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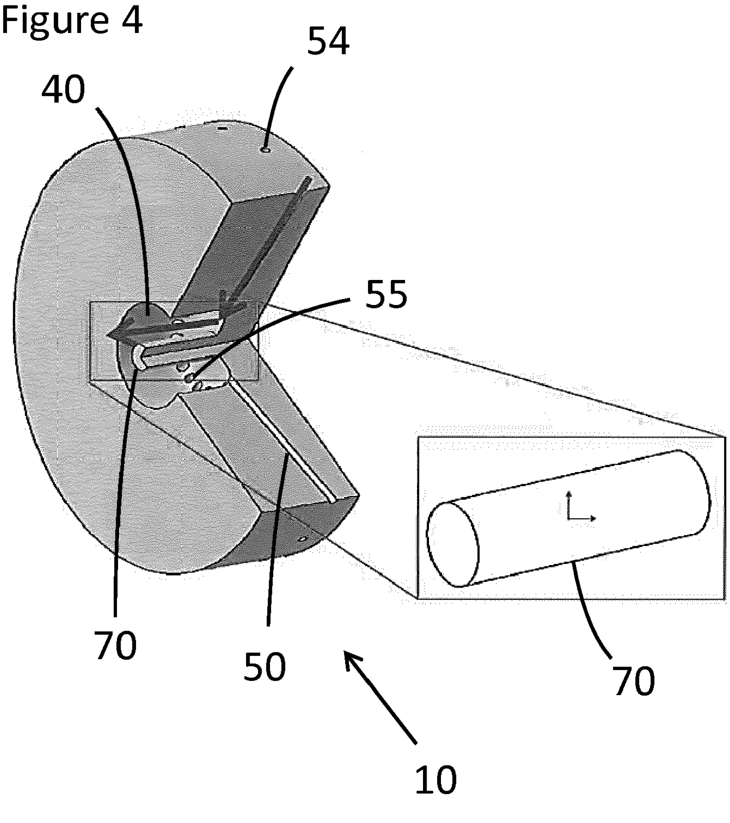
(54) ANTI-VORTEX STRUCTURE FOR A GAS TURBINE

(57) This application describes a gas turbine rotor (10) extending along a rotor axis (12), the gas turbine rotor comprising a rotor body, a cooling bore (50) extending inside the rotor body, a cavity (40) extending inside the rotor body at the rotor axis, the cavity being in fluid communication with the cooling bore and the cooling bore being configured and arranged to direct a cooling fluid to the cavity from a compressor adjacent to the rotor body, and an anti-vortex structure (70, 72) attached to the rotor body and arranged inside the cavity at the rotor axis.

Figure 4



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to gas turbines with anti-vortex structures, and particularly to gas turbine rotors with an anti-vortex structure arranged at the rotor axis in a cavity in the rotor body.

BACKGROUND OF THE INVENTION

[0002] In today's gas turbines, various parts are subject to extreme temperatures, particularly within the combustor and the turbine, and as a result providing effective cooling systems is critical. In some gas turbines, air is bled from the compressor and passed through the rotor to cool parts in the turbine. Due to the high rotation speeds of gas turbines, the existing systems to pass air through the rotor can create vortices that reduce the effectiveness of the air flow through the rotor.

SUMMARY OF THE INVENTION

[0003] The invention is defined in the appended independent claims to which reference should now be made. Advantageous features of the invention are set forth in the dependent claims.

[0004] An aspect of the invention provides a gas turbine rotor extending along a rotor axis, the gas turbine rotor comprising a rotor body, a cooling bore extending inside the rotor body, a cavity extending inside the rotor body at the rotor axis, the cavity being in fluid communication with the cooling bore and the cooling bore being configured and arranged to direct a cooling fluid to the cavity from a compressor adjacent to the rotor body, and an anti-vortex structure attached to the rotor body and arranged inside the cavity at the rotor axis.

[0005] The anti-vortex structure can fill space occupied by the vortex breakdown in the cavity at the rotor axis, which can minimise or avoid high swirls and as a consequence reduce or avoid vortex breakdown. This can reduce or avoid creation of a local low pressure area that can suck cooling fluid back in the direction opposite the main cooling fluid flow direction.

[0006] This gas turbine rotor can provide a number of potential benefits. Secondary air system losses can be reduced, and cooling fluid can be taken from the compressor to the turbine in a more thermodynamically efficient manner than in existing secondary air systems. In particular, the transfer of the cooling fluid can be carried out while minimising the associated losses and backflows generated by the large rotational speed of the cooling fluid. The need for extra cooling sources or external coolers can therefore be reduced or removed, potentially reducing costs and complexity (for example in piping arrangements). Gas turbine efficiency can also be increased.

[0007] This gas turbine rotor can provide cooler cooling fluid at the turbine compared to designs without an anti-vortex structure, as a reduction in the loss of pressure in the cooling system (cavity and cooling bores) means that cooling fluid can be bled from the compressor at a lower pressure, providing cooling fluid at a lower temperature. This can allow for a reduced cost of cooling fluid flow.

[0008] Preferably, the anti-vortex structure is cylindrical or substantially cylindrical. This can fill the space where a vortex would form without unduly blocking cooling fluid flow.

[0009] Preferably, the anti-vortex structure is an impeller. This can push the flow to make it rotate at the same speed as the rotor and to avoid high swirls, which can reduce the rotational velocity of the cooling fluid to a rotational velocity similar to the rotational velocity of the rotor.

[0010] Preferably, the anti-vortex structure is attached to a front wall of the cavity, the front wall being at the upstream end of the cavity relative to the flow of cooling fluid through the cavity during use. Alternatively, the anti-vortex structure is attached to a wall of the cavity downstream of a front wall of the cavity.

[0011] Preferably, the cooling bore extends in a radial direction relative to the rotor axis.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] An embodiment of the invention will now be described by way of example only and with reference to the accompanying drawings in which:

Figure 1 shows a simplified cross-section of part of a gas turbine;
Figure 2 shows a simplified cross-section of part of another gas turbine;
Figure 3 shows a part of a rotor of a gas turbine similar to that in Figure 2;
Figures 4, 5, 6 and 7 show perspective views of gas turbine rotor sections with an anti-vortex structure.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0013] Figure 1 shows part of a gas turbine comprising a rotor 10, a compressor 20 and a turbine 30. The rotor is typically constructed from multiple rotor discs, and the joins between these pieces are shown with dotted lines. The rotor rotates around a rotor axis (gas turbine rotor axis) 12 when in use. A cavity 40 extends inside the rotor at the rotor axis. A cooling bore 50 extends from the compressor to the cavity, and another cooling bore 52 extends from the cavity to the turbine, providing fluid communication through a cooling fluid path from the compressor to the turbine via the cavity in the rotor. The path that cooling fluid can take through the gas turbine is shown with arrows.

[0014] Figure 2 shows a gas turbine similar to that in Figure 1, but with a different cooling bore 50. In Figure 1, a short cooling bore is shown, extending from the outer edge of the rotor (from the compressor) to a part of the cavity 40 that is distal from the rotor axis 12. In Figure 2, in contrast, the bore extends from the outer edge of the rotor to a part of the cavity that is proximate the rotor axis 12, although the bore would normally not extend all the way to the rotor axis. As such, the bore in Figure 2 extends most of the way from the outer edge of the rotor to the rotor axis.

[0015] Figure 3 shows a portion of a rotor 10 with a long cooling bore from the compressor 20 to the cavity 40. Several arrows show the flow of cooling air in the cavity when the gas turbine is in use.

[0016] The resulting flow pattern in Figure 3 is related to the rotation of the rotor. The cooling fluid in the cooling bore rotates at the same rate as the rotor whilst it is in the bore. When the cooling fluid exits the bore into the cavity, it is still moving towards the centre of the rotor but no longer has the cooling bore to regulate its rotational velocity and the rotational velocity of the cooling fluid therefore rapidly increases as it passes towards the rotor axis. The resulting rotational velocity of the cooling fluid can easily be a factor of ten higher than the rotational speed of the rotor. If friction is neglected, high swirl velocity results as the flow follows the free vortex equation. The result is that low local static pressures form in the centre of rotor. The low local static pressure near the centre of the rotor sucks air from downstream regions. The result of this is the flow pattern shown in Figure 3, where cooling fluid passes through the cooling bore 50 from the compressor into the cavity 40. The bulk of the cooling fluid follows the flow 60 through the cavity towards the cooling bore 52 and the turbine 30, but in a portion of the cavity near the cooling bore 50 and around the rotor axis 12, a vortex 64 (vortex breakdown) forms. The vortex disrupts cooling fluid flow, partly by reducing the cross-section of the cavity available for cooling fluid to flow from cooling bore 50 to cooling bore 52, and partly due to reverse flows (backflows). That is, rather than all the cooling fluid in the flow 60 simply flowing through the cavity, as shown by the arrows in Figures 1 and 2, a portion of the flow 60 actually reverses direction and becomes a reverse flow 62, heading back towards the cooling bore 50.

[0017] To combat the vortex 64 shown in Figure 3, an anti-vortex structure can be placed in the region where the vortex would otherwise form. This can help with passing the cooling fluid through the cavity while minimising the losses and backflows generated by the large rotational speed of the air. Two examples of anti-vortex structures are shown in Figures 4 to 7.

[0018] In Figures 4 and 5, part of a rotor 10 with long cooling bores 50 such as in Figure 2 is shown. The long cooling bores can be seen extending from entrances 54 at the compressor to exits 55 at the cavity. A cylindrical anti-vortex structure 70 can be seen extending into the cavity in Figure 4. In Figure 5, the anti-vortex structure is an impeller 72. The impeller has blades that extend in the radial and axial directions. In Figure 5, the axial direction 13, radial direction 14 and circumferential direction 15 are shown for reference. Figures 6 and 7 each show a part of a rotor similar to Figures 4 and 5, but with short cooling bores 50 as shown in Figure 1.

[0019] In a method of cooling using a gas turbine with a rotor as described above, cooling fluid is compressed in a compressor 20, passed through a cooling bore 50 from the compressor to a cavity 40, through the cavity and through a cooling bore 52 from the cavity to a turbine 30. In the turbine, the cooling fluid could be used to cool components such as blades, for example. The cooling fluid would normally be cooling air, although other gases or liquids could also be used.

[0020] A gas turbine comprises a compressor, a combustor downstream of the compressor and a turbine downstream of the combustor. A gas turbine also comprises a rotor 10 extending from the compressor to the combustor. In the examples above, the rotor 10 is shown as comprising multiple smaller pieces (discs) that are joined together. These portions could be welded or bolted together, for example.

[0021] The cavity 40 extends from a front wall 42 to a back wall 44, with the front wall being at the upstream end of the cavity relative to the flow of cooling fluid through the cavity during use. In other words, the front wall is at the compressor end of the cavity and the back wall is at the turbine end of the cavity. As can be seen in Figures 1 and 2 in particular, the cavity extends along and around the rotor axis 12.

[0022] Various different cooling bores and cooling bore arrangements can be used. One or more cooling bores 50, 52 could be provided in the rotor. Normally multiple cooling bores are provided spaced around the circumference of the rotor, as shown in Figures 4 to 7. A short cooling bore will normally extend less than half of the distance in the radial direction 14 between the compressor 20 and the rotor axis 12, whereas a long cooling bore will normally extend more than 75% of the distance in the radial direction between the compressor and the rotor axis. The cooling bores will normally extend primarily in the radial direction, although they may also extend in other directions. In particular, the cooling bores may also extend in the axial direction to some extent, as is shown in the Figures.

[0023] The anti-vortex structure is configured to combat vortex formation in the cooling fluid in the cavity after it has entered the cavity from the cooling bore. Various different anti-vortex structures can also be provided besides those shown in the Figures. For example, rather than providing a cylindrical anti-vortex structure, the anti-vortex structure could be contoured with a varying diameter to maximise its effect, based on analysis of the flow within the cavity. This would generally still be a somewhat cylindrical shape. The anti-vortex structure shape can thereby be optimised to minimise the vortex. The anti-vortex structure normally extends along the rotor axis, and will normally be longer in the axial direction 13 than in the radial direction 14.

[0024] The anti-vortex structure is normally surrounded by the cavity as shown in Figures 4 to 7. The anti-vortex structure is normally attached to the cavity wall, for example to the cavity front wall 42, and normally extends partway between the cavity front wall and the cavity back wall 44. Attachment to other parts of the wall of the cavity is also possible, for example to a wall of the cavity downstream of the cavity front wall. When attached downstream of the cavity front wall, the anti-vortex structure would generally be attached to the part of a disc that is closest to the centre of the rotor. As an example, the disc 75 (delineated by dotted lines) in Figure 1, which is a part of the rotor 10, has an inner surface 76 which is part of the wall of the cavity, and the anti-vortex structure could be attached to the inner surface 76. Generally, the anti-vortex structure extends less than 20% or less than 10% of the distance from the front wall to the back wall. Generally, the anti-vortex structure extends only within the portion of the cavity that is surrounded by the compressor.

[0025] The anti-vortex structure can be manufactured as an integral part of the rotor, for example by forging, or can be manufactured separately and attached to the rotor, for example by welding or bolting. It is possible to retrofit an anti-vortex structure to an existing rotor.

[0026] With short bores in particular, it can be useful to attach ribs to the rotor, the ribs extending in the cavity in the radial direction in the space between the exit of the cooling bore and the anti-vortex structure. These ribs may be attached to the anti-vortex structure, may be an extension of the anti-vortex structure, or may be separate from the anti-vortex structure. These ribs can reduce or avoid an increase in the rotational velocity of the cooling fluid before it reaches the anti-vortex structure.

[0027] The impeller 72 would normally have two or more blades arranged around its circumference, such as those shown in Figures 5 and 7. The blades may be planar, as shown in Figures 5 and 7, or may describe other shapes such as more aerodynamically optimised shapes. This can provide better alignment to cooling fluid velocity vectors.

[0028] Various modifications to the embodiments described are possible and will occur to those skilled in the art without departing from the invention which is defined by the following claims.

REFERENCE NUMERALS

10	rotor	54	cooling bore entrance
12	rotor axis	55	cooling bore exit
13	axial direction	60	cooling fluid flow
14	radial direction	62	reverse cooling fluid flow
15	circumferential direction	64	vortex
20	compressor	70	cylindrical anti-vortex structure
30	turbine		
40	cavity	72	impeller
42	cavity front wall	75	disc
44	cavity back wall	76	inner surface
50	cooling bore		
52	cooling bore		

Claims

1. A gas turbine rotor (10) extending along a rotor axis (12), the gas turbine rotor comprising
a rotor body,
a cooling bore (50) extending inside the rotor body,
a cavity (40) extending inside the rotor body at the rotor axis, the cavity being in fluid communication with the cooling bore and the cooling bore being configured and arranged to direct a cooling fluid to the cavity from a compressor adjacent to the rotor body, and
an anti-vortex structure (70, 72) attached to the rotor body and arranged inside the cavity at the rotor axis.

2. The gas turbine rotor (10) of claim 1, wherein the anti-vortex structure is cylindrical (70) or substantially cylindrical.

3. The gas turbine rotor (10) of claim 1, wherein the anti-vortex structure is an impeller (72).

4. The gas turbine rotor (10) of any one of claims 1 to 3, wherein the anti-vortex structure (70, 72) is attached to a front wall (42) of the cavity (40), the front wall being at the upstream end of the cavity relative to the flow of cooling fluid through the cavity during use.

5. The gas turbine rotor (10) of any one of claims 1 to 3, wherein the anti-vortex structure (70, 72) is attached to a wall of the cavity downstream of a front wall (42) of the cavity (40), the front wall being at the upstream end of the cavity relative to the flow of cooling fluid through the cavity during use.

6. The gas turbine rotor (10) of any one of claims 1 to 5, wherein the cooling bore (50) extends in a radial direction relative to the rotor axis (12).

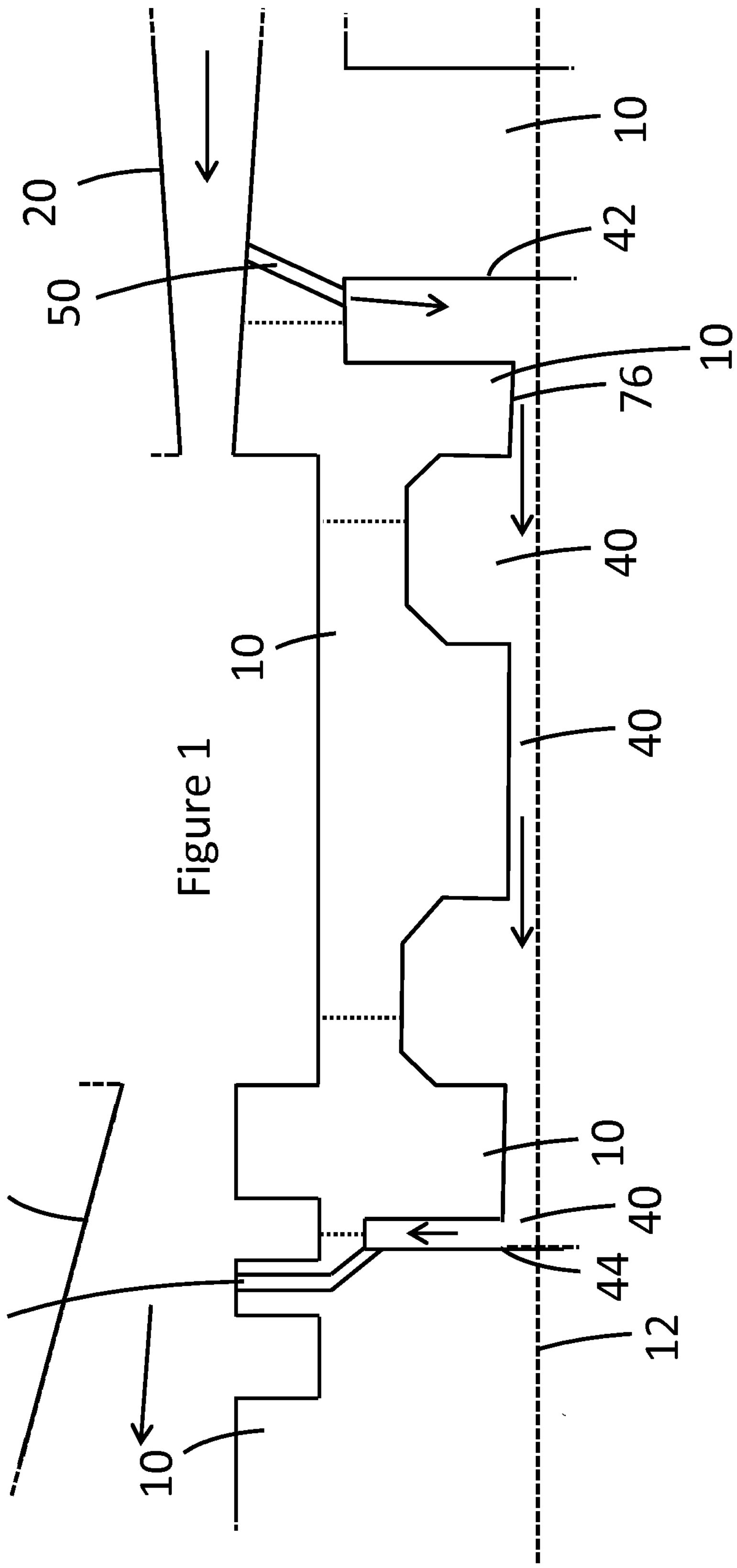


Figure 1

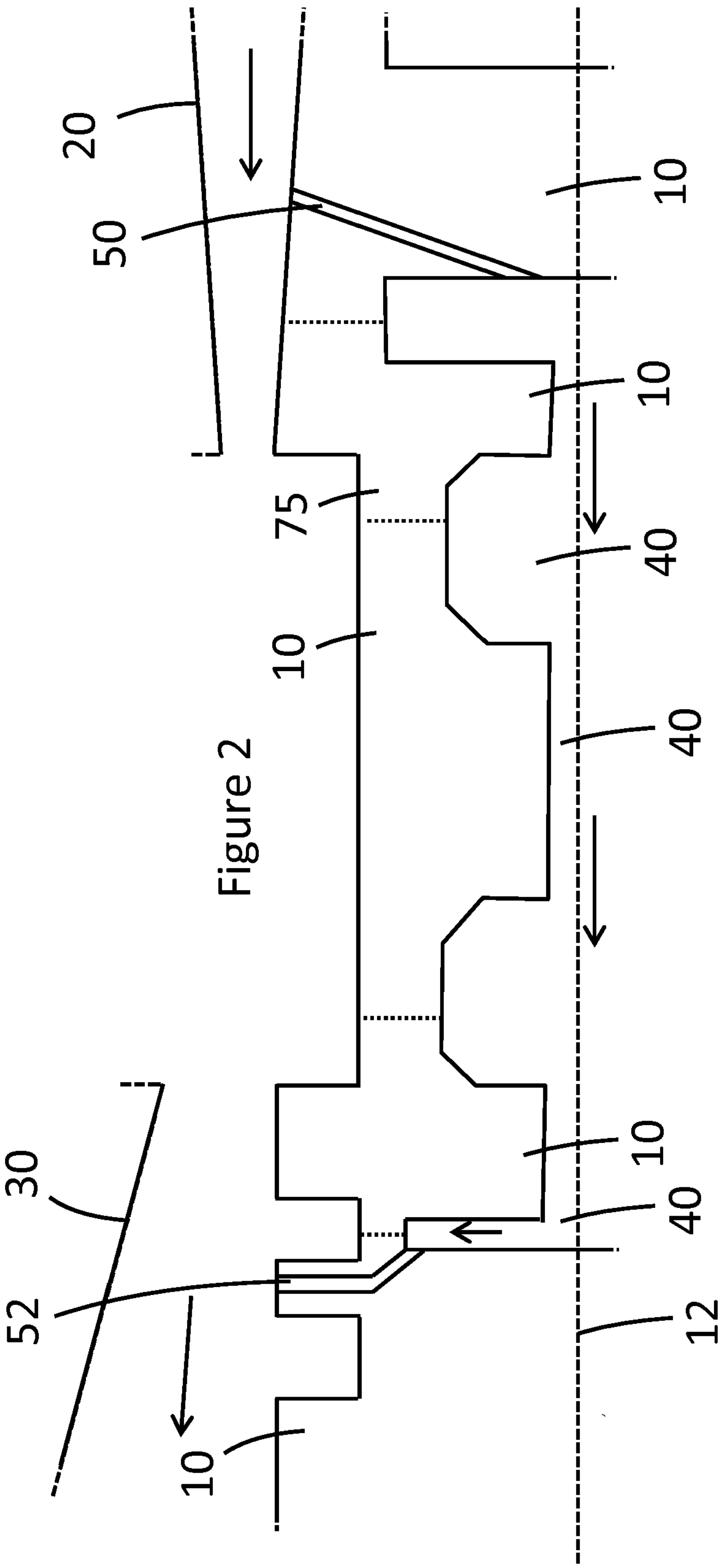


Figure 2

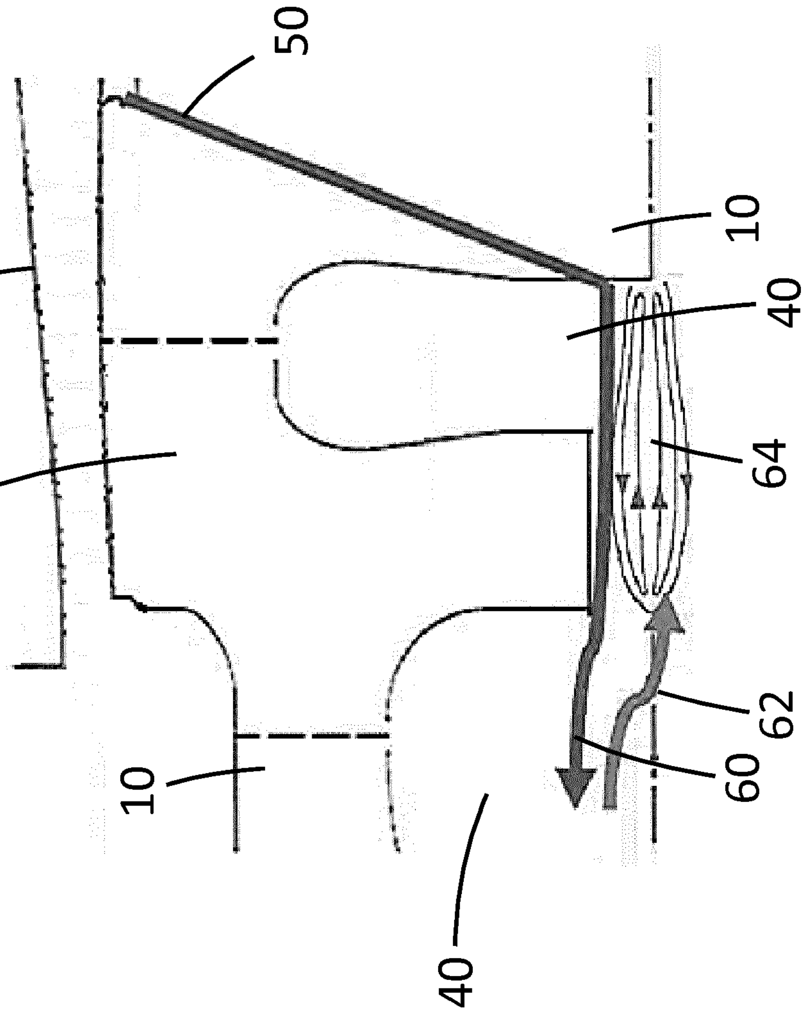


Figure 3

Figure 5

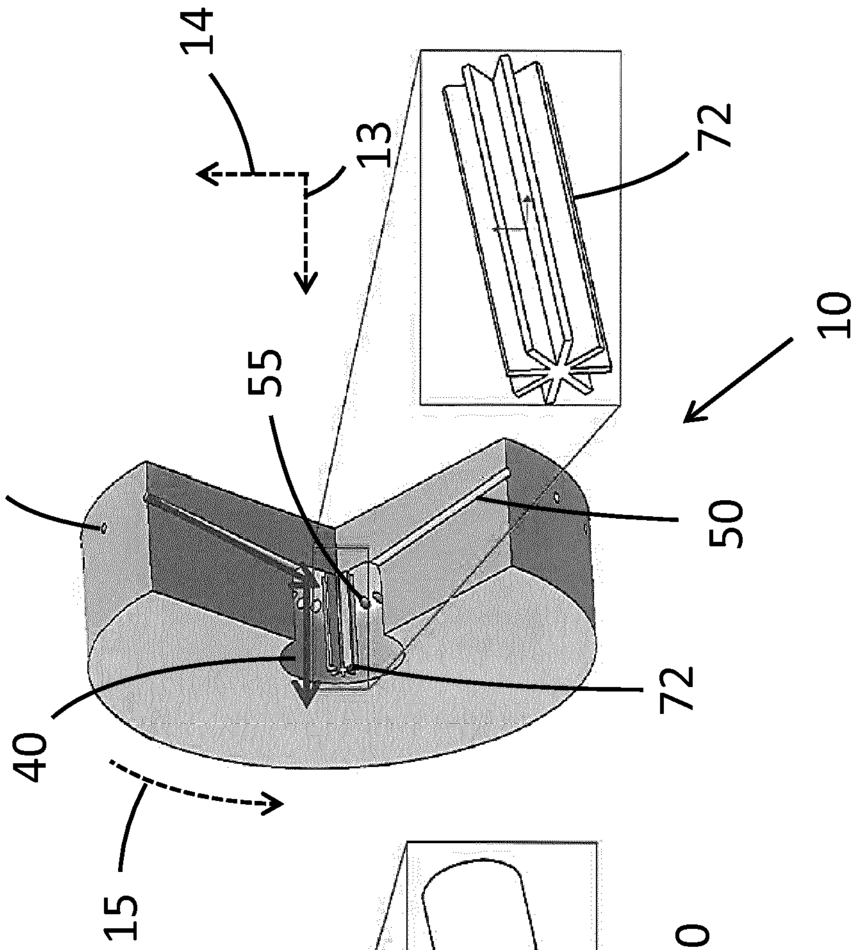


Figure 4

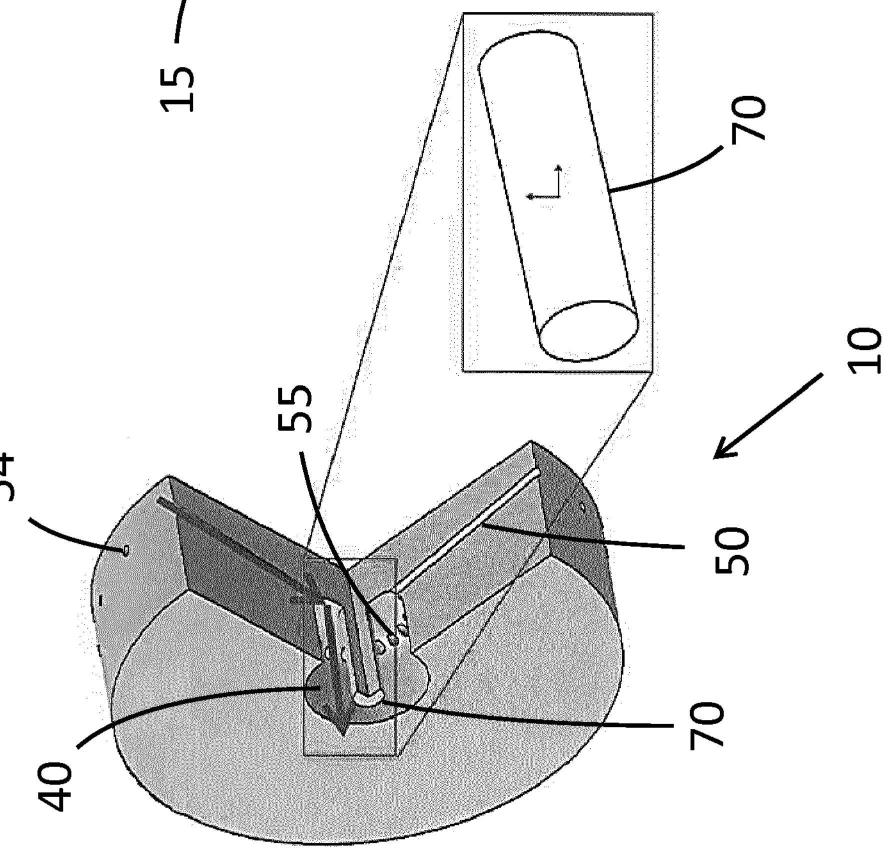


Figure 6

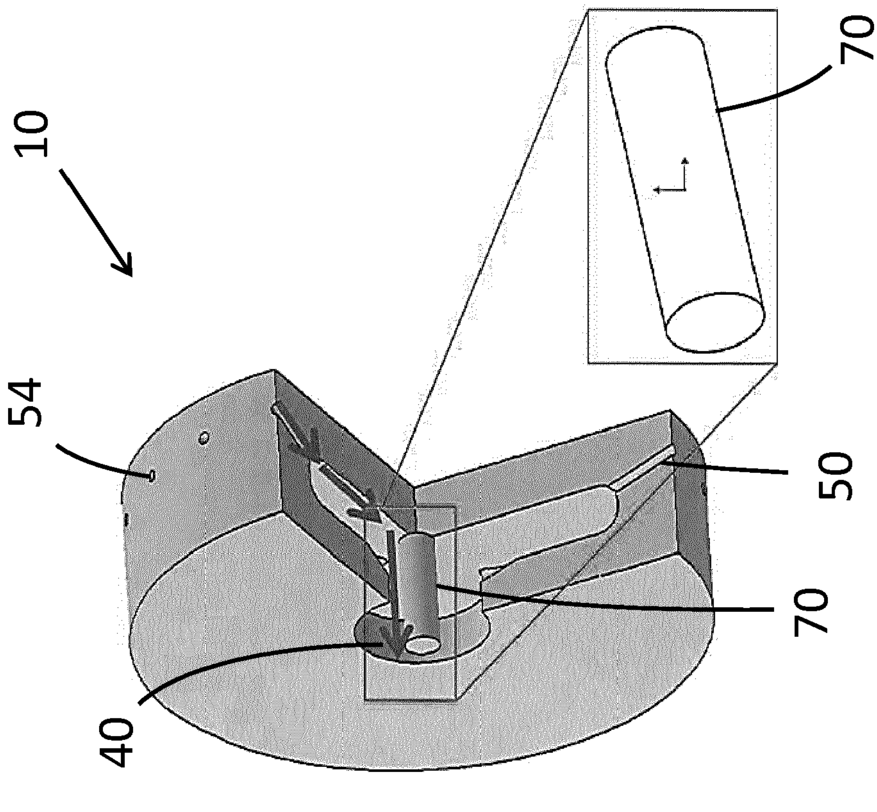
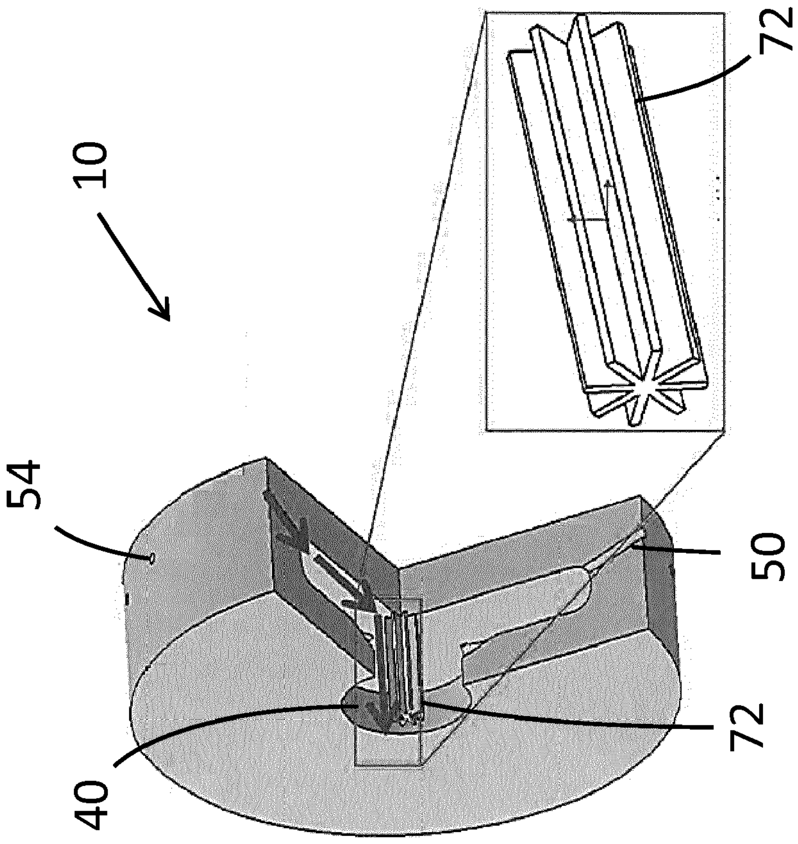


Figure 7



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EUROPEAN SEARCH REPORT

Application Number
EP 16 15 2938

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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Y	EP 2 826 956 A1 (SIEMENS AG [DE]) 21 January 2015 (2015-01-21) * paragraph [0026] - paragraph [0027]; figure 2 *	5	
E	WO 2016/072998 A1 (GEN ELECTRIC [US]) 12 May 2016 (2016-05-12) * paragraph [0017] - paragraph [0021]; figures 1-6 *	1-3,5,6	
A	EP 2 826 957 A1 (SIEMENS AG [DE]) 21 January 2015 (2015-01-21) * paragraph [0024] - paragraph [0030]; figures 2,3 *	1,3,4,6	TECHNICAL FIELDS SEARCHED (IPC) F01D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	21 July 2016	Coquau, Stéphane

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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