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- (73) Patenthaver: **Nuovo Pignone Tecnologie - S.r.l., Via Felice Matteucci 2, 50127 Florence, Italien**
- (72) Opfinder: **VENKATACHALAM, Kalyan Kumar, John F. Welch Technology Centre, Whitefield Road, Hoodi Village, Bangalore, Karnataka 560066, Indien**  
**KURVA, Lakshmanudu, John F. Welch Technology Centre, Whitefield Road, Hoodi Village, Bangalore, Karnataka 560066, Indien**  
**BIGI, Manuele, Via Felice Matteucci 2, I-50127 Florence, Italien**
- (74) Fuldmægtig i Danmark: **Novagraaf Brevets, Bâtiment O2, 2 rue Sarah Bernhardt CS90017, F-92665 Asnières-sur-Seine cedex, Frankrig**
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**CH-A- 341 030**  
**DE-C1- 4 128 673**  
**JP-A- 2006 138 255**  
**US-A- 3 184 153**



# DESCRIPTION

## TECHNICAL FIELD

**[0001]** Embodiments of the subject matter disclosed herein relate to methods of assembling a set of impellers, impellers and turbomachines.

## BACKGROUND ART

**[0002]** DE 41 28 673 C1 discloses a multi-stage centrifugal pump in which impellers are joined together by threads. US 3 184 153 A discloses a rotor construction with tie bolts to axially align impeller discs. CH 341 030 and JP 2006/138255 A disclose further examples of multistage rotor assemblies.

**[0003]** Assembling of a set of impellers may be done in different ways.

**[0004]** One known way consists in providing axial through holes in the impellers, placing all the impellers axially adjacent to each other, inserting an axial tie rod in the holes so that it protrudes both from the first impeller and from the last impeller, applying axial forces on the first impeller and last impeller by means of the tie rod so to tightly hold all the impellers together.

## SUMMARY

**[0005]** Such solution is simple and effective, but it has some drawbacks.

**[0006]** When the impellers assembly heats up due to the operation of the machine and to the fluid in contact with the impellers, also the tie rod heats up and loosens the impellers somewhat; this may cause relative rotations of the impellers and/or unbalance of the rotor and/or high vibrations of the machine and/or low power generation/absorption and/or fretting and wear of the connections between impellers. This drawback is proportional to the number of impellers and to the length of the tie rod. This drawback depends on the temperatures of the tie rod and of the impellers during the operation of the machine. This drawback depends also on the materials used for the tie rod and for the impellers in particular because of to the different thermal expansion coefficients.

**[0007]** When the tie rod is long, damping devices need to be associated to the axial tie rod and placed at some points between its two ends, this means inside the axial holes of the impellers. Such damping devices are subject to wear and/or damage and so they are a source of reliability reduction of the machine using them; furthermore, as such damping devices are

located inside the impeller axial holes, their maintenance operation requires complete disassembling of the machine.

**[0008]** Therefore there is a need for an improved way of assembling a set of impellers.

**[0009]** The present invention is defined in the accompanying claims.

**[0010]** The basic idea is to use a plurality of axial tie rods, typically two or three or four.

#### **BRIEF DESCRIPTION OF DRAWINGS**

**[0011]** The accompanying drawings, which are incorporated herein and constitute a part of the specification, illustrate exemplary embodiments of the present invention and, together with the detailed description, explain these embodiments. In the drawings:

Fig.1 shows a simplified cross-section view of a set of impellers assembled through only one axial tied rod,

Fig.2 shows a simplified cross-section view of a set of impellers assembled through three axial tie rods according to the claimed invention,

Fig.3 shows a simplified and partial cross-section view of one of the impellers according to the invention having a simple axial through hole,

Fig.4 shows a simplified and partial cross-section view of one of the impellers according to the invention having a shaped axial through hole with two cross-sections, and

Fig.5 shows the impeller of Fig.4 as it is used in the arrangement of Fig.2.

#### **DETAILED DESCRIPTION**

**[0012]** The following description of exemplary embodiments refers to the accompanying drawings.

**[0013]** The following description does not limit the invention. Instead, the scope of the invention is defined by the appended claims.

**[0014]** Reference throughout the specification to "one embodiment" or "an embodiment" means that a particular feature, structure, or characteristic described in connection with an embodiment is included in at least one embodiment of the subject matter disclosed. Thus, the appearance of the phrases "in one embodiment" or "in an embodiment" in various places

throughout the specification is not necessarily referring to the same embodiment. Further, the particular features, structures or characteristics may be combined in any suitable manner in one or more embodiments.

**[0015]** Fig.1 shows a set of five impellers 1A, 1B, 1C, 1D, 1E of a centrifugal compressor that is a five-stage centrifugal compressor. Impellers 1A, 1B, 1C, 1D, 1E are axially adjacent to each other and have respective axial through holes 2A, 2B, 2C, 2D, 2E; in particular, these holes are, for example, cylindrical and have the same diameter. Axial through holes 2A, 2B, 2C, 2D, 2E are axially aligned and a single axial tie rod 3 is inserted in these holes so that it protrudes (at least somewhat) both from the first impeller 1A and from the last impeller 1E. Axial forces are applied on the first impeller 1A and last impeller 1E by means of the tie rod 3 (as well as of two elements, according to this embodiment) so to tightly hold all the impellers 1A, 1B, 1C, 1D, 1E together.

**[0016]** Fig.2 shows an arrangement according to the invention similar to that of Fig.1, but wherein three axial tie rods 4A, 4B, 4C are used to tightly hold all the five impellers together, namely 1A, 5B, 1C, 5D, 1E. The first impeller (i.e. impeller 1A), the central impeller (i.e. impeller 1C) and the last impeller (i.e. impeller 1E) of this embodiment of Fig.2 are identical to those of the embodiment of Fig.1.

**[0017]** The second impeller 5B is shaped so that tie rod 4A tightly holds the first impeller 1A and the second impeller 5B together; the fourth impeller 5D is shaped so that tie rod 4B tightly holds the second impeller 5B and the third impeller 1C and the fourth impeller 5D together; the fourth impeller 5D and the fifth impeller 1E are held together by tie rod 4C through a further element 10 that will be described later on.

**[0018]** Each axial tie rod is used to hold together two impellers only and not all of them; therefore, the risk of loosening the impellers and the need of dampers for the tie rods are much reduced.

**[0019]** Advantageously, the impellers 1A, 5B, 1C, 5D, 1E of the set are tangentially coupled to each other by respective hirth joints 7A, 7B, 7C, 7D located around their axial through holes 2A, 6B, 2C, 6D, 2E; hirth joints assure a very good coupling and have the advantage of allowing exactly the same reciprocal position of the impellers even after several assembling and disassembling operations (due to e.g. maintenance). Impeller 5B comprises an axial through hole 6B; a first hole portion 6B1 of the axial through hole is located at a first side of the impeller and has a first cross-section; a second hole portion 6B2 of the axial through hole is located at a second side of the impeller and has a second cross-section; the first side is opposite to the second side; the first cross-section (see 6B1) is smaller than the second cross-section (see 6B2); the first hole portion 6B1 may be used as reference for tie rod 4A centering through nut 11A. A flat surface 6B3 connects the internal surfaces of the first and second hole portions 6B1 and 6B2 and is adapted to be coupled to an end of an axial tie rod; Fig.5 shows surface 6B3 coupled to a nut 11A of axial tie rod 4A. The second hole portion 6B2 is adapted to be coupled to an end of another axial tie rod; Fig.5 shows axial tie rod 4B screwed in hole

portion 6B2 (that is threaded); in particular, there is a threaded shank of an enlarged (specifically radially enlarged) end 12 of the axial tie rod 4B. The enlarged end 12 of axial tie rod 4B has a recess 13 (specifically an axial recess) for housing an end (specifically the tip of the end) of axial tie rod 4A; in this way, a very good connection may be achieved in a smaller axial length still allowing precision assembly and tightening. It is to be noted that a partial or total wall may be placed between hole portions 6B1 and 6B2

**[0020]** Impeller 5B is provided with teeth 7A2 of a first hirth joint 7A located around axial through hole 6B at a first side of the impeller, and teeth 7B1 of a second hirth joint 7B located around axial through hole 6B at a second side of the impeller.

**[0021]** Fig.3 shows an embodiment of impeller (1C) of the set to be assembled; impellers 1A, 1C and 1E are very similar to each other. Impeller 1C comprises an axial through hole 2C that is, for example, cylindrical. Impeller 1C is provided with teeth 7B2 of a second hirth joint 7B located around axial through hole 2C at a first side of the impeller, and teeth 7C1 of a third hirth joint 7C located around axial through hole 2C at a second side of the impeller.

**[0022]** According to the embodiment of Fig.2, the axial tie rods 4A, 4B, 4C are arranged in series; the first axial tie rod 4A of the serial arrangement is connected to an element 9 acting as head for tensioning the axial tie rod 4A and located in front of the first impeller 1A of said set. For example, an end of tie rod 4A is screwed in a threaded hole of element 9, and element 9 is connected to impeller 1A by means of a hirth joint 8A.

**[0023]** According to the embodiment of Fig.2, the axial tie rods 4A, 4B, 4C are arranged in series; the last axial tie rod 4C of the serial arrangement is coupled to an element 10 through a nut 11C of the tie rod 4C; element 10 is axially adjacent to the last impeller 1E at one of its sides and has an axial through hole 10F (specifically a shaped hole) for receiving the last axial tie rod 4C. For example, element 10 is connected to impeller 1E by means of a hirth joint 8B.

**[0024]** It is to be noted that elements 9 and 10 may have different shapes and sizes; in particular, they could comprise: journal bearings, shaft end seals, balance drums, thrust collars.

**[0025]** Assembling of the arrangement of Fig.2 is carried out gradually and for example as follows:

- rod 4A is fixed to element 9,
- rod 4A is inserted in hole 2A of impeller 1A till coupling of joint 8A,
- rod 4A is inserted in hole 6B of impeller 5B till coupling of joint 7A,
- nut 11 A is screwed on rod 4A till it is tightened,
- rod 4B is screwed in hole 6B till it is tightened,
- rod 4B is inserted in hole 2C of impeller 1C till coupling of joint 7B,
- rod 4B is inserted in hole 6D of impeller 5D till coupling of joint 7C,
- nut 11 B is screwed on rod 4B till it is tightened,

- rod 4C is screwed in hole 6D till it is tightened,
- rod 4C is inserted in hole 2E of impeller 1E till coupling of joint 7D,
- rod 4C is inserted in hole 10F of element 10 till coupling of joint 8B,
- nut 11 C is screwed on rod 4C till it is tightened.

[0026] At this point the arrangement is fully assembled.

[0027] It is to be noted that the above description of the assembling procedure is not intended to specify which parts are moved and which parts are maintained stationary.

## REFERENCES CITED IN THE DESCRIPTION

### Cited references

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### Patent documents cited in the description

- [DE4128673C1 \[0002\]](#)
- [US3184153A \[0002\]](#)
- [CH341030 \[0002\]](#)
- [JP2006138255A \[0002\]](#)

## PATENTKRAV

1. Flertrins-turbomaskine, der omfatter:

- en række skovlhjul (1A, 5B, 1C, 5D, 1E), der inkluderer mindst et skovlhjul (1A, 1C, 1E) omfattende et aksialt gennemgående hul (2C) og et skovlhjul (5B, 5D) omfattende et aksialt gennemgående hul (6B) med en første del med et første aksialt hul med et første tværsnit (6B1) og en anden del med et andet aksialt hul med et andet tværsnit (6B2), **kendetegnet ved, at** det første tværsnit (6B1) er mindre end det andet tværsnit (6B2), hvor det første og det andet aksiale hul udgør det aksiale gennemgående hul (6B);

10 - mindst en første og en anden aksial forbindelsesstang (4A, 4B, 4C), der er placeret i det mindste delvist inde i de aksiale gennemgående huller (2C, 6B) i skovlhjulet (1A, 1C, 1E) og i skovlhjulet (5B, 5D), hvor den første del med et første tværsnit (6B1) er koblet til en ende af den første aksiale forbindelsesstang (4A), og den anden del med et første tværsnit (6B2) er koblet til en ende af den anden aksiale forbindelsesstang (4B); og

- mindst en møtrik (11A);

hvor det mindst ene skovlhjul (5B, 5D) er koblet til en ende af den første aksiale forbindelsesstang (4A) ved hjælp af møtrikken (11A) og er direkte koblet til en ende af den anden aksiale forbindelsesstang (4B).

20 2. Turbomaskine ifølge krav 1, hvor tænder (7A2) på en første hirth-samling (7A) er placeret omkring det aksiale gennemgående hul (6B) på en første side af skovlhjulet, og tænder (7B1) på en anden hirth-samling (7B) er placeret omkring det aksiale gennemgående hul (6B) på en anden side af skovlhjulet.

3. Turbomaskine ifølge et hvilket som helst af de foregående krav, hvor 25 mindst en af de aksiale forbindelsesstænger (4B, 4C) har en forstørret ende (12) skruet i den anden del af det mindst ene skovlhjul (5B).

4. Turbomaskine ifølge krav 3, hvor den forstørrede ende (12) af en aksial forbindelsesstang (4B) har en fordybning (13) til anbringelse af en ende af en anden aksial forbindelsesstang (4A).

5. Turbomaskine ifølge et hvilket som helst af de foregående krav, hvor den mindst første og den mindst anden aksiale forbindelsesstang (4A, 4B, 4C) er anbragt i serie, hvor den første eller sidste aksiale forbindelsesstang (4A) i den serielle konstruktion er forbundet med et element (9), der fungerer som krone for spænding af den aksiale forbindelsesstang (4A) og er placeret foran et skovhjul (1A) i rækken af skovhjul.

6. Turbomaskine ifølge krav 5, hvor den sidste eller første aksiale forbindelsesstang (4C) i den serielle konstruktion er koblet til et element (10) gennem en møtrik (11C) på den sidste eller første aksiale forbindelsesstang (4C), hvor elementet (10) ligger aksialt op til et skovhjul (1E) på en af dets sider og har et aksialt gennemgående hul (10F) til modtagelse af den sidste eller første aksiale forbindelsesstang (4C).

7. Turbomaskine ifølge et hvilket som helst af de foregående krav, der er en flertrins-centrifugalkompressor.

8. Fremgangsmåde til samling af en rotor til en flertrins-turbomaskine, hvilken fremgangsmåde omfatter følgende trin:

- tilvejebringelse af en flerhed af skovhjul (1A, 5B, 1C, 5D, 1E) med respektive aksiale gennemgående huller (2A, 6B, 2C, 6D, 2E), herunder mindst et skovhjul (1A, 1C, 1E) omfattende et aksialt gennemgående hul (2C) og mindst et af skovhjulene (5B, 5D) omfattende et aksialt gennemgående hul (6B), en første del med et første aksialt hul med et første tværsnit (6B1) og en anden del med et andet aksialt hul med et andet tværsnit (6B2),

**kendetegnet ved, at** det første tværsnit (6B1) er mindre end det andet tværsnit (6B2), hvor det første og det andet aksiale hul udgør det aksiale gennemgående hul (6B);

- anbringelse af skovhjulene aksialt op mod hinanden;

- tilvejebringelse af mindst en første og en anden aksial forbindelsesstang (4A, 4B, 4C);

- brug af mindst et af skovlhjulene (5B, 5D) til fastgørelse, på den ene side af dets aksiale gennemgående hul (6B, 6D), af en ende af den første aksiale forbindelsesstang (4A, 4B) og, på den anden side af dens aksiale gennemgående hul (6B, 6D), en ende af den anden aksiale forbindelsesstang (4B, 4C);

5            hvor det mindst ene skovlhjul (5B, 5D) er koblet til en ende af den første aksiale forbindelsesstang (4A) ved hjælp af møtrikken (11A) og er direkte koblet til en ende af den anden aksiale forbindelsesstang (4B).

9.            Fremgangsmåde ifølge krav 8, hvor skovlhjulene (1A, 5B, 1C, 5D, 1E) er tangentielt koblet til hinanden gennem respektive hirth-samlinger (7A, 7B, 7C, 7D)

10           placeret omkring deres aksiale gennemgående huller (2A, 6B, 2C, 6D, 2E).

## DRAWINGS

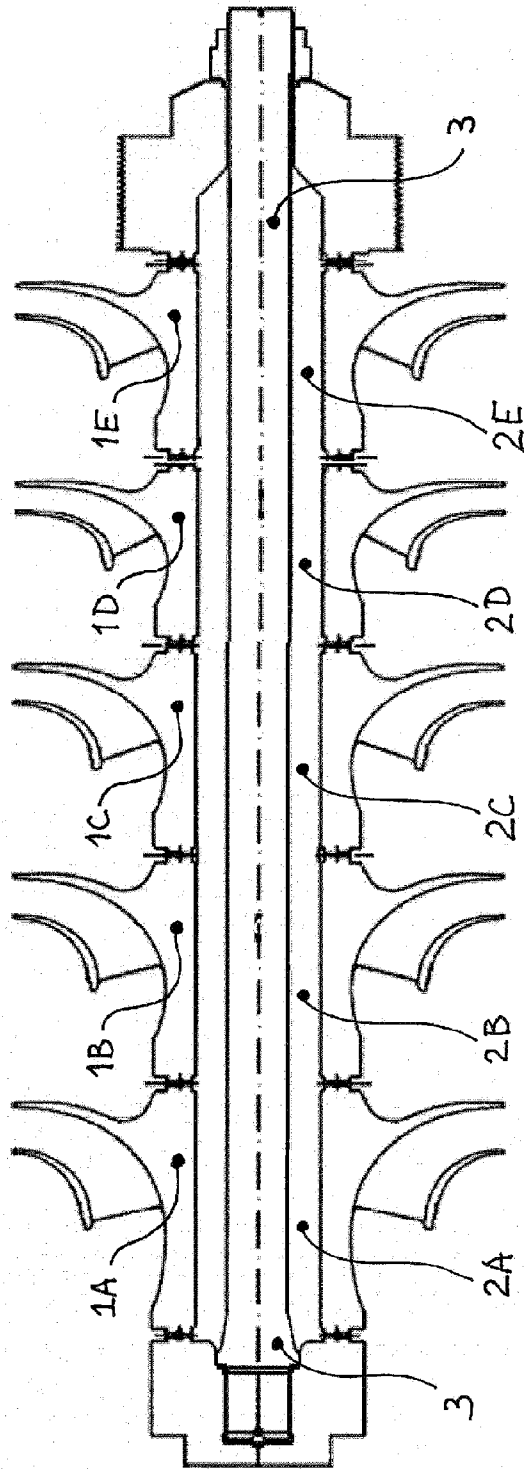


Fig. 1

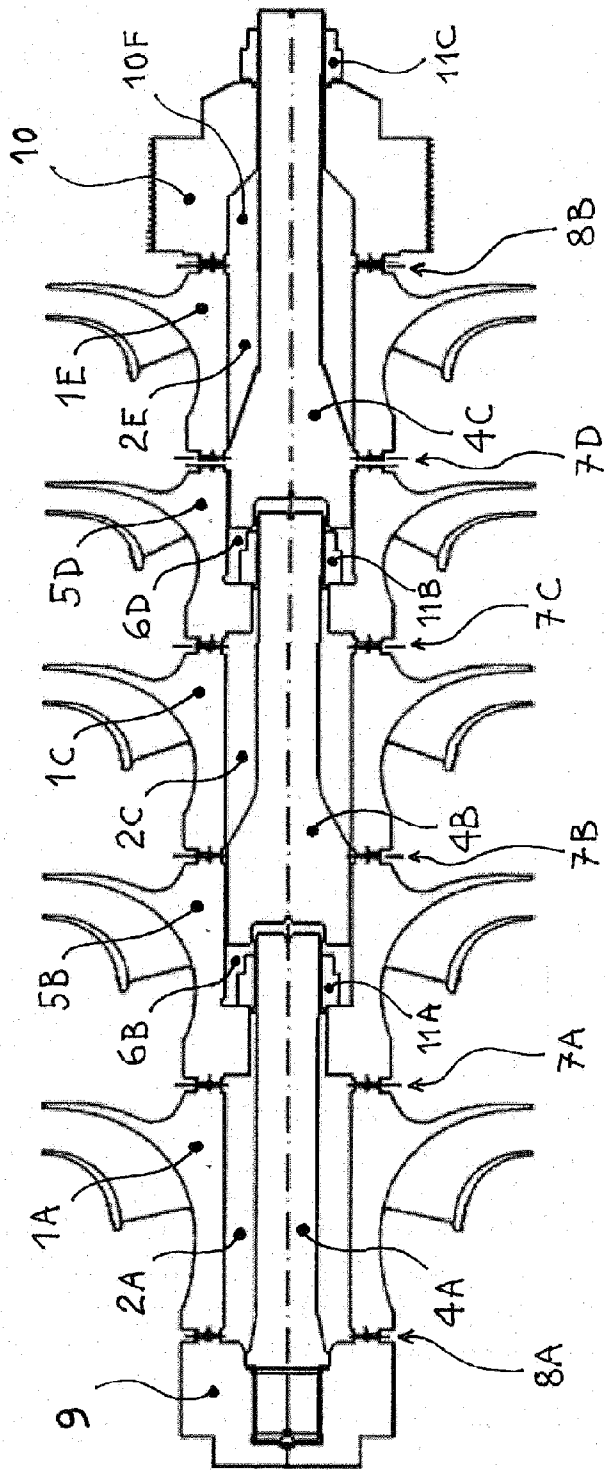


**Fig. 2**

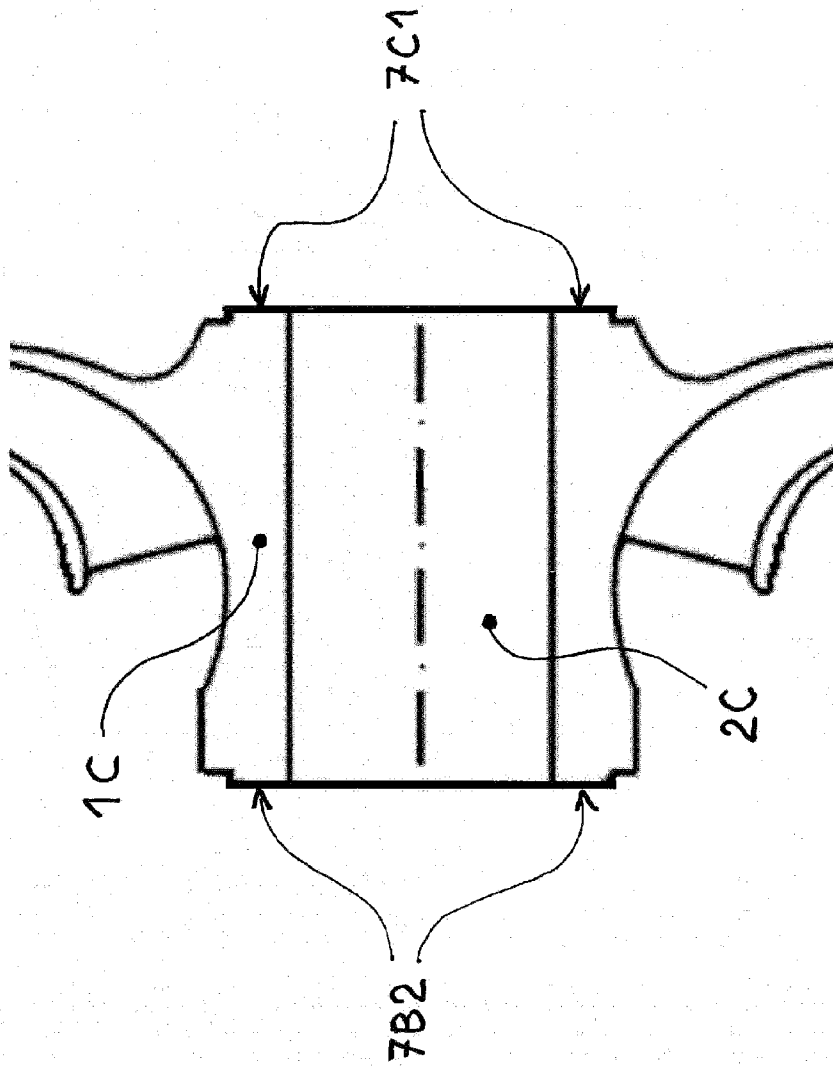


Fig. 3

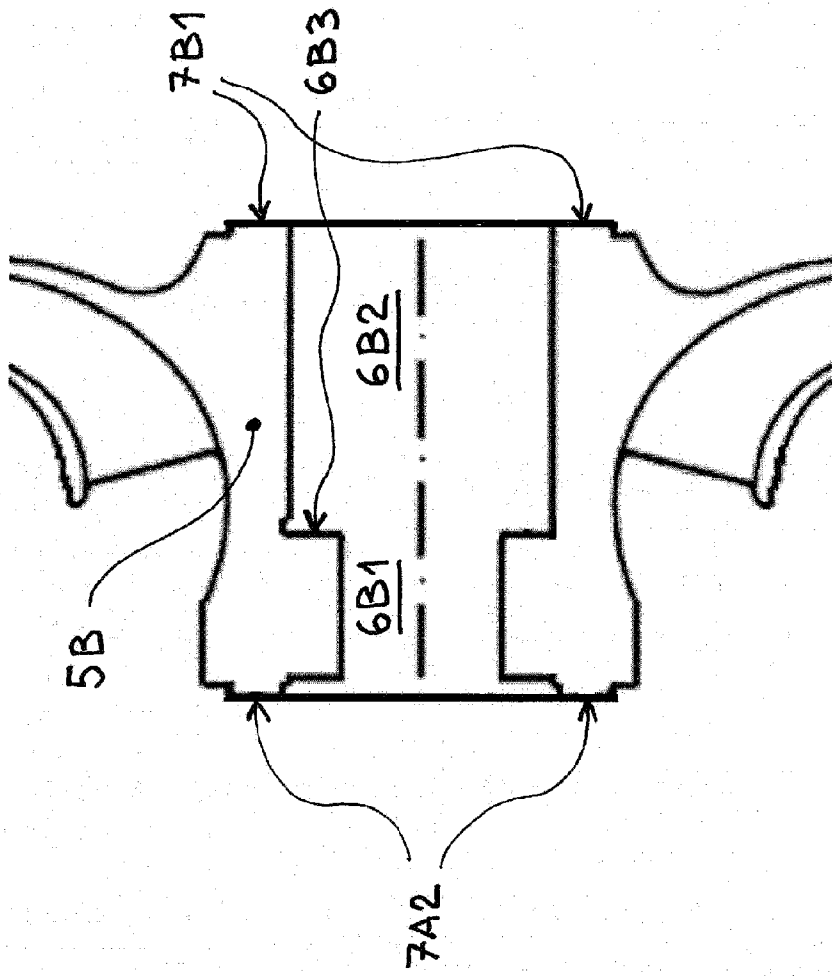


Fig. 4

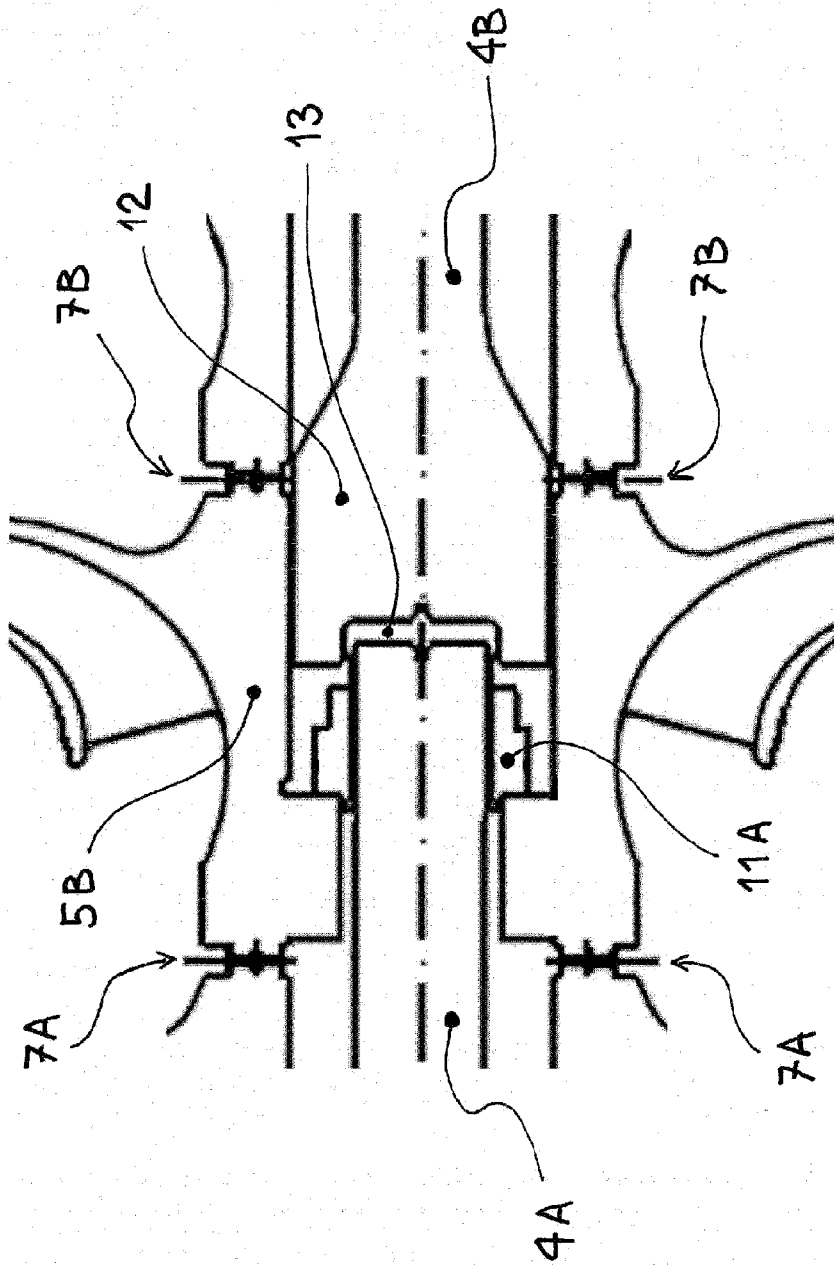


Fig. 5