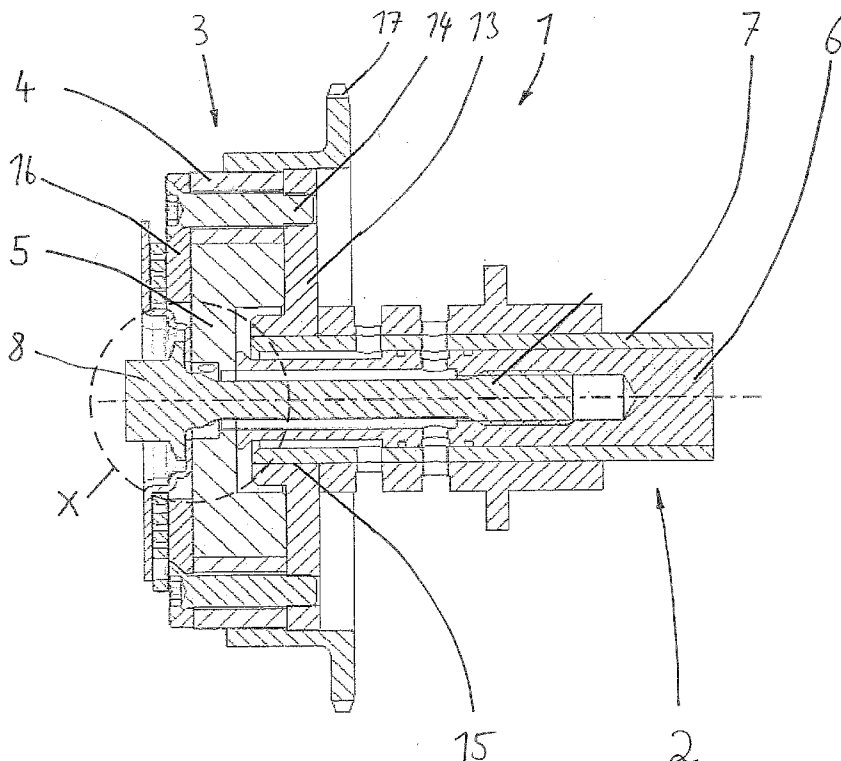




US 20120199085A1

(19) **United States**(12) **Patent Application Publication**
Kapp et al.(10) **Pub. No.: US 2012/0199085 A1**(43) **Pub. Date: Aug. 9, 2012**(54) **CAMSHAFT ARRANGEMENT**(52) **U.S. Cl. 123/90.15**(75) **Inventors:** **Matthias Kapp**, Oak Park, MI
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KG, Herzogenaurach (DE)(21) **Appl. No.:** **13/500,349**(22) **PCT Filed:** **Oct. 4, 2010**(86) **PCT No.:** **PCT/EP2010/064752**§ 371 (c)(1),
(2), (4) **Date:** **Apr. 5, 2012****Related U.S. Application Data**(60) **Provisional application No. 61/248,634, filed on Oct. 5, 2009.****Publication Classification**(51) **Int. Cl.**
F01L 1/344 (2006.01)(57) **ABSTRACT**

A camshaft arrangement (1) for changing the relative angle of at least one first cam of a camshaft (2) relative to a second cam of the camshaft (2), wherein the arrangement includes an angle adjusting device (3) having a stator (4) and a rotor (5) rotatably disposed relative to said stator, wherein the rotor (5) is rotationally fixed to a shaft (6), wherein the stator (4) is rotationally fixed to a hollow shaft (7), wherein the shaft (6) and the hollow shaft (7) are disposed concentric to each other, wherein the at least one first cam is rotationally fixed to the shaft (6), wherein the at least one second cam is rotationally fixed to the hollow shaft (7), and wherein the rotationally fixed connection between the rotor (5) and the shaft (6) is produced by at least one screw (8). In order to establish a fixed connection between the rotor and the shaft, taking up little space, according to the invention, the shaft (6) having an end face (9) contacts a contact surface (10) of the rotor (5) and is pulled against the contact surface (10) by the at least one screw (8), and the shaft (6) has a cross-sectional area (A1) along the axial extent thereof present in the area of the rotor (5), with the cross-sectional area expanding to a greater value (A2) out to the end face (9) thereof.



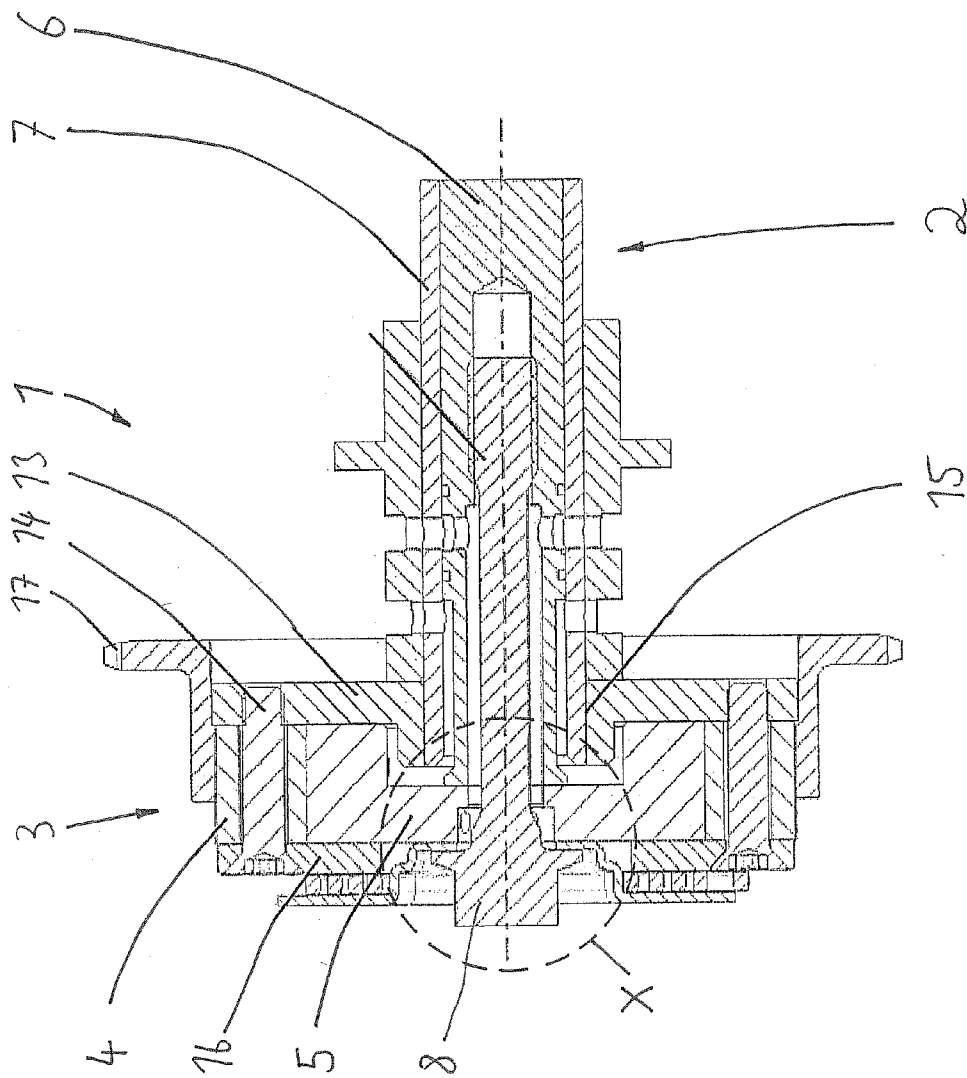


Fig. 1a

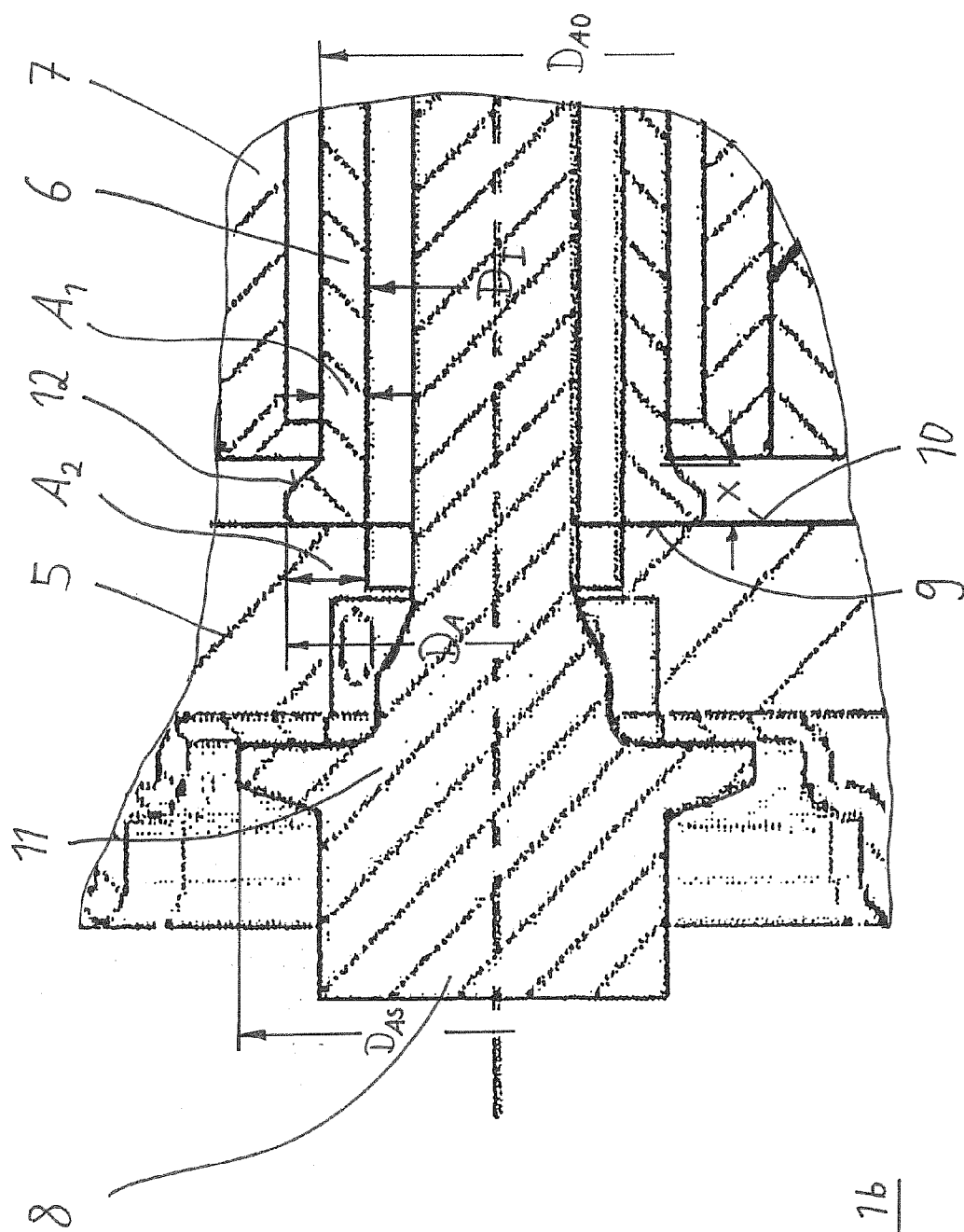


Fig. 1b

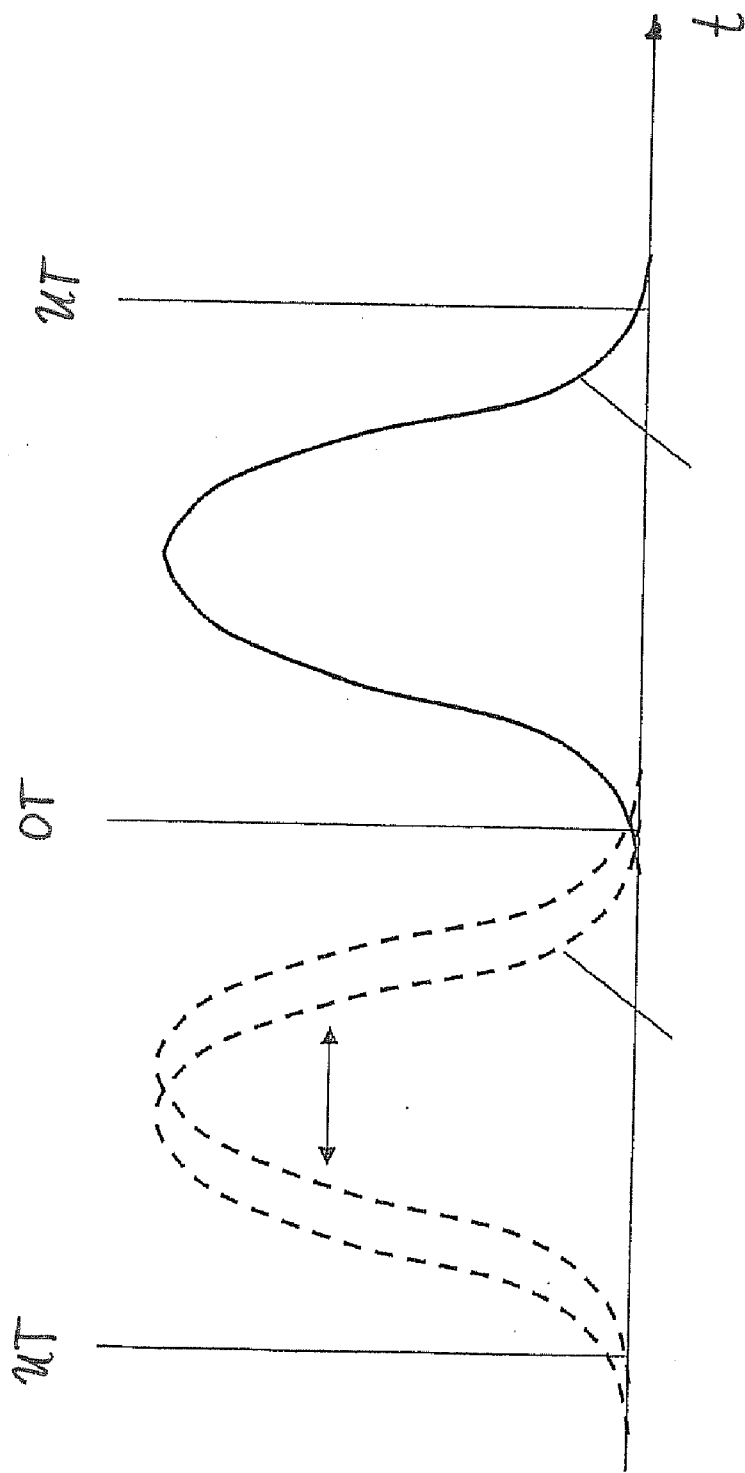


Fig. 2

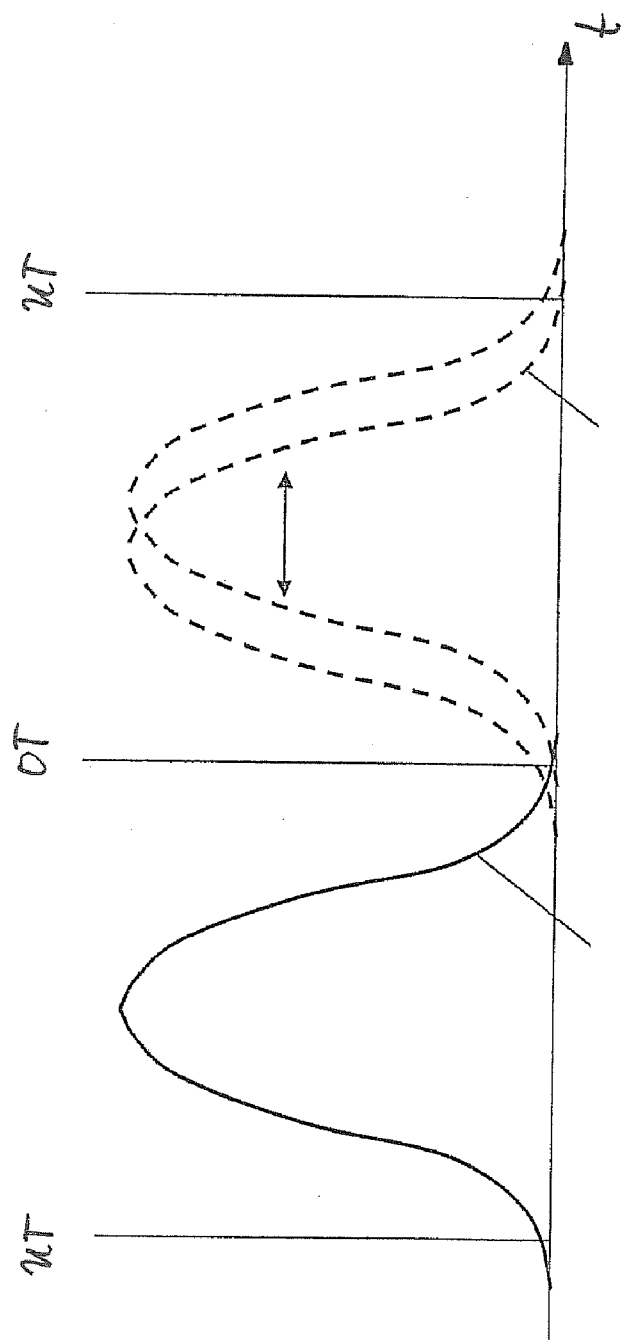


Fig. 3

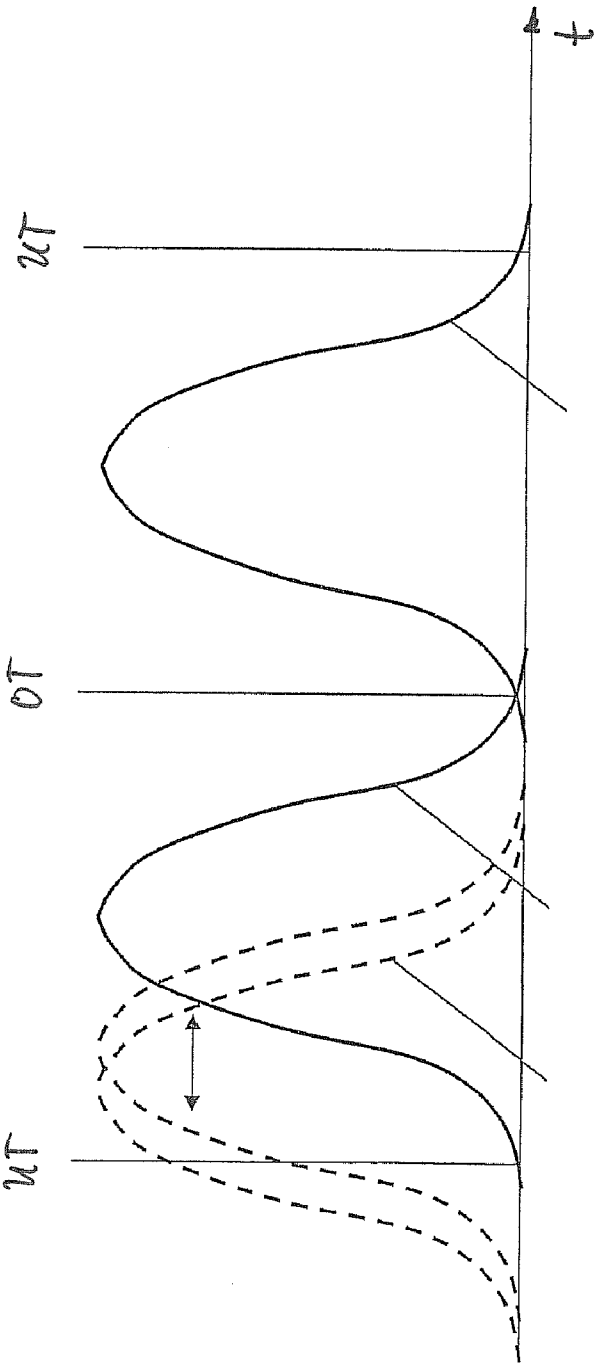


Fig. 4

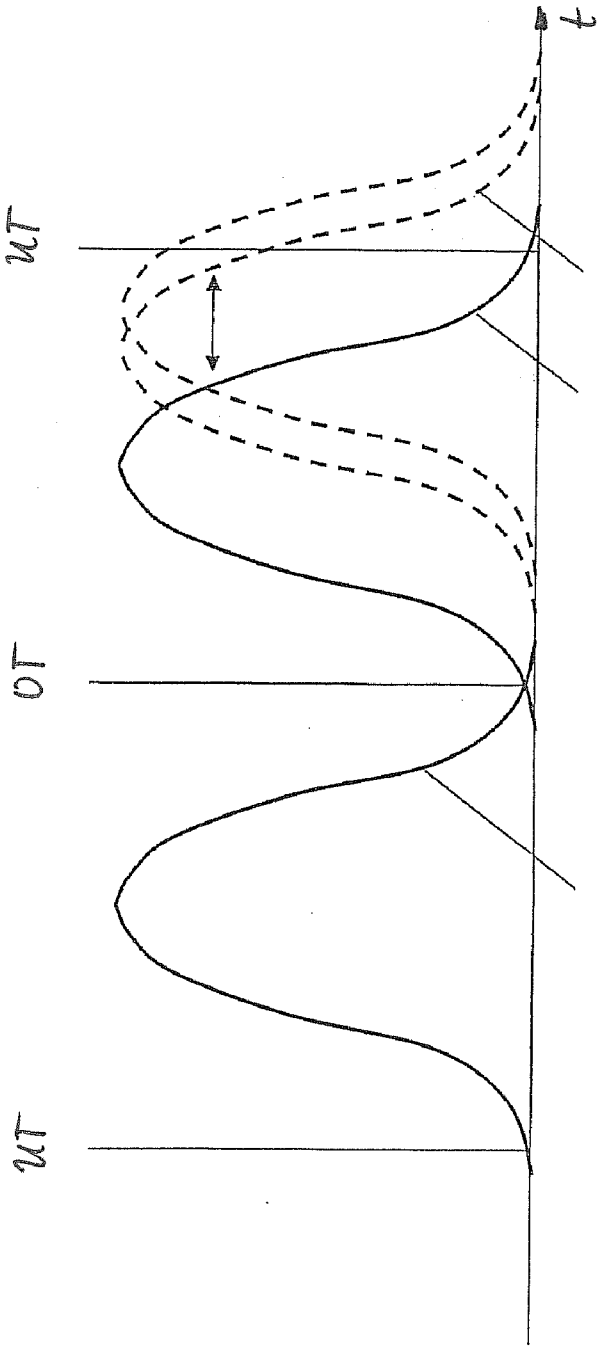


Fig. 5

CAMSHAFT ARRANGEMENT

BACKGROUND

[0001] The invention relates to a camshaft arrangement for varying the relative angle position of at least one first cam of a camshaft relative to a second cam of the camshaft, wherein the arrangement comprises an angle adjustment device which has a stator and a rotor which is arranged so as to be rotatable relative to said stator, wherein the rotor is connected in a rotationally fixed manner to a shaft, wherein the stator is connected in a rotationally fixed manner to a hollow shaft, wherein the shaft and the hollow shaft are arranged concentrically with respect to one another, wherein the at least one first cam is connected in a rotationally fixed manner to the shaft, wherein the at least one second cam is connected in a rotationally fixed manner to the hollow shaft, and wherein the rotationally fixed connection between the rotor and the shaft is produced by means of at least one screw.

[0002] Camshaft arrangements of said type are known as “cam in cam” systems. By means of these, it is possible for at least two cams of the camshaft—usually a number of respective cams—to be rotated relative to one another on the camshaft in order to vary the control times of the gas exchange valves of an internal combustion engine. Such camshaft systems are described for example in EP 1 945 918 B1, in GB 2 423 565 A and in WO 2009/098497 A1.

[0003] It is known to produce the rotationally fixed connection between the rotor or a part thereof and the shaft by means of a screw connection, wherein use is usually made of a central screw which is arranged concentrically with respect to the axis of the shaft and hollow shaft. The cited documents present, in part, a solution of this type.

[0004] It has been found that this connection constitutes, to a certain extent, a weak point. Only if the central screw is formed as an expansion screw can an adequate preload be ensured such that the connection is permanently secure. Release of the rotationally fixed connection between the shaft and rotor may nevertheless arise under intense loading. Accordingly, in generic adjusting devices, the connection of the shaft to the rotor constitutes a weak point which, in the event of failure, can lead to a malfunction of the camshaft arrangement.

SUMMARY

[0005] The objective addressed by the present invention is that of further developing a camshaft arrangement of the type mentioned in the introduction such that the connection between the rotor and the shaft is improved. Here, it should be possible for a permanently secure connection to be ensured without having to enlarge the available installation space.

[0006] This objective is met by means of the invention characterized in that the shaft abuts with an end face against an abutment surface of the rotor and is pulled against the abutment surface by means of the at least one screw, wherein the shaft has, along its axial extent which is situated in the region of the rotor, a cross-sectional area which increases in size up to the end face to a larger value.

[0007] The enlargement of the cross-sectional area is preferably restricted to the region in the direct vicinity of the end face. This is to be understood to mean in particular that the enlargement of the cross-sectional area is restricted to a region which extends at most over 10 mm from the end face of the shaft; it is particularly preferably provided that the

enlargement of the cross-sectional area is restricted to a region which extends between 3 mm and 8 mm from the end face of the shaft.

[0008] The shaft may have a constant cross section along its axial extent which is situated in the region of the rotor and outside the enlargement of the cross-sectional area.

[0009] The external diameter of the shaft at its end face preferably corresponds to at least 80% of the external diameter of a screw head of the screw, particularly preferably to at least 90% of the external diameter of the screw head.

[0010] Here, the transition of the external diameter of the shaft from the region of the smaller cross-sectional area to the region of the enlarged cross-sectional area is preferably continuous. It is provided in particular that the transition is of rounded design.

[0011] It is preferable for a single screw to be provided which is arranged as a central screw with its axis concentric with respect to the shaft; here, the screw is advantageously designed as an expansion screw.

[0012] The shaft may be formed, along its axial extent which is situated in the region of the rotor, as a hollow shaft and have a constant internal diameter up to the end face. The shaft may furthermore have, along its axial extent which is situated in the region of the rotor and up to the enlargement of its cross-sectional area, an external diameter which amounts to at most 90% of the external diameter of the shaft at its end face. It is particularly preferably provided that, up to the enlargement of the cross-sectional area of the shaft, the external diameter of said shaft amounts to between 80% and 90% of the external diameter of the shaft at its end face.

[0013] The angle adjustment device is preferably designed as a hydraulic adjustment device.

[0014] With this embodiment, it is possible to produce a very secure connection, which takes up little space, between the rotor and shaft. As a result of the enlargement of the face-side end region of the shaft, the contact surface to the rotor is significantly enlarged, thus yielding improved and more secure abutment of the shaft against the rotor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The drawings show an exemplary embodiment of the invention, in which:

[0016] FIG. 1a shows the radial section through a camshaft arrangement of an internal combustion engine, having a camshaft which is comprised of two concentric shafts, wherein the arrangement has an angle adjustment device,

[0017] FIG. 1b shows the detail “X” as per FIG. 1a,

[0018] FIG. 2 schematically shows the profile with respect to time of the opening and closing of intake and exhaust valves of an internal combustion engine, as per a first possible actuation method,

[0019] FIG. 3 schematically shows the profile with respect to time of the opening and closing of the valves as per a second possible actuation method,

[0020] FIG. 4 schematically shows the profile with respect to time of the opening and closing of the valves as per a third possible actuation method, and

[0021] FIG. 5 schematically shows the profile with respect to time of the opening and closing of the valves as per a fourth possible actuation method.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0022] FIG. 1a and FIG. 1b illustrate a camshaft arrangement 1 which comprises a camshaft 2 which has cams (not

illustrated) which interact in a known way with gas exchange valves in order to control the gas exchange in an internal combustion engine.

[0023] An arrangement of this type serves for varying the valve control times of an internal combustion engine. Use is usually made of hydraulically actuated adjusters.

[0024] In a first driving strategy, the control of an intake valve is varied relative to an exhaust valve—or vice versa—this usually being expedient in SOHC (single overhead camshaft) or OHV (overhead valves) engine types. This permits the variation of the intake phase or of the exhaust phase using a single camshaft.

[0025] A second driving strategy provides that the control times of one set of intake valves are changed relative to another set of valves using a single intake camshaft. This may be used if two or possibly three intake valves are provided per cylinder, and it is sought to vary the control times of one of the intake valves relative to the others on one cylinder.

[0026] In a third driving strategy, the control times of one set of exhaust valves are varied relative to another set of valves using a single exhaust camshaft. This may be used if two or possibly three exhaust valves are provided per cylinder, wherein it is sought to vary the control times of one exhaust valve relative to the others on one cylinder.

[0027] Here, the camshaft arrangement 1 has an angle adjustment device 3 which is connected to the camshaft 2. Cams for, for example, the intake and exhaust valves of the internal combustion engine are arranged on the camshaft. By means of the angle adjustment device 3, it is possible for one group of the cams to be rotated relative to another group of the cams. For this purpose, the camshaft 2 is comprised of two coaxially arranged shaft elements, specifically of a shaft 6 and of a hollow shaft 7 in which the shaft 6 is arranged coaxially. The cams situated on the camshaft 2 are connected in a rotationally fixed manner either to the shaft 6 or to the hollow shaft 7. Details regarding this are provided in EP 1 945 918 B1.

[0028] The angle adjustment device 3 has a stator 4 and a rotor 5 which can be rotated relative to one another—in the exemplary embodiment by means of hydraulic actuation—by a defined angle. This realization of this relative rotation function is known in the prior art, reference being made by way of example to DE 103 44 816 A1. In the device described in this document, a vane wheel is provided into which vanes are formed or in which vanes are arranged. The vanes are situated in hydraulic chambers which are formed in a rotor. An adjustment of the rotor relative to the stator can be realized through corresponding charging of the respective side of the hydraulic chambers with hydraulic fluid.

[0029] The rotor 5 is connected in a rotationally fixed manner to the shaft 6, wherein a central screw 8 is used for this purpose. A secure radial and axial connection between the rotor 5 and shaft 6 is ensured by means of the central screw 8.

[0030] To ensure that said connection is particularly secure, the invention provides that the shaft 6 abuts with one of its end faces 9 against an abutment surface 10 of the rotor 5 and is pulled against the abutment surface 10 by means of the central screw 8. To ensure improved abutment of the shaft end face against the abutment surface, it is provided that the shaft 6 has, along its axial extent which is situated in the region of the rotor 5, a cross-sectional area A_1 which increases in size up to the end face 9 to a larger value A_2 . The areas A_1 and A_2 are indicated in FIG. 1b; in the present case these are circular ring-shaped surfaces.

[0031] The preferred dimensioning of the face-side widening of the shaft 6 also emerges from the specified geometric data. The shaft 6 is formed, in the axial region of the rotor 5, as a hollow shaft, and accordingly has an internal diameter D_i . The external diameter of the shaft 6 is denoted by D_{A0} . The shaft 6 widens toward the end face side of the shaft 6, that is to say the external diameter increases to a value D_A . The axial region over which the enlargement of the cross-sectional area takes place is denoted by x .

[0032] Here, the external diameter D_A in the end face region of the shaft 6 is preferably approximately as large as the external diameter D_{AS} of the screw head 11 of the central screw 8, or is slightly smaller.

[0033] As can also be seen, the transition 12 from the smaller to the larger cross-sectional area is of rounded design, in order to eliminate stress concentrations.

[0034] The stator 4 furthermore has a cover element 13 which is connected to the stator 4 by means of screws 14. The hollow shaft 7 is connected in a rotationally fixed manner to the cover element 13. Here, the rotationally fixed connection between the stator 4 and hollow shaft 7 takes place via the cover element 13 which is connected to the stator 4, in that the cover element 13 has a bore for receiving a cylindrical portion of the hollow shaft 7. It is provided here that a non-positively locking and/or cohesive connection is provided in the cylindrical contact surface 15 between the cover element 13 and hollow shaft 7.

[0035] On the side opposite the cover element 13, the angle adjustment device 3 is closed off by means of a further cover element 16. The drive of the angle adjustment device 3, and therefore of the camshaft 2, is provided in a known way via a pinion 17 by means of a chain (not illustrated) driven by the crankshaft of the internal combustion engine. The pinion 17 is formed here as a separate component. It may however also be formed integrally with the stator 4.

[0036] It is thereby possible to influence, that is to say adjust, the phase relationship between the cams connected in a rotationally fixed manner to the hollow shaft 7 and the cams connected in a rotationally fixed manner to the shaft 6. Here, according to the invention, the connection between the rotor 5 and the shaft 6 is formed so as to be so secure that a torque adequate for effecting the actuation of the cams counter to the spring force of the gas exchange valves can be transmitted via said connection. The same self-evidently applies to the connection between the stator 4 and the hollow shaft 7.

[0037] The mode of operation of an internal combustion engine which is made possible by the camshaft arrangement is illustrated in FIGS. 2 to 5. The Figures each show the profile with respect to time of the opening travel imparted to a valve by a cam.

[0038] In an engine with a single camshaft (SOHC type—single overhead camshaft) or an engine of OHV (overhead valve) type, the shaft 6 actuates the exhaust valves, wherein the control of the exhaust valves can be adjusted relative to the crankshaft of the engine. Here, the actuation of the exhaust valves can be seen in the left-hand half of the Figure in FIG. 2, whereas the right-hand half of the Figure shows the actuation of the intake valves. The dashed curve profiles for the exhaust valves and the offset in the direction of the double arrow indicate that the adjustment facility of the angle adjustment device 3 is utilized for this purpose.

[0039] In the case of FIG. 2, this permits optimized control, that is to say opening and closing, of the exhaust valves as a function of the rotational speed and of the load state of the

internal combustion engine. This advantageously leads to increased fuel efficiency and reduced emissions.

[0040] FIG. 3 shows, for the same design of engine as in FIG. 2, the appearance of the profile if the shaft 6 actuates the intake valves. Again, the actuation of the exhaust valves is shown in the left-hand half of the Figure and that of the intake valves is shown in the right-hand half of the Figure. It is now possible here—shown again by the dashed curve profiles and the double arrow—for the phase relationship of the intake valves relative to the crankshaft to be varied.

[0041] In the case of FIG. 3, this permits optimized control, that is to say opening and closing, of the intake valves as a function of the rotational speed and of the load state of the internal combustion engine. Volumetric efficiency can be improved, which leads to improved torque delivery of the engine and increased fuel efficiency and improved running behavior of the engine.

[0042] In an engine with two overhead camshafts (DOHC type), it may be provided that the shaft 6 with the cams fastened in a rotationally fixed manner thereto actuates one or more exhaust valves per cylinder, whereas the remaining exhaust valves are actuated by the hollow shaft 7 and the cams arranged in a rotationally fixed manner thereon. Such a solution is shown in FIG. 4. In this case, it is possible to realize, for each cylinder, an adjustment of the actuation of one or more of the exhaust valves relative to the other exhaust valves. It can be seen in the left-hand half of the Figure in FIG. 4 that at least one exhaust valve (see solid line) is operated with fixed control times, whereas at least one further exhaust valve (see dashed lines and double arrow) is adjustable with regard to its control times. In the present case, the intake valves are non-adjustable in terms of their control times (see right-hand half of the Figure).

[0043] It is thereby possible for the duration of the opening of the exhaust valves to be varied such that the opening time of the exhaust valves can be optimized. An early opening of the exhaust valves before bottom dead center (BDC) permits a fast warm-up of the internal combustion engine, which reduces cold start emissions.

[0044] An analogous solution to FIG. 4 is depicted in FIG. 5. Here, too, a DOHC type engine is used. In this case, the shaft 6 actuates one or more intake valves per cylinder, while the other intake valves are actuated by the hollow shaft 7.

[0045] It is thereby possible in turn for control to be implemented such that the valve opening times at the intake can be varied. The solid lines in the right-hand half of the Figure of FIG. 5 in turn show the control of one or more intake valves with non-variable control times, whereas the dashed lines and the double arrow indicate that temporal variation of the control of the other intake valves can be realized by means of the angle adjustment device 3.

[0046] It is thus possible here, analogously to FIG. 4, for the duration of the opening of the intake valves to be varied. Furthermore, the closing time of the intake valves can also be optimized. This may be utilized to realize a late intake valve closing (LIVC) strategy.

[0047] The closing of the intake valves after bottom dead center (BDC) makes it possible for a part of the gas to be forced back into the intake tract, which reduces the length of the compression stroke. This leads to a reduction in pumping losses of the engine and thus to improved fuel efficiency. The

closing of the intake valves can be optimized as a function of the rotational speed and engine load.

LIST OF REFERENCE SYMBOLS

[0048]	1 Camshaft arrangement
[0049]	2 Camshaft
[0050]	3 Angle adjustment device
[0051]	4 Stator
[0052]	5 Rotor
[0053]	6 Shaft
[0054]	7 Hollow shaft
[0055]	8 Screw (central screw)
[0056]	9 End face
[0057]	10 Abutment surface
[0058]	11 Screw head
[0059]	12 Transition
[0060]	13 Cover element
[0061]	14 Screw
[0062]	15 Cylindrical contact surface
[0063]	16 Cover element
[0064]	17 Pinion
[0065]	A_1 Cross-sectional area
[0066]	A_2 Cross-sectional area
[0067]	x Region (axial extent)
[0068]	D_A External diameter
[0069]	D_{AS} External diameter of the screw head
[0070]	D_I Internal diameter
[0071]	D_{A0} External diameter

1. A camshaft arrangement for varying a relative angle position of at least one first cam of a camshaft relative to a second cam of the camshaft, comprising an angle adjustment device which has a stator and a rotor which is arranged so as to be rotatable relative to said stator, the rotor is connected in a rotationally fixed manner to a shaft, the stator is connected in a rotationally fixed manner to a hollow shaft, the shaft and the hollow shaft are arranged concentrically with respect to one another, the at least one first cam is connected in a rotationally fixed manner to the shaft, the at least one second cam is connected in a rotationally fixed manner to the hollow shaft, and the rotationally fixed connection between the rotor and the shaft is produced by at least one screw, the shaft abuts with a end face against an abutment surface of the rotor and is pulled against the abutment surface by the at least one screw, the shaft has, along its axial extent which is situated in a region of the rotor, a cross-sectional area (A_1) which increases in size up to the end face to a larger value (A_2) creating an enlargement.

2. The camshaft arrangement as claimed in claim 1, wherein the enlargement of the cross-sectional area (A_2) is restricted to a region in a direct vicinity of the end face.

3. The camshaft arrangement as claimed in claim 2, wherein the enlargement of the cross-sectional area (A_2) is restricted to the region (x) which extends at most 10 mm from the end face of the shaft.

4. The camshaft arrangement as claimed in claim 3, wherein the enlargement of the cross-sectional area (A_2) is restricted to the region (x) which extends between 3 mm and 8 mm from the end face of the shaft.

5. The camshaft arrangement as claimed in claim 1, wherein the shaft has a constant cross section along its axial extent which is situated in a region of the rotor that is outside the enlargement of the cross-sectional area.

6. The camshaft arrangement as claimed in claim 1, wherein the external diameter (D_A) of the shaft at the end face corresponds to at least 80% of the external diameter (D_{AS}) of a screw head of the screw.

7. The camshaft arrangement as claimed in claim 6, wherein the external diameter (D_A) of the shaft at the end face corresponds to at least 90% of the external diameter (D_{AS}) of the screw head of the screw.

8. The camshaft arrangement as claimed in claim 1, wherein a transition of the external diameter of the shaft from a region of the smaller cross-sectional area (A_1) to a region of the enlarged cross-sectional area (A_2) is continuous.

9. The camshaft arrangement as claimed in claim 8, wherein the transition of the external diameter of the shaft is rounded.

10. The camshaft arrangement as claimed in claim 1, wherein the at least one screw consists of a single screw which is arranged as a central screw with an axis thereof concentric with respect to the shaft.

11. The camshaft arrangement as claimed in claim 10, wherein the screw is an expansion screw.

12. The camshaft arrangement as claimed in claim 1, wherein the shaft is formed, along an axial extent thereof which is situated in a region of the rotor, as a hollow shaft and has a constant internal diameter (D_I) up to the end face.

13. The camshaft arrangement as claimed in claim 1, wherein the shaft has, along an axial extent thereof which is situated in a region of the rotor and up to the enlargement of the cross-sectional area, an external diameter (D_{A0}) which amounts to at most 90% of an external diameter (D_A) of the shaft at the end face.

14. The camshaft arrangement as claimed in claim 13, wherein, up to the enlargement of the cross-sectional area of the shaft, the external diameter (D_{A0}) of said shaft amounts to between 80% and 90% of the external diameter (D_A) of the shaft at the end face.

15. The camshaft arrangement as claimed in claim 1, wherein the angle adjustment device comprises a hydraulic adjustment device.

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