



(51) International Patent Classification:

G01N 21/88 (2006.01) G01J 5/48 (2006.01)
G01N 21/952 (2006.01)

(21) International Application Number:

PCT/US2014/061064

(22) International Filing Date:

17 October 2014 (17.10.2014)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

61/892,541 18 October 2013 (18.10.2013) US

(71) Applicant: UNITED TECHNOLOGIES CORPORATION [US/US]; One Financial Plaza, Hartford, Connecticut 06101 (US).

(72) Inventor: KOONANKEIL, James M.; 24 S. Buckboard Lane, Malborough, Connecticut 06447 (US).

(74) Agents: MURPHY, Timothy J. et al.; Carlson, Gaskey & Olds, P.C./Pratt & Whitney, 400 W. Maple, Suite 350, Birmingham, MI 48009 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: METHOD AND ASSEMBLY FOR INSPECTING ENGINE COMPONENT

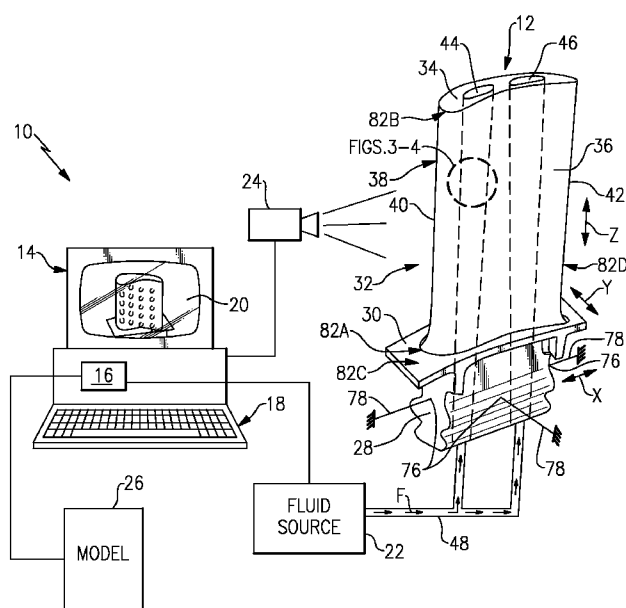


FIG.1

(57) Abstract: One exemplary embodiment of this disclosure relates to a method of inspecting a component of a gas turbine engine. The method includes performing a through-hole inspection, and determining a location of the plurality of holes from results of the through-hole inspection.

METHOD AND ASSEMBLY FOR INSPECTING ENGINE COMPONENT**BACKGROUND**

[0001] Gas turbine engine components, such as rotor blades and stator vanes, include core cooling passageways configured to communicate fluid within the component. These core passageways are in communication with cooling holes, which direct fluid toward an outer surface of the component. Components are often inspected to determine whether the cooling holes have been properly machined.

[0002] In one known inspection method, a component is placed in a first assembly where the component is visually inspected (e.g., using a camera) to determine the location of the cooling holes relative to an acceptable location for those holes. In a separate assembly, the component undergoes a through-hole (or thru-hole) inspection to determine whether the cooling holes are blocked.

SUMMARY

[0003] One exemplary embodiment of this disclosure relates to a method of inspecting a component of a gas turbine engine. The method includes performing a through-hole inspection, and determining a location of the plurality of holes from results of the through-hole inspection.

[0004] In a further embodiment of any of the above, the through-hole inspection includes a flow thermography process.

[0005] In a further embodiment of any of the above, the flow thermography process includes providing a flow of fluid within the component and taking a thermal image of the plurality of holes as the fluid exits the plurality of holes.

[0006] In a further embodiment of any of the above, the step of taking the thermal image includes taking a thermal video of the fluid exiting the plurality of holes.

[0007] In a further embodiment of any of the above, the results of the through-hole inspection include a plurality pixels, and wherein a blockage is identified when a number of pixels within an acceptable hole location is below a minimum threshold.

[0008] In a further embodiment of any of the above, a hole is determined to not be blocked if a number of pixels is greater than or equal to a minimum threshold within the acceptable hole location.

[0009] In a further embodiment of any of the above, a misaligned hole is identified if the determined hole location is outside an acceptable hole location.

[0010] In a further embodiment of any of the above, the results of the through-hole inspection include a plurality of sets of pixels, each of the sets of pixels corresponding to one of the plurality of holes.

[0011] In a further embodiment of any of the above, the determined location of each of the plurality of holes is a centroid of a corresponding one of the plurality of sets of pixels.

[0012] In a further embodiment of any of the above, the determined location of each of the plurality of holes is a pixel on a perimeter of a corresponding one of the plurality of sets of pixels.

[0013] In a further embodiment of any of the above, the determined location of the plurality of holes is expressed relative to secondary datums.

[0014] In a further embodiment of any of the above, the determined location of the plurality of holes is translated from being expressed in terms of secondary datums to being expressed in terms of primary datums.

[0015] In a further embodiment of any of the above, the component is an airfoil including an airfoil section and a root, the secondary datums located on the root, and the primary datums located on the airfoil section.

[0016] Another exemplary embodiment of this disclosure relates to an inspection assembly. The assembly includes a thermal imaging camera, a fixture for supporting an engine component a fluid source in communication with a passageway of the engine component, and a controller. The controller is configured to perform a through-hole inspection on the component, and is further configured to determine a location of the plurality of holes from results of the through-hole inspection.

[0017] In a further embodiment of any of the above, the assembly includes a conduit connecting the fluid source to the passageway.

[0018] In a further embodiment of any of the above, the controller is configured to identify blocked and partially blocked holes by comparing a number of pixels within an acceptable hole location with a minimum threshold.

[0019] In a further embodiment of any of the above, the controller compares the determined hole locations for each of the plurality of holes with acceptable hole locations to identify misaligned holes.

[0020] In a further embodiment of any of the above, the controller is in communication with a model, the model including a minimum pixel threshold and acceptable hole locations.

[0021] In a further embodiment of any of the above, the fixture supports the engine component at a root of the engine component.

[0022] The embodiments, examples and alternatives of the preceding paragraphs, the claims, or the following description and drawings, including any of their various aspects or respective individual features, may be taken independently or in any combination. Features described in connection with one embodiment are applicable to all embodiments, unless such features are incompatible.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The drawings can be briefly described as follows:

[0024] Figure 1 schematically illustrates an example inspection assembly according to this disclosure.

[0025] Figure 2 is a flow chart illustrating an example method according to this disclosure.

[0026] Figure 3 illustrates a portion of the component of Figure 1.

[0027] Figure 4 illustrates an example inspection result, relative to the portion of the component illustrated in Figure 3.

DETAILED DESCRIPTION

[0028] Figure 1 schematically illustrates an example inspection assembly 10 for inspecting an engine component 12. It should be understood that this disclosure is not limited to the details of the illustrated inspection assembly 10, and otherwise extends to other inspection assemblies. Further, while the engine component 12 illustrated herein as a turbine blade, it should be understood that this disclosure extends to other engine components, such as stator vanes, blade outer air seals (BOAS), combustor liners, and augmentor liners, as examples.

[0029] The inspection assembly 10 includes a computer 14 in communication with a controller 16 capable of receiving inputs, such as from the keyboard 18, and displaying an output in one example via a display, or monitor, 20. In one example, the controller 16 includes a microprocessor capable of executing instructions in accordance with the functionality described herein.

[0030] In this example, the controller 16 is in communication with a fluid source 22, which is in fluid communication with the engine component 12, as will be discussed

below. The controller 16 is further in communication with a camera 24. In one example, the camera 24 is a thermal infrared (IR) camera used to determine the temperature of an object by detecting radiation and producing a still image, or alternatively a video, of that radiation. In this sense, the assembly 10 provides a flow thermography system. The controller 16 is further in communication with a model 26, which may include information such as an acceptable cooling hole location, a minimum pixel threshold for determining an acceptable hole size, etc., as will be appreciated from the below.

[0031] In the example where the engine component 12 is a rotor blade, the engine component 12 includes a root 28, a platform 30, and an airfoil section 32. The airfoil section 32 extends radially (e.g., in the radial direction Z) from the platform 30 to a blade tip 34. The airfoil section 32 includes a pressure side wall 36 and a suction side wall 38, each of which extend between a leading edge 40, and a trailing edge 42 of the airfoil section 32.

[0032] A plurality of core cooling passageways 44, 46 extend radially from the root 28 to the blade tip 34. Here, two core cooling passageways 44, 46 are illustrated. As is known in the art, these core cooling passageways 44, 46 may be in communication with a plurality of cooling holes leading from the core cooling passageways 44, 46 to an outer surface of the airfoil section 32. A plurality of cooling holes are illustrated in Figure 3, which will be discussed in detail below. While core cooling passageways 44, 46 are illustrated, this disclosure extends to platform cooling holes that may not be in communication with a core cooling passageway.

[0033] The fluid source 22 is in communication with each of the core passageways 44, 46 by way of a conduit 48. Upon instruction from the controller 16, fluid F from the fluid source 22 is configured to be directed along the core passageways 44, 46. As the fluid F flows along the core passageways 44, 46, a portion of that fluid F is directed out the plurality of cooling holes and flows adjacent the outer surface of the airfoil section 32.

[0034] The camera 24 is configured to generate an image of the fluid F as it exits these cooling passageways. This image may then be used to conduct a through-hole inspection, which in turn may be used to determine the location of the cooling holes.

[0035] A flow chart illustrating an example method according to this disclosure is provided in Figure 2. The method according to this disclosure includes performing a through-hole inspection 50, determining a location of the plurality of holes machined in the component 12 based on the results from the through-hole inspection, at 52, and identifying blocked, partially blocked, and misaligned cooling holes, at 53.

[0036] In one example of this disclosure, a through-hole inspection, at 50, is performed using a flow thermography process. In this process, a flow of fluid F is introduced into the component 12, at 54. Figure 3 illustrates a portion of the airfoil section 32 of the component 12. The airfoil section 32, as mentioned above, has been machined to include a plurality of cooling holes 56.

[0037] The cooling holes 56 are intended to communicate fluid F from one of the core passageways 44, 46 to an outer surface of the airfoil section 32. Acceptable cooling hole locations 58 are illustrated herein for purposes of explanation. The acceptable locations 58 may be provided from engineering specifications and stored in the model 26.

[0038] In some instances, the cooling holes 56 are not machined within the acceptable location 58, resulting in a misaligned hole, illustrated at 56M, wherein the misaligned hole 56M falls outside the acceptable hole location 58.

[0039] In other instances, the hole may be blocked, or not drilled at all, as illustrated at 56B. Blocked holes 56B do not communicate any fluid F from the core passageways 44, 46 to the outer surface of the airfoil section 32. Further, a hole may be partially blocked, as illustrated at 56P, in which case the flow of fluid F communicated

between the core passageways 44, 46 and the outer surface of the airfoil section 32 is insufficient.

[0040] As fluid F flows through the holes 56, the camera 24 provides a thermal image of the cooling holes 56, at 60. Figure 4 illustrates an example thermal image of the cooling holes of Figure 3. The image, which may be displayed on the screen 20, is a plurality of sets 62 of pixels P. In one example, the pixels P are of a particular color that corresponds to the known temperature of the fluid F.

[0041] In the bottom left-hand corner of Figure 4, a first set of pixels P indicates that the cooling hole 64 is acceptable. In this example, the pixel count within the acceptable hole location 58 is greater than or equal to a minimum threshold. The minimum threshold is a predetermined value known to correspond to a cooling hole that provides adequate cooling. The minimum threshold may be stored in the model 26. When the pixel count is below the minimum threshold, a partially blocked hole, such as the partially blocked hole 66, will be identified, at 53. Where no pixels are shown within an expected location 58, a blocked hole, such as the blocked hole 68, will be identified (again, at 53).

[0042] From the results of the through-hole inspection (e.g., the image illustrated in Figure 4), the location of the cooling holes 56 can be determined, at 52. In one example, the location of the cooling holes 56 is determined first by analyzing the sets of pixels 62 from the results of the through-hole inspection, at 72. In a first example, the centroid 62C of the set of pixels 62 is reported as the determined cooling hole location. In another instance, a location on the perimeter, 62P of the set of pixels 62 is reported as the identified cooling hole location. While the centroid 62C may sufficiently indicate the cooling hole location, a point at the perimeter of the set of pixels 62 may be more representative of the center of the cooling hole 56, due to the possibility that the flow of the fluid F may immediately move away from the cooling holes 56 upon exiting the cooling holes 56.

[0043] At any rate, at 74, the cooling hole location is initially expressed, at 74, relative to secondary datums 76 located on the root section 28 of the component 12. For instance, during the through-hole inspection discussed above, the component 12 may be supported by its root section, by way a fixture 78. The locations where the fixture 78 interfaces with the root 28 are referred to as secondary datums 76. In examples where this disclosure is used relative to a stator vane, the secondary datums 76 would be adjacent an inner and/or outer platform.

[0044] These locations are then translated, at 80, to be expressed in terms of primary datums. As is known in this art, primary datums are points where a component is typically supported during machining. Engineering specifications, which include the acceptable cooling hole locations, are typically provided with reference to these primary datums. Example primary datums 82A-82D are illustrated at the leading edge 40 of the airfoil section 32 adjacent the platform (82A), at the leading edge of the airfoil section adjacent the blade tip 34 (82B), at the upper surface of the platform 30 (82C), and at the trailing edge 42 (82D).

[0045] At 53, the location of the cooling holes is compared with the engineering specifications to identify misaligned holes, such as the misaligned hole 56M, which is identified as a misaligned hole, at 70 in Figure 4, because the centroid 70C is located outside the acceptable hole location 58. Alternatively, if a perimeter is used to report the cooling hole locations, a misaligned hole may still be identified because at least some perimeter pixels 70P lie outside the acceptable hole location 58.

[0046] As known in the art, depending on the defects identified at 53, corrective measures, such as further manufacturing, can be undertaken to correct the defective cooling holes (such as the 56P, 56 M, and 56B).

[0047] It is possible to mount the component 12 relative to the primary datums 84A-84D during the initial inspection, however, this mounting may interfere with the flow of fluid F exiting the cooling holes 56, which may negatively impact the results of the through-hole inspection. Alternatively, it may be possible to probe the component 12 relative to the primary datums 84A-84D, such that the through-hole inspection would be reported relative to the primary datums in the first instance. However, probing adds time to the inspection process.

[0048] Accordingly, this disclosure provides a method and assembly for inspecting a component without multiple inspection steps, and therefore increases the overall efficiency of the inspection process.

[0049] Although the different examples have the specific components shown in the illustrations, embodiments of this disclosure are not limited to those particular combinations. It is possible to use some of the components or features from one of the examples in combination with features or components from another one of the examples.

[0050] One of ordinary skill in this art would understand that the above-described embodiments are exemplary and non-limiting. That is, modifications of this disclosure would come within the scope of the claims. Accordingly, the following claims should be studied to determine their true scope and content.

CLAIMS

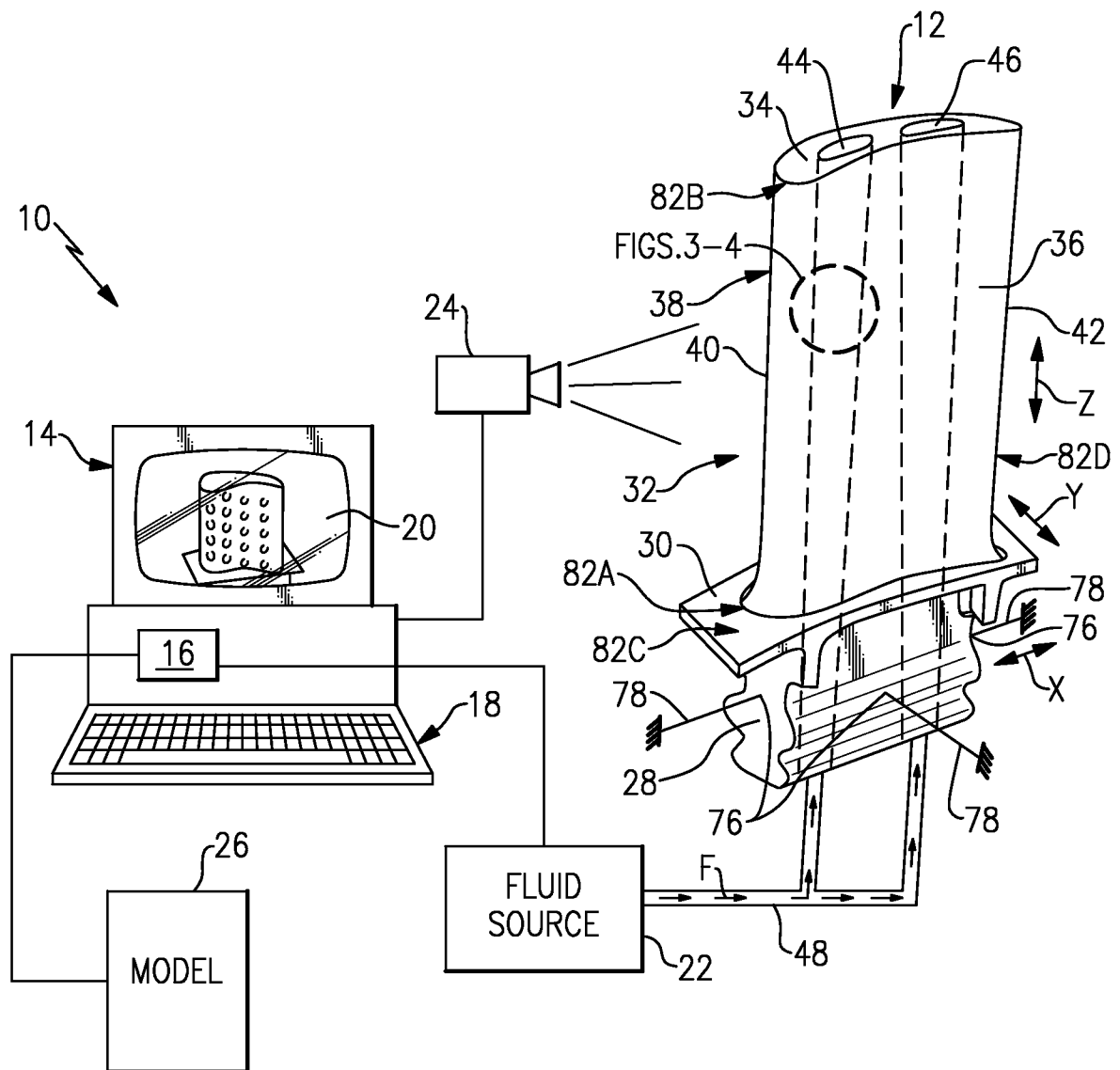
What is claimed is:

1. A method of inspecting a component of a gas turbine engine, comprising:
performing a through-hole inspection; and
determining a location of the plurality of holes from results of the through-hole inspection.
2. The method as recited in claim 1, wherein the through-hole inspection includes a flow thermography process.
3. The method as recited in claim 2, wherein the flow thermography process includes providing a flow of fluid within the component and taking a thermal image of the plurality of holes as the fluid exits the plurality of holes.
4. The method as recited in claim 3, wherein taking the thermal image includes taking a thermal video of the fluid exiting the plurality of holes.
5. The method as recited in claim 1, wherein the results of the through-hole inspection include a plurality pixels, and wherein a blockage is identified when a number of pixels within an acceptable hole location is below a minimum threshold.
6. The method as recited in claim 5, wherein a hole is determined to not be blocked if a number of pixels is greater than or equal to a minimum threshold within the acceptable hole location.

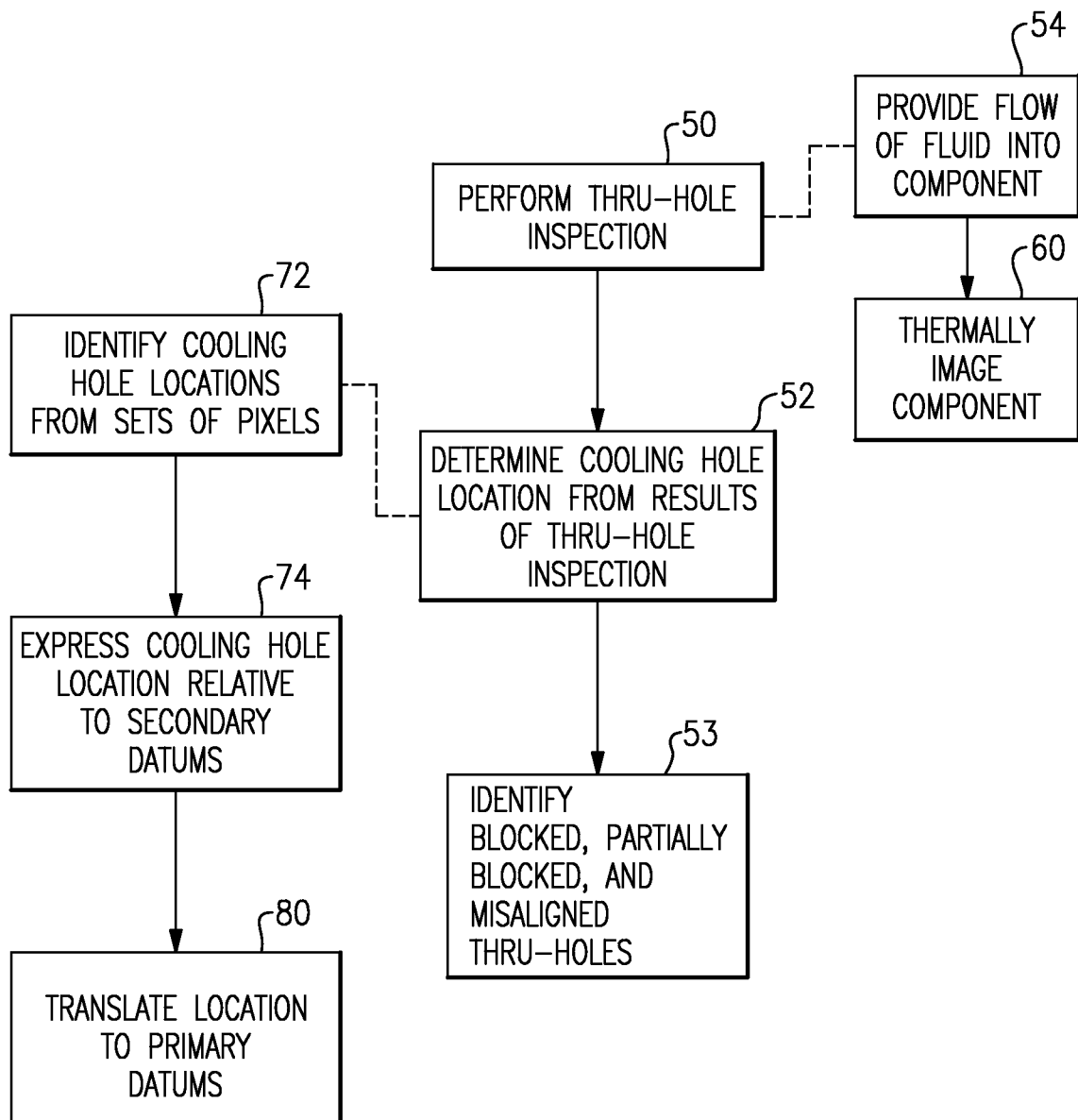
7. The method as recited in claim 1, wherein a misaligned hole is identified if the determined hole location is outside an acceptable hole location.
8. The method as recited in claim 7, wherein the results of the through-hole inspection include a plurality of sets of pixels, each of the sets of pixels corresponding to one of the plurality of holes.
9. The method as recited in claim 8, wherein the determined location of each of the plurality of holes is a centroid of a corresponding one of the plurality of sets of pixels.
10. The method as recited in claim 8, wherein the determined location of each of the plurality of holes is a pixel on a perimeter of a corresponding one of the plurality of sets of pixels.
11. The method as recited in claim 7, wherein the determined location of the plurality of holes is expressed relative to secondary datums.
12. The method as recited in claim 11, wherein the determined location of the plurality of holes is translated from being expressed in terms of secondary datums to being expressed in terms of primary datums.
13. The method as recited in claim 12, wherein the component is an airfoil including an airfoil section and a root, the secondary datums located on the root, and the primary datums located on the airfoil section.

14. An inspection assembly, comprising:
 - a thermal imaging camera;
 - a fixture for supporting an engine component;
 - a fluid source in communication with a passageway of the engine component; and
 - a controller configured to perform a through-hole inspection on the component, and configured to determine a location of the plurality of holes from results of the through-hole inspection.
15. The assembly as recited in claim 14, including a conduit connecting the fluid source to the passageway.
16. The assembly as recited in claim 14, wherein the controller is configured to identify blocked and partially blocked holes by comparing a number of pixels within an acceptable hole location with a minimum threshold.
17. The assembly as recited in claim 14, wherein the controller compares the determined hole locations for each of the plurality of holes with acceptable hole locations to identify misaligned holes.
18. The assembly as recited in claim 14, wherein the controller is in communication with a model, the model including a minimum pixel threshold and acceptable hole locations.
19. The assembly as recited in claim 14, wherein the fixture supports the engine component at a root of the engine component.

1/3

**FIG. 1**

2/3

**FIG.2**

3/3

FIG.3

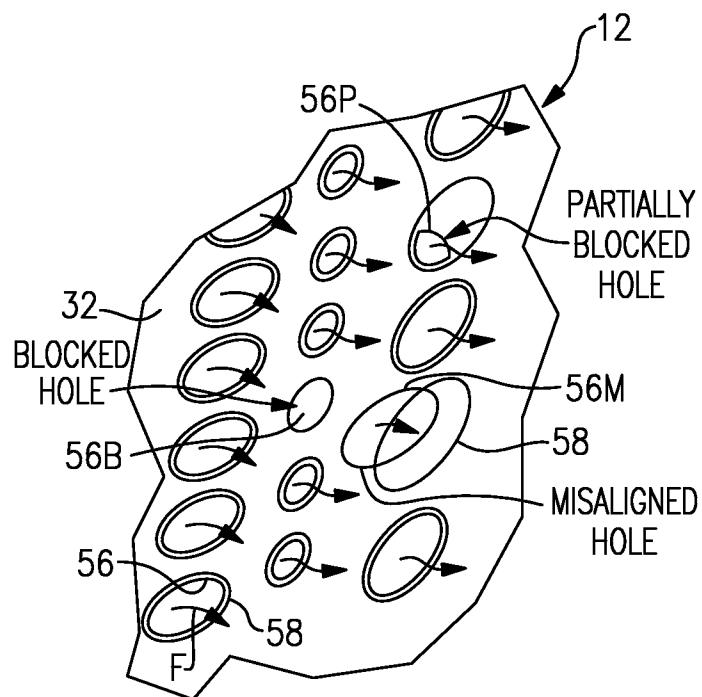
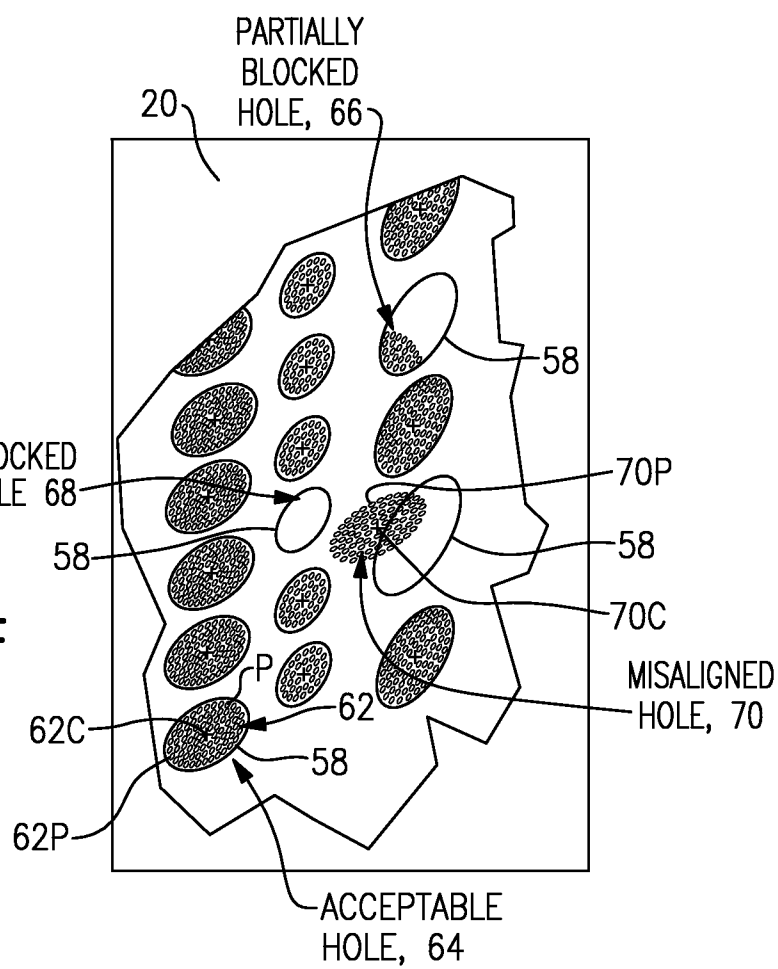


FIG.4



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/061064**A. CLASSIFICATION OF SUBJECT MATTER****G01N 21/88(2006.01)i, G01N 21/952(2006.01)i, G01J 5/48(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G01N 21/88; G01D 18/00; H04N 7/18; G01K 13/00; G01K 1/08; G01J 5/02; G02F 1/01; G01K 3/00; G01N 21/952; G01J 5/48

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & keywords: engine, inspection, thermography, pixel, block, hole and fluid

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011-0235672 A1 (SHEPARD et al.) 29 September 2011 See abstract, paragraphs [0064]-[0076], [0100]-[0125], claims 1, 26, 35 and figures 1-20.	1-19
A	US 2004-0101023 A1 (CHOI, SUKHWAN) 27 May 2004 See abstract, paragraphs [0013]-[0018], claims 1-5 and figures 1-5.	1-19
A	US 2007-0290134 A1 (KEY et al.) 20 December 2007 See abstract, paragraphs [0020]-[0024], claims 1-6 and figures 1-7.	1-19
A	US 2012-0154570 A1 (BUNKER et al.) 21 June 2012 See abstract, paragraphs [0012]-[0023], claims 1-13 and figures 1, 2.	1-19
A	US 2010-0224772 A1 (LEMIEUX et al.) 09 September 2010 See abstract, paragraphs [0015]-[0020], claims 1-5 and figures 1-4.	1-19



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

27 January 2015 (27.01.2015)

Date of mailing of the international search report

27 January 2015 (27.01.2015)

Name and mailing address of the ISA/KR

International Application Division
Korean Intellectual Property Office
189 Cheongsu-ro, Seo-gu, Daejeon Metropolitan City, 302-701,
Republic of Korea

Facsimile No. ++82 42 472 3473

Authorized officer

LEE, Hun Gil

Telephone No. +82-42-481-8525



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/061064

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2011-0235672 A1	29/09/2011	CN 103460000 A EP 2547995 A2 JP 05480997 B2 JP 2013-535000 A US 8287183 B2 WO 2011-156040 A2 WO 2011-156040 A3	18/12/2013 23/01/2013 23/04/2014 09/09/2013 16/10/2012 15/12/2011 27/03/2014
US 2004-0101023 A1	27/05/2004	US 6796709 B2	28/09/2004
US 2007-0290134 A1	20/12/2007	US 2008-0237466 A1 US 2009-0206261 A1 US 7388204 B2 US 7671338 B2 US 7791025 B2 WO 2007-067601 A2 WO 2007-067601 A3	02/10/2008 20/08/2009 17/06/2008 02/03/2010 07/09/2010 14/06/2007 22/05/2008
US 2012-0154570 A1	21/06/2012	CA 2760120 A1 EP 2466069 A1 JP 2012-127959 A US 8810644 B2	15/06/2012 20/06/2012 05/07/2012 19/08/2014
US 2010-0224772 A1	09/09/2010	US 8063372 B2	22/11/2011