(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
21 April 2022 (21.04.2022)

WIPO | PCT

(10) International Publication Number
WO 2022/077124 A1

(51) International Patent Classification:
G01N 21/954 (2006.01) *G02B 23/24* (2006.01)
B23C 3/00 (2006.01)

(21) International Application Number:
PCT/CA2021/051461

(22) International Filing Date:
18 October 2021 (18.10.2021)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
63/092,678 16 October 2020 (16.10.2020) US

(71) Applicant: **MAGNA INTERNATIONAL INC.** [CA/CA]; 337 Magna Drive, Aurora, Ontario L4G 7K1 (CA).

(72) Inventors: **DENIJS, Eric**; 187 Ontario Street, Toronto, Ontario M5A 2V6 (CA). **PENNER, Pavlo**; 238 Baronwood Crt., Brampton, Ontario L6V 3H9 (CA). **HENRI, Patrick**; 2921 Beachview Street, Ajax, Ontario L1S 1C9 (CA). **DEMELO, Jeff**; 42 Commonwealth Road, Barrie, Ontario L4M 0E1 (CA). **BONELLO, Mark**; 15 Mount Forest Drive, Brampton, Ontario L6Z 1W8 (CA).

(74) Agent: **TISDALL, Grant** et al.; GOWLING WLG (CANADA) LLP, Suite 1600, 1 First Canadian Place, 100 King Street West, Toronto, Ontario M5X 1G5 (CA).

(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, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, IT, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO,

(54) **Title:** TESTING OF WELD JOINTS

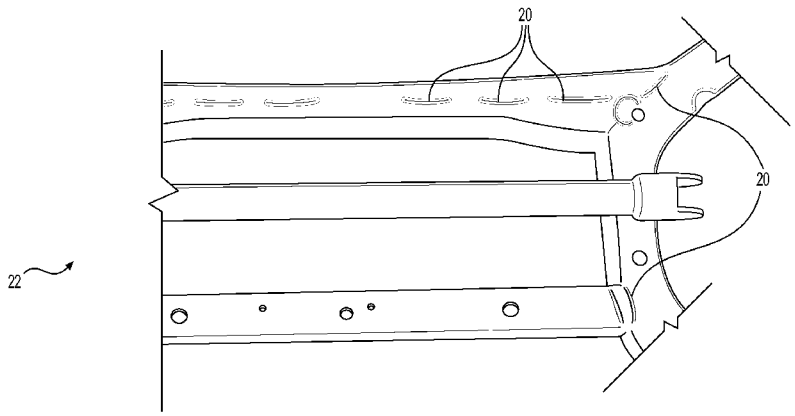


FIG. 1

(57) **Abstract:** A method of testing a weld joint includes: preparing a part that includes at least one weld joint which joins at least two metal components with one another; machining at least one hole in the at least one weld joint; inserting, into the at least one port hole, a probe that includes a mirror attached to a camera; and reflecting an image of the weld joint off of the mirror and to the camera while the probe is inserted into the at least one port hole. A method of analyzing a weld joint includes: machining a port hole in the weld joint; etching the weld joint; inserting a probe into the port hole, the probe including a mirror; reflecting an image of the weld joint off of the mirror towards a camera; capturing the image with the camera; and analyzing the weld joint using the image captured by the camera.

WO 2022/077124 A1

[Continued on next page]

NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, 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))*

— *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

TESTING OF WELD JOINTS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This PCT International Patent Application claims the benefit of and priority to U.S. Provisional Patent Application Serial No. 63/092,678, filed October 16, 2020, titled "Testing Of Weld Joints," the entire disclosure of which is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention is related generally to a process of testing weld joints.

2. Related Art

[0002] When manufacturing large volumes of automotive parts, it is often necessary to periodically conduct destructive testing of weld joints to ensure that those weld joints meet strength and durability requirements. One known process of testing weld joints involves plasma cutting the welded product into smaller pieces then abrasive saw cutting each weld joint and extracting a coupon of the weld joint and analyzing that coupon in a laboratory setting. This process can be very resource and time consuming. For example, it may take multiple days from the time the coupon is cut out of the weld joint until the analysis of the coupon is completed. Such a long turn-around time can may require the part manufacturer to store multiple days' worth of inventory until the verification is completed before shipping it to a customer.

[0003] There is a continuing need for an improved weld verification process which is less time and labor consuming.

SUMMARY OF THE INVENTION

[0004] The present disclosure provides a method of testing a weld joint. The method includes: preparing a part that includes at least one weld joint which joins at least two metal components with one another; machining at least one hole in the at least one weld joint; inserting, into the at least one port hole, a probe that includes a mirror attached to a camera; and reflecting an image of the weld joint off of the mirror and to the camera while the probe is inserted into the at least one port hole.

[0005] The present disclosure provides a method of analyzing a weld joint. The method includes: machining a port hole in the weld joint; etching the weld joint; inserting a probe into the port hole, the probe including a mirror; reflecting an image of the weld joint off of the mirror and towards a camera; capturing the image with the camera; and analyzing the weld joint using the image captured by the camera.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] These and other features and advantages of the invention will become more readily appreciated when considered in connection with the following description of the presently preferred embodiments, appended claims and accompanying drawings, in which:

[0007] Figure 1 is a top elevation view of an exemplary embodiment of a vehicle subframe that includes a plurality of weld joints;

[0008] Figure 2 is an enlarged view of a portion of the subframe of Figure 1;

[0009] Figure 3 is an image taken of a cross-section of one of the weld joints of the subframe of Figure 1;

[0010] Figure 4 illustrates a CNC milling machine forming a plurality of port holes into the subframe of Figure 1;

[0011] Figure 5 shows a portable microscope being used to capture one or more images of one of the weld joints through a port hole formed into the subframe of Figure 1;

[0012] Figure 6 also shows the portable microscope being used to capture images of a weld joint and also schematically illustrates the structure of a probe that is fixedly attached with the portable microscope;

[0013] Figure 7 shows a cross-sectional diagram of the portable microscope;

[0014] Figure 8 illustrates an etching operation being conducted on one of the port holes of the subframe of Figure 1; and

[0015] Figure 9 is a flow chart illustrating the steps of an exemplary embodiment of a process for analyzing a weld joint.

DESCRIPTION OF THE ENABLING EMBODIMENT

[0016] Referring to the Figures, wherein like numerals indicate corresponding parts throughout the several views, the present invention is related generally to the inspection of weld joints **20** such as the weld joints **20** on the vehicle subframe **22** shown in Figure 1. While the exemplary embodiment shows a vehicle subframe **22**, the part with the weld joints **20** to be analyzed could be a wide range of different automotive or non-automotive components and may be made of any suitable type of material for example, various steels, alloy steels, aluminum alloys, etc.). The weld joints **22** may be formed through any suitable type of welding operation (for example, gas metal arc welding [GMAW or MIG], tungsten inert gas [TIG] welding, laser welding, etc.). The part may also have any suitable number of weld joints **20** to be analyzed.

[0017] Figure 9 is a flow chart depicting the steps of an example method of analyzing a weld joint **20**, such as any one or more of the weld joints **20** found on the subframe **22** shown in Figures 1-8. At step **800**, a visual inspection is conducted on the weld joint **20** to look for visible

problems with the weld joint **20**. The visual inspection may be performed either automatically using a camera or some other imaging device or it may be performed manually.

[0018] At step **802**, a plurality of port holes **24** are automatically machined into at least the part using an automated machining means, such as the computer numerical control (CNC) milling machine **26** shown in Figure 4. The CNC milling machine **26** is pre-programmed to automatically machine the port holes **24** at specific locations that correspond with the weld joints **20** to be analyzed. Each port hole **24** extends all the way through the respective weld joint **20** so that the full thickness of the weld joint **20** can be analyzed. In the exemplary embodiment, each port hole **24** is generally square in shape and measures approximately 25 mm X 25 mm. After each port hole **24** is formed into the weld joint **20**, a tool on the CNC milling machine **26** is changed, and the CNC milling machine **26** makes a final finishing pass at a slow speed than what was used to initially form the port hole **24**. This finishing process improves a surface finish of an inner surface of the port hole **24**.

[0019] At step **804**, the inner surface of the port hole **24** is automatically grinded and polished to further improve the surface finish of the inner surface of the port hole **24**. Step **804** may be performed by the aforementioned CNC milling machine **26** or a different grinding and polishing means. In some embodiments, step **804** may be omitted where step **802** provides a satisfactory surface finish for analyzing the weld joint **20**.

[0020] At step **806**, a portion of the inner surface the port hole **24** is etched to increase contrast between a weld joint **20** and a base metal so that weld dimensions can be measured. In the exemplary embodiment, the etching process involves soaking a cotton swab **28** in Nital (a mixture of ethanol and nitric acid) and applying the Nital in a localized portion of the inner surface of the port hole **24**. In other words, the Nital is not applied to the entire inner surface of

the port hole **24**. The use of the cotton swab **28** has been found to minimize the amount of Nital necessary to sufficiently etch the weld joint **20**.

[0021] At step **808**, a probe **30** of a portable microscope **32** is inserted into the port hole **24**, and one or more images of the inner surface of the port hole **24** is/are captured for analysis. In the exemplary embodiment, the probe **30** includes a mirror **34** which is angled at a forty-five degree (45°) angle relative to a lens of the microscope **32** and faces an opening in the probe **30**. In operation, the opening in the probe **30** is pointed at the portions of the inner surface of the port hole **24** to be analyzed. The mirror **34** reflects an image of the inner surface of the port hole **24** by ninety degrees (90°) to the microscope **32**, thereby allowing to take an image of a weld section through a small port hole **24** that is smaller than a size of the microscope **32** when imaging the weld joint **20**. The mirror allows the lens of the microscope **32** to remain parallel to the welded surface of the part **22**. In some embodiments, the microscope **32** is linked with a computer **40** via an USB cable. The computer **40** may display images **42**, provided from the microscope **32**. The computer **40** may provide a live video feed of the images from the microscope **32**. Alternatively or additionally, still images may be displayed. Other wired or wireless data transmission means may be employed to transmit the images from the microscope **32** to any device which will allow a user to analyze the images, e.g., a computer, a tablet, etc. In some embodiments, the images **42**, which may include video and/or still images, may be stored for future use. At step **810**, measurement is taken of the weld joint **20** using one or more of the images. At step **812**, the results of the analysis are reported. In the exemplary embodiment, the probe **30** is made through a 3D printing operation. However, other manufacturing means may alternately be employed.

[0022] The entire process discussed above takes substantially less time and resources than other known destructive weld analysis procedures with no drawbacks. This may significantly reduce the amount of parts that must be held by a part manufacturer prior to shipping those parts to a customer, thereby providing savings to the part manufacturer.

[0023] Obviously, many modifications and variations of the present invention are possible in light of the above teachings and may be practiced otherwise than as specifically described while within the scope of the appended claims. Additionally, it is to be understood that all features of all claims and all embodiments can be combined with each other as long as they do not contradict each other.

CLAIMS

What is claimed is:

Claim 1. A method of testing a weld joint, comprising:

preparing a part that includes at least one weld joint which joins at least two metal components with one another;

machining at least one hole in the at least one weld joint;

inserting, into the at least one port hole, a probe that includes a mirror attached to a camera; and

reflecting an image of the weld joint off of the mirror and to the camera while the probe is inserted into the at least one port hole.

Claim 2. The method as set forth in claim 1, further including etching an inner surface of the at least one port hole prior to inserting the probe into the at least one port hole.

Claim 3. The method as set forth in claim 2, wherein etching the inner surface of the at least one port hole includes applying Nital to the inner surface.

Claim 4. The method as set forth in claim 3, wherein the Nital is applied to the inner surface of the at least one port hole using a cotton swab.

Claim 5. The method as set forth in claim 3, wherein the Nital is applied to only a portion of the inner surface of the at least one port hole.

Claim 6. The method as set forth in claim 1, wherein machining the at least one port hole in the at least one weld joint involves the use of a first tool to initially form the at least one port hole and the use of a second tool to perform a finishing pass around the at least one port hole to improve a surface finish of an inner surface of the port hole.

Claim 7. The method as set forth in claim 1, wherein the step of machining the at least one port hole in the at least one weld joint is using a computer numerical control (CNC) milling machine.

Claim 8. The method as set forth in claim 7, wherein the step of machining at least one port hole in the at least one weld joint further includes machining a plurality of port holes into a plurality of weld joints.

Claim 9. The method as set forth in claim 1, wherein the probe has a sidewall with an opening and wherein the mirror faces the opening and is angled relative to the camera such that, in use, the image enters the probe through the opening and is reflected off the mirror towards the camera.

Claim 10. A method of analyzing a weld joint, comprising:

machining a port hole in the weld joint;

etching the weld joint;

inserting a probe into the port hole, the probe including a mirror;

reflecting an image of the weld joint off of the mirror towards a camera;

capturing the image with the camera; and

analyzing the weld joint using the image captured by the camera.

Claim 11. The method as set forth in claim 10, wherein etching the weld joint includes applying Nital to the weld joint that is exposed at the port hole.

Claim 12. The method as set forth in claim 10, wherein etching the weld joint includes etching at least a portion of the inner surface of the at least one port hole.

Claim 13. The method as set forth in claim 12, wherein the at least a portion of the inner surface of the at least one port hole includes an entirety of the inner surface of the at least one port hole.

Claim 14. The method as set forth in claim 10, wherein machining the port hole in the weld joint further includes machining a plurality of port holes into a plurality of weld joints.

Claim 15. The method as set forth in claim 10, wherein the step of machining the port hole in the weld joint further includes machining the port hole using a computer numerical control (CNC) milling machine.

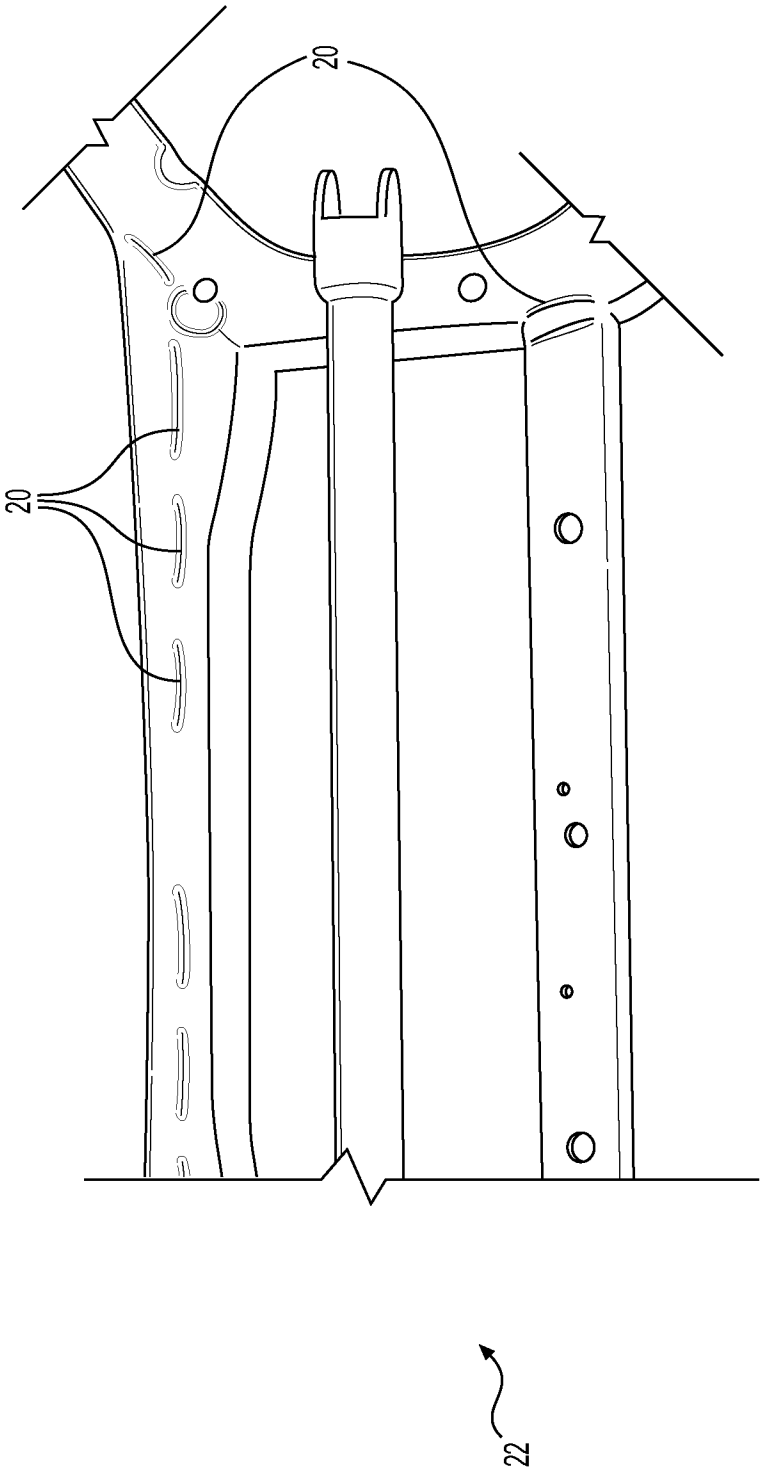


FIG. 1

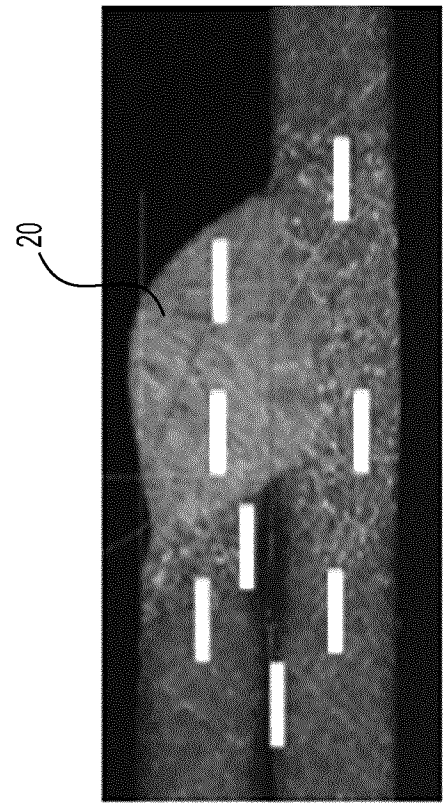


FIG. 3

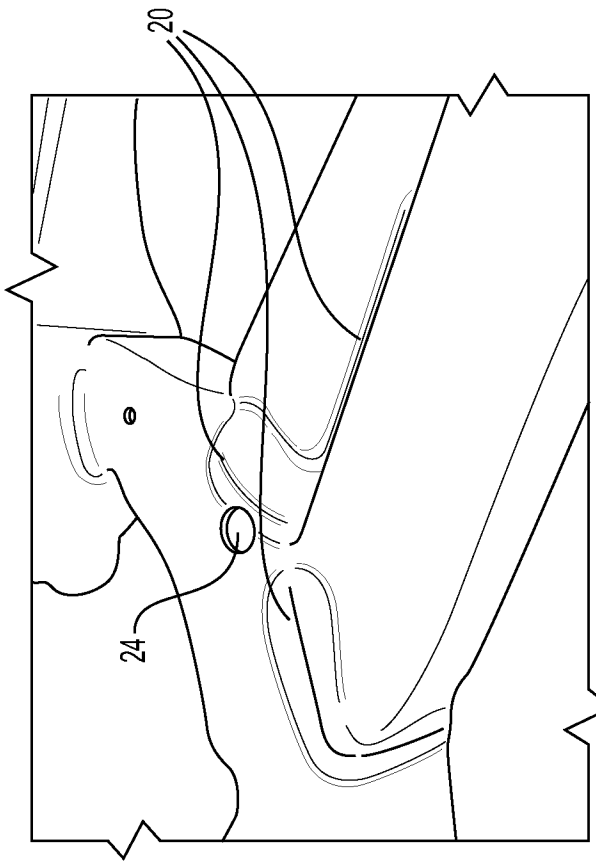


FIG. 2

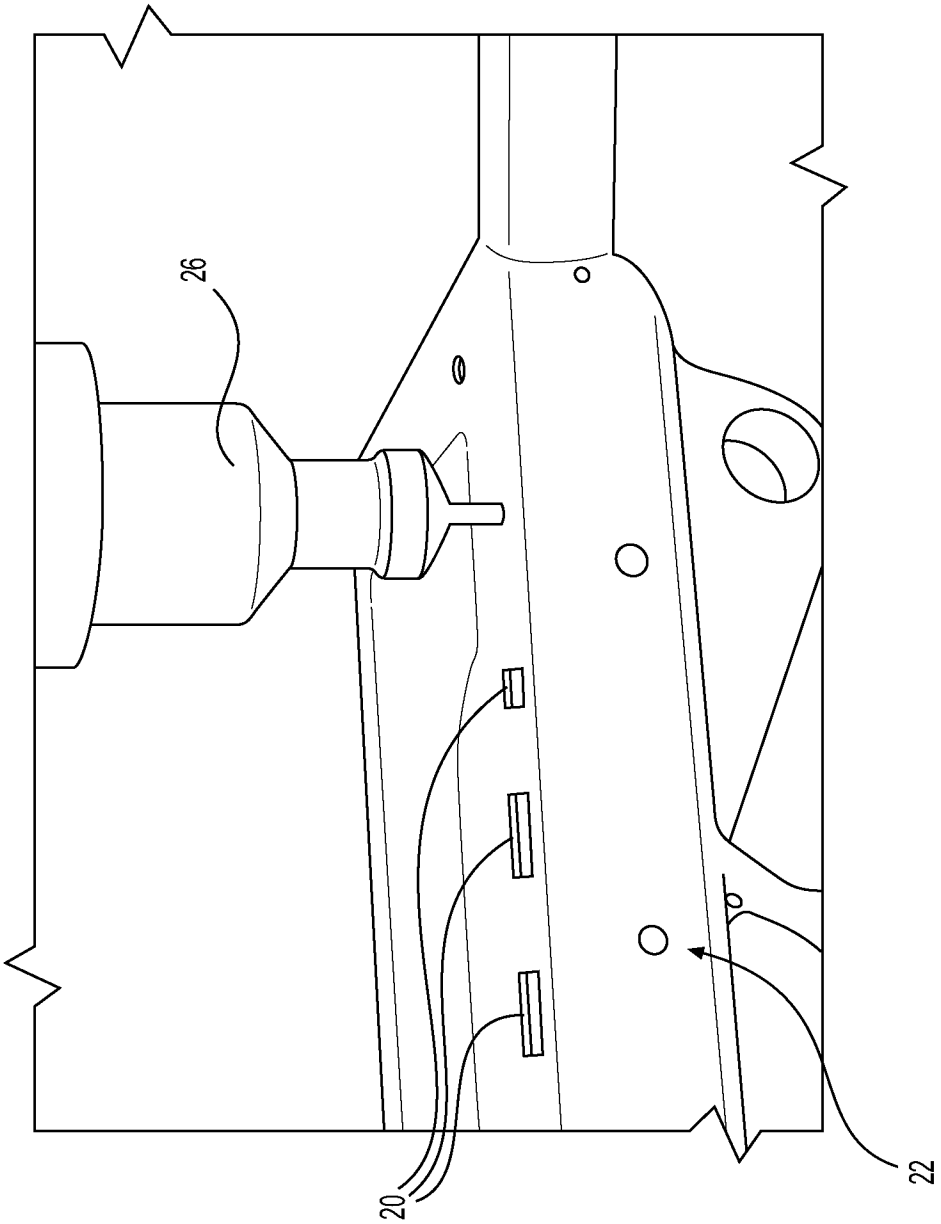


FIG. 4

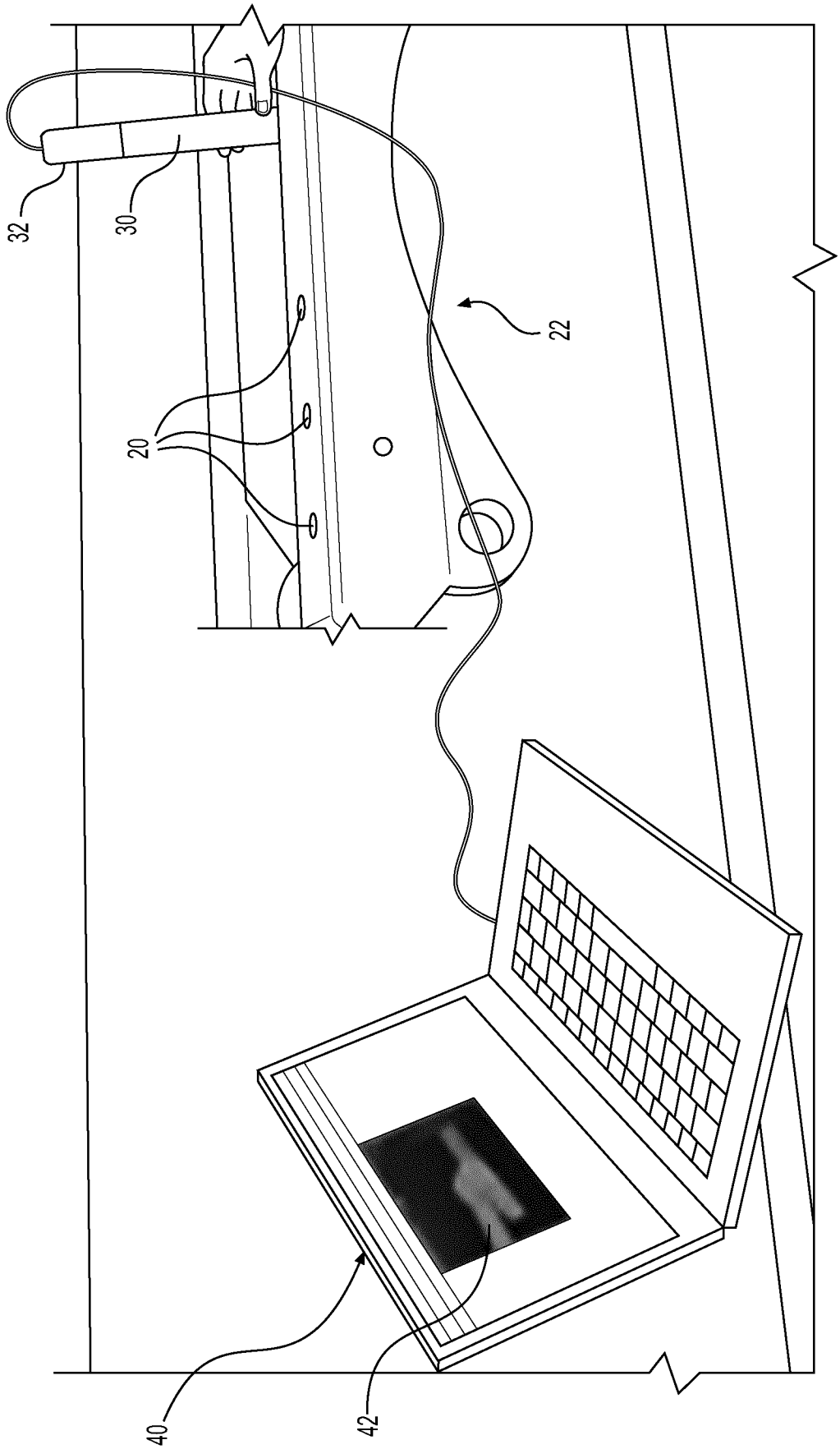


FIG. 5

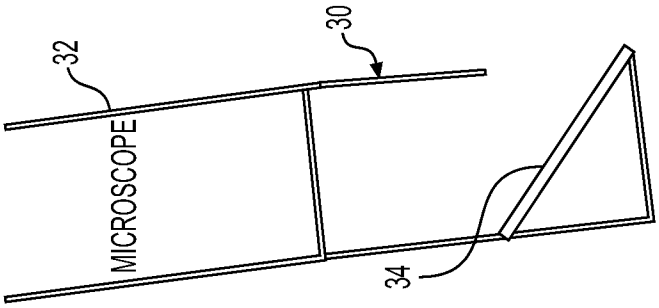


FIG. 7

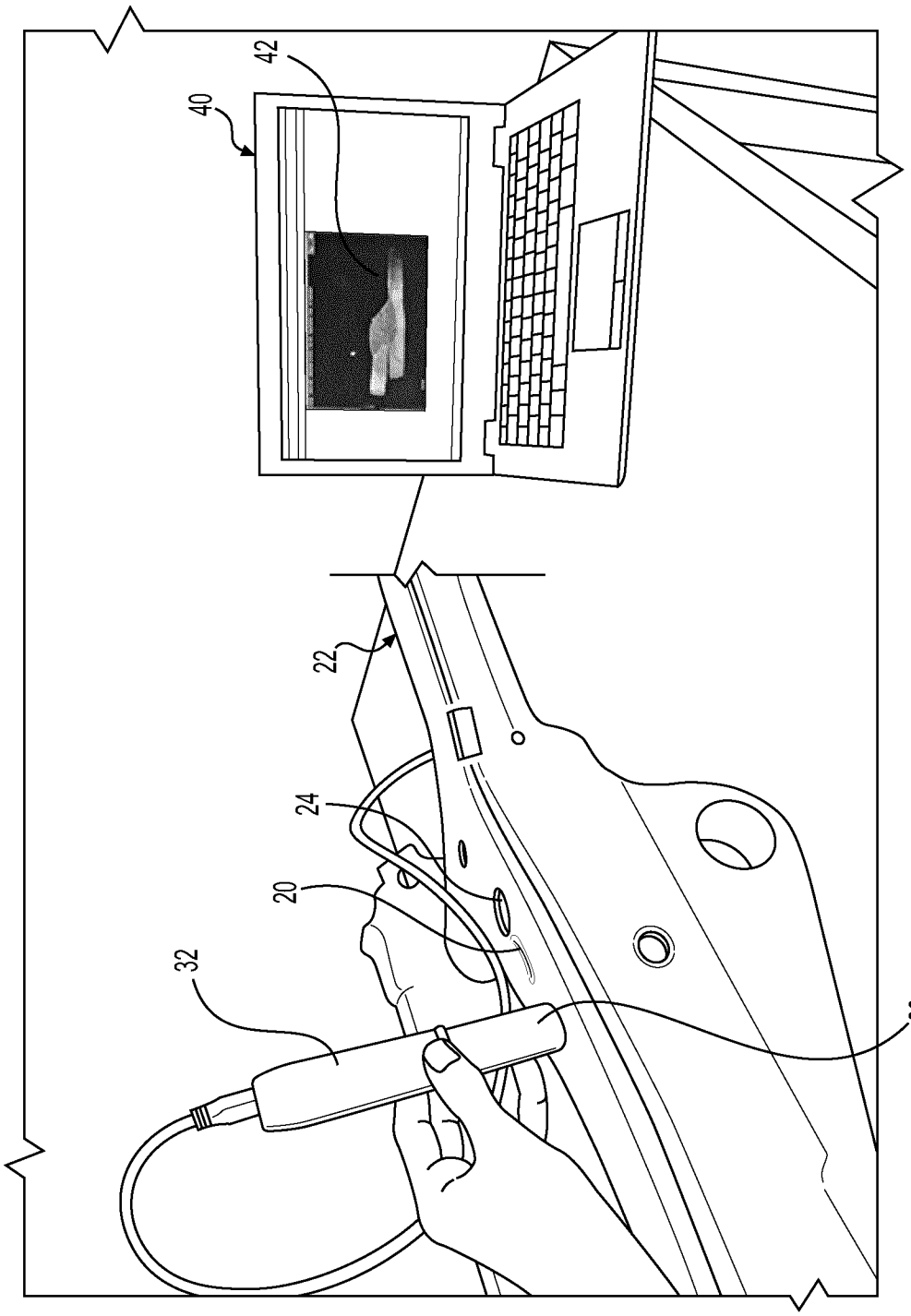


FIG. 6

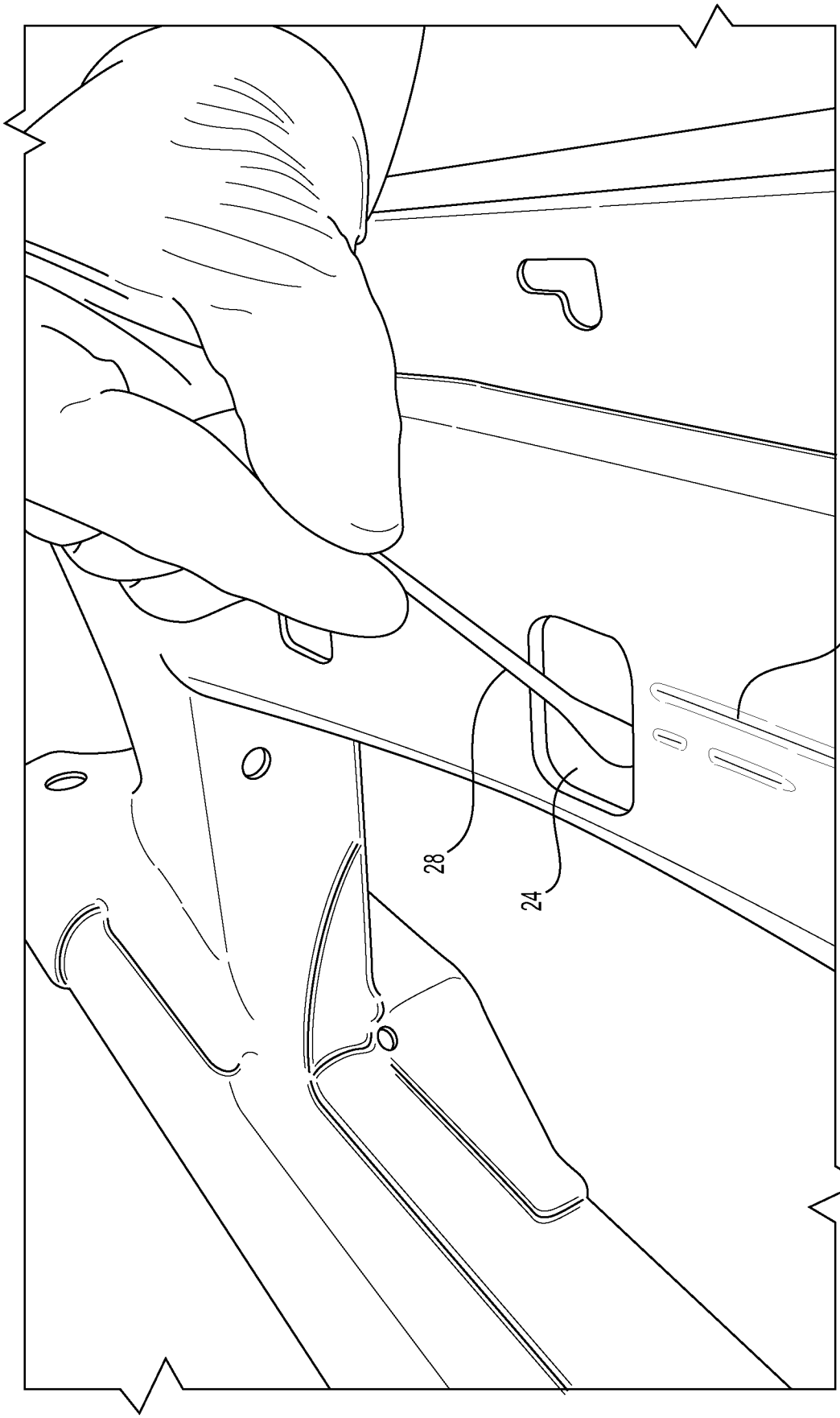


FIG. 8

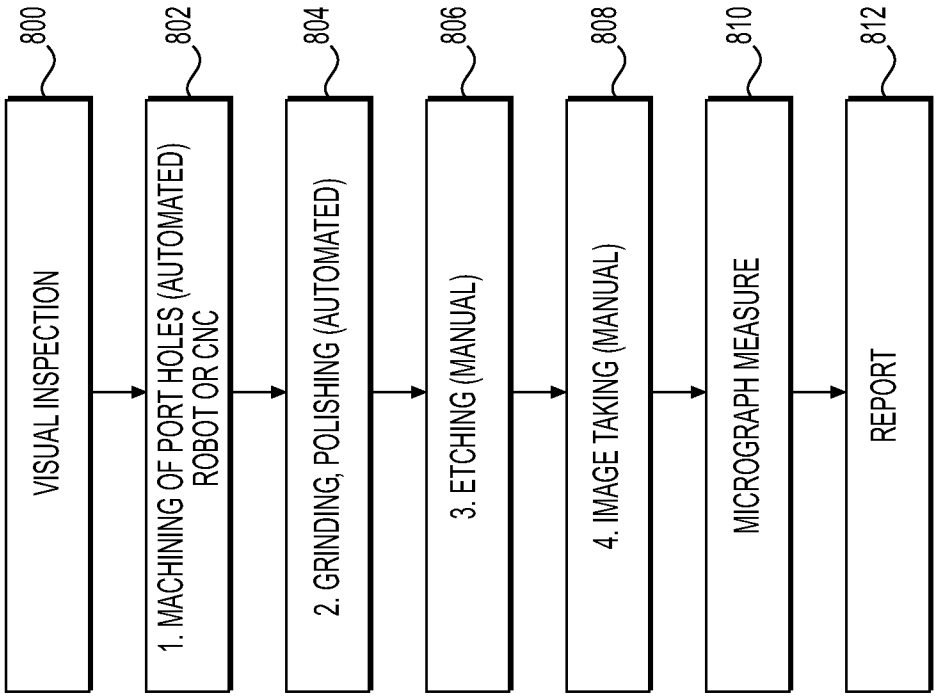

800
VISUAL INSPECTION
802
1. MACHINING OF PORT HOLES (AUTOMATED) ROBOT OR CNC
804
2. GRINDING, POLISHING (AUTOMATED)
806
3. ETCHING (MANUAL)
808
4. IMAGE TAKING (MANUAL)
810
MICROGRAPH MEASURE
812
REPORT

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2021/051461

A. CLASSIFICATION OF SUBJECT MATTER

IPC: ***G01N 21/954*** (2006.01) , ***B23C 3/00*** (2006.01) , ***G02B 23/24*** (2006.01)

CPC:

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)
IPC: ***G01N*** (2006.01) , ***B23C*** (2006.01) , ***G02B*** (2006.01) (using keywords)

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

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

Canadian Patent Database, Google, Questel Orbit, United States Patent Database (USPTO).
Keywords: camera, etching, hole, image, machining, mirror, reflect, weld joint.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 20180001422 A1 (Rajagopalan et al.) 04 January 2018 (04-01-2018) - Abstract - Paragraphs [0006]-[0008] - Paragraphs [0062]-[0063], [0066] - Paragraphs [0103]-[0105], [0124], [0128]-[0129] - Paragraphs [0144] - Paragraphs [0172]-[0179], [0196] - Paragraphs [0212], [0228]	1-15

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

*	Special categories of cited documents:	"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
"A"	document defining the general state of the art which is not considered to be of particular relevance	"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
"D"	document cited by the applicant in the international application	"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
"E"	earlier application or patent but published on or after the international filing date	"&"	document member of the same patent family
"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		

Date of the actual completion of the international search	Date of mailing of the international search report
29 December 2021 (29-12-2021)	29 December 2021 (29-12-2021)

Name and mailing address of the ISA/CA	Authorized officer
Canadian Intellectual Property Office Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street Gatineau, Quebec K1A 0C9 Facsimile No.: 819-953-2476	Tung Nguyen (819) 639-8246

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO2020000083 A1 (Gu et al.) 02 January 2020 (02-01-2020) - See entire document	1-15
A	US9501821 B2 (Pfitzner et al.) 22 November 2016 (22-11-2016) - See entire document	1-15
A	JP2010002459 A (Yokoyama et al.) 07 January 2010 (07-01-2010) - See entire document	1-15
A	US20180147647 A1 (Wang et al.) 31 May 2018 (31-05-2018) - See entire document	1-15
A	JP 4182589 B2 (Horikoshi) 19 November 2008 (19-11-2008) - See entire document	1-15

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CA2021/051461

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
US2018001422A1	04 January 2018 (04-01-2018)	AU2017314295A1	17 January 2019 (17-01-2019)
		BR112018006177A2	21 January 2020 (21-01-2020)
		CA2995952A1	23 December 2018 (23-12-2018)
		CN109429490A	05 March 2019 (05-03-2019)
		EP3641974A1	29 April 2020 (29-04-2020)
		EP3641974A4	31 March 2021 (31-03-2021)
		MX2018002790A	04 April 2019 (04-04-2019)
		RU2018120317A	03 December 2019 (03-12-2019)
		RU2018120317A3	05 October 2020 (05-10-2020)
		RU2750760C2	02 July 2021 (02-07-2021)
		WO2018002907A2	04 January 2018 (04-01-2018)
		WO2018002907A3	08 February 2018 (08-02-2018)
		WO2018002907A8	05 April 2018 (05-04-2018)
		WO2018236407A1	27 December 2018 (27-12-2018)
		ZA201800734B	31 March 2021 (31-03-2021)
		ZA201903996B	26 May 2021 (26-05-2021)
WO2020000083A1	02 January 2020 (02-01-2020)	CA3104899A1	02 January 2020 (02-01-2020)
		CN112368105A	12 February 2021 (12-02-2021)
		EP3814045A1	05 May 2021 (05-05-2021)
		US2021078106A1	18 March 2021 (18-03-2021)
US9501821B2	22 November 2016 (22-11-2016)	US2014175071A1	26 June 2014 (26-06-2014)
		CN103857490A	11 June 2014 (11-06-2014)
		CN103857490B	20 January 2016 (20-01-2016)
		DE102011078276B3	06 December 2012 (06-12-2012)
		DE102011078276C5	03 April 2014 (03-04-2014)
		EP2726244A1	07 May 2014 (07-05-2014)
		EP2726244B1	02 March 2016 (02-03-2016)
		WO2013000622A1	03 January 2013 (03-01-2013)
JP2010002459A	07 January 2010 (07-01-2010)	None	
US2018147647A1	31 May 2018 (31-05-2018)	US10870162B2	22 December 2020 (22-12-2020)
		CN104439620A	25 March 2015 (25-03-2015)
		CN104439620B	13 April 2016 (13-04-2016)
		WO2016090903A1	16 June 2016 (16-06-2016)
JP4182589B2	19 November 2008 (19-11-2008)	None	