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2,832,676

METHOD OF MAKING THIN-WALLED REENTRANT STRUCTURE

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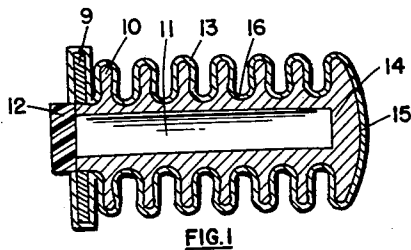


FIG. 1

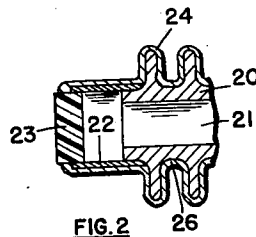


FIG. 2

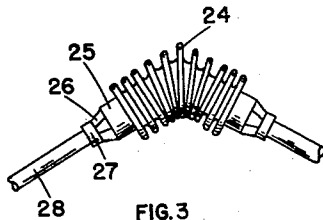


FIG. 3

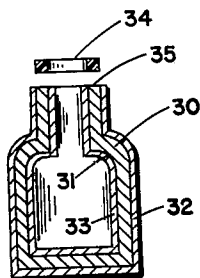


FIG. 4

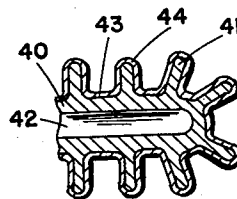


FIG. 5

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1

2,832,676

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8 Claims. (Cl. 41—41)

This invention is directed to a method of making a thin-walled structure having reentrant portions on the surface thereof. More particularly, this invention is directed to a method of forming an extremely flexible bellows.

Heretofore, various thin-walled structures have been made by an electroforming operation wherein a removable, shaped mandrel is placed in the electroplating bath and a metal from the bath is electrodeposited on the surface thereof. While such process is satisfactory for flat and rounded mandrel surface shapes, much difficulty has been experienced in forming certain shapes which include reentrant portions on the surface thereof. It has been found that the electrodeposited metal is build up at the edges of the reentrant portions and does not evenly plate to constant thickness within the reentrant portion itself. It has been found that extremely accurate parts with constant thickness in the reentrant portions as well as the other portions thereof can be made by subjecting the mandrel to a chemical deposition nickel plating process followed by an etching operation to remove the metal core material. It has been found that an extremely sensitive and accurate bellows having relatively deep convolutions therein can be made by the present process.

An object of this invention is to provide a process of making thin-walled structure having reentrant portions on the surface thereof.

A further object of this invention is to provide a method of making an extremely flexible bellows.

A still further object of this invention is to provide a process of making thin structures of complex shapes.

An additional object of this invention is to provide a process of making a sensitive bellows with reinforced end sections.

Another object of this invention is to provide various thin-walled structures made using an electroless nickel or electroless cobalt plating process.

Other objects of invention will become apparent from the following description taken in connection with the accompanying drawings, in which:

Fig. 1 is a sealed bellows after chemical deposition;

Fig. 2 shows a bellows portion with reinforcement after the chemical deposition;

Fig. 3 shows the completed bellows of Fig. 2;

Fig. 4 shows a double-walled container made by the process of this invention; and

Fig. 5 shows a heat exchanger element made by the present invention.

The method of this invention to make a thin-walled structure, having reentrant portions on the surface thereof, comprises first forming a metal core portion having an exterior configuration corresponding to a reentrant shape. A thin layer of an etch-proof dissimilar metal is then chemically deposited on the exterior of the core portion. This metal may be chosen from one of the group consisting of nickel and cobalt according to the particular use to which the thin-walled structure is to be put. After the chemical deposition, the core material is selectively etched away whereby the chemically deposited layer

2

forms the thin-walled structure. The details of the above process will be apparent from the following description of various thin-walled structures made by the process.

Fig. 1 shows a sealed bellows after the chemical deposition stage of the process. A metal core portion is formed by a machining, casting or other metal forming process to the desired configuration. Bore 11 is then drilled or otherwise formed centrally of the core to a depth sufficient to leave a web portion 14 at the bottom thereof. A masking 12, or other type of plug means, seals the bore 11 from the action of the chemical deposition bath. An apertured plate 9 may be fitted over the core end and itself subsequently plated as shown. Core 10 is placed within and exposed to electroless nickel or electroless cobalt deposition in a plating bath containing a nickel salt or cobalt salt and sodium hypophosphite. Prior to the deposition process, the core material may be degreased and cleaned with acid or alkali cleaners. Various materials may be employed for the core portion. While aluminum is preferred, due to the subsequent ease of removal by the action of a suitable caustic, steel, copper, or other etchable metals may be used when desired.

The nickel and cobalt plating baths used in this invention are patterned after those disclosed in U. S. Patent Nos. 2,532,283 and 2,532,284, by Brenner and Riddell. After a layer 13 of chemically deposited nickel or cobalt is placed on the exterior surface of the core 10 including an even plate in the reentrant portions 16, the plugs or masking portions 12 are removed and the entire structure is exposed to the action of an etching agent. In the case of aluminum, a 10% sodium hydroxide solution at a temperature of 180° to 212° F. is satisfactory. Acid etching, typically hydrochloric acid, is used if the core material is steel. It is, of course, obvious that bore 11 may be omitted from the core portion since it serves only to cut down the etching time. Thus, the core portion 10 may be solid and the ends thereof plated in the deposition process. These ends must then be cut off to allow the etching medium to attack the core material itself.

A portion of an extremely flexible bellows is shown in Fig. 2 in which a core portion 20 is formed with reentrant convolutions 26 on the exterior surface thereof, and a bore 21 completely through the core portion. A reinforcing end ring 22 is press-fitted or otherwise attached to the end portions of the core 20. Preferably, ring 22 has a knife edge which firmly presses into the softer aluminum core. A suitable end plug 23 is placed in the ring portion 22 to prevent subsequent plating interiorly of the core portion. The structure is then subjected to chemical deposition as above to form a thin layer of nickel or cobalt on the exterior surfaces thereof. After the plug 23 has been removed the more material is etched away leaving a bellows made up of a thin layer 24 and a reinforced end portion 22 attached thereto. It is to be understood that the material, normally steel, brass or copper, of the end ring 22 is resistant to the etching process. The end rings 22 serve as a means for attaching the bellows to adjacent structure. Difficulty in some instances is experienced in mechanically connecting the nickel or cobalt thin shell to adjacent surfaces by conventional means, when the above described end rings are not employed.

Fig. 3 shows a connected bellows structure using the bellows formed in the above process. A connecting fixture having a ring portion 25 which may seat internally or externally of the reinforced ends 22 of the bellows 24 is welded, brazed, soldered or otherwise joined to such portion. Tapered portions 26 on said connecting fixture lead to a portion 27 into or onto which an inlet tube 28 is attached by any of the above means. The extreme sensitivity and flexibility of the finished bellows can be seen in Fig. 3. The actual sensitivity is a function of the thickness of the chemically deposited layer, the diameter

of the core portion and the number and size of the convolutions.

Fig. 4 shows an additional use of the process in making thin-walled structure having reentrant portions. A portion 30 is first formed in the indicated configuration with reentrant portions as at 31. The entire inner and outer surfaces of the core 30, except for the top edge 35, is plated with nickel or cobalt by the chemical deposition process followed by removal of the core portion 30 by etching. A double wall structure is thus obtained. Disc means 34 may be used to mask the portions 35 during the chemical deposition process and then inserted between the neck portions to keep the inner and outer thin walls in spaced relationship.

Fig. 5 shows a single heat exchanger element which may be made by the present process. A core 40 is provided with a series of cylindrical embossments 41 around the periphery thereof with reentrant portions 43 therebetween. A layer of nickel or cobalt is chemically deposited on the exterior of the core portions and evenly into the reentrant portions 43. Following this, the interior 42 of the core portion 40 is exposed to etching action which etches out the embossment portions 41, leaving a thin-walled heat exchanger element. These elements may have reinforcing portions on the ends thereof similar to those disclosed in Fig. 2 and are normally attached as thin elements on a heat exchanger.

The following examples are given of the chemical deposition step of the present invention:

(1) The marked core portion 20 of Fig. 2 was placed in an electroless nickel bath containing 10 grams per litre of sodium hypophosphite, 40 grams per litre of sodium citrate, and 50 grams per litre of $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$ for a time sufficient to give the desired thickness of plate. The plating bath was kept at a temperature of from 190° to 215° at a pH of from 4 to 5. A 0.001 inch thick bellows was formed in two hours. A 0.0035 inch thick bellows layer was formed after 12 hours in the above bath.

(2) A cobalt plate was placed on the core portion of Fig. 2 by exposing a masked core portion to an electroless cobalt deposition in a plating bath containing 20 grams per litre of sodium hypophosphite, 100 grams per litre of ammonium hydroxide, 100 grams per litre of sodium citrate, and 30 grams per litre of cobalt sulphate. Operating conditions in this example, included a temperature of 190° to 215° F. and a pH of from 9 to 11. A layer 0.001 was formed after the core material had been in the chemical deposition bath for about two hours.

(3) A nickel-cobalt alloy plate was formed on a core portion similar to that shown in Fig. 2 by adding nickel sulphate to the cobalt bath described under Example 2 and varying the ratio of citrate and hydroxide to give optimum plating characteristics.

(4) A sealed bellows, corresponding to that illustrated in Fig. 1, was formed by placing the core portion 10 in a solution containing 40 grams per litre of nickel sulphate, 35 grams per litre of sodium citrate, and 12 grams per litre of sodium hypophosphite at a temperature of from 205° to 210° F. and a pH of from 3.5 to 4.2. A bellows wall thickness of 0.002 inch was obtained after 6 hours in this bath.

Each of the above examples used an aluminum core portion which was subsequently etched away in a 10 to 20% sodium hydroxide solution at a temperature of 190° to 200° F. for a period of from 1 to 2 hours. The etch-

ing out of the configurations seen in Fig. 4 and Fig. 5 will normally extend over a greater time range.

Although the invention has been described and illustrated in detail, it is to be clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of this invention being limited only by the terms of the appended claims.

We claim:

1. The method of making a thin-walled structure having reentrant portions on the surface thereof comprising first forming a metal core portion having an exterior configuration including desired reentrant portions, chemically plating a thin layer of a dissimilar metal chosen from the group consisting of nickel and cobalt on the exterior of said core portion and into said reentrant portions, and selectively etching away the core portion whereby said layer forms said thin-walled structure.
2. The invention as set out in claim 1 in which said core portion is aluminum.
3. The invention as set out in claim 1 in which said core portion is steel.
4. The method of making a thin-walled structure having reentrant portions on the surface thereof comprising first forming a metal core portion having an exterior configuration including desired reentrant portions, exposing the exterior of said core portion to an electroless metal deposition in a plating bath containing a salt of a metal selected from the group consisting of nickel and cobalt, and an alkali metal hypophosphite, chemically plating a thin layer of a metal selected from said group on said exterior surface and into said reentrant portions removing the resultant core portion from said bath, and selectively etching the core portion away whereby said layer forms said thin-walled structure.
5. A method of making a bellows comprising first forming a metal core portion having exterior convolutions corresponding to a desired bellows shape, chemically plating a dissimilar metal on the exterior of said core portion to a desired bellows wall thickness, and selectively etching the core portion away whereby said dissimilar metal forms the bellows.
6. A method of making a bellows comprising forming a metal core portion of an etchable metal into exterior convolutions and an interior passageway, placing an etch-proof high strength tube over at least one end of said core, plugging the interior passageway of said core, chemically plating a dissimilar metal on the exterior of said core and said tube, and etching the core portion away whereby said plating forms a flexible bellows having a high strength end.
7. The invention as set out in claim 6 in which said dissimilar metal is nickel.
8. The invention as set out in claim 6 in which said dissimilar metal is cobalt.

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