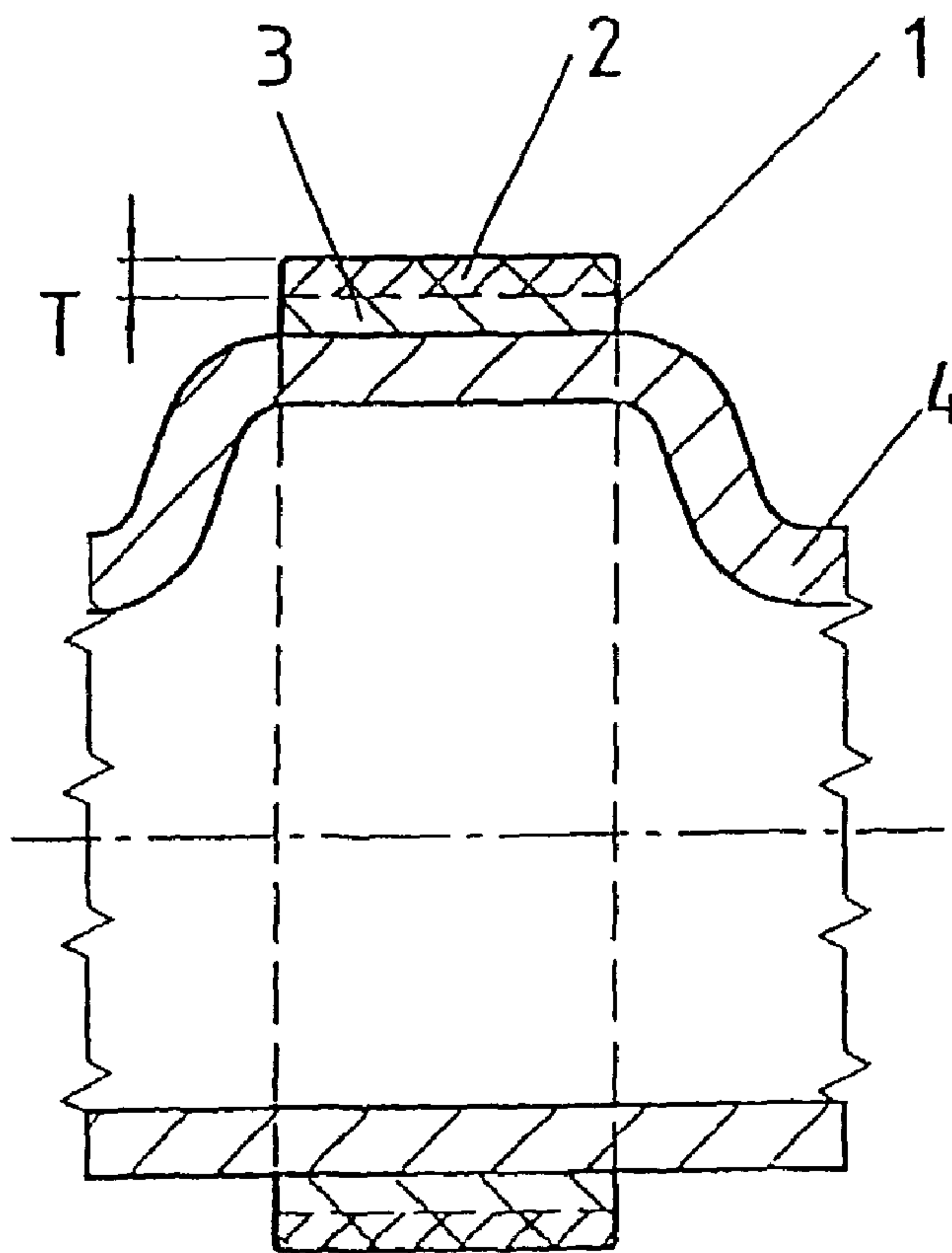




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(54) Titre : PROCÉDE POUR RELIER DES ELEMENTS A DES ARBRES CREUX, DE PREFERENCE POUR PRODUIRE
 DES ARBRES A CAMES, ET ARBRE A CAMES AINSI PRODUIT
 (54) Title: METHOD FOR LINKING ELEMENTS TO HOLLOW SHAFTS, PREFERABLY FOR PRODUCING
 CAMSHAFTS, AND RESULTING CAMSHAFT



(57) Abrégé/Abstract:

Standard camshafts, produced by an internal high-pressure forming method (IHU) and whereof the cam rings (1) are fixed on a hollow shaft by force-closure and form-closure, said rings being produced in accordance with their function in a separate process,

(57) **Abrégé(suite)/Abstract(continued):**

have the drawback that the cam rings are deformed, mainly in the tip zone (2) of the cams, can result in cracking or breaking. The invention is characterized in that the cam ring is produced in terms of its material properties such that in its outer zone (3) the material is hard and resilient over a specific length while exhibiting nevertheless low plastic deformation, the zone located beneath being relatively flexible and plastically deformable. The inventive camshafts are used almost exclusively in motor vehicles engines.

ABSTRACT

Standard camshafts, produced by an internal high-pressure forming method (IHU) and whereof the cam rings (1) are fixed on a hollow shaft by force-closure and form-closure, said rings being produced in accordance with their function in a separate process, have the drawback that the cam rings are deformed, mainly in the tip zone (2) of the cams, can result in cracking or breaking. The invention is characterized in that the cam ring is produced in terms of its material properties such that in its outer zone (3) the material is hard and resilient over a specific length while exhibiting nevertheless low plastic deformation, the zone located beneath being relatively flexible and plastically deformable. The inventive camshafts are used almost exclusively in motor vehicles engines.

Method for Linking Elements to Hollow Shafts, Preferably for Producing Camshafts, and Resulting Camshaft

5 The invention relates to a method for joining components, in particular individual cam rings, with a hollow shaft to form a camshaft produced in conformity with the internal high-pressure forming process (IHPF) process). Furthermore, the invention relates to a hollow shaft on which components, preferably cam rings, are mounted in a force- and form-closing manner. A preferred field of application
10 is the manufacture of camshafts, especially for use in motor-vehicle engines.

It is known to produce camshafts according to the IHPF process by placing the hollow shaft and mounted thereon components such as cam rings and drive elements according to their function into an IHPF tool. The internal pressure produced causes the shaft to expand and in this way connect the components
15 with the shaft in a force- und form-closing manner (DE 199 09 184 A1; DE 199 32 810 A1). The cam rings as well as other components are manufactured with the help of another process and are sized and possess material properties, i.e. wear resistance, conducive to their subsequent application. Drive elements, for example gearwheels, are attached in the same way. By the application of the
20 IHPF process the shaft first undergoes elastic and then plastic deformation which will result in the components to be accurately fixed and secured.

However, caused by the internal pressure also the component to be mounted, for example the cam ring, will undergo an elastic deformation. The elastic deformation of the cam ring spans the manufacturing tolerances existing
25 between the outer contour of the cam ring and the inner contour of the cam profile of the IHPF tool.

This method of adapting the properties of the cam ring only to its subsequent function is associated with the drawback that the permissible deformation of the cam ring may be exceeded and through the formation of an incipient crack breakage or initial damage may be encountered which during subsequent operation will result in a camshaft failure. This will occur if the cam ring has, for example, been incorrectly heat treated. Consequently, it is to be feared that the damage will only occur after the camshaft has been in use in the engine for a longer period of time. The same may be encountered with gearwheels or other drive elements mounted with the aid of the IHPF process. It has also been determined that a higher risk of breakage exists particularly at the cam ring locations where said ring has suffered maximum stresses during the IHPF process, which is the area ahead of and after the cam tip, especially in the radii transitions and at the cam tip.

It is, therefore, the object of the invention to provide a method by means of which components, especially cams, are joined according to the known IHPF process on a hollow shaft in a force- and form-closing manner such that the cam rings have an admissible residual expansion of $\geq 0.5\%$ as is required to bridge the expansion of the cam ring and the manufacturing tolerances in the cam ring and/or tool due to the internal pressure. It shall thus be avoided that breakage or incipient damage occurs that may impair a future use, in particular during continuous or long-term operation. The new method shall comprise a combination of processes known per se which are economical and require little expenditure in terms of equipment. A further objective of the invention relates to the provision of a camshaft that is cost-effective, features a high degree of reliability and is suited for use in automotive engines. It shall be made of material of customary quality. Camshafts shall be produced that will cause hardly any consequential damage to the engine.

In accordance with the invention the objective relating to the method for the linking of components to a hollow shaft, preferably a camshaft, is met in conformity with claims, 1, 2 or 3. Advantageous configurations of the method are described in claims 4 to 9. The objective relating to the camshaft is reached through the characteristics of claim 10; further configurations or embodiments are described under claims 11 to 20.

In accordance with the invention the known IHPF process is employed. In a first step of the process the components, in particular the cam rings that are to be joined with the shaft in a force- and form-closing manner, are manufactured so as to attain their form (contour) required for their function. For this purpose a material is employed that after hardening still has a permissible residual expansion of $\geq 0.5\%$, i.e. in hardened state the material, on its inside and outside and aside from its elastic deformability, may possess to a minor extent a permissible plastic deformability. Most suited for this purpose are low-alloyed steel grades, for example spring steel (58 CrMo V4) that after heat treatment still offers permissible residual expansion characteristics but also has an excellent wear resistance in continuous operation.

These prefabricated cam rings or other components are placed together with the hollow shaft in the IHPF tool in a manner to suit the respective function, and in a second process step said hollow shaft is expanded through axial pressure exerted within the shaft; as a result, the cam rings and/or other components are connected with the hollow shaft in a force- and form-closing manner.

In a second embodiment of the invention the cam rings or components are subjected to surface hardening after they have been manufactured so as to suit their respective function, that is the generation of an outer contour of the cam face and an inner contour. This will enable the outer zones subject to wear to become hard and elastically deformable whereas the inner contour on the cam ring side facing the shaft that due to the exerted internal pressure will expand remains soft to a certain extent, that is will be plastically deformable.

Surface hardening is effected by employing, for example, case hardening, nitriding, induction hardening processes or through the effect of a charge carrier beam.

In another embodiment of the invention the two methods mentioned above, the manufacture of the cam rings of steel that meets the prerequisites to attain the required residual expansion in the hardened state and the surface hardening of the components or cam rings, are combined in conjunction with the IHPF

process. For this purpose, the first process steps in each case are carried out one after the other followed by the second process step.

Another embodiment of the invention provides for the cam ring to comprise of two materials, i.e. on an inner ring consisting of a soft, plastically deformable material a ring made of a hard and elastic material is mounted. Both rings are firmly connected with each other, said connection may, for example, be brought about by press- or shrink-fitting processes. The cam ring thus consists of two zones so to speak, a design arrangement which in the embodiment described earlier is attained by surface hardening.

This design solution can furthermore be varied by providing a dissimilar cam ring thickness, i.e. have an increased thickness in the area of the cam tip. In this way the thickness in the area of the cam tip may be attained by providing an inner ring of varying thickness, i.e. a ring thicker in the area of the cam tip, and an outer ring of uniform thickness or by providing an inner ring of uniform thickness and an outer ring of varying thickness. The outer ring is always hard and resistant to wear.

It may also be expedient for all embodiments of the invention to mount onto the hollow shaft a round symmetrical ring of soft material, expediently similar to that of the hollow shaft or even softer, having the same thickness and mount on this ring the cam ring having its contour formed so as to suit the required function so that by applying the IHPF process the round inner ring is deformed together with the hollow shaft to such an extent that the inner contour of the outer ring, the cam ring, is reached. By means of the IHPF process the hollow shaft, the round ring mounted onto said shaft and the superimposed cam ring are thus connected in a force- and form-closing manner. The outer ring consists of a hard material whose permissible residual expansion is $\geq 0.5\%$; aside from its elastic deformability said ring must only have a permissible plastic deformability that is of minor extent. However, it is also possible to subject the outer ring to a surface hardening process.

Surprisingly, it has been found that the shortcomings in the state of the art could be eliminated by the cam rings, manufactured and/or treated according to the

invention, having characteristics to the effect that the stresses building up in the cam ring as a result of the maximum internal pressure exerted in the course of the IHPF process are lower than those experienced in the known through-hardened cam rings or rings consisting of a material that possesses this hardness throughout.

In the manufacture of the cam rings the impairment mechanism is further alleviated through an appropriate material selection including hardening and heat treatment by surface hardening during which additional internal compressive stresses are created in the hardened layer; in this case the cam rings as well as other components manufactured according to the method will withstand much higher loads and strains.

Significant to all embodiments of the method according to the invention is that the cam ring across its material thickness area has different material characteristics. The top layer which is mechanically strained during operation must be hard and elastically deformable whereas the layer below it has to be deformable both plastically and elastically. This will ensure that even in the event damage occurs no continuous or straight-through cracks can develop but in exceptional cases local damage only. Such spall-off will never result in a sudden destruction of an engine.

The camshaft manufactured according to the inventive method and consisting of an hollow shaft expanded through the application of the IHPF process and onto which cam rings and also other components such as gearwheels or coupling and drive elements are mounted has been joined with the cam rings and other components in a force- and form-closing manner, with said cam rings being made of a material that after a hardening treatment aside from its elastic deformability still has a minor permissible plastic deformability with a surface being hard and wear-resistant.

In a second embodiment the surface of the cam ring has been subjected to a surface hardening treatment applied to a defined thickness. This will render the top layer to be elastically deformable while the layer underneath will be plastically deformable. Both embodiments as they relate to the manufacture of

the cam ring may also be combined so as to offer advantages in terms of improved usage properties.

Another embodiment eventually provides that the hard and elastically deformable top layer of the cam ring generated according to the methods first mentioned above is produced in such a manner that it consists of two materials, one hard and elastically deformable and one soft and plastically deformable. Expediently, the connection of these two rings is to be made up before placing them into an IHPF press.

Furthermore, a beneficial design of the camshaft is provided in that the thickness of the cam rings differs in terms of the area of the cam tip being thicker. The zone of the material thickness treated by surface hardening remains equally thick over the entire circumference of the cam ring.

The method according to the invention may also be employed for other applications or the manufacture of other products, that is in all cases where components or elements have to be joined in a force- und form-closing manner with a thin-walled tube by means of the IHPF process.

Based on an application example a camshaft manufactured in accordance with the invention is described hereinafter.

The following is shown in the pertinent drawing:

- 20 Fig. 1: shows a cross section through a camshaft in the area of a cam of identical wall thickness,
- Fig.2: shows a longitudinal section through a camshaft,
- 25 Fig.3: shows a cross section through a camshaft in the area of a cam consisting of two materials and having different wall thicknesses.

In Fig. 1 and 2 the cam rings 1 are manufactured according to a separate known mechanical process with their contours formed to suit the respective function. For this purpose material 58 CrMoV6 is used. Following this the cam rings 1 are surface hardened in a known manner. This hardening process is controlled such that in a depth T a hardened layer 2 develops that is elastically deformable and still permits the material to be slightly plastically deformed. The area 3 located below layer 2 remains non-hardened, that is it can be deformed both plastically and elastically. The cam ring 1 is mounted on a hollow shaft in a force- and form-closing manner with the aid of the known IHPF process. The hollow shaft 4, originally a tube, consists of a rotationally symmetrical material that is plastically deformable.

The area where deficiencies occurred through crack formation in processes according to prior art has been marked 5 and is eliminated by the method in accordance with the present invention.

The cam rings 2 in Fig. 3 consist of an inner ring 6 directly mounted onto hollow shaft 4, said ring being made of a soft, plastically deformable material. In the area of the cam tip 7 the ring is considerably thicker than in its remaining portions. On this ring 6 an existing ring 8 of invariable thickness is arranged that consists of a hard, elastically deformable material. Its outer contour has been designed so as to suit the respective function.

Both rings 6 and 8 are joined with each other before being placed into the IHPF tool in a force- and form-closing manner, for example by a shrink-on technique.

Claims

1. A method for the linking of components to hollow shafts in the production of a camshaft wherein, in a first process step the components are manufactured so as to generate their function-related contour, with a hardenable material being used for this purpose which, aside from its elastic deformability after hardening, still has a permissible plastic deformability of a minor extent, wherein, these components together with the hollow shaft to be deformed are placed into an IHPF tool to suit the respective function, and wherein, in a second process step, through the application of the IHPF process and due to the internal pressure exerted the components are joined to the hollow shaft in a force- and form-closing manner, characterized in that the hardenable material has a permissible residual expansion of $\geq 0.5\%$.
2. A method for the linking of components to hollow shafts in the production of a camshaft wherein, in a first process step, the components are manufactured so as to generate their function-related contour, with the contact faces of the components being subsequently subjected to a surface-hardening process, wherein these components, together with the hollow shaft to be deformed, are placed into an IHPF tool to suit the respective function, and that, in a second process step, through the application of an IHPF process and due to the internal pressure exerted, the components are joined to the hollow shaft in a force- and form-closing manner, characterized in that after surface-hardening the surface of the components has a permissible residual expansion of $\geq 0.5\%$.
3. A method for the linking of components to hollow shafts in the production of a camshaft wherein, in a first process step, the components are cam rings manufactured so as to generate their function-related contour as two individual rings of different material

connected to each other in a force- and form-closing manner with the material of the outer ring being hard and elastic and that of the inner ring being soft and plastically deformable, wherein these components, together with the hollow shaft to be deformed are placed into an IHPF tool to suit the respective function, and that, in a second process step, through the application of an IHPF process and due to the internal pressure exerted, the components are joined to the hollow shaft in a force- and form-closing manner, characterized in that the material of the outer ring has a permissible residual expansion of $\geq 0.5\%$.

4. A method for the joining of components to a hollow shaft according to claim 1, characterized in that the surface of the components, in particular the contact face of the cams, is surface-hardened, and the second process step is carried out thereafter.

5. A method according to either one of claims 2 and 4, characterized in that the surface hardening process is selected from the group of surface hardening processes consisting of: induction hardening; case hardening; nitriding; and, charge carrier beam hardening.

6. A method according to claim 3, characterized in that the inner ring in the area of the cam tip is thicker and the outer ring has a uniform thickness.

7. A method according to claim 3, characterized in that the outer ring in the area of the cam tip is thicker and the inner ring has a uniform thickness.

8. A method according to any one of claims 3, 6 and 7, characterized in that the inner ring and the outer ring are joined to each other by means of a joining process selected from the group of joining processes consisting of: shrink-on joining and press-fit joining.

9. A camshaft manufactured according to the method of any one of claims 1 to 4, wherein the components are made with appropriate contours in a separate process, which

components are mounted onto a hollow shaft by an IHPF process in a force- and form-closing manner, and wherein the components have a defined thickness area on their surface that is hard and elastic, and to a minor extent plastically deformable, with the area below being plastically deformable, characterized in that the defined thickness area has a permissible residual expansion of $\geq 0.5\%$.

10. A camshaft according to claim 9, wherein the components are cam rings, and wherein, when the manufacturing process is completed, are hardened in their function-related form.

11. A camshaft according to claim 9, wherein the components are cam rings, and wherein, when the manufacturing process is completed, are surface-hardened in their function-related form.

12. A camshaft according to claim 9, wherein the components are cam rings consisting of two rings joined with each other in a force- and form-closing manner.

13. A camshaft according to claim 12, wherein the two rings consist of different materials, with the inner ring being made of a soft, plastically deformable material and the outer ring being made of a hard, elastic material.

14. A camshaft according to either of claim 12 and 13, wherein the inner ring in the area of the cam tip is thicker, and the outer ring has a uniform thickness.

15. A camshaft according to either of claim 12 and 13, wherein the outer ring in the area of the cam tip is thicker and the inner ring has a uniform thickness.

16. A camshaft according to any one of claims 9 to 11, wherein the cam rings have a varying wall thickness in that the area of the cam tip is thicker.

17. A camshaft according to any one of the claims 13 and 14, wherein the inner ring is only a volume-filling segment between the outer ring and hollow shaft in the area of the cam tip.

18. A camshaft according to any one of the claims 9 to 17, wherein a ring of uniform thickness of a material which is the same hardness as the hollow shaft, is mounted on the hollow shaft in the area of a cam ring, and wherein the cam ring is mounted on this ring, said cam ring consisting of a material the surface of which has been surface hardened.

19. A camshaft according to any one of the claims 9 to 17, wherein a ring of uniform thickness of a material which is the same hardness as the hollow shaft, is mounted on the hollow shaft in the area of a cam ring, and wherein the cam ring is mounted on this ring, said cam ring consisting of a hard, elastic material.

20. A camshaft according to any one of the claims 9 to 17, wherein a ring of uniform thickness of a material which is the same hardness as the hollow shaft, is mounted on the hollow shaft in the area of a cam ring, and wherein the cam ring is mounted on this ring, said cam ring comprising two rings of different material which are connected to each other.

21. A camshaft according to any one of the claims 9 to 17, wherein a ring of uniform thickness of a material which is softer than the hollow shaft, is mounted on the hollow shaft in the area of a cam ring, and wherein the cam ring is mounted on this ring, said cam ring consisting of a material the surface of which has been surface hardened.

22. A camshaft according to any one of the claims 9 to 17, wherein a ring of uniform thickness of a material which is softer than the hollow shaft, is mounted on the hollow

shaft in the area of a cam ring, and wherein the cam ring is mounted on this ring, said cam ring consisting of a hard, elastic material.

23. A camshaft according to any one of the claims 9 to 17, wherein a ring of uniform thickness of a material which is softer than the hollow shaft, is mounted on the hollow shaft in the area of a cam ring, wherein the cam ring is mounted on this ring, with the cam ring comprising two rings of different material which are connected to each other.

24. A camshaft according to claim 9, wherein the further components are selected from the group of components consisting of gearwheels, sprockets and force-transmitting functional elements that possess, over a defined thickness from the root circle towards the inside of the elastically deformable layer.

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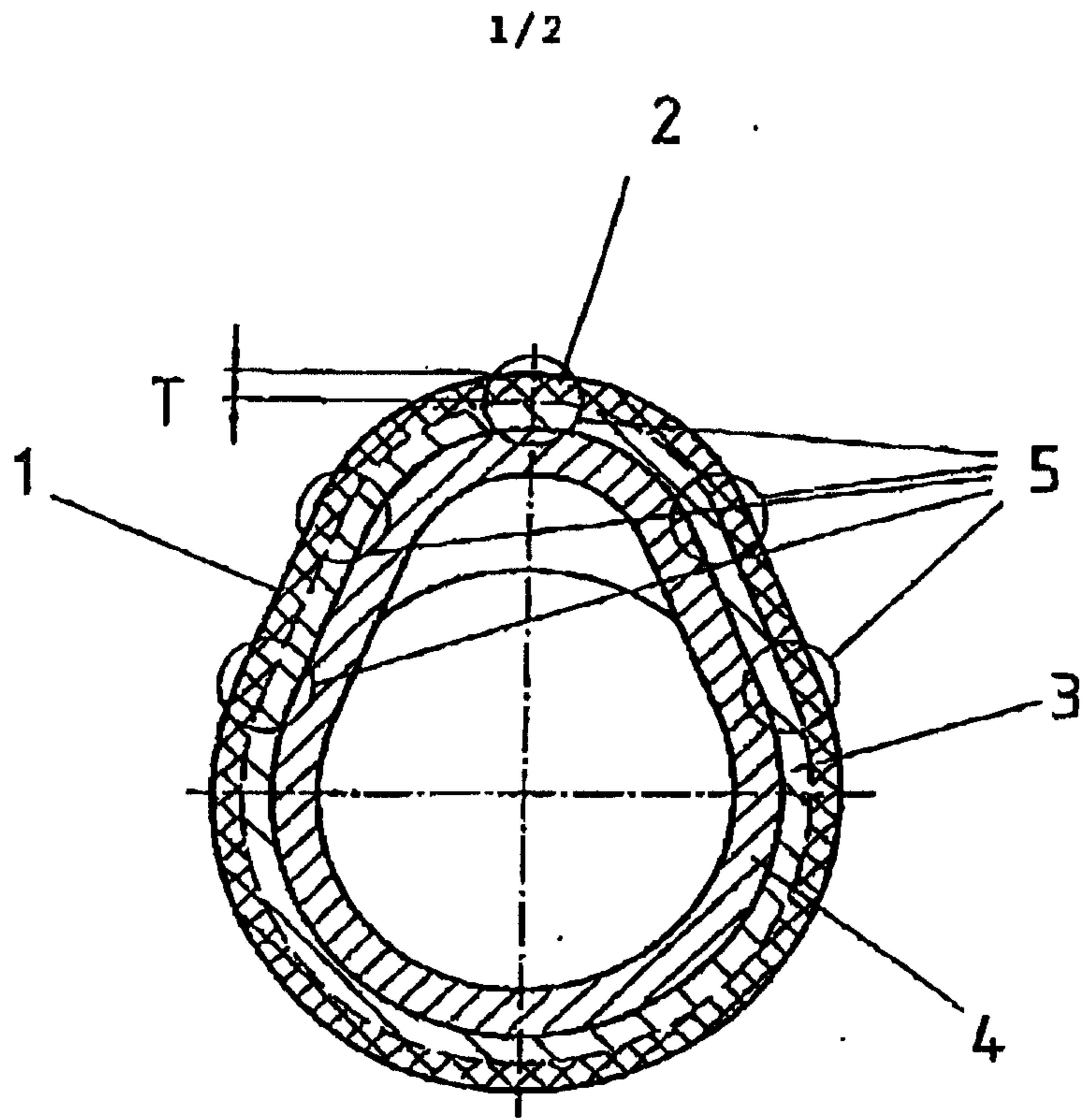


Fig. 1

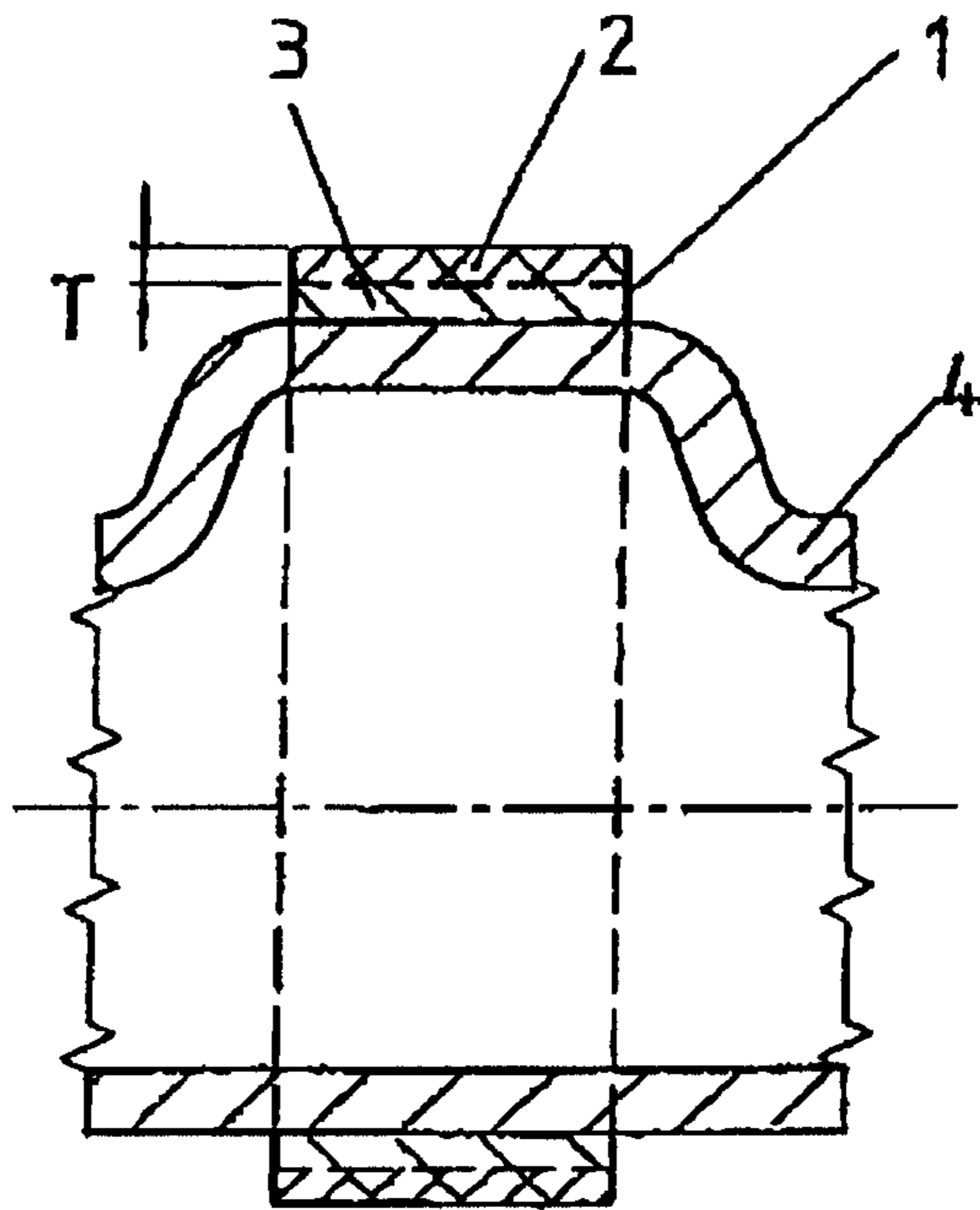


Fig. 2

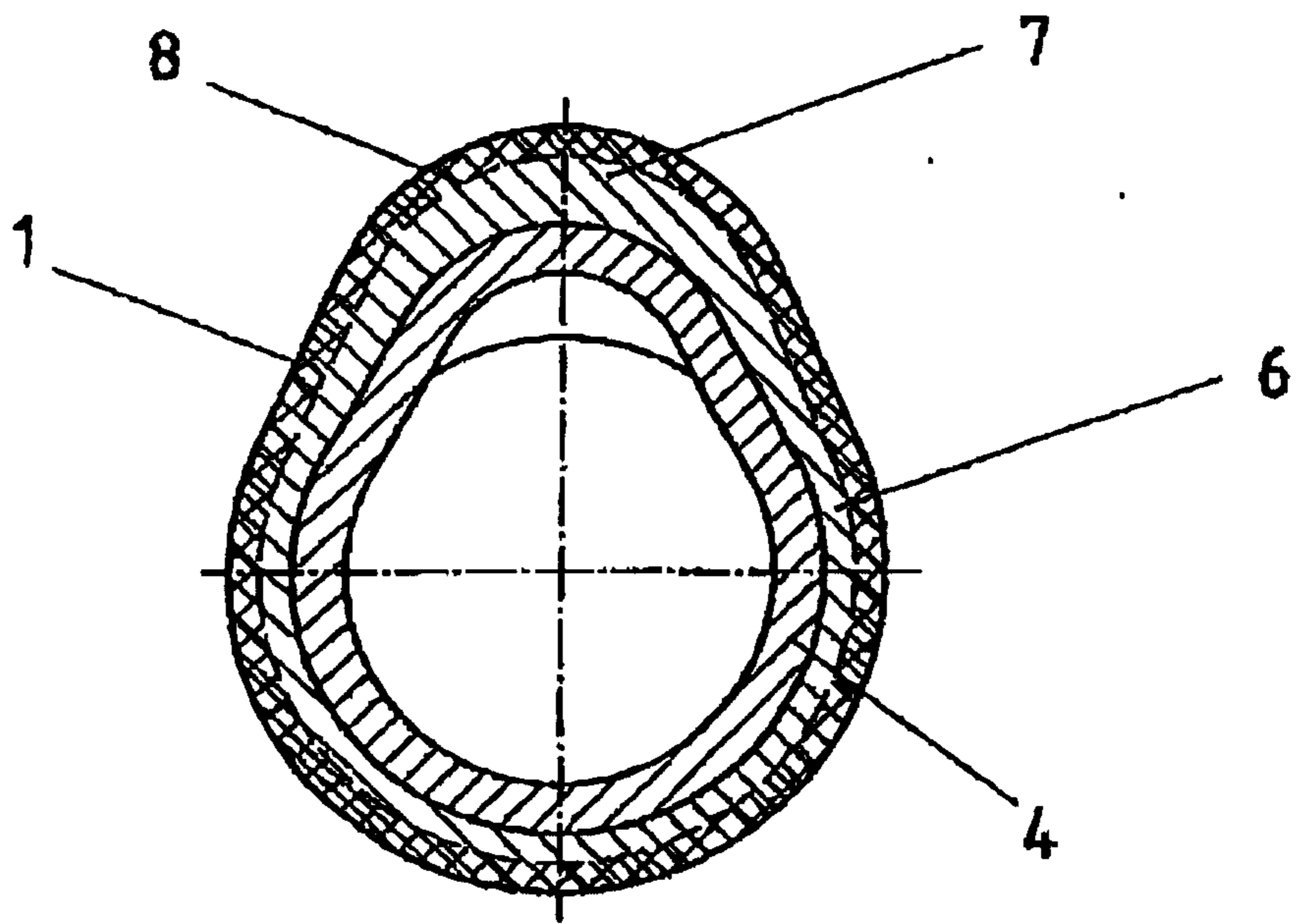


Fig. 3

