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(54) **METHOD FOR PRODUCING HOLLOW BLADES**

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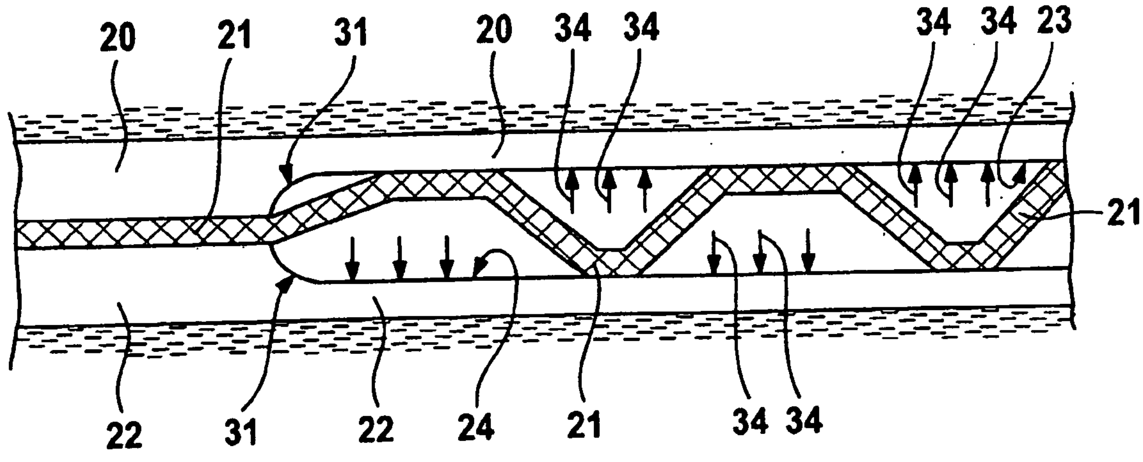
(57) **ABSTRACT**

A method for producing hollow blade blades, in particular for gas turbines such as aircraft jet engines is provided. At least three elements (**20**, **21**, **22**) are located one on top of the other in a sandwich structure, are joined together at least in sections by diffusion welding and are then superplastically formed by expansion in such a way that a first element (**20**) forms a first external wall of the hollow blade to be produced, a second element (**22**) forms a second external wall of the hollow blade to be produced and a third element (**21**) forms a central element running between the two external walls of the hollow blade to be produced. At least one nick-minimizing structure is introduced into the first element (**20**) and the second element (**22**), which form the two external walls of the hollow blade to be produced, before said elements are arranged together with the third element (**21**) in the sandwich structure.



Prior Art

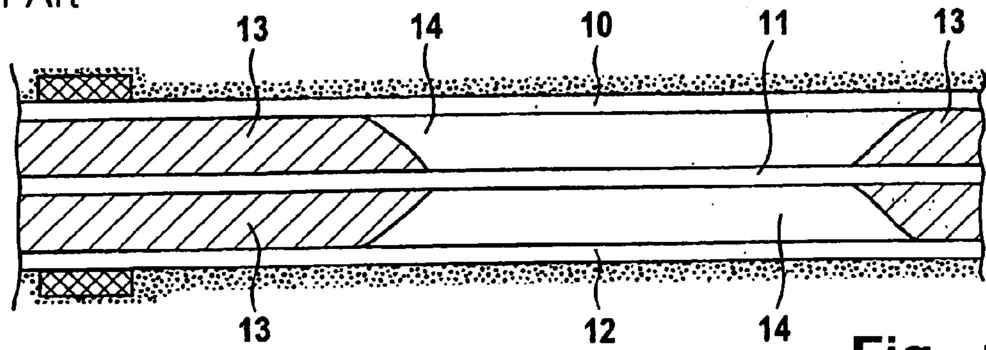


Fig. 1

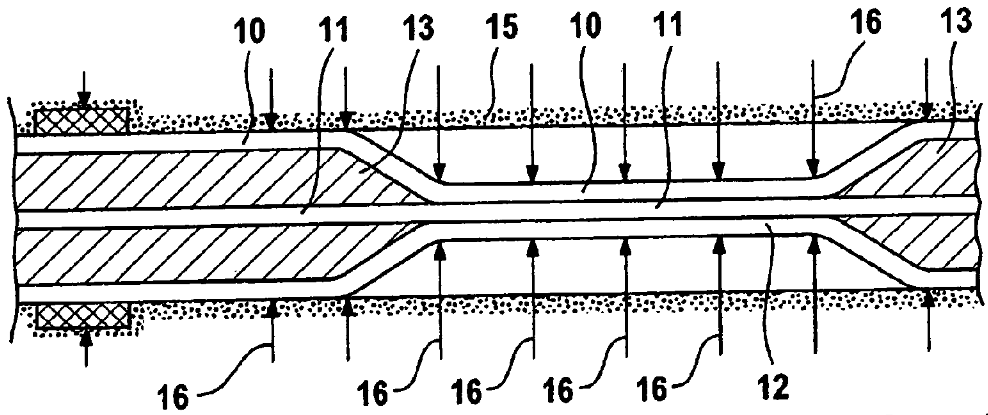


Fig. 2

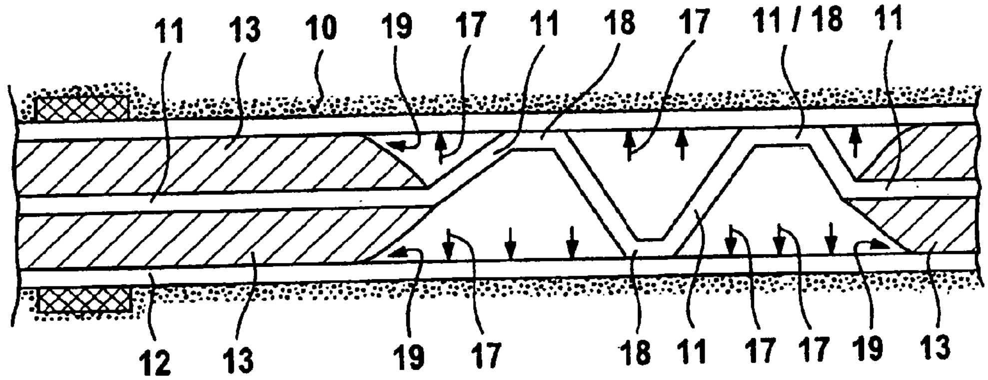


Fig. 3

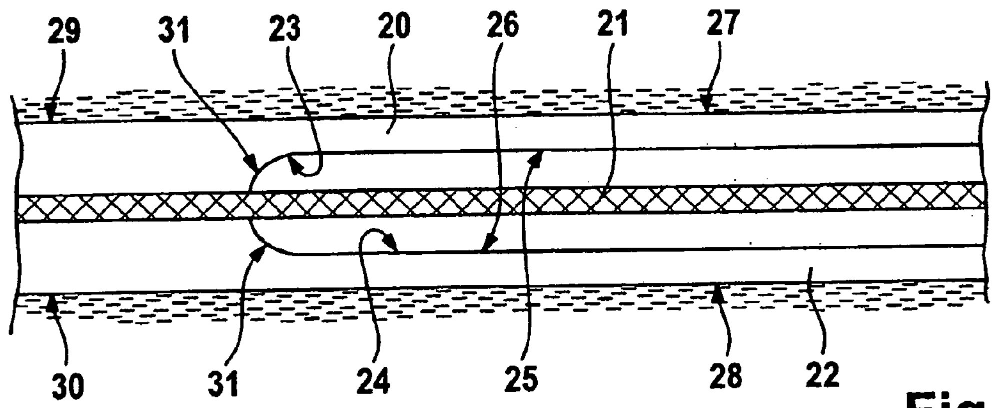


Fig. 4

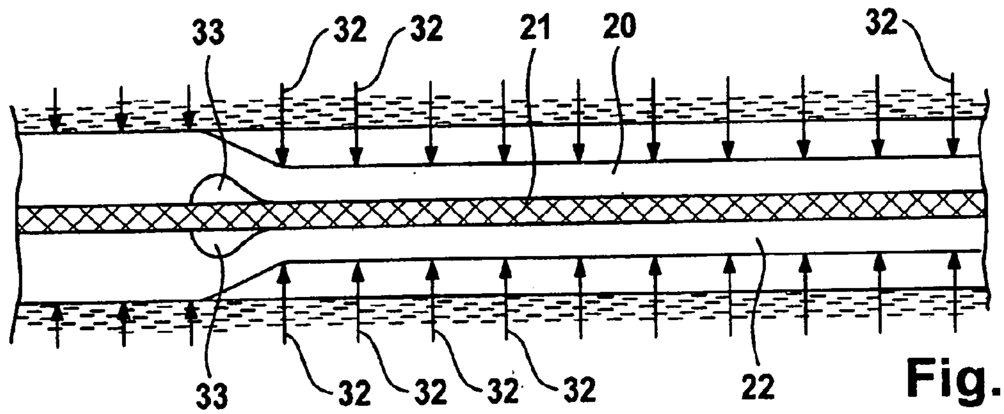


Fig. 5

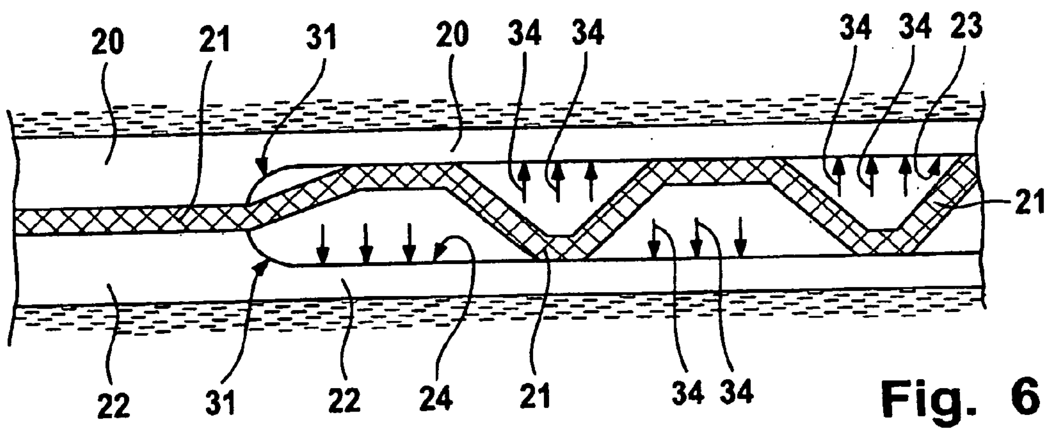


Fig. 6

METHOD FOR PRODUCING HOLLOW BLADES

[0001] The present invention relates to a method for manufacturing hollow blades, in particular for gas turbines, according to the definition of the species set forth in claim **1**.

[0002] Present-day gas turbines, in particular aircraft engines, must meet exceedingly stringent requirements in terms of reliability, weight, performance, economy and service life. In recent decades, aircraft engines have been developed, particularly for use in the civil sector, which have fully satisfied the above requirements and have attained a high level of technical perfection. The selection of material, the search for new types of suitable material, as well as the quest for novel manufacturing processes play a decisive role in aircraft engine development.

[0003] To reduce the weight of gas turbine components, it is already known from the related art to design gas turbine blades as hollow blades. The blades of a gas turbine account namely for a considerable proportion of its weight. The more appreciably the weight of the gas turbine can be reduced, the more favorable the so-called thrust-to-weight ratio of the aircraft engine is obtained, which is a decisive feature for aircraft engines in terms of achieving a competitive advantage.

[0004] A related art method commonly used for manufacturing hollow blades is the so-called SPF DB method, SPF being an acronym for super plastic forming and DB an acronym for diffusion bonding. In the SPF DB method for manufacturing hollow blades, at least three elements are arranged one over another in a sandwich-type structure, joined to one another at least in portions thereof by diffusion welding, and subsequently superplastically deformed by inflation or blow-up processes. A first element forms a first outer wall of the hollow blade to be manufactured, a second element forms a second outer wall of the hollow blade to be manufactured, and a third element, which is placed prior to the diffusion welding process in a sandwich-type structure between the first and the second element, forms a middle element of the hollow blade to be manufactured that extends in between the two outer walls. In the SPF DB methods known from the related art for manufacturing hollow blades, nicks, which have a strength-reducing effect, may form inside of the hollow blade. This is disadvantageous.

[0005] Against this background, the object of the present invention is to devise a novel method for manufacturing hollow blades.

[0006] This objective is achieved in that the method mentioned at the outset is further refined by the features set forth in the characterizing portion of claim **1**. In accordance with the present invention, at least one nick-minimizing structure is introduced in each case into the first element and the second element which form the two outer walls of the hollow blade to be manufactured, before assembling the same, together with the third element, to form a sandwich-type structure. In the method according to the present invention presented here, an SPF DB method for manufacturing hollow blades is provided, the hollow blades not having any strength-reducing, internal nicks.

[0007] One advantageous further refinement of the present invention provides for the or each nick-minimizing structure to be introduced into an inner side of the first element and of the second element in a way that results in a smaller material thickness for the elements in a middle section than in the lateral sections. Between the middle section and the lateral sections, the elements have a continuous or stepless transitional profile.

[0008] The pressure required for diffusion welding is preferably supplied in such a way that, during the diffusion welding process, the first element and the second element are pressurized in the area of the or of each continuous or stepless transitional profile in such a way that, following the diffusion welding in the area of the or of each transitional profile, a groove space is formed.

[0009] Preferred embodiments of the present invention are derived from the dependent claims and from the following description. The present invention is described in greater detail in the following on the basis of exemplary embodiments, without being limited thereto. Reference is made to the drawing, whose:

[0010] FIG. **1**: shows a schematized representation for clarifying a method according to the related art for manufacturing hollow blades;

[0011] FIG. **2**: shows another schematized representation for explaining the method according to the related art for manufacturing hollow blades;

[0012] FIG. **3**: shows another schematized representation for clarifying the method according to the related art for manufacturing hollow blades;

[0013] FIG. **4**: shows a schematized representation for illustrating the method according to the related art for manufacturing hollow blades;

[0014] FIG. **5**: shows another schematized representation for clarifying the method according to the related art for manufacturing hollow blades; and

[0015] FIG. **6**: shows another schematized representation for explaining the method according to the present invention for manufacturing hollow blades.

[0016] Prior to describing the method according to the present invention for manufacturing hollow blades in detail in the following with reference to FIG. **4** through **6**, the SPF DB method known from the related art for manufacturing hollow blade shall be described first, in order to elucidate the differences between the related art and the invention presented here.

[0017] In the SPF (super plastic forming) DB (diffusion bonding) method known from the related art for manufacturing hollow blades, three plate-shaped or sheet-shaped elements **10**, **11** and **12** are arranged one over the other in a sandwich-type structure, frame elements or frame strips **13** being positioned between each of two adjacent, plate-shaped elements **10** and **11**, as well as **11** and **12**. This sandwich-type structure is illustrated in FIG. **1**, hollow spaces **14** being formed in those regions in which no frame strips **13** are positioned between two adjacent elements **10** and **11**, as well as **11** and **12**, respectively.

[0018] In accordance with the related art, elements **10**, **11**, **12** and **13** assembled in this manner one over another in a sandwich-type structure are joined to one another at least in portions thereof by diffusion welding. To this end, the sandwich-type structure of FIG. I is placed in a suitable device **15**, and a pressure required for diffusion welding is applied to the sandwich-type structure. Elements **10**, **11**, **12** and **13** are diffusion-welded to one another, at least in portions thereof, under the action of the pressure that is graphically represented by arrows **16**. This is illustrated by FIG. **2**.

[0019] Thus, in accordance with the related art as shown in FIG. **3**, the diffusion-welded stack composed of elements **10** through **13** is superplastically deformed by inflation or blow-up processes. To this end, gas in introduced into the diffusion-welded stack made up of elements **10**, **11**, **12** and **13**, in the direction of arrows **17**. During the superplastic deformation process, elements **10** and **12** acquire a shape that corresponds to the desired blade profile of the hollow blade. This blade profile is curved in order to provide an intake side as well as a thrust side for the blades. For the sake of a simpler representation, in FIG. **3**, the two elements **10** and **12**, which form the outer walls of the hollow blade to be manufactured, extend in parallel to one another following the inflation or superplastic deformation process.

[0020] As can be inferred from FIG. **3**, element **11**, which extends in between the two elements **10** and **12** functioning as outer walls, takes on the shape of a meander structure in the region between frame strips **13**. As can likewise be inferred from FIG. **3**, element **11**, which extends in between the two elements **10** and **12** functioning as outer walls, is joined in portions thereof to one of the two elements **10** and **12** functioning as outer walls. In those portions in which middle element **11** is not joined to one of the two elements **10** and **12**, subsequently to the superplastic deformation, element **11** extends in a zigzag or meander shape between the two elements **10** and **12** forming the two outer walls. To ensure that middle element **11** is joined in parts or portions thereof to the two elements **10** and **12** along the lines of FIG. **3**, middle element **11** is coated in sections with an antidiffusion coating, middle element **11** not being joined to elements **10** or **12** in the region of the antidiffusion coating.

[0021] As can be inferred from FIG. **3**, under the related art, nicks **19**, which seriously degrade the strength of the manufactured hollow blades, form in a transitional region between elements **10** and **12** and frame strips **13**.

[0022] The method according to the present invention for manufacturing hollow blades is described in the following with reference to FIG. **4** through **6**. In accordance with the present invention, three elements **20**, **21** and **22** are again arranged one over another in a sandwich-type structure, joined to one another at least in portions thereof by diffusion welding, and, subsequently to the diffusion welding process, superplastically deformed. A first element **20** forms a first outer wall of the hollow blade to be manufactured, a second element **22** forms a second outer wall of the hollow blade to be manufactured, and a third element **21**, which extends in between the two outer walls of the hollow blade to be manufactured, forms a middle element.

[0023] Along the lines of the present invention, nick-minimizing structures are introduced into first element **20**, as well as into second element **22**, which form the two outer walls of the hollow blade to be manufactured, before assembling the same, together with third element **21**, to form a sandwich-type structure. In this context, the nick-minimizing structures are introduced into one inner side **23** and **24** of the two elements **20** and **22**, respectively. FIG. **4** shows that, once elements **20**, **21** and **22** are assembled to form a sandwich-type structure, inner sides **23** and **24** face middle element **21**.

[0024] The nick-minimizing structures are constituted of recesses **25** and **26**. Recesses **25** and **26** extend as planar regions over respective inner sides **23** and **24** of elements **20** and **22**. Recesses **25** and **26** are introduced into inner sides **23** and **24** of elements **20** and **22** in such a way that, in one middle section **27** or **28**, elements **20** and **22** have a smaller material thickness or cross-sectional area than in lateral sections **29** or **30**. In a transitional region between middle section **27** and **28** and lateral sections **29** and **30**, respectively, recesses **25** and **26** exhibit a continuous or stepless transitional profile **31**. In cross section, transitional profiles **31** have a circular or elliptical form. Recesses **25** and **26** are machined into inner sides **23** and **24** of elements **20** and **22**, respectively, in particular by milling.

[0025] In accordance with FIG. **4**, elements **20** through **22** designed in this manner are arranged one over another to form a sandwich-type structure, as already mentioned, inner sides **23** and **24** having recesses **25** and **26**, respectively, facing middle element **21**.

[0026] A sandwich-type structure designed in this manner is then diffusion-welded together at least in portions or regions thereof in a diffusion welding process. To this end, here as well, an appropriate pressure is applied to the sandwich-type structure in the direction of arrows **32**. The pressure required for diffusion welding is supplied in such a way that, following the diffusion welding process, a groove space **33** is formed in the region of transitional profiles **31**. To prevent groove spaces **33** from collapsing during the diffusion welding process, the pressure required for diffusion welding is supplied by a mechanical press which limits the pressure introduced in the region of transitional profiles **31**. FIG. **5** shows the structure that forms following the diffusion welding process, as well as groove spaces **33** which form following the diffusion welding process in the region of transitional profiles **31**.

[0027] The assembly of elements **20** through **22** diffusion-welded in the above manner is subsequently superplastically deformed, in turn, by inflation or blow-up processes. To this end, by introducing gas into the diffusion-welded structure, pressure acts, in turn, in the direction of arrows **34** on inner sides **23** and **24** of elements **20** and **22**. Following the superplastic deformation, a nick-free structure of the hollow blade is produced, particularly in the region of transitional profiles **31** (see FIG. **6**).

[0028] Accordingly, the method according to the present invention along the lines of FIG. **4** through **6** is distinguished from the known related-art method along the lines of FIG. I through **3** in that specially designed elements **20** and **22**, which later form the outer walls of the hollow blade to be manufactured, are provided. In this manner, strength-reducing nicks may be avoided, on the one hand, inside of the hollow blade; on the other hand, the need is eliminated for separately formed frame strips. The function of the frame strips required in accordance with the related art is assumed in the method according to the present invention by the lateral sections **29** and **30** of elements **20** and **22**, respectively. In this way, the manufacturing method is able to be clearly simplified over the related art.

1-11. (canceled)

12. A method for manufacturing hollow blades, comprises:
providing at least a first element, a second element, and a third element, an inner side of each of the first and second elements having a planar recess;
arranging the first, second and third elements one over another in a sandwich-type structure;
joining the first, second and third elements to one another at least in portions thereof by diffusion welding;
superplastically deforming the sandwich-type structure via an inflation processes, such that the first element forms a first outer wall of a hollow blade to be manufactured, the

second element forms a second outer wall of the hollow blade to be manufactured, and the third element forms a middle element of the hollow blade to be manufactured which extends in between the first and second outer walls, and a portion of the third element is spaced apart from the planar recesses.

13. The method of claim **12**, wherein the inner side of the first element faces one side of the third element, and the inner side of the second element faces an opposite side of the third element.

14. The method as recited in claim **13**, wherein the planar recesses extend over a portion of the inner sides of the first element and of the second element., such that a middle section of the first element and a middle section of the second element has a smaller material thickness than lateral sections of the first and second elements respectively.

15. The method as recited in claim **14**, wherein, between the middle section and the lateral sections of each of the first and second elements, the respective recesses have a continuous or stepless transitional profile.

16. The method as recited in claim **15**, wherein, in cross section, the continuous or stepless transitional profile has a circular or elliptical form.

17. The method as recited in claim **16**, wherein the recesses are introduced into the inner sides of the first element and of the second element, respectively, by milling.

18. The method as recited in claim **13**, wherein the pressure required for diffusion welding is supplied such that, during the diffusion welding process, the first element and the second element are pressurized in the area of the or of each continuous or stepless transitional profile such that, following the diffusion welding in the area of the or of each transitional profile, a groove space is formed.

19. The method as recited in claim **18**, wherein the pressure is supplied by a mechanical press.

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