Examiners' Report - Paper A 2021

The examiners' report sets out the expected answer, explains why this answer provides a good solution to the paper and shows how the marks were distributed for this answer. In addition, the scheme highlights the most common mistakes and explains which point deductions were made for these mistakes.

Purpose and extent of the examiners' report

The purpose of the present examiners' report is to enable candidates to prepare for future examinations (cf. Article 6(6) of the Regulation on the European qualifying examination for professional representatives).

1. Outline

The paper concerns engines containing components that are used at very high temperatures, notably in gas turbine engines. It is explained that such components are typically made from a particular class of alloys, known as superalloys, which have very good properties at high temperatures. The operating temperatures of the hottest part of the engine exceed the melting point of the superalloys used and thus when superalloys are used in these parts of the engine, the components need to be protected against the very high temperatures. The components are thus provided with a thermally insulating coating of a ceramic oxide or in some case with other cooling means such as cooling holes.

The client´s letter describes a **problem** with this approach. The coating is subject to thermal stress, due to the mismatch between the coefficient of thermal expansion of the superalloy substrate and that of the ceramic oxide, eventually leading to the coating being partially lost. The lifetime of the coated component is thus not sufficient.

The invention proposes as a **solution** to this problem, a ceramic oxide layer that has a columnar microstructure. The columns as explained in paragraph [005] must be at an angle of 75 to 105° to the substrate to provide the desired effect and thus this feature is essential to the invention. The columnar microstructure allows the ceramic oxide layer to expand and contract, as it heats up and cools down, minimising the thermal stress. The thermal insulation afforded by the inventive coating is stated to be as good as that obtained with conventional coatings.

The client´s letter describes three possible embodiments of the coated engine component.

The first embodiment has the ceramic oxide layer deposited directly on the engine component. This embodiment, although it does not obtain the longest possible lifetime, is stated to be advantageous for aircraft engines as it can be implemented with a low coating weight.

The second embodiment contains a further intermediate adhesion layer with an intermediate coefficient of thermal expansion between the engine component and the ceramic oxide layer. This embodiment provides the longest lifetimes.

The third embodiment is a turbine blade with cooling holes, which is further coated in accordance with either the first or the second embodiment. The third embodiment provides the best thermal insulation.

The letter furthermore describes two methods for making the inventive coated components.

In the first method, the ceramic oxide is deposited using electron beam evaporation. This method is able to directly deposit a ceramic oxide layer with a columnar microstructure on the component.

In the second method, a ceramic oxide is formed conventionally, and the columnar microstructure formed afterwards using a laser. This method is stated to be particularly useful when making coated engine components with cooling holes.

The first method is stated only to form a coating with the desired columnar microstructure under certain conditions. These conditions are thus essential features of a claim seeking to protect the first method.

The client´s letter cites two prior art documents D1 and D2.

Document D1 describes an engine component coated with ceramic oxide and states that an intermediate layer can improve the lifetime of the coating. This document also importantly notes that the term ceramic oxide when used for turbine components can define different groups of materials and is thus unclear. The document proposes a clear definition for this term.

Document D2 discloses an apparatus and a method for depositing a ceramic oxide layer using the same electron beam evaporation method proposed in the applicant´s letter. This method has been used to deposit a very thin (ca. 1 micrometre thick) layer of zirconium oxide with a columnar microstructure on a turbine blade made from a superalloy. This layer is used as a security marking and is often removed before the component is used.

The client´s letter finally in paragraph [007] refers to a component of a bus engine made from aluminium coated with an aluminium oxide (a ceramic oxide) layer with a columnar microstructure. The information available in the paper does not show that this engine component is part of the prior art. Aluminium components are, however, stated not to withstand the conditions in gas turbine engines and thus this information provides evidence that not all metals can be used to make the engine components for use at very high temperatures that interest the client.

None of the cited prior art suggests that a ceramic oxide layer with a columnar microstructure could solve the problem of providing engine components for use at very high temperatures with a longer lasting coating.

The closest prior art document for the client´s invention is considered to be document D1 as this document as well as having many features in common with the invention described in the letter, addresses the same problem

The major **challenges** of the paper were firstly to provide a set of claims that on the basis of this concept, provided an optimal protection for all the aspects of the invention of interest to the client and secondly to formulate claims that are both novel with respect to document D2 and provide the protection required.

2. Expected Claims

2.1 Candidates were expected to draft a claim to an engine component. This claim could have the following wording:

> Engine component (10, 20) comprising a superalloy substrate (11, 21) coated with a ceramic oxide (13, 23) layer with a thickness of at least 25 micrometres, wherein the ceramic oxide is a metal oxide with a melting point of above 1600°C characterised in that the ceramic oxide layer has a columnar microstructure where the angle between the columns (14a, 14b, 14c, 24a, 24b, 24c) and the surface of the substrate is between 75 and 105 °.

This claim was worth up to **40 marks.** It is also considered to be acceptable to specify that the ceramic oxide layer comprises columns with spaces between the columns rather than or as well as specifying the that the layer has a columnar microstructure.

2.2 Candidates were also expected to formulate claims directed to the two methods for making the coated engine components, which could be worded as follows:

First method:

A method for making the engine component of any the claims 1 to 7 comprising placing the superalloy substrate in a vacuum chamber along with a source of ceramic oxide, evacuating the vacuum chamber and using an electron beam to evaporate the ceramic oxide and deposit a coating on the substrate, wherein the substrate is held a temperature of 920-1050°C.

This claim was worth up to 10 **Marks.**

Second method:

A method for making the engine component of any of claims 1 to 7 comprising the steps of: depositing the ceramic oxide coating on a superalloy substrate and machining the ceramic oxide coating to form a columnar microstructure in the ceramic oxide coating.

This claim was worth up to **10 Marks**.

3. **Alternative Solutions**

It was also acceptable to define a single independent method claim covering both methods, e.g., with an or combination, rather than two separate independent claims.

4. Marking of the Independent claims

4.1 Product claim

4.1.1 Claims that are not novel receive no marks.

In the claim suggested above, the thickness of the coating makes the product claim novel with respect to document D2. A claim directed to an engine component coated with a ceramic oxide with a columnar structure of any thickness, or to a coating with these features, is not novel (unless the novelty is established by other features) with respect to the security coating disclosed in document D2.

A claim to an engine component that is supposed to differ from that of document D2 by the fact that it is supposed to be used at very high temperatures without defining them

would similarly not be novel, as the component of document D2 is exposed to high temperatures during its manufacture. A claim which specifies that the component is configured to be used at a temperature of at least 1600°C is considered to be novel. The engine component of document D2 was not stated to be used at temperatures of at least 1600°C and only has a very thin coating, whereas paragraph [006] states that a coating 25 times as thick would typically be needed to provide a sufficient thermal insulation. The component of document D2 is thus not considered to be configured for use at temperatures of at least 1600°C.

A claim in which the engine component is supposed to differ from that of the document D2 in that the component is “useful” is also not novel. The component of document D2 is also useful.

Features that were presented in the claim as being optional or preferred are not considered to limit the scope of the claim and cannot establish the novelty.

It is also possible to make the engine component novel with respect to document D2 by specifying that an adhesion layer is present.

4.1.2 Product claims that exclude one or more of the embodiments, lose **15 marks** per embodiment excluded.

A claim to an engine component in which an adhesion layer is present excludes the embodiment in which the coating is deposited directly on the superalloy and thus can be awarded a maximum of **25 marks**. A claim in which the substrate is made of aluminium excludes all three of the client’s embodiments and thus received **0 marks**.

4.1.3 Limiting the product claims to a specific type of engine (e.g. turbine) or to a specific type of ceramic oxide lost **10 marks** for each limitation. The client´s letter states that engine components for turbine engines and rocket engines may be coated. Document D1 makes it clear that the ceramic oxide is not limited to the zirconium oxide used in the client´s letter. Other unnecessary limitations led to a deduction of **7 marks** each.

4.1.4 The use of the unclear term “ceramic oxide” in the claim without defining it led to a deduction of **5 marks** (2 marks were lost if only metal oxide is missing and 3 marks were deducted if only the temperature is missing).

A claim which is only supposed to differ from that of document D2 by being configured to be useful at 1600°C, but which did not contain the essential features (thickness, superalloy) making it suitable for this use lost 2**0 marks** (no marks are deducted if the essential features are present). This formulation is considered to be unclear, as the limitations implied by the feature cannot readily be determined.

4.1.5 If the claim does not define the orientation between the columns and the surface **10 marks** were deducted. The angle between the columns and the surface is stated in the applicant´s letter to be essential to obtain the effect. The use of the expression “substantially perpendicular” instead of defining the angles led to a lower deduction of **7 marks** for unnecessary limitation (narrower scope of protection, see Guidelines F-IV 4.7.1). If the range is specified in the description, **5 marks** are deducted for inconsistency between the claims and description. The expression substantially perpendicular in accordance with usual practice would be interpreted to mean that the columns are perpendicular to within measurement error. Paragraph [005], however, indicates that the expression has a different meaning, which thus has to be claimed to make the claim clear.

4.1.6 Omitting the requirement that the substrate is a superalloy resulted in a deduction of **5 marks**. The problem addressed by the claims, according to the applicant´s letter, is only present when superalloy substrates are used and thus the letter only supports the use of this material as the substrate. **10 Marks** were also deducted if a minimum thickness of the ceramic oxide layer below 25 micrometres is defined. The applicant´s letter indicates that a 25 micrometre thick layer is preferable, because otherwise a sufficient thermal insulation is not obtained (see paragraph [006]). The information

available is not considered to support thicknesses significantly below this value. For the same reasons, **10 marks** are deducted for a claim lacking the minimum thickness, but which is new in view of other features (e.g. the adhesion layer). A minimum thickness of 30 micrometres, a maximum thickness of 2 millimetres or limiting the component to components of the combustion zone (components of the exhaust zone can also be coated) are considered to be unnecessary limitations and thus attracted a deduction of **7 marks**.

4.1.7 Other clarity issues led to a deduction of up to **5 marks** each. A claim to a coating without a substrate is unclear, as a coating must be on a substrate and thus **5 marks** were lost for such a claim. There was no need to formulate the product claims as product by process claims, as a clear definition of the product terms is possible. Thus **5 marks** were also lost for product by process claims. Claiming any component or just a coated substrate resulted in a deduction of **2 marks**, the applicant's letter only supports the invention when it is applied to engine components.

4.1.8 If the set of claims submitted contained multiple independent product claims directed to the same product (e.g. two different claims to engine components), that do not fulfil the requirements of Rule 43(2) EPC then only the claim which will receive the lower number of marks is marked. The same approach was applied if two alternative definitions of the component were present in the same claim. No marks were awarded or deducted for a claim to a coating without a substrate in addition to a claim to a coated engine component. No marks were deducted for formulating, as independent claims, the claims to specific components (for example to a turbine blade), in addition to the independent product claim to an engine component.

4.1.9 **2 Marks** are deducted from an independent claim formulated in the two-part from in which the characterising features are identified incorrectly. **1 mark** is lost if no reference signs are used.

4.2 Method claims

4.2.1 In general when marking the method claims no double penalisation is applied. Thus, no marks are deducted in the method claims for features already subject to a mark deduction in the product claim. Similarly, a mark deduction applied to one method claim is not applied to the other method claim. The exceptions to this rule are defined below.

4.2.2 Claims that are not novel receive no marks. A claim directed to the first method may lack novelty with respect to document D2. In order to ensure that the claim is novel it is typically necessary to specify that the method forms a component in accordance with claim 1 or that the thickness of the layer is at least 25 micrometres.

4.2.3 A claim to the first method lacking the essential features need to form a columnar microstructure (temperature, electron beam) lost **3 marks** per feature missing.

4.2.4 Unnecessary limitations to the claims resulted in a deduction of **3 marks** per feature. Clarity issues led to a deduction of up to **2 marks**.

In respect of the first method, specifying that the component is rotated is not necessary and is an unnecessary limitation. Similarly, the temperature for depositing the adhesion layer was stated in the client's letter to be optional and was also not necessary for independent method claims in which an adhesion layer was deposited. Therefore **3 marks** were deducted for each of these features.

Specifying that the component is fixed to a holder placed in a vacuum chamber which is then evacuated are presented in paragraph [009] as being a part of the method and thus no marks are deducted if these features are present. Omitting the use of the holder and a vacuum chamber was also acceptable as it is implicit that these steps are always performed in electron beam evaporation.

In respect of the second method, it is not necessary to specify that a laser is used to form the columnar structure, or that plasma spraying was used to form the layer, such

limitations each resulted in a deduction of 3 marks. The method must, however, produce the coating required to solve the problem and thus it is necessary to specify that the columns form an angle of 75 to 105° with the surface. If this feature is missing **4 marks** are lost (**2 marks** if the columns are substantially perpendicular). Stating that the method forms the component of claim 1 is sufficient to fulfil this requirement.

4.2.5 Both methods must deposit a coating on a superalloy, if this limitation is not present then 2 marks are lost.

4.3 Dependent claims

4.3.1 Up to **25 marks** were available for the dependent claims. No marks were awarded for any claims going beyond the 15th claim. When more than 15 claims were present only the first 15 claims were marked. This rule was applied irrespective of how the claims were numbered.

The claims are marked as a whole and if appropriate up to **2 marks** are deducted for unclear claims or for incorrect dependencies from the total number of marks awarded. The marks for dependent claims are awarded independently of the marks awarded for the independent claims (thus marks are awarded for claims dependent upon a product claim that is not novel).

4.3.2 If an individual claim was directed to feature A **or** feature B only the marks for the feature entitled to the higher number of marks were awarded. Full marks are not awarded if the dependent claim is more limited than necessary (e.g. a claim to an adhesion layer with the preferred range of thicknesses would be marked as a claim to an adhesion layer, but would not receive all 4 of the marks available for such a claim, as the claim is more limited than necessary). No marks were awarded for optional features in an independent claim.

4.3.3 Dependent claims directed to the following features attracted marks:

Product:

Adhesion layer (**4 marks)**

Composition of adhesion layer (**2 marks)**

Ceramic oxide directly on component (**4 marks)**

Thickness of adhesion layer (1 mark)

Zirconium oxide or list of oxides mentioned in application and D1 (**3 marks, 1 mark** for an incomplete list e.g. only including the oxides mentioned in the letter and not also those mentioned in document D1 **)**

Components mentioned in application (**2 marks)**

Turbine blade with cooling holes (**3 marks)**

Maximum thickness (**1 mark**)

Method Claims:

First Method

Source of adhesion layer

Temperature for zirconium oxide (**1 mark each**)

Second Method

Laser

Plasma spray

Adhesion layer (**1 mark each)**

Cooling holes by laser **(2 marks)**

4.4 Description

Candidates were expected to draft the introductory part of a description in accordance with Rule 23(4) IPRE. A total of **15 marks** is available for the description.

5 marks are available for describing the two prior art documents. A detailed description of these documents was expected. A candidate using the two-part form in their claims, can, however, provide a shorter description of the closest prior art document.

5 marks are available for adapting the client's letter to the claims filed and providing support for all of the claims. The remaining **5 marks** are awarded for formulating the problem showing how the problem is solved. The difference to the closest prior art, document D1, is the columnar microstructure. The technical effect of this difference is that the coating is able to withstand very high temperatures for longer and thus the problem can be formulated as the provision of a component with a coating that is more resistant to the conditions in turbine or rocket engines. It was expected that the description explained how the columnar microstructure of the coating is able to solve this problem. It was also expected that the description discussed how the more resistant coating could be used in the different embodiments to maximise the lifetime of the component, minimise its weight or obtain the best cooling. When providing support for the claims it was expected that all the claims are identified. Additional advantages of any features claimed should also be highlighted.

Annex - Example set of claims:

1. Engine component (10, 20) comprising a superalloy substrate (11, 21) coated with a ceramic oxide (13, 23) layer with a thickness of at least 25 micrometres, wherein the ceramic oxide is a metal oxide with a melting point of above 1600°C characterised in that the ceramic oxide layer has a columnar microstructure where the angle between the columns (14a, 14b, 14c, 24a, 24b, 24c) and the surface of the substrate is between 75 and 105 °.
2. Engine component in accordance with claim 1 in which an adhesion layer (12,22) is present between the superalloy and the ceramic oxide layer.
3. Engine component in accordance with claim 2 wherein the adhesion layer is a nickel or cobalt alloy containing 10-50 wt.% aluminium.

4. Engine component in accordance with claim 1 in which the ceramic oxide layer is deposited directly on the substrate.
5. Engine component in accordance with any previous claim in which the ceramic oxide is zirconium oxide.
6. Engine component in accordance with any previous claim in which the component is a turbine blade, a liner of a combustion chamber or a part of a pump used in a rocket engine.
7. Engine component in accordance with claim 6 in which the component is a turbine blade (30) with cooling holes (31a, 31b, 31c).
8. A method for making the engine component of any of claims 1 to 7 comprising placing a superalloy substrate in a vacuum chamber along with a source of ceramic oxide, evacuating the vacuum chamber and using an electron beam to evaporate the ceramic oxide and deposit a coating on the substrate, wherein the substrate is held a temperature of 920-1050°C.
9. A method according to claim 8 in which a source of an adhesion layer is also present in the coating chamber and the electron beam is used to deposit an adhesion layer before the ceramic oxide layer is deposited.
10. A method according to claims 8 or 9 in which the ceramic oxide is zirconium oxide and the temperature is 950-1000°C.
11. A method for making the engine component of any of claims 1 to 7 comprising the steps of: depositing the ceramic oxide coating on a superalloy substrate, machining the ceramic oxide coating to form a columnar microstructure in the ceramic oxide coating.
12. A method in accordance with claim 11 in which a laser is used to machine the coating.

13. A method in accordance with claim 12 in which the component is a turbine blade with air cooling holes and where the laser is also used to drill the holes through the walls of the component.
14. A method in accordance with any one of the claims 11-13 in which plasma spraying is used to deposit the coating.
15. A method in accordance with any one of the claims 11-14 in which an adhesion layer is also deposited and in that plasma spraying is also used to deposit the adhesion layer.

Examination Committee I: Paper A - Marking Details - Candidate No

Category		Max. possible	Marks Marker 1	Marker 2
Claims	Product claim	40		
Claims	Methods for making the product	20		
Claims	Dependent claims	25		
Description	Description	15		
Total				