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(54) Titre : SECTEUR ANGULAIRE D'AUBAGE DE TURBOMACHINE A ETANCHEITE PERFECTIONNEE
(54) Title: ANGULAR SECTOR FOR TURBOMACHINE BLADING WITH IMPROVED SEALING

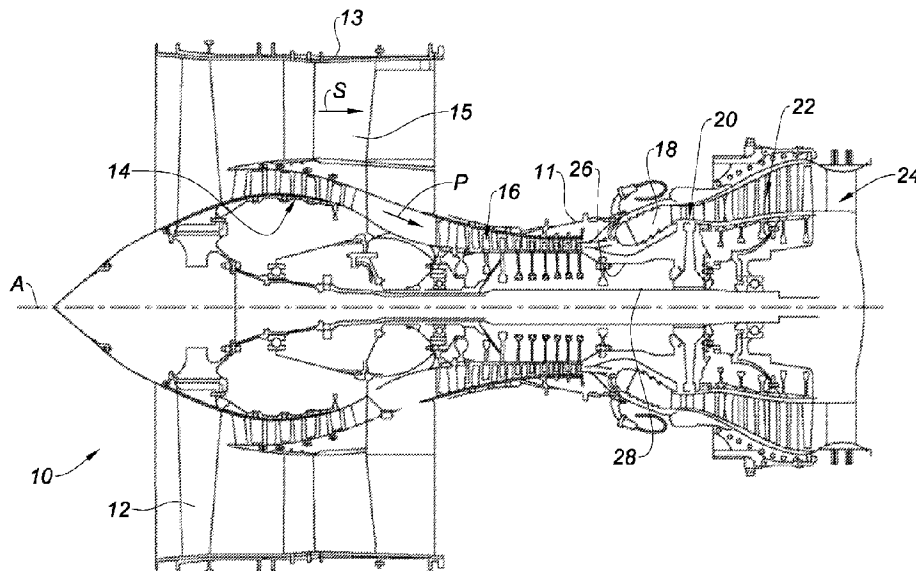


Fig. 1

(57) **Abrégé/Abstract:**

The invention concerns an angular sector (34a) of a fixed blade ring of a turbomachine, in particular a stator or a guide vane assembly, said sector (34a) extending according to a predetermined angle around an axis of the fixed blade ring and comprising, relative to the axis of said fixed blade ring, a radially outer platform (38a), a radially inner platform (40a), at least two blades (42a) that extend between said platforms (38a, 40a), and at least one block of abradable honeycomb material (44a) that extends on the inside of the inner platform (38a) between transverse ends of the sector (34a), characterised in that the block (44a) of abradable material comprises at least one transverse end wall (52a) that is shaped according to a toothed profile (54a1, 54a2) comprising at least one radially oriented (R) tooth (56a1, 56a2) extending across an entire radial thickness of said block (44a). Abstract drawing: Figure 4. .

Abstract

The invention concerns an angular sector (34a) of a fixed blade ring of a turbomachine, in particular a stator or a guide vane assembly, said sector (34a) extending according to a predetermined angle around an axis of the fixed blade ring and comprising, relative to the axis of said fixed blade ring, a radially outer platform (38a), a radially inner platform (40a), at least two blades (42a) that extend between said platforms (38a, 40a), and at least one block of abradable honeycomb material (44a) that extends on the inside of the inner platform (38a) between transverse ends of the sector (34a), characterised in that the block (44a) of abradable material comprises at least one transverse end wall (52a) that is shaped according to a toothed profile (54a1, 54a2) comprising at least one radially oriented (R) tooth (56a1, 56a2) extending across an entire radial thickness of said block (44a).

ANGULAR SECTOR FOR TURBOMACHINE BLADING WITH IMPROVED SEALING

The invention relates to an angular sector of a turbomachine blading, in particular an angular sector of a blading such as a rectifier equipping a compressor or such as a
5 stator equipping a turbine of this turbomachine.

BACKGROUND

Gas turbine engines comprise, in a known manner, fixed internal blading rings,
10 which are mounted in external casings of a primary flow duct of the engine and which are axially interposed between compressor moving blading wheels or between turbine moving blading wheels of these engines. Each fixed blading ring is dynamically sealed around a compressor or turbine rotor. For this purpose, each fixed blading ring comprises an internal block of abradable material which is designed to cooperate with lip sealing
15 elements that are rotationally integral with the associated compressor or turbine rotor to ensure gas-tightness.

Part of the gas is nevertheless likely to enter between the stationary and moving blading of the compressor or turbine rotors, in the opposite direction to the main flow circulating in the primary flow duct.

20 The fixed internal blading ring constitute rectifiers when they are interposed between compressor wheels, or constitute stators when they are interposed between turbine wheels.

In order to facilitate their assembly and reduce their manufacturing cost, the fixed blading rings are often made as an assembly of angular sectors that are juxtaposed
25 next to each other to form a whole fixed blading ring. These rings thus leave an inter-sector clearance which leaves recirculation passages for the gases, no longer around the roots of the angular sectors, but between them.

Indeed, conventionally, part of the gases that pass through the fixed blading from upstream to downstream tend to recirculate from downstream to upstream through the
30 seal that is made between the block of abradable material and the lip sealing element according to a leakage flow rate that we try to keep as minimal as possible, because it affects the performance of the corresponding compressor or turbine. Another part of the

gas that passes through these blading from upstream to downstream tends to recirculate from downstream to upstream by insinuating itself between the sectors through the clearance between the sectors, also called the inter-sector clearance.

5 The difficulty in ensuring a satisfactory level of sealing lies in the fact that the angular sectors of the ring move due to the mechanical and thermal deformations that occur during engine operation. Thus, the inter-sector clearance and leakage flow rate vary during engine operation. Furthermore, the clearance under during hot engine operation must never be zero because contact between the sector platforms could cause ovalization of the casing, which is outside the fixed blading, and/or matting of the
10 surfaces in contact, which could drastically increase the stresses exerted on the fixed blading, resulting in particular in a transfer of these stresses to the outer casing of the engine, which receives the fixed blading.

A transfer of these stresses could cause an ovalization of the outer casing and significantly modify the radial clearances between this casing and the adjacent moving
15 blading, with a very negative impact on the engine in terms of service life.

Conventional sealing between two immediately adjacent angular sectors of a fixed blading ring is ensured by lip seal systems interposed between these sectors to limit leakage between sectors. These sealing systems can be used to seal ring sectors of the fixed blading in the primary flow duct, and also, in the case of a double-flow engine, to
20 seal ring sectors of the fixed blading in the secondary flow duct.

In this technology, lips are housed between two adjacent sectors in housings that have been machined into the sectors. The lips are used to prevent the flow of gas of passing through the inter-sector clearance.

Conventionally, an angular sector of the blading ring comprises, with respect to
25 the axis of the ring, a radially outer platform substantially in the shape of an angular section of a cylinder, a radially inner platform in the shape of an angular section of a cylinder, at least two vanes extending between said platforms, a root attached to the inner platform, and at least one block of abradable honeycomb material extending inwardly to the root. The lips interposed between two sectors are embedded in the mass
30 of the two adjacent roots of the two sectors and in housings facing the adjacent interior and exterior platforms of the two sectors.

However, these lips are not easy to install. In addition, they require the construction of housings in the angular sectors of the fixed blading, which are expensive to manufacture.

In addition, the lips cannot be arranged along the entire radial thickness of the root for the sealing on the inside of the inner platform. Consequently, clearances remain
5 between the sectors through which the gases can flow.

Therefore, there is a need for an alternative sealing technology to dispense with such lips and to improve the sealing between the fixed blading sectors.

Document FR-2.552.159-A1 describes a technology in which the edges of the inner platforms are shaped into a Z-profile. This configuration improves sealing efficiency,
10 but is limited to the platforms and is only applicable to a dispenser with an unsectorized block of abradable material.

DISCLOSURE OF THE INVENTION

15

The invention proposes to take advantage of the existing abradable material block arranged inside the inner platform to provide a seal directly between transverse end walls of two adjacent angular sectors.

For this purpose, the invention proposes an angular sector of a fixed blading ring of a turbomachine, in particular of a rectifier or stator, said sector extending at a
20 given angle around an axis of the fixed blading ring and comprising, relative to the axis of said fixed blading ring a radially outer platform, a radially inner platform, at least two vanes extending between said platforms, and at least one abradable honeycomb material block extending on the inside of the inner platform between transverse ends of the
25 sector.

The abradable honeycomb material block comprises, for example, a radially inner radial sealing face which is configured to cooperate with lips of a labyrinth seal carried by a rotor of the turbomachine.

In accordance with the invention, this angular sector is characterized in that the abradable material block comprises at least one transverse end wall which is shaped
30 according to a toothed profile comprising at least one tooth with a radial direction extending along an entire radial thickness of said block.

According to other characteristics of the angular sector:

- the abradable material block extends to the inner platform,
- each at least one tooth projects transversely from said block and is made of said abradable honeycomb material of said block,
- 5 - the tooth profile has a sawtooth shape in cross-section in a plane perpendicular to the radial direction,
- the tooth profile has a crenellated shape in cross-section in a plane perpendicular to the radial direction,
- the tooth profile has a single tooth in the form of a pin,
- 10 - the single tooth in the form of a pin extends from one of the axial ends of the block,
- the abradable honeycomb material of the block comprises radially oriented tubular cells.

The invention also relates to an assembly of two adjacent angular sectors of the
15 type described above, characterized in that said at least one transverse end wall shaped according to a toothed profile of said adjacent angular sectors faces each other, and in that said toothed profiles are complementary.

Finally, the invention concerns a fixed blading ring of a turbomachine comprising a plurality of angular sectors of the fixed blading ring, characterized in that it
20 comprises a given number of sectors whose juxtaposition forms the entire fixed blading ring, in that each angular sector comprises two opposite transverse end walls which are shaped into toothed profiles each comprising at least one radially oriented tooth, and in that each angular sector is assembled with each of the angular sectors adjacent thereto in an assembly of the type described above.

25

DESCRIPTION OF THE FIGURES

The invention will be better understood and other details, characteristics and
30 advantages of the present invention will appear more clearly when reading the following description made as an example, which is not limitative, and with reference to the appended drawings, in which :

- Figure 1 is a schematic sectional view of a turbomachine according to the prior art,

- Figure 2 is a detailed cross-sectional view of a turbine of the turbomachine of Figure 1,

5 - Figure 3 is a detailed cross-sectional view of a compressor of the turbomachine in Figure 1,

- Figure 4 is a perspective view of an assembly of angular blading sectors according to the invention,

- Figure 5A is a sectional view of a blading ring sector according to the prior art,

10 - Figure 5B is a sectional view of a blading ring sector according to the invention,

- Figure 6 is a schematic cross-sectional view of a first tooth profile of an abradable material block of a blading ring sector according to the invention,

- Figure 7 is a schematic sectional view of a second tooth profile of an abradable material block of a blading ring sector according to the invention,

15 - Figure 8 is a schematic cross-sectional view of a third tooth profile of an abradable material block of a blading ring sector according to the invention,

- Figure 9 is a schematic cross-sectional view of a fourth tooth profile of an abradable material block of a blading ring sector according to the invention.

20 DETAILED DESCRIPTION

In the following description, identical reference numbers refer to parts that are identical or have similar functions.

25 Axial direction means by extension any direction parallel to an axis A of a turbomachine, and radial direction means any direction perpendicular and extending radially with respect to the axial direction.

Figure 1 shows a turbomachine 10 of axis A of the double flow type. Such a turbomachine 10, here a turbojet engine 10, comprises in a known manner a fan 12, a low pressure (LP) compressor 14, a high pressure (HP) compressor 16, a combustion
30 chamber 18, a high pressure (HP) turbine 20, a low pressure (LP) turbine 22 and an exhaust nozzle 24. The rotor of the HP compressor 16 and the rotor of the HP turbine 20 are connected by a HP high pressure shaft 26 and form a high pressure body with it. The

rotor of the LP compressor 14 and the rotor of the LP low pressure turbine 22 are connected by a LP shaft 28 and form with it a low pressure body.

A primary air flow "P" passes through the high- and low-pressure bodies and fan 12 produces a secondary air flow "S" that circulates in the turbojet engine 10, between a casing 11 and an outer casing 13 of the turbojet engine, in a cold flow channel 15. At the outlet of the nozzle 24, the gases from the primary flow "P" are mixed with the secondary flow "S" to produce a propulsion force, the secondary flow "S" providing most of the thrust here.

The LP and HP compressors 14, 16 and the HP and LP turbines 20, 22 each comprise several compressor or turbine stages respectively. As shown for example in Figure 2, the LP turbine 22 comprises several turbine moving blading wheels 22a, 22b, 22c, 22d, 22e whose bladings are carried by associated shrouds 30a, 30b, 30c, 30d, 30e which are assembled together by bolts 36.

The LP turbine 22 also comprises rings of fixed bladings 32a, 32b, 32c, 32d of a diffuser 32 which are interposed between the turbine moving blading wheels 22a, 22b, 22c, 22d, 22e.

Each fixed blading ring 32a, 32b, 32c, 32d of the diffuser is formed by an assembly of sectors 34a, 34b, 34c, 34d of a fixed blading ring, assembled around the axis A of the turbomachine over 360° so as to constitute a complete fixed blading ring 32a, 32b, 32c, 32d around the axis A of the turbomachine.

In the same way, as illustrated in figures 3 to 5B, the HP compressor 16 of the turbomachine 10 can comprise a series of compressor moving blading wheels 22a, 22b between which are interposed rings 32a of the fixed bladings of a rectifier which are themselves made in the form of an assembly of angular sectors 34a of fixed blading rings. It will therefore be understood that the invention applies to any assembly of angular sectors 34a of the fixed blading rings 32a, whether it is an assembly of angular sectors 34a of a rectifier for a compressor or angular sectors 34a of a diffuser for a turbine.

As illustrated in more detail in Figure 3, a compressor fixed blading ring 32a consists of an assembly of angular sectors 34a of the blading ring. It can be seen that each fixed blading ring, and in particular ring 32a, is placed in the primary flow duct P forming a clearance with the adjacent compressor impellers 22a and 22b, and in particular with shrouds 30a and 30b of these impellers 22a, 22b. Part of the pressurized gases of the

primary flow P, which flows from upstream to downstream, tends to insinuate itself between the shrouds 30a and 30b and the angular sector 34a to recirculate from downstream to upstream according to a recirculation flow rc, represented by the arrows in figure 3, which tends to bypass the angular sector 34a.

5 The existence of this recirculation flow rc is particularly penalizing. The recirculation flow rc tends to reduce the performance of the compressor, or similarly in the case of a turbine, the performance of the said turbine. This is why current designs tend to minimize this recirculation flow rc by equipping the angular sector 34a with sealing means with the shroud it surrounds.

10 As shown in Figure 3, each sector 34a extends at a given angle around the axis of the ring 32a, which corresponds to the axis A of the turbomachine previously illustrated in Figure 1.

 The term "lower" refers to any position close to the axis A in the radial direction, while the term "upper" refers to any position further from the axis A in the radial
15 direction than the lower position. Finally, by "transverse" is meant any plane or surface comprising the axis A and parallel to a sectional plane of a sector 34.

 Conventionally, each sector 34a comprises, with respect to the axis A of the ring 32a, a radially outer platform 38a, a radially inner platform 40a, at least two vanes 42a which extend between said platforms 38a, 40a, a root 43a which extends radially inward
20 from the inner platform 40a and at least one block 44a of abradable honeycomb material which therefore also extends inward to the inner platform 40a between transverse ends (not shown) of the angular sector 34a.

 A radially inner radial sealing face 46a is configured to cooperate with lips 48a of a labyrinth seal 50a carried by a rotor of the turbomachine, here the shroud 30a.

25 This configuration significantly reduces the intensity of the recirculation flow rc circulating between the sector 34a and the shroud 30a. However, it has no influence on the recirculation flow between two adjacent sectors 34a.

 Conventionally, the sealing between adjacent sectors 34a is achieved by means of lips (not shown) that are received in housings facing the adjacent sectors 34a and that
30 are arranged between these sectors 34a to form a barrier to the recirculation flow rc between the sectors 34a. This configuration is particularly costly because it requires the creation of housings for the lips, especially in the roots 43a, and because it imposes

particular assembly precautions, especially with regard to the sectors that are intended to close the entire blading during its assembly.

As illustrated in Figure 4, the invention proposes to simplify the sealing between the sectors 34a by taking advantage of the block 44a of abradable material already
5 present radially inside the inner platform 40a so as to ensure a sealing directly between transverse end walls of two adjacent angular sectors.

For this purpose, as illustrated in Figure 4, the invention proposes an angular sector 34a of a turbomachine fixed blading ring of the type described above, characterized in that the block 44a of abradable material comprises at least one
10 transverse end wall 52a which is shaped according to a toothed profile 54a1, 54a2 comprising at least one tooth 56a1, 56a2 with a radial direction R, said at least one radial tooth 56a1, 56a2 extending along an entire radial thickness of said block 44a.

Thus, Figure 4 shows an assembly of two angular sectors 34a of a fixed blading ring. Each of these two angular sectors 34a of the fixed blading ring comprises a
15 transverse end wall 52a which faces the transverse end wall 52a of the other sector 34a of the fixed blading ring.

As shown in particular in Figure 6, the block 44a of one of the sectors 34a comprise a tooth profile 54a1 comprising at least one tooth 56a1 and the block 44a of the other of the sectors 34a comprises a tooth profile 54a2, complementary to the tooth
20 profile 54a1, with at least one tooth 56a1. Sealing is thus ensured in the opposite direction to the primary flow P by the cooperation of the transverse end walls 52a and their complementary tooth profiles 54a1 and 54a2.

The fixed blading ring 32a comprises a specific number of ring sectors 34a, the juxtaposition of which forms the entire fixed blading ring 32a and it comprises at least
25 two of these angular sectors 34a of the blading ring comprising complementary tooth profiles 54a1, 54a2. It is to be understood that all ring sectors 34a preferably comprise toothed profiles. Thus, each angular sector 34a is assembled with each of the adjacent angular sectors 34a in an assembly of the type described above, and each block 44a comprises at both ends opposite transverse end walls 52a which are shaped according to
30 toothed profiles 54a1, 54a2 intended to cooperate with the toothed profiles 54a1, 54a2 with radially oriented teeth of the adjacent blocks 44a.

In the preferred embodiment of the invention, the abradable material block 44a of the sector 34a extends to the inner platform 40a. This configuration has been shown in Figure 5B. Compared to a conventional angular sector 34a as shown in Figure 5A, the root 43a has been removed and the block 44a of honeycomb material has been extended
 5 radially to the inner platform 40a so as to impart maximum height to the block 44a of honeycomb material, thereby providing maximum sealing. Furthermore, this configuration eliminates the need for a conventional lip and groove sealing system on the root 43a.

Preferably, as shown in Fig. 4, each inner platform 40a has an end edge 58a
 10 which is shaped into a toothed profile 60a1, 60a2 which is superimposed on the toothed profile 54a1, 54a2 of the corresponding honeycomb material block 44a. Thus the toothed profiles 60a1, 60a2 are also complementary to each other. However, this configuration is not limiting the invention, and the end edges 58a of the inner platforms 40a could be straight.

15 Each tooth 56a1 or 56a2 of each block 44a can be made in different ways. For example, teeth 56a1 or 56a2 could be attached to block 44a, provided they protrude from the block 44a. However, each tooth 56a1 or 56a2 is preferably made directly from the abradable honeycomb material of the block 44a.

The tooth profile 54a1, 54a2 of the honeycomb material block 44a can be
 20 configured in different ways, depending on the desired seal. The higher the number of teeth 56a1 or 56a2, the better the profile 54a1, 54a2 is able to provide a labyrinth that effectively reduces the flow rate of the recirculating flow rc between adjacent angular sectors 44a. On the other hand, the higher the number of teeth 56a1 or 56a2, the more the fitting tolerances of two adjacent angular sectors 44a are reduced and the more
 25 complex these adjacent sectors 44a are to achieve. It will therefore be understood that the number of teeth 56a1 or 56a2 will be the result of a compromise between the efficiency of the reduction of the recirculating flow rc and the cost of obtaining the ring 32a formed of the angular sectors 34a, this cost including the realization of these sectors 34a and their assembly.

30 In this configuration, as shown in Figures 6 and 7, the tooth profile 54a1, 54a2 can present, in section in a plane perpendicular to a radial direction R, a crenellated shape, i.e. with teeth of substantially rectangular or square section.

Alternatively, as shown in Fig. 8, the toothed profile 54a1, 54a2 can have a sawtooth shape in cross-section in a plane perpendicular to the radial direction R.

Alternatively, as shown in Fig. 9, the tooth profile 54a1, 54a2 of each sector 44a may comprise a pin which forms the single tooth 56a1, 56a2. In this case, the single tooth
5 56a1, 56a2 shaped as a pin extends from one of the axial ends 62a1 or 62a2 of the block 44a.

Although this configuration is not limiting the invention, it will be understood that the abradable honeycomb material of the block 44a comprises tubular cells (not shown) that are radially oriented in the radial direction R. This configuration provides
10 maximum strength to the block 44a of material.

In the preferred embodiment of the invention, the honeycomb material of the block 44a is obtained by an additive manufacturing process. This configuration allows for the formation of regular cells and a regular conformation of the tooth profiles 54a1, 54a2 without any risk of deterioration as might be caused by a material removal process.

15 The invention thus makes it possible to ensure the sealing between angular sectors 32a of the fixed blading ring in a simple and effective manner, and to limit the flow rate of the recirculation flow rc between these angular sectors 32a, which allows to improve the performance of a compressor or a turbine equipped with such angular sectors of the blading ring 32a in a consequent manner.

20

CLAIMS

1. An angular sector (34a) of a fixed blading ring (32a) of a turbomachine (10), in particular of a rectifier or stator, said sector (34a) extending at a given angle around an axis A of the fixed blading ring (32a) and comprising, relative to the axis A of said fixed
5 blading ring (32a), a radially outer platform (38a), a radially inner platform (40a), at least two vanes (42a) extending between said platforms (38a, 40a), and at least one abradable honeycomb material block (44a) extending on the inside of the inner platform (38a) between transverse ends of the sector (34a), characterized in that the abradable material
10 block (44a) comprises at least one transverse end wall (52a) which is shaped according to a toothed profile (54a1, 54a2) comprising at least one tooth (56a1, 56a2) with a radial direction (R), extending along an entire radial thickness of said block (44a).

2. The angular sector (34a) according to the preceding claim, characterized in
15 that the abradable material block (44a) extends to the inner platform.

3. The angular sector (34a) according to one of the preceding claims, characterized in that each at least one tooth (56a1, 56a2) projects transversely from said block (44a) and is made of said abradable honeycomb material of said block (44a).

20

4. The angular sector (34a) according to one of the preceding claims, characterized in that the tooth profile (54a1, 54a2) has a sawtooth shape in cross-section in a plane perpendicular to the radial direction (R).

25 5. The angular sector (34a) according to one of the claims 1 to 3, characterized in that the tooth profile (54a1, 54a2) has a crenellated shape in cross-section in a plane perpendicular to the radial direction (R).

6. The angular sector (34a) according to one of claims 1 to 3, characterized in
30 that the tooth profile (54a1, 54a2) has a single tooth (56a1, 56a2) in the form of a pin.

7. The angular sector (34a) according to the preceding claim, characterized in that the single tooth (56a1, 56a2) in the form of a pin extends from one of the axial end walls of the block.

5 8. The angular sector (34a) according to one of the preceding claims, characterized in that the abradable honeycomb material of the block (44a) comprises radially oriented tubular cells.

10 9. An assembly of two adjacent angular sectors (34a) according to one of the claims 1 to 8, characterized in that said at least one transverse end wall (52a) shaped according to toothed profiles (54a1, 54a2) of said adjacent angular sectors (44a) face each other, and in that said toothed profiles (54a1, 54a2) are complementary.

15 10. A turbomachine fixed blading ring (32a) comprising a plurality of angular sectors of the fixed blading ring (34a), characterised in that it comprises a given number of sectors (34a) whose juxtaposition forms the entire fixed blading ring (32a), in that each angular sector (34a) comprises two opposite transverse end walls (52a) which are shaped into toothed profiles (54a1, 54a2) each comprising at least one radially oriented tooth (56a1, 56a2), and in that each angular sector (34a) is assembled with each of the angular
20 sectors (34a) adjacent thereto in an assembly according to claim 9.

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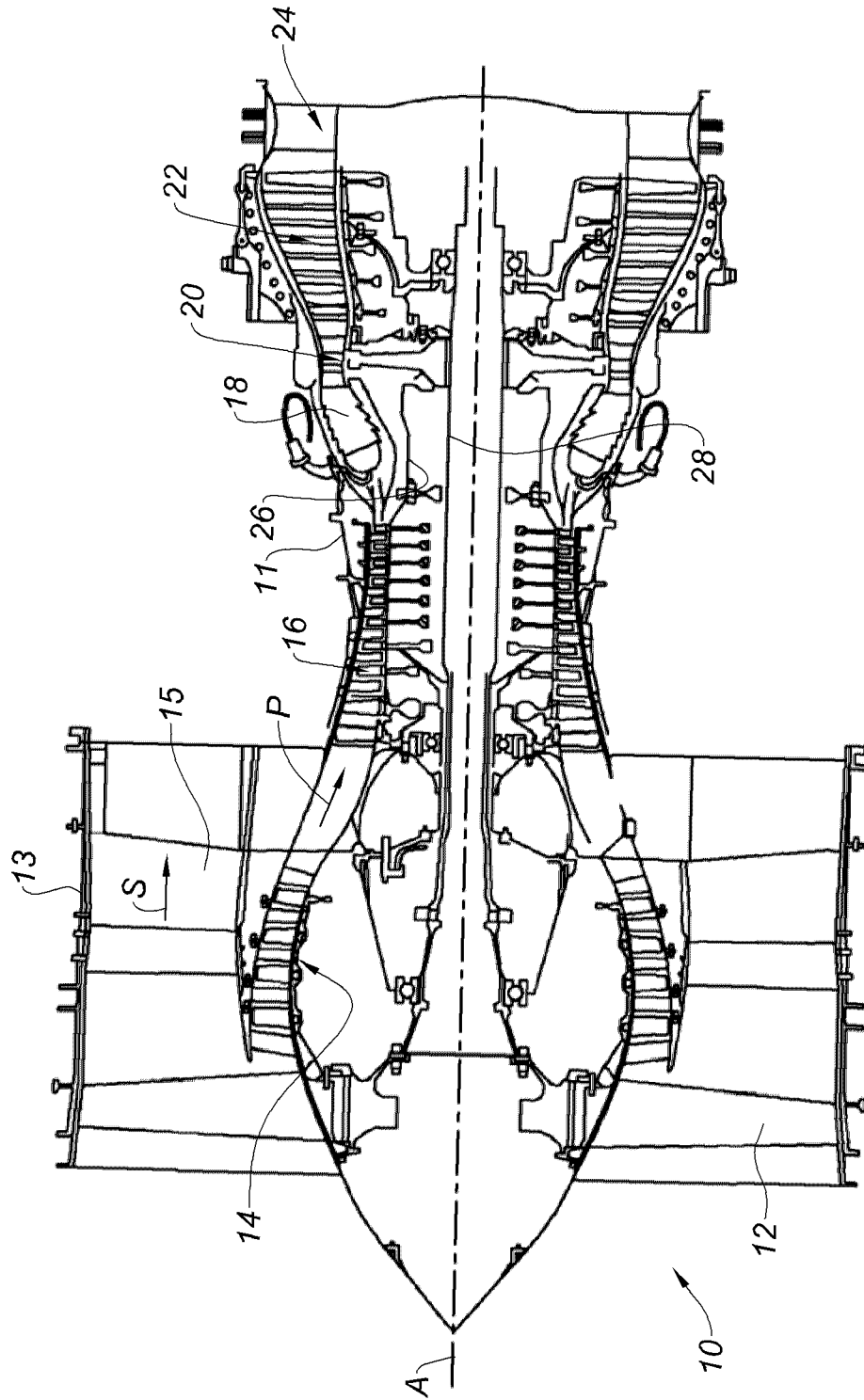


Fig. 1

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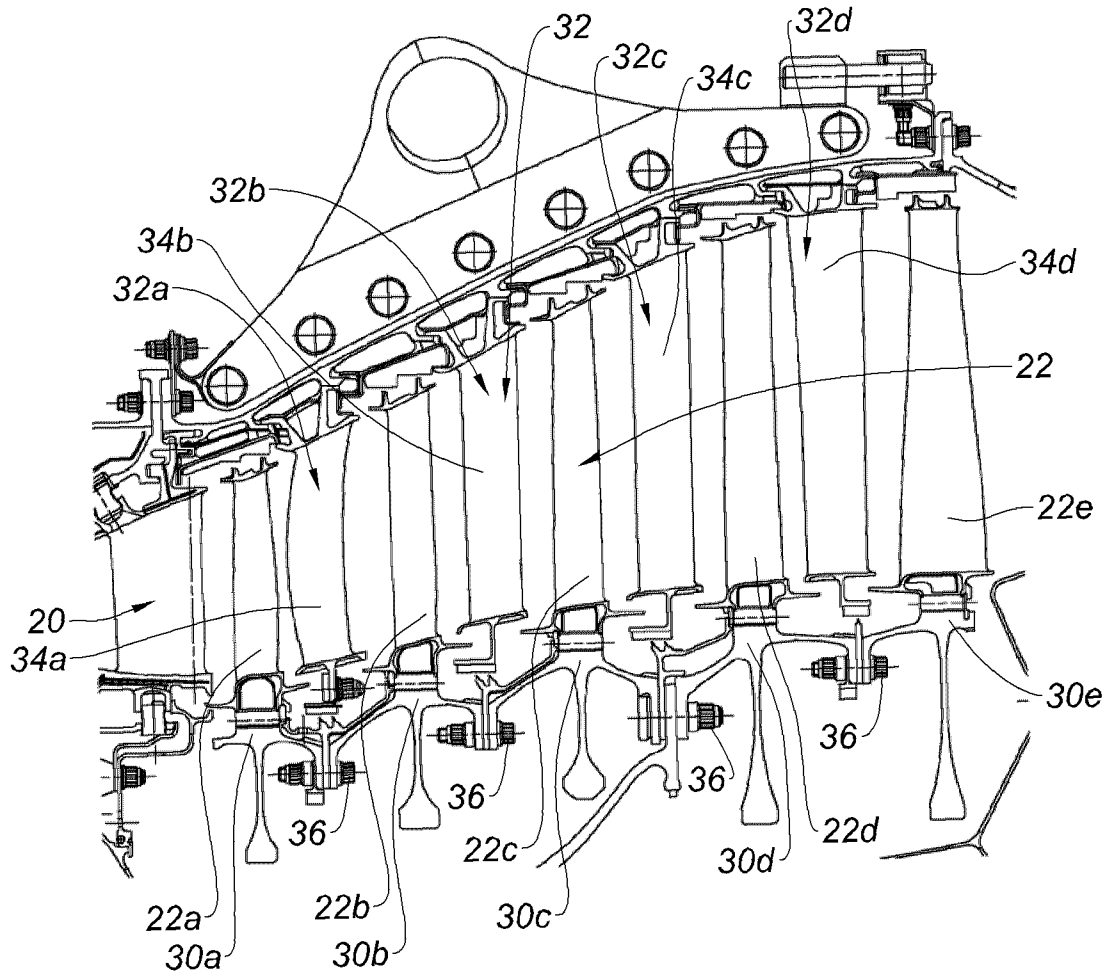


Fig. 2

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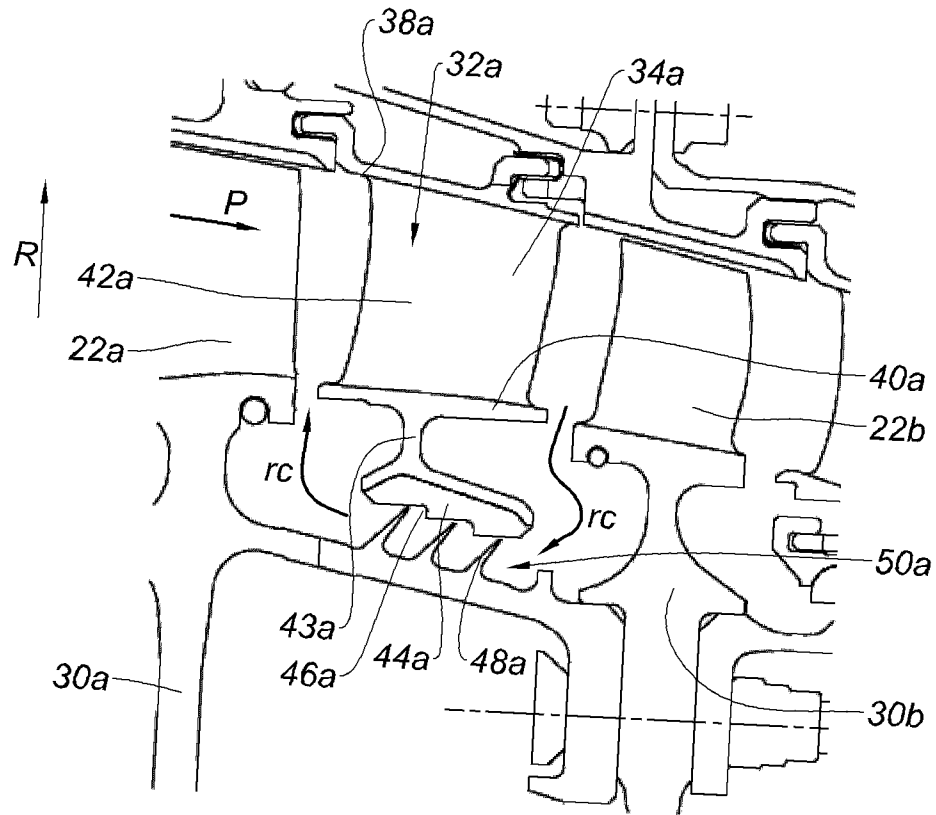


Fig. 3

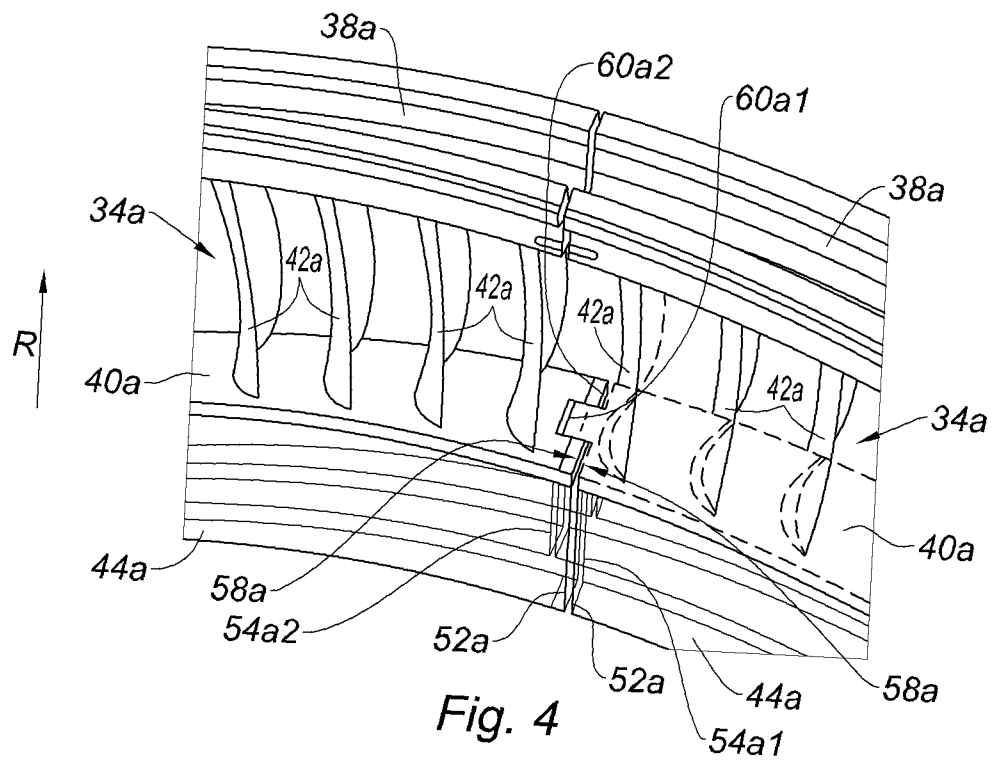


Fig. 4

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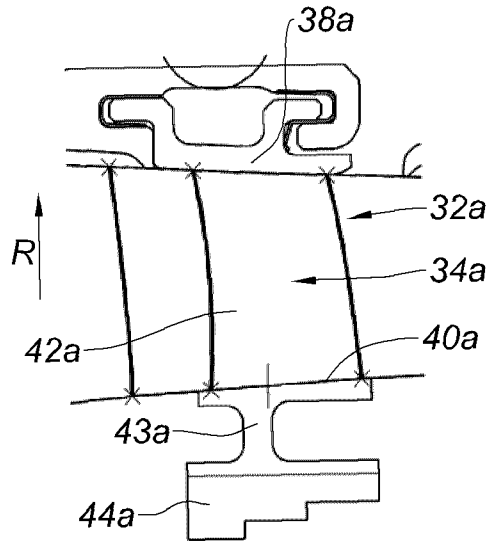


Fig. 5A

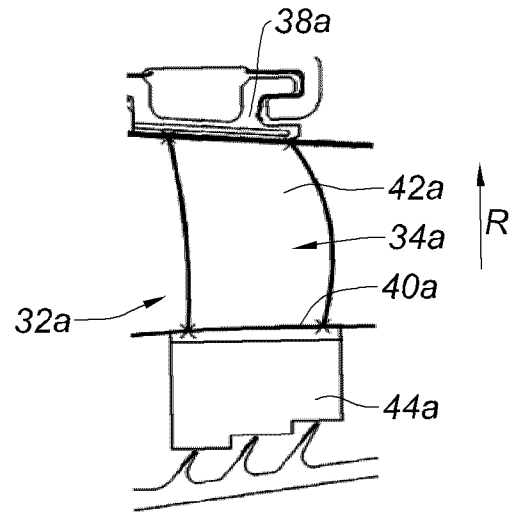


Fig. 5B

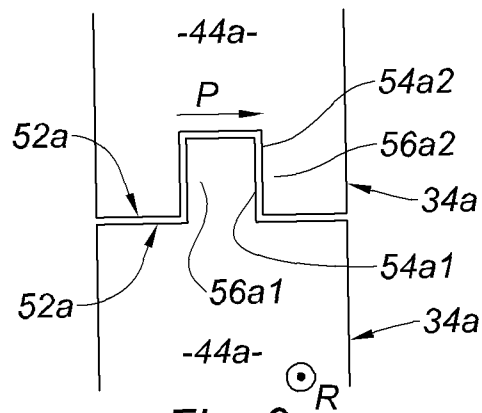


Fig. 6

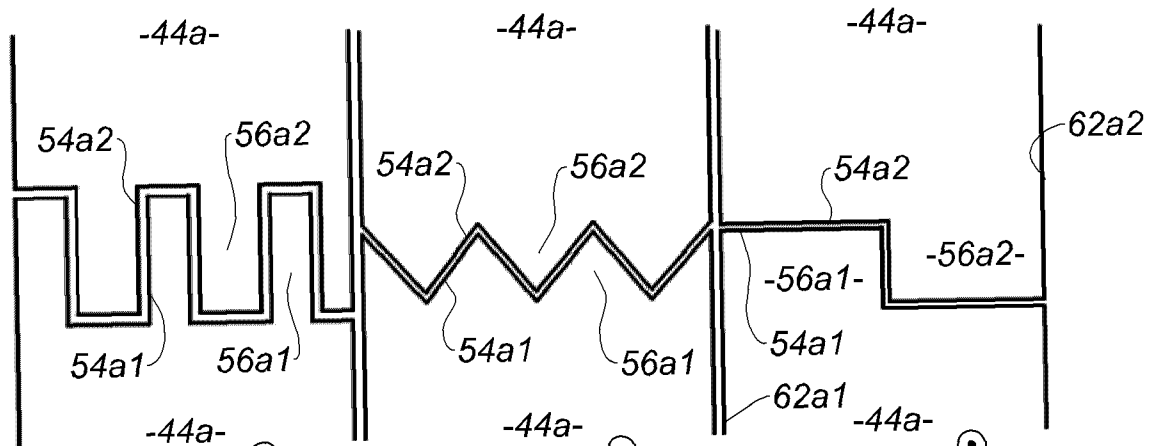


Fig. 7

Fig. 8

Fig. 9

