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METHOD AND APPARATUS FOR WINDING RESIN-IMPREGNATED FILAMENTS TO REDUCE ENTRAINED AIR

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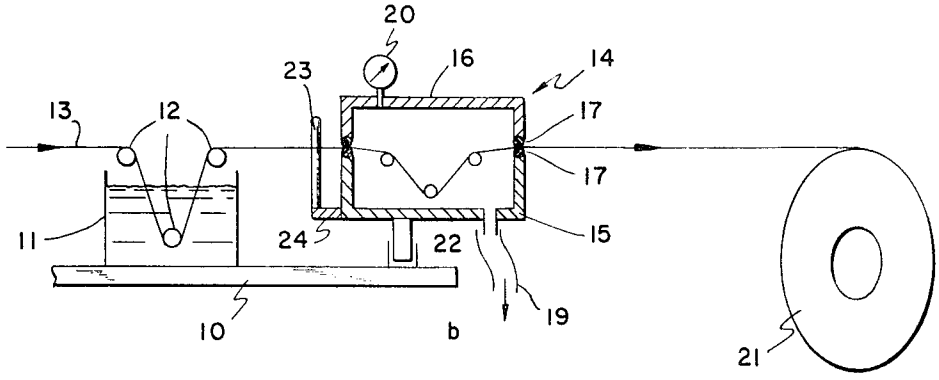



FIG. 1

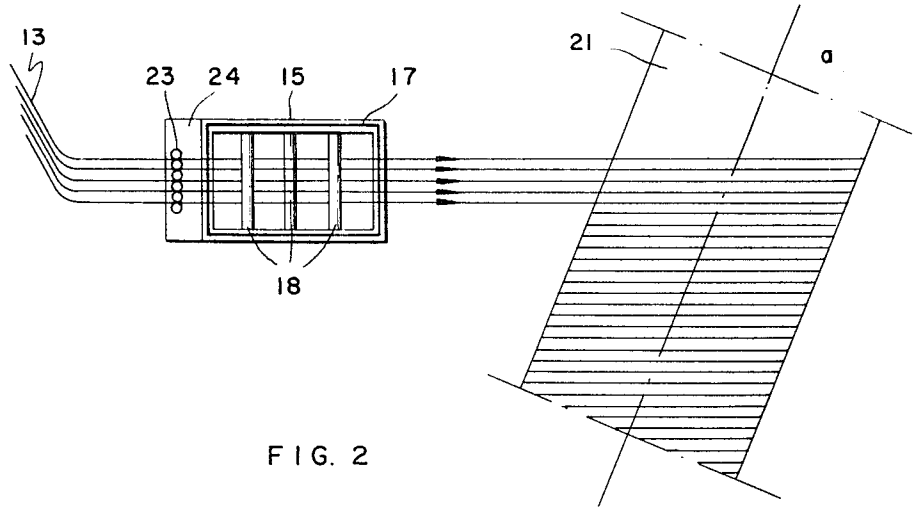



FIG. 2

INVENTOR:
HERMAN F. SCHWENCKE
BY:
Norris E. Faringer
HIS ATTORNEY

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# METHOD AND APPARATUS FOR WINDING RESIN-IMPREGNATED FILAMENTS TO REDUCE ENTRAINED AIR

Herman F. Schwencke, Delft, Netherlands, assignor to Shell Oil Company, New York, N.Y.

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U.S. Cl. 156—175 3 Claims

## ABSTRACT OF THE DISCLOSURE

A method for reducing the entrained air in an article prepared from a resin-impregnated filament is described which comprises impregnating composite filament with a liquid resin, passing the filament through a vacuum chamber, moving the filament from said vacuum chamber to a mandrel in a substantially rectilinear direction, winding said impregnated filament on a mandrel to form an article thereon, and allowing the resin to harden.

## BACKGROUND OF THE INVENTION

It is possible to form an article by impregnating a composite filament with a liquid thermosetting resin, winding the impregnated filament on a mandrel to shape the article, and allowing the resin in the article to harden. When the filament is being impregnated the liquid resin can drive out most but not all of the air contained or entrained by the filament. The result is that the finished article made of the impregnated filament contains at least some 3 to 5% by volume of free air finely distributed throughout the article in the form of micro bubbles or tiny streaks. The air inclusions in the article have detrimental effects on many desired properties of the article. For example, air entrapments give stress concentrations which initiate cracks in the material. For this reason, the article if it is to contain a fluid under pressure such as a pipe, starts leaking or "weeping" at a lower pressure than a similar article having less or no air therein. Also, electrical properties are adversely affected, which is very undesirable for high voltage applications of the material, such as for circuit breaker tubes.

It has therefore been attempted to reduce the air volume of the article as much as possible, but owing to difficulties such as high viscosity of the liquid resin and small dimensions of the air bubbles, a satisfactory possibility of substantially reducing the volume of residual air in the article had not yet been provided.

Some improvement can be obtained by carrying out the entire method under vacuum, which means that the necessary apparatus including reels of filament, impregnation chamber, winding mandrel and all associated equipment must be enclosed to preserve a subatmospheric environment. Under these circumstances operations such as repairing broken filaments, replacing empty reels of filaments, and replenishing the resin bath, are very complicated. Therefore, this proposition is rejected as being impractical. On the other hand, subjecting only part of



the equipment to a vacuum, for example passing the filament through a vacuum chamber or applying vacuum to the impregnation chamber alone, heretofore did not give the desired degree of improvement.

## SUMMARY OF THE INVENTION

When an impregnated filament is passed through a vacuum chamber and after leaving the vacuum chamber is moved over guide rolls deviating the path followed by the filament to direct the filament towards a rotating mandrel and to lay the filament in a predetermined direction on the mandrel, a significant amount of air, e.g., 3% or more, is still retained in the resin.

It has now been discovered, quite unexpectedly, that a substantial reduction in the air volume in the article is achieved by not allowing the filament to divert its course, as over guide rolls or other diverting means, once the filament has passed through the vacuum chamber and thereby has regained contact with the atmospheric air. In other words, the amount of entrained air is significantly reduced by drawing the impregnated filament in a straight line (rectilinear direction) from the vacuum chamber to the take-up mandrel.

It is an object of the invention to provide a technologically acceptable method of forming an article from a resin-impregnated filament, in which the air volume in the finished article is as low as 1% or less.

## BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is an elevation (vertical) schematic view of the preferred embodiment of an apparatus for the application of the instant process wherein the vacuum chamber is shown in vertical section.

FIG. 2 is a plan view of the instant apparatus wherein the removable lid has been removed from the vacuum chamber.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention is particularly directed to a method for forming an article from a resin-impregnated filament comprising impregnating a composite filament with a liquid macromolecular resin, passing the filament through a vacuum chamber, winding the impregnated filament on a mandrel to form an article therefrom, and allowing the resin in the article to harden, in which the filament from where it leaves the vacuum chamber to where it contacts the mandrel is moved in a substantially rectilinear direction.

The produced article can be a pipe, container, circuit breaker tube or it can have any other shape that can be formed by winding filaments on a mandrel, and the invention is not limited to any specific shape of article.

The liquid macromelocular resin used as an impregnation liquid can be synthetic thermosetting resin composition capable of hardening, if desired or necessary with external heat being supplied to accelerate the hardening process. Examples of such impregnation liquids are

epoxy resin, polyester resin, polyether and polyurethane.

Other suitable impregnation liquids are synthetic thermoplastic resins in the molten or dissolved state, which become solid by cooling or evaporation of the solvent respectively. Examples of these resins are polyvinylchloride, acrylate and saturated polyesters.

In practicing the invention it is easy to produce articles containing less than 1% by volume of air. The percentage of residual air in the article is approximately proportional to the absolute pressure in the vacuum chamber, down to an absolute pressure of approximately 0.3 kg./cm.$^2$, wherebelow a further reduction in pressure becomes less effective. With an absolute pressure of 0.3 kg./cm.$^2$ in the vacuum chamber the articles can be produced with less than 0.5% by volume of air.

The removal of air from the filament in the vacuum chamber is facilitated if the filament within the vacuum chamber is moved in a non-rectilinear path by passage over guide elements.

The vacuum chamber may contain impregnation liquid in which the filament is being submerged on its passage through the chamber, in which case the vacuum chamber is at the same time an impregnation chamber.

However, it is generally preferred to impregnate the filament with liquid resin prior to its introduction into the vacuum chamber, whereby the resin acts as a sealing and lubricating liquid at the place where the filament enters the vacuum chamber to seal the subatmospheric environment within the chamber from the atmospheric air around the chamber. Therefore, instead of or in addition to an impregnation bath in the vacuum chamber it is desirable to mount a separate impregnation unit for submersion of the filament therein before it passes on to the vacuum chamber.

The vacuum chamber is suitably shaped as a box having a removable closure thereon. The filament can be allowed to enter and leave the chamber between elastic sealing strips interposed between opposite edges of the lid and the box-shaped portion of the vacum chamber. Preferably, the line through which the vacuum is applied is connected to the lowest part of the vacuum chamber, so that any resin draining from the impregnated filament in the chamber is removed together with the air from the chamber. Usually the composite filament is a glass fiber filament, normally termed "roving" which is composed of a plurality of individual monofilaments. Other filaments, however, may be employed as desired, such as nylon; polyolefins (polypropylene); polyethylene terephthalate and other synthetic polymeric materials. In practice the method will normally be carried out with a plurality of such filaments in separate or bundled arrangement, the filaments being simultaneously impregnated, passed through the vacuum chamber, and wound on the mandrel. Preferably the vacuum chamber is mounted so that it can pivot on an axis being normal to an axis of rotation of the mandrel, so that during the winding operation the vacuum chamber can orient itself automatically in the direction in which the filament is wound on the mandrel. If desired, the vacuum chamber may comprise a series of parallel pins between which the filaments are guided to maintain them separated.

The invention will be further explained by way of example with reference to the accompanying diagrammatic drawing.

FIG. 1 shows a portion of a base plate **10** on which is mounted a container **11** filled with a liquid resin. The container **11** serves as an impregnation chamber for impregnation of a series of filaments **13** drawn off supply reels (not shown) and guided into and out of the container **11** over a series of guide rolls **12**. From the container **11** the filaments **13** are passed between guiding rods **23** and are then moved through a vacuum chamber **14**, formed as a rectangular box **15** having a removable closure **16**. The guide rods **23** are mounted on a bracket **24** which is connected to the vacuum chamber. The opposite edges of the box and closure of the vacuum chamber each have secured thereto a sealing strip **17** of rubber or another elastic material. The strips **17** are identically formed and extend along the full circumference of the opposite edges of the box and closure to seal the inner space within the vacuum chamber from the atmosphere around this chamber when the closure is pressed on the box with the sealing strips in opposite relationship. A flexible hose **19** is connected with one end to the closure **16** in communication with the interior of the vacuum chamber. The other end of the hose **19** is connected with a vacuum pump (not shown). Within the vacuum chamber the filaments are passed over guide rolls **18** mounted in the box **15** to cause the filaments to follow a broken path. A pressure gauge **20** is mounted on the vacuum chamber to control the subatmospheric pressure in the chamber. The differential pressure caused by the vacuum in the chamber and atmospheric pressure around the chamber firmly presses the closure **16** on the box **15**. The filaments **13** enter and leave the vacuum chamber between the two sealing strips **17**. Since the filaments **13** are impregnated before entering the vacuum chamber the impregnation liquid acts as a lubrication and sealing fluid on passage of the filaments between the sealing strip **17**. In the vacuum chamber air left in the filaments after their impregnation is removed therefrom. After leaving the vacuum chamber the filaments are directly wound on a rotating cylindrical mandrel **21** to form a tube. The filaments between the point of leaving the vacuum chamber and the point of contacting the mandrel traverse a rectilinear path, in other words, the filaments are not passed over any guiding elements which would deviate the filaments from a straight course.

During the winding operation the base plate **10** is moved reciprocatingly and parallel to the rotational axis *a* of the mandrel so that the mandrel is covered uniformly over its length with one or more layers of the filaments. Preferably the vacuum chamber **14** is mounted on the base plate **10** with a pivot **22** allowing the vacuum chamber to swing on an axis *b* which is directed normal to the axis *a* of the mandrel. The vacuum chamber **14** is then automatically oriented in the direction in which the filaments are drawn towards and by the rotating mandrel.

Apart from the illustrated type of vacuum chamber the necessary equipment for winding articles from resin impregnated filaments, including impregnation chamber and rotatable mandrel, are well known in the art and need no detailed description.

Illustrative of the invention is the following experiment.

A series of eight glass filament rovings were simultaneously impregnated in an epoxy resin bath, passed through a vacuum chamber in which an absolute pressure of 0.3 kg./cm.$^2$ was maintained, and from the vacuum chamber the filaments were drawn in a straight line to the mandrel at a speed of 50 m./min. The eight rovings were wound parallel as a band on the mandrel, and several layers of these bands were laid on top of each other closely together to form a pipe. After the resin in the pipe had been allowed to harden the material of the pipe was found to contain 0.5% by volume of air.

When the test was repeated under exactly the same circumstances but with the only difference that the rovings between the vacuum chamber and mandrel were passed over a guide roll, with the running up and running down portions of the rovings including an angle of approximately 120°, the volume of air in the pipe was 3%.

I claim as my invention:

1. A method for forming an article containing reduced entrained air prepared from a resin-impregnated filament comprising:

(1) impregnating a composite filament with a hardenable liquid resin composition prior to the introduction of said filament into a vacuum chamber,

(2) passing said impregnated filament through a vacuum chamber,

(3) reducing the amount of entrained air to less than 1% by volume by moving said impregnated filament from said vacuum chamber to where is contacts a mandrel in a substantially rectilinear direction,

(4) winding said impregnated filament on said mandrel to form an article thereon, said

(5) curing said resin in said article.

2. A method as in claim 1 wherein the filament is glass.

3. A method as in claim 1 wherein the resin is an epoxy resin.



**References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 3,068,134 | 12/1962 | Cilker et al. | 156—286 X |
| 3,258,379 | 6/1966 | Ponemon et al. | 156—175 |
| 3,480,499 | 11/1969 | Paul, Jr. | 156—382 X |


CARL D. QUARFORTH, Primary Examiner

E. E. LEHMANN, Assistant Examiner

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