March 31, 1970 T. G. BERRY ET AL 3,503,164

TUBULAR EXTENDABLE STRUCTURE

Filed Jan. 3, 1968 2 Sheets-Sheet 1

FIG. 2

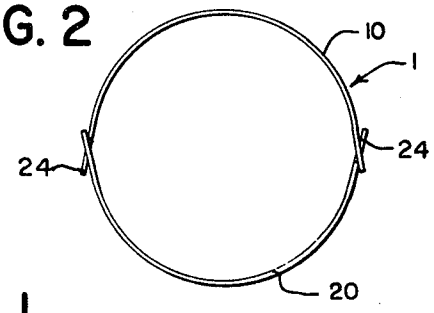

FIG. 1

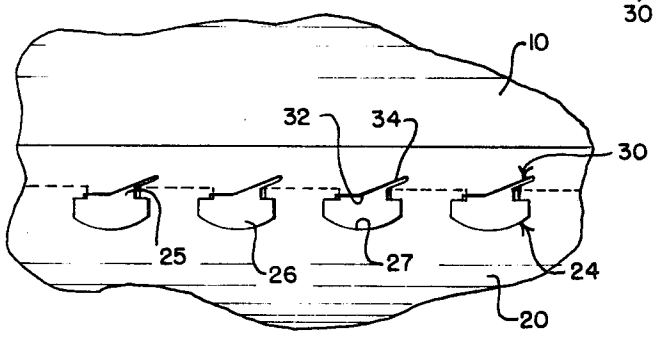

FIG. 3

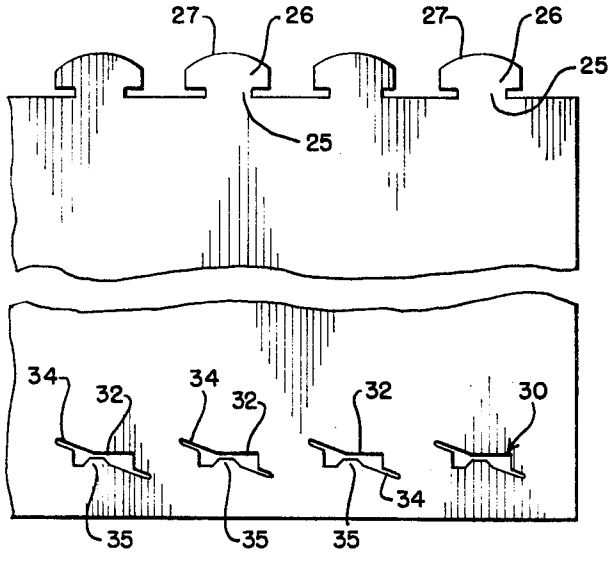

FIG. 4

INVENTORS
THOMAS GORDON BERRY
EINAR MEDAL
DONALD REICHLE

BY Darby & Darby

ATTORNEYS

March 31, 1970 T. G. BERRY ET AL 3,503,164

TUBULAR EXTENDABLE STRUCTURE

Filed Jan. 3, 1968 2 Sheets-Sheet 2

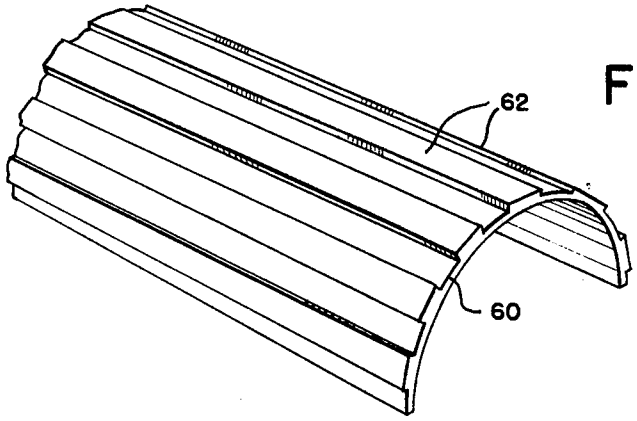

FIG. 5

INVENTORS
THOMAS GORDON BERRY
EINAR MEDAL
DONALD REICHLE

BY Darby & Darby
ATTORNEYS

United States Patent Office 3,503,164
Patented Mar. 31, 1970

3,503,164

TUBULAR EXTENDABLE STRUCTURE

Thomas G. Berry, Silver Spring, Einar Medal, Rockville, and Donald Reichle, Kensington, Md., assignors to Fairchild Hiller Corporation, Hagerstown, Md., a corporation of Maryland

Filed Jan. 3, 1968, Ser. No. 695,403
Int. Cl. E04h 12/18
U.S. Cl. 52—108 4 Claims

ABSTRACT OF THE DISCLOSURE

A tubular extendable element formed by a pair of sheets of material which are interlocked by hinges and rolled up. When unwound, the sheets form a tubular structure which is self-supporting. The element may also use sheets formed with longitudinally extending ribs which increase the allowable bending and column loads of the element.

Tubular extendable elements, that is, elements which are formed by a sheet of material wound on a drum and which assume a tubular shape when unrolled, are well known in the art. Several types of such elements are, for example, disclosed in U.S. Patents 2,905,282; 3,168,263 and 3,213,573.

Many problems still exist in the design of such extendable elements. One problem is the long ploy lengths, that is, the length of material off the drum before the tube is formed, associated with large diameter tubes. These long ploy lengths give rise to torsional instability of the structure due to the open section of the partially formed tube adjacent the drum prior to the complete formation of the tube. An additional problem encountered is the relatively large amount of power required to unwind the sheet of material from the drum and to retract it. Of course it is also desirable, if possible, to improve the strength-to-weight ratio of the elements, to simplify their fabrication, and to increase the allowable bending and column loads that they can handle.

The present invention relates to a tubular extendable element which alleviates the foregoing problems to a great extent and in addition offers a more reliable mechanism to deploy and retract and requiring less power than prior art extendable elements. In addition the extendable element of the present invention is capable of having a large strength-to-weight ratio while also eliminating many of the fabrication problems which are associated with tubular antenna elements in which welded tubes are utilized or elements in which two or more sheets of material forming the tube are locked together as the element is being deployed.

In the present invention, an extendable tubular element is provided which is formed by two or more sheets of a suitable material, such as plastic or metal which are preformed to a curved shape brought to an opposing relationship and fastened mechanically at or near their edges by interlocking hinges. After both sheets are joined, the tube formed thereby is flattened and is rolled on a drum. The two joined sheets may thereafter be readily unrolled from the drum to form a tube having good structural stability and a high strength-to-weight ratio. The present invention can also utilize a novel type of sheet, having a plurality of longitudinal ribs which greatly increase the allowable bending and column loads of the member. This novel sheet can be used with the hinge lock structure of the present invention or in extendable elements using only one sheet.

It is therefore an object of the present invention to provide a tubular extendable structure formed by two

sheets of material which are pre-fastened before being rolled on a drum.

A further object is to provide a tubular extendable element in which two opposing sheets of material are joined together by interlocking hinges.

Yet another object of the invention is to provide a tubular extendable element formed by a plurality of sheets of material which are joined together by interlocking hinges, flattened and then wound on a drum.

Other objects and advantages of the present invention will become more apparent upon reference to the following specification and annexed drawings, in which:

FIG. 1 is a perspective view of the tubular extendable element showing a portion wound on a drum and a portion deployed therefrom;

FIG. 2 is an end view of the element of FIG. 1;

FIG. 3 shows a plan view of a portion of a preferred embodiment of hinge;

FIG. 4 shows a plan view of the sheets, flattened showing details of the hinge construction; and

FIG. 5 is a perspective view of another type of sheet.

Referring to FIGS. 1 and 2, the tubular extendable element **1** of the present invention comprises a pair of elongated sheets of material **10** and **20** both of which are pre-stressed in a predetermined manner so that they curl around their respective longitudinal axes when unrestrained. The sheets **10** and **20** can also be flattened for rolling onto a drum and when in this condition they store the energy produced by the pre-stressing. That is, when the sheets are released from the drum, the stored energy therein causes them to assume the curl around their longitudinal axes. Suitable materials for the sheets **10** and **20** are, for example, plastics, beryllium-copper which has been heat-treated to obtain a predetermined pre-stressing characteristic, etc. Many of the materials are described in the aforementioned patents and the particular materials used in themselves form no part of the present invention. The same or different material can be used for the two sheets, as desired. Since two sheets of material are used to form the tubular element, the pre-stressing of each sheet can be less than if a single sheet is used since each sheet does not have to close back upon itself.

While the material for the sheets **10** and **20** is shown as being solid, it should be understood that if a completely closed surface is not necessary the material also can be perforated to reduce the overall weight of the element. Also as described below, one or more of the sheets can have longitudinal stiffening ribs for increased strength.

As shown in FIGS. 1 and 2, the two elongated sheets **10** and **20** oppose each other and are joined together near their edges by a series of interlocking hinges **22** running along each side of the element. Many different types of hinges may be utilized, one such preferred hinge being shown in greater detail in FIGS. 3 and 4.

As shown in FIGS. 3 and 4, each sheet **10** and **20** is formed with a series of spaced T-shaped tabs or tangs **24** extending from one edge thereof. Each of the tabs **24** has a narrow neck portion **25** extending from the edge of the sheet which terminates in a wider head portion **26** with a curved outer edge **27**.

The other side of each sheet **10** and **20** is formed near its edge with a series of slots **30** spaced to receive a corresponding series of tabs **24**. Each slot **30** has a central portion **32** which is generally parallel to the edge of the sheet and has a length which is smaller than the length of the head **26** of the tab members **24**. A cross slot **34** is also formed at an angle with respect to the central slot **32**. The cross slot **34** has a length which is greater than the head **26** of a tab member **24** to permit insertion of a tab member into a corresponding slot **30**. A small tang

35 extends into the central slot 32 to reduce its width, and thereby reduce play and provide a firmer lock when the two members of the hinge are joined.

It should be understood that each of the sheets 10 and 20 has the same hinge arrangement shown in FIG. 4. To assemble the two sheets together, they are brought into opposing relationship with the tabs of one sheet aligned with the slots of the other. The tabs 24 of one sheet are then inserted into the slots 30 of the other sheet. This is done by slightly turning the tabs (male) 24 with respect to the slots (female) 30 and inserting them into the longer portion 34 of the slots. The sheets are then turned slightly relative to each other so that the neck 25 of each of the tabs moves into the shorter and wider slot portion 32. Thus the two sheets 10 and 20 are aligned parallel to each other with the tabs locked into the slots 30 and the heads 25 preventing their withdrawal. The mechanical joint formed by the hinges 22 is roughly equivalent to a mechanical intereference type hinge.

While a preferred type of hinge 22 has been shown, it should be understood that numerous other types can be used. For example, rather than having both male and female members on one of the sheets, one sheet can have two male members and the other two female members. Of course, the preferred embodiment simplifies fabrication since both sheets may be similarly formed to produce the hinges. Also, many other different types of hinge shapes can be used. For example, instead of making the tabs with rounded heads, the tabs can be square, triangular or any other suitable shape. The slots would be of a shape suitable to receive the tabs. The main requirement of any hinge arrangement used is that it permits the two sheets to go from a flattened condition to a tubular condition when the element is deployed and from a tubular to a flattened condition when the element is retracted.

The preferred embodiment of hinge 22 described has an advantage in that when the two sheets are flattened, the tabs 24 lie substantially flat on the sheets. This facilitates deployment and retraction of the element since there is no interference between the tabs as the joined sheets lie on the drum.

After the two sheets 10 and 20 are joined by the hinges 22, they are flattened and then rolled on a drum, as shown in FIG. 1. The drum 40 is of any conventional construction and has a central shaft 32. The longitudinal axes of the two sheets 10 and 20 lie transverse to the drum axis and the sheets are restrained by the drum in the flattened condition.

The tubular element formed by the two sheets is unwound from the drum by any suitable mechanism such as for example that of the copending application of Thomas G. Berry and Thomas F. Kline Ser. No. 572,743 which is assigned to the same assignee. Conventional brake and clutch arrangements also can be used such as shown, for example, in the aforesaid Patent 3,168,263. Upon being unwound from the drum, the sheets expand from their flattened condition to the tubular condition as shown in FIG. 1 due to the energy stored in the sheets.

The tubular extendable element 1 of the present invention has several advantages. First of all, it provides a stable rigid structure when fully deployed since the two sheets 10 and 20 locked together give a greater amount of structural rigidity than obtainable with only a single sheet as in many of the prior art extendable elements. Further, by using two sheets, it makes it easier and requires less power to deploy the element. This is so because force is available from two sheets, as they go from a flattened to a tubular shape, rather than just a single sheet. Further, the two sheets curl in opposite directions as they come off the drum and the sheet 10 which faces the drum expands outwardly and tends to push the element off of the drum.

The tubular element 1 will also ploy into a complete tube in a shorter distance after extension from the drum than a comparable tubular element which is formed by only a single sheet. For example, a two inch diameter tube made in accordance with the present invention will ploy fully when only nine inches off the drum as compared to the distance of fifteen inches required to fully ploy a two inch diameter tube formed by a single sheet. This gives the element of the present invention greater torsional strength since it remains in a partially formed shape adjacent the drum for a shorter distance.

Another advantage obtained with the subject invention is that the need for tube forming members adjacent the drum is eliminated. In single sheet elements it is conventional for a rigid tubular member to be located adjacent the drum and the sheet is formed into a tube around this member. This is not necessary in the present invention since the use of two sheets makes the tube self-forming.

As an alternative way of making the tubular element, two unstressed sheets of material can be locked together and then processed, such as by heating, to achieve the prestressing of the material needed to produce the curl. The heating can take place before or after the sheets are wound in a roll.

While the element 1 is shown as having a circular cross-section, it will be understood that other shapes can be used, for example, elliptical.

FIG. 5 shows another type of sheet 60 which can be used with the two sheet tubular element of the present invention or with a single sheet tubular element. As shown, the sheet 60 is provided with a plurality of longitudinally extending ribs 62 running the length of the sheet. The sheet 60 is of any conventional material which can produce the needed curl around its longitudinal axis and the ribs 62 can be placed thereon by any suitable process such as extrusion during original manufacture of the sheet or bonding or welding the ribs separately. The ribs may also be etched onto the sheets by removing material from a thicker sheet. As shown, the sheet 60 has a space without a rib at each edge thereof to permit the use of a hinge at each edge or to permit a single sheet tubular element to close back on itself.

The use of the longitudinally extending ribs 62 strengthens the sheet by increasing its sectional moment of inertia. This permits an increase in the allowable bending and column loads of the tubular element. It should be understood that the sheet 60 can be used in the more conventional type tubular extendable elements of the prior art using only a single sheet of material or in the two sheet hinge lock arrangement of the present invention. For the latter it is only necessary to provide suitable hinge members, as discussed above. In both cases the sheets are processed to obtain the needed degree of curl.

For a tubular extendable element of either the one sheet or two sheet type, the use of the ribbed sheet or sheets 60 greatly improves the structural capability of the extended tubular element without appreciably increasing the minimum diameter of the formed tube. The diameter of the drum or reel will increase however due to the added thickness occasioned by the ribs. An additional advantage of the ribbed sheet 60 is that the ribs provide an arrangement for tracking as the element is deployed since members can be provided to engage the ribs to keep the sheet or sheets aligned with respect to the drum.

While a preferred embodiment of the invention has been described above it will be understood that this embodiment is illustrative only.

What is claimed is:

1. A collapsible tubular, extendable element comprising a pair of elongated sheets of material located in an opposing relationship, each sheet of material pre-formed to curl around its respective longitudinal axis when unrestrained from a flattened condition, each sheet of material also capable of being rolled into a coil about an axis generally transverse to its longitudinal axis in a substantially flattened condition, and hinge means formed adjacent opposing edges of said two sheets of material

and as a part of said material, said hinge means comprising a tab formed on one sheet and a slot for receiving the tab on the other sheet, said tab being generally T-shaped and said slot having a first portion at an angle with respect to the longitudinal axes of the sheets for permitting the head of a corresponding tab to pass therethrough and a second portion generally parallel to the longitudinal axes of the sheet to lock the tab, said hinge means permitting one sheet to pivot with respect to the other about the hinge means so that the material lying outwardly of said hinge means on a sheet can also curl with respect to its longitudinal axis.

2. The extendable element of claim 1 wherein a sheet of material has a plurality of longitudinally extending ribs formed thereon.

3. The extendable element of claim 1 wherein there is a said hinge means formed adjacent each opposing pair of edges of said two sheets of material.

4. The extendable element of claim 3 wherein said two sheets when unrestrained curl to form a substantially cylindrical structure.

References Cited

UNITED STATES PATENTS

298,321	5/1884	Sack	138—128
937,876	10/1909	Sicklesteel	138—162
1,940,657	12/1933	Woodford	138—172
2,750,232	6/1956	Stanley	138—172
3,032,151	5/1962	Allen	52—108
3,208,478	9/1965	Baines	138—162
3,295,556	1/1967	Gertsma	138—128
3,298,142	1/1967	Isaac	52—108
1,947,392	2/1934	Guntermann et al.	52—108
3,134,468	5/1964	Toti et al.	52—731

HENRY C. SUTHERLAND, Primary Examiner

U.S. Cl. X.R.

52—731