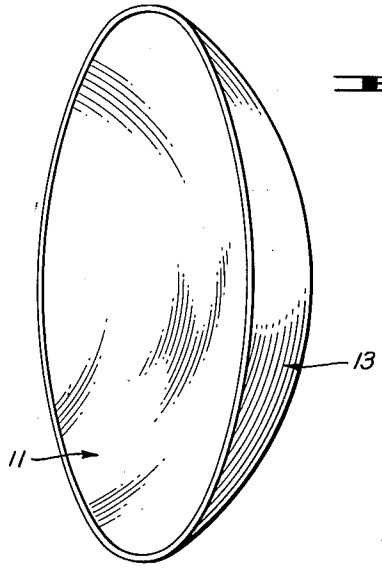
June 29, 1954 S. H. HAHN 2,682,491

SKIN FOR DOUBLY CURVED SANDWICH-TYPE PANELS

Filed Feb. 23, 1952

FIG. 1



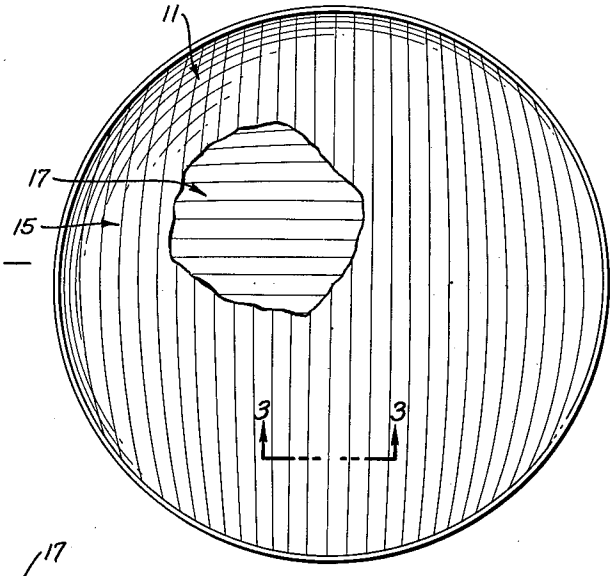


FIG. 2

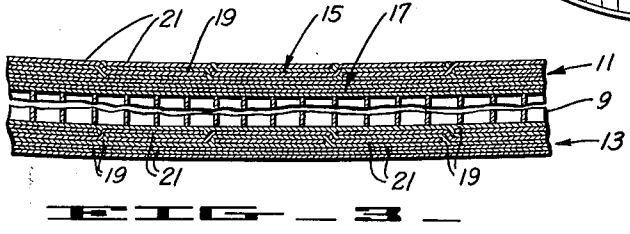


FIG. 3

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SKIN FOR DOUBLY CURVED SANDWICH-TYPE PANELS

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3 Claims. (Cl. 154—110)

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This invention relates to a doubly curved product and to a method of forming the same.

There is very little difficulty encountered in producing a so-called singly curved product, such as a segment of a cylinder, since a laminated article can be readily fabricated by providing a suitable core and facing the same with a sheet on either side thereof. It is obvious that a flat thin sheet readily conforms to a cylindrical shape. However, when producing a doubly-curved product, such as a segment of a sphere or a paraboloid etc., difficulties are immediately encountered in trying to provide the doubly curved facings or skins, since it is equally apparent that a flat sheet does not readily conform to a spherical or other doubly curved surface.

In an attempt to circumvent the problem of providing doubly curved skins, some doubly curved articles have been cast. These cast articles have been satisfactory where weight is not a problem and where a high stiffness to weight ratio is not required. However, certain doubly curved articles, such as doubly curved radar reflectors, must be both light in weight and have a high stiffness to weight ratio. In an attempt to lighten cast articles, they have been perforated but unfortunately this produces a relatively flexible product. Flexing of these reflectors during use obviously distorts the beam transmitted and the signals received by these reflectors.

In order to provide a light stiff doubly curved reflector, it has been the practice in the prior art to form a laminated or sandwich-type article having a cellular core and front and back sheet metal skins. However, unless the core material has a varying thickness from the center outwardly, it is necessary to use two sets of very expensive die equipment to accurately form the concave and convex skins, it being obvious that both skins cannot be formed by the same die equipment. If the core is made of variable thickness so that the front and rear skins can be formed by the same die equipment, the die equipment requirements are reduced but a high cost is encountered in forming such a variable thickness core.

It is therefore a main object of the present invention to provide a doubly curved sandwiched article, particularly one having a metallic surface for use as a radar reflector, which article, although being very light in weight, has a high stiffness to weight ratio.

Another main object of the present invention is to provide a method for forming an article having a doubly curved surface, which method is simple and does not necessitate the use of expensive and complex equipment.

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Another object of the present invention is to provide a simple and improved metal faced radar dish having accuracy of contour and a high stiffness to weight ratio.

Various other objects of the invention will be apparent from the following description taken in connection with the accompanying drawings wherein:

Fig. 1 is a three-dimensional view of a radar dish or reflector embodying the concepts of the present invention.

Fig. 2 is a front elevational view of the dish disclosed in Fig. 1.

Fig. 3 is an enlarged cross-sectional view of the dish taken on line 3—3 of Fig. 2.

Referring to the accompanying drawings wherein similar reference characters indicate similar parts throughout, the radar dish or reflector shown and representing one embodiment of my invention comprises a doubly curved cellular core 9 having a front facing or skin 11 secured to the concave side thereof and a rear facing or skin 13 secured to the convex side thereof. Since the facings are identical in construction, only the front facing 11 need be described in detail.

Front facing 11 comprises two layers 15 and 17 joined together by an adhesive material, such material throughout the construction being generally entitled 19. Each of the layers 15 and 17 comprises a plurality of narrow metallic foil strips 21 arranged and adhesively secured in overlapping or shingled relation to one another. Layer 17 is adhesively secured to the front concave surface of the cellular core 9 and layers 15 and 17 are adhesively secured to one another.

As is apparent from Fig. 2, the strips of one layer of facing 11 are arranged at an angle, preferably 90°, to the other layer of the facing to achieve a maximum amount of strength and stiffness. The strips 21 of rear facing 13 are similarly arranged and adhesively secured in place to the rear convex surface of cellular core 9.

It is pointed out that by making the strips 21 thin and relatively narrow, the amount of wrinkling of the strips is kept to a minimum. These strips can be built up on the core without any appreciable wrinkling if at least two of their dimensions are small in comparison to the curvature of the cellular core. The two dimensions selected are the thickness of the strip and its width. Although, of course, some wrinkling does

occur, the extent thereof is not sufficient to detrimentally effect the transmission of signals from or the reception of signals by the dish, since it is the general contour of the dish (apart from severe wrinkling) that determines to a large degree whether reception and transmission of radio frequency energy by the radar reflector will be distorted or not.

By using thin foil-like forms of light metals, such as aluminum, maximum advantage can be taken of the hardness and strength which are inherent in severely cold-worked metal, whereas a comparable single-ply sheet of metal would necessarily be much softer and weaker.

A novel and inexpensive manner of forming a doubly-curved article as above described comprises the steps of forming a male form having a doubly curved convex working surface conforming to the curvature desired of the concave side of the final product. Such a form can be inexpensively constructed of wood. After the provision of such a form, strips 21 of layer 15 are then laid on the form and overlapped in a shingle fashion, it being preferable that the overlap be approximately 50 per cent of the width of a strip so that each layer has in effect an even two-ply thickness, thereby distinctly lessening the irregularities on the faces of the dish which would otherwise be produced with a lesser or greater amount of overlapping at the overlapped joints of the strips of the two layers. Concurrent with the laying of the strips, a suitable adhesive material is applied to the strips so that the strips are secured to one another. A suitable adhesive for this purpose is a phenolic thermo-setting resin or an epichlorhydrin polymer, commercially given the name of "Epon VI." The latter adhesive has a low curing temperature and low shrinking characteristics upon polymerization. A primary advantage of such an adhesive is that all differential expansion difficulties inherent in the use of the usual adhesives, which have high curing temperatures, is avoided.

Strips 21 of layer 17 are next applied or built upon the wooden form on top of layer 15 and adhesively secured thereto and are adhesively secured to one another in shingled fashion and arranged at an angle, preferably 90°, to the strips of layer 15 to achieve maximum strength from the strip construction. Next, a cellular core of uniform or non-uniform thickness, which may be previously formed doubly curved by any simple process, is applied and adhesively secured to layer 17, the adhesive material assuring good conformity of the core to the layer. Such a core can be readily formed from a fiberglass honeycombed panel by a simple heating step or, if the cellular core is to be a metallic honeycombed panel, such can be made up of triangular segments bent to a doubly curved configuration.

Finally, the two layers of facing 13 are laid and adhesively secured to one another and to the core 9. The adhesive material is then allowed to dry or polymerize. However, it may be desired to insure an accurate conformity of the built-up structure to the form and this can be readily accomplished and insured by enclosing the built-up structure and the form in a bag and then evacuating the air from the bag to apply atmospheric pressure to the laminated or sandwiched product and force it against the curvature of the form.

It is preferable that a separant such as a soap, grease or a commercial mold lubricant be applied to the form prior to building up the layers thereon to enable easy removal of the completed product.

In the above-described process and in the previously described product, only two cross layers per facing were described, but it is obvious that as many layers as desired can be added. In fact, it is contemplated that a multiplicity of plied-up layers of strips will be utilized in forming the usual product.

By way of example and not by way of limitation, foil used in the above process for producing a dish 6 feet in diameter had a thickness of from .0005 inch to .005 inch and a width approximately 4 inches, the overall thickness of the resulting article being from ½ inch to 3 inches thick. Ordinarily, at least two layers per facing will be used so that one layer can cross the other layer. However, in special circumstances, it is contemplated that only one layer might be used although it is obvious that a two-layer facing will have considerably more strength than a single layer even taken in proportion to the thickness of the two facings.

Although the building up process has been described with reference to the use of strips, it is contemplated that such a construction could be built up by the use of individual shingles or fish-scale-like pieces, although it is believed that the strip formation is less expensive and more readily carried out than a fishscale-type construction.

It is additionally pointed out that metallic bonding of the individual foil strips to one another is found unnecessary in the case of radar reflectors because of the inherent high capacitative coupling of the closely adjacent foil pieces which are separated by a few thousandths of an inch or less by the adhesive bonding material which is normally a dielectric. However, conducting or semi-conducting adhesives may be used as well.

By the present invention a doubly curved sandwich-type article has been provided having an extremely high stiffness to weight ratio and which can be easily fabricated with a minimum use of equipment and time, yet which article can be produced having an accurate contour suitable for use as a radar reflector. Obviously, the invention has wide application in the construction of a wide range of doubly curved articles, both metal faced and otherwise, and that the reference to a radar reflector merely illustrates a practical application of the concepts of the present invention.

While I have shown the preferred form of my invention, it is to be understood that various changes may be made in its construction by those skilled in the art without departing from the spirit of the invention as defined in the appended claims.

Having thus described my invention, what I claim and desire to secure by Letters Patent is:

1. A doubly curved article having a doubly curved honeycomb core with a facing on each of its opposite sides, each facing having a first and second layer, each layer including a plurality of thin strips arranged and secured in shingled fashion to one another with a constant width of exposed surface throughout the length of each strip, the innermost layers of the facings being secured to the honeycomb core, the strips of each layer running at an angle to the strips of the immediately adjacent layer.

2. A doubly curved radar reflector comprising a central honeycombed core, and interior and exterior metallic skins covering said core, each of

said skins having a first layer of thin foil strips adhesively secured to said core, said strips being adhesively secured to one another in overlapping shingled relation with a constant width of exposed surface throughout the length of each strip, a second layer of thin foil strips adhesively secured to each first layer and arranged at an angle to the strips of the first layer, the strips of each second layer being adhesively secured to one another in overlapping shingled relation with a constant width of exposed surface throughout the length of each strip.

3. The method of making a doubly curved article comprising providing a male form having a doubly curved convex working surface; laying a layer of strips of constant width across the convex surface, arranging and securing the strips to one another in overlapping shingled fashion with a constant degree of overlap; laying a second layer of strips of constant width across the first layer of strips, adhesively securing the strips of the second layer to the first layer at an angle to the strips of the first layer, arranging the strips of the second layer and securing them to one another in overlapping shingled fashion with a constant degree of overlap, laying a honeycombed cellular core onto the second layer and securing

the core to said second layer, laying a third layer of strips of constant width onto the cellular core with the strips being arranged and secured to one another in overlapping shingled relation with a constant degree of overlap, and laying a fourth layer of strips of constant width across the third layer of strips with the strips of the fourth layer being adhesively secured to the third layer at an angle to the strips of the third layer, arranging the strips of the fourth layer in parallel relation and securing them to one another in overlapping shingled fashion with a constant degree of overlap.

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