



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
10.08.2011 Bulletin 2011/32

(51) Int Cl.:
F01D 11/00 (2006.01) B22C 9/04 (2006.01)

(21) Application number: **11151690.2**

(22) Date of filing: **21.01.2011**

(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

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(30) Priority: **25.01.2010 US 692718**

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(54) **Cast shroud slots with pre-swirled leakage**

(57) A system (30') for forming a seal slot in a shroud assembly has a first element (32') having a longitudinally extending slot (36') and a second element (34') having a longitudinally extending slot (38') for receiving a portion of the first element (32'). The first element (32') has a pair of opposed surfaces and the second element (34')

has a pair of opposed surfaces which are oriented at an angle to the surfaces of the first element (32'). The second element (32') may have a planar portion (134') and a curved portion (42') adjacent the planar portion (134') for forming a slot which allows a flow of fluid to exit the slot at a desired angle.

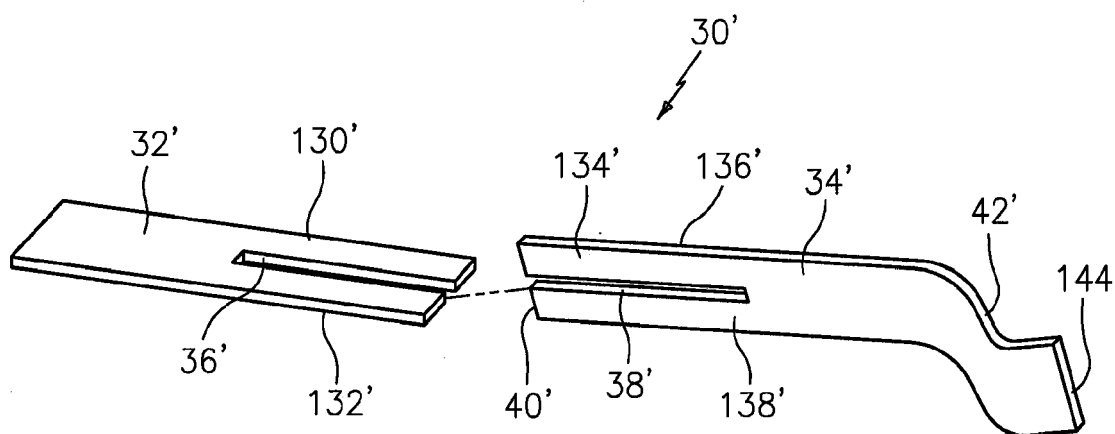


FIG. 3

Description**BACKGROUND**

[0001] The present disclosure is directed to a refractory core assembly for forming cast shroud slots with pre-swirled leakage, a process for casting turbine engine components, such as turbine vane shrouds, having as-cast shroud slots with pre-swirled leakage, and to a cast turbine engine component having shroud slots for providing pre-swirled leakage.

[0002] U.S. patent application publication no. US 2008/0145226 A1 addresses the use of refractory metal cores to cast slots into a turbine vane shroud, and avoid later manufacturing operations such as electro-discharge machining to cut the shrouds.

[0003] It is desirable to manage turbine shroud leakage flows in ways that minimize leakage mixing and acceleration to rotational speed by injecting the leakage flow at a sharp angle to the shroud to accelerate it to the rotating flow next to the shroud. It is physically difficult to angle the segmentation line of the shroud, without interfering with the structural attachment of the airfoil to the shroud wall. It is desirable to have a variable shroud segmentation cut, that addresses the need for segmentation, and acceleration of the leakage flow associated with the segmentation cut.

SUMMARY

[0004] In accordance with the present disclosure, there is provided a system for forming a seal slot in a shroud portion of a turbine engine component, which seal slot forming system broadly comprises a first element having a longitudinally extending slot and a second element having a longitudinally extending slot for receiving a portion of said first element.

[0005] Further in accordance with the present disclosure, there is provided a turbine engine component which broadly comprises a plurality of airfoils, an as-cast shroud surrounding said airfoils, and said shroud having a tailored segmentation with a curvature which alters the leakage flow to be more aligned with the rotating flow.

[0006] Still further in accordance with the instant disclosure there is provided a process for forming a turbine engine component comprising the steps of: placing a refractory core assembly comprising a first element and a second element with a non-planar position joined to said first planar element in a die; encapsulating said refractory core assembly in a wax pattern having the form of said turbine engine component; forming a ceramic shell mold about said wax pattern; removing said wax pattern; and pouring molten material into said ceramic shell mold to form said turbine engine component.

[0007] Other details of the as-cast shroud slots with pre-swirled leakage are set forth in the following detailed description wherein like reference numerals depict like elements.

BRIEF DESCRIPTION OF THE DRAWINGS**[0008]**

Fig. 1 is a top view of a portion of a turbine engine component having a segmented shroud;

Fig. 2 is a top view of a portion of a turbine engine component having a segmented shroud which provides a pre-swirled leakage;

Fig. 3 illustrates a refractory metal core system for forming the segmented shroud of Fig. 2;

Fig. 4 is a top view of the system of Fig. 3;

Fig. 5 is a side view of the system of Fig. 3;

Fig. 6 illustrates an as-cast turbine engine component having a segmented shroud;

Fig. 7 is a sectional view taken along lines 7 - 7 of Fig. 6;

Fig. 8 is a rear view of the as-cast turbine engine component of Fig. 6; and

Fig. 9 is a flow chart illustrating the process for forming the turbine engine component.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

[0009] Fig. 1 illustrates a typical turbine engine component 10 having a plurality of airfoils 12 and a segmented shroud ring 14 having a linear slot 16 between two of the airfoils 12. The angle of the slot 16 is constrained by the geometry of the airfoils 12. Steep slot angles are not possible due to the airfoil geometry.

[0010] Fig. 2 illustrates a turbine engine component 10' fabricated in accordance with the present invention. As can be seen from Fig. 2, the turbine engine component 10' has a segmented shroud ring 14' with a plurality of airfoils 12'. However, in this case, the slot 16' is not linear. The slot 16' has a contour which is curved to turn leak flow 18' to match rotor motion and the flow of fluid around the turbine engine component 10' as exemplified by the arrow 20'.

[0011] One or more as-cast slots 16' may be produced in a wall of a shroud ring 14' in between two of the airfoils 12'. Each slot 16' may be cast integrally using the metal refractory core system 30' shown in Figs. 3 - 5.

[0012] The refractory metal core system 30' is formed from two thin plates 32' and 34'. The thin plates 32' and 34' are constructed so that they can be interlocked perpendicular to each other. As can be seen from Fig. 3, the plate 32' may have a planar construction with two opposed surfaces 130' and 132'. The plate 32' further may

have a longitudinally extending slot 36' for receiving the plate 34'. Still further, the plate 32' may have a length which is shorter than the length of the plate longitudinally extending 34'. While the plate 32' has been described as having a planar, it may also be non-planar if desired.

[0013] The plate 34' may have a planar portion 134' with opposed surfaces 136' and 138'. Still further, the plate 34' may have a longitudinally extending slot 38' extending from a leading edge 40', which slot receives a planar portion of the plate 32'. The plate 34' may have a curved trailing edge portion 42' in the shape of the desired configuration for the trailing edge portion 42' of the slot 16'. The exact curvature of the trailing edge portion 42' and the angle are determined by the swirl needs and any airfoil limitations. If desired, the trailing edge portion 42' may also have a twist portion 144' to tailor the radial swirl.

[0014] Each of the plates 32' and 34' may be formed from any refractory metal or refractory metal alloy. While the plates 32' and 34' may be formed from molybdenum or a molybdenum alloy, they could also be formed from any other suitable refractory material. If desired, each plate 32' and 34' may have a thin ceramic coating applied to the base refractory metal, refractory metal alloy, or refractory material forming the respective plate.

[0015] When assembled, as shown in Figs. 4 and 5, the plates 32' and 34' form an assembly in which the surfaces 130' and 132' are at an angle with respect to surfaces 136' and 138' and the plates 32' and 34' are interlocked. For example, the surfaces 130' and 132' may be perpendicular to the surfaces 136' and 138'.

[0016] The turbine engine component 10' including the airfoils 12', and the shroud ring 14' may be formed using any suitable technique known in the art. For example, as set forth in Fig. 9, in a step 202, the refractory core assembly comprising a first planar element, namely plate 32', and a second non-planar element, namely plate 34', joined to the first planar element may be placed in a die. In step 204, the refractory core assembly is encapsulated in a wax pattern having the form of the turbine engine component 10'. In step 206, a ceramic shell mold is formed about the wax pattern. In step 208, the wax pattern is removed. In step 210, molten material is poured into the ceramic shell mold to form said turbine engine component. In step 212, the airfoils and the turbine engine component may be removed from the ceramic shell mold. In step 214, the refractory core assembly is removed after said molten material has solidified so as to form an as-cast slot in a shroud portion of the turbine engine component. The refractory core assembly removal step may be performed using an acid leach operation.

[0017] In step 202, the refractory core assembly placing step preferably comprises placing a refractory core assembly wherein said first element is fitted into a slot in said second non-planar element and said second non-planar element is fitted into a slot in said planar element.

[0018] If desired, in step 202, a plurality of refractory core assemblies may be placed in the die. Further, each refractory core assembly may be placed in a portion of

the die to be used to form an outer shroud ring and/or an inner shroud ring.

[0019] If desired, in step 210, the molten material pouring step may comprise pouring a molten material into said die to form a plurality of airfoils, such as pouring a nickel based superalloy.

[0020] The resultant turbine engine component 10' formed by the foregoing process, as shown in Figure 6, has an as-cast shroud 14' having a tailored segmentation in the form of an integral feather seal slot 16' with a curved trailing edge portion 50'. Fig. 7 is a sectional view taken along lines 7 - 7 in Fig. 6 and shows the internal portion 52' of the slot 16' formed by the plate 32'. The curved trailing edge portion 52' alters the leakage flow so that it is more aligned with the rotating flow. As can be seen from Fig. 6, the slot 16' may have a linear portion 53' adjacent a first edge 56' and the curved or angled portion 50' adjacent a second edge 58'.

[0021] Fig. 8 illustrates the segmented shroud ring 14' with a flow of fluid 54' being discharged from the slot 16'. As can be seen from this figure, the fluid is pre-swirled and flows in the direction of rotation. Such a flow reduces losses.

[0022] Separation (segmentation) of the shroud is useful because it relieves stress caused by the ring-strut-ring structure, i.e. a hot airfoil is overly constrained by cold inner and outer diameter rings.

[0023] Using the refractory metal core plates such as plates 32' and 34' is advantageous because one can form complex slot shapes directly into the casting, without complex machining operations. The more complex the shape, the less likely the slot can be machined.

[0024] The refractory metal core plates can be made very thin compared to a ceramic core. A ceramic core of similar thickness, i.e. 0.008 to 0.010" (0.203 to 0.254 mm) or less, would likely result in low casting yield because it could easily break during handling, assembly, wax injection, or during the pour of molten metal. Ceramics are very fragile compared to metals.

[0025] It is apparent that there has been described herein as-cast shroud slots with pre-swirled leakage. While the disclosure has been set out in the form of specific embodiments, other unforeseeable variations, modifications, and alternatives may become apparent to those skilled in the art having read the foregoing specification. Accordingly, it is intended to embrace those unforeseen alternatives, modifications, and variations as fall within the broad scope of the appended claims.

Claims

1. A system (30') for forming a seal slot (16') in a shroud assembly, said system comprising a first element (32') having a longitudinally extending slot (36') and a second element (34') having a non-planar portion (42') and a longitudinally extending slot (38') for receiving a portion of said first element (32').

2. The system of claim 1, wherein said first element (32') has a pair of opposed surfaces and said second element (34') has a pair of opposed surfaces which are oriented at an angle with respect to said surfaces of said first element (32').
3. The system of claim 1 or 2, wherein said second element (34') has a planar portion (134') and said non-planar portion (42') comprises a curved portion adjacent said planar portion (134').
4. The system of any preceding claim, wherein said first element (32') has a first length and said second element (34') has a second length greater than said first length.
5. The system of any preceding claim, wherein each of said first and second elements (32', 34') is formed from a refractory metal material.
6. The system of any preceding claim, wherein said second element (34') has a portion (144') with a twist.
7. A turbine engine component comprising:
 - a plurality of airfoils (12');
 - an as-cast shroud (14') surrounding said airfoils; and
 - said as-cast shroud (14') having a tailored segmentation with a curvature which alters the leakage flow to be more aligned with the rotating flow.
8. The turbine engine component of claim 7, wherein said tailored segmentation has a linear portion (53') adjacent a first edge (56') of said shroud (14') and an angled portion (50') adjacent a second opposed edge (58') of said shroud (14').
9. The turbine engine component of claim 8, wherein said angled portion (50') of said slot has an angle sufficient to turn said fluid flow to match a rotational flow about said turbine engine component.
10. A process for forming a turbine engine component comprising the steps of:
 - placing a refractory core assembly (30') comprising a first element (32') and a second element (34') having a non-planar portion (42') joined to said first element in a die;
 - encapsulating said refractory core assembly (30') in a wax pattern having the form of said turbine engine component;
 - forming a ceramic shell mold about said wax pattern;
 - removing said wax pattern; and
 - pouring molten material into said ceramic shell mold to form said turbine engine component.
11. The process of claim 10, wherein said refractory core assembly placing step comprises placing a refractory core assembly (30') wherein said first element (32') is fitted into a slot (38') in said second element (34') and said second element (34') is fitted into a slot (36') in said first element (32').
12. The process of claim 10 or 11, further comprising removing said refractory core assembly (30') after said molten material has solidified so as to form a slot in a wall of a portion of said turbine engine component, for example using an acid leach operation.
13. The process of claim 10, 11 or 12 wherein said placing step comprises placing a plurality of refractory core assemblies (30') in said die.
14. The process of any of claims 10 to 13, wherein said placing step comprises placing said refractory core assembly (30') in a portion of said die to be used to form at least one of an outer shroud ring and an inner shroud ring.
15. The process of any of claims 10 to 14, wherein said molten material pouring step comprises pouring a nickel based superalloy.

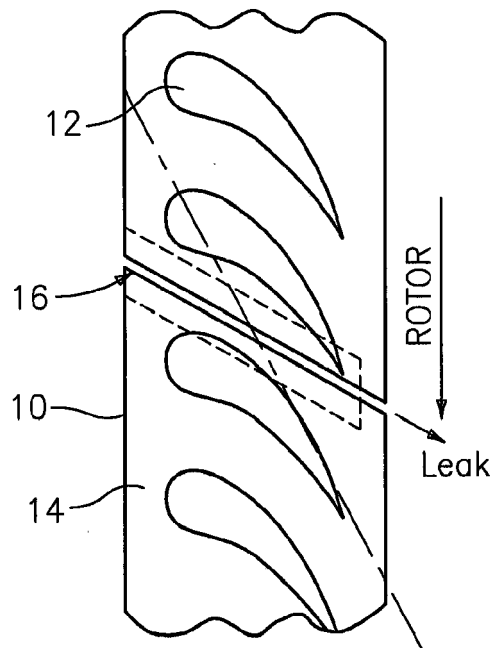


FIG. 1

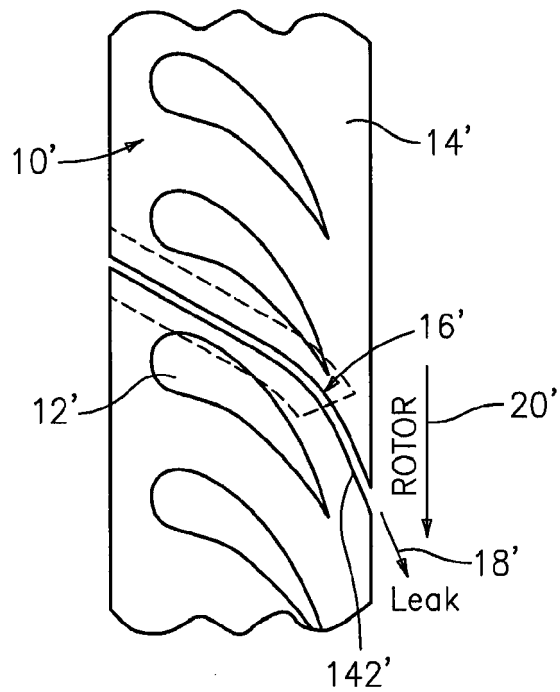


FIG. 2

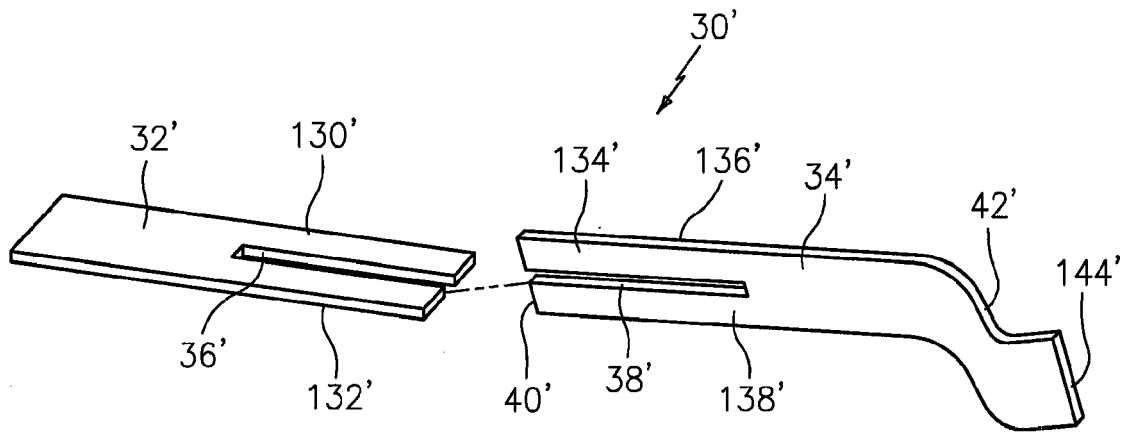


FIG. 3

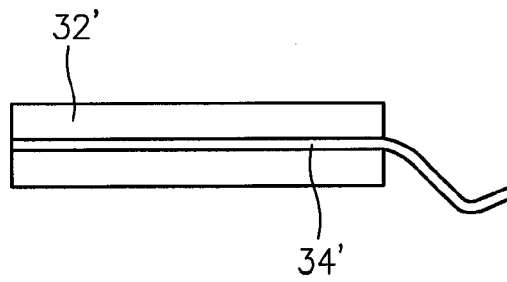


FIG. 4

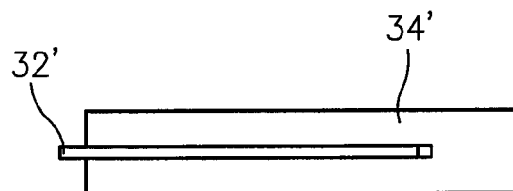


FIG. 5

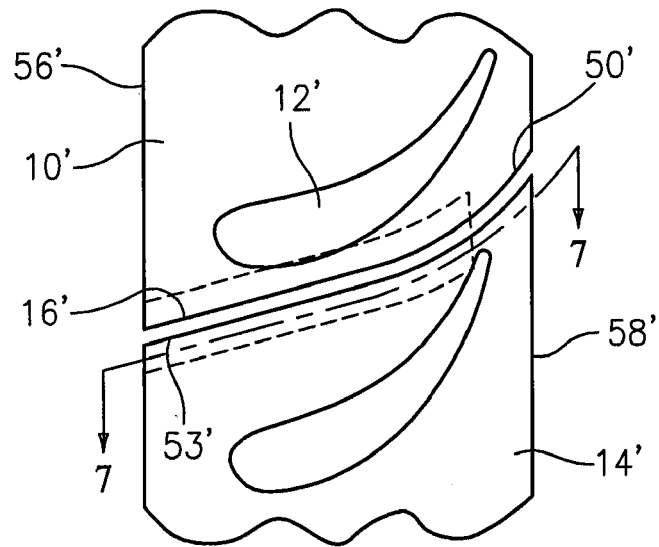


FIG. 6

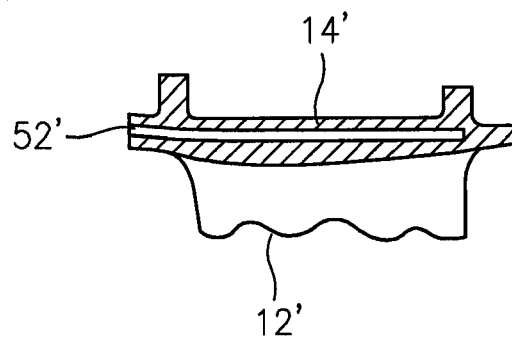


FIG. 7

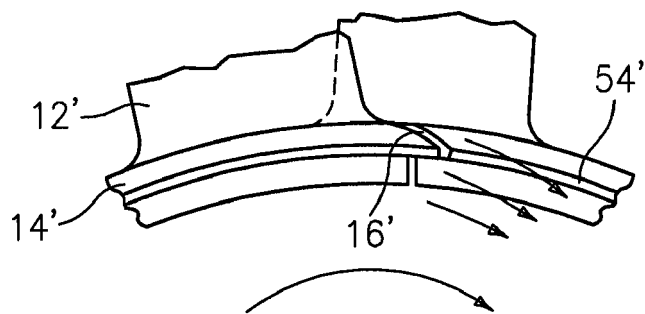


FIG. 8

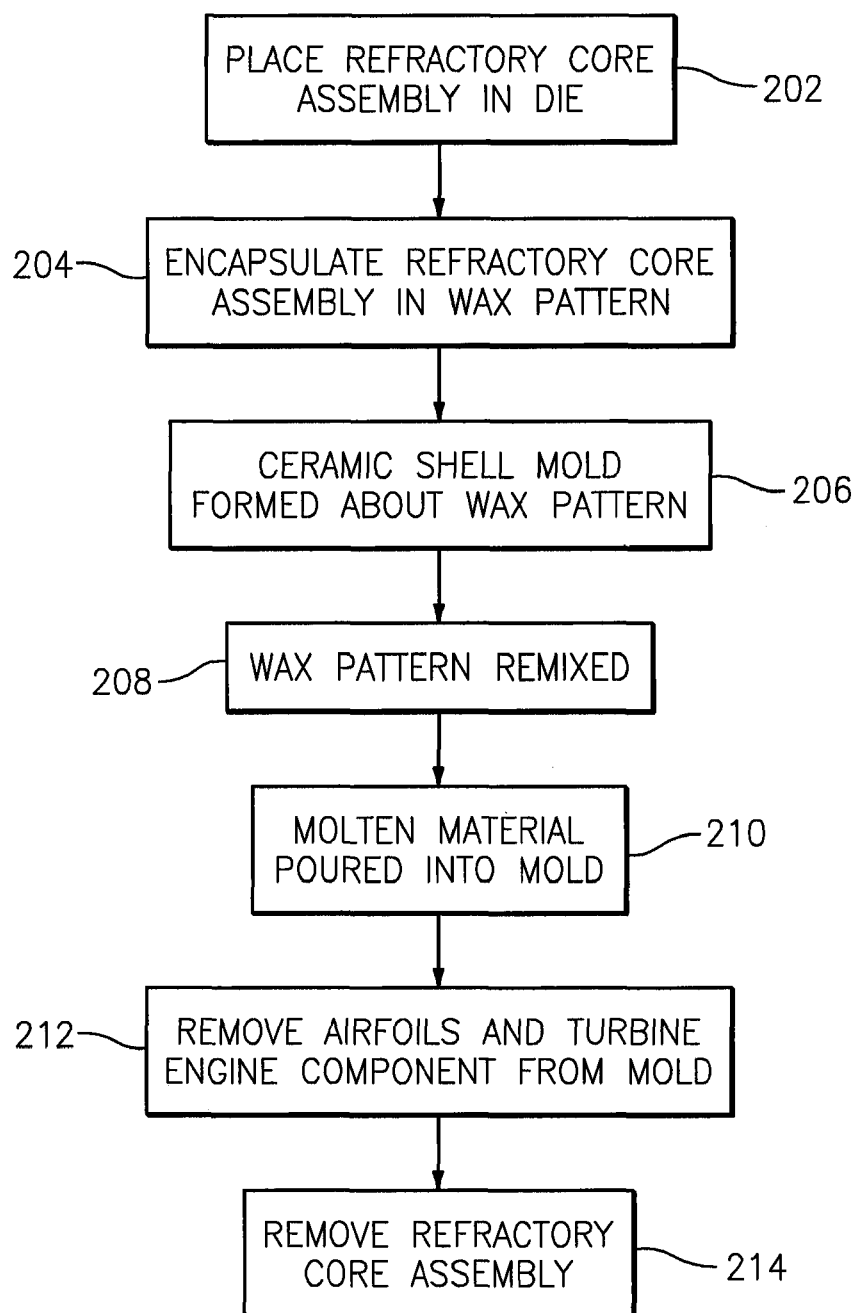


FIG. 9

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 20080145226 A1 [0002]