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(54) **Method of forming a cast component**

(57) A method of forming a turbine nozzle guide vane (2) for a gas turbine engine, the guide vane (2) comprising an internal cavity (14) and having internal features (16), comprises investment casting metal around a core member (30) that defines the internal cavity (14) and internal features (16) of the guide vane, removing the core mem-

ber (30), and machining the guide vane (2). The process of investment casting around the core member (30) includes the step of casting at least one feature (40) external to the guide vane (2). The external feature (40) is used as a reference point to indicate the location of the internal features (16) of the guide vane (2) during the machining of the guide vane (2).

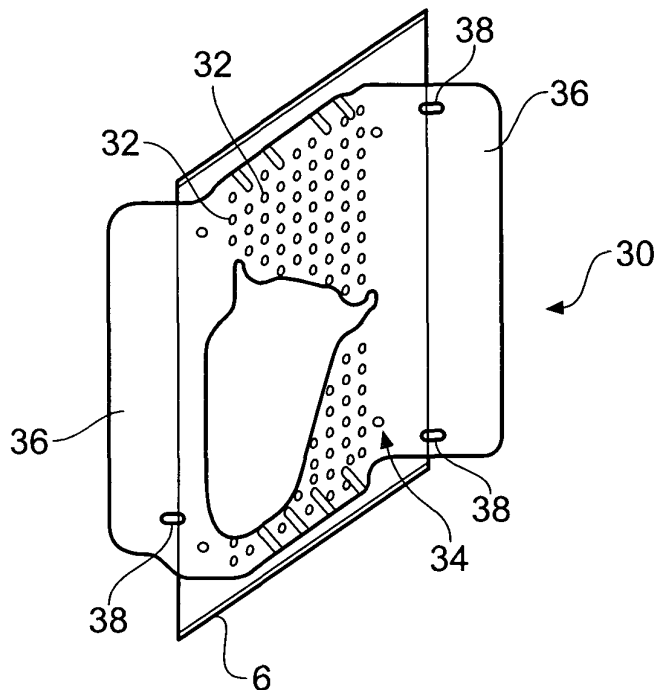


Fig. 5

Description

[0001] This invention relates to a method of forming a cast component, especially a turbine nozzle guide vane.

[0002] Gas turbine engines use nozzle guide vanes within the turbine section of the engine to direct gas flow onto the turbine blades in the most effective manner. A standard nozzle guide vane includes an aerofoil that extends between an inner and an outer platform. The aerofoil directs the gas flow between the inner and outer platforms such that each platform has a first, gas washed side and a second, non gas washed side. It is standard practice to cool turbine blades and the aerofoils of nozzle guide vanes in a gas turbine engine. In certain engine applications it is also necessary to cool the platforms of the nozzle guide vanes. Several methods of nozzle guide vane cooling exist and an appropriate method may be selected according to the magnitude of the temperatures experienced in the area to be cooled.

[0003] One method of nozzle guide vane platform cooling is illustrated in Figures 2 and 3. The method calls for a double skin platform design, whereby an internal cavity is created in the nozzle guide vane platform between the two skins. Cooling air is fed into the cavity via impingement holes formed on the non gas washed surface of the platform and flows through the cavity to cool the platform. Columns or pedestals extend across the cavity between the two skins in order to allow for load and heat transfer across the platform. Conventionally, the non gas washed skin of the platform is constructed as a separate component that is pre drilled with impingement holes and attached to the main component to form the double skinned design. This procedure is time consuming and produces an inferior component. Poor joint integrity at the column/skin interface results in reduced load and heat transfer across the platform.

[0004] The problem of joint integrity can be addressed by forming the platform cavity during the casting process using a platform core. In this manner the entire component is cast in a single process step and a good connection between the columns and both skins can be achieved. However, the position of the columns within the cavity cannot be detected once the component has been cast. Movement of the platform core during the casting process is not uncommon, so the exact position of the columns within the cavity cannot be determined. There is therefore a risk that, during the subsequent drilling process, an impingement hole could be drilled over the top of a column, rather than between columns, as is intended. This situation is illustrated in Figure 4. Wrongly positioned impingement holes reduce cooling effectiveness and can cause component failure under normal operating conditions.

[0005] According to the present invention, there is provided a method of forming a hollow, cast component in which the exact position of internal features of an internal cavity must be determined accurately for the purposes of a post-casting machining operation, the method com-

prising investment casting metal around an internal core member that defines the internal cavity and internal features of the component, removing the internal core member, and performing a machining operation on the component, the orientation of which is to be relative to the internal features of the internal cavity, characterised in that the internal core member includes at least one part thereof which produces in the cast component at least one externally accessible feature having a known relationship to the said internal features in the cast component, and in that the at least one externally accessible feature is used in the post-casting machining operation as a reference to indicate the position and orientation of the internal features of the component so as to determine the required orientation of the machining operation.

[0006] In such a method, any movement of the core member during casting is reflected in the position of the external feature(s). It is an advantage of the invention that the external feature(s) reflects the location of the internal features of the guide vane, allowing machining of the guide vane to take place accurately with respect to the position of the internal features. It is a further advantage of the invention that casting of the external feature does not require an additional process step.

[0007] The external reference feature is preferably cast using an aperture through a portion of the core member that extends outside the guide vane. Consequently, the external reference feature is a protrusion. However the feature may take any appropriate form. For example, the reference feature may be in the form of a recess.

[0008] Preferably, the process of investment casting around the core member includes the step of casting three external reference features. Preferably, the external feature or features define three separate faces that lie in mutually perpendicular planes, so that the position of the core can be determined precisely in three dimensional space. Each external feature may be cast adjacent to a specific area of the cavity so as to correspond to specific internal features.

[0009] The cast component may comprise a guide vane platform having a double skin construction in which the internal cavity is formed between first and second skins and a post casting machining operation is carried out on one of the skins relative to internal features formed in the internal cavity. The guide vane platform may be an inner or an outer platform.

[0010] The internal features of the guide vane may comprise columns that extend across the internal cavity to connect the first and second skins.

[0011] Machining the guide vane may comprise forming at least one hole through one of the first and second skins to intersect the internal cavity at a predetermined location, the desired position of the hole being established by reference to the external feature. The hole may be an impingement hole and may be one of a plurality of holes located across the guide vane skin.

[0012] The external feature may be removed after the guide vane has been machined. This removal may be

accomplished as part of the normal fabrication process, for example during sealing of the exit slot created during removal of the core member.

[0013] According to another aspect of the present invention, there is provided for a gas turbine engine, for example a nozzle guide vane, the aerofoil having internal cooling passages, internal features and at least one externally accessible feature, characterised in that the cooling passages, internal features and externally accessible features are formed by a common core component whereby the position of the at least one externally accessible feature is indicative of the position of the internal features formed by the common core.

[0014] For a better understanding of the present invention, and to show more clearly how it may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:

Figure 1 is a perspective view of a turbine nozzle guide vane; and

Figure 2 is a partial sectional view of an outer nozzle guide vane platform; and

Figure 3 is a partial sectional view of the nozzle guide vane platform of Figure 1 indicating cooling air flow; and

Figure 4 is a partial sectional view of an outer nozzle guide vane platform illustrating core movement during casting; and

Figure 5 is a perspective view of the core component with the outline of the resulting nozzle guide vane platform shown behind; and

Figure 6 is a perspective view of a nozzle guide vane platform.

[0015] Referring to Figure 1, a turbine nozzle guide vane 2 comprises an aerofoil 4 that extends between inner and outer platforms 6, 8. In use, hot combustion gas flows across the guide vane 2, between the inner and outer platforms 6, 8 and is directed by the aerofoil 4 into the path of turbine blades (not shown). The surfaces of the platforms 6, 8 that are adjacent to the aerofoil are washed by the passing gas stream.

[0016] Referring to Figures 2 to 4, the outer nozzle guide vane platform 8 comprises first and second skins 10, 12 that are disposed on opposite sides of a cavity 14. The first skin 10 forms the gas washed surface of the platform 8 and the second skin 12 forms the non gas washed surface of the platform 8. Impingement holes 18 extend through the skin 12 into the cavity 14, such that the non gas washed surface of the platform 8 communicates with the interior of the cavity 14. Columns 16 extend across the cavity 14, connecting the first and second skins 10, 12.

[0017] Referring to Figure 1, the structure of the inner nozzle guide vane platform 6 is complementary to that of the outer nozzle guide vane platform 8. The inner platform 6 comprises first and second skins 20 and 22 disposed on opposite sides of a cavity (not shown). Impingement holes (not shown) extend through the second skin 22 into the cavity, and columns (not shown) extend across the cavity connecting the first and second skins 20, 22.

[0018] The nozzle guide vane platforms 6, 8 are constructed using an investment casting process. During this process, a ceramic core member is placed in a die into which wax is injected. Once the injected wax has set it is removed and the ceramic cored wax model is then repeatedly dipped into a slurry and invested with ceramic particles to build up a ceramic wall. When the outer ceramic coating is dry, the wax model and ceramic shell are fired in an oven to remove the wax and harden the ceramic material. The resulting cored shell is then used as a mould and the molten metal is poured in to cast the hollow guide vane including platforms 6, 8. When the metal has cooled, the hard outer ceramic shell is removed normally by being broken up. The inner ceramic core is then dissolved out by chemical means, for example, by immersion in a hot, caustic solution.

[0019] At this stage the component is in its "as cast" form and is then subject to a number of machining operations to produce the finished component. In the case of an airfoil component designed to utilise surface film cooling a multiplicity of small holes are drilled through the outer wall into the hollow interior. Also in the present example, in which the outer of the double platform skins is cooled by impingement jets directed at the surface of the skin inside the internal cavity, impingement holes are drilled through the inner skin. Clearly it is important to achieve the designed cooling effect in such cases that the holes are drilled in the correct places. The holes are drilled from the outside inwards into the internal cavity left by the dissolved core, but the core may have shifted from its initial position during the investment, firing and casting steps and the ceramic shrinks during firing albeit by an predictable amount. Therefore in the absence of means for checking the current position of the cavity left by the dissolved core there is strong possibility that some of the drilled holes will be in a wrong position, that is in a position where the operational effect is compromised. Furthermore, where there are internal walls, columns, pillars or the like internal features in the cavity it is inevitable that some drilled holes will intersect the features and will be blind, and thus totally ineffective. This will seriously disrupt the intended pattern of cooling leading to premature failure if undetected. Defective components of this kind must be detected and rejected if failures are to be avoided. The present invention offers a solution to this problem by providing a method by which the position of the internal cavity can be accurately located thus allowing the datum reference employed in the machining operation to be adjusted to suit.

[0020] An inner platform core 30 is illustrated in Figure 5, with the outline of the resulting inner platform 6 indicated behind the core. The core 30 comprises a central region 34, which remains within the platform 6 during casting, and two side regions 36, which extend beyond the platform 6 during casting. The central region 34 of the core 30 includes a series of apertures 32 through which molten metal flows during the casting process to form the columns 16 within the cavity 14. The core 30 also includes three larger apertures 38, which are located on the boundary between the central and outer regions 34, 36 of the core 30. Molten metal flows through the apertures 38 to create three protrusions 40 on the sides of the platform 6, as illustrated in Figure 6.

[0021] The protrusions 40 on the edges of the platform 6 are formed at the same time as the columns 16. The position of the protrusions 40 is fixed with respect to that of the columns 16. Protrusions 40 are therefore used as reference members to indicate the position of the columns 16 within the cavity 14 during subsequent machining of the platform 6. Any deviation of the columns 16 from their intended position, caused by movement of the core 30 during the casting process, will be reflected by a similar deviation in the position of the protrusions 40 from their intended position.

[0022] The platform 6 is mounted on drilling apparatus in order to drill the impingement holes 18 through the skin 12. The platform 6 is located on the drilling apparatus using only the protrusions 40 so that the drilling operation is conducted relative to the position of the internal columns 16 and not the external surfaces of the platform 6.

[0023] This method may be employed in conjunction with any machining operation, not simply drilling. For example, it may be used together with an operation to remove material from the external surface of the component. In such an operation it may be advantageous to predict wall thickness by knowledge of the orientation of the cavity.

Claims

1. A method of forming a hollow, cast component 2 in which the exact position of internal features of an internal cavity 14 must be determined accurately for the purposes of a post-casting machining operation, the method comprising:

investment casting metal around an internal core member 30 that defines the internal cavity 14 and internal features 16 of the component, removing the internal core member 30, and performing a machining operation on the component 12, the orientation of which is to be relative to the internal features 16 of the internal cavity 14,

characterised in that

the internal core member 30 includes at least one part 38 thereof which produces in the cast component at least one externally accessible feature 40 having a known relationship to the said internal features 16 in the cast component 2, and in that

the at least one externally accessible feature 40 is used in the post-casting machining operation as a reference to indicate the position and orientation of the internal features 16 of the component 2 so as to determine the required orientation of the machining operation.

2. A method as claimed in claim 1, wherein the at least one externally accessible feature 40 is cast using an aperture 38 that passes through a portion of the core member 30 that extends outside the guide vane.
3. A method as claimed in claim 1 or 2, wherein the at least one externally accessible feature 40 is a protrusion.
4. A method as claimed in any one of the preceding claims wherein the process of investment casting around the core member 30 includes the step of casting three externally accessible features 40.
5. A method as claimed in any one of the preceding claims wherein the externally accessible feature or features 40 define three separate faces in mutually perpendicular planes.
6. A method as claimed in claim 5 wherein the three separate faces are spaced apart.
7. A method as claimed in any one of the preceding claims wherein the cast component 2 comprises a guide vane platform 6 having a double skin construction in which the internal cavity 14 is formed between first and second skins 20,22 and a post casting machining operation is carried out on one of the skins relative to internal features 16 formed in the internal cavity 14.
8. A method as claimed in claim 7, wherein the internal features 16 formed in the internal cavity 14 comprise columns that extend between the first and second skins 20,22 and the machining operation comprises drilling holes through a skin into the spaces around the said columns 16.
9. A method as claimed in any one of the preceding claims, further comprising removing the externally accessible feature 40 after the component has been machined.
10. For use in the method of any of the preceding claims a core member 30 for defining the internal cavity 14

of the cast component 2 provided with at least one part thereof which in the process of casting produces at least one externally accessible feature 40 in the cast component.

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11. An internally cooled aerofoil for a gas turbine engine, the aerofoil having internal cooling passages, internal features and at least one externally accessible feature 40, **characterised in that** the cooling passages 16, internal features and externally accessible features are formed by a common core component 30 whereby the position of the at least one externally accessible feature 40 is indicative of the position of the internal features 16 formed by the common core.

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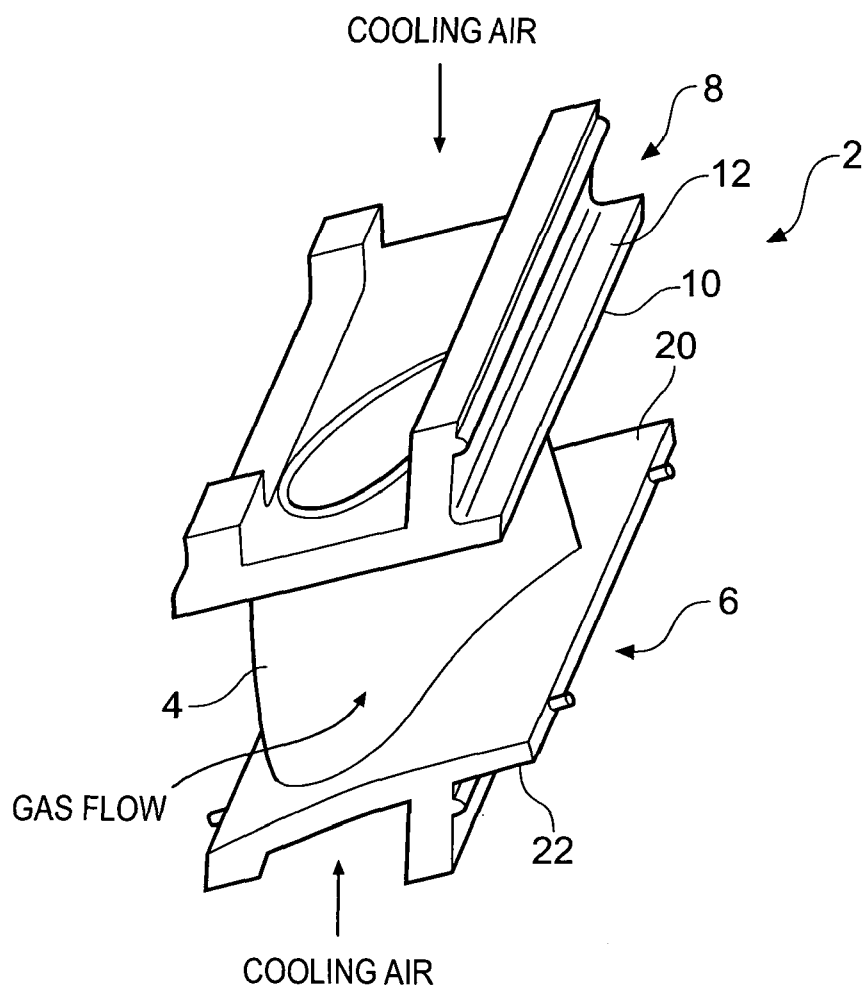


Fig. 1

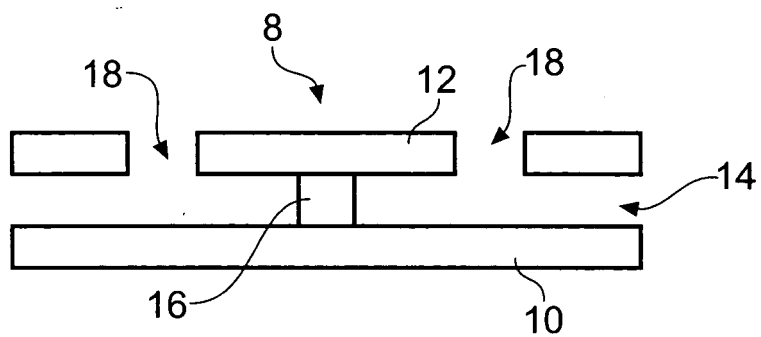


Fig. 2

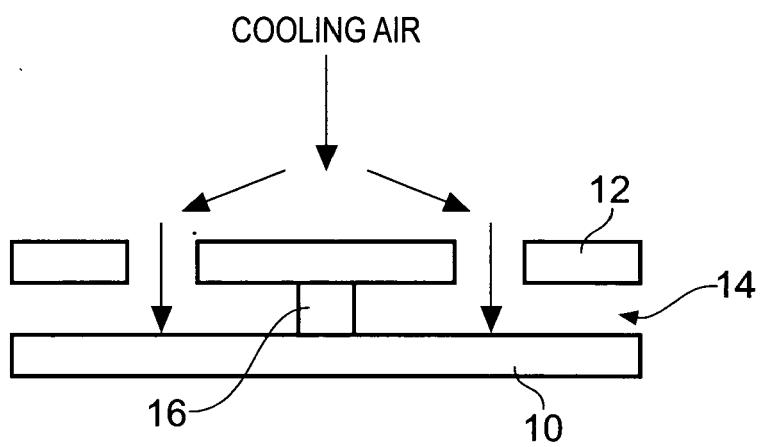


Fig. 3

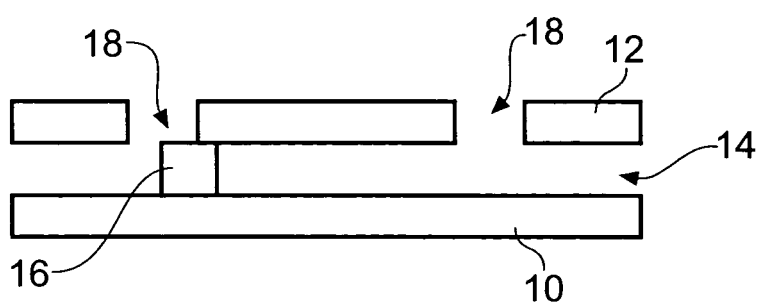


Fig. 4

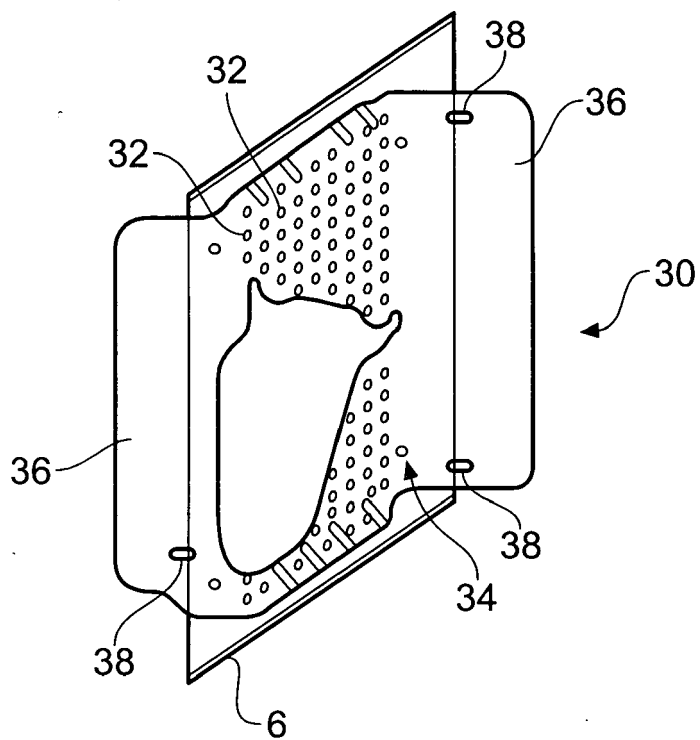


Fig. 5

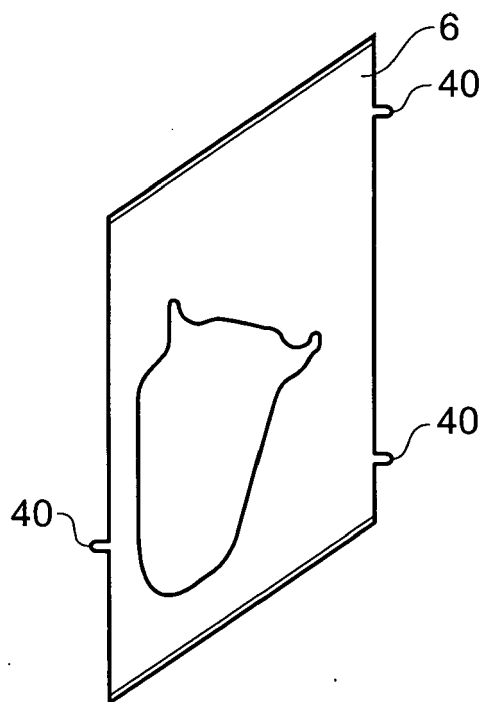


Fig. 6



European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 06 25 4256

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			B22C F01D B23H B23B
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		9 January 2007	Scheid, Michael
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

4

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 06 25 4256

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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09-01-2007

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