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

(11) EP 3 957 827 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
23.02.2022 Bulletin 2022/08

(21) Application number: **20425031.0**

(22) Date of filing: **18.08.2020**

(51) International Patent Classification (IPC):
F01D 5/28 (2006.01) ***C23C 4/134*** (2016.01)
C23C 28/02 (2006.01) ***C23C 4/073*** (2016.01)
C23C 28/00 (2006.01) ***C23C 4/11*** (2016.01)

(52) Cooperative Patent Classification (CPC):
F01D 5/288; C23C 4/02; C23C 4/073; C23C 4/11; C23C 4/134; C23C 4/18; C23C 28/3215; C23C 28/3455; F05B 2270/1091; F05D 2240/15; F05D 2240/35; F05D 2250/63; F05D 2300/175; F05D 2300/2118; F05D 2300/514; (Cont.)

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

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(54) A COATING SYSTEM FOR A COMPONENT OF A GAS TURBINE ENGINE

(57) The coating system for a component of a gas turbine engine comprises a bond coat BC layer (2) and a thermal barrier coating TBC layer (3) above the BC layer (2) . The BC layer (2) has a thickness in the range 180-300 micrometers and a roughness Ra of its surface facing the TBC layer (3) in a range 12.8-19.0 micrometers. The TBC layer (3) has a thickness in the range 200-700 micrometers and a porosity in the range 15.0-23.0 vol %. The ends of ranges are included in the ranges.

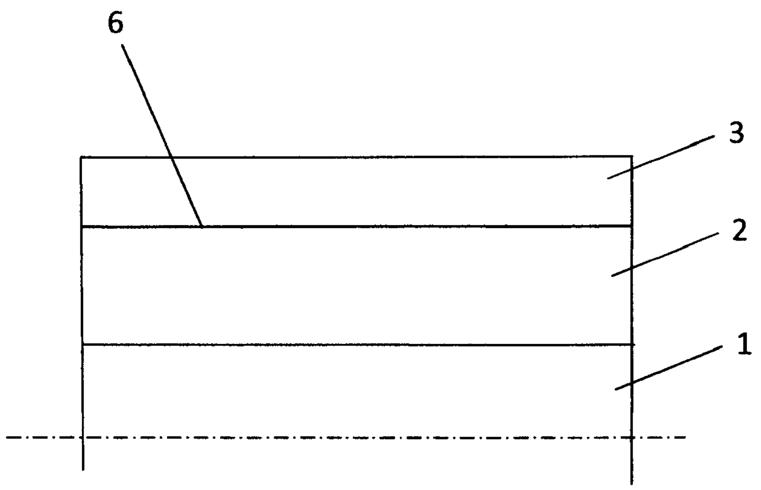

Fig. 1

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(52) Cooperative Patent Classification (CPC): (Cont.)
F05D 2300/516

Description

TECHNICAL FIELD

[0001] The present invention relates to a coating system for a component of a gas turbine engine.

BACKGROUND

[0002] Gas turbine engines comprise a compressor, one or more sequential combustion chambers, with or without a high-pressure turbine or a diluter in-between, and a turbine (low pressure turbine). Air is compressed at the compressor, a fuel is mixed with the compressed air and combusted at the combustors, generating a high-pressure hot gas that is expanded in the turbine.

[0003] The components of the gas turbine engine that come into contact with the hot gas are highly thermally stressed and often also highly mechanically stressed. For example, these components can include the combustion chambers and their components such as liner, burners, etc., the turbines and their components, such as vanes (non-rotating blades), blades (rotating blades), heat shields, etc.

[0004] In order to increase the lifetime of these components, usually they are made of a base material, e.g. a metal alloy or a ceramic material, and they are then coated with a coating system including a bond coat layer (BC layer) e.g. made of a MCrAlY alloy (in the case of a metallic BC layer) and a ceramic thermal barrier coating layer (TBC layer) e.g. made of Zirconia fully stabilized or partially stabilized with Yttria (YSZ).

[0005] Traditionally, in case of damage of the coating system the parts protected by it demonstrated enhanced degradation or consumption, but the damage did not result in a failure or forced outage.

[0006] New gas turbine engines have increased flame temperatures, which result in higher material temperatures, and/or they require longer lifetime; consequently the coating has to provide higher temperature capability and/or longer minimum lifetime.

[0007] In order to improve these features, many different compositions for the BC layer and TBC layer have been investigated. Alternatively, the spraying processes and equipment have been investigated, with the aim of improving a stable and reproducible formation process of the coating system.

[0008] Using a different approach, ASME Turbo Expo 2008, GT2008-51366, "Manufacturing optimization for bond-coat/thermal barrier coating systems" investigates parameters that influence the lifetime of a coating system first independently from one another (first order influence) and then in couples (second order influence). The result of the investigations was that no cumulative effect could be observed, i.e. the influence of couples of parameters was varying for each couple and it was expected that the benefit obtained by producing a system with a combination of all optimal parameters would not be a cumulative effect of the first order influences.

SUMMARY

[0009] An aspect of the invention includes providing a coating system for a component of the hot gas part of a gas turbine engine with longer minimum lifetime.

[0010] These and further aspects are attained by providing a coating system in accordance with the accompanying claims.

[0011] The invention is based on the recognition that tight ranges (tighter than in existing solutions) for the BC layer roughness, BC layer thickness, TBC layer thickness and TBC layer porosity can be selected in order to achieve a minimum lifetime that shows a surprisingly high peak compared to the selection of other parameters or, for the selected parameters, compared to broader ranges.

[0012] Cyclic testing carried out on a large amount of samples with coating systems of different materials and combinations of parameters showed a significant higher minimum and mean life when the selected parameters had values in the identified ranges.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Further characteristics and advantages will be more apparent from the description of a preferred but non-exclusive embodiment of the coating system, illustrated by way of non-limiting example in the accompanying drawings, in which:

Figures 1 and 2 show examples of coating systems;

Figure 3 shows the minimum FCT-life of coating systems with 1, 2, 3 or 4 parameters in the identified ranges and also 4 parameters in particularly advantageous ranges;

Figures 4 through 7 show the relationship between FCT-life and respectively the BC thickness, BC roughness, TBC thickness, TBC porosity of some of the investigated samples.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0014] With reference to figures 1 and 2, a component of the hot gas part of a gas turbine engine comprises a base element 1 and a coating system with a BC layer 2 (bond coat layer) and a TBC layer 3 (thermal barrier coating layer); optionally, a second TBC layer 4 (second thermal barrier coating layer) can be provided on the TBC layer 3; in this case, the second TBC layer 4 is the outer layer of the coating and the TBC layer 3 is an intermediate layer between the BC layer 2 and the second TBC layer 4. As an example, the base element 1 can be made of a Nickel superalloy, the BC layer 2 of a MCrAlY alloy, the TBC layer 3 of Yttria partially stabilized Zirconia (e.g. 7YSZ, where 7YSZ stands for Zirconia partially stabilized with 7wt% Yttria) and the second TBC layer 4 (if provided) of Yttria fully stabilized Zirconia (e.g. 14YSZ, i.e. Zirconia fully stabilized with 14wt% Yttria).

[0015] It has been found that by appropriately selecting some features of the BC layer and TBC layer, the minimum lifetime of the coating system can be increased, and this can be achieved independently from the particular materials of the BC layer, TBC layer and, if provided, second TBC layer.

[0016] The BC layer has a thickness in the range 180-300 micrometers and a roughness Ra of its surface 6 facing the TBC layer in a range 12.8-19.0 micrometers. In addition, the TBC layer has a thickness in the range 200-700 micrometers and a porosity in the range 15.0-23.0 vol%. In the above ranges, the ends of the ranges are to be considered included in the ranges.

[0017] Advantageous embodiments of the ranges include a BC layer with a thickness in the range 185-280 micrometers and a roughness Ra of its surface facing the TBC layer in a range 13.0-18.0 micrometers, and the TBC layer with a thickness in the range 210-640 micrometers and a porosity in the range 15.5-20.2 vol%, wherein the ends of ranges are included in the same ranges.

[0018] Further preferred embodiments include the BC layer with a thickness in the range 201-217 micrometers and a roughness Ra of its surface facing the TBC layer in a range 13.0-16.5 micrometers, and the TBC layer with a thickness in the range 220-249 micrometers and a porosity in the range 15.6-20.2 vol%, with ends of ranges included in the ranges.

[0019] The following table summarizes the ranges.

	BC Thickness	BC Roughness	TBC Thickness	TBC Porosity
Range 1 (R1)	180	12.8	200	15.0
	300	19.0	700	23.0
Range 2 (R2)	185	13.0	210	15.5
	280	18.0	640	20.2
Range 3 (R3)	201	13.0	220	15.6
	217	16.5	249	20.2

[0020] A number of tests to investigate the coating system behaviour for different values of the BC layer thickness and roughness and TBC layer thickness and porosity were carried out.

[0021] The tests were carried out on samples with different coating systems and aimed at evaluating the "FCT-life", i.e. the lifetime of each sample in hours for cyclic test carried out at 1100°C.

[0022] The samples were discs made of nickel superalloy provided with different coating systems.

[0023] For the BC layer and TBC layer of the coating system (and when provided also for the second TBC layer) different commercially available materials were used; in addition, same materials provided by different suppliers were also used. The different materials and same materials from different suppliers were used alone or mixed one another in different proportions. In addition, the coating systems of the samples had none of the relevant parameters (i.e. BC layer thickness and roughness and TBC layer thickness and porosity) in the ranges R1, R2, R3 (these ranges are summarized in the above table) or only one or two or three or all four relevant parameters in the ranges R1, R2, R3.

[0024] The tests were carried out as follows:

a. each sample was maintained in a tubular furnace for 23 hours at a temperature of 1100°C;
b. then each sample was cooled down for 1 hour in still ambient air; the ambient air had a temperature of about 20-30°C;
c. then each sample was put back into the furnace and steps a and b were repeated until end life was reached;

d. during the weekend the samples were kept in the furnace at a temperature of 1100°C for about 71 hours;

e. the end of life for each sample was considered achieved when 25% of the surface of each sample was delaminated, i.e. the TBC layer was detached from the BC layer.

[0025] The BC layer was made of different MCrAlY alloys.

[0026] The BC Thickness, i.e. the thickness in micrometers of the BC layer, was measured by cutting a cross section of each sample and obtaining an image by optical microscopy of the cross section and then applying computer based image analysis to obtain the required measurement. The images of the cross section were captured using an optical microscope and on the basis of these images the thickness was measured by an appropriate software. A commercially available software for this task is IMAGE PRO premier of Media Cybernetic.

[0027] The BC Roughness, i.e. the roughness of the surface of the BC layer that faces the TBC layer, i.e. with reference to figures 1 and 2 this is the roughness of the surface 6, was measured by a roughness tester (perthometer) using a 2.5 mm cut-off wavelength; alternatively the roughness can be measured by computer based image analysis technique; in this case the images have to be captured with the required magnification.

[0028] The TBC layer was made of 7YSZ por, i.e. porous Zirconia partially stabilized with 7 wt% Yttria.

[0029] In some samples, the TBC layer was applied by spray technique, in this case the required porosity is achieved by spraying zirconia powder having a size 20-90 micrometers with a plasma spray gun. In other samples the TBC layer was applied by mixing polypropylene (or other polymeric powders) to the 7YSZ powders having a size of 20-120 micrometers and then applying the mixed powder by spraying with a plasma gun with parameters that don't produce complete burning of the polymer grains; after spraying a heat treatment in air was carried out to burn the polymer grains embedded in the TBC, producing the porosity.

[0030] The TBC Thickness, i.e. the thickness in micrometers of the TBC layer, was measured in the same manner as the thickness of the BC layer.

[0031] The TBC Porosity, i.e. the porosity of the TBC layer in %vol, was measured by computer-based image analysis technique on the cross section of the TBC layer; preferably the porosity of the TBC layer was measured at the same positions where the thickness of the TBC layer was measured. The porosity was measured by measuring the cross section area with material and the cross section area without material (empty area), porosity was thus obtained by dividing the empty area by the total area (i.e. material area + empty area).

[0032] Some samples were also provided with a second TBC layer provided above the TBC layer, the material of this second TBC layer was porous Zirconia fully stabilized with 14 wt% Yttria applied by spray technique.

[0033] Figure 3 shows the minimum FCT-life for samples having respectively 1, 2, 3 and 4 parameters in the ranges R1; the same figure 3 also shows the minimum FCT-life for samples having 4 parameters in the ranges R2 and R3.

[0034] From this figure it is apparent that with four parameters in the range R1, the minimum FCT-line is double the FCT-life with less than four parameters in the range R1.

[0035] From figure 3 it can also be derived that the preferred ranges R2 and R3 provide additionally advantageous embodiments, with minimum FCT-life further increased.

[0036] The tests, which were carried out with samples having coating systems made of numerous different materials, show that the results are independent from the specific selected materials, but are determined by the selected combination of ranges.

[0037] Figure 3 shows that when the values of all four parameters are in the range R1, the minimum FCT-life is 2004 h, whereas when less than four parameters lie in the range R1 the minimum lifetime drastically drops down to 1024 h for three parameters or 535 h for two parameters or 1187 h for only one parameter in the selected range. Thus samples with all four parameters in the range R1 have a minimum FCT-life at least about double the FCT-Life of samples with 3 or less parameters in the range R1. Samples with parameters in the range R2 showed an increased minimum FCT-life of 2305 h and samples with parameters in the range R3 showed a further increased minimum FCT-life of 4100 h.

[0038] It is here remarked the relevance of the results achieved, when it is considered that the materials in gas turbine often operate at the limits of their properties and also small increase or decrease of temperatures (in the order of 10 °C more or less) can result in long decrease or increase of the FCT-life of the component.

[0039] It is also remarked the relevance of the minimum lifetime (FCT-Life) compared to the maximum or even average lifetime of the coating system, because design of the components is typically made based on the minimum lifetime of the coating system; therefore a coating system that can achieve a longer minimum lifetime is generally to be preferred to a coating system with scattered lifetime ranging from a very short to a very long lifetime.

[0040] Figures 4-7 show the FCT-life achieved for the different samples during the tests; figures 4-7 are linked, because the four parameters of the coating system of each sample are shown with reference to the FCT-life achieved.

[0041] These figures show the large amount of tests carried out and the surprisingly high FCT-Life achieved in connection with the selected ranges R1, R2 and R3. These tests also show that the high FCT-Life achieved was independent from the materials used for the coating system of each sample, because the FCT-Life was consistently achieved for coating systems according to the identified combination of BC layer thickness and roughness and TBC layer thickness and porosity, and independently from the specific materials of the coating systems.

[0042] The proposed coating system achieves longer minimum lifetime (and/or higher temperature capabilities) compared to existing coating systems.

Claims

1. A coating system for a component of a gas turbine engine, the coating system comprising a BC layer (2) and a TBC layer (3) above the BC layer (2), **characterised in that** the BC layer (2) has a thickness in the range 180-300 micrometers and a roughness Ra of its surface facing the TBC layer (3) in a range 12.8-19.0 micrometers, and the TBC layer (3) has a thickness in the range 200-700 micrometers and a porosity in the range 15.0-23.0 vol %, with ends of ranges included in the ranges.

2. The coating system of claim 1, **characterised in that** the BC layer (2) has a thickness in the range 185-280 micrometers and a roughness Ra of its surface facing the TBC layer (3) in a range 13.0-18.0 micrometers, and the TBC layer (3) has a thickness in the range 210-640 micrometers and a porosity in the range 15.5-20.2 vol %, with ends of ranges included in the ranges.

3. The coating system of claim 1 or 2, **characterised in that** the BC layer (2) has a thickness in the range 201-217 micrometers and a roughness Ra of its surface facing the TBC layer (3) in a range 13.0-16.5 micrometers, and the TBC layer (3) has a thickness in the range 220-249 micrometers and a porosity in the range 15.6-20.2 vol %, with ends of ranges included in the ranges.

4. The coating system of any of the previous claims, **characterized in that** the BC layer (2) consists of a MCrAlY alloy.

5. The coating system of any of the previous claims, **characterized in that** the TBC layer (3) consists of partially stabilized Zirconia.

6. The coating system of any of the previous claims, **characterized by** further comprising a second TBC layer (4) above the TBC layer (3).

7. The coating system of claim 6, **characterized in that** the second TBC layer (4) consists of fully stabilized Zirconia.

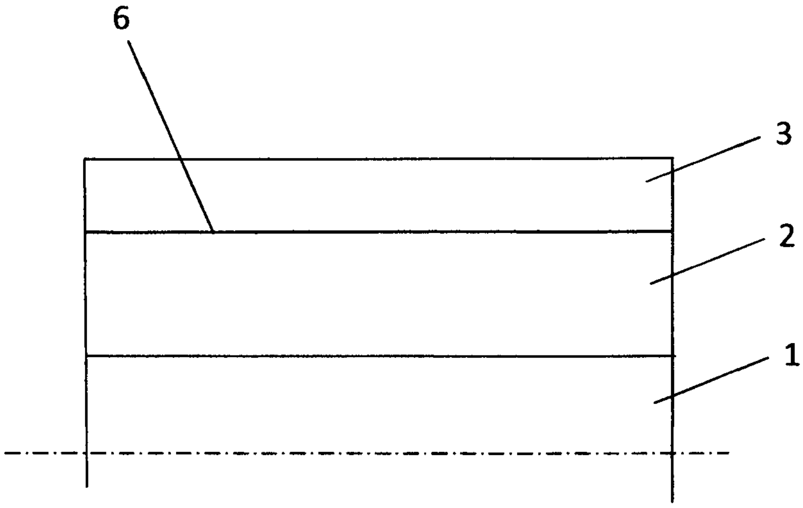


Fig. 1

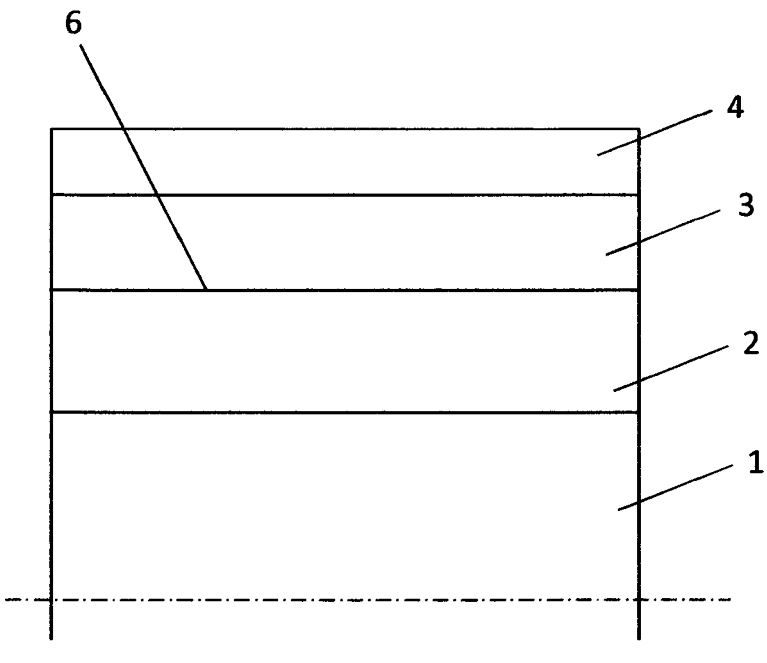


Fig. 2

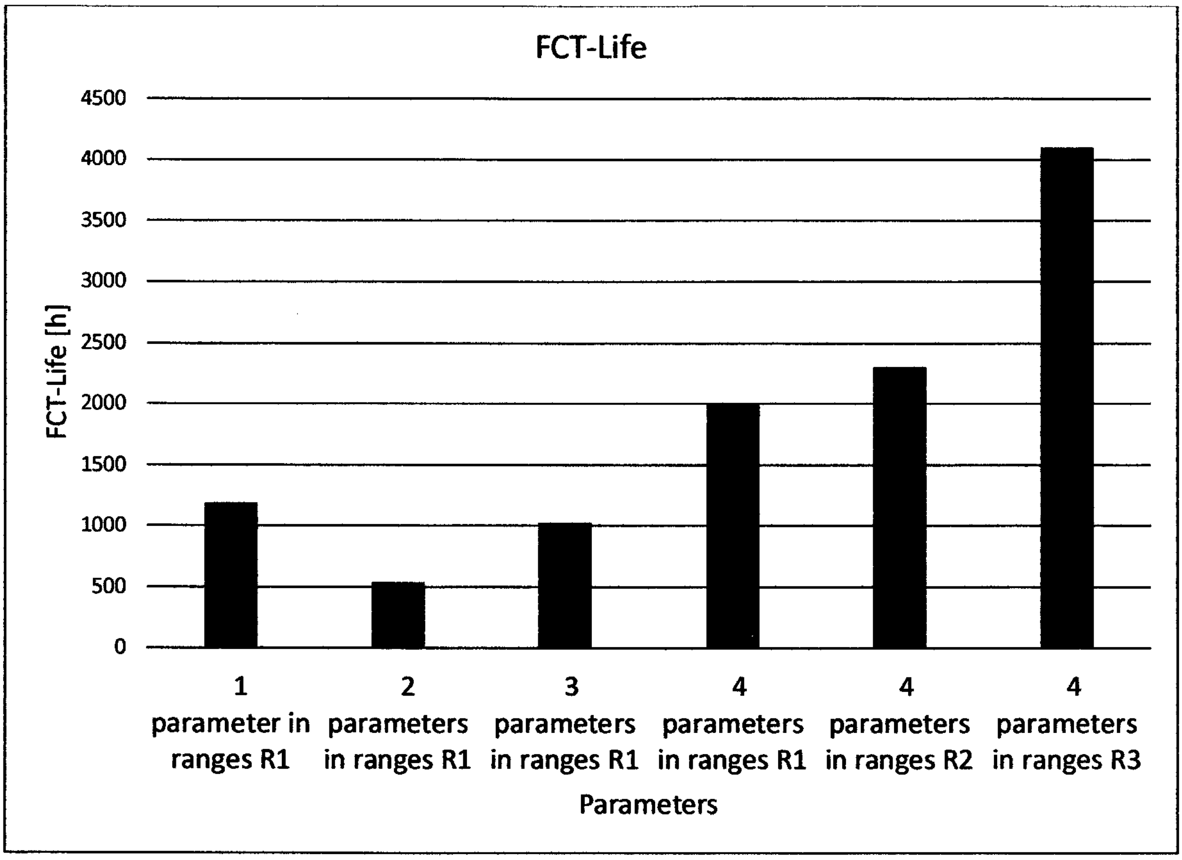

FCT-Life
FCT-Life [h]
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1 parameter in ranges R1
2 parameters in ranges R1
3 parameters in ranges R1
4 parameters in ranges R1
4 parameters in ranges R2
4 parameters in ranges R3
Parameters

Fig. 3

Fig. 4

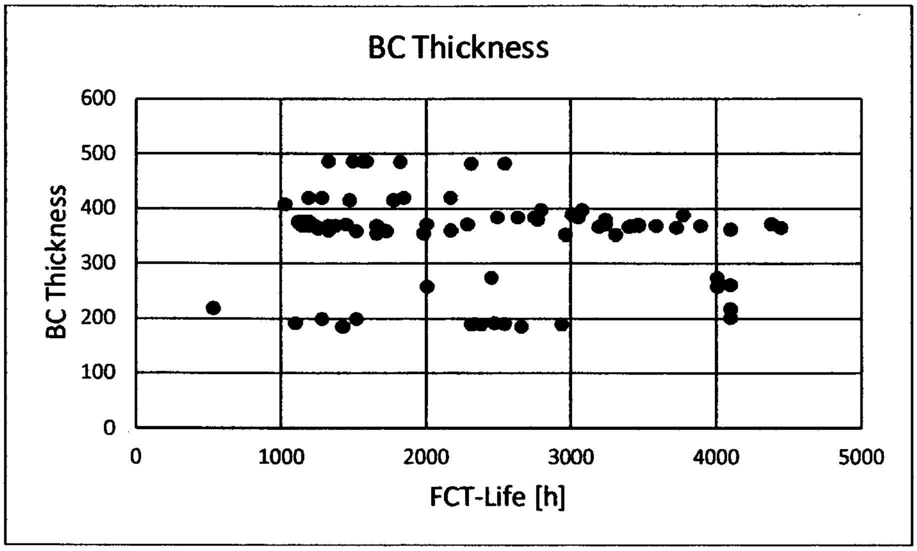

BC Thickness
600
500
400
300
200
100
0
BC Thickness
0
1000
2000
3000
4000
5000
FCT-Life [h]

Fig. 5

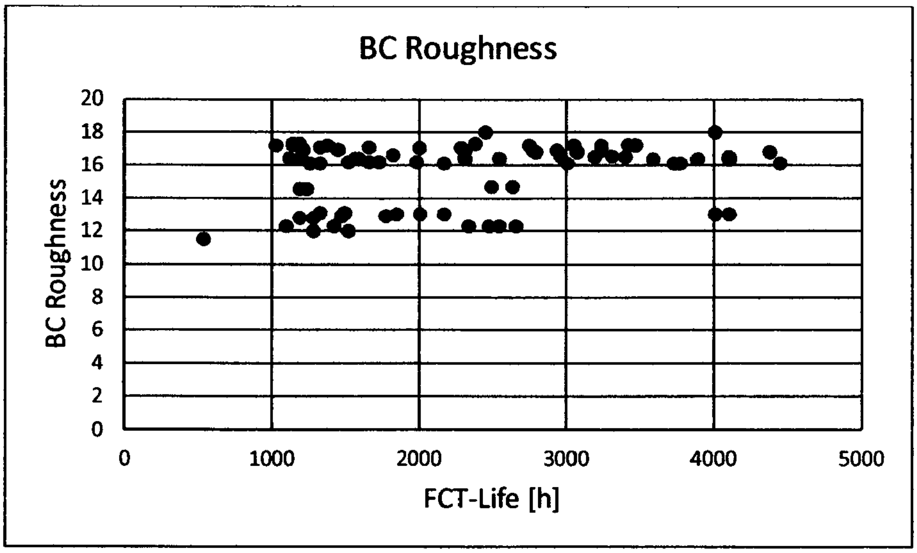

BC Roughness
20
18
16
14
12
10
8
6
4
2
0
BC Roughness
0
1000
2000
3000
4000
5000
FCT-Life [h]

Fig. 6

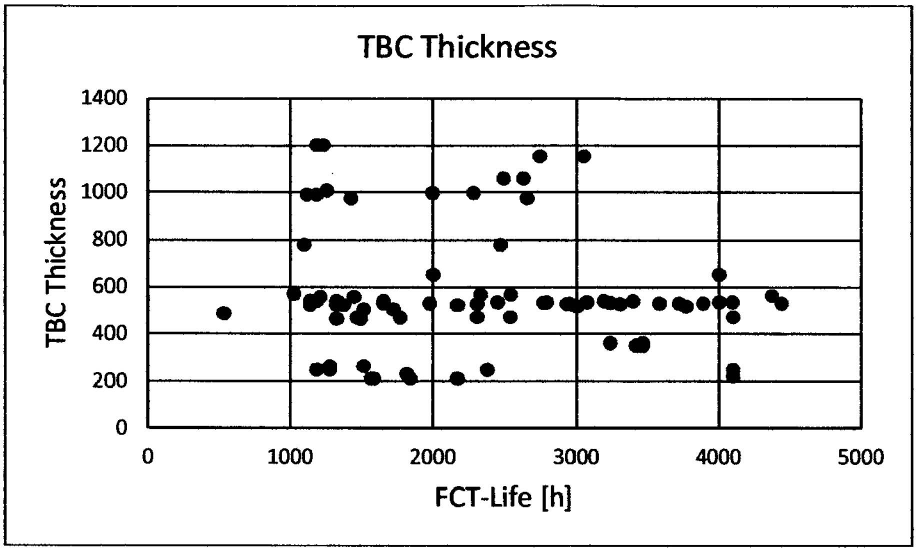
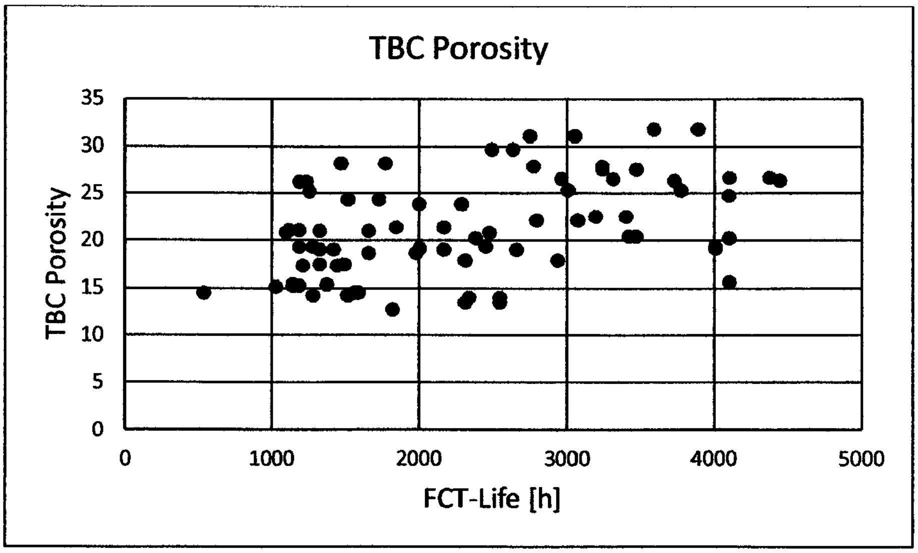

TBC Thickness
TBC Thickness
1400
1200
1000
800
600
400
200
0
0
1000
2000
3000
4000
5000
FCT-Life [h]

Fig. 7


TBC Porosity
TBC Porosity
35
30
25
20
15
10
5
0
0
1000
2000
3000
4000
5000
FCT-Life [h]

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EUROPEAN SEARCH REPORT

Application Number
EP 20 42 5031

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	21 December 2020	Di Giorgio, F

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CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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