



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:  
**30.07.2014 Bulletin 2014/31**

(51) Int Cl.:  
**B22C 9/10 (2006.01)**

(21) Application number: **13194178.3**

(22) Date of filing: **23.11.2013**

(84) Designated Contracting States:  
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB  
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO  
PL PT RO RS SE SI SK SM TR**  
Designated Extension States:  
**BA ME**

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(30) Priority: **23.01.2013 US 201313747653**

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(54) **Quasi self-destructive core for investment casting**

(57) A composite core for forming a passage in an investment casting mold is provided including a generally hollow structural element. The structural element is configured to deform when a force is applied to an end thereof. A rigid shell element is formed about the structural

element. The shell element extends beyond both an interior surface and an exterior surface of the structural element. The shell element is configured to shatter when the structural element deforms.

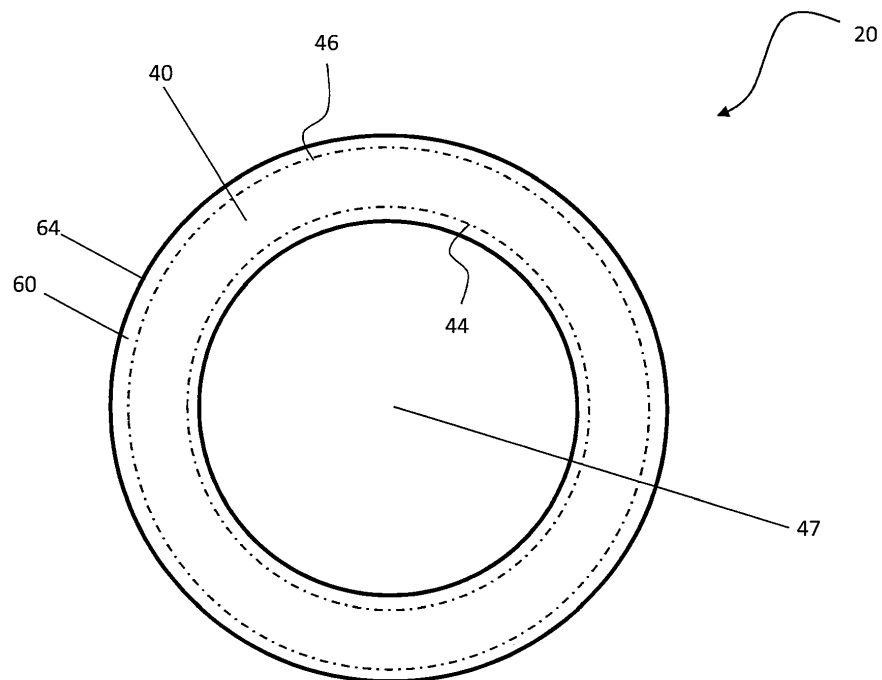


FIG. 1

## Description

**[0001]** Exemplary embodiments of the invention generally relate to investment casting, and more particularly, to a core for forming a passage in an investment casting mold.

**[0002]** Investment casting is a commonly used technique for forming metallic components having complex shapes and geometries, especially hollow components such as those used in aerospace applications for example. The production of an investment cast part generally involves producing a ceramic casting mold having an outer ceramic shell with an inside surface corresponding to the shape of the part, and one or more ceramic cores positioned within the outer ceramic shell, corresponding to interior passages to be formed within the part. Molten alloy is introduced into the ceramic casting mold and is then allowed to cool and to harden. The outer ceramic shell and ceramic core(s) are then removed to reveal a cast part having a desired external shape and hollow interior passages in the shape of the ceramic core(s).

**[0003]** In comparison to other processes, for example sand casting or permanent mold casting, investment casting provides flexibility while maintaining tight tolerances. In particular, controlled solidification investment casting (CSIC) uses rapid directional cooling to enhance microstructure and mechanical properties. CSIC, therefore, may be useful for an expanded range of applications, particularly in the aerospace industry. However, investment casting is limited by the design of passages within the mold. Unlike a sand core used in a sand casting process, the ceramic cores used in CSIC are difficult to remove or destroy without affecting the molded part. As a result, the process of designing passages severely restricts the use of CSIC for applications requiring complex cored passages.

**[0004]** According to one embodiment of the invention, a composite core for forming a passage in an investment casting mold is provided including a generally hollow structural element. The structural element is configured to deform when a force is applied to an end thereof. A rigid shell element is formed about the structural element. The shell element extends beyond both an interior surface and an exterior surface of the structural element. The shell element is configured to shatter when the structural element deforms.

**[0005]** Particular embodiments may include any of the following optional features, alone or in combination:

The rigid shell element may be integrally formed with the structural element.

The structural element may comprise a coiled wire.

A material of the structural element may be substantially identical to a material of a component to be formed from the investment casting mold.

The structural element may be generally the same size as the passage being formed.

The shell element may be formed by arranging multiple layers of slurry having particles of varying sizes, and curing the layers of slurry to form the rigid shell element.

A material of the slurry may be substantially identical to a material of the investment casting mold.

The material of the slurry may be generally ceramic.

**[0006]** According to one embodiment of the invention, a preform for making a composite core configured for use in an investment casting mold is provided including a generally hollow structural element. The structural element is configured to deform when a force is applied to an end thereof. A core element having a shape is positioned adjacent an interior of the structural element. The core element is configured to melt when heat is applied to the preform such that the structural element retains the shape of the core element. Particular embodiments may include any of the following optional features, alone or in combination:

The structural element may be formed from coiled wire.

The core element may be a wax element.

The core element may be a metallic mesh or foil.

The core element may be coupled to the interior surface of the structural element.

The preform further may comprise multiple layers of slurry having particles of varying sizes arranged about the structural element.

The slurry may extend from a surface of the core element adjacent the interior surface to beyond an exterior surface of the structural element.

A material of the slurry may be substantially identical to a material of the investment casting mold.

**[0007]** According to yet another embodiment of the invention, a method for manufacturing a composite core for forming a passage in an investment casting mold is provided including arranging a core element adjacent an interior surface of a generally hollow structural element to form a preform. Slurry having particles of varying sizes is layered about the structural element. Heat is then applied to the preform.

**[0008]** Particular embodiments may include any of the following optional features, alone or in combination:

The slurry may cure into a rigid shell element during the firing of the preform.

The core element may melt away from the structural element during the firing of the preform.

The slurry may extend from adjacent a surface of the core element to beyond an outer surface of the structural element.

**[0009]** According to another embodiment, a method of forming a passage in a cast component is provided including arranging a composite core into an interior of a mold. Material of the component is then poured into the mold. The material is cured to form the component. A force is then applied to an exposed portion of the composite core such that the composite core deforms inside the component.

**[0010]** Particular embodiments may include any of the following optional features, alone or in combination:

The composite core may include a structural element and a rigid outer shell element formed about the structural element such that deformation of the structural element causes the shell element to break.

**[0011]** The subject matter, which is regarded as the invention, is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other features, and advantages of the invention are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a cross-sectional view of a composite core according to an embodiment of the invention;

FIG. 2 is a cross-sectional view of a preform according to an embodiment of the invention;

FIG. 3 is side view of a structural element of the preform according to an embodiment of the invention;

FIG. 4 is a perspective view of a preform including layers of slurry according to an embodiment of the invention; and

FIG. 5 is a cross-sectional view of a component formed from an investment casting mold having a passage formed by a composite core according to an embodiment of the invention.

**[0012]** The detailed description explains embodiments of the invention, together with advantages and features, by way of example with reference to the drawings.

**[0013]** With reference now to FIG. 1, a cross-section of a composite core 20 for forming a passage in an investment casting mold is illustrated. When inserted into

a mold (not shown), the composite core 20 includes a generally hollow structural element 40 and a shell element 60 arranged about the exterior 46 of the structural element 40. The structural element 40 is configured to deform, and therefore break the shell element 60 coupled thereto, when a force is applied to an end 42 (FIG. 2) of the structural element 40.

**[0014]** The composite core 20 is formed using a preform 30, illustrated in more detail in FIG. 2. The preform 30 includes the generally hollow structural element 40 as well as a core element 50 positioned adjacent the interior surface 44 of the structural element. The structural element 40 may be pre-formed and the core element 50 inserted into the hollow center 47 of the structural element 40, or alternatively, the structural element 40 may be formed around the exterior of the core element 50.

**[0015]** An example of the structural element 40, shown in FIG. 3, is the general size of a passage being formed within an investment casting mold. The material used to form the structural element 40 is selected based on the material of the component being cast. For example, the material of the structural element 40 may be the same alloy as the component being cast. Exemplary metallic materials include, but are not limited to, steel, copper, and nickel for example. In the illustrated embodiment, the structural element 40 is fabricated from a coiled wire 48 such that the structural element 40 behaves in a manner similar to a tensile or compression spring. The specifications of the wire 48 are selected to facilitate contact between the structural element 40 and the core element 50, as well as the ultimate breakdown of the composite core 20. As a result, the cross-section of the wire 48 may be any of a variety of shapes, such as circular, square, triangular, or trapezoidal for example, and the coils of the wire 48 need not be evenly spaced as shown. Considerations for the strength and ductility of the structural element 40 include the ability of the structural element 40 to support itself once coupled to the core element 50, the ability of the structural element 40 to support the composite core 20 once the shell element 60 is formed, and the ability of the structural element 40 to deform when a force is applied thereto.

**[0016]** The core element 50 acts as a base to support the outer shell element 60 as it is formed about the structural element 40. The core element 50 is made from a material configured to melt during the formation of the composite core 20, prior to the casting process, or during the casting process. In one embodiment, the core element 50 is a wax core, the contour of which is substantially similar to a passage being formed in a mold. In another embodiment, the core element 50 is a metallic mesh or foil, for example made from the same material as the working metal to be poured into the investment casting mold. The metallic mesh or foil 50 is bonded to the interior surface 44 of the structural element 40, such as through a brazing process for example. The gauge of the foil or mesh 50 is selected to support the shell element 60 as

it is formed about the structural element 40. Once the metallic mesh or foil 50 and the structural element 40 are coupled, the contour of the preform 30 may be altered to a desired shape.

**[0017]** After the preform 30 is assembled, the outer shell element 60 is formed, for example through a shelling process. As illustrated in FIG. 4, the preform 30 is coated with a slurry 62 having particles of varying sizes. In one embodiment, the material of the slurry 62 used to form the outer shell 60 is substantially identical to the material used to form the investment casting mold, such as ceramic for example. Alternatively, the material of the slurry 62 may be modified to facilitate breakdown of the outer shell 60 when a force is applied to the structural element 40. The slurry 62 is arranged in a plurality of layers extending outwardly from the surface 52 of the core element 50 to at least the outer surface 46 of the structural element 40 such that the structural element 40 and the shell element 60 are integrally formed. In one embodiment, for example where the core element 50 is a wax core, the surface 52 of the core element 50 may be dipped in the slurry 62 before being inserted into the structural element 40, to aid in the formation of an inner surface of the shell element 60. As a result, slurry 62 is positioned about the structural element 40 such that when the composite core 20 is formed, the shell element 60 extends beyond both the inner diameter 44 and the outer diameter 46 of the structural element 40 (see FIG. 1).

**[0018]** After layering the slurry 62 about the structural element 40, the slurry 62 is hardened, such as by firing the preform 30 in an oven or kiln for example. Heat causes the slurry 62 to strengthen and solidify into a cured, rigid, shell element 60. The core element 50 is designed to melt, or otherwise degrade during the making of the composite core 20, or during the formation of the finished component. Therefore, application of heat transforms the preform 30 to a composite core 20, having a generally hollow cross section that allows the structural element 40 and the shell element 60 to be easily removed. When the composite core 20 is formed, the outer surface 64 of the shell element 60 may be substantially uniform, or alternatively, may include slight variations, such as waves or grooves for example.

**[0019]** Referring now to FIG. 5, a component 80 formed using an investment casting mold and at least one composite core 20 is illustrated. To remove the composite core 20 from a passage 82 of the component 80, a portion of the shell element 60 is broken to reveal an end 42 of the structural element 40. A force is then applied to the exposed end 42, causing the structural element to deform 40. Because the shell element 60 is formed about the structural element 40, deformation thereof causes the brittle shell element 60 to shatter and break away from coiled wire 48 of the structural element 40. The pieces of the shell element 60 and the structural element 40 may then be easily removed from the passage 82 of the component 80.

**[0020]** The composite core 20 may be constructed to

create a complex cored passage within an investment casting mold, thereby expanding the range of applications to which controlled solidification investment casting (CSIC) may be applied. Further, by incorporating waves or grooves into the outer surface 64 of the shell element 60, the passage 82 can have specific patterns such as rifling. The rapid and directional solidification of the investment casting process will result in high quality castings having enhanced microstructures. Because a significant portion of the CSIC process is automated, more stringent quality control measures may be implemented to improve and stabilize the casting process. Forming parts that were previously too complex using a CSIC process will reduce both scrap rates and production cycle time.

**[0021]** While the invention has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the invention is not limited to such disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the invention. Additionally, while various embodiments of the invention have been described, it is to be understood that aspects of the invention may include only some of the described embodiments. Accordingly, the invention is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

**[0022]** This invention was made with Government support under N00019-06-C-0081 awarded by the Department of the Navy. The Government has certain rights in this invention

## Claims

1. A composite core (20) for making a passage in an investment casting mold comprising:
  - a generally hollow structural element (40) configured to deform when a force is applied to an end thereof; and
  - a rigid shell element (60) formed about the structural element (40), the shell element (60) extending beyond an interior surface (44) and an exterior surface (46) of the structural element (40), the shell element (60) being configured to shatter when the structural element (40) deforms.
2. The composite core (20) according to claim 1, wherein the rigid shell element (60) is integrally formed with the structural element (40).
3. The composite core (20) according to claim 1 or 2, wherein the structural element (40) comprises a coiled wire (48).

4. The composite core (20) according to any of claims 1 to 3, wherein a material of the structural element (40) is substantially identical to a material of a component to be formed from the investment casting mold.
5. The composite core (20) according to any of claims 1 to 4, wherein the structural element (40) is generally the same size as the passage being formed.
6. The composite core (20) according to any of claims 1 to 5, wherein the shell element (60) is formed by arranging multiple layers of slurry (62) having particles of varying sizes, and curing the layers of slurry to form the rigid shell element (60).
7. The composite core (20) according to claim 6, wherein a material of the slurry (62) is substantially identical to a material of the investment casting mold.
8. The composite core (20) according to claim 6 or 7, wherein the material of the slurry (62) is generally ceramic.
9. A preform (30) for making a composite core (20) according to any of the previous claims, the composite core (20) configured for use in an investment casting mold, the preform (30) comprising:
  - a generally hollow structural element (40) configured to deform when a force is applied to an end thereof; and
  - a core element (50) having a shape and positioned adjacent an interior surface (44) of the structural element (40), the core element (50) being configured to melt when heat is applied to the preform (30) such that the structural element (40) retains the general shape of the core element (50).
10. The preform (30) according to claim 9, wherein the structural element (40) is formed from coiled wire (48); and/or the core element (50) is a wax element; and/or the core element (50) is a metallic mesh or foil.
11. The preform (30) according to claim 9 or 10, wherein the core element (50) is coupled to the interior surface (44) of the structural element (50).
12. The preform (30) according to any of claims 9 to 11, further comprising:
  - multiple layers of slurry (62) having particles of varying sizes arranged about the structural element (40); the slurry (62) particularly extending from a surface (52) of the core element (50) adjacent the interior surface (44) to beyond an exterior surface (46) of the structural element (40);
13. A method for manufacturing a composite core (20) for forming a passage in an investment casting mold, comprising:
  - arranging a core element (50) adjacent an interior surface (44) of a generally hollow structural element to form a preform;
  - layering slurry (62) having particles of varying sizes about the structural element (40) of the preform (30); and
  - applying heat to the preform (30).
14. The method according to claim 13, wherein the slurry (62) cures into a rigid shell element (60) during the firing of the preform (30); and/or the core element melts (50) away from the structural element (40) during the firing of the preform (30); the slurry (62) particularly extending from adjacent a surface (52) of the core element (50) to beyond an exterior surface (46) of the structural element (40).
15. A method for forming a passage in a cast component comprising:
  - manufacturing a composite core (20) according to claim 14;
  - arranging the composite core (20) into an interior of a mold;
  - pouring material of the component into the mold;
  - curing the material to form the component;
  - applying a force to an exposed portion of the composite core (20) such that the composite core (20) deforms inside the component.

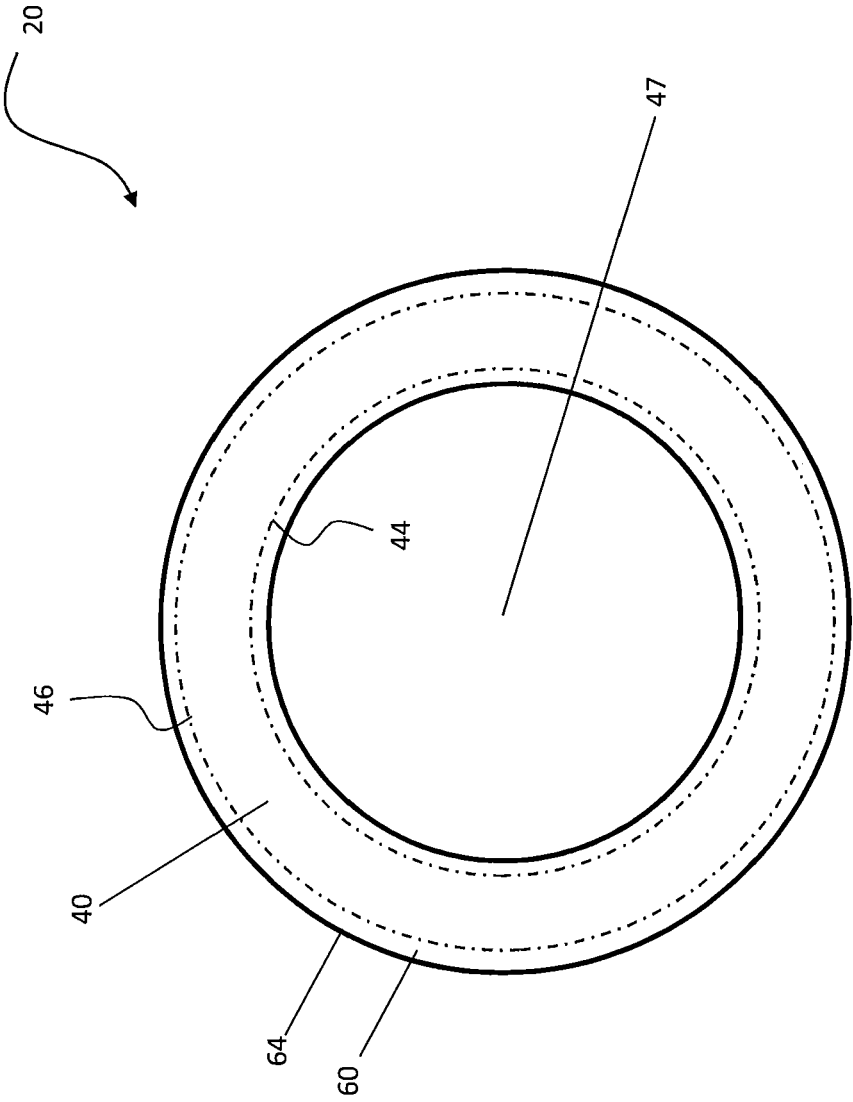


FIG. 1

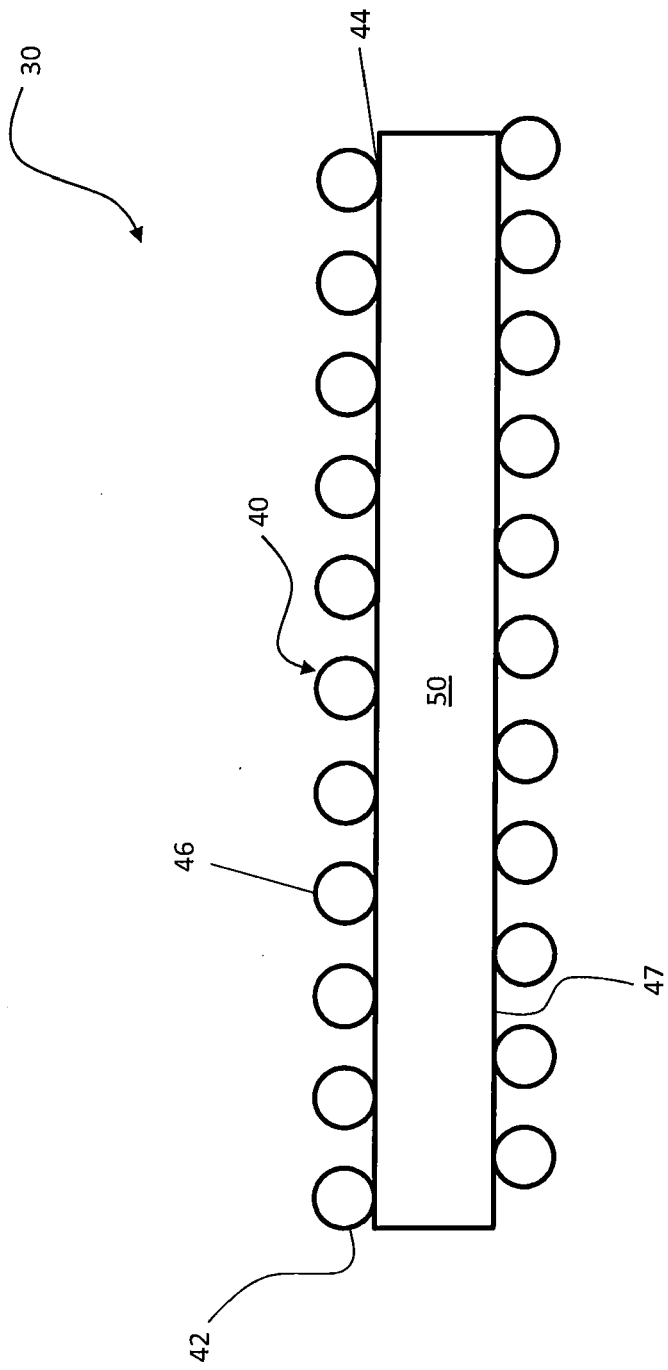


FIG. 2

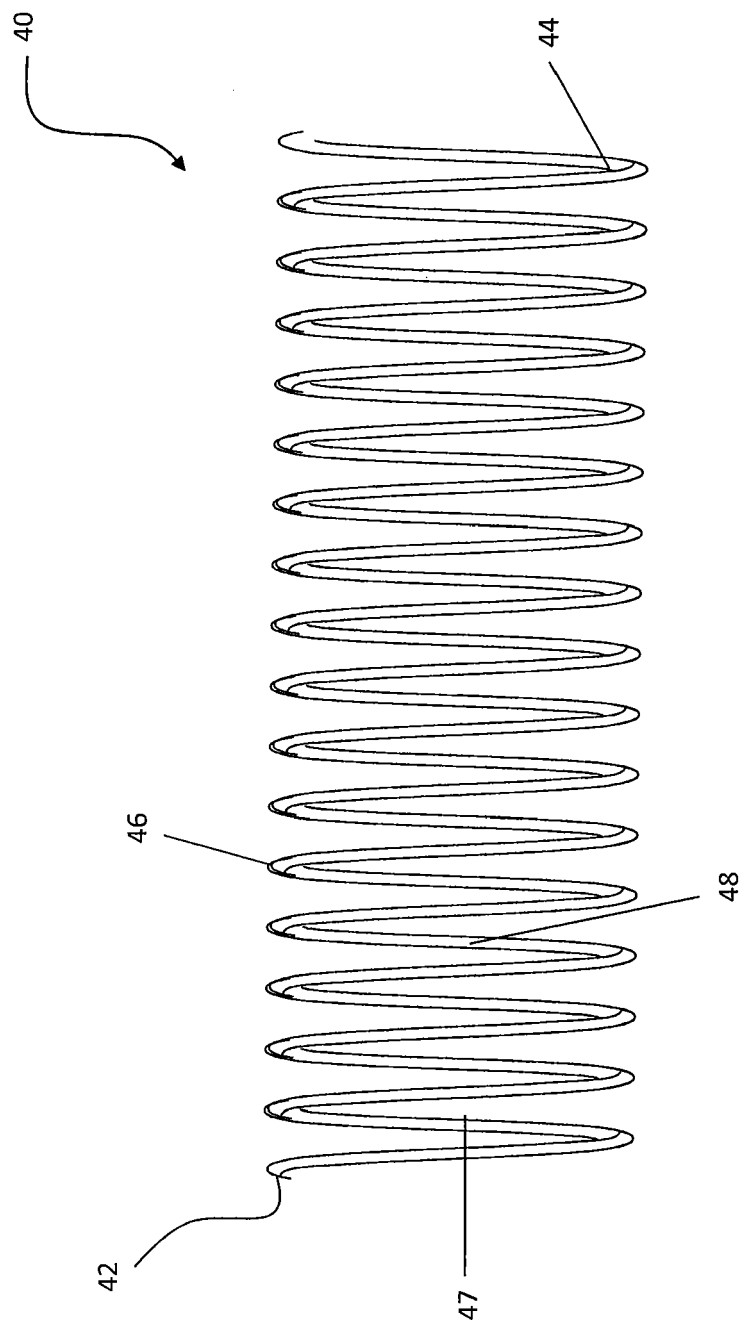


FIG. 3

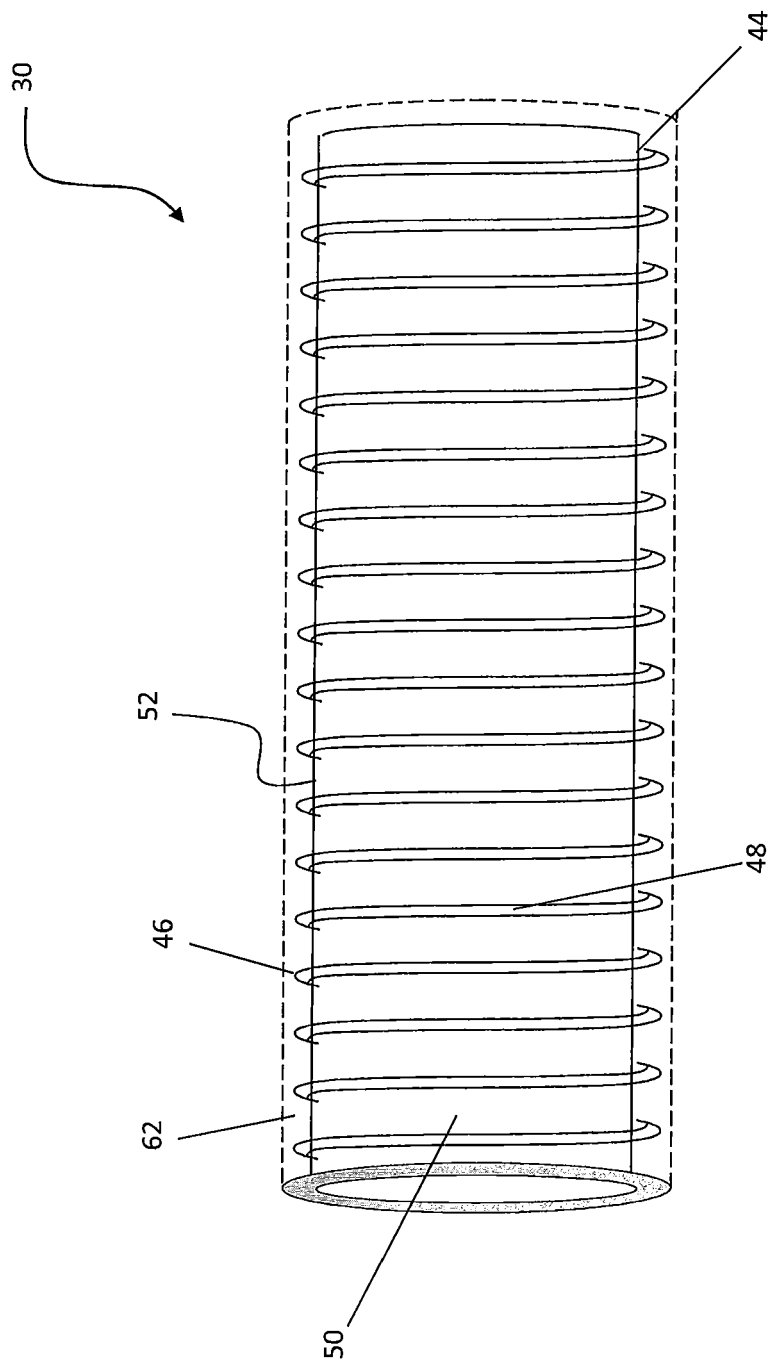


FIG. 4

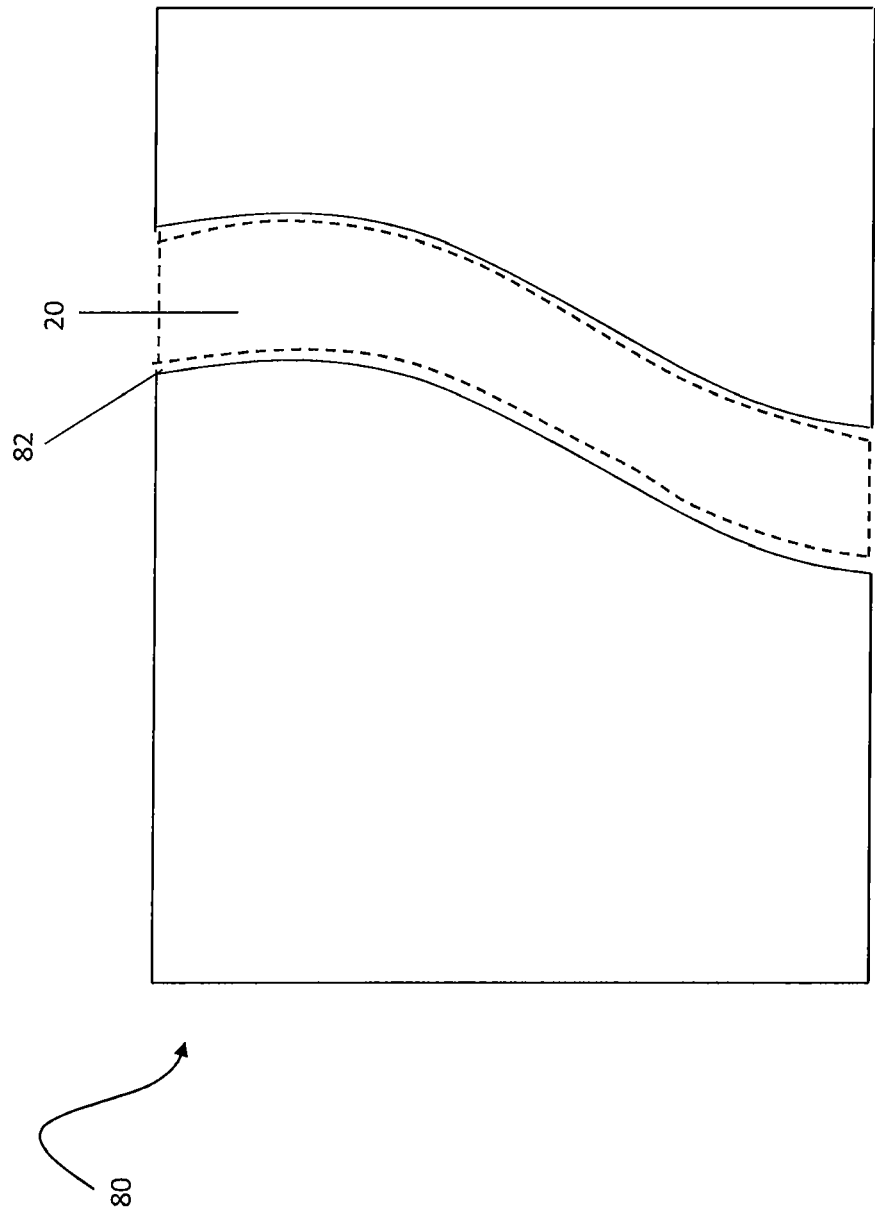


FIG. 5