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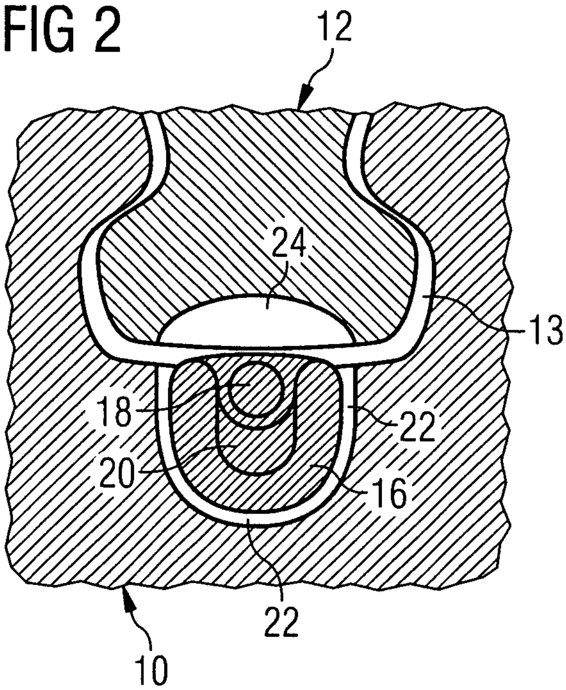
(71) Applicant: **SIEMENS AKTIENGESELLSCHAFT**
80333 München (DE)

(72) Inventors:
- **Hopkinson, Derek**
DH3 4DG Co. Durham (GB)
- **Richter, Christoph, Dr.**
49477 Ibbenbüren (DE)

(54) **Turbine for a thermal power plant comprising a locking device**

(57) A turbine for a thermal power plant comprising a rotor (10), at least one blade having a blade root (12) engaged to the rotor (10) via a groove/bar-connection (12, 13) and a locking device (14) being arranged between said blade root (12) and said rotor (10) for blocking a relative movement in at least one direction between said blade root (12) and said rotor (10) is characterised according to the invention in that said locking device (14) comprises a rotatable cam-disc (16) having at least one lobe (26, 28).

FIG 2



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Description

Background of the invention

[0001] The invention relates to a turbine for a thermal power plant comprising a rotor, at least one blade having a blade root engaged to the rotor via a groove/bar-connection and a locking device being arranged between the blade root and the rotor for blocking a relative movement in at least one direction between the blade root and the rotor.

[0002] Turbines currently known in the state of the art comprise axially assembled blades. For example low pressure steam turbine blades comprise blade feet, which are secured in axial and radial direction in order to keep the blade in the rotor groove and to prevent it from rocking motion. Such rocking motion would eventually damage the surfaces of the blade feet and/or rotor grooves leading to early retirement of the parts involved.

[0003] In order to secure the blade feet in the rotor groove currently a caulking piece is inserted in respective rotor grooves for radial locking. Axial locking is achieved by inserting locking strips in tangential rotor grooves.

Summary of the invention

[0004] It is an object of the present invention to provide a turbine for a thermal power plant of the type mentioned above, in which the at least one blade can be secured cost efficiently and safely to the rotor, particularly in a simple and efficient assembly operation.

[0005] In order to solve the above object, according to the present invention a turbine for a thermal power plant according to the above type is provided, which is characterized in that the locking device comprises a rotatable cam-disc having at least one lobe.

[0006] By rotating the cam-disc of the locking device from a position, in which the blade root and the rotor abut to the cam-disc at locations away from the lobe to a position, in which the lobe contacts the blade root or the rotor, the blade root and the rotor are pushed apart. This results in the engagement between the blade root and the rotor via the groove/bar-connection to be tightened, as respective engagement surfaces of the blade root and the rotor are pushed firmly together. The resulting locking of the respective blade root to the rotor can therefore be achieved in a simple assembly operation, namely by merely rotating the cam-disc. This results in a cost efficient assembly process. Further, the locking device can be manufactured of only one single part, which further reduces the cost of the device.

[0007] Further, the locking of the respective blade root to the rotor can easily be resolved by rotating the cam-disc back into its original position. The blade root can therefore be easily disassembled according to the inventive solution. A new turbine blade can subsequently be installed using the same locking device by rotating the same into its locking position. As compared to solutions currently known in the art, in which caulking pieces are inserted in respective rotor grooves and/or locking strips are inserted in tangential rotor grooves, in the turbine according to the current invention no grooves in highly loaded zones of the rotor and the blade have to be provided. This increases the durability of the rotor and the respective blades and therefore of the overall turbine.

[0008] According to the invention it is further practical, if the cam-disc is arranged to create a radial force between the rotor and the blade root in the area of the groove/bar-connection by rotating the cam-disc. Preferably, the cam-disc is arranged such that its rotational axis is substantially parallel to the longitudinal axis of the rotor. In particular, it is practical of the rotational axis of the cam-disk is arranged with respect to the longitudinal axis of the rotor at an angle in the range from 0° to 40°, preferably in the range from 20° to 30°. This allows a locking of the respective turbine blade in at least a radial direction.

[0009] It is further advantageous, if the locking device further comprises a preferably bendable cam-shaft connected to the cam-disc and arranged in parallel or substantially in parallel to the longitudinal axis of the rotor, in particular at an angle in the range from 0° to 40°, preferably in the range from 20° to 30° with respect to the longitudinal axis of the rotor. The cam-shaft allows the rotatable cam-disc to be easily operated from the outside of the turbine. The locking device is therefore accessible from one side, preferably from the outlet side of the turbine. It is further practical, if the cam-shaft has a turn-key insert, preferably an Inbuskey insert. This way, the locking device can be operated using standard tools. The operation of the inventive turbine is designed service friendly due to the cam-shaft. The cam-shaft further improves the positional stability of the cam-disc, as due to the cam-shaft being arranged between the blade root and the rotor the cam-disc attached thereto is stabilized in a position in which its face sides are perpendicular to the longitudinal axis of the rotor. By designing the cam-shaft bendable an "elastic" force can be created between the blade root and the rotor by turning the cam-disc to a position in which the cam-shaft is bent due to the interaction of the lobe on the cam-disc with the blade root. The "elastic" force created therewith keeps a sufficient value over a wide range of rotor operation. This also allows an intentional radial motion of the blade relative to the rotor.

[0010] It is further expedient, if the blade root and/or the rotor each have a respective disc recess adapted to accommodate a respective portion of the cam-disc when oriented with its rotation axis being parallel or substantially parallel to the longitudinal axis of the rotor, in particular at an angle in the range from 0° to 40°, preferably in the range from 20° to 30° with respect to the longitudinal axis of the rotor. That means, the cam-disc extends perpendicular to the longitudinal axis of the rotor. The respective disc recesses in the blade root and the rotor allow for axial locking of the turbine blade to the rotor. In order to move the turbine blade relative to the rotor in longitudinal direction, the cam-disc would have to be sheared off the cam-shaft. Hence, a positive fit is achieved. According to the inventive turbine, only one locking device is required for blocking both radial and axial movement of a respective blade root relative to the rotor.

[0011] It is further advantageous, if the rotor has a shaft recess adjoining the disc recess in the rotor and extending along a portion of the cam-shaft, the radial depth of the shaft recess being smaller than the radial depth of the disc recess in the rotor. A correspondingly configured shaft recess allows for the cam-shaft to be bent when rotating the cam-disc to a locked position. Further, the above described advantages with respect to the provision of a bendable cam-shaft can be achieved more fully with the provision of the above shaft recess.

[0012] It is further expedient, if the cam-disc comprises at least two lobes, one of which preferably has a larger peak radius than the other one. Advantageously, the respective minimum radii of the angular ranges between the at least two lobes have at least two different values. That allows the cam-disc to be arranged in a first rotational position, in which the angular range between the at least two lobes having the smaller value faces towards the blade root. In this rotation position the blade root can be engaged with the rotor by sliding the same along the rotor in a longitudinal direction of the rotor, such that the bar and the groove of the groove/bar connection slide into each other. In this sliding operation the blade root can slide over the cam-disc. Then the cam-disc can be rotated to an orientation, in which the angular range between the at least two lobes having the larger radius faces towards the blade root and therewith protrudes into the disc recess of the blade root. Therewith, the cam-disc can be oriented in a so-called equilibrium range, which means the cam-disc is in a stable locking position between the at least two lobes. An undesired unlocking of the blade root by a rotation of the cam-disc induced by vibration movement during the operation of the turbine is prevented by the at least two lobes delimiting the possible movement of the cam-disc with respect to the blade root to the angular range between the two lobes.

[0013] For facilitating the assembly operation, in which the blade root is slid in a longitudinal direction of the rotor for engaging in the groove/bar-connection, it is advantageous, if one of the minimum radii is adapted such that the respective portion of the cam-disc does not protrude into the disc recess in a rotational position of the locking device, in which the respective portion faces towards the disk recess. This way the sliding operation is not obstructed by the cam-disc. As the cam-disc does not protrude into the disc recess of the blade root, the blade root is not touched by the cam-disc during the assembly operation when oriented in the proper position.

[0014] It is further practical, if the at least one lobe contains a blocking lobe, which has a peak radius being adapted, such that the respective portion of the cam-disc exceeds the depth of the disc recess in the blade root and/or the rotor in a way that it blocks and/or resists a full revolution of the cam-disc. For this purpose the peak radius of the blocking lobe can be made larger than the peak radius of the safeguard lobe, but can also be made equal to that radius. This feature improves the locking reliability of the blade root to the rotor, as it helps prevent an undesired unlocking of the connection. The connection between the blade root and the rotor can only easily be unlocked by rotating the cam-disc reversely to the rotation direction employed for locking the connection. Rotating the cam-disc in the same direction is not or not easily possible due to the presence of the locking lobe. This effect also increases the user friendliness of the locking device, as the operator is prevented by the blocking lobe of rotating the cam-disc too far during the locking operation.

[0015] In order to provide an equilibrium range with respect to the rotational position of the cam-disc, in which the groove/bar-connection is blocked safely, it is expedient, if the at least one lobe contains a safeguard lobe, which has a peak radius being adapted, such that the respective portion of the cam-disc exceeds the depth of the recess in the blade root in a way that the cam-disc can only be rotated beyond by simultaneously bending the cam-shaft. That means, in order to unlock the groove/bar-connection the cam-disc has to be rotated against a "resistance" generated by the safeguard lobe, which can only be overcome by causing the cam-shaft to bend. This feature further prevents an unintentional unlocking of the groove/bar-connection caused for example by vibrations generated during the operation of the turbine.

[0016] It is further advantageous, if the groove/bar-connection comprises an undercut groove and a correspondingly bulged bar, preferably a groove and a bar each having a fir-tree profile. In an alternative embodiment the groove and the bar can have a dove tail profile. This way the engagement between the blade root and the rotor is particularly robust. A radial force generated by the locking device, pushing the rotor and the blade root apart causes the engagement between the undercut groove and the correspondingly bulged bar to be locked.

Brief description of the drawings

[0017] A detailed description of an embodiment of the present invention is provided herein below with reference to the following schematic drawings, in which,

Fig. 1 is a sectional view of a connection portion between a turbine rotor and a turbine blade using a locking device according to the present invention,

Fig. 2 depicts the section II-II according to Fig. 1,

Fig. 3 is a perspective view of the locking device shown in Figs. 1 and 2 comprising a cam-disc,

Fig. 4a illustrates the variation of the radius of the cam-disc according to Fig. 3 in Cartesian and polar coordinates,

Fig. 4b shows the radial variation of the cam-disc of Fig. 4a against the angle φ,

Fig. 5a illustrates the shape of the locking device according to Fig. 3 being subjected to an insignificant amount of radial force, and

Fig. 5b illustrates the shape of the locking device according to Fig. 3 being subjected to a significant amount of radial force.

Description of a preferred embodiment

[0018] Fig. 1 depicts a sectional view of a connection portion between a turbine rotor 10 of a thermal power plant having a rotor axis 11 and a blade root 12 of a turbine blade. The blade root 12 can have a straight bottom, as shown in Fig. 1, or a curved bottom. The turbine blade is a substantially axially assembled blade that means for assembly the blade root 12 is slid in a linear or curved path oriented at a small angle towards the direction of the rotor axis 11, which is the horizontal direction in Fig. 1, into a rotor groove 13 shown in Fig. 2. The rotor groove 13 has a fir-tree profile and is adapted to the profile of the correspondingly shaped blade root 12. In a further embodiment, not shown in the figures the rotor groove 13 and the blade root 12 can have a dove tail profile.

[0019] Due to the fir-tree profiles the blade root 12 and the rotor groove 13 engage in a radial direction of the turbine rotor 10, which corresponds to the vertical direction in Fig. 1 and 2. That means, the engagement between the blade root 12 and the rotor groove 13 prevents the blade root 12 from slipping out of the rotor groove 13 in a radial direction.

[0020] Between the turbine rotor 10 and the blade root 12 a locking device 14, as shown in Fig. 1 and 2 is arranged. The locking device 14 comprises a cam-shaft 18 arranged parallel to the rotor axis 11 and a cam-disc 16 arranged at one end of the cam-shaft 18. In the position shown in Fig. 1 the cam-disc 16 protrudes both into a disc recess 22 of the rotor 10 and a disc recess 24 of the blade root 12. Adjoining the disc recess 22 of the rotor 10 a shaft recess 20 of smaller radial depth in comparison to the disc recess 22 is provided in the rotor 10. As illustrated in Figs. 5a and 5b, the shaft recess 20 allows a bending of the cam-shaft 18 if a radial force F is applied to the cam-disc 16 arranged at the front end of the cam-shaft 18. The cam-shaft 18 fixed in radial direction at an end fixation point 36 between the rotor 10 and the blade root 12 and supported at a rotor support point 38 bends downwards mostly with the portion of the cam-shaft 18 protruding towards the right.

[0021] Fig. 3 shows a perspective view of the locking device 14. The profile of the cam-disc 16 in the plane of the face of the cam-disc 16 is shown in detail in Figs. 4a and 4b. Fig. 4a shows the profile of the cam-disc 16 in Cartesian and polar coordinates, whereas Fig. 4b shows this profile in polar coordinates. For this purpose the radius r is plotted developed against the angle φ. As can be seen from the graphs, the cam-disc 16 has two lobes, namely a first safeguard lobe 26 and a second longer blocking lobe 28. Between the safeguard lobe 26 and the blocking lobe 28, an equilibrium zone 30 of smaller radius is located. At the angle φ=0 the cam-disc 16 has a minimum radius 32.

[0022] For the assembly operation of the blade root 12 and the rotor 10, the locking device 14 is arranged in a rotation position, as shown in Fig. 2, in which the portion with the minimum radius 32 faces radially outwards with respect to the rotor axis 11. In this rotational position of the cam-disc 16 the blade root 12 can be slid in and out of rotor groove 13 without interference with the cam-disc 16, that means the blade root 12 can slide over the cam-disc 16.

[0023] Once the blade root 12 is in its final axial position the cam-disc 16 is rotated via a turn-key insert 34 at the opposite face of the cam-shaft 18 and/or at the face of the cam disc 16 (not shown in the figures). The turn-key insert 34 can be operated via an Inbuskey or a similar tool. By rotating the cam-disc 16 its outer perimeter is extended into the disc recess 24 of the blade root 12. At a certain point of the rotation, the safeguard lobe 26 hits against the bottom portion of the disc recess 24. This creates a force acting on the blade root 12 and reacting on the cam-disc 16. In turn the cam-shaft 18 bends as shown in Fig 5b. When continuing the rotation movement beyond the safeguard lobe 26 the portion of the cam-disc 16 in the area of the equilibrium zone 30 (lowest potential) is located within the disc recess 24 of the blade root 12. In this rotation position the radial force on the cam-disc 16 is released, such that the cam-shaft bends into a less bent shape or reverts completely back into a straight unbent shape, as shown in Fig. 5a. A continued rotation of the cam-disc 16 in the same direction is blocked by the blocking lobe 28.

[0024] With the blocking device 14 in a rotation position, in which the cam-disc 16 protrudes into the disc recess 24 of the blade root 12 in the area of the equilibrium zone 30 the blade root 12 is both locked in axial as well as in radial direction. The cam-disc 16 would have to be sheared off to allow for axial movement, hence a positive fit is achieved. The locking in the radial direction on the other hand is implemented with an elastic component. A movement of the blade root 12 in a radial direction towards the turbine rotor 10 is possible to a certain extent under an elastic bending of the cam-shaft 18, as shown in Fig. 5b. The radial force present in equilibrium position prevents the blade from rocking or tilting motion during turn gear operation.

[0025] In order to unlock the blade root 12 the locking device 14 has to be rotated reversely to the rotation direction employed for locking the blade root 12. That means, using an Inbuskey the locking device 14 is rotated via the safeguard lobe 26 back to a position with the minimum radius 32 facing towards the disc recess 24 of the blade root 12.

Claims

1. Turbine for a thermal power plant comprising a rotor (10), at least one blade having a blade root (12) engaged to said rotor (10) via a groove/bar-connection (12, 13) and a locking device (14) being arranged between said blade root (12) and said rotor (10) for blocking a relative movement in at least one direction between said blade root (12) and said rotor (10), **characterized in that** said locking device (14) comprises a rotatable cam-disc (16) having at least one lobe (26, 28).

2. Turbine according to claim 1,
wherein said cam-disc (16) is arranged to create a radial force between said rotor (10) and said blade root (12) in the area of said groove/bar-connection (12, 13) by rotating said cam-disc (16).

3. Turbine according to claim 1 or 2,
wherein said locking device further comprises a preferably bendable cam-shaft (18) connected to said cam-disc (16) and arranged substantially in parallel to the longitudinal axis of said rotor (10), in particular at an angle in the range from 0° to 40°, preferably in the range from 20° to 30° with respect to the longitudinal axis of said rotor (10).

4. Turbine according to any one of the preceding claims,
wherein said blade root (12) and/or said rotor (10) each have a respective disc recess (22, 24) adapted to accommodate a respective portion of said cam-disc (16) when oriented with its rotation axis being substantially parallel to the longitudinal axis of said rotor (10), in particular at an angle in the range from 0° to 40° preferably in the range from 20° to 30° with respect to the longitudinal axis of said rotor (10).

5. Turbine according claim 4,
wherein said rotor (10) has a shaft recess (20) adjoining said disc recess (22) in said rotor (10) and extending along a portion of said cam shaft (18), the radial depth of said shaft recess (20) being smaller than the radial depth of said disc recess (22) in said rotor (10).

6. Turbine according to any one of the preceding claims,
wherein said cam-disc (16) comprises at least two lobes (26, 28), one of which preferably has a larger peak radius than the other one.

7. Turbine according to claim 6,
wherein respective minimum radii of the angular ranges between said at least two lobes (26, 28) have at least two different values.

8. Turbine according to claim 6 or 7,
wherein one of said minimum radii is adapted such that the respective portion of said cam-disc (16) does not protrude into said disc recess (24) of said blade root (12) in a rotational position of said locking device, in which said respective portion faces towards the disk recess (24).

9. Turbine according to any one of the preceding claims,
wherein said at least one lobe (26, 28) contains a blocking lobe (28), which has a peak radius being adapted, such that the respective portion of said cam-disc exceeds the depth of said disc recess (24) in said blade root (12) and/or said rotor (10) in a way that it blocks and/or resists a full revolution of said cam-disc (16).

10. Turbine according to any one of the preceding claims,
wherein said at least one lobe (26, 28) contains a safeguard lobe (26), which has a peak radius being adapted, such that the respective portion of said cam-disc (16) exceeds the depth of said disc recess (24) in said blade root (12) in a way that said cam-disc (16) can only be rotated beyond by simultaneously bending said cam-shaft (18).

11. Turbine according to any one of the preceding claims,
wherein said groove/bar-connection (12, 13) comprises an undercut groove (13) and a correspondingly bulged bar (12), preferably a groove (13) and a bar (12) each having a fir-tree shaped profile.

FIG 1

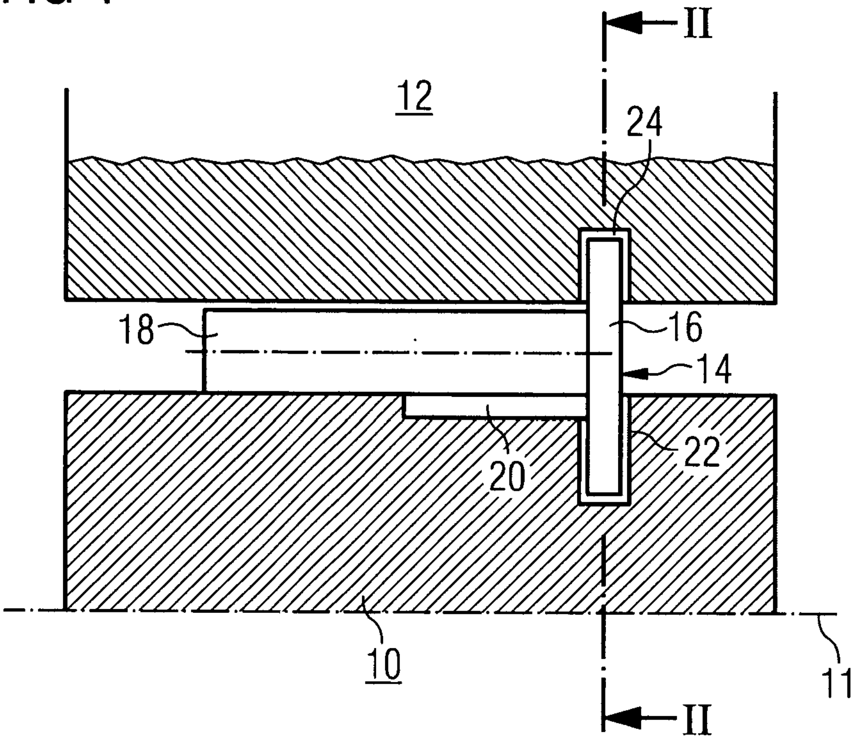


FIG 2

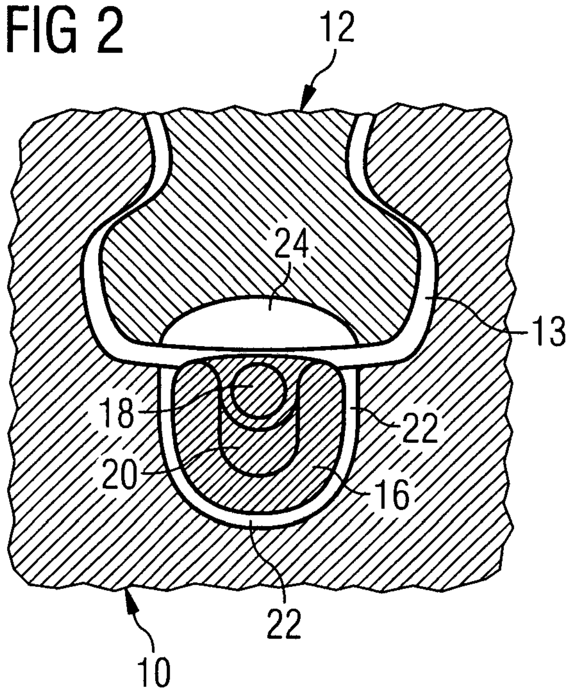


FIG 3

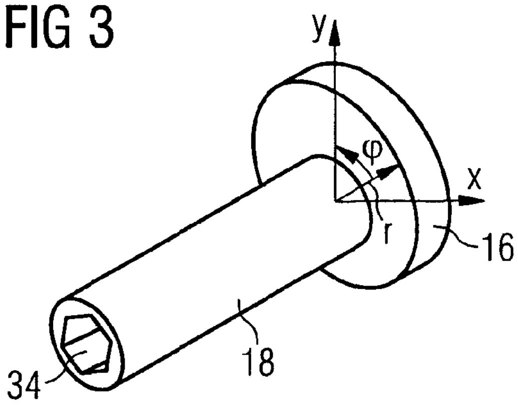


FIG 4A

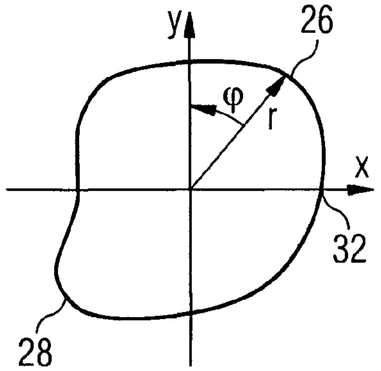


FIG 4B

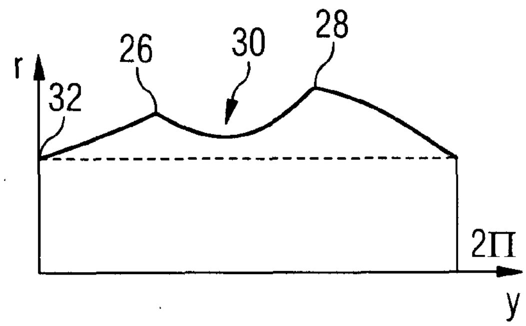


FIG 5A

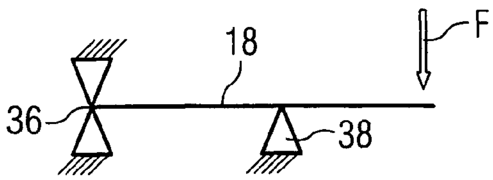
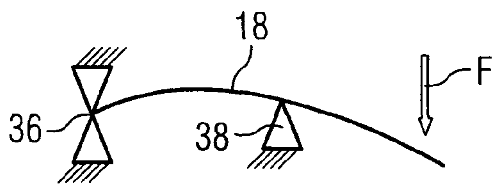


FIG 5B



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EUROPEAN SEARCH REPORT

Application Number
EP 05 01 7643

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 3 986 779 A (BECKERSHOFF ET AL) 19 October 1976 (1976-10-19) * column 1 - column 6, lines 42-68; figures 7-11 * * column 7, lines 1-42 *	1-5,8-11 6,7	F01D5/30 F16C35/063
Y	DE 101 41 113 A1 (INA-SCHAEFFLER KG) 6 March 2003 (2003-03-06) * paragraphs [0018], [0021]; figures 1-3,5 *	6,7	
Y	DE 42 31 339 A1 (KUEHL, HANS, 73207 PLOCHINGEN, DE) 24 March 1994 (1994-03-24) * column 2, lines 20-68 - column 3; figures 1-9 *	6,7	
A	US 5 100 292 A (MATULA ET AL) 31 March 1992 (1992-03-31) * abstract; figures 1,3 *	11	

TECHNICAL FIELDS SEARCHED (IPC)

F01D
F16C

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	22 March 2006	Chatziapostolou, A

CATEGORY OF CITED DOCUMENTS

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22-03-2006

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 3986779 A	19-10-1976	CH 572155 A5	30-01-1976
		DE 2433043 A1	11-12-1975
		DE 7423406 U	01-07-1976
		FR 2273155 A1	26-12-1975
		GB 1514724 A	21-06-1978
		IT 1038322 B	20-11-1979
		JP 51007324 A	21-01-1976
		NL 7506123 A	01-12-1975
		SE 403501 B	21-08-1978
		SE 7505856 A	28-11-1975
DE 10141113 A1	06-03-2003	NONE	
DE 4231339 A1	24-03-1994	NONE	
US 5100292 A	31-03-1992	CA 2034374 A1	20-09-1991
		DE 4108085 A1	26-09-1991
		FR 2659688 A1	20-09-1991
		GB 2243193 A	23-10-1991
		IT 1245238 B	13-09-1994
		JP 4224202 A	13-08-1992

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