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PROCESS FOR THE PRODUCTION OF SEAMLESS HOLLOW STRUCTURES

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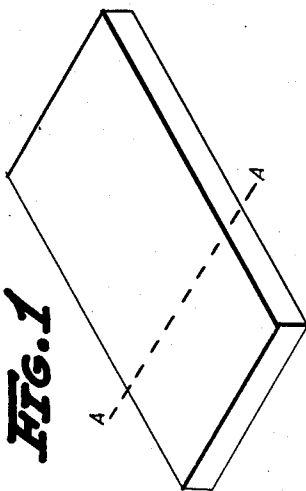


FIG. 2

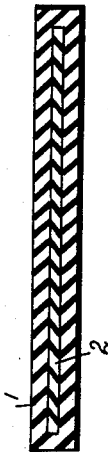


FIG. 3

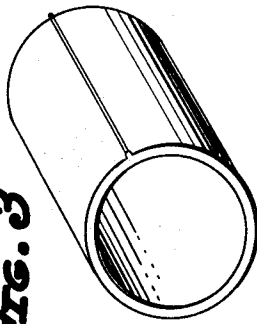


FIG. 4

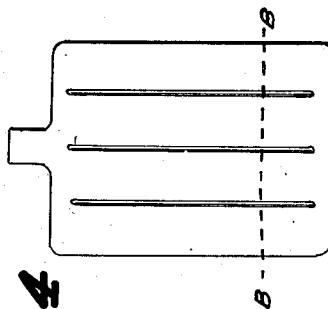
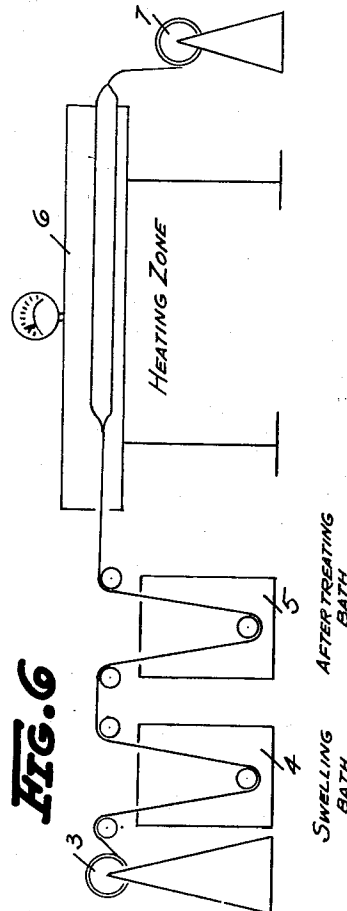


FIG. 5



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FIG. 6



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PROCESS FOR THE PRODUCTION OF
SEAMLESS HOLLOW STRUCTURES

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17 Claims. (Cl. 18—48)

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The invention relates to the manufacture of seamless hollow articles from foils, sheets, films and the like of various compositions such as cellulose, cellulose derivatives, rubber and rubber-like substances, plastics, e. g. thermoplastic synthetic resins, proteins and protein-like substances.

The invention is based on the principle to treat blanks of the recited materials with liquids which are capable of diffusing at room or slightly elevated temperatures into the blank with simultaneous swelling of the same, and to control said treatment so as to leave a stable thin core layer which is completely surrounded by the swollen mass of the blank and holds the structure together. This structure is then subjected to a preferably abrupt heat treatment in a temperature range which causes a rapid complete or partial evaporation of the swelling agent present in the surface layer and consequently a solidification of said surface layer. Simultaneously herewith the thin core layer is swollen or even dissolved by the combined action of the swelling agent which has penetrated into said layer, and the heat treatment, whereby the vapor generated inside the structure, which vapor cannot escape through the solidified surface layer, causes splitting up of the structure in the core layer and inflation with formation of a seamless hollow structure.

As swelling agents I prefer to use low boiling liquids which are capable of diffusing quickly at room or slightly elevated temperature into the material of the blank and of causing thereby a uniform, preferably strong swelling with the exclusion of objectionable side effects, e. g. without strong dissolving action. In general I have found it advisable to use solvents or solvent mixtures which are capable of exerting in addition to the swelling action a slight dissolving action at room temperature and of swelling and dissolving the previously not affected core layer of the blank when the temperature is raised.

In carrying out the invention uniform liquids may be used which possess the desired properties with respect to the material of the blank. Such liquids are for instance methylene chloride or methanol for cellulose triacetate. In general, however, I prefer to use mixtures of solvents which consist of two, three or more components and form a combination most suitable to attain the desired effect. Such mixtures may be composed, for instance, of solvents for the respective material of the blank, and non-solvents; they may consist either entirely of low boiling or relatively low boiling components, for instance so as

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to have a boiling point between about 35 to 100° C., or of low and higher boiling components, for instance so as to have a boiling point between about 100 to 200° C. A critical feature of the invention is that the swelling agents contain a proportion of low boiling components sufficient to ensure that in the heat treatment of the swollen blanks, in which thin stable core layers are still present, a quick evaporation from the surface layers takes place so as to bring about a quick strengthening and compacting of said surface layer, thereby preventing an undesired escape of vapors from the interior of the swollen blanks. When mixtures of solvents and non-solvents are used it has been found of advantage to provide for the presence of low boiling solvents.

The swelling agents may contain additional components capable of obtaining specific effects, such as softeners.

According to the invention films, foils or sheets are cut to blanks of a shape corresponding to the desired hollow article, for instance, strips or bands will be used for the production of cylindrical hollow structures. The swelling is obtained by suitable operations such as hanging the blanks in a bath containing the swelling agent or, in the case of strips, of passing said strips or bands through the bath. The contact time is so controlled that the desired swelling takes place but that a stable core layer of the blank remains unaffected; for a blank of about .1 mm. thickness, the thickness of said unaffected core layer may amount to .01 to .02 mm., which core layer serves to support the structure. The necessary time of contact for blanks of particular materials and particular swelling agents is readily ascertained by tests.

The swollen structure obtained as set forth hereinbefore is then subjected, preferably abruptly, to a temperature which is substantially above the boiling point of the swelling agent or at least of the more volatile components of the swelling agent. In this manner, the swelling agent or the volatile components thereof in the surface layer of the blank are vaporized so quickly as to cause solidification of said surface layer, which is thereby stabilized, retains its form and prevents the escape of vapors from the inside of the swollen structure. The heating of the structures, which progresses from the outside towards the inside, will cause a further effective swelling and convert the core layer, not swollen during the pretreatment, by swelling and/or solution into a state which allows a ready splitting of the structure by the vapor generated by the

heat treatment. During the heat treatment, therefore, an inversion of the conditions takes place insofar as at the beginning the blanks have an inner stabilizing core, which disappears during heating, whereas the outer surfaces of the structures are strengthened. The strengthening of the outer faces is, of course, not limited to the upper and lower face of the structures but extends also to the small lateral faces (cut edges), which is of utmost importance for the aim of the invention, i. e. the production of seamless hollow articles. When the pretreated swollen blanks are passed into the heating zone and the swelling agent is rapidly driven out of the surface layer, a superficial and transitory dissolution of the edges joining the main surfaces and the cuts takes place, which results in rounding off said edges.

The heating of the pretreated blanks may be carried out by introducing, e. g. by hanging the same in a heating zone (oven) maintained at a suitable temperature, or by passing e. g. strip-shaped blanks through the heating zone. The heat treatment may, however, also be carried out by passing the blank in or through a heating liquid such as paraffin oil. In this way specific effects may be obtained, for instance by incorporating in the heating bath softeners, such as phthalic esters, vulcanization accelerators, or the like.

The heat may preferably be produced by means of heat generating radiation, e. g. infrared or high frequency radiation. In this way, the heating of the core layer is accelerated while the outer layers enclosing the core layer are not adversely affected.

By the action of the vapor of the swelling liquid generated during the heat treatment of the blanks splitting up in the core layer of the blanks is obtained with separation of the walls by distention. The seamless structures thus obtained may be subjected to an after-treatment, for instance for driving out swelling agents still embedded in the walls. This after-treatment may be carried out, for instance in the case of cylindrical structures, by passing gases, gas mixtures or liquids at suitable temperatures in or through said structures. This treatment may be combined with the application of agents modifying or improving the properties of the structures, e. g. by introducing softeners, vulcanizing agents, vulcanization accelerators, and the like.

Generally, the structures are split up in the center so as to produce seamless hollow structures of uniform wall strength. It is, however, also possible to split the blanks in another plane or place so as to produce hollow structures of which one wall has e. g. $\frac{2}{3}$ and the other wall e. g. only $\frac{1}{3}$ of the thickness of the original blank.

This effect may be obtained in a simple manner by screening the one main surface against the action of the swelling agent in such a way that less swelling agent penetrates into said surface than in the other main surface. Such a differential action of the swelling agent in the two main surfaces of the blanks may be brought about for instance by passing a strip-shaped blank on a support into or through the swelling agent so as to protect the surface lying on the support against the penetration of the swelling agent at the beginning of the treatment and to expose said surface to the action of the swelling agent only later by disengaging it from the support.

In the accompanying drawings,

Fig. 1 is a perspective view of a rectangular blank of a swellable thermoplastic material;

Fig. 2 is a view of the same blank in cross section along line A—A of Fig. 1 after it has been subjected to the action of a swelling agent in accordance with the process of the invention, and shows the outer swollen layer surrounding an unswollen core, and

Fig. 3 is a perspective view of the finished hollow structure;

Fig. 4 is a plan view of a blank suitable for the production of an air cushion; and

Fig. 5 is a diagrammatic cross-section along line B—B of Fig. 4, showing the air cushion prepared from said blank;

Fig. 6 is a diagrammatic side view of an apparatus suitable to carry out the novel process in continuous operation.

In the drawings, the numeral 1 designates the swollen outer layers, and 2 the substantially unswollen core of the blanks which are obtained and treated as more fully explained in the following examples which are given to illustrate the process of the invention and are not to be considered as limiting the invention. Unless indicated otherwise, parts are given by volume.

Example 1

A strip of .2 mm. thickness of acetyl cellulose or cellulose triacetate is submerged for 30 seconds in a swelling bath which consists of 50 parts of methylene chloride and 50 parts of methanol or ethanol. The strip is then brought into a drying oven which has a temperature of 120 to 130° C. At 120° C. splitting of the blank in the core layer and distending to a seamless structure takes place in 40 seconds.

Example 2

A nitrocellulose film which has a thickness of .5 mm. is submerged for 3 minutes in a bath which consists of 1 part of methanol, 2 parts of ethanol, 2 parts of acetone and 1 part of toluene, and which contains as much water as is compatible with said mixture (about 12%). After soaking, the film is placed in a heating chamber having a temperature of 150° C. After 45 seconds the seamless structure has been formed.

Example 3

A strip of a nitrocellulose-chamber mixture known under the trade-name "Celluloid," which has a thickness of .5 mm., is dipped for 2 minutes in a bath consisting of 4 parts of acetone and 3 parts of methylene chloride. By subsequent heat treatment at 180° C. the seamless hollow article is formed in 60 seconds.

Example 4

An uncured rubber sheet of a thickness of .5 mm. is placed for 2 minutes in a bath composed of 3 parts of benzene, 1 part of benzene and 1 part of methanol. The strongly swollen sheet is then passed into a drying oven and maintained for 90 seconds at a temperature of 150° C. At the end of that period of time a seamless hollow body of uncured rubber has been formed which may be used as such or which may be subsequently vulcanized.

Example 5

A polyvinyl chloride (Igelit) foil of .5 mm. thickness is treated for 1 minute in a bath consisting of 5 parts of methylene chloride and 1 part of methanol. Subsequently, the structure is heated in a drying chamber at 130° C. for 120 seconds whereby the foil is converted to a seamless hollow body.

Example 6

A gelatin film of a thickness of .5 mm. is treated 5 minutes in a bath consisting of 3 parts of water, 2 parts of methanol and 1 part of glycerol. The proportion of glycerol may be increased by one more part in order to soften the final product. The swollen foil is subjected to a heat treatment of 2 minutes at 120° C. which results in the formation of a seamless hollow body.

An apparatus suitable for the continuous production of tubes or casings is shown in Fig. 6. A strip of the swellable plastic material is placed on the roll 3, passes through the swelling baths 4 and 5 and subsequently through the heating zone 6 where the splitting up is obtained, and is wound up on roll 7. The obtained hollow structure may then be cut into tubes or casings of the desired length.

It was proposed already, some time ago, to make hollow articles from cellulose derivatives by splitting up suitably shaped solid blanks. According to that known process, the strength of the solid cellulosic blanks was reduced in a progressively greater degree from the outside towards the inside by partial saponification, e. g. with caustic soda, and by the simultaneous action of swelling agents; subsequently, the blanks were split up, whereby the connection between the edge layers was maintained. This method has, among others, the drawback that the partial saponification causes a chemical modification, for instance a depolymerization or deacetylation of the cellulose derivative. Thus, the saponification converts a cellulose acetate film more or less to a form of regenerated cellulose which has other properties than the starting material. A cellulose acetate tube or casing made by the process referred to is, in its whole structure, sensitive to water, and swells therein, whereas, due to the absence of saponifying agents, a tube prepared from the same starting material according to the process of the present invention does not present these objectionable properties. The known process for the preparation of seamless hollow articles from cellulose derivatives did not find commercial application.

Although I have described my invention setting forth specific embodiments thereof, my invention is not limited to the details described, for instance, instead of blanks having a rectangular cross section, I may use blanks of other, for instance circular cross section, and of various shapes. The blanks may be subjected to a step-wise swelling treatment in subsequent baths of the same or of different composition. It will be understood by those skilled in the art that my novel process is susceptible of considerable variations and that my invention is not to be limited except by the scope of the claims appended hereto.

What I claim is:

1. A process for the production of seamless hollow structures comprising the steps of subjecting a solid blank of a swellable plastic composition to a swelling treatment with a swelling liquid, said swelling liquid containing a portion of low boiling liquid sufficient to produce an impervious surface layer on the outside of the blank when it is heated, completely swelling said blank from the outside toward the inside except the innermost core thereof, and heating the blank to a temperature above the boiling point of said low boiling portion of the swelling liquid to solidify the surfaces of said blank by the evaporation of said low boiling liquid, to cause the previously unswollen innermost core to become swollen, to

force apart said solidified surfaces by the development of vaporized liquid under pressure in the swollen innermost core, and thus to convert said blank to a seamless hollow structure.

2. A process as defined in claim 1 wherein the swelling treatment is carried out at temperatures between about 60° C. to 200° C.

3. A process as defined in claim 1 wherein the swelling liquid contains softening agents.

4. A process as defined in claim 1 wherein the swollen blanks are heated in a liquid bath.

5. A process as defined in claim 4 wherein the swollen blanks are heated in a liquid bath containing a softening agent.

6. A process as defined in claim 1 wherein the swollen blanks are heated by means of heat generating radiation.

7. A process as defined in claim 6 wherein infrared radiation is used for heating the swollen blanks.

8. A process as defined in claim 6 wherein high frequency radiation is used for heating the swollen blanks.

9. A process as defined in claim 1 wherein the split and extended hollow structures are subjected to an aftertreatment by the introduction of gases.

10. A process as defined in claim 1 wherein the split and extended hollow structures are subjected to an aftertreatment by the introduction of liquids.

11. A process as defined in claim 1 wherein blanks of vulcanizable material are used and wherein the obtained split and extended hollow structures are vulcanized.

12. A process as defined in claim 1 wherein the surfaces of the blank are uniformly subjected to the action of the swelling agent so as to obtain a symmetrical diffusion of said swelling agent towards the inside and retaining a substantially unswollen core layer in the center of the blank.

13. A process as defined in claim 1 wherein one main surface of the blank is treated with a larger amount of the swelling liquid than the other main surface, so as to obtain a substantially unswollen core layer located nearer to said second surface than to said first surface.

14. A process for the production of seamless hollow structures comprising the steps of subjecting a solid blank of a swellable plastic composition to a swelling treatment with a swelling liquid, said swelling liquid being capable of dissolving said plastic composition at higher temperatures and containing a portion of low boiling liquid sufficient to produce an impervious surface layer on the outside of the blank when it is heated, completely swelling said blank from the outside toward the inside except the innermost core thereof, and heating the blank to a temperature above the boiling point of said low boiling portion of the swelling liquid to solidify the surfaces of said blank by the evaporation of said low boiling liquid to dissolve at least partially the previously unswollen innermost core, to force apart said solidified surfaces by the development of vaporized liquid under pressure in the at least partially dissolved innermost core, and thus to convert said blank to a seamless hollow structure.

15. A process as defined in claim 14 wherein the swelling liquid is a mixture of at least two components, one component being a solvent for the material of the blank and the other component decreasing the solvent action of the first component.

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16. A process for the production of seamless hollow structures comprising the steps of subjecting a solid blank of a swellable plastic composition to a swelling treatment with a swelling liquid, said swelling liquid containing a portion of low boiling liquid sufficient to produce an impervious surface layer on the outside of the blank when it is heated, completely swelling said blank from the outside toward the inside except the innermost core thereof, and heating the blank quickly to a temperature above the boiling point of said low boiling portion of the swelling liquid to solidify the surfaces of said blank by the evaporation of said low boiling liquid, to cause the previously unswollen innermost core to become swollen, to force apart said solidified surfaces by the development of vaporized liquid under pressure in the swollen innermost core, and thus to convert said blank to a seamless hollow structure.

17. A process for the production of seamless hollow structures comprising the steps of subjecting a solid blank of a swellable plastic composition to a swelling treatment with a swelling liquid, said swelling liquid being capable of dissolving said plastic composition at higher tem-

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peratures and containing a portion of low boiling liquid sufficient to produce an impervious surface layer on the outside of the blank when it is heated, completely swelling said blank from the outside toward the inside except the innermost core thereof, and heating the blank quickly to a temperature above the boiling point of said low boiling portion of the swelling liquid to solidify the surfaces of said blank by the evaporation of said low boiling liquid, to dissolve at least partially the previously unswollen innermost core, to force apart said solidified surfaces by the development of vaporized liquid under pressure in the at least partially dissolved innermost core, and thus to convert said blank to a seamless hollow structure.

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