, consisting of spaced metal sheets separated by metal ribs, of exceptional strength may be manufactured by roll-bonding techniques such as is described in U.S. Patent 3,044,160. Particularly desirable structures of this type are described in my copending patent application Ser. No. 410,971 filed Nov. 13, 1964, and entitled "Sandwich Structures and Method." Stiffened skin assemblies having angularly positioned ribs (juxtapositioned V-shaped structures) such as depicted by FIGS. 11 to 15 of that patent application are particularly significant when utilized in the construction of high-speed aircraft or spacecraft vehicles.

The prior known technique employed for removing the matrix metal or spacers positioned between the ribs for support during roll bonding has been to corrode away these members by flowing a chemical reagent onto the panel ends. Such a procedure is slow and inefficient. Additionally, long time exposure of the titanium to the effects of such corrosive chemicals sometimes results in corrosion or erosion of portions of the ribbed structure.

It is obvious that if a post-fabrication "throughhole" in made in each filler bar, the leaching rate would be greatly accelerated. Furthermore, the volume of material to be leached is significantly reduced. Providing such passageways by mechanical techniques, such as drilling, is not practical, since this would be a time-consuming, laborious, and expensive task and would be confined to small flat panels where excessively long drill bits would not be required.

My technique for providing passageways through the filler bars is to utilize bimetallic filler bars that have a metal core capable of being physically removed from the

assembly after roll bonding is completed. This may be accomplished by applying the bimetallic bar structures utilized for hollow-drill steel manufacture to the roll-welded sandwich process. This structure has a core that differs in its mechanical properties from its case in a manner that the core can be separated and removed from the case. This is accomplished by providing a core metal that possesses greater toughness than the case and which is disposed to uniformly deform when placed in tension. For example, one such material is austenitic steel stabilized with manganese and/or nickel. Such composite structures may be shaped to form the spacers or fillers utilized in the sandwich structure roll-bonding process. At the conclusion of roll bonding, the ends of the austenitic steel cores are exposed and placed under sufficient tension to cause them to elongate. The toughness and elongation properties of such a core causes them to separate from the mild steel core so that they can be readily removed to provide the desired passageways for subsequent leaching.

Due to the fact that the core material in the bimetallic filler assemblies possess greater toughness than the case metal, such cores offer greater resistance to deformation during roll bonding of the assembled hollow rib structure pack. As a result where such cores are in the form of rounds, they cause uneven lateral pressure to be exerted on the ribs of the structure which effects some rib distortion or deformation (bending) during rolling. Such rib distortion materially detracts from the strength properties of the ultimate product.

I have found that rib distortion occasioned by using spacers having a relatively tough core can be reduced or eliminated by providing a spacer with a core with a high height-to-width ratio that is preferably shaped similar to the spacer itself, e.g., isoceles triangular core in an isoceles triangular spacer, rectangular core within a rectangular spacer, etc.

DRAWINGS

FIG. 1 is an enlarged cross-sectional view of a pack assembly prior to roll bonding showing triangular steel filler bars machined from conventional round-cored steel bars (used to manufacture the so-called hollow-core drill rod).

FIG. 2 is an enlarged fragmented cross-sectional view of a portion of the ribbed structure of FIG. 1 after roll bonding showing the resulting oval shape of "through holes" after core removal, exhibiting some distortion of the ribs in the section adjacent to the cores.

FIG. 3 is an enlarged fragmented cross-sectional view of a portion of a ribbed structure similar to that of FIG. 1 before roll bonding constructed in accordance with the preferred method of the present invention showing shaped, cored, filler bars.

FIG. 3A is an enlarged fragmented cross-sectional view of the structure of FIG. 3 after roll bonding.

FIG. 4 is an enlarged fragmented cross-sectional view of a ribbed structure showing triangular steel bar spacers and complementary shaped core.

FIG. 4A shows the structure of FIG. 4 after roll bonding.

FIG. 5 shows an enlarged fragmented cross-sectional view of a ribbed structure having rectangular spacer bars and rectangular cores.

FIG. 5A shows the structure of FIG. 5 after roll bonding.

DESCRIPTION

In the drawings, FIG. 1 is a cross-sectional view of a pack constructed in accordance with the teachings of my Patent No. 3,044,160 and copending patent application (Ser. No. 410,971 filed Nov. 13, 1964). The titanium

ribbed structure (unbonded) **8** consists of skin members (titanium sheets) **10** and **12**. Angularly positioned ribs **14** span the distance between skin members **10** and **12** and abut these members. Ribs **14** are separated by the spacers **16** which are appropriately shaped to position the ribs in a desired V shape configuration.

Spacers **16** are constructed of drill core stock having a core portion **18** which is made from an austenitic manganese steel that has greater toughness than the surrounding mild steel.

The assembly **8** designed for roll bonding and leaching is positioned within a steel yoke **20** to which there is welded steel cover plates **22** and **24** and end plates (not shown).

Air is withdrawn from the assembly and, in accordance with the teachings of the aforementioned patent application and issued patent, the assembly is roll bonded to obtain the structure of FIG. 2.

The structure of FIG. 2 consists of the ribbed metal structure after roll bonding and removal of cover plates **22** and **24** and yoke **20** but before leaching of the spacer members **16**. The manganese austenitic steel cores **18**, however, have been removed by exposing their ends and applying sufficient tension stress to cause them to elongate and separate from the mild steel casings (due to a reduction in cross-sectional dimensions). They were then simply pulled from the assembly to leave passageways **26**. The remainder of the separators may now be removed by simply passing a corrosive acid through passageways **26** that will dissolve the mild steel but which will not attack the titanium base metal.

It will be noted that the passageways **26** of the assembly of FIG. 2 were reduced in height. This, of course, is caused by hot rolling which reduces the gage of the assembly, and, consequently, flattens the spacers **16** including the initially round austenitic steel cores **18**.

Since the cores **18** are tougher than the mild steel of spacers **16** they exert lateral pressure on the ribs **14** during roll bonding to cause distortion (see FIG. 2). Such rib distortion materially weakens the ribbed-metal structures and detracts from their usefulness in the air and space vehicle industry.

I have found that the rib distortion experienced during roll bonding when utilizing hollow drill steel-type cores may be materially reduced or eliminated by providing spacers with cores that are cross-sectionally shaped similar to the spacer itself prior to roll bonding. This type of assembly is shown by FIG. 3 wherein a titanium rib structure **38** positioned within a yoke and cover plates (not shown) is provided with spacers **46** having cores **48** formed with a high height-to-width ratio.

Cores **48** are positioned so that when the pack assembly is hot rolled to effect roll bonding or welding of the ribs **34** to the skins **30** and **32** the elongated cores become round (see openings **50** of FIG. 3A). Since the cores **48** do not exert lateral pressure, ribs **34** are not distorted.

It will be appreciated that the degree of distortion of the ribs of ribbed-metal sandwich structures caused by the spacer or filler cores is relative. The greater the reduction in gage of the roll pack the greater the degree of distortion. In a similar manner, the desired ratio of height over width of the cores (such as cores **48**) will vary with the size of the pack assembly, reduction in gage or thickness during roll bonding, etc. These parameters must be determined for each individual assembly, however, any high ratio (greater than 1:1) of height-to-width will have some advantageous effect in reducing rib distortion.

Further, the core need not be oval shaped in cross section. For example, it may be desirable to utilize a roughly elongated triangular configuration that follows the cross-sectional triangular configuration of a spacer similar to spacers **16** and **46** of the drawings or it may be desirable to utilize a generally rectangular elongated core where the ribs of the ribbed-metal sandwich structure are vertically disposed.

FIG. 4 shows a hollow-ribbed pack structure prior to roll bonding (yoke and cover plates, not shown) wherein the triangular shaped filler bars **52** are provided with complementarily shaped austenitic cores **54**. FIG. 4A shows the same structure after roll bonding and gage reduction (the cores having been removed). The core shape after rolling had the final (flattened) contour of passageways **56**. Ribs **58** are not distorted.

In the embodiment of FIG. 5 hollow-ribbed structure assembly **60** is provided with rectangular fillers or spacers **62** which are provided with high height-to-width rectangular cores **64**. FIG. 5A shows the same structure as FIG. 5 after roll bonding and core removal. Holes **66** show the final contour of the cores after hot rolling and before leaching.

The tough core material may, of course, be fabricated by preshaping the core and machining a complementary shaped hole to receive the shaped hole in the filler metal. Shaping may, of course, also be effected by controlled mechanical deformation of the bimetallic structure (i.e., rolling).

An advantage of the method of the present invention relates to the great savings effected in leaching time. After providing the hollow cores leaching times are cut from days and weeks to less than an hour.

Another significant advantage of the present invention relates to forming. Ribbed structures must be formed (bending) with the filler bars in place to avoid rib buckling. I have found that after removing the cores but before leaching, the panels can be bent to a smaller radius than with solid fillers.

Although any through-hole effected in the filler bars contributes significantly to the advantageous features discussed above in conjunction with the utilization of the method of the present invention, it is preferred that the cross sectional surface area of the tough core constitute from about 5 percent to 50 percent of the area of the composite filler bar. Optimum results have been experienced where the core consists of about 15 percent of the cross-sectional area of the composite bar. If the core area is less than about 5 percent of the filler bar, it becomes difficult to accomplish acid leaching and where such area exceeds 50 percent there is danger of rib buckling (when forming the completed structure after core removal).

The means for manufacturing core spacers such as sapcers **16**, **46**, **52**, and **62** are well known (particularly in the hollow-drill steel art). A bimetallic assembled unit is hot rolled to obtain the rod-core assembly.

The core metal or the case metal may consist of any metal as long as the core metal is tougher than the case metal and is capable of relatively uniform elongation and the case metal is capable of being leached or eroded from the ribbed metal structure. I have had particular success in the manufacture of titanium ribbed metal structures in using a mild steel case and a high manganese (austenitic) steel core. Austenitic steels in general possess satisfactory uniform elongation properties and are tougher than mild steel grades. Particularly useful austenitic steels for core materials (in mild steel) are those which form some martensite (or bainite) in their structure upon the application of strain. These are the high manganese grades such as A1S1 Type 200, 201, etc. Other particularly useful grades are the precipitation hardening austenitic steels.

The tough core material may, of course, be elongated by simply rolling the bimetallic assembly along one direction prior to forming the spacers.

Although the examples (below) and the description above are directed to the manufacture of titanium ribbed-metal sandwich structures, it will be appreciated that the basic principles of the present invention are applicable to many metals (i.e., Zr, Hf, stainless steel, etc.).

The following specific examples serve to illustrate the present invention and in no way limit the claims to the exact embodiment set forth:

Example I

A small pack 18 x 8 inches was assembled using 12-inch-long composite filler bars. These bars were machined from 1-inch-diameter Atlas Steel Corporation "Ottawa-grade" hollow-drill steel stock. The "Ottawa-grade" drill-steel stock consists of a 1080 carbon steel outer jacket (approximately ½ inch base x ¾ inch high) and a tough manganese austenitic steel core (¼ inch diameter) which is mechanically extracted after fabrication. The filler bar design was the same as that illustrated by filler bar **16** of FIG. 1.

The pack was assembled so as to allow the filler bars to extend beyond the sandwich structure after rolling to provide a gripping area for mechanical extraction. After rolling, the total sandwich structure length was 17½ inches with 6¼ inches of filler bars extending beyond the sandwich structure at each end.

The pack was rolled on 60-inch production plate mill using standard practice developed for production rolling of Ti–6A1–4V alloy panels. A gas-fired horizontal batch furnace was used to heat the pack for rolling. After rolling, the carbon steel yoke material was trimmed from the sides and ends of the panel with an abrasive cut-off wheel. The carbon steel pack covers were then stripped mechanically from the panel. Transverse saw cuts were made about 1 inch beyond the sandwich structure ends through the mild steep spacers and to a depth of about 1/16 inch in the 1080 carbon steel filler bar jackets. The entire assembly was then placed in a tensile machine and loaded in tension. The 1080 carbon steel jackets fractured at the saw cut on one end of the panel and were stripped away exposing the austenitic steel cores. The specimen was then reloaded in the tensile machine so that the bare austenitic steel cores were gripped in the machine on one end of the panel and the carbon steel jackets gripped on the opposite end. The specimen was loaded in tension and the austenitic steel cores were gang-pulled from their surrounding steel jackets leaving a continuous hold through each filler bar.

The result was a panel that looked very much like the one illustrated by the drawing of FIG. 2.

Example II

Two-and-one-half inch lengths of 1018 steel filler wedges were drilled longitudinally, and ¼ inch lengths were cut from each end. Each composite bar was assembled over approximately machined Manganol rods so that the longer portion was sandwiched between the two separate ¼ inch lengths (for gripping). A lime wash was applied to the drilled hole of the longer center portion. This was to facilitate mechanical parting of components in these regions after fabrication.

A 2 inch long, 5½ cycle Ti–6A1–4V corrugation was mated to the central portions of the filler bars. Spaces between the end (gripping) portions of the core assembly were shimmed with steel strip to position the Ti–6A1–4V corrugation over the center filler segments. Titanium-6A1–4V covers overlapped the corrugation section by ¾ inch on each end. This assembly was encapsulated in the usual steel yoke and cover assembly, and routinely fabricated to 60 percent reduction (hot rolling).

After fabrication, yoke sides were cut away, and pack and sandwich covers were ground away. The ends of this panel were gripped in a tensile machine and pulled to failure. Two of the Manganol cores were successfully removed.

I claim:

1. A method for providing passageways in the spacer members between the ribs of a roll-bonded ribbed-metal sandwich structure, comprising:

(a) positioning bimetallic spacer members, formed with metal cores that exhibit greater toughness than the case metal and which are disposed to elongate uniformly, between the ribs of a pack assembly disposed to provide said roll-bonded ribbed-metal sandwich structure when hot rolled;

(b) hot rolling said pack assembly at a temperature and pressure disposed to provide said roll-bonded ribbed-metal sandwich structure;

(c) applying tensile stress to said cores of a magnitude to cause said cores to elongate and shrink in cross-sectional dimensions so as to break away from said case metal; and

(d) removing said separated cores from said roll-bonded ribbed-metal sandwich structure.

2. The method of claim **1** wherein said cores are formed with a high ratio of height-to-width.

3. The method of claim **1** wherein said cores and case are constructed of steel and said ribbed-metal sandwich structure consists of titanium or titanium alloy.

4. The method of claim **3** wherein said case is constructed of mild steel and said core consists of an austenitic steel.

5. The method of claim **4** wherein said core consists of a high manganese grade of ausenitic steel.

6. The method of claim **1** wherein said cores have a complimentary cross-sectional shape to the cross-section shape of said case.

7. The method of claim **2** wherein said cores have a substantially complimentary cross-sectional shape to the cross-sectional shape of said case.

8. The method of claim **1** wherein the relative size of said metal cores to the balance of said spacer members is such as to occupy from 5 percent to 50 percent of the cross-sectional area of said members.

9. The method of claim **1** wherein the relative size of said metal cores to the balance of said spacer members is such as to occupy about 15 percent of the cross-sectional area of said members.

Refereances Cited

UNITED STATES PATENTS

3,044,160	7/1962	Jaffee	29—423
3,061,713	10/1962	Eggert.	
3,321,826	5/1967	Lowy	29—423
3,380,146	4/1967	Babel et al.	29—423

JOHN F. CAMPBELL, *Primary Examiner.*

J. L. CLINE, *Assistant Examiner.*

U.S. Cl. X.R.

29—497.5, 504