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(11) **EP 1 402 975 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
31.03.2004 Bulletin 2004/14

(51) Int Cl.7: **B21K 1/36**, B21K 3/04,
F04D 19/04

(21) Application number: **03017613.5**

(22) Date of filing: **11.08.2003**

(84) Designated Contracting States:
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
HU IE IT LI LU MC NL PT RO SE SI SK TR**
Designated Extension States:
AL LT LV MK

(72) Inventor: **Casaro, Fausto**
10141 Torino (IT)

(74) Representative: **Robba, Pierpaolo et al**
INTERPATENT S.R.L.,
Via Caboto No.35
10129 Torino (IT)

(30) Priority: **06.09.2002 IT TO20020770**

(71) Applicant: **VARIAN S.p.A.**
I-10040 Leini (Torino) (IT)

(54) **Method of manufacturing vacuum pump rotors, and rotors obtained thereby**

(57) The invention concerns a method of manufacturing a rotor for a turbine pump, in which a set of radial peripheral vanes is obtained on a generally cylindrical

metal body by means of mechanical workings, wherein said generally cylindrical body (1, 11) is a piece obtained by forging.

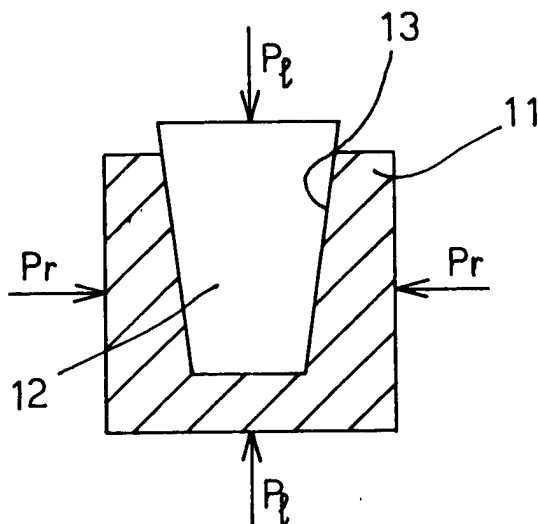


FIG. 2B

Description

[0001] The present invention relates to turbine pumps and more particularly to a method of manufacturing vacuum pump rotors for a turbine pump, in particular a turbomolecular pump, as well as to the rotors obtained thereby. Hereinafter the invention will be disclosed with special reference to the manufacture of a rotor for a turbomolecular pump, but this is not to be intended as a limitation of the applications of the invention.

[0002] As known, the rotor of a turbomolecular pump comprises a group of impellers mounted onto a rotating shaft, each impeller comprising a disk equipped with a set of peripheral radial vanes. During operation, the rotor rotates at peripheral speeds that can be as high as several ten thousand turns per minute. The severe working conditions and the search for higher and higher performance for turbomolecular pumps, in terms of compression ratio and pumping speed, require that each impeller and the rotor in the whole be made as a structure that is robust and balanced at the same time. Moreover the impeller vanes must be so shaped as to optimise the pump performance.

[0003] According to the prior art, manufacturing starts from an extruded metal bar, from which cylinders are cut that are subsequently worked by different methods, such as turning, milling, electric discharge machining and so on. For instance, according to GB 2 171 942, the impeller is made by forming the blades by milling, by using an apparatus allowing simultaneous working of several disks.

[0004] Moreover, it has been proposed to make each vane of the impeller by means of an electric discharge machining technique, as disclosed for instance in FR-A-2 570 970 and EP-A 0 426 233, the latter being in the name of the present Applicant.

[0005] The known manufacturing methods have some drawbacks and limitations. In particular, the mechanical properties and the density of the material are not homogenous enough to ensure a long operating life of the rotors. For instance, in the prior art rotors, the transversal mechanical properties are far worse than the longitudinal properties. Moreover, the permanence time of the rotor at high temperature cannot be too long: it is of the order of a few hundred hours for a rotor made of aluminium alloy 2014 exposed in continuous manner to temperatures of the order of 130°C, with equivalent stresses (determined for instance according to the Von Mises criterion) of the order of 300 MPa.

[0006] Finally, since the prior art starts from an extruded bar which is subsequently worked, and the commercial bars are available only with standard diameters, it may be necessary to start from a bar of greater diameter than that required and then to reduce the bar size, with additional workings and waste of material.

[0007] Therefore, it is a first object of the present invention to provide a method of manufacturing rotors for vacuum pumps, and more particularly for turbomolecular pumps, which overcomes the drawbacks and limitations of the prior art methods, and in particular a method which allows obtaining a rotor with homogeneous mechanical properties and material density, with an improved temperature resistance, while moreover avoiding additional workings and waste of material in case of non-standard diameters.

[0008] The method of the invention comprises preparing an intermediate semi-finished piece, which is obtained by forging and is then finished by a conventional mechanical working.

[0009] The method of the invention is especially suitable for obtaining bell-shaped rotors or in general non-monolithic rotors with shaft driving into an axial bore, even if this is not to be intended in a limiting sense.

[0010] The invention further concerns the rotors obtained by the method starting from a forged semi-finished piece.

[0011] The above and other objects are achieved by a method of manufacturing a rotor for a turbine pump, as claimed in claim 1.

[0012] Further features and advantages of the invention will become more apparent from the following description of preferred but not exclusive embodiments thereof, shown by way of non limiting examples in the accompanying drawings, in which:

- Fig. 1 is a diagrammatic view showing the formation, by forging, of a cylindrical billet according to the invention;
- Figs. 2A and 2B are diagrammatic view showing the formation, by forging, of a bell-shaped billet according to the invention;
- Figs. 3 and 4 are cross-sectional views of two rotors obtained by the method of the invention.

[0013] Referring to Fig. 1, a cylindrical billet 1 is obtained by forging through an axial compression, schematised by forces P1, while preventing radial expansion through means not shown in Fig. 1, schematised by forces Pr.

[0014] In case the rotor is a so-called bell-shaped rotor, starting from a bar portion, billet 11 would be first shaped into a substantially cylindrical shape by axial compression, as schematically shown in Fig. 2A and indicated by forces P1. Subsequently an axial cavity would be formed through a punch 12, which would be forced into billet 11, while preventing the billet radial expansion by retaining it in a mould (forces Pr), as shown in Fig. 2B.

[0015] Subsequently, billet 11 is mechanically worked by known techniques to form the vanes, for instance by milling, turning, etc.

[0016] In case of bell-shaped rotors, axial cavity 13 is preferably only partly formed by means of the punch by forging,

the remaining part being finished by mechanical working.

[0017] The axial size of the cavity obtained by means of the punch is usually half the total height of the billet after forging.

[0018] The aluminium alloys commonly used to manufacture turbomolecular pump rotors are alloys 2014 (Al-Cu alloy) and 7075 (Al-Zn alloy) in the form of extruded bars that are then submitted to tempering and ageing. For the forging step of the method of the invention, it is still possible to start from bars of such kind, then to cut portions thereof, to forge such portions, to bore them and then to perform a thermal treatment.

[0019] Forming a central bore on the bottom of the bell obtained by forging allows a further homogenisation of the mechanical properties obtained through the subsequent thermal treatment.

[0020] Figs. 3 and 4 show two rotors obtained by the method of the invention. The solid lines show the profile of the bell-shaped billet 11 (intermediate piece) that is subsequently refined by mechanical working. The dashed lines show the profile of the rotor that can be obtained by turning the forged billet.

[0021] By manufacturing the rotors of vacuum pumps, in particular turbomolecular pumps, by forging, the Applicant has seen that the following advantages are obtained.

1) A homogenisation of the mechanical properties of the rotor, in particular of the tensile ultimate strength R, of the corresponding elongation at break A of the test specimen, and of value R0.2 (tensile yield strength) at which the tensile strength no longer linearly varies with the corresponding elongation.

It is to be appreciated that the prior art rotors are obtained from extruded bars, in which the above mentioned strength parameters considerably change when passing from the centre to the periphery of the bar, and depending on whether the corresponding cylindrical tensile test specimens are obtained with their axes in the extrusion direction (axis parallel with the bar axis) or perpendicular to such direction (in radial or tangential direction in the bar).

The Applicant has established that, by manufacturing the billets by forging, the values of R, A and R0.2 become considerably constant, both in the different points of the piece and in the different directions in which the test specimens for measuring said parameters are obtained. Moreover said values, corresponding with the highest ones that can be found in the non-forged piece, exhibit little changes from a forged product to another.

This entails clear advantages in the exploitation of the material, the mechanical properties of which are precisely known and may be introduced during the design phase, without need to introduce too high safety coefficients, which would lead to a unnecessary overdimensioning of the rotor.

Experimental tests carried out by the Applicant have given the following results for aluminium elements.

Extruded bars		Forged billets, all directions
Longitudinal direction	Transversal direction	
R = 480 MPa	R = 400 MPa	R = 480 MPa
R0.2 = 420 MPa	R0.2 = 350 MPa	R0.2 = 420 MPa
A = 8%	A = 2%	A = 8%

It is evident that the rotors obtained from forged elements have, in all directions, properties identical to those of the bars extruded in longitudinal direction.

2) The aluminium alloys further undergo a permanent degradation of the mechanical properties in time, if the operating temperature exceeds 120-130°C. The forged pieces, starting from uniformly higher properties, can also remain at high temperatures for longer times, while retaining a sufficient residual strength with respect to the operating loads.

3) The rotors obtained by the method of the invention exhibit a homogenisation of the material density. This feature is of particular interest in parts that have to rotate at high speed (with tangential speeds of the order of 300-400 m/sec), as is the case for rotors of turbomolecular pumps.

Indeed, the non-uniform density would lead to a rotor mass that is not distributed in axially symmetrical manner, with negative effects on the balancing. On the contrary, in case of a uniform density, only the effects of geometrical errors (manufacturing and assembling of the rotor components) would have theoretically to be compensated.

4) A further advantage of the method of the invention is that, by means of the forging, a rotor is obtained that is much closer to the final shape, so that a smaller turning or other mechanical working is required to obtain the finished product.

[0022] Even though the invention has been described with particular reference to a preferred embodiment, the invention is not intended as being limited to such embodiment; on the contrary it includes all changes and modifications

that will be evident to the skilled in the art.

Claims

1. A method of manufacturing a rotor for a turbine pump, comprising the step of obtaining one or more sets of radial peripheral vanes on a generally cylindrical metal body, **characterised in that** said generally cylindrical body (1, 11) is a piece obtained by forging.
2. A method as claimed in claim 1, **characterised in that** said generally cylindrical body is a cylindrical billet (1) obtained by forging through an axial compression (P1), while preventing at the same time the radial expansion of the billet.
3. A method as claimed in claim 1 for manufacturing a bell-shaped rotor, **characterised in that** said generally cylindrical body is a cylindrical billet (1) obtained by forging through an axial compression (P1), and **in that** subsequently a cavity is formed therein by means of a punch (12) that is forced into the billet, while preventing at the same time radial expansions of the billet through confinement in a mould.
4. A method as claimed in claim 3, **characterised in that** said cavity (13) extends over only a part of the billet and is completed by a subsequent mechanical working.
5. A method as claimed in claim 4, **characterised in that** subsequently to the forging step said body is bored and is then submitted to a thermal treatment through which the mechanical properties of the rotor are homogeneously improved, thanks also to the bore obtained in the preceding step.
6. A method as claimed in any preceding claim, **characterised in that** said sets of radial peripheral vanes are made by one or more techniques chosen out of the following ones: milling, turning, electric discharge machining.
7. A method as claimed in any preceding claim, **characterised in that** said turbine pump is a turbomolecular pump.
8. A rotor for a turbine pump, obtained by the method according to one or more preceding claims.
9. A rotor for a turbine pump as claimed in claim 8, **characterised in that** it has parameters R (tensile ultimate strength), elongation A and R0.2 that are constant in all directions.
10. A rotor for a turbine pump as claimed in claim 8, **characterised in that** said turbine pump is a turbomolecular pump.

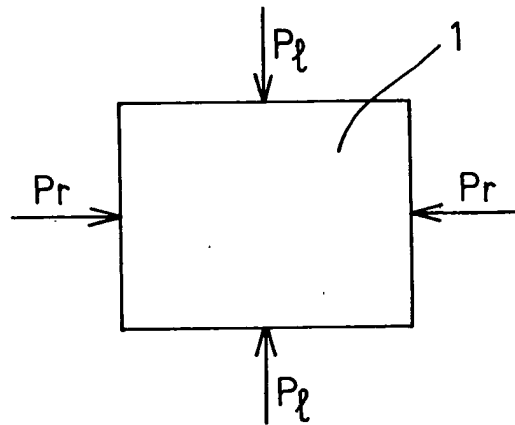


FIG. 1

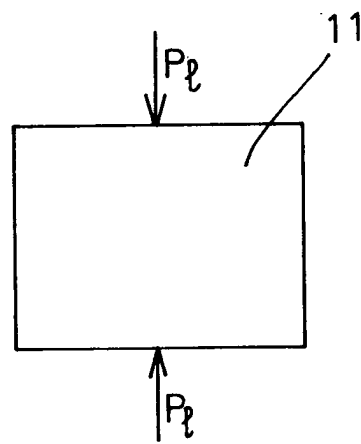


FIG. 2A

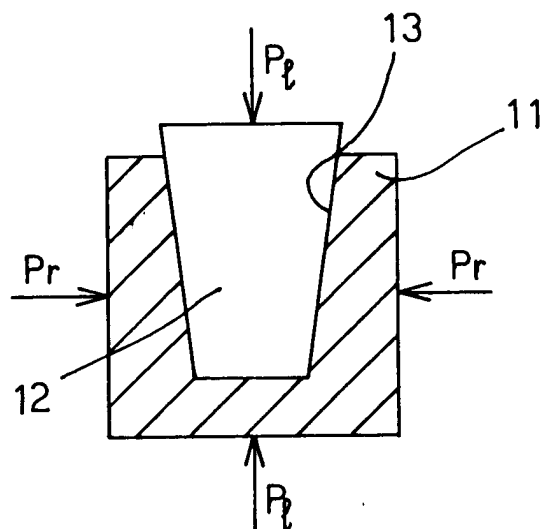


FIG. 2B

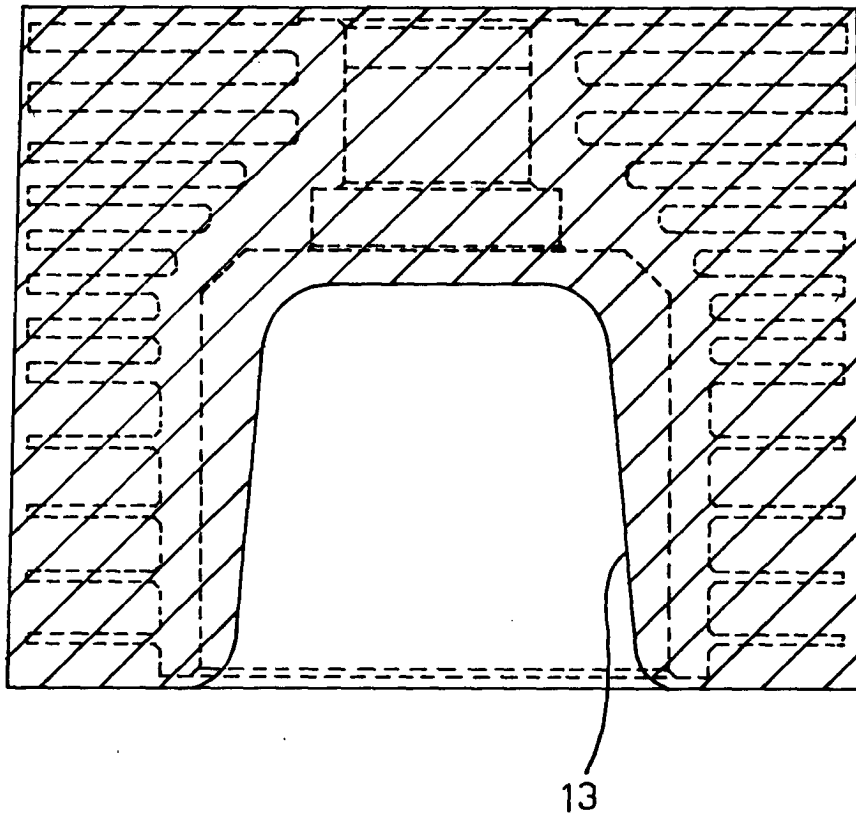


FIG. 3

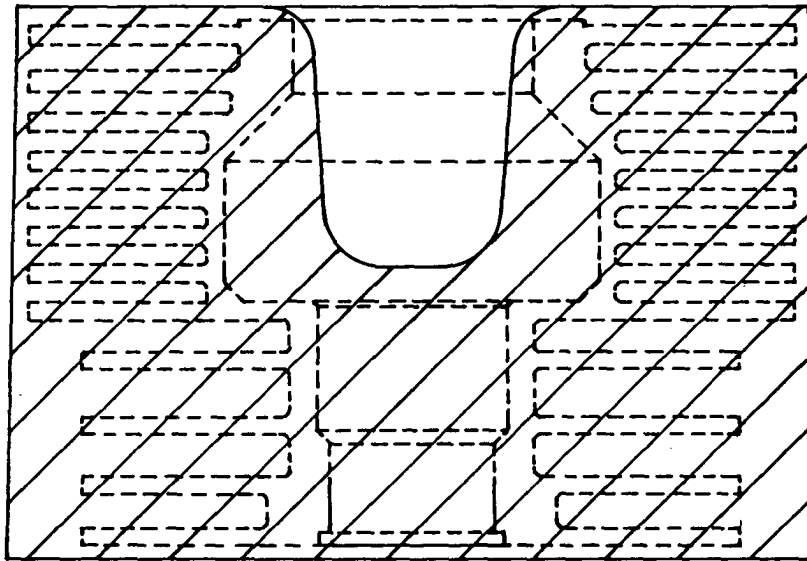


FIG. 4



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EUROPEAN SEARCH REPORT

Application Number
EP 03 01 7613

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 2 February 2004	Examiner Barrow, J
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EUROPEAN SEARCH REPORT

Application Number
EP 03 01 7613

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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 2 February 2004	Examiner Barrow, J
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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