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Robinson et al. [45] **Jan. 12, 1982**

[54] **FUSELAGE STRUCTURE USING ADVANCED TECHNOLOGY FIBER REINFORCED COMPOSITES**

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[21] Appl. No.: **878,540**

[22] Filed: **Feb. 16, 1978**

[51] **Int. Cl.**³ **B64C 1/06;** B64C 1/12

[52] **U.S. Cl.** **244/119;** 244/123; 244/132

[58] **Field of Search** .... 244/117 R, 119, 120, 244/123, 131–133; 428/375, 404, 457, 538, 902; 416/230 R, 230 A

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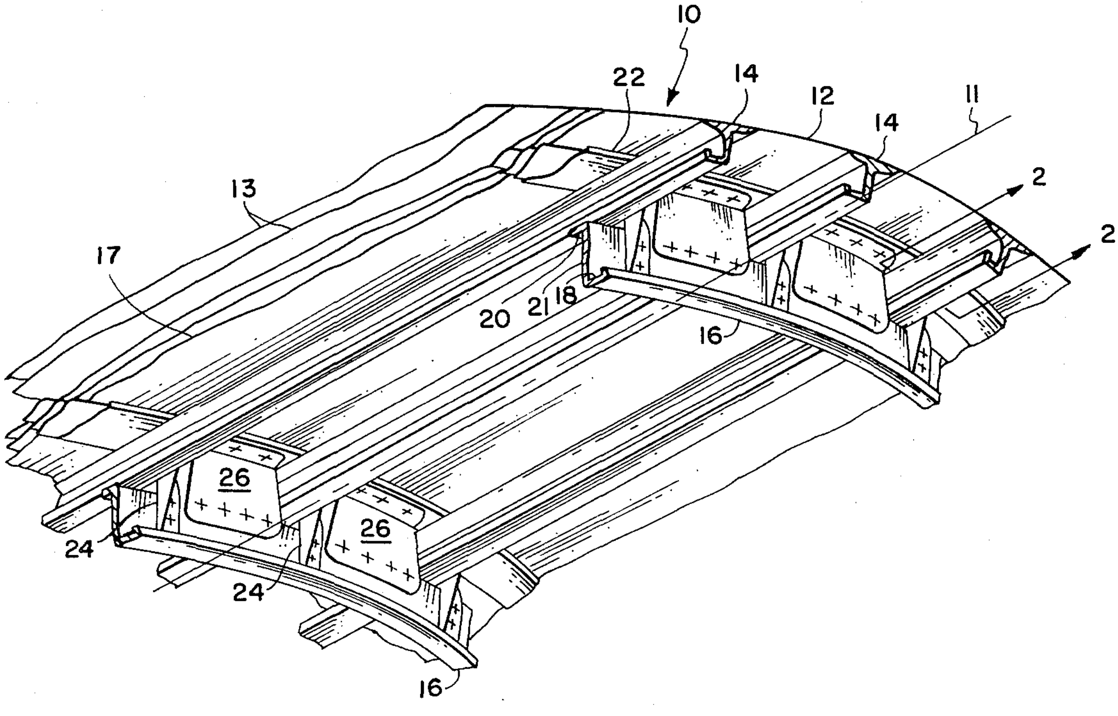
[57] **ABSTRACT**

A fuselage structure is disclosed in which the skin is comprised of layers of a matrix fiber reinforced composite, with the stringers reinforced with the same composite material. The high strength to weight ratio of the composite, particularly at elevated temperatures, and its high modulus of elasticity, makes it desirable for use in airplane structures.

25 Claims, 6 Drawing Figures



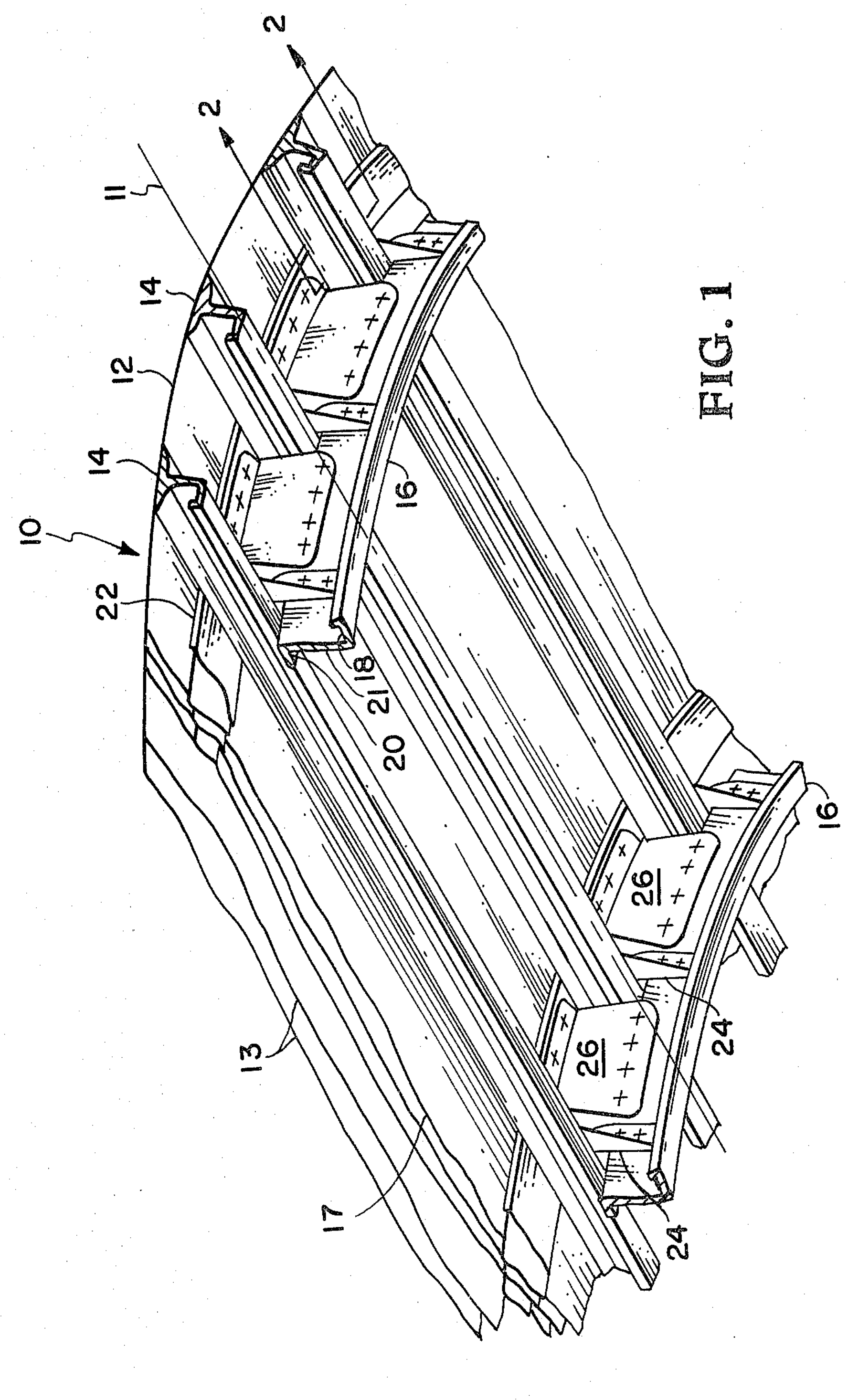


FIG. 1

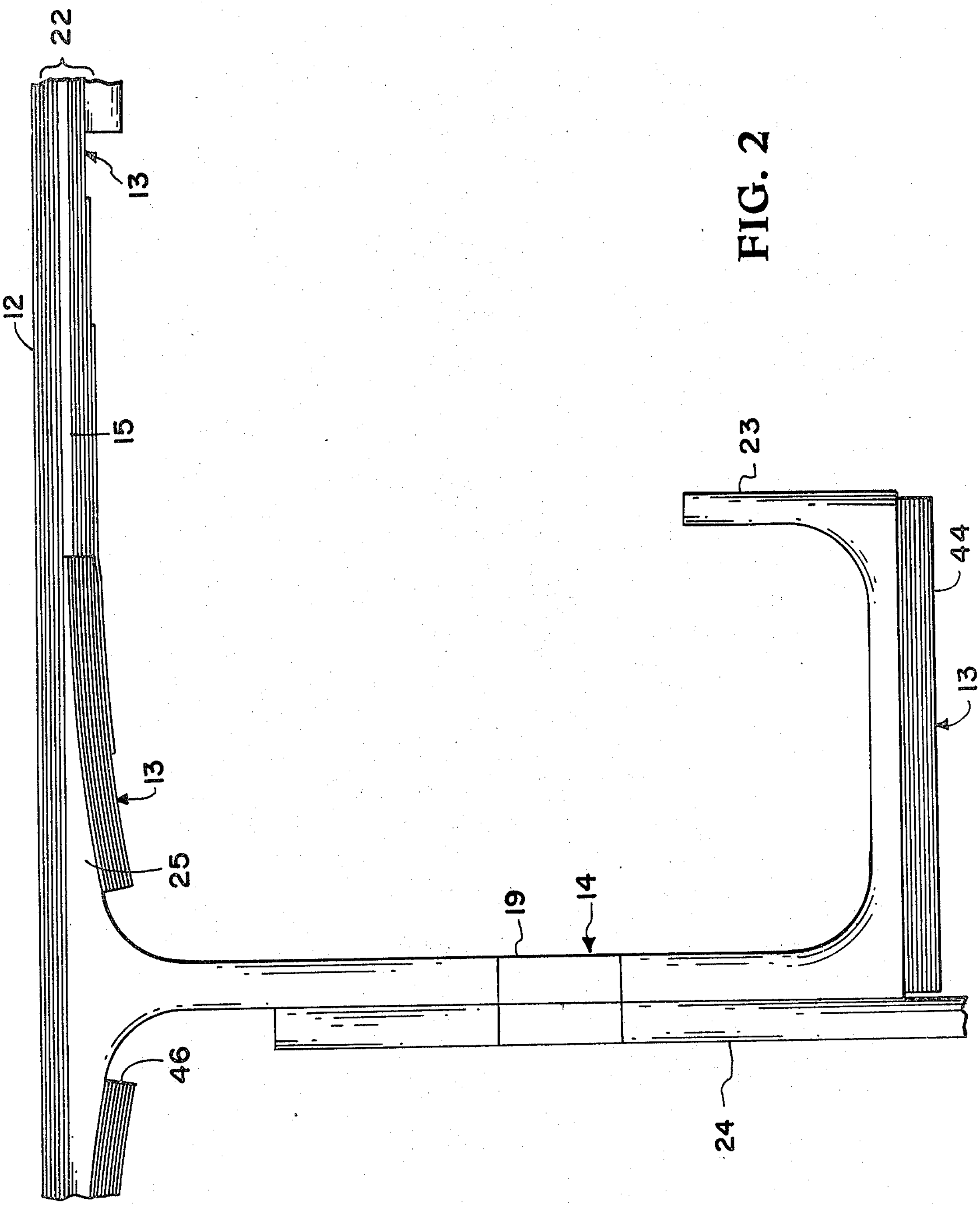


FIG. 2

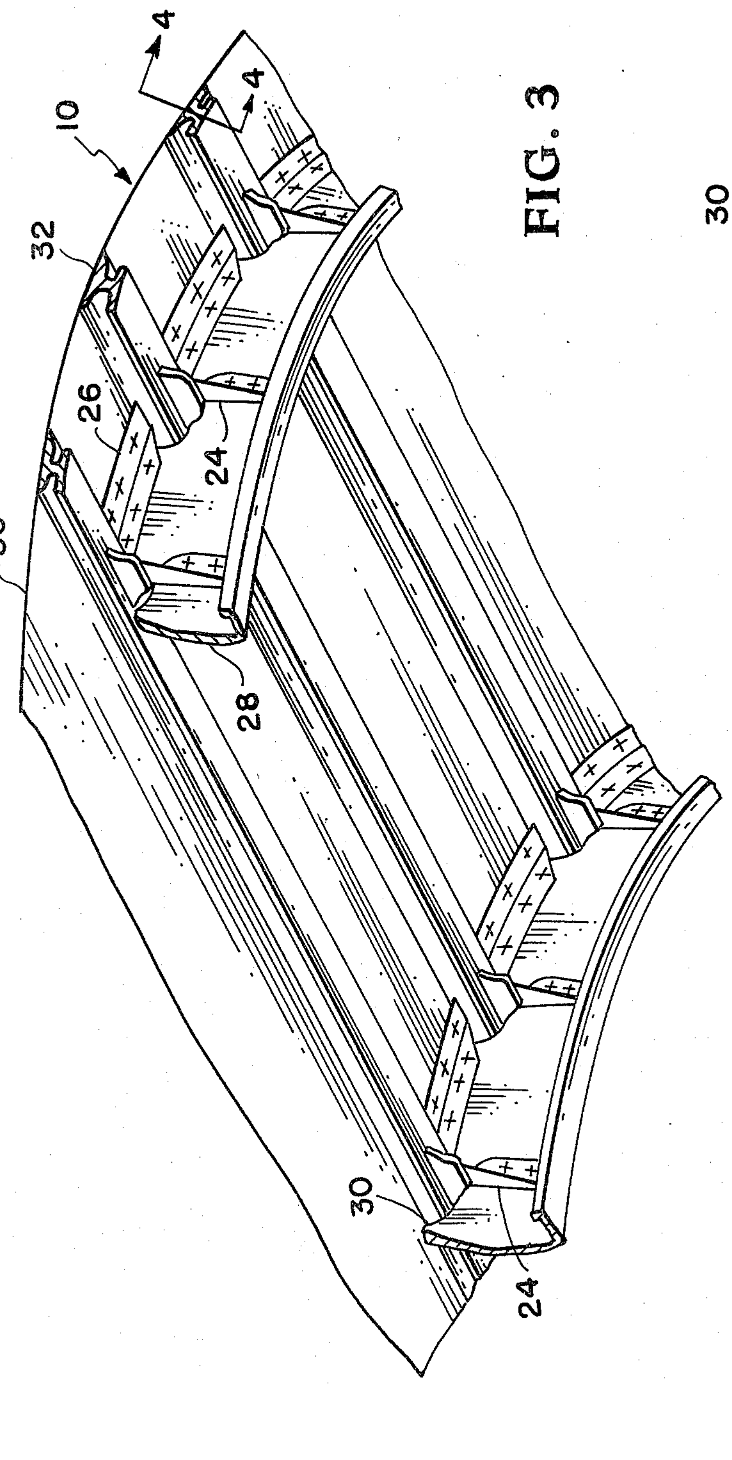


FIG. 3

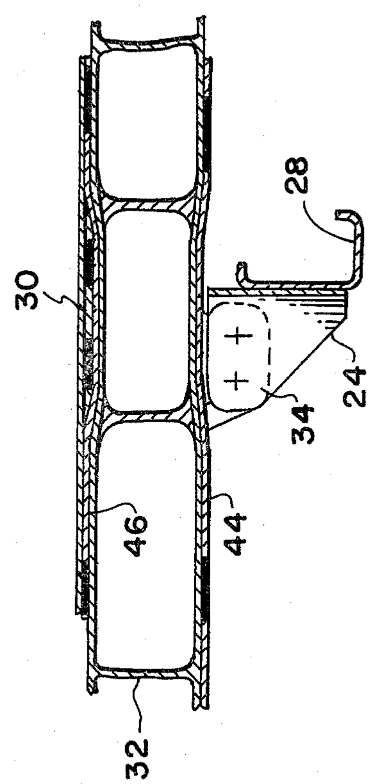


FIG. 6

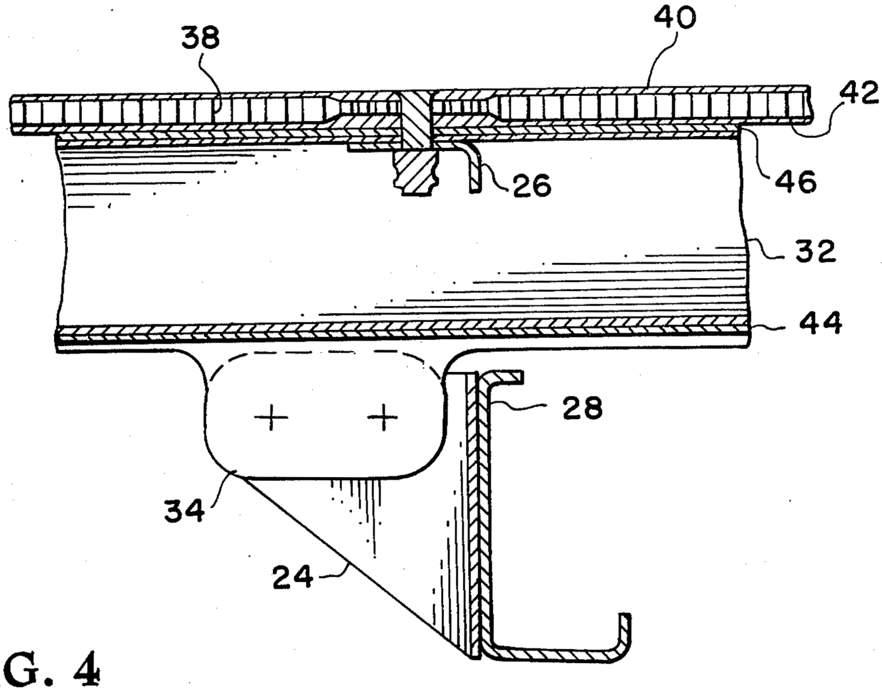


FIG. 4

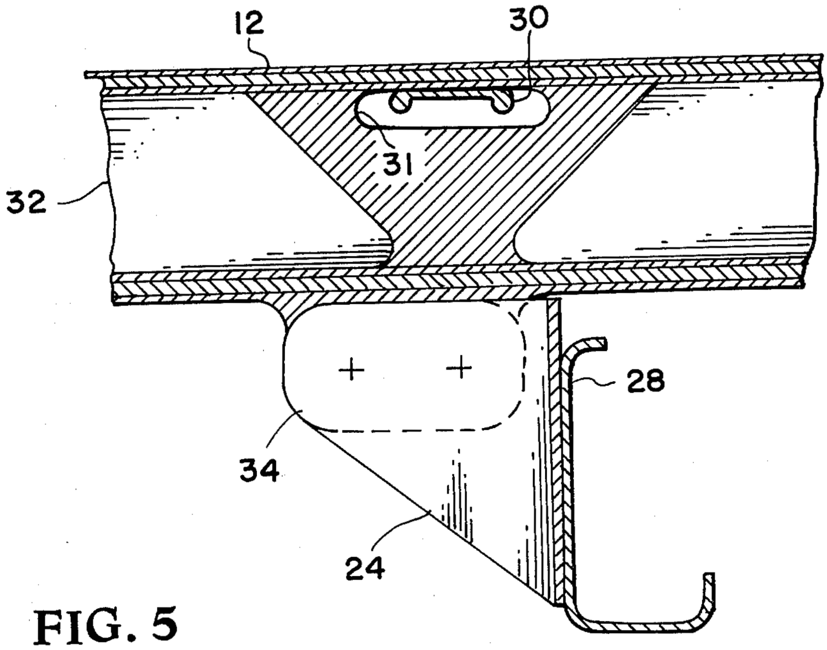


FIG. 5

FUSELAGE STRUCTURE USING ADVANCED TECHNOLOGY FIBER REINFORCED COMPOSITES

ORIGIN OF THE INVENTION

The invention described was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-586 (72 STAT. 435; 42 USC 2457).

BACKGROUND OF THE INVENTION

This invention relates to a fuselage structure having a skin comprised of layers of matrix fiber reinforced composites and stringers reinforced with the same material.

DESCRIPTION OF THE PRIOR ART

The use of laminated material and composite material for fabrication of aircraft parts is well known. This type of material is used for certain aircraft parts because of its great strength and rigidity. An early patent in this area teaches the use of thin strips of veneer, wound around a mold in layers of alternating steep pitch angles and shallow pitch angles, to form an aircraft fuselage. These strips of veneer are preferably bound with a waterproof glue. After assembly, the mold is removed and the fuselage structure is sanded and painted as necessary. This type of fuselage does not have stringer or frame supports.

Later patents on this subject teach the use of wood veneer at various grain orientations to better utilize its strength characteristics and the use of layers of fabric in combination with the wood veneer. None of the patents using cloth or wood veneer in a laminated fuselage teach the use of frames or stringers, reinforced or otherwise.

Other patents teach the use of fiber reinforced plastic composites for parts of aircraft structure. Some of the fibers used have been glass fibers, graphite fibers, or boron fibers, embedded in a plastic matrix. The high strength of the composite is due to the transmittal of fiber characteristic to the plastic matrix which in turn protects and unifies the fibers. The axis of the fiber orientation is varied between layers to take advantage of the anisotropic properties of the fibers. However, none of the described plastic composite structures or wood veneer composite structures have the necessary characteristics to be useful as a structural material under conditions expected to be encountered by a supersonic transport.

It is therefore an object of the present invention to provide a fuselage structure with a high strength to weight ratio capable of withstanding conditions expected to be encountered during supersonic flight.

It is another object of the present invention to provide an aircraft structure comprised of parts made from fiber composite matrix materials combined to optimally employ their high strength/weight ratio and anisotropic rigidity while distributing stress smoothly throughout the structure.

A further object of the present invention is to provide a structure constructed in such a manner that there is a minimum of fasteners through load-bearing material.

An additional object of the present invention is to provide a fuselage structure comprised of a skin of layers of matrix fiber reinforced composite oriented in alternate layers at 45° and 315° to the fuselage longitudinal axis.

Yet another object of the present invention is to provide a fuselage structure with high strength, lightweight stringers, reinforced with matrix fiber reinforced composite oriented at 0° with respect to the fuselage longitudinal axis.

SUMMARY OF THE INVENTION

The present invention comprises a fuselage structure wherein the external skin is constructed of layers of matrix fiber reinforced composite. The plies of the composite material are built up so as to take advantage of the unidirectional properties of strength and stiffness of the composite material.

In the preferred embodiment of the invention the composite material has alternate plies oriented at approximately 45° and approximately 315° to the fuselage longitudinal axis. Additional bands of the composite material, oriented at approximately 90° to the fuselage longitudinal axis, are located on the skin between the frames.

The stringers, which run longitudinally and support the skin, are reinforced with layers of matrix fiber reinforced composite material. The composite material reinforcing the stringers is oriented at approximately 0° relative to the fuselage longitudinal axis and runs lengthwise on the stringers, which are also oriented at 0° relative to the fuselage longitudinal axis.

The matrix fiber reinforced composite used in the preferred embodiment is borsic aluminum. Borsic aluminum is comprised of silicone coated boron fibers embedded in an aluminum matrix. The use of the borsic aluminum composite in the fuselage structure as described above, results in a significant weight reduction compared to a similar fuselage of titanium.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a perspective view of a fuselage structure showing the arrangement of the stringers, frames, skins, shear ties, and clips in the preferred embodiment of the invention;

FIG. **2** illustrates a section taken along lines **2—2** of the fuselage shown in FIG. **1**;

FIG. **3** illustrates a perspective view of a fuselage showing an alternate version of the invention;

FIG. **4** illustrates a section along lines **4—4** of the fuselage shown in FIG. **3** showing the titanium honeycomb core;

FIG. **5** illustrates a longitudinal sectional view of the fuselage showing an alternate version of the invention in which the frame outer channel consists of a separate composite reinforced metal circumferential strap running through slots in the stringers; and

FIG. **6** illustrates a longitudinal sectional view of the fuselage showing an alternate version of the invention in which the frame outer channel is a composite reinforced metal circumferential strap running under a notched section of the stringer.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, there is illustrated a preferred embodiment of the present invention as it would be used in the fuselage of a supersonic transport aircraft. FIG. **1** shows a fuselage structure, designated generally by the reference numeral **10**, comprised of three major components, the skin **12**, stringers **14** and frames **16**.

The skin **12** consists of a continuous pair of plies of borsic aluminum **13**, a metal matrix composite material, oriented in alternate layers at approximately 45° and approximately 315° to the fuselage longitudinal axis **11**. Wide circumferential bands of borsic aluminum composite **17** are located on the skin **12** between the frames **16** and bear the body pressurization loads. The circumferential bands of borsic aluminum composite **17** are oriented at approximately 90° to the fuselage longitudinal axis **11**. The skin **12** is consolidated by applying heat and pressure to the borsic aluminum plies **13** and the circumferential bands of borsic aluminum composite **17**.

The stringers, designated generally by the reference number **14**, run longitudinally along the fuselage **10** and stabilize and support the skin **12**. The stringers **14**, as shown in FIG. **2**, are machined titanium extrusions **19** with the stringer inboard end **23** reinforced with uniaxial borsic aluminum **44**. Stringers of graphite/epoxy or boron/epoxy would also be suitable. The borsic aluminum stringer reinforcement **44** is comprised of layers of borsic aluminum plies **13** oriented at approximately 0° to the fuselage longitudinal axis **11**. The stringer outboard end **25** is "T" shaped with the trunk of the "T" being thicker and tapering to thinner portions at the extremities. The inner face of the stringer outboard end **25** is also reinforced with uniaxial borsic aluminum **46**. The outboard borsic aluminum stringer reinforcement **46** is also comprised of layers of borsic aluminum plies **13** oriented at approximately 0° to the fuselage longitudinal axis **11**. The outboard borsic aluminum stringer reinforcements **46** and the inboard borsic aluminum stringer reinforcements **44** are diffusion bonded to the stringer outboard end **25** and the stringer inboard end **23**, respectively. The stringers **14** are attached to the skin **12** by spot brazing which reduces the number of fastener holes required through the skin **12**. Tests have shown minimal degradation of borsic material properties by spot brazing. The stringers could also be compacted to the skin.

The frames **16**, as shown in FIG. **1**, are oriented at approximately 90° to the fuselage longitudinal axis **11**. The frames **16** are conventional metal structures of formed titanium sheet and serve to maintain the cross section shape of the fuselage **10**. The frames **16** are comprised of an inner generally "U"-shaped channel **18**, an outer channel **20**, and the web **21** between the two channels. The frame inner channel **18** and the frame outer channel **20** run parallel to the skin **12** and face respectively forward and aft, while the frame web **21** is perpendicular to the skin **12**. The frames **16** are loaded in bending, tension and compression.

The stringers **14** are attached to the frames **16** by the use of generally "L"-shaped clips **24**. The clips **24** are parallel to the stringers **14** in the area in which they fasten to the stringers **14**, and the clips **24** make a 90° bend and are parallel to the frames **16** in the area in which they fasten to the frames **16**. The clips **24** are mechanically fastened to both the stringers **14** and the frames **16**, by fasteners such as bolts or rivets and are subject to radial loading, by both internal pressure and differential thermal expansion.

A pad **22** has been built up on the skin **12** in the area of the frames **16**, between the stringers **14**. The pad **22**, shown in FIG. **2**, is comprised of plies of borsic aluminum **13**, in alternating layers oriented at 45° and at 315° to the fuselage longitudinal axis **11**, with a core of aluminum shim stock **15**. The skin **12** is mechanically fastened to the frames **16** through the pads **22** and shear ties **26**.

The shear ties **26** are "L"-shaped members with one edge parallel to the frames **16** and the perpendicular edge parallel to the skin **12** at the pads **22**. The shear ties **26** are located between the stringers **14** and carry the shear loads from the skin **12** to the frames **16**.

FIG. **3** shows an alternate embodiment of the invention in which the stringers **32** are "H"-shaped with one edge of the "H" against the skin **36** and the other edge facing inboard. There are tabs **34** on the stringers **32** in the vicinity of the frames. Clips **24** are mechanically fastened to the tabs **34** and the frames **28**. Fastening the clips **24** to tabs **34** on the stringers **32**, rather than to the stringer **32** themselves, ensures that there are no fasteners in the highly loaded portion of the stringers **32**. The clips **24** in this embodiment are similar to those described in the preferred embodiment above and the stringers **32** are reinforced in a manner similar to that described in the preferred embodiment.

The frames **28** in this embodiment are similar to those described in the preferred embodiment except they are notched to surround the stringers **32**, and reach almost to the skin **36**. The frames **28** are attached to the skin **36** by shear ties **26** which are described above in the preferred embodiment. This provides high structural efficiency of the frames **28**.

FIG. **4** shows a section view of the skin **36** taken along lines **4—4** of FIG. **3**. The skin **36** is comprised of a titanium honeycomb core **38**, sandwiched between an inner face sheet of borsic aluminum **42** and an outer face sheet of borsic aluminum **40**. The inner face sheet **42** and the outer face sheet **40** are comprised of plies of borsic aluminum built up with the following orientation to the fuselage longitudinal axis **11**: 0° ply, 45° ply, 90° ply, 315° ply, 0° ply. The titanium honeycomb core **38** is approximately 1.25 inches in depth to provide skin buckling stability. The inner borsic aluminum face sheet **42** and the outer borsic aluminum face sheet **40** are brazed to the titanium honeycomb core **38**. This skin design allows the skin **36** to carry the body pressure and bending loads.

FIG. **5** shows an alternate embodiment of the section shown in FIG. **4**. In this embodiment the skin **12** is comprised of layers of borsic aluminum **13** as described in the preferred embodiment. Other members are as described in the alternate embodiment illustrated in FIG. **4** except that the frame outboard channel **30** runs through slots **31** in the stringers **32** and is fastened to the skin **12** through a pad **22**, which is described in the preferred embodiment. The frame outboard channel **30** consists of a separate borsic aluminum reinforced metal circumferential strap running through slots **31** in the stringers **32** and provides fail safety for circumferential hoop tension pressure loads. The notches between frame **28**, pads **22**, and stringers **32** are filleted by aluminum wire to reduce potential fatigue problems.

FIG. **6** is an alternate embodiment of the section shown in FIG. **5**. In this embodiment the stringers **32** are notched allowing the stringer **32** to step over the frame outer channel **30**, thus providing fail safety for circumferential hoop tension pressure loads while using frames **28** with no structural discontinuities. Other features of the embodiment shown in FIG. **6** are the same as those shown in FIG. **5**.

In the preferred embodiment the borsic aluminum skin **12** covers the stringers **14** and gives shape to the fuselage **10**. The stringers **14** are members which run longitudinally in the fuselage **10** and stabilize and support the skin **12** between the frames **16**. The stringers **14** carry the body bending loads and are loaded primarily in tension and compression. The frames **16** are cross sectionally oriented curved beams which maintain the cross sectional shape of the fuselage **10** and support the stringers **14**. The frames **16** are loaded in bending, tension and compression. The high strength to weight ratio of the borsic aluminum plies **13** which comprise the skin **12** and reinforce the stringers **14**, results in a fuselage **10** which is significantly lighter than a similar structure of titanium and yet still able to withstand the conditions expected to be encountered by a supersonic transport.

It will be understood that the foregoing descriptions are of the preferred embodiments of the invention and are therefore merely representative. Obviously there are many variations and modifications of the present inventions in light of the preceding teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A fuselage structure comprising:

a fuselage having a longitudinal axis;

an external skin of alternate layers of composite material, oriented at a biased angle relative to the longitudinal axis and at approximately 90° to the biased angle;

stringers, having outboard and inboard ends;

frames;

circumferential pads of composite material located on an inner surface of the external skin between said external skin and said frames and oriented at approximately 90° relative to the longitudinal axis;

first reinforcement means, associated with the outboard ends of the stringers, said first reinforcement means being composite material oriented as approximately 0° relative to the longitudinal axis;

second reinforcement means, associated with the inboard ends of the stringers, said second reinforcement means being composite material oriented at approximately 0° relative to the longitudinal axis; and

third reinforcement means associated with the frames and the external skin whereby the frames are fastened to the external skin through the reinforcement means and through shear ties.

2. A fuselage structure as in claim **1** wherein said frame means consists of inner and outer channels and webs between the channels, said frame means being connected to said stringer means, to maintain the cross-sectional shape of the fuselage, wherein the said skin means, stringer means, and frame means are so disposed as to provide maximum continuity to the primarily load-bearing material.

3. A fuselage structure as in claim **1** wherein said external skin is alternate layers of borsic aluminum, oriented at approximately 45° and approximately 315° to the longitudinal axis.

4. A fuselage structure as in claim **3** wherein said stringer means are reinforced with borsic aluminum oriented at approximately 0° to the fuselage longitudinal axis.

5. A fuselage structure as in claim **1** wherein said stringers are brazed to the external skin.

6. A fuselage structure as in claim **1** wherein said stringers are diffusion bonded to the external skin.

7. A fuselage structure as in claim **1** wherein said stringers are compacted to the external skin.

8. A fuselage structure as in claim **1** wherein said stringers are weld brazed to the external skin.

9. A fuselage structure as in claim **1** wherein said third reinforcement means associated with the frames and the external skin is a pad of aluminum shim stock.

10. A fuselage structure as in claim **1** wherein clips fasten the frames to the stringers.

11. A fuselage structure as in claim **10** wherein shear ties fasten said frame means to said skin means.

12. A fuselage structure as in claim **10** wherein said clips are fastened by diffusion bonding to the frames and stringers.

13. A fuselage structure as in claim **10** wherein said clips are fastened by brazing to the frames and stringers.

14. A fuselage structure as in claim **1** wherein said circumferential pads associated with the frames and the external skin is alternate layers of composite material located between the external skin and the frames, oriented at a biased angle relative to the longitudinal axis and at approximately 90° to the biased angle.

15. A fuselage structure as in claim **14** wherein said third reinforcement means associated with the frames and the external skin includes a core of aluminum shim stock.

16. A fuselage structure as in claim **1** wherein said stringers are made of a graphite/epoxy composite.

17. A fuselage structure as in claim **1** wherein said stringers are made of a boron/epoxy composite.

18. A fuselage structure as in claim **1** wherein said stringers are machined titanium extensions.

19. A fuselage structure as in claim **1** wherein said composite material is borsic aluminum.

20. A fuselage structure comprising:

a fuselage;

skin means covering said fuselage with metal matrix fiber reinforced composites;

stringer means; and

means for reinforcing the connection of said stringer means to said skin means; said reinforcing means attached to and supporting said skin means on said stringer means;

said fuselage including a frame means consisting of inner and outer channels and webs between the channels, said frame means being connected to said stringer means, to maintain the cross-sectional shape of the fuselage, wherein the said skin means, stringer means, and frame means are so disposed as to provide maximum continuity to the primary load-bearing material;

said skin means is alternate layers of borsic aluminum, oriented at approximately 0°, approximately 45°, approximately 90°, and approximately 315° to the fuselage longitudinal axis;

said stringer means being reinforced with borsic aluminum oriented at approximately 0° to the fuselage longitudinal axis;

clips fastening said frame means to said stringer means and shear ties fastening said frame means to said skin means;

a pad means of borsic aluminum, oriented in alternate layers at approximately 45° and approximately 315° to the fuselage longitudinal axis, attached to said skin means in the area of the shear ties; and

the stringer means including tabs in the vicinity of the frame means and clips fastened to said tabs, to attach the stringer means, so that there are no fasteners in the highly loaded portion of the stringer means.

21. A fuselage structure as in claim 20 wherein said skin means includes a honeycomb core, sandwiched between said layers of borsic aluminum.

22. A fuselage structure as in claim 21 wherein said honeycomb core consists of titanium.

23. A fuselage structure as in claim 20 wherein the frame means are notched around said stringer means whereby said frame means extend almost to the skin means and are attached to the skin means by shear ties, providing high structural efficiency of the frame means.

24. A fuselage structure as in claim 23 wherein the frame means has an outer channel consisting of a separate, composite reinforced, metal circumferential strap, running through slots in the stringer means providing fail safety for hoop tension and pressure loads.

25. A fuselage structure as in claim 24 wherein the stringer means are notched, said notch allowing stringer means to step over the frame outer channel.

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