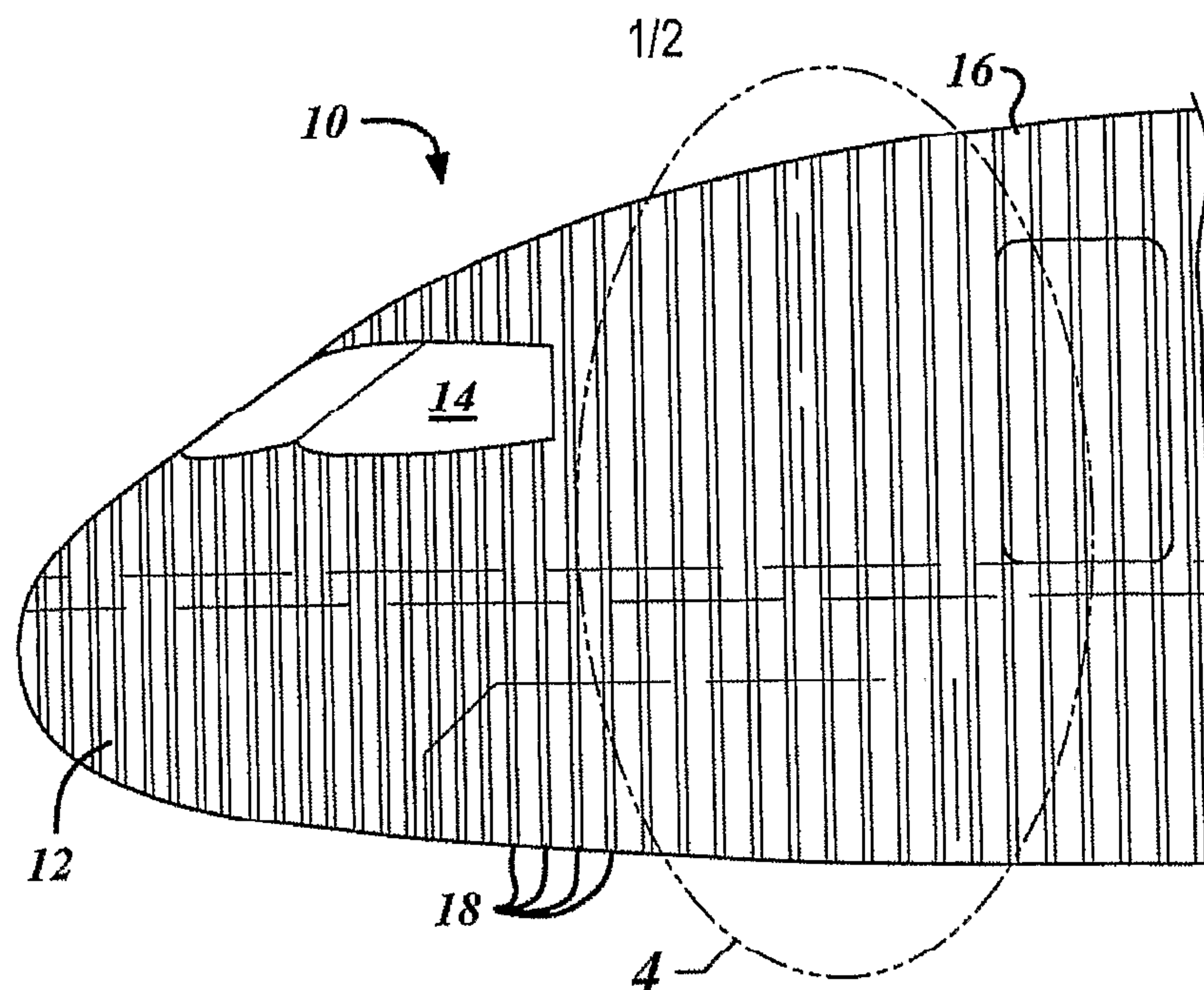




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(57) **Abrégé/Abstract:**

In accordance with the present invention an aircraft stringerless fuselage structure is provided comprising an impact compliant outer skin having a plurality of resin impregnated skin fibers forming an outer skin surface, an inner stringerless skin surface, and a skin thickness. A plurality of stiffeners is included, each comprising a plurality of resin impregnated stiffener fibers integrated into the inner stringerless skin structure. The plurality of resin impregnated skin fibers are not aligned with the plurality of resin impregnated stiffener fibers.

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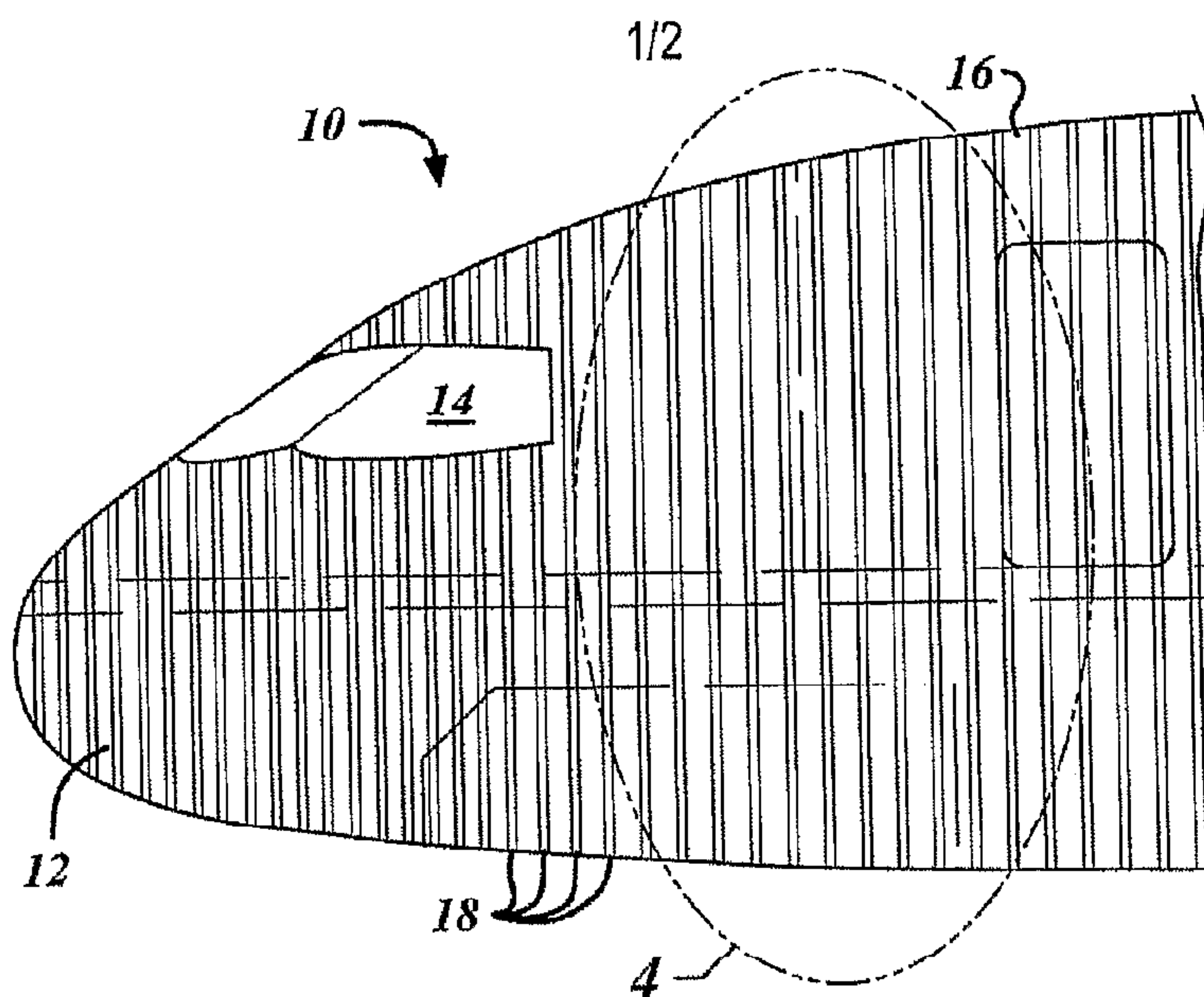
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(54) Title: SINGLE PIECE FUSELAGE BARREL



(57) Abstract: In accordance with the present invention an aircraft stringerless fuselage structure is provided comprising an impact compliant outer skin having a plurality of resin impregnated skin fibers forming an outer skin surface, an inner stringerless skin surface, and a skin thickness. A plurality of stiffeners is included, each comprising a plurality of resin impregnated stiffener fibers integrated into the inner stringerless skin structure. The plurality of resin impregnated skin fibers are not aligned with the plurality of resin impregnated stiffener fibers.

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SINGLE PIECE FUSELAGE BARREL

TECHNICAL FIELD

5 The present invention relates generally to an apparatus and method for reducing the cost and complexity of the fuselage barrel section of an aircraft and more particularly to an apparatus and method for integrating a cost effective and compliant structure that absorbs energy during bird strike impact.

10 BACKGROUND OF THE INVENTION

Aircraft structures often provide complex and costly challenges to both design and manufacturing. The underlying structures must not only meet strength requirements, but must also survive constant weight reduction requirements and manufacturing cost and time restraints. As such, a reanalysis and creative investigation into existing structures bears the possible reward
15 of considerable benefits during implementation.

Such is the case with the fuselage section of the aircraft. Specifically the forward section commonly referred to as section 41. This fuselage section includes complex geometry and structure by way of the inclusion of both the nose section as well as the cockpit windows and similar features. Additionally, this portion of the aircraft comes under close scrutiny for its
20 ability to have bird strike resistance. As such, section 41 barrel sections are often over designed which may lead to excess weight and more commonly excess cost.

Present fuselage sections are commonly are centered around designs that are stout and heavy. Often the outer skin and other structural supports are formed from aluminum which when overloaded may result in costly damage or repair. Bird strike incidents, even on designs that are
25 not overloaded, may leave large dents in the aluminum structure that eventually require costly repairs. When overloaded, however, portions of the aluminum structure may rupture requiring extremely expensive repair or replacement. The aluminum skin also requires complex manufacturing and assembly as the skin is commonly backed by very heavy and complex beam structures. Structures such as stringers are required for support and add both considerable cost in
30 addition to weight to the aircraft. The complex curvatures of the skins, especially in the nose region, often require manufacturing using expensive computer controlled machines. The quantity and complexity of manufacturing and assembling these aluminum structures often make section 41 the most expensive barrel section in the entire aircraft body.

What is needed is a design and method for manufacturing this complex section of the fuselage that allowed for simplification of manufacturing while simultaneously allowing for a compliant approach to bird strike resistance. Additionally, it would be highly desirable to have such a design and method that provided opportunities to reduce section weight in addition to manufacturing costs.

SUMMARY OF THE INVENTION

In accordance with the present invention an aircraft stringerless fuselage structure is provided comprising an impact compliant outer skin having a plurality of resin impregnated skin fibers forming an outer skin surface, an inner stringerless skin surface, and a skin thickness. A plurality of stiffeners is included, each comprising a plurality of resin impregnated stiffener fibers integrated into the inner stringerless skin structure. The plurality of resin-impregnated skin fibers are not aligned with the plurality of resin impregnated stiffener fibers.

Other objects and features of the present invention will become apparent when viewed in light of the detailed description and preferred embodiment when taken in conjunction with the attached drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is an illustration of an aircraft stringerless fuselage section in accordance with the present invention.

FIGURE 2 is a detailed illustration of the impact compliant outer skin utilized in the fuselage section illustrated in Figure 1.

FIGURE 3 is a detailed cross-sectional illustration of a portion of the aircraft fuselage section illustrated in Figures 1 and 2. and

FIGURE 4 is an illustration of a lay-up tool for use in the manufacturing of the aircraft fuselage section illustrated in Figures 1 and 2.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to Figure 1, which is an illustration of an aircraft stringerless fuselage section 10 in accordance with the present invention. The section 10 is illustrated as the commonly known section forty-one section although it is contemplated that the present invention is applicable to a variety of aircraft build zones. The section 10 presented includes the nose portion 12 in addition to the cockpit windows 14 wherein the geometry of the barrel section 10 is varied considerably in addition to requiring additional strength requirements. One of these requirements is the ability to withstand bird impact loads during operation. Existing designs contemplate the use of aluminum skins and complex and costly support structures underneath such as the use of complex curved stringers or other beams. In addition, existing approaches often result in costly repairs during bird strike due to their rigid approach to bird strike protection.

The present invention accomplishes both weight savings and bird strike protection through a unique combination of the use of a uniquely bird strike compliant outer skin 16 (impact resistant) that allows a redirection of bird path without damage in combination with the integration therein of a plurality of stiffeners 18, preferably circumferentially orientated, that provide sufficient structural support of the skin 16 without debonding during bird strike and without diminishing the skin compliance. It should be understood that in addition to pure circumferential orientation, perpendicular to the axis, variations of angled circumferential orientation, including intersecting stiffeners angled relative to the axis, are contemplated. The present invention contemplates the use of an impact resistant outer skin 16 that is tailored to be compliant and absorb or redirect the impact of bird strikes. The present invention accomplishes this through the use of a skin 16 formed from a plurality of resin impregnated skin fibers 20

forming a skin 16 having an outer skin surface 22, an inner stringerless skins surface 24, and a skin thickness 26. It is contemplated that the plurality of impregnated skin fibers 20 is intended to include both pre-preg tape or dry fibers with infused resin.

A key characteristic, however, is that the skin thickness 26 is contemplated to be variable
5 to accommodate the strength requirements of differing bird impact zones or structural zones (such as the cockpit windows 14) of the barrel section 10. It is contemplated that skin thickness 26 be variable between the range of 0.08 inches and 0.25 inches to provide the proper strength to weight ration. It is contemplated that the skin 16 be formed using high strain fibers such as spectra, vectran, low modulus GR, or even fiberglass. These fibers are chosen to provide a
10 compliant structure that instead of crushing or rupturing during impact, instead deforms and deflect the bird trajectory. Additional contemplated feature include the use of hybrid laminates wherein two or more fiber types are utilized in order to achieve the desired strength/compliance characteristics. One specific embodiment contemplates that the skin 16 be formed using an intermediate modulus (22-25 MSI) toughened carbon pre-preg tape. It is further contemplated
15 that the use of 0/45/90 degree laminate mixture at 20/80/0 percentage ratios provides the preferably structural characteristics for the skin 16. The present invention contemplates the use of non-traditional fiber angles in laminates to achieve the desired strength/conformity properties.

By designing an impact conforming (resistant) outer skin 16 with unique construction and properties, the present invention paves the way for elimination of the need for stringers in the
20 barrel section 10. This sâves weight in addition to manufacturing costs. The present invention, instead, relies on the use of low profile and low modulus stiffener elements such as the hat frame assembly 28 illustrated in Figure 3 for use as the circumferentially orientated stiffeners 18. Although hat frames are specifically described and illustrated, it is contemplated that the stiffener elements 28 may include, but are not limited to, hat frames, c-channels, Z-beams, J-beams, T-
25 Beams and I-beams, and blade stiffened beams. The hat frames 28 are preferably formed to comply with toughened outer skin 16 and are formed using a plurality of resin impregnated stiffener fibers 30 (preferably low-modulus fibers). These low modulus stiffener fibers 30 are preferably fully integrated into the skin fibers 20 of the inner stringerless skin surface 24 and co-cured to form a single element. The low modulus stiffener fibers 30 are preferably high strain
30 fibers such as fiberglass, spectra, vectran, or low modulus GR. Similar to the skin 16 it is contemplated that hybrid laminates and non-traditional lay-up angles may be utilized to achieve the desired conformity during impact while retaining sufficient structural support. In one embodiment, the low modulus frame stiffener fibers 30 are preferably layed up as +/- 60 degree

laminates. Although a variety of lay-up arrangements may be utilized, it is preferably that the stiffener fibers 30 are not aligned (0 or 90 degrees) with the skin fibers 20. The hat frame assembly 28 preferably is designed with both a low profile and a low modulus to resist debonding with the outer skin 16 during bird impact. It is contemplated that low profile is intended to comprise a profile height 31 of less than 3 inches and preferably less than 2 inches. It is further contemplated that low modulus is intended to comprise approximately 3-25 MSI. One embodiment contemplates the use of carbon fiber impregnated with epoxy for use in forming the hat frame assembly 28.

In one embodiment of the hat frame assembly 28, the assembly includes a first frame foot 32 and a second frame foot 34. A first angled sidewall 36 and second angled sidewall 38 proceed out of their respective feet and extend toward a hat top portion 40 joining the sidewalls 36,38. This hat frame assembly 28 thereby defines a hat frame interior 42 which is located between the hat top 40 and the outer skin 16 when the feet 32, 34 are bonded to the inner stringerless skin surface 34. Although a variety of hat frames 28 are contemplated, one embodiment contemplates a frame wall thickness 44 of approximately 0.05 inches. This, in combination with the low profile helps provide the low modulus characteristics suitable for impact protection and stringerless support.

The hat frame assembly 28 can further include one or more cap elements 46 integrated into the hat top portion 40 of the hat frame assembly 28. As is illustrated, one embodiment contemplates the use of a pair of vertically stacked cap elements. The cap elements 46 are preferably low density caps such as fiberglass caps or preferably S-2 glass plies. In one embodiment it is contemplated that the cap comprise a cap width 48 between the range of 0.08 inches and 0.15 inches. It is desirable that the cap elements 46 be comprised of 0 degree laminates interleaved with the resin impregnated stiffener fibers 30. The hat frame assembly 28 may also include a pcf foam element 50 (3-7 pcf) that also may be tailored to individual impact zones or skin thicknesses 26. The use of the foam element 50 allows for a further tailoring of impact resistance without negatively impacting either weight or the low modulus nature of the hat assembly 28 and skin 16 interaction that provides compliance and prevents damage or debonding during impact while continuing to provide enough structural rigidity to allow for the elimination of stringers.

The present invention, in addition to providing a vastly improved structure and approach to bird strike damage reduction, also provides a vastly improved methodology of manufacturing and assembling the aircraft fuselage section. Prior approaches required the use of aluminum skin

with complex multi-curved shapes and corresponding beam stringers with matching curves. The present invention, however, yields a far more cost effective and efficient method of manufacturing and assembly. The present invention contemplates the use of a fuselage lay-up tool 52 incorporating a plurality of multi-curved shapes 54 along its length. The lay-up tool 52 includes a plurality of stiffener grooves 56 on its upper tool surface 58. The stiffener grooves 56 are configured to allow the low modulus stiffener fibers 30 to be laid up directly onto the grooves 56 and thereby form a hat frame assembly 28 or other stiffener configuration. The stiffener grooves 56 further allow the stiffeners 28 to be located precisely in relation to both each other and the overall fuselage section 10. The skin fibers 20 may then be laid-up over the low modulus stiffener fibers 30 to complete the integrated skin/frame assembly and then the whole assembly may be cured as a single entity. This contemplates co-curing where the stiffener fibers 30 are laid in green, the skin fibers 20 are applied on top, and the whole assembly is simultaneously cured. This further contemplates co-bonding wherein the stiffener fibers 30 are cured prior to the application of the skin fibers 20. This allows the fuselage to be created as a single entity with double curved or multi-curved characteristics. Thereby complex skin shapes are accommodated in addition to the bonding of complex frames concurrently. This has the potential for generating both savings as well as performance improvements to fuselage design and production.

While the invention has been described in connection with one or more embodiments, it is to be understood that the specific mechanisms and techniques which have been described are merely illustrative of the principles of the invention, numerous modifications may be made to the methods and apparatus described without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. An aircraft stringerless fuselage structure comprising:
an impact compliant outer skin comprising a plurality of resin impregnated skin fibers forming an outer skin surface, an inner stringerless skin surface, and a skin thickness; and
a plurality of stiffeners comprising a plurality of resin impregnated stiffener fibers, each
5 of said stiffeners integrated into said inner stringerless skin structure;
wherein said plurality of resin impregnated skin fibers are not aligned with said plurality of resin impregnated stiffener fibers.
2. An aircraft stringerless fuselage structure as described in claim 1, wherein each of said axially orientated frames comprises a low profile and low modulus frame.
- 10 3. An aircraft stringerless fuselage structure as described in claim 1, wherein each of said stiffeners comprises:
a hat frame assembly comprising:
a first frame foot;
a second frame foot;
15 a first angled frame sidewall extending from said first frame foot;
a second angled frame sidewall extending from said second frame foot; and
a hat top connecting said first angled frame sidewall to said second angled frame sidewall, said hat frame assembly defining a hat frame interior.
- 20 4. An aircraft stringerless fuselage structure as described in claim 3, further comprising:
at least one cap element positioned within said hat top.
5. An aircraft stringerless fuselage structure as described in claim 3, further comprising a pcf foam element filling said hat frame interior.
- 25 6. An aircraft stringerless fuselage structure as described in claim 4, wherein:
said impact compliant outer skin comprises 0/45/90 degree layup at 20/80/0 percent ratios;
each of said axially orientated frames comprises +/- 60 degree layup; and
said at least one cap element comprises 0 degree layup interweaved with said resin impregnated fame fibers.

7. An aircraft stringerless fuselage structure as described in claim 4, wherein said at least one cap element comprises a pair of vertically stacked cap elements.

8. An aircraft stringerless fuselage structure as described in claim 1, wherein:
said skin thickness is varied between 0.25 inches and 0.08 inches to be specifically
5 tailored to bird impact requirements; and
said stiffeners comprise a frame wall thickness of 0.05 inches.

9. An aircraft stringerless fuselage structure as described in claim 4, wherein each of said cap elements comprises a cap width of 0.08 to 1.5 inches.
10

10. An aircraft stringerless fuselage structure comprising:
an impact compliant outer skin comprising an outer skin surface, an inner stringerless skin surface, and a skin thickness, said impact compliant outer skin comprising a plurality of resin impregnated skin fibers; and
15 a plurality of circumferentially orientated hat frames, each of said circumferentially orientated frames integrated into said inner stringerless skin structure.

11. An aircraft stringerless fuselage structure as described in claim 10, wherein:
said plurality of circumferentially orientated hat frames comprises a plurality of resin impregnated stiffener fibers, said plurality of resin impregnated skin fibers are not aligned with
20 said plurality of resin impregnated stiffener fibers

12. An aircraft stringerless fuselage structure as described in claim 10, wherein each of said circumferentially orientated hat frames comprises:
at least one low density cap element positioned in a hat top of said axially orientated hat frame.

25 13. An aircraft stringerless fuselage structure as described in claim 10, wherein said plurality of resin impregnated skin fibers comprise high strain fibers.

14. An aircraft stringerless fuselage structure as described in claim 11, wherein said resin impregnated stiffener fibers are co-cured to said resin impregnated skin fibers.

15. An aircraft stringerless fuselage structure as described in claim 10, wherein said impact compliant outer skin comprises a hybrid laminate tailored to provide bird strike impact compliance.

16. An aircraft stringerless fuselage structure as described in claim 15, wherein said
5 hybrid laminate comprises a plurality of varied lay-up angles tailored to provide bird strike impact compliance.

17. An aircraft stringerless fuselage structure as described in claim 10, wherein said plurality of circumferentially orientated hat frames comprise low modulus hat frames configured to resist debonding from said impact compliant outer skin during bird impact.

10 18. A method of forming an aircraft fuselage structure void of stringers comprising:
utilizing a fuselage lay-up tool comprising an upper tool surface, a plurality of stiffener grooves formed into said upper tool surface;

laying-up a plurality of resin impregnated stiffener fibers within said plurality of stiffener grooves to form a plurality of stiffeners, said plurality of resin impregnated skin fibers laid-up
15 such that they are not aligned with said plurality of resin impregnated stiffener fibers;

laying up a plurality of resin impregnated skin fibers onto said upper tool surface and over said plurality of resin impregnated stiffener fibers to form an impact compliant outer skin, said impact compliant outer skin comprising an outer skin surface, an inner stringerless skin surface, and a skin thickness;

20 curing said plurality of resin impregnated skin fibers to said plurality of resin impregnated stiffener fibers such that said plurality of stiffeners become integrated into said inner stringerless skin surface .

19. A method as described in claim 18, wherein:
said impact compliant outer skin comprises 0/45/90 degree layup at 20/80/0 percent
25 ratios;
each of said plurality of stiffeners comprises +/- 60 degree layup; and
said plurality of stiffeners comprises hat frames including at least one cap element positioned therein comprising a 0 degree layup interweaved with said resin impregnated stiffener fibers.

20. A method as described in claim 18, wherein said upper tool surface comprises a plurality of multi-curved shapes

21. A method as described in claim 18, further comprising:

co-curing said plurality of resin impregnated stiffener fibers and said plurality of resin
5 impregnated skin fibers to cure said plurality of stiffeners onto said inner stringerless skin surface.

22. A method as described in claim 18, further comprising:

co-bonding said plurality of resin impregnated skin fibers to said plurality of resin
impregnated stiffener fibers to bond said plurality of stiffeners onto said inner stringerless skin
10 surface.

23. A method as described in claim 18, further comprising:

filling a hat frame interior with foam prior to laying up said plurality of resin impregnated
skin fibers onto said plurality of resin impregnated stiffener fibers, said foam tailored to meet
15 varying impact requirements.

24. A method as described in claim 18, further comprising:

varying the lay-up angles of said plurality of resin impregnated skin fibers to generate
said impact compliant outer skin.

20

25. A method as described in claim 18, wherein said plurality of stiffeners comprises
a plurality of circumferentially orientated frames including at least one cap element positioned
therein, said cap element comprising S-2 glass plies

