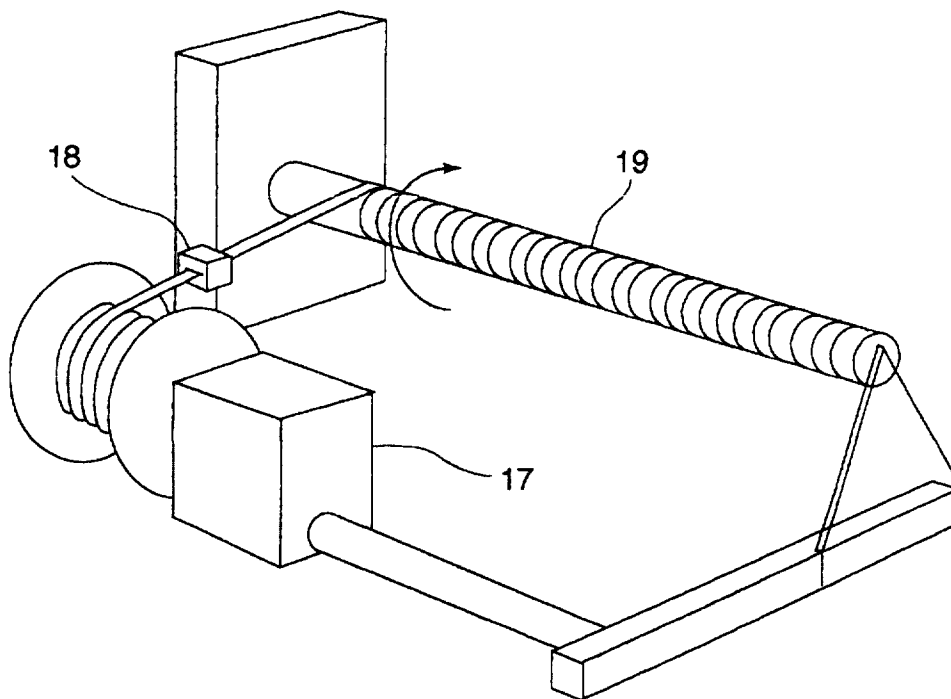




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<p>(51) International Patent Classification ⁶ : B27J 1/00, 7/00, B65B 81/00</p>	<p>A1</p>	<p>(11) International Publication Number: WO 98/10906 (43) International Publication Date: 19 March 1998 (19.03.98)</p>
<p>(21) International Application Number: PCT/US97/14262 (22) International Filing Date: 14 August 1997 (14.08.97)</p> <p>(30) Priority Data: 08/714,420 16 September 1996 (16.09.96) US Not furnished 8 August 1997 (08.08.97) US</p> <p>(71)(72) Applicant and Inventor: RYAN, Dale, B. [US/US]; 1001 Chalkstone Drive, Mitchell, SD 57301 (US).</p> <p>(74) Agent: HUFF, Richard, L.; Law Offices of Richard L. Huff, 19304 Olney Mill Road, Olney, MD 20832 (US).</p>		<p>(81) Designated States: AL, AM, AT, AU, AZ, BA, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LR, LT, LV, MN, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, UA, UG, UZ, VN.</p> <p>Published <i>With international search report.</i></p>

(54) Title: LINEAR BAMBOO FIBER CORE FOR FILAMENT WINDING APPLICATIONS



(57) Abstract

A linear bamboo tape (15) containing a series of adhesively connected bamboo sections (12, 13) is disclosed. The tape (15) is made by splitting cut and dried bamboo culms to obtain bamboo sections (12, 13) and adhesively bonding the bamboo sections (12, 13) to form a joint (14) therebetween. The bamboo tape (15) may be used to manufacture a cylindrical container by mounting the tape (15) onto a filament winder (17), passing the bamboo tape (15) through a resin bath (18) and winding the resin coated bamboo onto a mandrel (19).

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LINEAR BAMBOO FIBER CORE FOR FILAMENT WINDING APPLICATIONS

Technical Field

This invention relates to linear bamboo fibers, processes of preparing them, and processes of using them as structural cores in circumferentially wound pressure vessels such as pipes, tanks, and hollow products.

Background Art

Conventional pipes made of clay or iron have relatively short life spans. Clay and iron have been replaced by stronger and longer-lasting fiberglass products.

Hollow, wound products such as pipes and tanks are currently manufactured by pulling glass fibers which have been treated in a resin bath around rotating mandrels. The resulting product can be of greatly varying diameters and capable of withstanding substantial internal pressures. Very large amounts of pressure pipes are used throughout the world for drinking water, oil pipelines, waste water, sewage, and natural gas. Solid, uncured composite pipe is very heavy and quite expensive. These disadvantages become more apparent in the manufacture of large storage tanks, which may be over 100 feet in diameter due to their relatively thick wall cross-sections.

The prior art is aware of coating bamboo poles with plastic. Thus, U.S. Pat. No. 4,774,906 teaches a process for coating bamboo poles with plastics in order to protect and improve the appearance of the poles. No utility is proposed for the resulting polymer-coated bamboo poles and this patent fails to disclose pretreating the bamboo poles with a binder to improve the adhesion of the polymer to the bamboo poles.

Disclosure of Invention

The present invention seeks to overcome the disadvantages inherent in the prior art materials by providing a low-cost tape or roving which may be wound around pressure vessels such as pipe, tanks, and hollow vessels while meeting or exceeding the performance and strength characteristics of the existing solid products.

The present invention discloses a method of treating bamboo fibers processed into tape or roving which will allow the fibers to be circumferentially wound as fiberglass is wound in the prior art. The material of the present invention, when treated with a binder, especially those recited in this specification, is compatible with thermoplastic or thermosetting resins. This treatment prevents slippage between the bamboo fibers and the polymers.

The manufacturing operation of the present invention can be carried out in factories when pipes or small tanks or vessels are being manufactured. Alternatively, the fibrous product of the present invention can be transported to the site of construction for the manufacture of large storage tanks, structural columns, or other large structures.

Brief Description of Drawings

Fig. 1 is an elevational view of a bamboo culm split into the proper width to produce a linear, unidirectional tape product and the tape product.

Fig 2 is a side elevational view of a tape-producing machine used in the present invention.

Fig. 3 is an schematic representation showing one end of a tape length connected to another to produce a reel of tape.

Fig. 4. is an elevational view of a pipe-winding machine which is used to wind bamboo linear fiber upon a pipe-forming mandrel.

Fig. 5 is an elevational view of a storage tank showing on-site winding of bamboo linear tape and a sprayer for preparing an outer surface coating.

Best Mode for Carrying Out the Invention

The invention will now be described with reference to the above Figures, wherein like numerals refer to like features.

Bamboo is cut and dried to the optimum moisture content, to produce a culm 6 useful for the present invention. The culm 6 is split to form a split bamboo section 7 having the proper width indicated by the final tape width necessary. The split bamboo section 7 is then processed in a tape slicing machine 1 which shaves the sections to a predetermined thickness allowing it to be flexible enough to be wound around a forming mandrel. The tape splicing machine 1 is capable of accommodating many various bamboo split section 7 widths and is able to produce tape lengths 12 of any practical thickness.

The tape slicing machine 1 contains a plurality of pairs of upper 8 and lower 2 drive gears. The upper drive gear 8 floats under the lifting force of springs 3 to accommodate the bumps and other variations in the split bamboo sections 7. The tape slicing machine 1 contains an adjustable blade 9 which is capable of shaving the tape length 12 to the desired thickness. The tape slicing machine 1 further contains take-up gears 10 that push the final tape length 12 out of the machine 1 and enable the looping around of the split section 7 for another pass through the machine 1.

A coating apparatus 11 is on or near the machine 1. The coating apparatus 11 coats the tape length 12 with at least one of the binders recited above, preferably acrylic acid or maleic anhydride salt or ester derivatives. The coating may be done by any conventional method, including spraying, dipping, or roller painting. The binder promotes interfacial bonding of the tape 15 with the polymer matrix.

Following removal of a tape length 12 from the tape slicing machine 1, the end of one tape length 12 is joined to the end of another tape length 13. This operation is repeated a plurality of times in order to form a long tape 15 having a desired length. Preferably, joining is accomplished by first feathering the ends to be joined as shown in Figure 3. Then, an adhesive 14, such as hot melt glue or a quick-drying epoxy cement is applied to at least one feathered end and the two ends are brought into contact. The rapidity of the setting of the adhesive allows the resulting tape 15 of uninterrupted linear bamboo fiber to be taken onto a spool 16

without stopping the manufacturing process. In this way, sufficient tape **15** can be produced to continuously wind various products, such as tanks or pipes.

Uninterrupted linear bamboo fibers in the form of roving can be produced by using narrow pieces of split bamboo sections **7** and twisting a plurality of such sections together to form a roving, which is then taken up on a reel **16**. This process is within the skill of the art.

In accordance with the present invention, a high tensile strength core comprising linear bamboo fibers processed into tape or roving will allow the fibers to be circumferentially wound as fiberglass is wound in the prior art. The material of the present invention, when treated with a binder, is compatible with thermoplastic or thermosetting resins. This treatment prevents slippage between the bamboo fibers and the polymers.

It has been discovered that excellent binding results are obtained by using the following binding agents: maleated polypropylene, maleated polyethylene, maleic anhydride, hydroxyl methacrylate, N-vinyl pyridine, silane compounds, N-vinyl caprolactam, N-vinyl carbazole, methacrylic acid, ethyl methacrylate, isobutyl methacrylate, sodium styrene sulfonate, bis-vinyl phosphate, divinyl ether-ethylene glycol, vinyl acetate, vinyl toluene, vinylidene chloride, chloroprene, isoprene, dimethylaminoethyl methacrylate, isocetylvinyl ether, acrylonitrile, glycidyl methacrylate, N-vinyl pyrrolidone, acrylic acid, ethyl acrylate, itaconic acid, methyl acrylate, sodium vinyl sulfonate, cetyl vinyl ether, divinyl ether-butanediol, and octadecyl vinyl acetate.

For use in manufacturing a cylinder, a reel **16** of binder-treated bamboo tape **15** or roving is mounted on a carrier **17** or filament winder. The linear bamboo tape **15** or roving is unwound from the reel **16** and pulled through a bath **18** of polymer. Any thermosetting or thermoplastic resin useful in the fiberglass art is satisfactory in the process of the present invention. The treated linear bamboo fiber is then wound upon a mandrel **19** to form a bamboo/resin cylinder which may then be separated from the mandrel.

In the formation of pressure pipe, a single layer of fiberglass is wound on the mandrel **19** to form an interior working surface. Then, the binder/resin-treated bamboo fiber of this invention is wound onto the fiberglass followed by the winding of a single layer of a fiberglass outer surface. In such a way, a cylinder having a wall cross-section of 5% inner layer of resin-treated fiberglass, 90% core of resin-treated bamboo fiber, and 5% outer layer of resin-treated fiberglass is manufactured. This cylinder may then be removed from the mandrel. The final thickness and composition of the cylinder sidewall determines the pressure resisting strength, the weight-per-foot, and the outside diameter of the cylinder. One configuration of a cylinder suitable for a pipe is a cylinder with a sidewall thickness of one inch consisting of a one-eighth inch thick resin-treated fiberglass interior surface, a three-quarter inch thick resin-treated linear bamboo fiber core, and a one-eighth inch thick resin-treated fiberglass outer cosmetic surface. This pipe is equal in strength to a solid fiberglass pipe and is manufactured at a fraction of the cost of the fiberglass pipe.

Storage tanks are produced in a similar manner with various types of liners and outer surfaces, or even 100% resin-treated bamboo fiber construction.

Larger storage tanks may be manufactured on site by a method illustrated in Figure 5. A self-contained winding machine **22** travels around the exterior of a pre-form **20**, paying out the binder-treated linear bamboo tape **15** through a resin bath **18** so that the resin-treated tape **15** is tightly wound on the pre-form **20**. The interior surface of the pre-form **20** is then treated with a liner which will be left in the tank upon completion. Alternatively, the exterior surface of the pre-form **20** is wound by linear bamboo tape **15** which has been treated with a binder, and this resulting surface is treated, preferably by spraying using the spraying apparatus **21**, with a resin. The pre-form may be removed to leave a free-standing bamboo/resin storage tank. To enhance the visual appearance and longevity, a gel coat or acrylic coat may be applied to the resin-treated bamboo fiber surface. As another alternative, only the resin-treated linear bamboo fiber is applied to the pre-form. The pre-form may be left in place or removed. A storage tank constructed in this manner is made at a much lower cost than one using steel, concrete, or fiberglass.

This invention dramatically lowers the cost of composite pipes and tanks, while retaining all of the superior properties. This allows the widespread use of composite tanks and pipes in countries where their cost is now prohibitive. Some of the most economically disadvantaged countries in the Pacific Rim, and in Central and South America already have the highest quality bamboo fiber. Thus, raising bamboo as a structural fiber cash crop would prove an excellent alternative to rainforest slash-and-burn agriculture techniques.

Technical Applicability

The present invention allows for the preparation of inexpensive, strong hollow vessels and solid structures with bamboo fibers surrounded by polymers.

I CLAIM

1. A process for the preparation of a bamboo tape or rope, which comprises:
 - (a) splitting cut and dried bamboo culms to produce split bamboo sections having ends,
 - (b) sizing the split bamboo sections to the desired width and thickness,
 - (c) applying a binder to the bamboo sections,
 - (d) connecting ends of bamboo sections to form a bamboo tape or rope, and
 - (e) winding the bamboo tape or rope onto a storage device.
2. The process of claim 1, wherein binder is at least one member selected from the group consisting of maleated polypropylene, maleated polyethylene, maleic anhydride, hydroxyl methacrylate, silane compounds, N-vinyl pyridine, N-vinyl caprolactam, N-vinyl carbazole, methacrylic acid, ethyl methacrylate, isobutyl methacrylate, sodium styrene sulfonate, bis-vinyl phosphate, divinyl ether-ethylene glycol, vinyl acetate, vinyl toluene, vinylidene chloride, chloroprene, isoprene, dimethylaminoethyl methacrylate, isocetylvinyl ether, acrylonitrile, glycidyl methacrylate, N-vinyl pyrrolidone, acrylic acid, ethyl acrylate, itaconic acid, methyl acrylate, sodium vinyl sulfonate, cetyl vinyl ether, divinyl ether-butanediol, and octadecyl vinyl acetate.
3. The process of claim 1, wherein the ends of bamboo sections are connected by a process comprising feathering the ends and applying an adhesive to the feathered ends.
4. The process of claim 3, wherein the adhesive is an epoxy resin or hot-melt glue.
5. A linear bamboo tape, which comprises a series of adhesively connected bamboo sections, each section being of a predetermined width and thickness
6. The linear bamboo tape of claim 5, wherein the tape is coated with a binder.
7. The linear bamboo tape of claim 6, wherein the binder is at least one member selected from the group consisting of maleated polypropylene, maleated polyethylene, maleic anhydride, hydroxyl methacrylate, silane compounds, N-vinyl pyridine, N-vinyl caprolactam, N-vinyl carbazole, methacrylic acid, ethyl methacrylate, isobutyl methacrylate, sodium styrene sulfonate, bis-vinyl phosphate, divinyl ether-ethylene glycol, vinyl acetate, vinyl toluene, vinylidene chloride, chloroprene, isoprene, dimethylaminoethyl methacrylate, isocetylvinyl ether, acrylonitrile, glycidyl methacrylate, N-vinyl pyrrolidone, acrylic acid, ethyl acrylate, itaconic acid, methyl acrylate, sodium vinyl sulfonate, cetyl vinyl ether, divinyl ether-butanediol, and octadecyl vinyl acetate.

8. The linear bamboo tape of claim 5, wherein the sections are joined together by connections which comprise feathered ends of bamboo sections joined together by an adhesive.
9. A process for preparing a cylinder, which comprises:
- (a) unwinding a linear bamboo tape from a reel, which linear bamboo tape comprises a series of adhesively connected bamboo sections, each section being of a predetermined width and thickness, and wherein the tape is coated with a binder,
 - (b) passing the tape through a resin bath containing a resin to coat the tape with the resin, and
 - (c) applying the tape to the inner or outer surface of a predetermined material in cylindrical form to produce a layer of predetermined material and a layer comprising resin-coated bamboo tape.
10. The process of claim 9, wherein the binder is at least one member selected from the group consisting of maleated polypropylene, maleated polyethylene, maleic anhydride, hydroxyl methacrylate, silane compounds, N-vinyl pyridine, N-vinyl caprolactam, N-vinyl carbazole, methacrylic acid, ethyl methacrylate, isobutyl methacrylate, sodium styrene sulfonate, bis-vinyl phosphate, divinyl ether-ethylene glycol, vinyl acetate, vinyl toluene, vinylidene chloride, chloroprene, isoprene, dimethylaminoethyl methacrylate, isocetylvinyl ether, acrylonitrile, glycidyl methacrylate, N-vinyl pyrrolidone, acrylic acid, ethyl acrylate, itaconic acid, methyl acrylate, sodium vinyl sulfonate, cetyl vinyl ether, divinyl ether-butanediol, and octadecyl vinyl acetate.
11. The process of claim 9, which comprises the addition step (d), which is:
- (d) applying a predetermined cosmetic outer surface to the layer comprising resin-coated bamboo tape.
12. The process of claim 9, wherein the predetermined material comprises a glass/resin composition in filament form wound around a mandrel.
13. The process of claim 11, wherein the cosmetic outer surface comprises a glass/resin composition.
14. The process of claim 11, wherein the cosmetic outer surface is applied by winding glass/resin fibers.

15. The process of claim 11, wherein the cosmetic outer surface is applied by spraying a resin coat.
16. The process of claim 9, wherein the linear bamboo tape is wound directly upon a liner which will form part of the cylinder.
17. The process of claim 11, wherein the cylindrical form is removed following step (d).
18. The process of claim 9, wherein the cylinder is a storage tank.
19. The process of claim 9, wherein the cylinder is a pipe.
20. The process of claim 9, wherein the binder is acrylic acid.

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Fig. 1

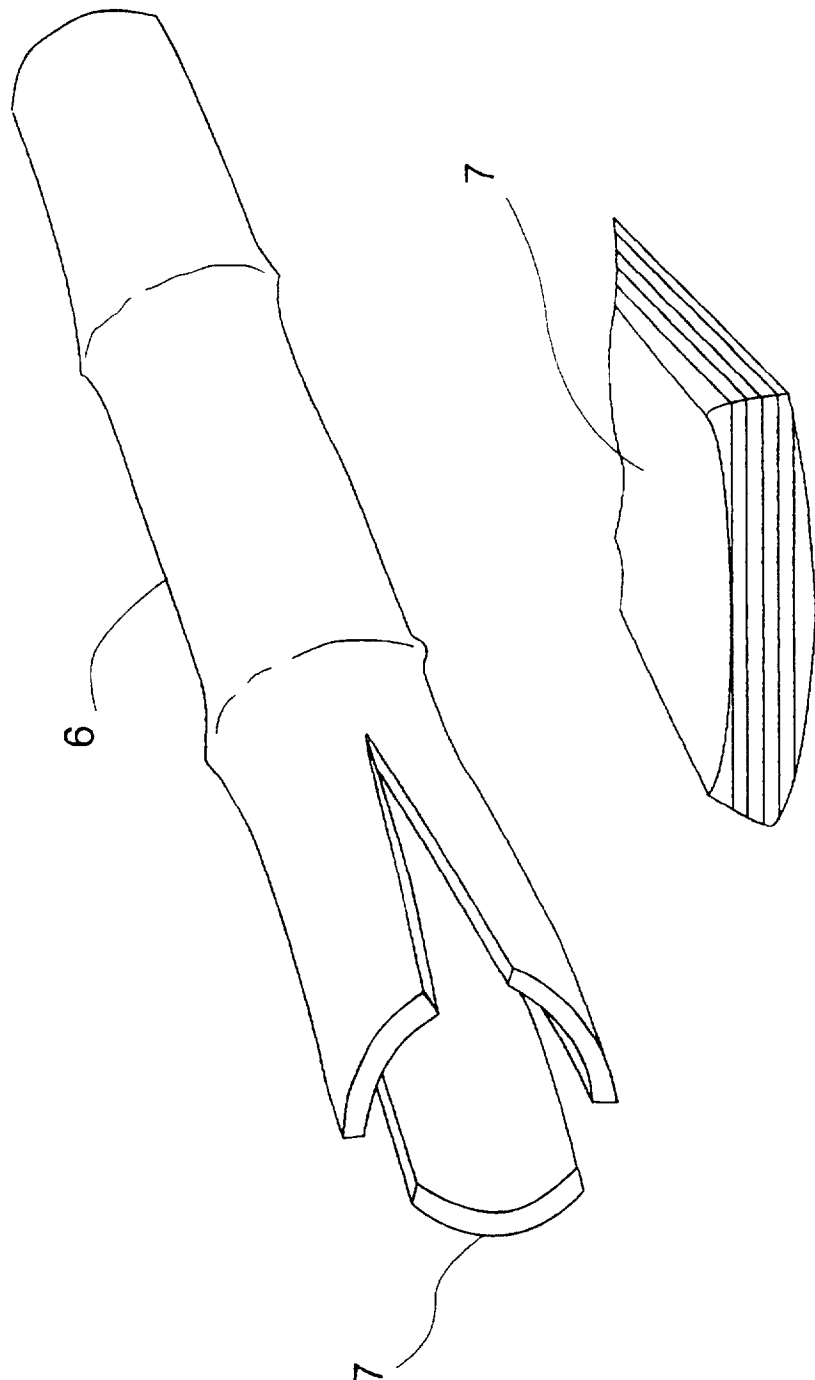


Fig. 2

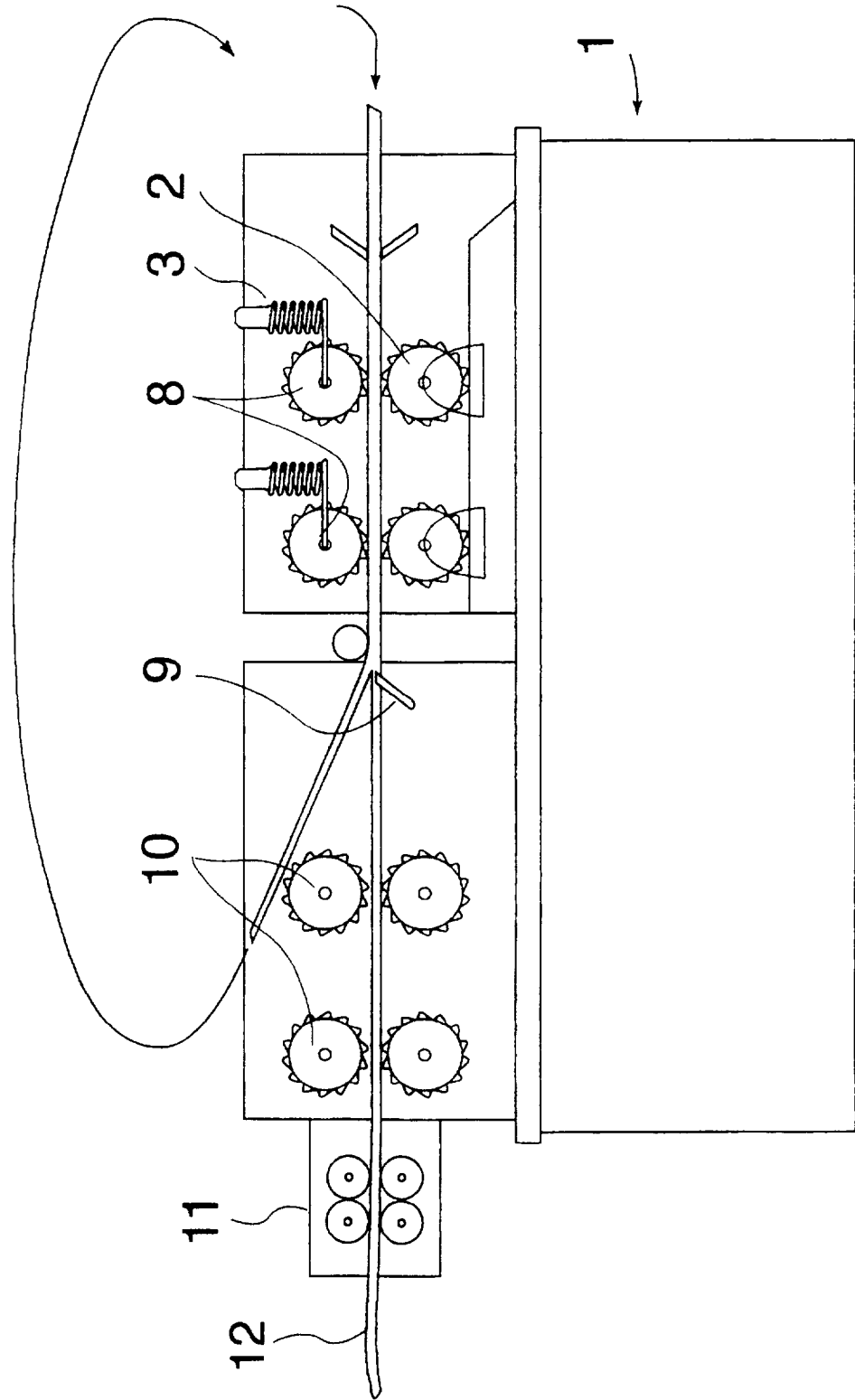


Fig. 3

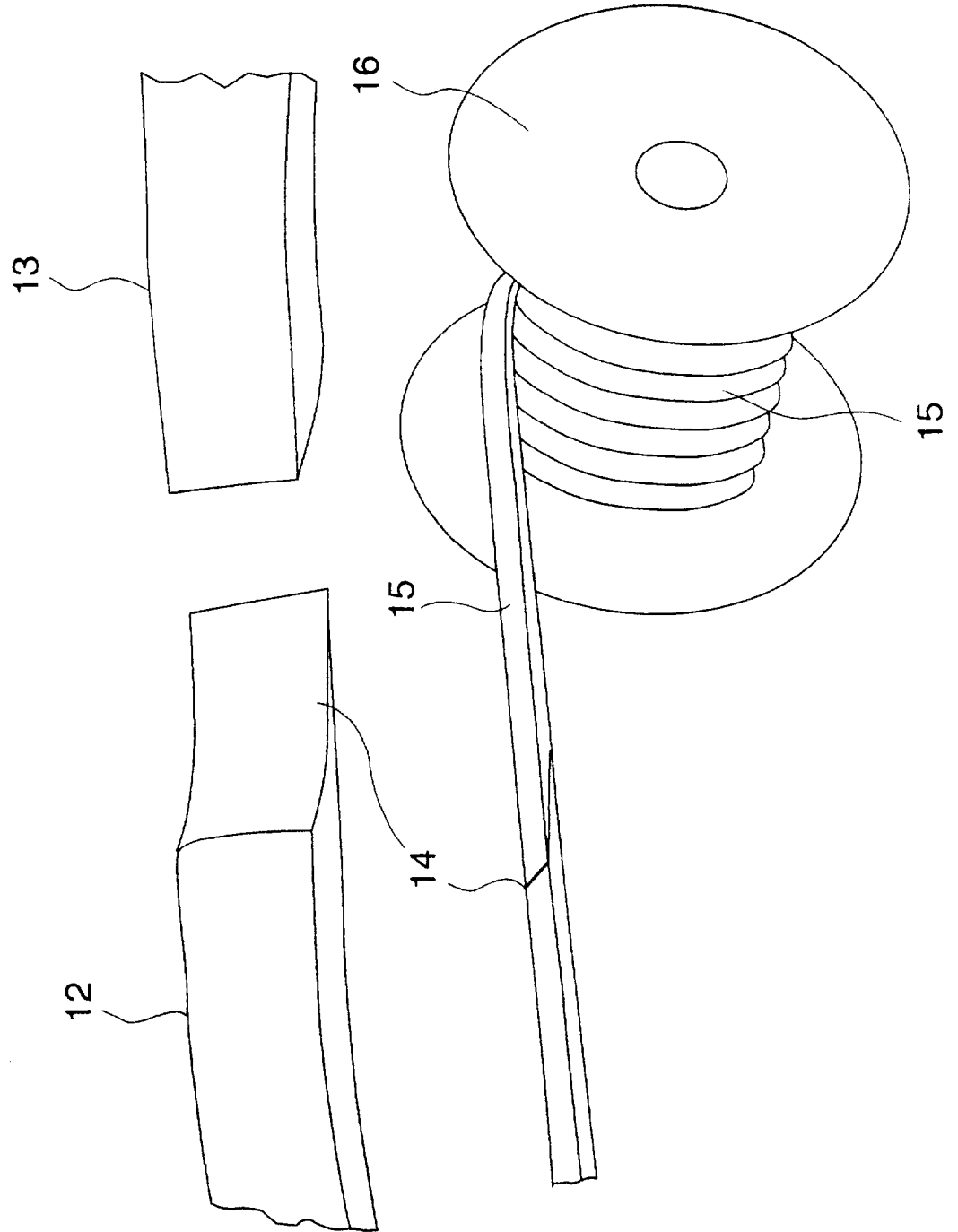
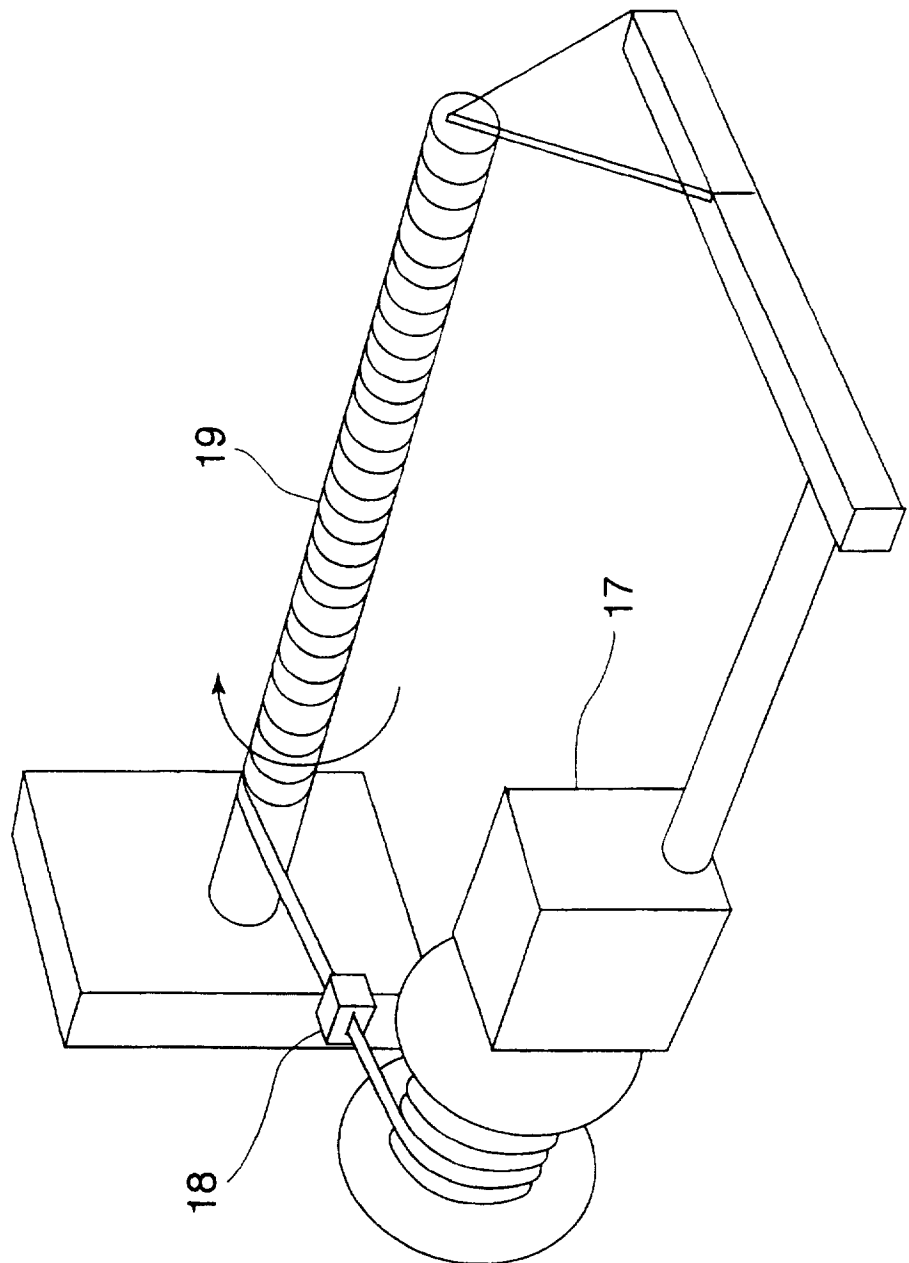
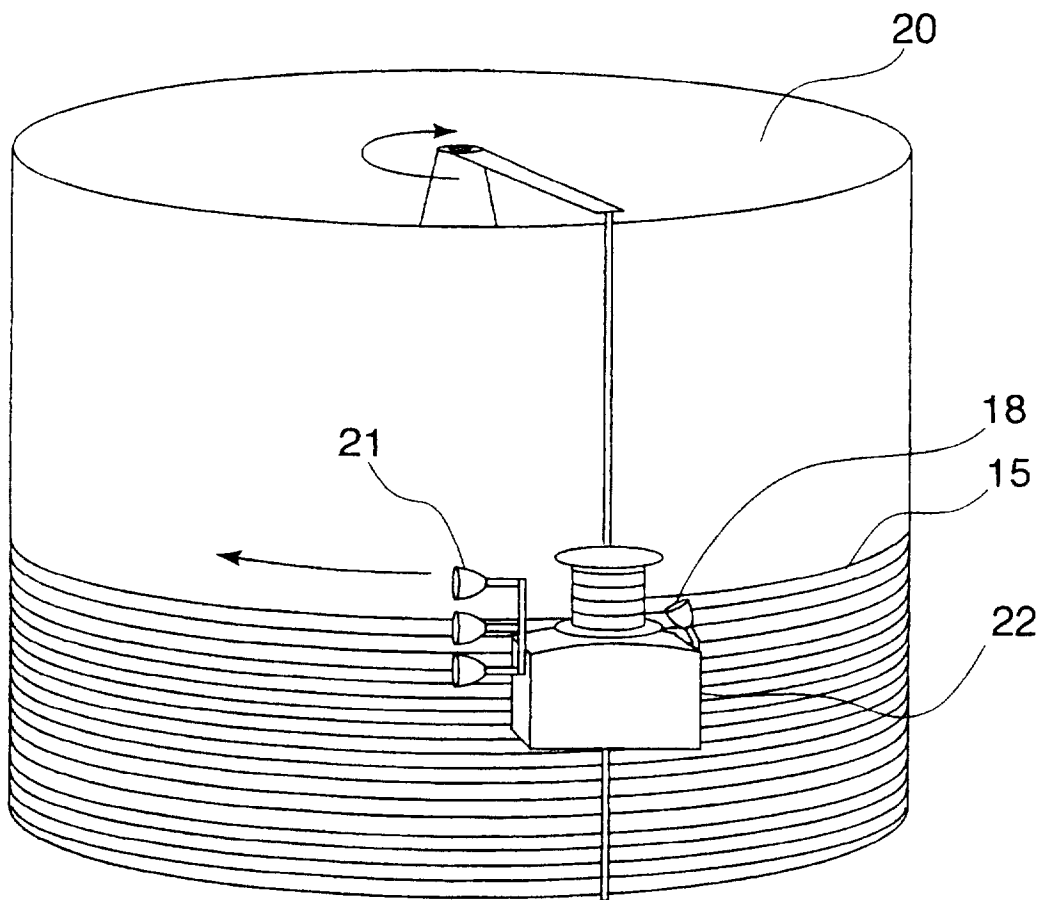


Fig. 4



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Fig. 5



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/14262

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B27J 1/00, 7/00; B65B 81/00

US CL : 144/333; 156/166, 169, 173, 175, 296; 428/60

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 144/333; 156/166, 169, 173, 175, 296; 428/60

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

none

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

none

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 3,464,877 A (R.B. MILLER, ET AL) 02 September 1969 (02.09.69), entire document.	1-8
Y	JP 46-40741 B (SAWADA T) 01 December 1971 (01.12.71), entire document.	9-14

Further documents are listed in the continuation of Box C. See patent family annex.

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Date of the actual completion of the international search

17 OCTOBER 1997

Date of mailing of the international search report

12 NOV 1997

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