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(54) A GAS TURBINE PART COMPRISING A LIFETIME INDICATOR

(57) The invention concerns a gas turbine part (10) comprising a lifetime indicator (30). The lifetime indicator comprises at least one protrusion (32) protruding from a surface (28) of the gas turbine part. The lifetime indicator is configured and arranged to give an indication of the remaining lifetime of the gas turbine part when the gas turbine part is inspected during maintenance. Different types of lifetime indicator and a method of inspecting a gas turbine part including inspection of the lifetime indicator are also described.

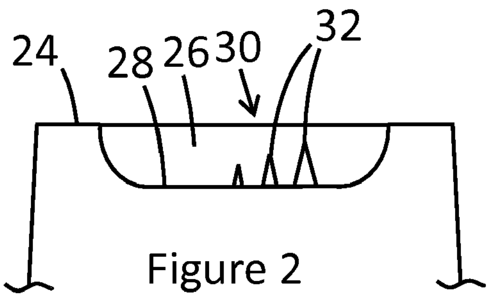

Figure 2

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Description

TECHNICAL FIELD

[0001] The present disclosure relates to gas turbine parts, and particularly to gas turbine parts comprising a lifetime indicator.

BACKGROUND OF THE INVENTION

[0002] In today's gas turbines, various parts are subject to extreme loads and temperatures, and as a result it is necessary to undertake regular gas turbine maintenance to carry out inspection, repairs and replacement of parts.

[0003] For certain parts, it is impractical to ascertain when the part needs to be replaced, and it is therefore common practice to replace these parts based on a fixed schedule, such as after a certain number of hours of use or a certain number of use cycles.

[0004] In some parts, it is possible to see roughly how much remaining lifetime a part has by visual assessment, but this visual assessment is subjective and it is generally necessary to err on the side of caution when replacing parts to avoid part failure.

[0005] In both these scenarios, parts are often replaced significantly earlier than is actually necessary. An improvement in the assessment of remaining lifetime could lead to a reduction of such lifetime waste, which in turn can lead to various benefits such as reductions in cost, service frequency and turbine outage time.

SUMMARY OF THE INVENTION

[0006] The invention is defined in the appended independent claims to which reference should now be made. Advantageous features of the invention are set forth in the dependent claims.

[0007] A first aspect provides a gas turbine part comprising a lifetime indicator comprising at least one protrusion protruding from a surface of the gas turbine part, wherein the lifetime indicator is configured and arranged to give an indication of the remaining lifetime of the gas turbine part when the gas turbine part is inspected during maintenance. This can help improve part lifetime assessment in various gas turbine parts and can help reduce costs associated with unnecessarily early part replacement.

[0008] In one embodiment, the lifetime indicator comprises two or more protrusions. In one embodiment, two or more protrusions are of a different length and/or a different width to one another. In one embodiment, the indication of the remaining lifetime is given by the number of protrusions that remain when the gas turbine part is inspected during maintenance. In one embodiment, the lifetime indicator comprises a protrusion with an indentation. These embodiments, either alone or in combination, can help improve lifetime assessment. An indentation can provide a weakness at which deterioration occurs more quickly when in use, compared to deterioration of another part of the protrusion. The protrusion will normally fail at the point of the indentation first.

[0009] In one embodiment, the lifetime indicator gives an indication of the remaining lifetime based on deterioration due to at least one of creep, oxidation and low cycle fatigue. This can help improve assessment of part deterioration based on these factors.

[0010] In one embodiment, the lifetime indicator protrudes less than 5 mm, less than 3 mm or less than 1 mm from the surface of the gas turbine part.

[0011] In one embodiment, the gas turbine part is made using selective laser melting or casting. This can provide a lifetime indicator of appropriate size and proportions. In one embodiment, the gas turbine part is made as a single integral part.

[0012] In one embodiment, the gas turbine part is a gas turbine blade, a gas turbine vane, a gas turbine heat shield or a gas turbine combustor wall.

[0013] A second aspect provides a gas turbine comprising a gas turbine part as described above.

[0014] A third aspect provides a method of manufacturing a gas turbine part, comprising the step of manufacturing a gas turbine part comprising a lifetime indicator comprising at least one protrusion protruding from a surface of the gas turbine part, wherein the lifetime indicator is configured and arranged to give an indication of the remaining lifetime of the associated gas turbine part when the gas turbine part is inspected during maintenance.

[0015] In one embodiment, the lifetime indicator and the gas turbine part are manufactured together as a single integral part. In one embodiment, the lifetime indicator is manufactured using selective laser melting or casting. This can provide features with the necessary size, shape and tolerances (accuracy of manufacture).

[0016] A fourth aspect provides a method of inspecting a gas turbine part, the gas turbine part comprising a lifetime indicator comprising at least one protrusion protruding from a surface of the gas turbine part, wherein the lifetime indicator is configured and arranged to give an indication of the remaining lifetime of the associated gas turbine part when the gas turbine part is inspected during maintenance, the method comprising the steps of inspecting the lifetime indicator, estimating the remaining lifetime of the part based on the deterioration of the lifetime indicator, and ascertaining whether the gas turbine part needs repair or replacement based on the estimate of the remaining lifetime.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] An embodiment of the invention will now be described by way of example only and with reference to the accompanying drawings in which:

Figure 1 shows a cross-section of a gas turbine blade;

Figure 2 shows a cross-section of the tip of the gas turbine blade of Figure 1 with a lifetime indicator;

Figure 3 shows a cross-section of the tip of the gas turbine blade of Figure 1 with an alternative lifetime indicator;

Figure 4 shows a cross-section of the trailing edge of the gas turbine blade of Figure 1 with a lifetime indicator.

Figures 5A, 5B, 5C, 5D, 5E and 5F show side-view cross-sections through various lifetime indicators; and

Figure 6 shows a perspective view of a fin-shaped lifetime indicator.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0018] Figure 1 shows a gas turbine blade 10 with an aerofoil 12, a platform 14 and a root 16. The aerofoil portion has a leading edge 20, a trailing edge 22 and a tip 24.

[0019] Figure 2 shows the area around the tip 24 of the gas turbine blade 10 in greater detail. In a recess 26 in the tip, a lifetime indicator 30 is arranged. The lifetime indicator protrudes from the surface 28 of the tip. In this embodiment, a lifetime indicator comprising three conical pins 32 of different lengths and different base widths is shown.

[0020] Figure 3 shows an alternative embodiment in which the three pins 32 are of the same length and of different widths. Indentations can be seen in the pins; these indentations are explained in more detail below with reference to Figure 5C.

[0021] Figure 4 shows an alternative embodiment in which two pins 32 of the same length and different widths are attached to the surface of the trailing edge 22 of the blade 10.

[0022] Figures 5A to 5E show examples of lifetime indicators on a cross-section in the x-z plane, where the plane x-y contains a surface 28 to which the lifetime indicator is attached. Each lifetime indicator comprises one or more protrusions, such as pins and/or fins.

[0023] Figure 5A shows three pins 32 with different base widths and different lengths. Each pin 32 extends from a base 40 that is attached to the surface to an end 42 distal from the surface. The pins are truncated cones (frusto-conical) with rounded ends. The number of pins that have deteriorated (for example, the number that has deteriorated completely and therefore disappeared) gives an indication of lifetime.

[0024] Figures 5B shows three pins 32 with the same length, different widths and square ends. In such an example, the pin with the narrowest width (on the left) would disappear first, with the widest pin lasting longest.

[0025] Figure 5C shows two pins 32 with the same length, the same width and indentations 44. The indentations reduce the width for a portion of the length of the pin. The two pins are the same; providing duplicate pins can provide redundancy and/or greater confidence in the lifetime assessment. Providing an indentation in the pin can provide a lifetime indicator that gives an indication of creep, by visible narrowing of the width of the pin at the indentation and/or by the complete failure of the pin at the point of the indentation, resulting in the loss of the part of the pin above the indentation.

[0026] Figure 5D shows another type of protrusion, namely a fin 46. Unlike the pins described above, which generally have the same or a similar width in both the x and y directions (so in a plane parallel to the plane of the surface), the fin extends considerably more in the x direction than in the y direction. The fin contains a hole 48. As the hole provides a point of weakness in the fin, cracks may form between the hole and the end of the fin, which can gived an indication of low cycle fatigue (LCF).

[0027] Figure 5E shows a pin of a somewhat different shape, namely a stepped pyramid shape. Deterioration, either by loss of layers of the pyramid starting with the end 42 and/or by a smoothing of the sharp corners of the pyramid shape, can give an indication of lifetime.

[0028] Figure 5F shows a lifetime indicator combining the principles of the lifetime indicators of Figures 5C and 5E. Two indentations are provided on the same pin along with a graduated overall pin structure (pyramidal in this case). The width of the pin is smaller at the end 42 than at the base 40. One of the indentations is on the wider portion of the pin near the base and the other indentation is on the narrower portion of the pin.

[0029] Figure 6 shows a perspective view of a lifetime indicator made up of a fin rather than a pin, similar to the embodiment in Figure 5D. The fin extends significantly further (e.g. at least 2, 3 or 5 times further) in the y direction compared to in the x direction.

[0030] In a method of manufacturing a lifetime indicator, the lifetime indicator is manufactured as an integral piece of a part, for example using selective laser melting (SLM) or a casting method such as precision casting. The lifetime indicator could also be manufactured separately, for example using casting or SLM, and then attached to a part, for example using brazing or welding.

[0031] A lifetime indicator could be added to an existing part as part of a retrofit or reconditioning method. A lifetime indicator could also be added to an existing part, such as a repaired part, to replace a worn out lifetime indicator. In such a case, it may be appropriate to replace the worn out lifetime indicator with a replacement lifetime indicator that is the same as the original lifetime indicator, or it may be preferable to provide a different lifetime indicator.

[0032] In a method of maintaining a gas turbine, a lifetime indicator can be inspected so as to estimate the remaining lifetime of the part based on the deterioration of the lifetime indicator, and to ascertain whether the gas turbine part needs repair or replacement based on the estimate of the remaining lifetime. In general, the lifetime indicator can be in any location that can be made accessible during maintenance, be it by inspection in situ or by inspection after partially dismantling the gas turbine for inspection. Various methods of inspection could be used, including visual inspection (either direct or indirect, for example using a borescope) or inspection using tools to provide measurements of the deterioration.

[0033] During inspection, deterioration of the lifetime indicator can be assessed in various ways depending on the type of lifetime indicator. Different lifetime indicators will show deterioration in different ways, for example one or more of a reduction in lifetime indicator length, a reduction in lifetime indicator width, a reduction in the number of pins remaining in the lifetime indicator, and cracking of the lifetime indicator.

[0034] A certain level of deterioration can be equated to an estimate of lifetime. For example, in a lifetime indicator with three pins, disappearance of the first, second and third pins may respectively indicate that 25%, 50% and 75% of the lifetime of the part has elapsed. In another example, disappearance of the first, second and third pins may respectively indicate that 65%, 85% and 100% of the lifetime of the part has elapsed. Disappearance of two of the three pins may be an indicator that enough of the lifetime has elapsed, and that part repair or replacement is needed. In a basic example, disappearance (complete deterioration) of the lifetime indicator (perhaps a lifetime indicator with just a single pin) could indicate that the part requires repair or replacement, and the part is not repaired or replaced until the lifetime indicator has disappeared.

[0035] When a lifetime is estimated, the resulting estimated lifetime could be a percentage of the lifetime of the part that has been used or the percentage of the lifetime of the part that remains. Using this, an estimate of the remaining lifetime, which is generally the most useful measure in practical terms, can be provided in terms of variables such as time and/or number of load cycles, based on the amount of time that the part has already been in use and/or the number of load cycles the part has already been subjected to.

[0036] Refinement of the remaining lifetime can also be carried out based on the prior and expected conditions of use. For example, if the part has been subject to a large number of load cycles or a long period of sustained use at low load operation, but the part is subsequently used in a period of sustained full load operation, the remaining lifetime of the part may be adjusted to account for the difference in operating conditions.

[0037] The determination of the level of lifetime indicator deterioration that corresponds to a given lifetime would generally be carried out during a development phase, for example by testing and/or by using computer modelling. For example, data on parameters such as oxidation, creep and cycle fatigue could be useful during this calibration.

[0038] The estimate of the remaining lifetime can then be used to ascertain whether the gas turbine part needs repair or replacement. Based on this, a decision can be made as to whether (and when) a part should be replaced or repaired. For example, upon deterioration of the lifetime indicator to a certain level, it could either be necessary to immediately repair or replace the part, or it could be ascertained that the part needs to be repaired or replaced after a certain amount of subsequent use, for example a number of hours of further use or a number of further load cycles.

[0039] The embodiments shown above describe lifetime indicators on the tip and the aerofoil trailing edge of a gas turbine blade. Lifetime indicators can also be placed in various other locations on a gas turbine blade, such as elsewhere on the aerofoil or on the platform, for example on the platform trailing edge. Lifetime indicators could also be used in various other places in a gas turbine. A gas turbine comprises a compressor, a combustor downstream of the compressor and a turbine downstream of the compressor. Possible locations for lifetime indicators in a gas turbine include on a rotor cover, on a gas turbine combustor wall, and on a heat shield, for example a turbine heat shield adjacent to a blade root or a vane root. Locations without a thermal barrier coating may be preferable. In general, lifetime indicators could be useful in many locations where conditions in the gas turbine lead to deterioration, particularly in locations subject to high temperatures or corrosive environments, such as in places exposed to hot gases. Lifetime indicators could be particularly useful in lifetime critical areas.

[0040] More than one lifetime indicator (either identical lifetime indicators or different ones) can be placed in the same gas turbine and/or on the same gas turbine part. For example, a gas turbine blade similar to the one in Figure 1 could be provided with the lifetime indicators of Figures 2 and 4, Figures 3 and 4 or even Figures 2, 3 and 4. Providing multiple lifetime indicators can provide redundancy (providing multiple measurements for the same part), extra information on lifetime (indicating whether one area is deteriorating more rapidly than another), and/or indications regarding more than one type of deterioration (for example creep and oxidation).

[0041] Generally, the lifetime indicator is made of the same material as gas turbine part to which it is attached, although part or all of the lifetime indicator could also be made of a different material to the gas turbine part.

[0042] As described above, a lifetime indicator can give an indication of the level of deterioration based on one or more deterioration factors such as oxidation, low cycle fatigue or creep. For example, the lifetime indicator shown in Figure 5A or 5B might give an indication of lifetime based primarily on oxidation, whereas the lifetime indicator in Figure 5C might give an indication of lifetime based primarily on creep. Two or more deterioration factors might be relevant in the same lifetime indicator, for example in the lifetime indicator in Figure 3 where both creep and oxidation could be relevant.

[0043] The surface 28 may be planar or substantially planar (such as in Figures 2 and 3) or may be non-planar, such as a curved surface or an irregularly shaped surface. The trailing edge 22 shown in Figure 4, for example, would not normally have a planar surface and would generally be curved (at least in the direction not shown in the cross-section of Figure 4). The surface is generally an external surface of the part; this allows for ease of access during maintenance.

[0044] The lifetime indicator is for estimating the remaining lifetime of the gas turbine part. As such, the lifetime indicator 30 is normally a non-structural element, and is generally placed in a position where it can be accessed for visual inspection during maintenance. This can help with ease of use. The lifetime indicator is normally configured and arranged such that during use of the gas turbine part, the lifetime indicator is subject to the same or substantially the same conditions as the surface of the gas turbine part. If the lifetime indicator were subject to different conditions, then the lifetime indicator would generally deteriorate in a different way or at a different speed, potentially limiting the usefulness of the measurement. One particular consideration in this regard is to ensure that there is clearance between the lifetime indicator and any adjacent parts, as rubbing against an adjacent part would provide very different conditions when compared to a surface of the part that is not rubbing against adjacent components. To achieve this, the lifetime indicator is normally arranged to remain spaced apart from other parts during use, so that the lifetime indicator does not rub on other parts.

[0045] The description above gives a number of examples of lifetime indicators to provide an idea of the various options available. Various combinations and alterations may be made to provide lifetime indicators for different situations. Some of the variables that can be altered are now described.

[0046] The size and shape of lifetime indicator, that is parameters such as the width, length, height, and surface shape, can be varied. For example, protrusions could be cuboid, cylindrical, conical, pyramidal, blade-shaped or another regular or irregular shape. Ends could be square, rounded or pointed. Many other variations in size and shape are possible, with the Figures showing just a few examples. Variations in size (and shape) can help tailor a lifetime indicator to a particular part by varying the length of time that the lifetime indicator lasts; for example, increasing protrusion size to provide a longer-lasting lifetime indicator.

[0047] The difference between adjacent protrusions can be varied. Two or more protrusions (pins or fins) of different thicknesses or lengths can be provided, and multiple identical protrusions can be provided for redundancy. Adjacent protrusions can be spaced apart, or adjacent protrusions can be directly touching one another, at least at the base. The number of protrusions can be varied. In some cases, one protrusion will be sufficient, and the part will be replaced based on when the protrusion deteriorates. In other cases, multiple protrusions are provided (either identical protrusions or different protrusions), and the number of protrusions remaining gives an indication of the level of deterioration. Providing multiple protrusions of varying size, shape or properties can provide better lifetime indication than a single protrusion. Providing multiple identical protrusions (identical within given manufacturing tolerances) can also improve lifetime indication by improving the confidence in the measurements, as even protrusions that are theoretically the same are likely to be somewhat different and to deteriorate at slightly different rates.

[0048] Other features such as indentations and holes can be added; these would generally be features that can incite deterioration. Where indentations are provided, one or more indentations may be provided, either extending part way or all of the way around the protrusion. Indentations could be various shapes, such as graduated indentations (such as the curved shape shown in Figure 5C) or stepwise indentations. Various options are available with holes as well, including various shapes. For example, one or more holes of the same or differing sizes can be provided in a protrusion, such as that shown in Figure 5D, or multiple protrusions can be provided, each with a different sized hole and/or a different depth of hole (in the y direction as shown in Figure 6).

[0049] The lifetime indicator will typically be small relative to the gas turbine and to the part it is attached to. For example, the lifetime indicator will typically protrude less than 5 mm, 3 mm or 1 mm from the surface. Typically, the lifetime indicator will also protrude at least 0.1 mm, 0.5 mm or 1 mm from the surface. In one example, three pins such as those shown in Figure 5A are provided, with heights (distance from base to tip) of 1 mm, 2 mm and 3 mm respectively and widths (in the x and y directions) of 0.3, 0.5 and 0.7 mm respectively. In another example, a pyramid structure like the one shown in Figure 5E is provided, in which the total height is 4 mm, with each step of the pyramid being 1 mm high and 0.5 mm wide and the total width of the pyramid (in the x and y directions) being 4 mm. In another example, a fin is provided extending 2mm from the surface, extending 5 mm in length (x direction) and extending 0.5 mm in width (y direction) with a circular hole 48 of 0.5 mm in diameter (in the x direction).

[0050] Various modifications to the embodiments described are possible and will occur to those skilled in the art without departing from the invention which is defined by the following claims.

REFERENCE NUMERALS

10	gas turbine blade	28	surface
12	aerofoil	30	lifetime indicator
14	platform	32	protrusion
16	root	40	base
20	leading edge	42	end
22	trailing edge	44	indentation
24	tip	46	fin
26	recess	48	hole

LCF low cycle fatigue
SLM selective laser melting

Claims

1. A gas turbine part (10) comprising a lifetime indicator (30) comprising at least one protrusion (32) protruding from a surface (28) of the gas turbine part, wherein the lifetime indicator is configured and arranged to give an indication of the remaining lifetime of the gas turbine part when the gas turbine part is inspected during maintenance.

2. The gas turbine part of claim 1, wherein the lifetime indicator comprises two or more protrusions.

3. The gas turbine part of claim 2, wherein the two or more protrusions are of a different length and/or a different width to one another.

4. The gas turbine part of claim 2 or 3, wherein the indication of the remaining lifetime is given by the number of protrusions that remain when the gas turbine part is inspected during maintenance.

5. The gas turbine part of any one of claims 1 to 4, wherein the lifetime indicator comprises a protrusion with an indentation (44).

6. The gas turbine part of claim 1, wherein the lifetime indicator gives an indication of the remaining lifetime based on deterioration due to at least one of creep, oxidation and low cycle fatigue.

7. The gas turbine part of any one of claims 1 to 6, wherein the lifetime indicator protrudes less than 5 mm, less than 3 mm or less than 1 mm from the surface of the gas turbine part.

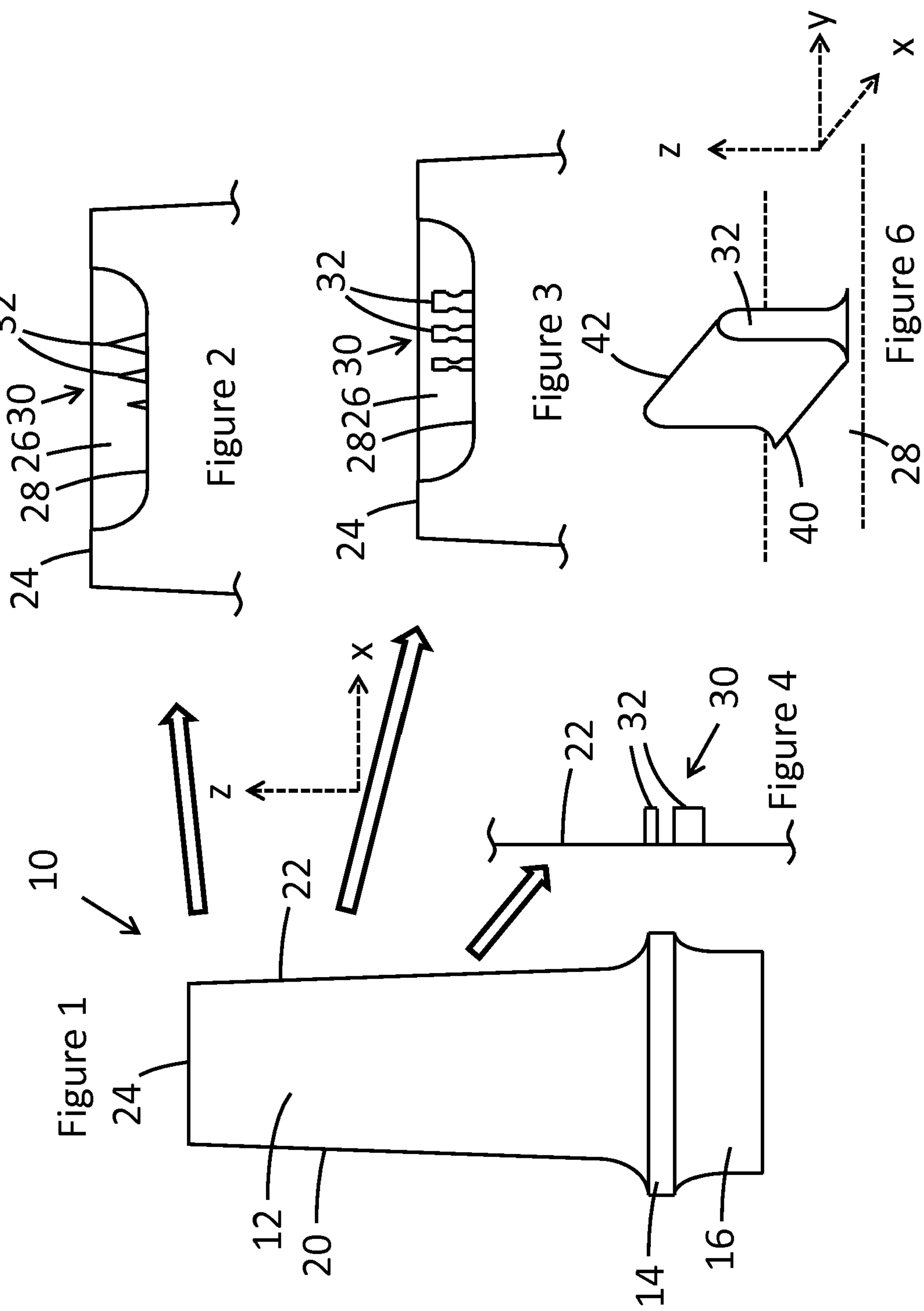
8. The gas turbine part of any one of claims 1 to 7, wherein the gas turbine part is made using selective laser melting or casting.

9. The gas turbine part of any one of claims 1 to 8, wherein the gas turbine part is made as a single integral part.

10. The gas turbine part of claim 1, wherein the gas turbine part is a gas turbine blade, a gas turbine vane, a gas turbine heat shield or a gas turbine combustor wall.

11. A gas turbine comprising a gas turbine part according to claim 1.

12. A method of inspecting a gas turbine part (10), the gas turbine part comprising a lifetime indicator (30) comprising at least one protrusion (32) protruding from a surface (28) of the gas turbine part, wherein the lifetime indicator is configured and arranged to give an indication of the remaining lifetime of the gas turbine part when the gas turbine part is inspected during maintenance, the method comprising the steps of
inspecting the lifetime indicator,
estimating the remaining lifetime of the part based on the deterioration of the lifetime indicator, and
ascertaining whether the gas turbine part needs repair or replacement based on the estimate of the remaining lifetime.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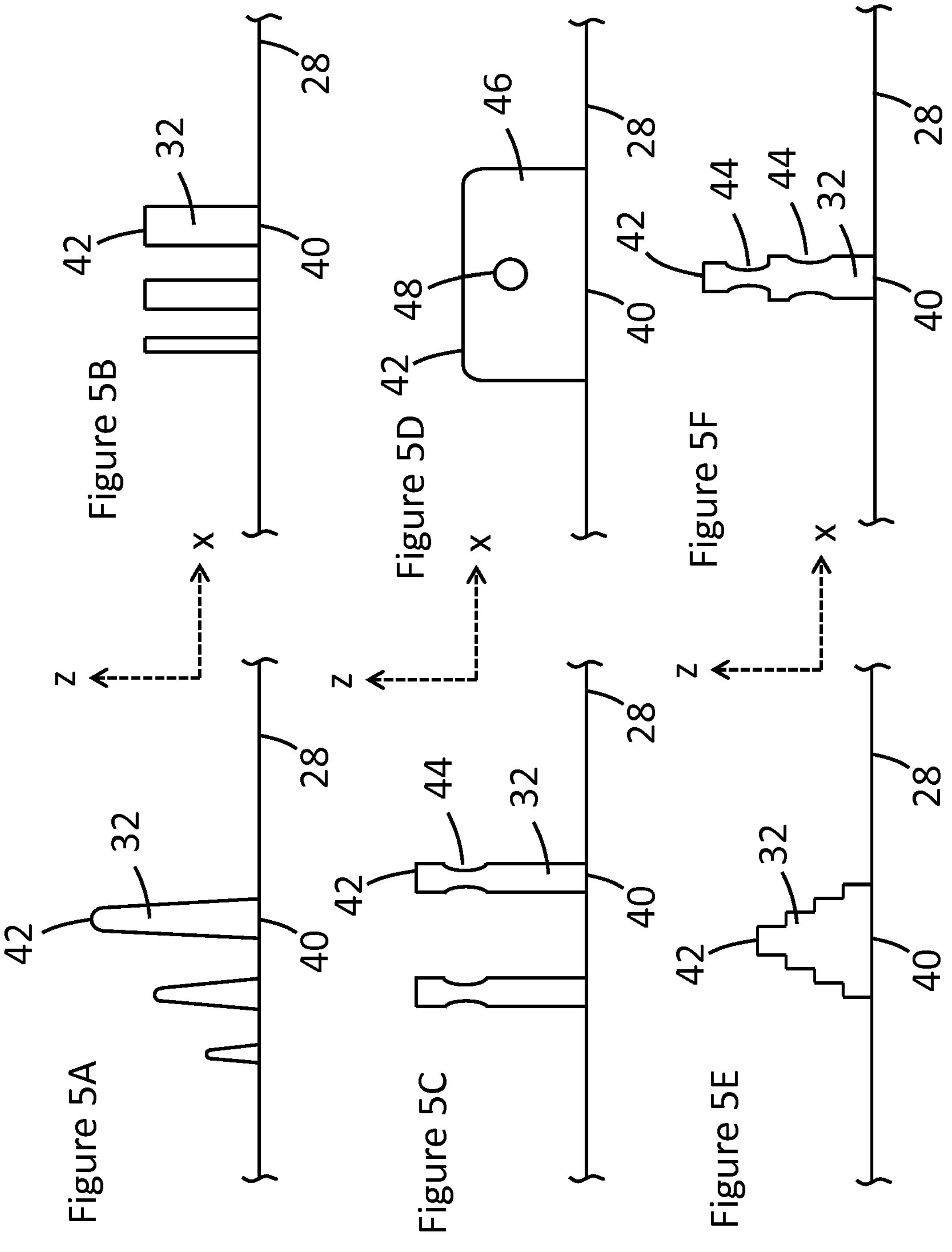

Figure 5A
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Figure 5B
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Figure 5C
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Figure 5D
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EUROPEAN SEARCH REPORT

Application Number
EP 15 19 8558

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 2012/285226 A1 (LAURER KURT NEAL [US] ET AL) 15 November 2012 (2012-11-15) * paragraphs [0026] - [0034]; figures 4-7 *	1-4,6-12 5	INV. F01D17/04
X Y	US 2011/296687 A1 (HEBUTERNE DAMIEN [FR] ET AL) 8 December 2011 (2011-12-08) * paragraphs [0042], [0043]; figures 2-6 *	1-4,6, 8-12 5,7	
X	US 2008/312847 A1 (SAFAI MORTEZA [US] ET AL) 18 December 2008 (2008-12-18) * the whole document *	1-4,6,7, 10-12	
X	US 2012/207586 A1 (CHEHAB ABDULLATIF M [US] ET AL) 16 August 2012 (2012-08-16) * paragraphs [0021], [0024], [0033], [0037]; figures 4-10 *	1,2,5,7, 10-12	
X	JP 2004 044423 A (ISHIKAWAJIMA HARIMA HEAVY IND) 12 February 2004 (2004-02-12) * abstract; figures 1-3 *	1,2,5-12	TECHNICAL FIELDS SEARCHED (IPC)
X	EP 2 270 314 A2 (ROLLS ROYCE PLC [GB]) 5 January 2011 (2011-01-05) * paragraph [0038]; figures 1-8 *	1-8, 10-12	F01D
X	US 5 275 536 A (STEPHENS PAUL S [US] ET AL) 4 January 1994 (1994-01-04) * column 4; figures 3-6 *	1,6-12	
X	US 2012/301276 A1 (SINGH RAM BAHADUR [IN] ET AL) 29 November 2012 (2012-11-29) * paragraphs [0003], [0004]; figures 1-5 *	1,2,4,6, 10-12	
	-/--		

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	11 May 2016	Koch, Rafael

CATEGORY OF CITED DOCUMENTS

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EUROPEAN SEARCH REPORT

Application Number
EP 15 19 8558

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 2 698 503 A1 (SIEMENS AG [DE]) 19 February 2014 (2014-02-19) * paragraphs [0022], [0040] - [0044]; figures 2,3 *	1,2,6-12	
Y	US 2015/086334 A1 (JACTAT PAUL-ETIENNE [FR] ET AL) 26 March 2015 (2015-03-26) * paragraphs [0041], [0042]; figures 2-5 *	1-4,6-12	
Y	WO 2015/088834 A1 (UNITED TECHNOLOGIES CORP [US]) 18 June 2015 (2015-06-18) * pages 4,5; figures 1-4 *	1,5-12	
Y	WO 2015/088832 A1 (UNITED TECHNOLOGIES CORP [US]) 18 June 2015 (2015-06-18) * claims 1-15; figures 1-4 *	1-4,12	
			TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	11 May 2016	Koch, Rafael

CATEGORY OF CITED DOCUMENTS

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EPO FORM 1503 03.82 (P04C01)

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11-05-2016

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2012285226 A1	15-11-2012	DE 102012103991 A1	15-11-2012
		FR 2975125 A1	16-11-2012
		RU 2012118087 A	10-11-2013
		US 2012285226 A1	15-11-2012
US 2011296687 A1	08-12-2011	FR 2960807 A1	09-12-2011
		US 2011296687 A1	08-12-2011
US 2008312847 A1	18-12-2008	EP 2003439 A1	17-12-2008
		US 2008312847 A1	18-12-2008
US 2012207586 A1	16-08-2012	EP 2676002 A1	25-12-2013
		US 2012207586 A1	16-08-2012
		WO 2012112366 A1	23-08-2012
JP 2004044423 A	12-02-2004	NONE	
EP 2270314 A2	05-01-2011	EP 2270314 A2	05-01-2011
		US 2011000183 A1	06-01-2011
US 5275536 A	04-01-1994	NONE	
US 2012301276 A1	29-11-2012	CN 103562501 A	05-02-2014
		EP 2715070 A1	09-04-2014
		US 2012301276 A1	29-11-2012
		WO 2012162016 A1	29-11-2012
EP 2698503 A1	19-02-2014	CN 104541026 A	22-04-2015
		EP 2698503 A1	19-02-2014
		EP 2885509 A1	24-06-2015
		JP 2015531843 A	05-11-2015
		US 2015204207 A1	23-07-2015
		WO 2014026775 A1	20-02-2014
US 2015086334 A1	26-03-2015	CA 2849413 A1	11-04-2013
		CN 103857919 A	11-06-2014
		EP 2764253 A1	13-08-2014
		ES 2546911 T3	29-09-2015
		FR 2981131 A1	12-04-2013
		JP 2014530320 A	17-11-2014
		KR 20140089515 A	15-07-2014
		RU 2014114054 A	20-11-2015
		US 2015086334 A1	26-03-2015
		WO 2013050688 A1	11-04-2013
WO 2015088834 A1	18-06-2015	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 15 19 8558

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

11-05-2016

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2015088832 A1	18-06-2015	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82