SHOCK-ABSORBING SHIPPING ASSEMBLY FOR ROTOR BLADES

John Theron Parsons, Donald E. Goodland, and Alb C. Bullauer, Traverse City, Mich., assignors to Parsons Corporation, Detroit, Mich., a corporation of Michigan

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This invention relates to the protective packing for shipment of helicopter rotor blades, as well as other elongated, somewhat resilient objects which have relatively delicate surfaces.

The objects of the present invention include: harmlessly dissipating the shock loads to which a rotor blade shipping container is subjected during handling; and providing a rugged, re-usable, readily fabricated shipping container of small over-all dimensions so designed as to be readily handled, lifted, hoisted, skidded and stacked. Other objectives are set forth in the specification which follows.

Protective shipping containers for helicopter rotor blades have usually been designed to attain a maximum of rigidity. A rigid container transmits shocks to its contents; therefore such containers employed various types of blade support means within them for lessening the shock; but such means have been relatively unsatisfactory.

In the present invention, advantage is taken of the fact that helicopter rotor blades are not inflexible, but are themselves designed to bend and twist severely under air loads distributed across their rather delicate airfoil surfaces. The present container is therefore not intended to be rigid. Instead it is designed so as to possess a fairly high degree of flexibility in both bending and torsion, substantially commensurate with the flexibility of the rotor blades themselves in bending and torsion. Blade support means within the container so transform its deflections that concentrated shock loads are diminished, cushioned, and harmlessly distributed over the surfaces of the blades supported therein.

The shipping container itself is locally rigid. However, as an elongated structural unit subjected to bending and twist under handling loads it is remarkably elastic. This combination of results is obtained by using thin panels for the container top and bottom and continuous flanged extrusions as its sides, with the flanges interrupted at intervals spaced to achieve elasticity.

Furthermore, the continuous extrusions used for the upper and lower sides have nesting attach flanges, flanges to support the container top and bottom, flanges for skidding the container and for stacking one on top of another, all formed integrally for ruggedness and simplicity of fabrication. This design renders the container well suited for rough handling, as by skidding and hoisting; and among the inventive features herein are those which provide skidding and hoisting attachments.

Co-acting with the resilient shipping container are resilient blade support means, to transform loads not otherwise absorbed into distributed loads on the blade. This is accomplished by having the outer edge portion of the blade support means, adjacent the shipping box, deflect and twist with the bending and twisting of the box. Each rotor blade is supported in a molded cavity, cushioned, and reacting those impact loads which reach it, as harmlessly distributed loads.

With this preliminary description, reference will now be made to the drawings (two sheets), in which:

Fig. 1 is a side elevation of a shipping container embodying the present invention, partly broken away to show only a portion of its length;
Fig. 2 is an end elevation of the shipping container of Fig. 1, together with a sectional view, taken as along line 2—2 of Fig. 1, of a similar container stacked thereon;
Fig. 3 is a sectional view taken along line 3—3 of Fig. 1, the bolts for the attachment flanges being opened outward;
Fig. 4 is a sectional view taken along line 4—4 of Fig. 1;
Fig. 5 is an end elevation of a modified embodiment of the present invention;
Fig. 6 is an exploded sectional view of said modified embodiment otherwise corresponding to Fig. 3; and
Fig. 7 is a plan view of one end of one of the elongated blade-support membranes shown in section in Fig. 6.

The blade container shipping box has a top, or upper shipping box portion, generally designated 1 and a bottom or lower portion generally designated 2, each fabricated principally of four lengths of a beam-like structural member, preferably extruded aluminum. Referring to Fig. 2 for a cross-sectional view, the top 1 consists of two longer lengths of an upper extrusion which form the top sides; two shorter lengths of the same extrusion are utilized to form the top ends 4. The side extrusions 3 and end extrusions 4 of the top 1 may be joined at their corners by rivets, as shown in Fig. 2, using ordinary interior corner angles 4'. Each of the lengths of upper extrusion 3, 4, includes a rigid vertical web 5, an inward-extending stacking flange 6 at the upper margin of the web 5, and a top panel support flange 7 extending upwardly and inwardly from the stacking flange 6. The stacking flange 6 is substantially horizontal, and is utilized as a base for stacking an additional container, as shown in Fig. 2. To this top panel support flange 7 is attached a top panel 8, which extends between and is supported by the support flanges 7 of each of the side extrusions 3 and end extrusions 4. The top panel 8 may be stiffened by a series of lateral stiffeners 9 attached at intervals, as by riveting, to form a light-weight assembly sufficient to bear local loads. It is designed to add little rigidity to the shipping box as a structural unit; and for this purpose it might be made of a material having a lesser modulus of elasticity than the extrusions 3, 4; for example, a laminated plastic.

At the lower margin of the web 5 of the extrusions 3, 4 is an outward-extending top attachment flange 10, preferably formed with a small upward-extending lip 11. The attachment flange 10 has an undersurface 12 which may include a broad tapering groove as shown in Fig. 2.

The bottom 2 of the shipping box likewise consists principally of two longer, or lower side, lengths 13 and two shorter or lower end lengths 14 of an extrusion having a vertical web 15 positioned to align with the webs 5 of the upper shipping box portion 1. At the upper margin of the web 15 of each of the lengths 13, 14, a top attachment flange 16 extends outwardly so as to register with the attachment flanges 10 of the container top 1; and each has an upper surface 17 which is so ridged or crowned, as shown in Fig. 2, as to fit snugly against the under surface 12 of the attachment flange 10 of the container top 1. The under side 18 of each attachment flange 16 may be concavely grooved as shown, for easy attachment of T-bolts hereinafter described.

At approximately mid-height of the web 15, an integrally formed box bottom support flange 19 projects horizontally inward. To the inner ends thereof is secured a bottom panel 20, which may be stiffened at intervals by bottom stiffeners 21 riveted thereto. Like the top panel 8, the bottom panel 20 may be of light-weight construction, so as to add little to the stiffness of the container bottom 2 in bending or twist.

The lower side lengths of extrusion 13 have inward-extending skid flanges 22 at the lower margin of the
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3. webs 15. These skid flanges 22 are present only on the longer sides of the bottom 2; if identical extrusion are utilized to fabricate the lower end lengths 14, such flanges 22 are threaded therethrough prior to assembly, so as to present the end appearance shown in Fig. 2. The skid flanges 22 of the side extrusions 13 thus serve as parallel skids for sliding the container endwise. Being integral, they are extremely rugged.

The skid flanges 22, like the stacking flanges 6 of the container top 1, are positioned at the inner side of the webs 5, 15 and are thus in vertical alignment. Therefore, an upper container may readily be stacked on a lower one, as indicated in Fig. 2, and for purposes of storage and handling four or five containers may be stacked upon each other.

If the box bottom support flanges 19 were eliminated, the bottom panel 20 might extend sideward to the inner sides of the webs 15, there to be joined at the level of the box bottom securing line 23. This level is sufficiently above the level of the skid flanges 22 to permit access by a fork-lift truck.

The lower side lengths 13 and lower end lengths 14 of extrusion are secured to each other at the box corners not merely by interior angles such as are used for joining the container top 1, but by four rugged external lower corner brackets 24, which are preferably cast of aluminum or steel. These brackets 24 each have a corner angle portion 25 having inner planar surfaces which meet at right angles and subtend the outer end surfaces of the webs 15 to which they are joined by a plurality of rivets. The corner brackets 24 have skid portions 26 which extend longitudinally, forming extensions of the skid flanges 22. Each skid portion 26 has an under face 27 aligned with the under face of a skid flange 22 and sloping upward and outward therefrom at an angle of approximately 45°. Above the skid portion 26 of each of the corner brackets 24 is an integrally-cast hoist-ring portion 28. Both the hoist-ring portion 28 and the skid portion 26 of each bracket 24 are adapted to receive loads having substantial vertical components; and it is particularly advantageous to have such loads transmitted through the corner angle portions 25 directly to the webs 15, which react such loads by shear stresses.

To achieve the purposes hereof it is essential that the elongated shipping box as a whole be characterized by a substantial degree of flexibility in bending and twist. The upper and lower side extrusions 3, 13 would ordinarily tend to coact with each other as a single beam on each side of the shipping container, providing excessive stiffness in both bending and torsion. To overcome such excess of stiffness, effective structural interruptions are provided at spaced intervals along the length of the box. These structural interruptions may take various forms. One of the most convenient is a plurality of inward-extending notches or cut-outs 29 into the attachment flanges 10, 16 of the container top 1 and bottom 2, respectively, as shown in Fig. 3.

The notches or cut-outs 29 are indented into the attachment flanges 10, 16 through substantially the entire width by which said flanges extend outward from the webs 5, 15. The depth of indentation is at least through the major portion of the cross-sectional area of the flanges 10, 16, sufficient to disrupt the beam chord structure and thus reduce the structural stiffness of the container sides.

Other structural interruptions which interfere with the beam stiffness of the top side extrusions 3 are several handle bracket cut-out 30, which extend deeply into the stacking flanges 6 and provide space for attaching handle brackets 31 beneath the exterior contour of the box, so as to offer no exterior projection. The handle brackets 31 are preferably castings riveted to the top side extrusions 3 and have horizontal, rod-like hand holds 32.

For purposes of providing access to the lifting prongs of a fork-lift truck, the web 15 of each of the lower side lengths of extrusion 13 is provided with at least one fork-lift access cut-out 33 on each side of the center of gravity of the container. The cut-out 33 is formed by extending from the box bottom securing line 23 down to a level adjacent the skid flanges 22. These fork-lift access cut-outs add flexibility to the lower side lengths of extrusion 13. They are bridged, from one side of the shipping container to the other, by inverted reinforcing channels 34, which provide rugged areas of contact for the fork-lift.

The box top 1 may be secured to the bottom 2 by any convenient mode of releasable attachment. Inverted T-bolts 35 are provided, having their cross-members 36 clipped into the grooved under side 18 of the attachment flange 16 of each of the lengths of lower extrusion 13, 14, so that the T-bolt stem portions 37 may swing upward and inwardly into the notches 29. They may be secured by attachment nuts 38 which seat on the upper surface of the top attachment flanges 10 inwardly of the flange lips 11. A few turns raise the nuts 38 above the level of the flange lips 11, without removing them from the stem portions 37, so that they may be swung outward and the container top 1 readily removed. For convenience, the number of T-bolts 35 should be kept at a minimum; and it may be possible to utilize fewer bolts 35 than the number of notches 29.

Interruptions include a corner planar surface 18 of the extrusions 3, 13, as by the notches 29, handle bracket cut-outs 30, fork-like access cut-outs 33, results in increased flexibility which, because the members 3, 13 are continuous, is substantially spring-like. This flexibility may be adjusted by adding to or lessening the number of notches in the attachment flanges 10, 16, with a view to the bending curvature which the rotor blades to be shipped may safely undergo, and also the twist to which the rotor blades may be safely subjected in torsion. The shipping box may safely be rendered flexible to the extent that its bending and twist under anticipated handling loads equals or is at least comparable to the flexibility of the rotor blades under their design loads.

There remains the problem of providing support means for the blades. The several criteria for such support means are illustrated in the two embodiments herein shown. One criteria is that the support means includes outer portions or surfaces which fit snugly against the shipping container along its sides and deflect therewith. Another criteria is that the support means include a relatively flexible cavity portion contoured to the shape of the airfoil surface of the blade to be shipped therein.

Fig. 2 shows schematically the positions of an upper rotor blade a and a lower rotor blade b, cushioned in place by three cushions which substantially fill the entire volume within the container not filled by the rotor blades themselves. These are the upper resilient cushion 39, the lower resilient cushion 40 and a third intermediate cushion 41, each made of a resilient material such as rubberized hair, each extending substantially the full length of the inside of the container except where space therein is occupied by a root end attachment hereinafter described, and each molded to the contours of the blade surfaces with which it comes into contact, as well as to the interior surfaces of the container.

The rotor blades a and b have their leading edges facing opposite sides of the container, and the blade portions afof the leading edges overlap each other. The space between the overlapping portions of the blades a, b is substantially filled by the intermediate cushion 41, which spaces the blades vertically in relation to each other.

The upper and lower cushions 39, 40 mate at their outer portions along a parting line 42, inward of which each cushion has a cushion rim surface 43. Inward of the rim surface of each of the upper and lower cushions 39, 40 is molded a blade support cavity 44, 44', for the upper or lower blade a, b, respectively, with its leading edge
portion 45, 45' facing outward toward opposite sides of the container. Chordwise aft of each blade support cavity 44, 44' of each of the cushion: 39, 40 is a thickened ridge portion 46, 46', which extends to the level of the blade other than the one which is supported by the blade support cavity 44, 44' of the particular cushion. Notice that the support cavity 44 of the upper cushion 39 is in its under surface; and its thickened ridge portion 46 extends downward to the level of the upper surface of the leading edge of the lower rotor blade b. Thus the thickened ridge portion 46 of each of the upper and lower cushions 39, 40 supports the leading edge of one of the blades in support cavity of the other cushion; while the intermediate cushion 41 serves as a support for the blade portions aft of their leading edges in opposition to the support cavities of both the upper and lower cushions 39, 40. The side margins of the intermediate cushion 41 extend between and are closely adjacent the inner side 47, 47' of the thickened ridge portions 46 of these upper and lower cushions. Thus the resilient cushions exert almost fluid-like pressure against the blade surfaces which they support so as to resist loads applied in any direction.

It is evident from the cross-sectional view Fig. 3 that the thickened ridge portions 46, 46' interfere with any tendency of the slender trailing edges of the blades a and b to force their way through the cushions and move chordwise aft.

The heavier root ends of the blades a and b are secured, one at each end of the container, in the manner shown in Fig. 4. The blade root end fitting c is penetrated by a main root bushing which extends substantially vertically through the blade. Affixed within the container top 1 and bottom 2 at each end is a top pin bracket assembly 48 and bottom pin bracket assembly 49, each preferably formed of riveted sheet metal and enclosing a horizontal shock pad 50 and a vertical shock pad 51, each having a central bore to accommodate the end of a vertical pin 52 whose mid-portion passes through the main root bushing d of the rotor blade supported. The horizontal shock pads 50 restrain each end of the pin 52 from horizontal movement, whereas the vertical shock pads 51 are positioned adjacent the upper and lower surfaces of the blade root fitting c. The shock pads 51, 51' are made of suitable resilient material, such as heavy rubber or other resilient composition. Each rotor blade is thus restrained by a pin 52 through its root from longitudinal movement within the container; and the root end of each blade is supported and cushioned by the shock pads 50, 51.

The top pin bracket assembly 48 and bottom pin bracket assembly 49 are located at a different level at one end of the container from their level at the other. They are so spaced as to fix the position of the root ends of the upper rotor blade a and lower rotor blade b at levels corresponding to the levels at which the cushions 39, 40, 41 support the airfoil surfaces of the blades.

The support means described possesses the advantage that, to the extent shock loads applied to the container are transmitted to the rotor blades a, b, these are distributed and reacted in almost precisely the manner for which the structure was designed. The support cavity 44 of the rotor blade is designed to withstand flight loads. Thus, the cushions 39, 40, 41 transmit their distributed loads much as air loads to the blade surfaces, whereas the vertical pins 52 distribute their reactions to the blade root through its root fitting c. Deformation of the shipping container in bending and twist imposes only such loads and deflections on the rotor blades as they are designed to receive.

A modified embodiment of blade support means, not incorporating such root reaction, is illustrated in Figs. 5, 6 and 7. The shipping box there shown is identical with the box heretofore described except for the insertion between the box top, designated 1, and box bottom, designated 2, of an intermediate frame generally designated 53, hereinafter described; and for the use of T-bolts 35' having stem portions 37' sufficiently long to extend completely across the intermediate frame 53. Since the box top 1 and bottom 2 of the modified embodiment are otherwise identical with those heretofore described, they are not again described herein; but their parts corresponding to those heretofore described bear the same reference figure 44 of the particular cushion. The intermediate frame 53 is formed from four lengths of an extrusion shown in cross-section in Fig. 6, the two longer lengths serving as the frame sides 54 and the short lengths as the frame ends 54'. Said extrusion has an upper attachment flange 55 whose shape corresponds to that of the top attachment flange 16 of the container bottom 2; and a lower attachment flange 17 whose shape corresponds to that of the attachment flange 10 of the container top 1. The flanges 55, 56 of such extrusion are positioned to register with the attachment flanges 10, 16 of the container top and bottom, and they are similarly provided with notches 29 in registration with the notches 27. The frame sides 54 and ends 54' further have intermediate web portions 57 which serve as a continuation of the sides of the top 1 and bottom 2, and are in registration therewith.

As blade support means for an upper rotor blade, an upper blade support membrane 58 extends continuously across the upper attachment flanges 55 of the intermediate frame 53; and a similar support membrane 59 for a lower blade extends continuously across the top attachment flange 16 of the container bottom 2. The membranes 58, 59 are molded preferably of some strong, semi-flexible material, such as several layers of cloth made of glass fibers and impregnated with structural resin.

Each of the membranes 58, 59 has outer edges 60, molded downward so as to fit securely over the attachment flanges 55, 16 of the intermediate frame 53 and bottom 2, and notched by a plurality of membrane notches 68 to permit entrance of the T-bolt stem portions 37'. Intermediate its edges, each of the membranes 58, 59 is provided with a membrane blade cavity 61, molded to conform to the contour of the rotor blade to be accommodated therein on the under side of its chord plane. To serve as abutments against chordwise movement of the blades a', b' within the membrane blade cavities 61 so provided, there are molded adjacent the long edge of each blade cavity 61 a leading edge ridge 62 and a trailing edge ridge 63, each interrupted at intervals by the opposite ends of molded channel-like chordwise depressions 64. The ends of these extend chordwise beyond the leading edge ridge 62 and trailing edge ridge 63, to provide spaces for manually gripping the blade.

Such channel-like chordwise depressions provide lateral bending stiffness to the membranes 58, 59 which preserves the contour of the blade cavity 61. However, they also tend to stiffen the membrane as a whole. This stiffening tendency is at least partly overcome by providing slot-like openings 65 across the channel-like depressions 64 near their ends. These slot-like openings are provided for another use: passing through them attachment straps 66, so that a portion of each strap extends beneath the molded channel-like depression in which the slot is cut, and exerts its force against the portion of the membrane locally stiffened by it. The ends of each strap are fastened over the blade so that it is held snugly against the membrane.

Each of the forms of support means shown provides support of the rotor blades by contoured, somewhat resilient support cavities, and in each, a portion of the shock loads applied to the container is absorbed by cushioned flexure of the support means, responsive to the deflection of the container sides. However, the support means shown in Figs. 3 and 4 is a purer embodiment of the theory of the present invention because the loads transmitted to the blade are reacted in a manner closer to the manner in which the blade reacts airloads.

The present invention is capable of a variety of uses.
It has especial value in packing fairly flexible, elongated objects whose surfaces are delicate and can withstand only distributed loads. Variations of embodiment and use will readily occur to those skilled in the art of packaging, the attachment flange should not be construed narrowly, but broadly co-extensive with the claims which follow.

Having described the present invention, there is claimed:

1. A readily fabricated shock-absorbing shipping container comprising elongated objects of a type characterized by flexibility in bending and torsion, comprising a shipping container top having sides, each side being integral, a shipping container bottom having sides, each side being integral, parallel skids integral with the longer sides of the container bottom, upper and lower attachment flanges integral, respectively, with the lower margin of the top sides and the upper margin of the bottom sides, means whereby the attachment flanges of said top and bottom sides are releasably secured to each other, said attachment flanges being of sufficient cross-sectional area to add stiffness locally to the container, and spaced flange notches provided through the major cross-sectional area at intervals along their length whereby to provide, despite such local stiffness, a degree of flexibility to the container as a whole under anticipated loadings in bending and torsion, commensurate to the extent to which the objects to be shipped therein may deflect without damage.

2. A readily manufactured resilient shipping container for rotor blades, comprising an assembly including a container top section and a container bottom section, the container top section being fabricated principally from two shorter and two longer lengths of an upper extrusion joined together as a rectangular frame, the upper extrusion having a vertical web, an outer attachment flange at its lower margin and a top flange at its upper margin, the container top section further having a top panel joined to and extending between the said top flanges, the container bottom section being fabricated principally from two shorter and two longer lengths of a lower extrusion joined as a rectangular frame, the lower extrusion having a vertical web, an attachment flange at its upper margin, a skid flange at its lower margin extending inwardly of the attachment flange at its upper margin, said skid flange being cut away from the two shorter lengths of lower extrusion, the shorter lengths serving as ends and the longer lengths as sides for said bottom section, the said attachment having a vertical web, an outward-extending attachment flange at its upper margin, a skid flange at its lower margin, said skid flange being cut away from the two shorter lengths of extrusion, the container bottom section further having a bottom panel joined to said attachments at their sides opposite their attachment flanges and at a level below said attachment flanges and above said skid flanges, means whereby the attachment flanges at the upper margins of said extrusions are releasably secured to the container top section, and four external lower corner brackets, each having a corner angle portion joining the web ends of said extrusions into rectangular corners, each bracket having a longitudinally extending skid portion including a sloping underface aligned with the skid flange of the side extrusion, the corner angle portion serving to transmit vertical loads from the skid end portion to the webs of the said extrusions joined thereto.

6. A readily manufactured shipping container adapted for skidding and hoisting, comprising a container top section and a container bottom section, the container bottom section being fabricated principally from two shorter lengths and two longer lengths of a lower extrusion, the shorter lengths serving as ends and the longer lengths as sides for said bottom section, the said attachment having a vertical web, an outward-extending attachment flange at its upper margin, a skid flange at its lower margin, said skid flange being cut away from the two shorter lengths of extrusion, the container bottom section further having a bottom panel joined to said attachments at their sides opposite their attachment flanges and at a level below said attachment flanges and above said skid flanges, means whereby the attachment flanges at the upper margins of said extrusions are releasably secured to the container top section, and four external lower corner brackets, each having a corner angle portion joining the web ends of said extrusions into rectangular corners, each bracket having a longitudinally extending skid portion including a sloping underface aligned with the skid flange of the side extrusion,
each bracket further having a hoist ring portion over the skid end, the corner angle portion serving to transmit vertical loads from the skid end and hoist ring portions to the webs of said extrusions.

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