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## (54) Method and apparatus for mitigating out of roundness effects at a turbine

(57) A turbine and a method of mitigating out-of-roundness effects at a turbine is disclosed. An inner turbine shell and an outer turbine shell of the turbine is provided. The inner turbine shell is coupled to the outer turbine shell using a ring insert. The ring insert is segmented into a plurality of ring insert segments (302) that reduce a transfer of load from the outer turbine shell to the inner turbine shell to mitigate out-of-roundness of the inner turbine shell.

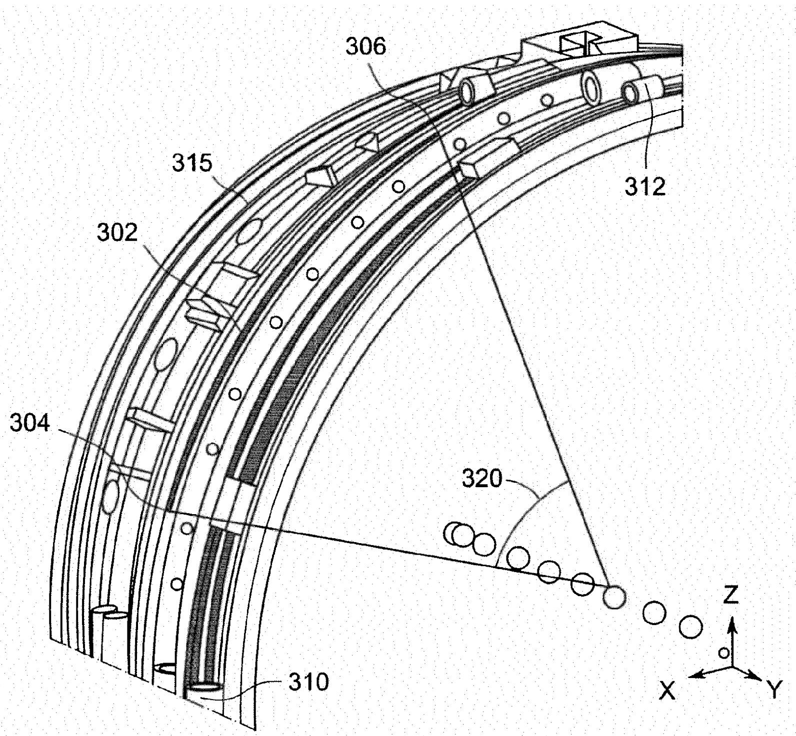


FIG. 3

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## Description

BACKGROUND OF THE INVENTION

**[0001]** The subject matter disclosed herein relates to an apparatus and method for mitigating out-of-roundness effects at an inner turbine shell of a gas turbine. Several turbine section designs include an inner turbine shell that provides a flow path for a working gas through the turbine and an outer turbine shell that surrounds the inner turbine shell. Generally, a rotor having a plurality of blades is disposed within the inner turbine shell and rotates as a result of the working gas passing through the turbine. The clearance between the inner turbine shell and the plurality of turbine blades determines turbine efficiency and power production and can be affected by a deviation of the inner turbine shell from a circular cross-section, also known as out-of-roundness. Due to connections between inner turbine shell and outer turbine shell, loads due to various operational stresses are often transferred from the outer turbine shell to the inner turbine shell and cause the inner turbine shell to distort, a condition known as out-of-roundness. There is therefore a desire to design turbine shells that mitigate out-of-roundness effects. The present disclosure provides a method and apparatus that reduces load transfer between outer turbine shell and inner turbine shell to reduce out-of-roundness effects.

BRIEF DESCRIPTION OF THE INVENTION

**[0002]** According to one aspect, the present invention resides in a method of mitigating out-of-roundness effects at a turbine, the method including: providing an inner turbine shell of the turbine within an outer turbine shell of the turbine; and coupling the inner turbine shell to the outer turbine shell using a ring insert that is segmented into a plurality of ring insert segments that reduce a transfer of load from the outer turbine shell to the inner turbine shell to mitigate out-of-roundness of the inner turbine shell.

**[0003]** According to another aspect, the present invention resides in a turbine including an outer turbine shell; an inner turbine shell; and a ring insert configured to couple the inner turbine shell to the outer turbine shell and segmented into a plurality of ring insert segments to reduce a load transfer from the outer turbine shell to the inner turbine shell.

**[0004]** These and other advantages and features will become more apparent from the following description taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWING

**[0005]** 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 shows a side view cross-section of an exemplary inner turbine shell of a turbine generator in one embodiment of the present disclosure;

FIG. 2 shows a section of the inner turbine shell of FIG. 1 that includes a thrust collar;

FIG. 3 shows a profile view of an exemplary shell sector in an exemplary embodiment; and

FIGS. 4 and 5 show plots of circumference of an exemplary inner turbine shell of the present disclosure at various times during an operation cycle of an exemplary turbine.

**[0006]** The detailed description explains embodiments of the invention, together with advantages and features, by way of example with reference to the drawings.

DETAILED DESCRIPTION OF THE INVENTION

**[0007]** FIG. 1 shows a side view cross-section of an exemplary inner turbine shell 100 of a gas turbine in one embodiment of the present disclosure. The exemplary inner turbine shell 100 provides a hollow casing extending along a longitudinal axis 102 and having an inlet 104 at a first end of the longitudinal axis and an outlet 106 at a second end of the longitudinal axis. The turbine shell is substantially rotationally symmetric about its longitudinal axis 102. A rotor having a plurality of turbine blades (not shown) is disposed substantially along the longitudinal axis 102 within the inner turbine shell 100. A working gas injected into the inner turbine shell 100 at the inlet 104 displaces the turbine blades to cause the turbine blades to rotate, thereby causing the rotor to rotate to generate power. In various embodiments, the inner turbine shell 100 is composed of two or more sections, also referred to herein as shell sectors, that are mated together to form the inner turbine shell 100. An exemplary shell sector generally spans a selected azimuthal angle around the longitudinal axis 102. The two or more shell sectors are mated together at interfaces 110 via bolts 112. The mated shell sectors provide a cooling hole or air passage 114 passing through the inner turbine shell 100 that provides air to nozzles (not shown) that are assembled at the inner turbine shell. The inner turbine shell is coupled to the outer turbine shell at a thrust collar 116 of the inner turbine shell 100. The inner turbine shell includes a thrust collar 116.

**[0008]** FIG. 2 shows a section of the inner turbine shell of FIG. 1 that includes a thrust collar 116. In various embodiments, the thrust collar 116 is segmented. The segmented thrust collar 116 of the inner turbine shell includes a slot 118 into which a ring insert can be inserted. The ring insert couples the inner turbine shell to the outer turbine shell to provide support for the inner turbine shell. The ring insert provides an area of contact between the outer turbine shell and the inner turbine shell. In an exemplary embodiment, the ring insert is segmented into a plurality of ring insert segments that are separated from each other to provide gaps between them along the circumference. Thus, the total angle subtended by the plurality of ring insert segments is less than 360 degrees.

**[0009]** FIG. 3 shows a profile view of a shell sector in an exemplary embodiment of the present disclosure. The exemplary inner turbine shell is composed of four shell sectors, each of which forms a quadrant of the inner turbine shell 300. Exemplary shell sector 315 is shown. A ring insert segment 302 is shown on the exemplary shell sector 315. The ring insert segment 302 extends from a first azimuthal location 304 to a second azimuthal location 306 along a circumference of sector 315 to subtend angle 320. In one embodiment, angle 320 is less than 90 degrees. In another embodiment, angle 320 is between about 15 degrees and 85 degrees. In yet another embodiment, angle 320 is between about 30 degrees and about 70 degrees. In an exemplary embodiment, the ring insert segment 302 is disposed evenly between the first mating interface 310 and second mating interface 312 of shell sector 315 such that a distance between the first azimuthal location 304 and the first mating interface 310 is substantially the same as a distance between the second azimuthal location 306 and the second mating interface 312. Thus, the area of contact between the outer turbine shell and the inner turbine shell is less than 360 degrees. This reduced contact area reduces a load transfer area between the outer turbine shell and the inner turbine shell. In alternate embodiments, the exemplary shell sector 315 can include two or more ring segments separated from each other.

**[0010]** In one aspect, the length of the ring insert segment can be determined using a processor. The exemplary processor can run a simulation to determine the length of the ring insert segment at which an out-of-roundness of the inner turbine shell meets a selected criterion. The processor can simulate various operating cycles of the turbine and determine out-of-roundness of the inner turbine shell at various times during the cycle.

**[0011]** Alternately, a turbine having the exemplary ring insert segments can be constructed and operated. Sensors can be disposed at various locations of the inner turbine shell and the out-of-roundness of the inner turbine shell can be observed as the turbine is run through various operational cycles. A ring insert segment length and spacing can thereby be determined by observing an effectiveness of the various ring insert segment lengths with respect to mitigating out-of-roundness effects.

**[0012]** In one aspect, the length of the ring segment is selected at which the out-of roundness meets a selected criterion. In various embodiments, the right segment is selected when a length of the ring segment keeps the out-of-roundness of the inner turbine shell within an acceptable tolerance level. In another embodiment, the selected criterion can be an out-of-roundness tolerance over a selected time frame.

**[0013]** FIG. 4 shows a plot of a circumference of an exemplary inner turbine shell of the present disclosure at various times during operation of an exemplary turbine. The plot of FIG. 4 is output from an analytical model in measurements of radial displacement of the circumference are obtained at approximately every 5 degrees around the circumference. A plot may alternatively be obtained for a test of a constructed shell, generally using about 10 sensors placed around the circumference. Radial measurements are obtained at various times, as indicated by reference numbers 401 (1654 seconds after start-up), 402 (2374 seconds), 403 (2874 seconds), 404 (4174 seconds), 405 (100000 seconds) and 406 (100967 seconds). FIG. 5 shows a plot of the circumference of the exemplary inner turbine shell of FIG. 4 at later times. Radial measurements are obtained at various times indicated by 501 (105618 seconds), 502 (114400 seconds), 503 (116055 seconds), 504 (116271 seconds), 505 (116775 seconds) and 506 (214400 seconds). The exemplary inner turbine shell is generally run through one or more cycles of increasing and decreasing power output. The circumference of the inner turbine shell generally increases with heating and decreases with cooling. Early times (i.e., time 401) show an inner turbine shell that has a substantially round cross-section. The turbine operating at high output levels (i.e. times 404, 405 and 406) are shown. Time 404 in particular shows an inner turbine shell with large out-of roundness effects at high output levels. Times 503 and 504 shown the circumference as the operation cycle is lowered to a lower output levels. Various degrees of out-of-roundness is shown. Time 506 shows the circumference as the operation cycle is raised again to high output levels. As seen in FIG. 5, the degree of out-of-roundness of the shell at time 506 is relatively little. When the out-of-roundness effects are within an acceptable tolerance an operator can select the ring segment for use in a turbine.

**[0014]** Therefore, in one aspect, the present disclosure provides a method of mitigating out-of-roundness effects at a turbine, the method including: providing an inner turbine shell of the turbine within an outer turbine shell of the turbine; and coupling the inner turbine shell to the outer turbine shell using a ring insert that is segmented into a plurality of ring insert segments that reduce a transfer of load from the outer turbine shell to the inner turbine shell to mitigate out-of-roundness of the inner turbine shell. In one embodiment, the plurality of ring insert segments includes four ring insert segments. At least one of the ring insert segments subtends an angle measured from a longitudinal axis of the inner turbine shell selected from the group consisting of: (i) less than 90 degrees; (ii) between about 15 degrees and about 85 degrees; and (iii) between about 30 degrees and about 70 degrees. A processor can be used to determine a length and position of the ring insert segments at which an out-of-roundness of the inner turbine shell meets a selected criterion. The length of a ring insert segment is selected to reduce a load path between the outer turbine shell and the inner turbine shell. In various embodiments, the load is a result of a thermal stress at the outer turbine shell. The ring insert segments are disposed at a thrust collar of the inner turbine shell at equidistant locations around a circumference of the inner turbine shell. In various embodiments, the inner turbine shell is formed of at least two azimuthal shell sectors.

**[0015]** A turbine including an outer turbine shell; an inner turbine shell; and a ring insert configured to couple the inner turbine shell to the outer turbine shell and segmented into a plurality of ring insert segments to reduce a load transfer from the outer turbine shell to the inner turbine shell. In an exemplary embodiment, the ring insert is segmented into four ring insert segments. An angle subtended by at least one of the ring insert segments is selected from the group consisting of: (i) less than 90 degrees; (ii) between about 15 degrees and 85 degrees; and (iii) between about 30 degrees and about 70 degrees. A processor running a program of a model of the turbine can be used to determine a length of the ring insert. The length of the ring insert segments is generally selected to reduce a load path between the outer turbine shell and the inner turbine shell. The load is generally related to thermal stress at the outer turbine shell. In an exemplary embodiment, the ring insert segments are evenly spaced around a circumference of the inner turbine shell. In various embodiments, the inner turbine shell is formed of at least two shell sectors extending over a selected azimuthal angle.

**[0016]** 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.

## Claims

1. A method of mitigating out-of-roundness effects at a turbine, comprising:

    disposing an inner turbine shell (100,300) of the turbine within an outer turbine shell of the turbine; and
    coupling the inner turbine shell (100,300) to the outer turbine shell using a ring insert that is segmented into a plurality of ring insert segments (302) that reduce a transfer of load from the outer turbine shell to the inner turbine shell (100,300) to mitigate out-of-roundness of the inner turbine shell (100,300).

2. The method of claim 1, wherein the plurality of ring insert segments (302) further comprises four ring insert segments.

3. The method of claim 2, wherein at least one of the ring insert segments (302) subtends an angle (320) measured from a longitudinal axis (102) of the inner turbine shell (300) selected from the group consisting of: (i) less than 90 degrees; (ii) between about 15 degrees and about 85 degrees; and (iii) between about 30 degrees and about 70 degrees.

4. The method of any of claims 1 to 3, further comprising using a processor to determine a length of the ring insert segments (302) at which an out-of-roundness of the inner turbine (300) shell meets a selected criterion.

5. The method of any of claims 1 to 4, wherein a length of a ring insert segment (302) is selected to reduce a load path between the outer turbine shell and the inner turbine shell (300).

6. The method of any of claims 1 to 5, wherein the load is a result of a thermal stress at the outer turbine shell.

7. The method of any of claims 1 to 6, wherein the ring insert segments (302) are disposed at a thrust collar (116) of the inner turbine shell (100,300) at equidistant locations around a circumference of the inner turbine shell (100,300).

8. The method of any preceding claim, wherein the inner turbine shell (100,300) is formed of at least two azimuthal shell sectors (315).

9. A turbine, comprising:

    an outer turbine shell;
    an inner turbine shell (100,300); and
    a ring insert configured to couple the inner turbine shell (100,300) to the outer turbine shell and segmented into a plurality of ring insert segments (302) to reduce a load transfer from the outer turbine shell to the inner turbine shell (100,300).

10. The turbine of claim 9, wherein the ring insert is segmented into four ring insert segments (302).

11. The turbine of claim 10, wherein an angle (320) subtended by at least one of the ring insert segments (302) is selected from the group consisting of: (i) less

than 90 degrees; (ii) between about 15 degrees and 85 degrees; and (iii) between about 30 degrees and about 70 degrees.

**12.** The turbine of any of claims 9 to 11, wherein a length of the ring insert segments (302) is determined using a processor running a program of a model of the turbine.

**13.** The turbine of any of claims 9 to 12, wherein a length of the ring insert segments (302) is selected to reduce a load path between the outer turbine shell and the inner turbine shell (100,300).

**14.** The turbine of any of claims 9 to 13, wherein the load is related to thermal stress at the outer turbine shell.

**15.** The turbine of any of claims 9 to 14, wherein the ring insert segments (302) are evenly spaced around a circumference of the inner turbine shell (300).

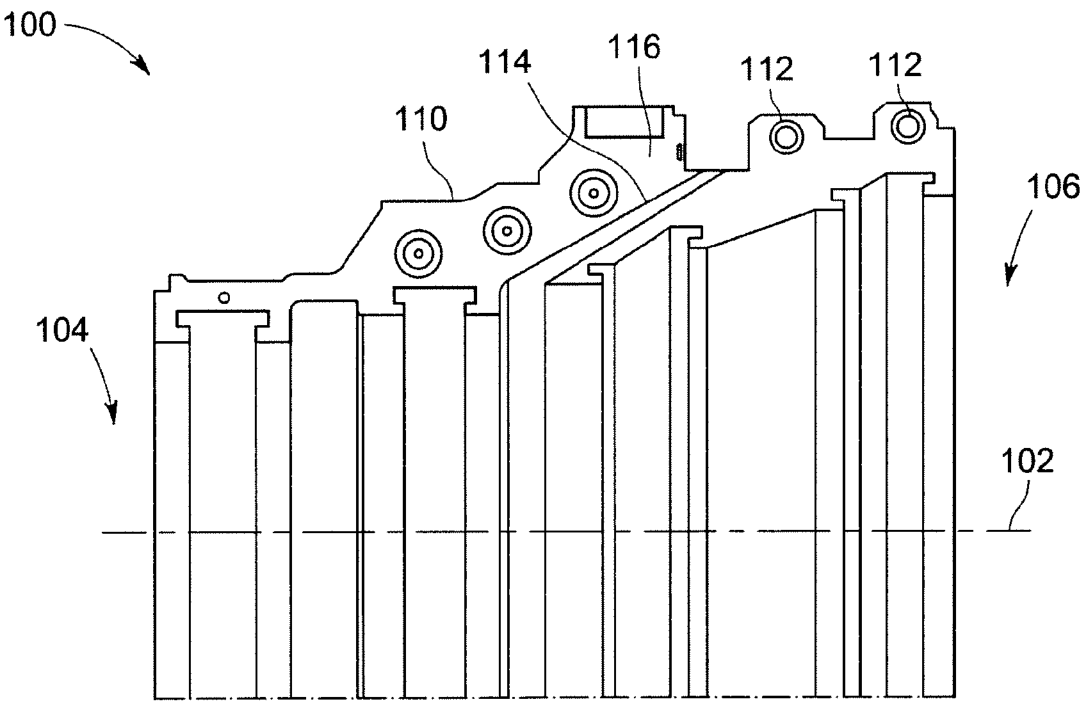


FIG. 1

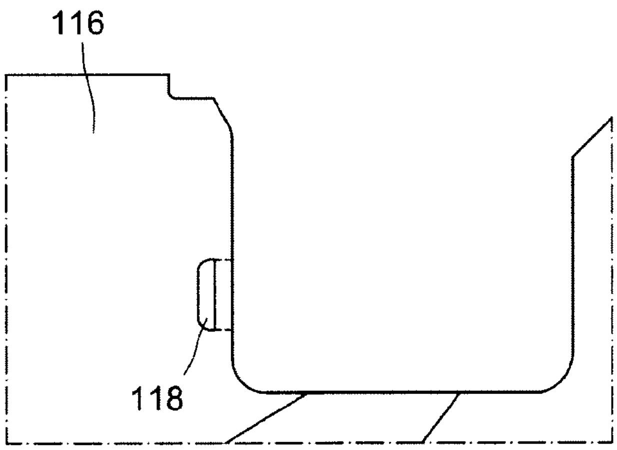


FIG. 2

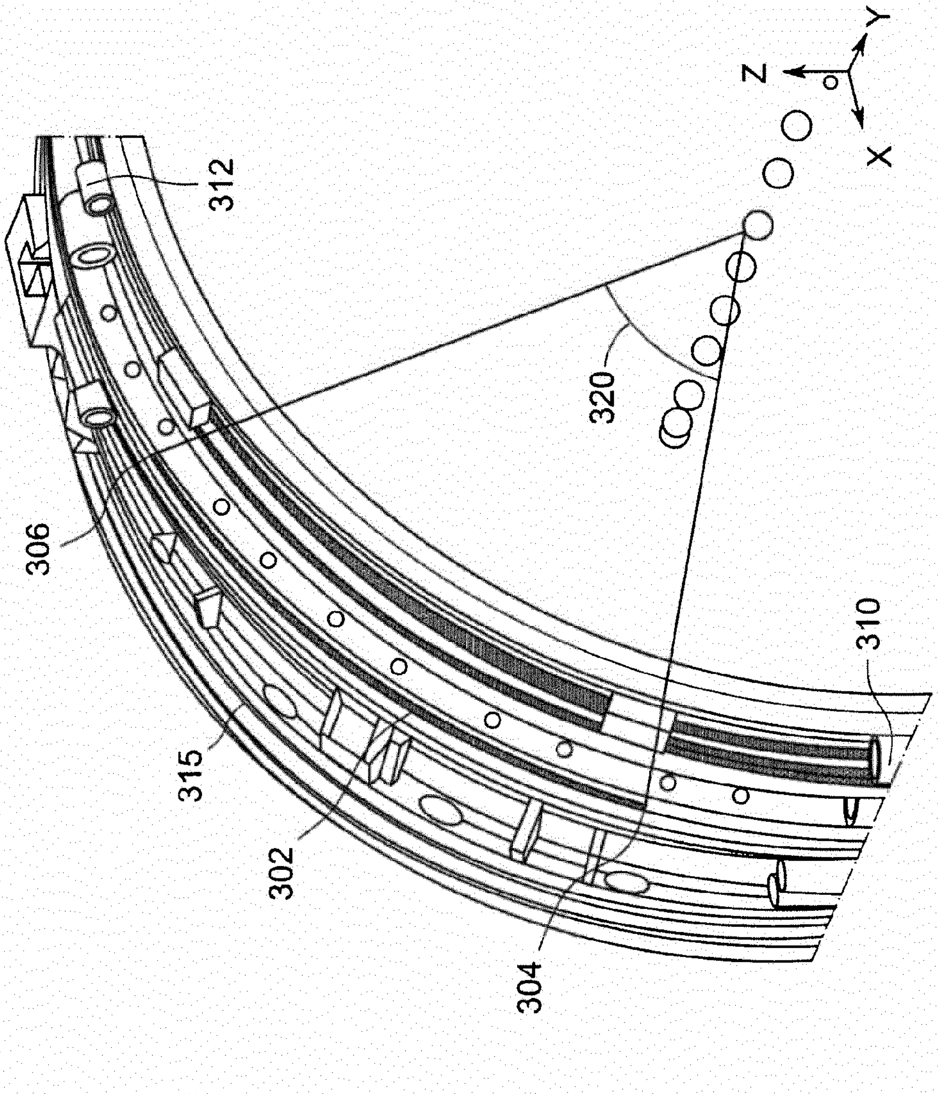


FIG. 3

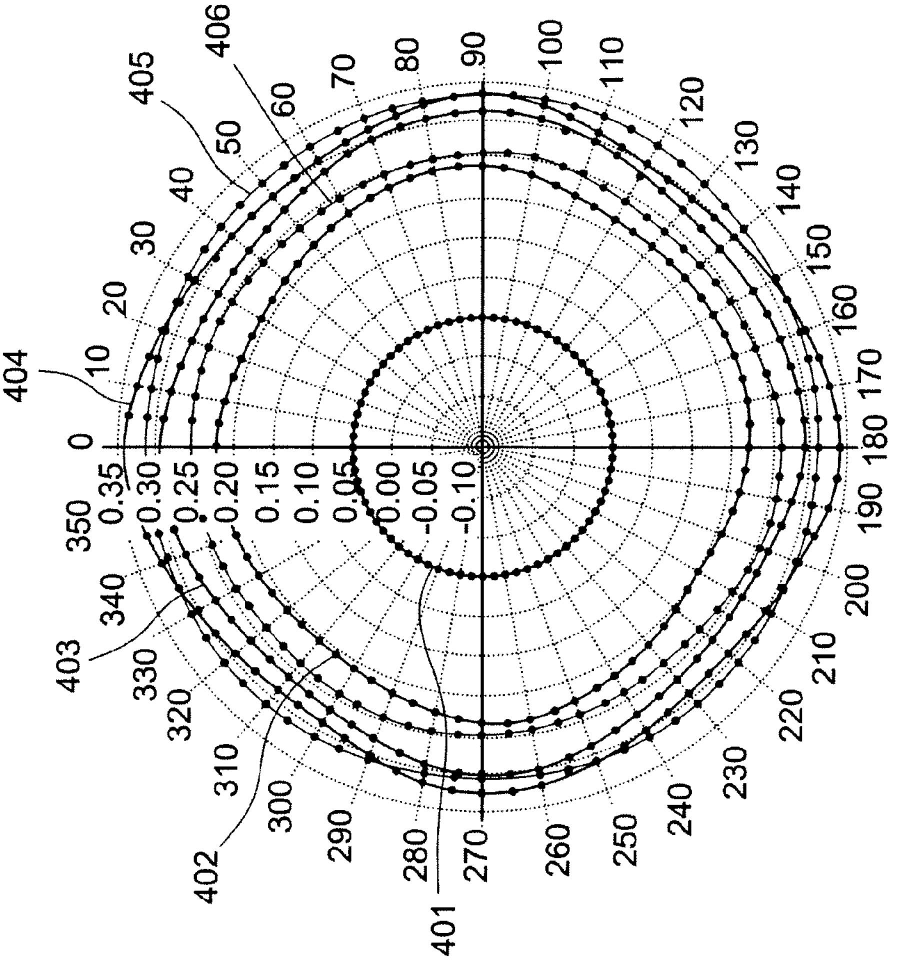
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FIG. 4

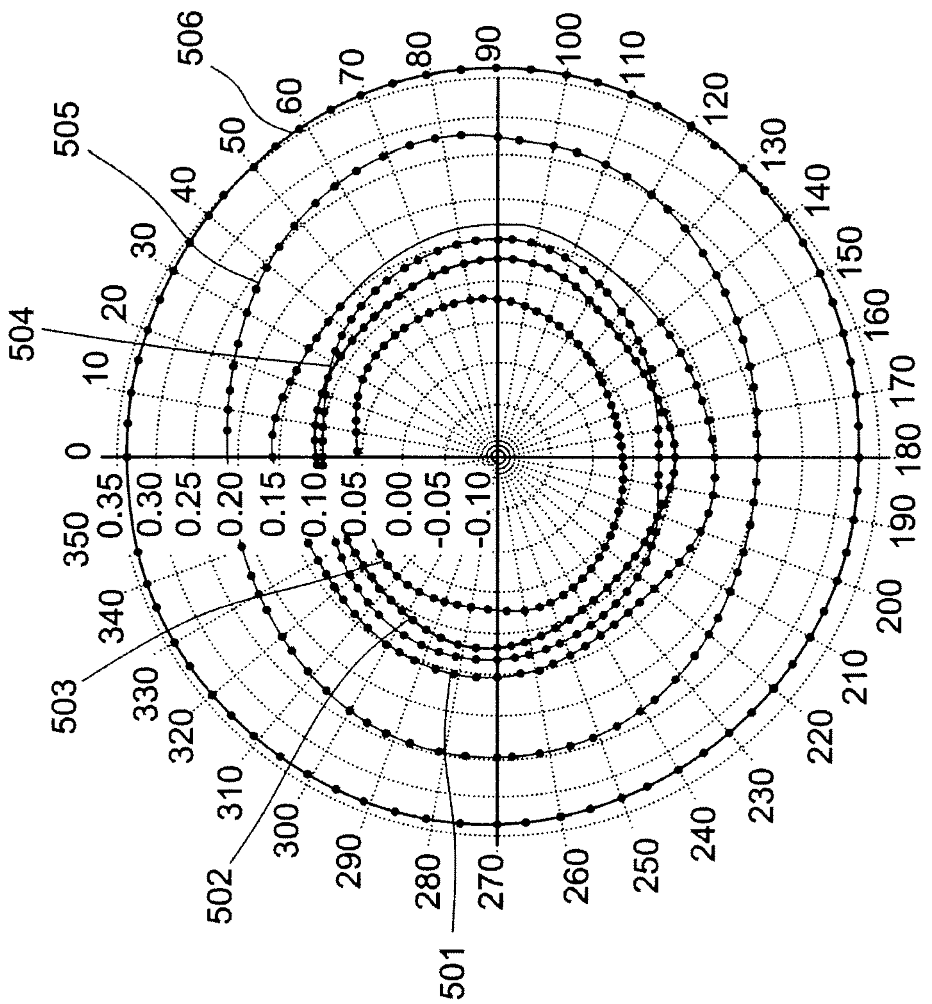
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FIG. 5

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# EUROPEAN SEARCH REPORT

Application Number
EP 13 17 1178

## 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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TECHNICAL FIELDS SEARCHED (IPC)

F01D

The present search report has been drawn up for all claims

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| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| Munich | 2 October 2013 | Rau, Guido |

CATEGORY OF CITED DOCUMENTS

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## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 13 17 1178

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