United States Patent

Earl

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[54] **AIR CUSHION SUPPORT SPACE DEFINING STRUCTURE AND STOCKSHEET FABRICATION THEREFOR**

[72] Inventor: **I. T. Desmond Earl,** Buffalo, N.Y.

[73] Assignee: **Textron, Inc.,** Providence, R.I.

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[21] Appl. No.: **75,608**

[52] **U.S. Cl.** **180/124,** 161/47, 161/57, 180/128

[51] **Int. Cl.**.....**B60v 1/16**

[58] **Field of Search** 180/124, 127, 128; 161/47, 161/57, 70, 76, 77, 144, 166

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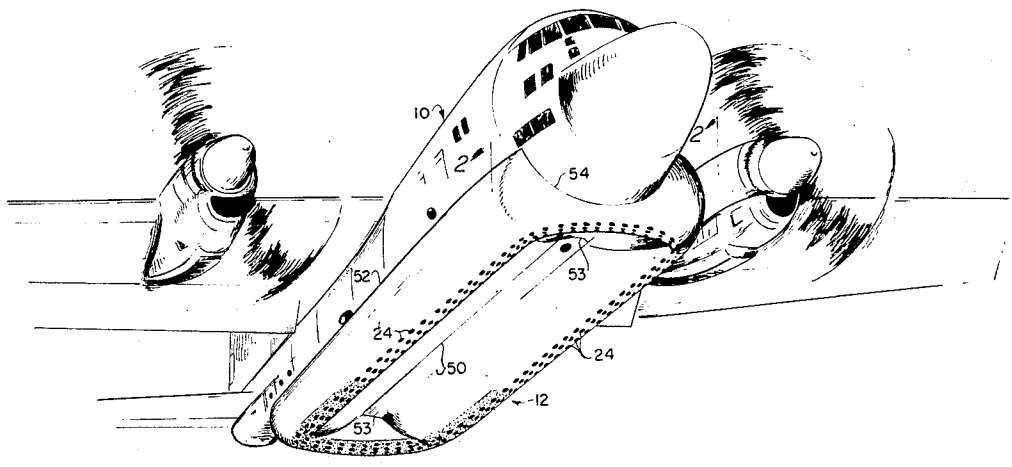
Primary Examiner—A. Harry Levy

Attorney—Bean & Bean

[57] **ABSTRACT**

An improved base support or "undercarriage" of the inflatable trunk type for attachment to a machine such as an airplane, air cushion vehicle, or the like, so as to render the machine supportable by means of an air film relative to a reaction surface. The trunk structure comprises a novel, elastic (within different limitations in different directions) sheet fabrication, which is patterned to incorporate within various areas of the sheet fabrication specifically prescribed elasticity characteristics (but only within prescribed limits); either omni-directionally or bi-directionally or uni-directionally, within the plane of the sheet, as dictated by the functional prerequisites of the system.

9 Claims, 8 Drawing Figures



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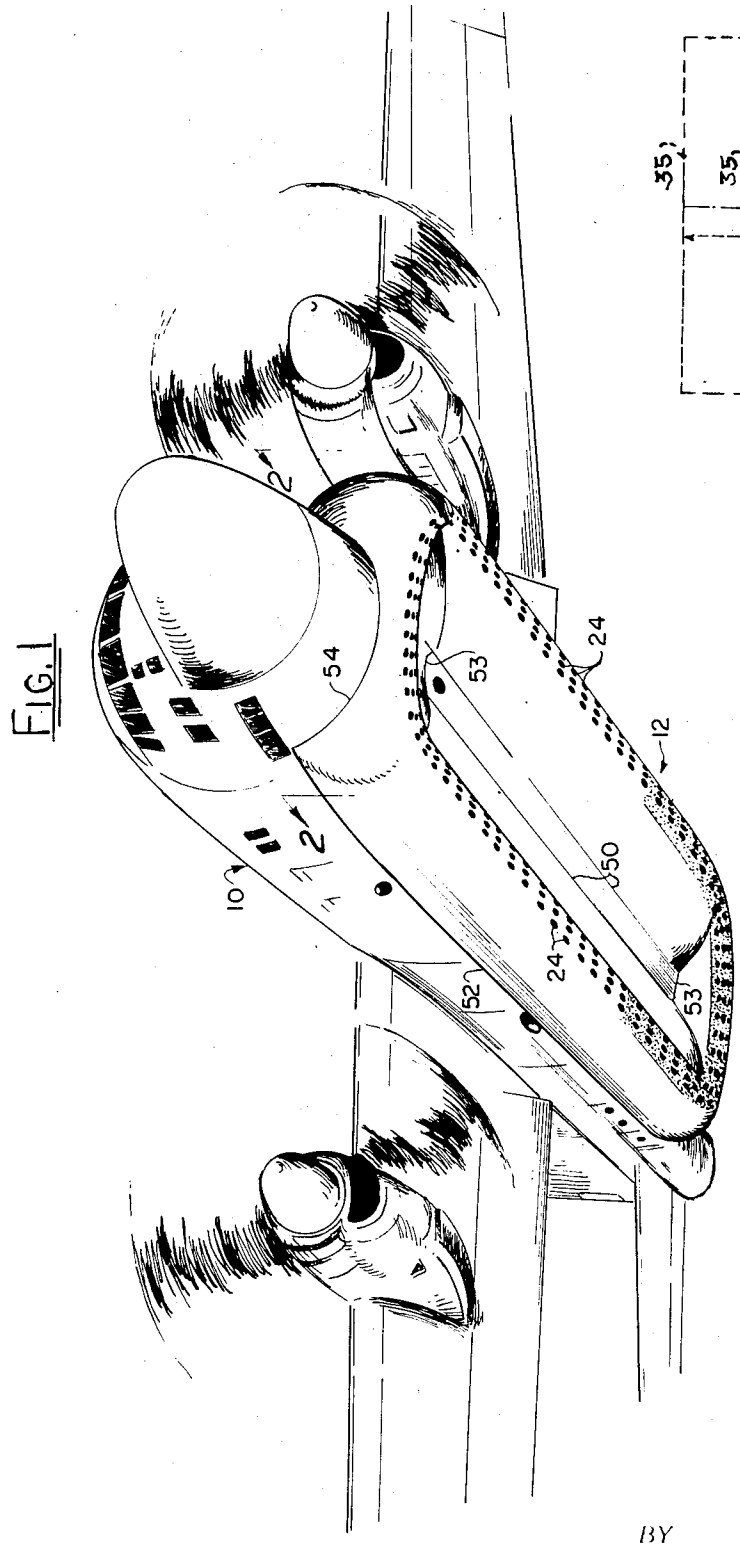

FIG. 1

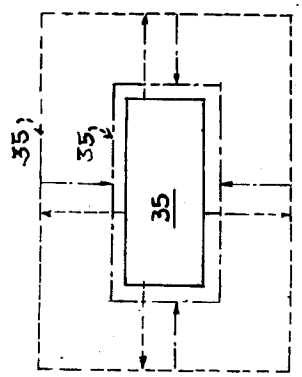

FIG. 7

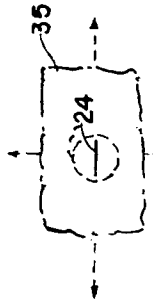

FIG. 8

INVENTOR.
T. DESMOND EARL
BY
Bean & Bean
ATTORNEYS

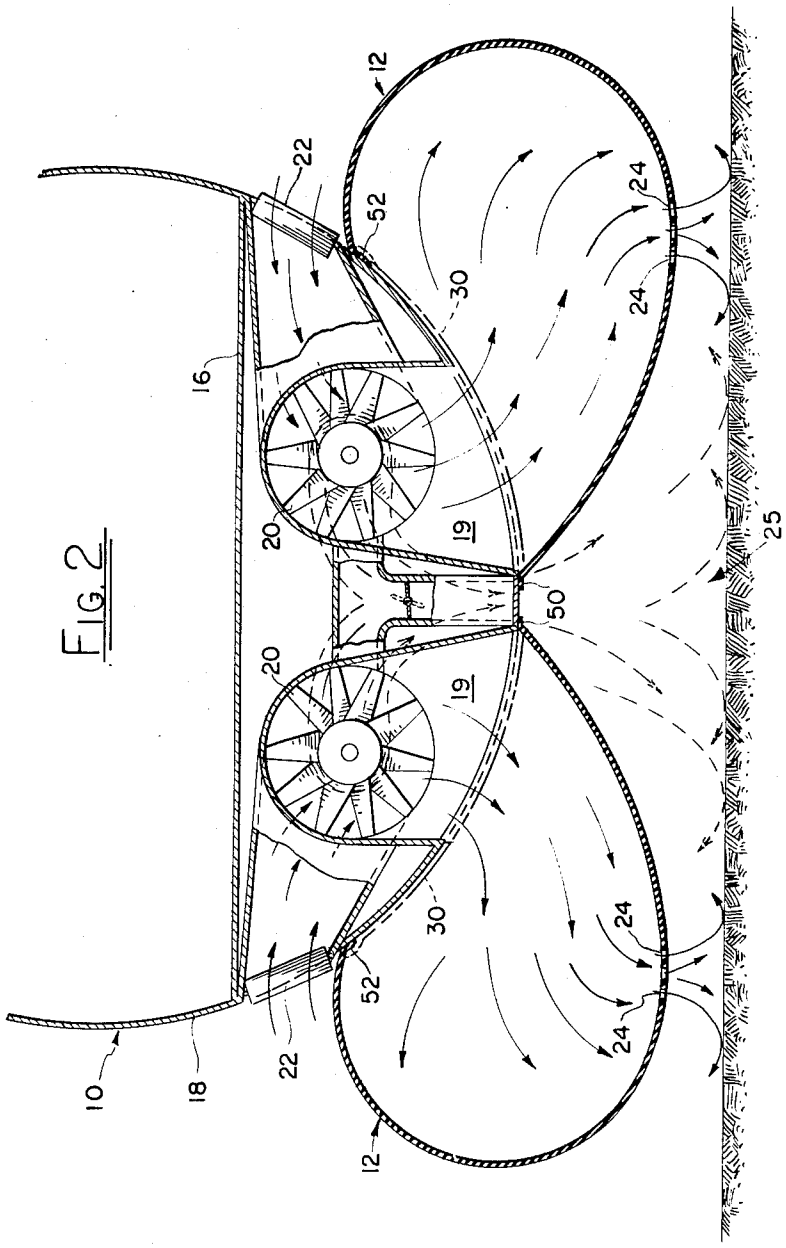

FIG. 2

INVENTOR.
T. DESMOND EARL
BY
Bean & Bean
ATTORNEYS

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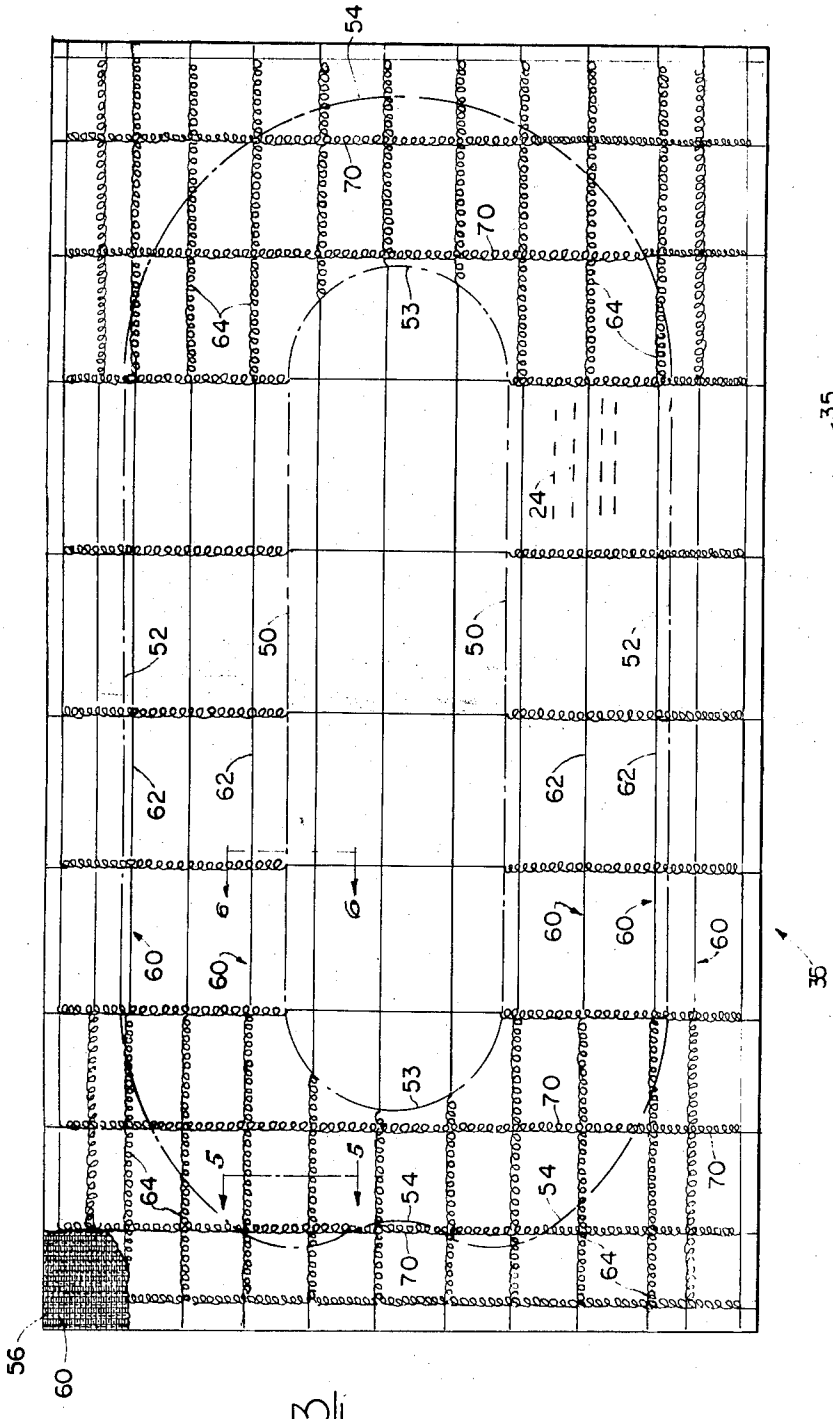

FIG. 3

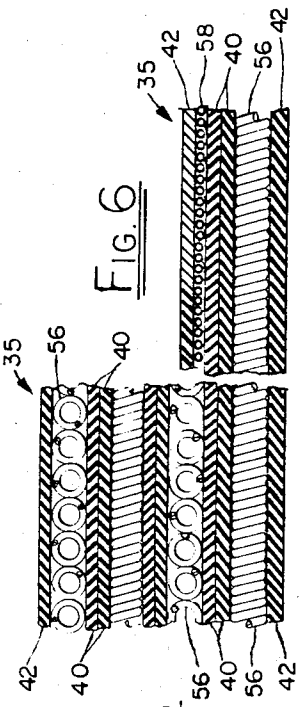

FIG. 6

FIG. 5

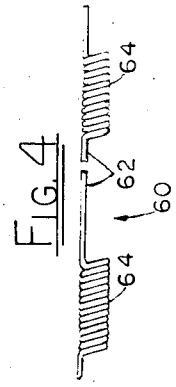

FIG. 4

INVENTOR.
T. DESMOND EARL

BY

Bean & Bean
ATTORNEYS

AIR CUSHION SUPPORT SPACE DEFINING STRUCTURE AND STOCKSHEET FABRICATION THEREFOR

BACKGROUND AND GENERAL DESCRIPTION OF THE INVENTION

This invention relates to "air cushion" supported machines, such as airplanes of the type disclosed for example in U.S. Pat. No. 3,275,270, or ground effect machines as disclosed for example in U.S. Pat. Nos. 3,246,711; 3,252,534; and 3,365,017; and in general to machines which employ inflated trunk type skirt arrangements for confining the machine lift air cushion. More specifically, the invention relates to an improved trunk type skirt construction for such machines, and to the stocksheet fabric material of which the flexible wall structurès thereof are made.

By way of example, the present invention may be employed in an air cushion defining inflatable trunk system of the "sausage" or toroidal planform types as shown in U.S. Pat. No. Re. 26,812. In such case the invention provides an improved, variantly elastic, trunk wall fabrication embodying within certain areas thereof elastically extendible (within limits) combinations of control strands providing omni-directionally elastic characteristics, and in other areas thereof combinations of longitudinally coiled or undulant or otherwise elastically extendible (within limits) high tensile strength strands extending in the girthwise directions of the wall structure, in combination with lengthwise rigid high tensile strength strands disposed to extend in directions transversely to the first named strands; all embodied within or in layered association with an air-sealing elastomeric matrix or sheet. In consequence, the trunk cell structure embodying such areas is readily adaptable along the straight-run portions thereof to girth-wise expansion-contraction deformations (but only with prescribed limits) to provide improved elastic expansion control procedures throughout various sections of the structure so as to regulate the inflated shape of the structure; while also being operable to resist undesired deformations of the inflated shape of the system, such as would otherwise be induced by drag forces in fore-and-aft directions of the structure incidental to taxiing, takeoff, and landing maneuvers of the aircraft. It is contemplated that the stocksheet fabrication may preferably comprise multiple layers of transversely disposed strands within a matrix as aforesaid. Adjacent layers thereof may be separated by air cooling spaces therebetween, and a wear/heat resistant layer of coating material is preferably applied to the environmentally exposed external surfaces of the structure.

Thus, with regard to the prescribed planform of a given trunk system, a stockpiece of differentially flexible/elastic sheet material is fabricated and "tailored" to the prescribed trunk system planform as well as to any typically encountered three-dimensionally curviformed fuselage to which it is to be attached; so that when the trunk structure so produced is inflated it will assume the desired balloonlike configuration without inherent fabric stress concentrations at localized areas thereof. When deflated, the structure will by nature retract and compactly hug the hull or fuselage or frame of the attended vehicle, as the case may be. When inflated, the system features improved resistance to planform distortion, such as would otherwise occur and adversely affect the vehicle support "air cushion effect" operation. In consequence, integrity of the prescribed air cushion space planform shape and dimensions is preserved; and the physical well-being of the trunk structure is protected against accidental injury.

THE DRAWING AND DETAILED DESCRIPTION

By way of example, the invention is described in the specification hereinafter and the accompanying drawing wherein:

FIG. **1** is a front-bottom perspective view of an airplane having an air cushion type undercarriage system such as may beneficially embody the present invention;

FIG. **2** is a fragmentary sectional view, on enlarged scale, taken as suggest by line **2—2** of FIG. **1**; showing by means of solid lines the trunk system in inflated and "ground effect" operational mode; and showing in broken lines the system in deflated and "air-flight" mode;

FIG. **3** is a schematic plan view, illustrating a typical stocksheet constructed in accordance with the present invention, and such as is suitable for fabrication into an inflatable undercarriage trunk system adaptable to a typical aircraft hull or fuselage form;

FIG. **4** is a fragmentary elevational view of a typical parti-non-elastic strand as employed in constructing the stocksheet of FIG. **3**;

FIG. **5** is a fragmentary sectional view taken as suggested by line **5—5** of FIG. **3**; showing a multiple layered form of assembly of components of the invention prior to being heat/compression integrated into an omni-directionally elastic section of the stockpiece fabric;

FIG. **6** is a fragmentary sectional view taken as suggested by line **6—6** of FIG. **3**; corresponding to FIG. **5** but showing assembly of a uni-directionally elastic portion of the structure;

FIG. **7** is a diagrammatic illustration of a fabrication processing step of the invention; and

FIG. **8** is a fragmentary view of a portion of the fabrication; illustrating operation of the fabric incidental to expansion-retraction functionings thereof.

SPECIFICATION

As shown by way of example herein at FIGS. **1-2**, the invention is embodied in an air cushion confining trunk system comprising the undercarriage of an airplane wherein the fuselage or hull thereof is indicated generally at **10**. More specifically, as shown by way of example herein the trunk system comprises a rectangularly-toroidal-shaped trunk as indicated generally at **12** which is formed of a special fabric sheeting; attached to the belly of the airplane fuselage to provide an air cushion confining space therebelow, for supporting the aircraft in friction-free relation above a reaction surface incidental to landings, takeoffs, and taxiing maneuvers. It is to be understood however that the invention is equally applicable to other air cushion defining inflatable trunk shapes and/or arrangements, such as are typically used in connection with ground effect machines, or the like.

In any case the frame of the machine **10** is illustrated at FIG. **2** to include a deck plate **16**; an outside wall shell **18**; dual inner air delivery ducts **19—19**; and lift

air pressure generating fan means such as indicated at **20—20**. The fans **20—20** draw air from externally of the machine, as through ports **22**, and deliver the air through the ducts **19—19** into the interior of the inflatable trunk devices to thereby inflate the latter as shown in FIG. **2**. The bottom "footprint" surfaces of trunk device **12** are typically formed with holes or slot-like nozzles as indicated at **24**, through which compressed air jets issue, as illustrated by the directional arrows, to establish a machine supporting air cushion and at the same time a pheripheral air curtain circumscribing the air cushion generating space as is indicated at **25** (FIG. **2**). For this purpose the apertures **24** are preferably arranged to direct their air jets somewhat inwardly so as to operate with appreciably inwardly directed thrust vectors, thereby contributing to the strength of the peripheral "curtain" air which operates to generate the transient air cushion **25** between the machine and the reaction surface.

Typically, such trunk devices are constructed of flexible sheet material, whereby when air pressure is supplied therein they balloon out and downwardly below the vehicle as disclosed for example in U.S. Pat. No. 3,275,270. As explained in the aforesaid U.S. Pat. No. 3,275,270, the air cushion defining trunk device (or devices) is to be alternately inflated into undercarriage operative condition, and collapsed into flattened or retracted condition against the belly of the vehicle for aerodynamic reasons; and various means may be provided for such purposes as are not related to the present invention.

Thus, for example, whenever it is desired to render the machine operational in "ground effect" mode, the lift air supply fans are first operated to discharge through means such as the air ducts **19** in the drawing herewith and into the trunk **12**. Thus, the trunk will be caused to balloon out to the condition such as is shown herein at FIGS. **1–2**. At the same time air from within the trunks now blasts downwardly through the slots **24** as shown in FIG. **2**. Thus the inflated trunk and the curtains of air blasting out of the slots **24** cooperate to build and maintain a transient "air cushion" under the belly of the machine which is operative to hold it off the reaction surface as illustrated by FIG. **2**. Therefore, when operational in "ground effect" mode the machine propulsion system and the directional control system enable the craft to be maneuvered as desired while still being suspended (by a matter of inches or a few feet) above the reaction surface; whether it be land, water, marsh, soft dirt, sand, rock, or snow or ice. In any case the craft will be held above and away from actual physical contact with the reaction surface, and will simply skim along above it in friction-free manner.

However, as illustrated by the broken lines **30—30** of FIG. **2**, by virtue of fabrication of the trunk wall material of the present invention (as will be explained more fully hereinafter), when the compressors **20–20** are deenergized the trunk wall sheet material elastically contracts into closely compacted condition thereby conforming in aerodynamically efficient relation to the profile of the machine fuselage. It is of course to be understood that suitable valve and other control devices will be employed in conjunction with the lift air supply fan engines and discharge ducts under pilot control (either manual or automatic) to provide the pilot with requisite differential controls for these mechanisms.

The present invention features employment in such trunk devices as aforesaid, of novel flexible and airtight sheet material fabrications, the details of construction thereof being illustrated by FIGS. **3–6**, herewith. Basically, and in any case, the sheet fabrication will comprise a combination of layered transversely disposed "-stretch control" strands of high tensile strength material, embedded within or otherwise associated with an airtight film or layer; the various "stretch control" strands being appropriately and selectively oriented so as to accomplish the objects of the invention as set forth hereinabove.

As shown, only by way of example at FIGS. **3,5,6,7,8**, the fabric stocksheet **35** may generally comprise a pair of inner "core" sheets **40–40** formed of natural rubber, and outer "wall" sheets **42—42** formed of elastomer material as neoprene or silicone rubber, or some other suitable elastomer selected according to the environmental requisites and other such parameters; the aforesaid sheets being interleaved with layers of transversely aligned Nylon strands or the like as illustrated at **60**. Some of the strands are precoiled (or crimped) as illustrated as **64** before assembly within selected areas of the fabrication, whereas in other portions of the fabrication the strands are assembled in their simple straight line form as indicated at **62** in order to provide the stocksheet at various portions thereof with the prerequisite uni-directionally/bi-directionally/omni-directionally elastic characteristics, as will more fully be explained hereinafter.

Thus, for example, as illustrated diagrammatically at FIG. **3**, a stocksheet **35** of the present invention is illustrated as being adapted to attachment to the three-dimensionally curved form of the lower surface of a typical airplane fuselage of the type shown at FIGS. **1**, **2**, of the drawing herewith. It will be apparent that the elastically inflatable trunk system as indicated generally at **12** therein requires to be attached in air sealing relation to the rounded fuselage along centrally running inboard parallel lines of attachment **50—50**; parallel outboard lines of attachment **52—52**; and along curved inner end lines **53—53** and outer end attachment lines **54—54**; some parts of which may or may not be of straight line form. The correspondingly projected lines of attachment of the trunk sheet fabrication to the aircraft fuselage are also indicated on FIG. **3**.

It will of course be appreciated that the straight-line portions of the trunk sheet need be elastic only in the girthwise directions thereof. However, the rounded corner portions of the trunk sheet must be omni-directionally elastic in order to provide a trunk system which when inflated will balloon out to the configuration shown in FIGS. **1**, **2**, in order to provide the desired smoothly contoured form thereof without internal restraint or stress concentrations in the areas of transition from cylindrically to spherically curved forms.

In accordance with the present invention this objective is accomplished as illustrated by FIGS. **3–6** herein. For example, as illustrated at FIG. **5** the portions of the stocksheet which are destined to provide the rounded corner portions of the trunk system are formed of a layered composite of cover sheets interleaved by layers of transversely aligned strands of Nylon or the like **56** which are coiled (or crimped) prior to assembly into the stocksheet fabrication. When relatively assembled

as shown in the drawing at FIG. 5, they are then heat/press welded or adhesively bonded together; thereby providing a compact sheet fabrication which is omni-directionally elastic and thereby adapted to stretch without internal stress concentrations into the sperically curved form which is requisite to be assumed when the trunk system is inflated into the condition shown at FIGS. 1, 2.

On the other hand, the straight-run side and end wall portions of the trunk system may be fabricated as shown for example at FIG. 6, whereby the outer layers of the stocksheet are interleaved with alternately disposed layers of coiled (or crimped) Nylon or the like strands 56 and straight Nylon or the like strands as illustrated at 58. Thus, these portions of the stocksheet will be fabricated to be elastic only in the girthwise directions of the elastic ballooning action. Hence, it will be appreciated that when that portion of the assembly as illustrated at FIG. 3 is heat-pressured and/or adhesively bonded into an integrally compacted flexible sheet-like structure, it will be dimensionally elastic (but only within limits) in girthwise directions while being dimensionally rigid in directions transverse thereto.

It is to be understood however, that in order to provide an air cushion space defining trunk structure as aforesaid which will be of sufficient ruggedness to withstand the wear and tear thereon during taxiing operation, the fabrication as illustrated at FIGS. 5–6 must be of extremely tough materials and of substantial thickness; especially in the case of relatively large vehicles such as are now being designed and/or contemplated in the air cushion vehicle and airplane industries. Accordingly, a stocksheet as contemplated herein may be of the order of 2 or more inches thick, or less; and in any such case will of course be initially quite solid and stiff and non-pliable, and quite uninflatable into ballooned form by means of a relatively low-pressure air source. Inasmuch as the typical air cushion vehicle rides on a cushion of air which is generated by compressed air furnished at only 1 to 2 p.s.i. or the like, it is apparent that the fabrication shown and described hereinabove would not respond to such pressures, and would be inoperable for the intended purpose.

Therefore, in accordance with the present invention it is contemplated that such fabrications as illustrated at FIGS. 5–6 are preferably subjected (subsequent to their heat-press consolidation treatment) to a further "elasticity liberation" treatment, as shown diagrammatically by FIG. 7 of the drawing herewith. As shown therein, a stocksheet as illustrated by way of example at FIG. 3 is subjected to a two-way stretch operation by means of a high strength mechanism, so as to cause the fabrication to be extended in the order of 300–400 percent in its original planform dimensions. This operation, which may be performed either by use of high pressure hydrostatic or compressed air means, or by any suitable mechanical stretching means or the like, will provide release of certain internal interlock factors of the structure without impairment of the elasticity and air-proof characteristics of the essential components of the fabrication system. In fact, this operation further contributes to the efficacy of the system because cooling air transport channels are thereby caused to occur between various layers of the laminate material; whereby frictional heat encountered during taxiing operations is thereby more effectively dissipated.

It is to be noted however, that upon termination of the "liberation" stretch operation the sheet fabrication does not quite return to its original dimensions. Thus, as illustrated for example at FIG. 7, a stocksheet as shown in solid lines may be stretched to the broken line dimensions thereof, and then upon relaxation will return to a condition such as shown by the dot-dash line configuration. Accordingly, the stocksheet should be so stretched before being cut or tailored to the planform required for any given installation. As explained hereinabove, the "cut" should be so dimensioned that when the patterned sheet is first attached to the vehicle hull in air-sealed relation around the inner and outer peripheries of the sheet, the sheet should be under slight tension in all directions so as to hug itself flatwise against the hull. Subsequent introduction of compressed air or the like between the hull and the sheet will then cause the latter to balloon out as into the configuration shown in the drawing herewith without any regionalized stress concentrations, as explained hereinabove. In consequence, it is readily adapted to elastically stretch and balloon out as illustrated at FIG. 2 in response to internally applied compressed air forces or the like; while being highly resistant when so inflated to any forces tending to cause deformation and/or elongation thereof in directions longitudinally of the aircraft.

FIG. 4 illustrates still another form of high tensile strength strand such as may be employed in certain parts of the stocksheet in accordance with the invention. Thus, as illustrated at 60 (FIGS. 3 and 4) the Nylon strands running lengthwise of the trunk system may be of straight line form as indicated at 62 throughout the extents of their "runs" of the straight wall portions of the trunk system; while being coiled (or crimped) as indicated at 64 throughout the extents of their "runs" of the spherically ballooning "corner" portions of the structure. Also it is to be understood that the transverse strands 70 which are to be embodied in the spherically ballooning portions of the structure may be coiled (or crimped) throughout their lengths, as shown at FIG. 3.

Therefore it is to be appreciated that in accordance with the present invention whenever it is required to provide an appropriately operable inflatable air cushion confining trunk system, a multilayered sheet fabrication such as illustrated diagrammatically by FIG. 3 may be laid down upon a flat work table so as to encompass the plan view dimensional extend of the prerequisite zones of attachment of the undercarriage structure to the airplane fuselage, and then cut or "-tailored" to appropriate shape and dimensions. Any variants of dimensionally elastic/rigid requirements for the various parts of any given trunk planform configuration may thus be readily accommodated, so that the trunk system will expand to the desired form when inflated and will hold this form against shape distortions such as would otherwise be induced by drag forces operating thereon incidental to taxiing, takeoff and landing maneuvers of the craft. Furthermore, it will be apparent that a trunk system of the invention may be readily fabricated and tailored to the configurations of

a large variety of hull shapes, so that in any case when the trunk system is deflated it will elastically contract into flat and smoothly fitting, compactly nested, relation against the vehicle hull; thereby maximizing aerodynamic efficiencies for such craft when so equipped.

FIG. 8 illustrates another feature and advantage of the present invention by way of illustrating how the air exit apertures 24 of the trunk system may be advantageously provided by simply slitting the fabric at intervals lengthwise thereof, as indicated by the solid line showing of item 24 in FIG. 8. This operation will, of course, be performed while the fabric stockpiece is lying flatwise upon a table or the like in substantially relaxed condition. Then, subsequent to mounting of the tailored fabrication against the vehicle hull as explained hereinabove, and upon introduction of air or the like under pressure into the interior of the structure, the sheet fabrication will expand elastically, whereupon the slotted apertures 24 expand into substantially circular-shaped apertures as indicated by the broken line showing thereof at FIG. 8. Thus, the air exit apertures 24 (see FIG. 1) automatically open into effective air exit configurations.

I claim:

1. In an air cushion supported vehicle such as an airplane, air cushion vehicle, or the like, having a hull carrying an air cushion support generating means thereunder;

said means comprising an air pressure inflatable trunk system including a generally cylindrically shaped straight run portions joined by spherically curved corner portions;

said trunk system comprising a flexible stocksheet cut to a prescribed pattern and including means for allowing said straight run portions to expand only in girthwise direction and for allowing said corner portions to expand bi-directionally;

said cut sheet being attached to the vehicle hull along the perimetral edges thereof.

2. A sheet fabrication for attachment to a vehicle to provide therebelow an air-expandable trunk adapted to establish an air cushion space below the vehicle for vertical support thereof above a reaction surface; said fabrication being in the form of a band circumscribing said space and having straight run portions on opposite sides of said space, which extend longitudinally of the vehicle and transverse portions joining opposite ends of said straight run portions and merging at corner portions with such straight run portions; said straight run portions being elastic only in the girthwise direction of the trunk transverse to the longitudinal direction of the vehicle; and said corner portions being bi-directionally elastic.

3. A sheet fabrication as defined in claim 2 wherein the longitudinal and transverse straight run portions and said corner portions are provided with at least one series of slits located to be in the bottom footprint of the air-expanded trunk, the slits of said series being spaced apart to circumscribe the air cushion space and each slit being aligned in the circumscribing direction so as to be opened up into substantially circular aperture form when the trunk is inflated.

4. A sheet fabrication for attachment to a vehicle to provide therebelow an air-expandable trunk adapted to establish an air cushion space below the vehicle for vertical support thereof above a reaction surface; said fabrication being in the form of a band circumscribing said space an having straight run portions on opposite sides of said space which extend longitudinally of the vehicle and transverse portions joining opposite ends of said straight run portions and merging at corner portions therewith;

said fabrication being formed of elastic material to allow said band to be expanded from a condition substantially conforming to the contour of said vehicle to said air-expanded trunk configuration; and

means in said elastic material for allowing the straight run portions to stretch only in the girthwise direction of the trunk for allowing said corner portions to stretch bi-directionally whereby the bottom of the air-expanded trunk defining the footprint thereof lies substantially in a single plane to preserve the integrity of the air cushion.

5. A sheet fabrication as defined in claim 4 wherein the longitudinal and transverse straight run portions and said corner portions are provided with at least one series of slits located to be in the bottom footprint of the air-expanded trunk, the slits of said series being spaced apart to circumscribe the air cushion space and each slit being aligned in the circumscribing direction so as to be opened up into substantially circular aperture form when the trunk is inflated.

6. A sheet fabrication for attachment to a vehicle hull to provide therebelow an air-expandable trunk adapted to establish an air cushion space below the vehicle for vertical support thereof above a reaction surface, said sheet fabrication being cut to a prescribed pattern so as to be adapted to be laid flatwise and attached in fluid-pressure sealing relation along its peripheral edges to the vehicle, whereby air under pressure may be applied so as to cause said cut sheet to balloon out and provide an inflated trunk extending from the vehicle, said sheet being uni-directionally elastic throughout one portion thereof and bi-directionally elastic throughout another portion thereof, the cut sheet fabrication being of rectangular-toroidal planform and the sheet fabrication comprising the straight-run portions of the trunk system being elastic in girthwise directions only.

7. A sheet fabrication as set forth in claim 6 wherein the planform corner portions of the sheet fabrication comprising the trunk system are omni-directionally elastic.

8. A sheet fabrication as set forth in claim 7 wherein said sheet fabrication comprises multiple layers of fabric each comprising interwoven strands of Nylon or the like, and an air sealing layer of omni-directionally elastic material.

9. A sheet fabrication as set forth in claim 6 wherein said sheet fabrication comprises multiple layers of fabric each comprising interwoven strands of Nylon or the like and an air sealing layer of omni-directionally elastic material.

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