(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 735 799 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
28.05.2014 Bulletin 2014/22

(51) Int Cl.:
F23R 3/20 *(2006.01)* ***F23R 3/28*** *(2006.01)*
F23R 3/34 *(2006.01)*

(21) Application number: **13191880.7**

(22) Date of filing: **07.11.2013**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **21.11.2012 US 201213683015**

(71) Applicant: **General Electric Company**
Schenectady, New York 12345 (US)

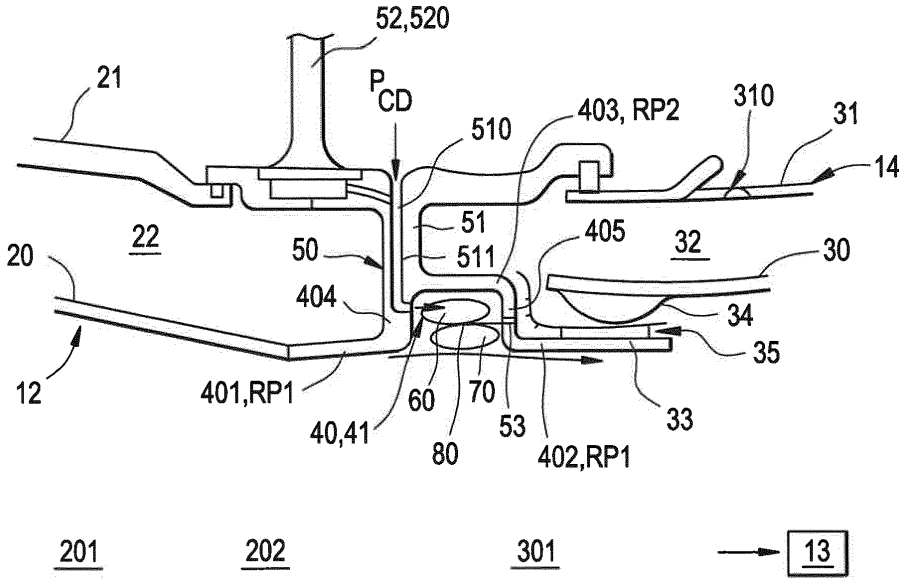
(72) Inventors:
- **Stoia, Lucas John**
  Greenville, SC South Carolina 29615 (US)
- **Romig, Bryan Wesley**
  Greenville, SC South Carolina 29615 (US)

(74) Representative: **Cleary, Fidelma et al**
GPO Europe
GE International Inc.
The Ark
201 Talgarth Road
Hammersmith
London W6 8BJ (GB)

(54) Turbomachine with trapped vortex combustor

(57) A turbomachine (10) with a trapped vortex feature (41) includes a unibody liner (30) formed to define a flow path (510) for combustion products, the unibody liner (30) including first and second portions (401, 402) defining first radial planes, a third portion (403) defining a second radial plane and fourth and fifth portions (404, 405) extending substantially radially between proximal ends of the first and third portions (401, 403) and proximal ends of the second and third portions (402, 403), respectively, and an injector (50) configured to deliver a fuel or a fuel/air mixture to a space partially bound by the third, fourth and fifth portions (403, 404, 405).

FIG. 2



EP 2 735 799 A2

Description

[0001] The subject matter disclosed herein relates generally to turbomachines and, more particularly, to turbomachines with trapped vortex features.

[0002] A typical turbomachine includes a compressor to compress inlet air, a combustor in which the compressed inlet air is combusted along with fuel, a turbine in which products of the combustion are receivable for power generation purposes and a transition piece. The transition piece is fluidly interposed between the combustor and the turbine.

[0003] In some cases, the typical turbomachine is configured to support axially staged or late lean injection. In these cases, fuel and air are injected into downstream sections of the combustor or the transition piece in order to cause secondary combustion within the downstream sections of the combustor or the transition piece. This secondary combustion tends to reduce emissions of pollutants, such as oxides of nitrogen.

[0004] According to one aspect of the invention, a unibody liner formed to define a flow path for combustion products, the unibody liner including first and second portions defining first radial planes, a third portion defining a second radial plane and fourth and fifth portions extending substantially radially between proximal ends of the first and third portions and proximal ends of the second and third portions, respectively, and an injector configured to deliver a fuel or a fuel/air mixture to a space partially bound by the third, fourth and fifth portions.

[0005] According to another aspect of the invention, a turbomachine is provided and includes a unibody liner formed to define a flow path for combustion products, the unibody liner being formed to define a trapped vortex feature into which a portion of combustion products flow, and an injector configured to deliver a fuel or a fuel/air mixture to the trapped vortex feature.

[0006] According to yet another aspect of the invention, a turbomachine is provided and includes a combustor liner defining a first interior in which combustion occurs and a second interior through which products of combustion flow, a transition piece disposed downstream from the combustor liner, the transition piece defining a third interior, which is receptive of the products of combustion and through which the products of combustion continue to flow, at least one of the combustor liner and the transition piece being formed to define a recess into which a portion of the products of combustion flow and an injector configured to deliver combustible materials to the recess whereby the combustible materials and the portion of the products of combustion form respectively trapped vortices.

[0007] Various advantages and features will become more apparent from the following description taken in conjunction with the drawings.

[0008] The subject matter, which is regarded as the invention, is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other features, and advantages of the invention are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic illustration of a turbomachine; and

FIG. 2 is an enlarged view of a portion of the turbomachine of FIG. 1.

[0009] The detailed description explains embodiments of the invention, together with advantages and features, by way of example with reference to the drawings.

[0010] With reference to FIGS. 1 and 2, a turbomachine 10 includes a compressor 11 to compress inlet air, a combustor 12 in which the compressed inlet air is combusted along with fuel, a turbine 13 in which products of combustion are receivable for power generation purposes and a transition piece 14. The transition piece 14 is fluidly interposed between the combustor 12 and the turbine 13. The turbomachine 10 is configured to support axially staged injection or late lean injection (LLI) whereby fuel and air are injected into downstream sections of the combustor 12 or the transition piece 14 in order to cause secondary combustion processes. This secondary combustion tends to reduce emissions of pollutants, such as oxides of nitrogen, from the turbomachine 10.

[0011] In some axially staged injection or LLI configurations, it has been found that almost all of the air available for turbomachine operations is utilized for combustion in one form or another and that little to no air is bypassed in the form of combustor dilution air. This means that air used for axially staged injection or LLI robs the head end of the combustor 12 of some portion of air that could have otherwise been used to improve head end performance for a given amount of fuel. Accordingly, the turbomachine 10 is provided with a trapped vortex feature (which is described below) that allows most of the air available for combustion to be provided through the premixers at the head end of the combustor 12 and then be re-utilized later for axially staged injection or LLI.

[0012] With reference to FIG. 2, the combustor 12 includes a combustor liner 20 and a flow sleeve 21. The combustor liner 20 is formed to define a first interior 201, in which a first stage of the combustion occurs, and a second interior 202. The products of combustion flow through the second interior 202 toward the turbine 13. The first interior 201 is generally defined proximate to a head end of the combustor 12 at an axially upstream location and the second interior 202 is defined fluidly and axially downstream from the first interior 201. The flow sleeve 21 is disposed about the combustor liner 20 to define a first annulus 22.

[0013] The transition piece 14 is disposed fluidly and axially downstream from the combustor 12 and includes a transition piece liner 30 and an impingement sleeve 31. The transition piece liner 30 is formed to define a third

interior 301, which is fluidly interposed between the second interior 202 and an interior of the turbine 13. Thus, the third interior 301 is receptive of the products of combustion from the second interior 202 of the combustor 12 and provides for a flow path along or through which the products of combustion can continue to flow toward the turbine 13. The impingement sleeve 31 is disposed about the transition piece liner 30 to define a second annulus 32. The second annulus 32 is fluidly coupled with the first annulus 22. The impingement sleeve 31 is formed to define impingement holes 310.

[0014] For purposes of clarity and brevity, in the following description and claims, the combustor liner 20 and the transition piece liner 30 may be referred to separately or as a unibody liner. Thus, it will be understood that a unibody liner includes at least portions of both the combustor liner 20 and the transition piece liner 30.

[0015] Compressed air is exhausted from the compressor 11 and enters a compressor discharge casing (CDC). From an interior of the CDC, the compressed air enters the second annulus 32 via the impingement holes 310. The compressed air then flows from the second annulus 32 through the first annulus 22 toward the head end of the combustor 12 where the compressed air is mixed with fuel and combusted.

[0016] In some cases, a portion of the compressed air entering the second annulus 32 may be used as a coolant for the transition piece liner 30 within the third interior 301. In such cases, the transition piece liner 30 may include a flange 33 that is sealed to the transition piece liner 30 by hula seal 34. The flange 33 is formed to define a cooling path 35 by which the portion of the compressed air can be delivered to the third interior 301 along an interior surface of the transition piece liner 30.

[0017] At least one or both of the combustor liner 20 and the transition piece liner 30 is formed to define a substantially annular recess 40 proximate to a connection of the combustor liner 20 and the transition piece liner 30. The recess 40 acts as a trapped vortex feature 41 that extends radially outwardly from the second interior 202 and/or the third interior 301. Thus, as the products of combustion travel downstream through the second interior 202 and then through the third interior 301 as a main flow, a portion of the products of combustion flow into the recess 40 with a flow pattern (i.e., a second trapped vortex 70) to be described below. In accordance with embodiments, the portion of the products of combustion include air provided through the pre-mixers at the head end of the combustor 12 and which is to be re-utilized in the recess 40/trapped vortex feature 41.

[0018] In being formed to define the recess 40, the at least one of the combustor liner 20 and the transition piece liner 30 includes a first axial portion 401, a second axial portion 402, a third axial portion 403, a fourth radial portion 404 and a fifth radial portion 405 with the recess at least partially bounded by the third axial portion 403, the fourth radial portion 404 and the fifth radial portion 405. The first axial portion 401 may be disposed upstream from the second axial portion 402. The first and second axial portions 401 and 402 may have annular shapes while respectively defining first radial planes, RP1, which may be but need not be substantially similar to one another. The third axial portion 403 may have an annular shape and defines a second radial plane, RP2, which is displaced radially outwardly from the first radial planes, RP1, by a predefined amount. The fourth radial portion 404 and the fifth radial portion 405 each extend substantially radially to connect the first and second axial portions 401 and 402 to the third axial portion 403. That is, the fourth radial portion 404 extends substantially radially between proximal ends of the first axial portion 401 and the third axial portion 403 while the fifth radial portion 405 extends substantially radially between proximal ends of the second axial portion 402 and the third axial portion 403.

[0019] In accordance with embodiments, the recess 40 may have a substantially rectangular cross-sectional shape. In accordance with further embodiments, the corners of the recess 40 (i.e., the connections between the first axial portion 401 and the fourth radial portion 404, the fourth radial portion 404 and the third axial portion 403, the third axial portion 403 and the fifth radial portion 405 and the fifth radial portion 405 and the second axial portion 402) may be rounded to facilitate smooth fluid flow into and out of the recess 40.

[0020] The turbomachine 10 further includes an injector 50. The injector 50 is configured to deliver combustible materials, such as a fuel or a fuel and air mixture, to the recess 40. In so doing, the combustible materials form a first trapped vortex 60 while the portion of the products of combustion that have flown into the recess 40 form the second trapped vortex 70. The combustible materials may include, for example, fuel and a quantity of air derived from the CDC. As such, the combustible materials have a pressure, P_{CD}, which is substantially similar to the pressure in the CDC interior.

[0021] As shown, the combustible materials forming the first trapped vortex 60 tend flow in a first vortical pattern and the portion of the products of combustion forming the second trapped vortex 70 tends to flow in a second vortical pattern. The first and second vortical patterns may be substantially oppositely oriented. Thus, as the first and second vortices 60 and 70 are adjacent to one another, the respective fluids in each one mix along the shear line 80 such that the combustible materials injected into the recess 40 by the injector 50 auto-ignite due to the temperatures and pressures of the portion of the products of combustion. The respective fluids, including the auto-ignited combustible materials, are then returned to the main flow and proceed to flow toward the turbine 13.

[0022] With the auto-ignited combustible materials returned to the main flow, axially staged injection or LLI processes may be engaged. This allows for secondary combustion to occur with the associated advantages in terms of reduced pollutant emissions, for example, but without the need to deprive the head end of the combus-

tor 12 of any of the air necessary for a given amount of fuel.

[0023] The injector 50 may include a vane 51 and a fuel source 52. The vane 51 is formed to define a flowpath 510 by which the compressed air is transmittable from the CDC to the recess 40. The fuel source 52 may include a flexible hose 520 and is configured to provide a supply of fuel to the flowpath 510. The vane 51 is substantially radially oriented and traverses the first annulus 22 and/or the second annulus 32. The vane 51 may be cylindrical or otherwise aerodynamically formed to generate as little a disturbance as possible in compressed air moving through the first annulus 22 or the second annulus 32. The vane 51 may include a micromixer 511 that is formed to mix the combustible materials to be injected into the recess 40 and to prevent or substantially reduce the possibility of flameholding in the recess 40 or the vane 51.

[0024] For most of the radial length of the vane 51, the flowpath 510 is oriented substantially radially. At a radially inward location, however, the vane 51 may be configured such that the flowpath 510 runs along the axial dimension of the turbomachine 10. In this way, the injector 50 is configured to inject the combustible materials into the recess 40 in a substantially axial direction thus facilitating the formation of the first trapped vortex 60.

[0025] In accordance with further embodiments, the fifth radial portion 405 may be formed to define through-hole 53 by which compressed air may flow from the second annulus 32 into the recess 40. In this way, additional air may be provided to enhance the combustion of the fuel injected by the injector 50. Moreover, since the through-hole 53 is defined through the fifth radial portion 405, the through-hole has a substantially axial orientation whereby the compressed air flowing through the through-hole 53 flows in the axial direction and thereby facilitates the formation of the first trapped vortex 60. It will be understood that a similar effect can be achieved with the through-hole 53 defined through a downstream section of the third axial portion 403. In this case, the compressed air flowing into the recess flows in the radial direction and again facilitates the formation of the first trapped vortex 60.

[0026] While the invention has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the invention is not limited to such disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the invention. Additionally, while various embodiments of the invention have been described, it is to be understood that aspects of the invention may include only some of the described embodiments. Accordingly, the invention is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

[0027] Various aspects and embodiments of the present invention are defined by the following numbered clauses:

1. A turbomachine with a trapped vortex feature, comprising:

a unibody liner formed to define a flow path for combustion products, the unibody liner comprising:

first and second portions defining first radial planes, a third portion defining a second radial plane and fourth and fifth portions extending substantially radially between proximal ends of the first and third portions and proximal ends of the second and third portions, respectively; and

an injector configured to deliver a fuel or a fuel/air mixture to a space partially bound by the third, fourth and fifth portions.

2. The turbomachine according to clause 1, wherein the injector is configured to deliver the fuel or the fuel/air mixture to the space in a substantially axial direction.

3. The turbomachine according to any preceding clause, wherein the unibody liner comprises a combustor liner and a transition piece liner and the space is defined proximate to a connection of the combustor liner and the transition piece.

4. The turbomachine according to any preceding clause, wherein the space has an annular shape.

5. The turbomachine according to any preceding clause, wherein the space has a substantially rectangular cross-sectional shape.

6. A turbomachine, comprising:

a unibody liner formed to define a flow path for combustion products;

the unibody liner being formed to define a trapped vortex feature into which a portion of combustion products flow; and

an injector configured to deliver a fuel or a fuel/air mixture to the trapped vortex feature.

7. The turbomachine according to any preceding clause, wherein the injector is configured to deliver the fuel or the fuel/air mixture to the trapped vortex feature in a substantially axial direction.

8. The turbomachine according to any preceding clause, wherein the unibody liner comprises a com-

bustor liner and a transition piece liner and the trapped vortex feature is defined proximate to a connection of the combustor liner and the transition piece.

9. The turbomachine according to any preceding clause, wherein the trapped vortex feature has an annular shape.

10. The turbomachine according to any preceding clause, wherein the trapped vortex feature has a substantially rectangular cross-sectional shape.

11. A turbomachine, comprising:

a combustor liner defining a first interior in which combustion occurs and a second interior through which products of combustion flow;

a transition piece liner disposed downstream from the combustor liner, the transition piece liner defining a third interior, which is receptive of the products of combustion and through which the products of combustion continue to flow,

at least one of the combustor liner and the transition piece liner being formed to define a recess into which a portion of the products of combustion flow; and

an injector configured to deliver combustible materials to the recess whereby the combustible materials and the portion of the products of combustion form respectively trapped vortices.

12. The turbomachine according to any preceding clause, wherein the combustible materials comprise fuel or a fuel mixed with compressor discharge casing air.

13. The turbomachine according to any preceding clause, further comprising:

a flow sleeve disposed about the combustor liner to define a first annulus; and

an impingement sleeve disposed about the transition piece liner to define a second annulus,

the second annulus being fluidly coupled to the first annulus.

14. The turbomachine according to any preceding clause, wherein the injector comprises:

a vane formed to define a flowpath by which air is transmitted from a compressor discharge casing to the recess; and

a fuel source configured to provide a supply of fuel to the flowpath.

15. The turbomachine according to any preceding clause, wherein the vane comprises a micromixer.

16. The turbomachine according to any preceding clause, wherein the fuel source comprises a flexible hose.

17. The turbomachine according to any preceding clause, wherein the injector is configured to deliver the combustible materials to the recess in a substantially axial direction.

18. The turbomachine according to any preceding clause, wherein the recess is defined proximate to a connection of the combustor liner and the transition piece liner.

19. The turbomachine according to any preceding clause, wherein the recess has an annular shape.

20. The turbomachine according to any preceding clause, wherein the recess has a substantially rectangular cross-sectional shape.

Claims

1. A turbomachine (10) with a trapped vortex feature (41), comprising:

a unibody liner (30) formed to define a flow path (510) for combustion products, the unibody liner (30) comprising:

first and second portions (401, 402) defining first radial planes, a third portion (403) defining a second radial plane and fourth and fifth portions (404, 405) extending substantially radially between proximal ends of the first and third portions (401, 403) and proximal ends of the second and third portions (402, 403), respectively; and
an injector (50) configured to deliver a fuel or a fuel/air mixture to a space partially bound by the third, fourth and fifth portions (403, 404, 405).

2. The turbomachine (10) according to claim 1, wherein the injector (50) is configured to deliver the fuel or the fuel/air mixture to the space in a substantially axial direction.

3. The turbomachine (10) according to any preceding claim, wherein the unibody liner (30) comprises a combustor liner (20) and a transition piece liner (30)

and the space is defined proximate to a connection of the combustor liner (20) and the transition piece (14).

4. The turbomachine (10) according to any preceding claim, wherein the space has an annular shape.

5. The turbomachine (10) according to any preceding claim, wherein the space has a substantially rectangular cross-sectional shape.

6. A turbomachine (10), comprising:

a unibody liner (30) formed to define a flow path for combustion products;
the unibody liner (30) being formed to define a trapped vortex feature (41) into which a portion of combustion products flow; and
an injector (50) configured to deliver a fuel or a fuel/air mixture to the trapped vortex feature.

7. The turbomachine (10) according to claim 6, wherein the injector (50) is configured to deliver the fuel or the fuel/air mixture to the trapped vortex feature in a substantially axial direction.

8. The turbomachine (10) according to claim 6 or claim 7, wherein the unibody liner (30) comprises a combustor liner and a transition piece liner and the trapped vortex feature is defined proximate to a connection of the combustor liner and the transition piece.

9. The turbomachine (10) according to any of claims 6 to 8, wherein the trapped vortex feature (41) has an annular shape.

10. The turbomachine (10) according to any of claims 6 to 9, wherein the trapped vortex feature (41) has a substantially rectangular cross-sectional shape.

11. A turbomachine (10), comprising:

a combustor liner (30) defining a first interior in which combustion occurs and a second interior through which products of combustion flow;
a transition piece liner (30) disposed downstream from the combustor liner, the transition piece liner defining a third interior, which is receptive of the products of combustion and through which the products of combustion continue to flow,
at least one of the combustor liner (20) and the transition piece liner (30) being formed to define a recess into which a portion of the products of combustion flow; and
an injector (50) configured to deliver combustible materials to the recess whereby the combustible materials and the portion of the products of combustion form respectively trapped vortices.

12. The turbomachine (10) according to claim 11, wherein the combustible materials comprise fuel or a fuel mixed with compressor discharge casing air.

13. The turbomachine (10) according to claim 11 or claim 12, further comprising:

a flow sleeve (21) disposed about the combustor liner (20) to define a first annulus; and
an impingement sleeve (31) disposed about the transition piece liner to define a second annulus, the second annulus being fluidly coupled to the first annulus.

14. The turbomachine (10) according to any of claims 11 to 13, wherein the injector (50) comprises:

a vane (51) formed to define a flowpath (510) by which air is transmitted from a compressor discharge casing to the recess; and
a fuel source configured to provide a supply of fuel to the flowpath (510).

15. The turbomachine (10) according to claim 14, wherein the vane (51) comprises a micromixer (511).

FIG. 1

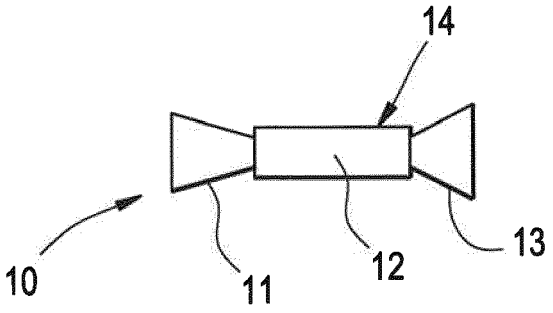
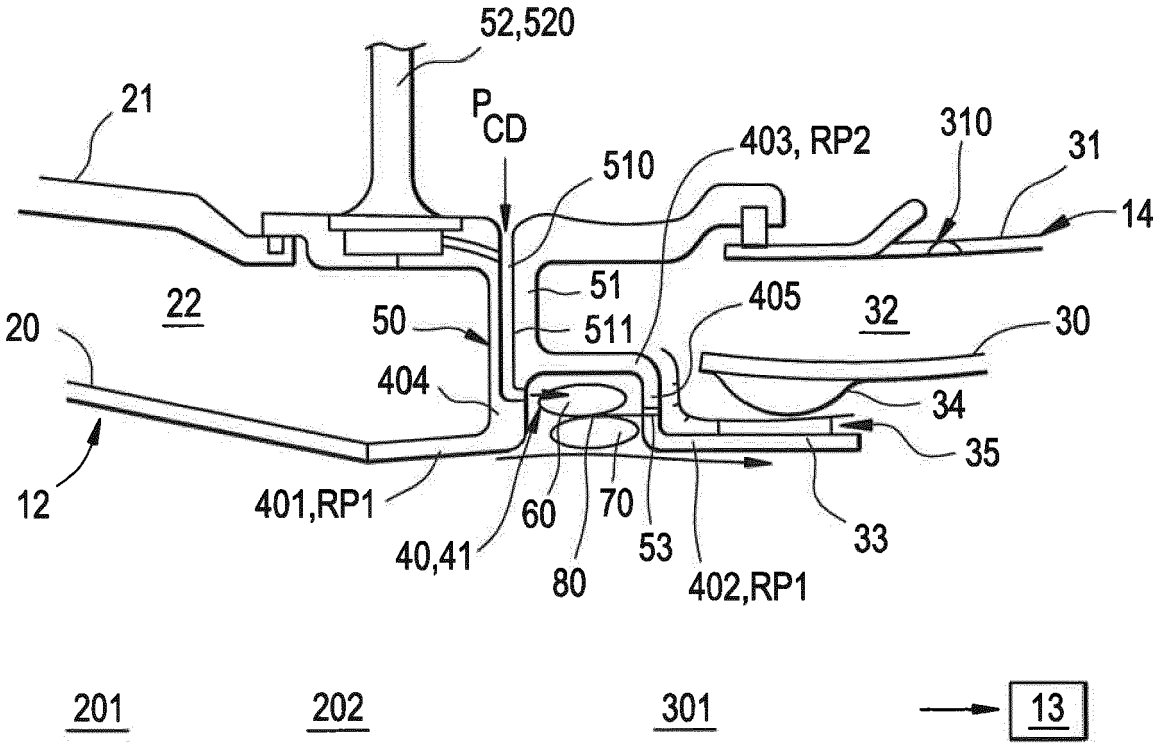

14
10
11
12
13

FIG. 2


52,520
21
P CD
510
403, RP2
310
31
14
22
51
405
32
20
50
511
30
404
34
35
12
401,RP1
60
70
53
33
40,41
80
402,RP1
201
202
301
13