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(54) **TURBINE BLADE**

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(57) **ABSTRACT**

A turbine blade is provided having a blade and a modular platform which follow one another along a longitudinal axis of the turbine blade. In order to provide a modular turbine blade that has an especially plain and simple design and that ensures an especially reliable, long-lasting, durable connection of the individual components among each other, the blade has an extension and the platform has an outer platform part and an at least two-part inner platform part which is radial in relation to the longitudinal axis and which lie laterally against the extension of the blade, and the outer platform part is designed as an endless platform frame that surrounds the outer edge of the inner platform part.

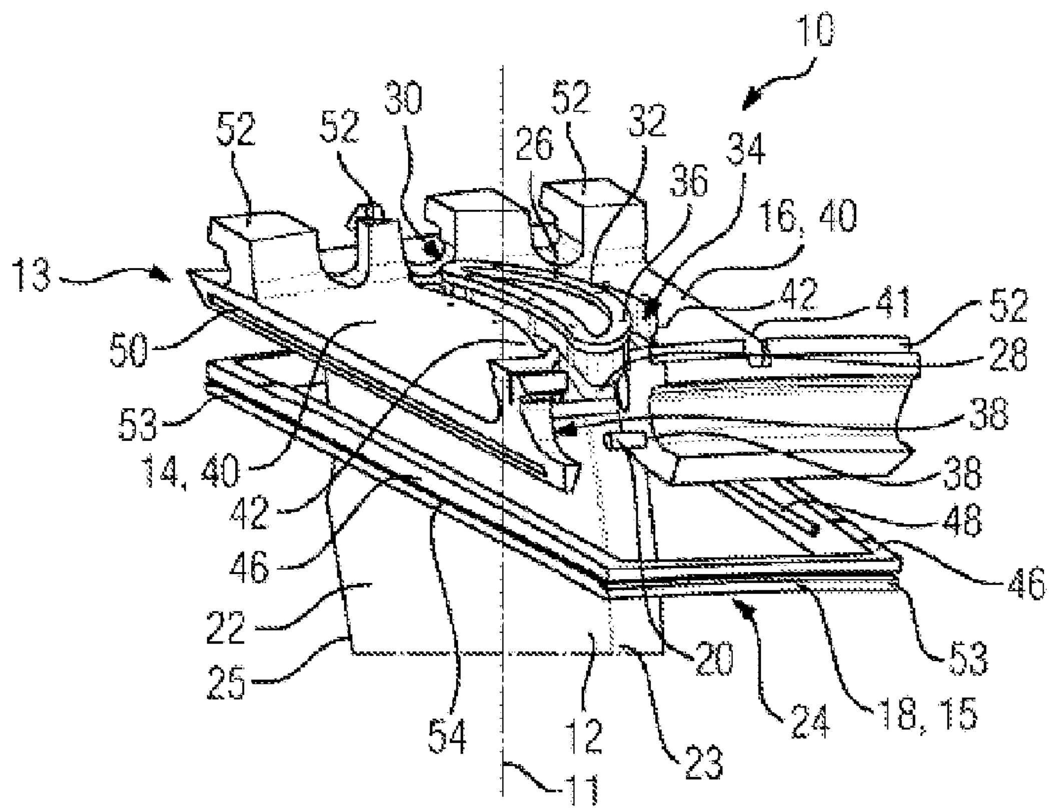

FIG 1

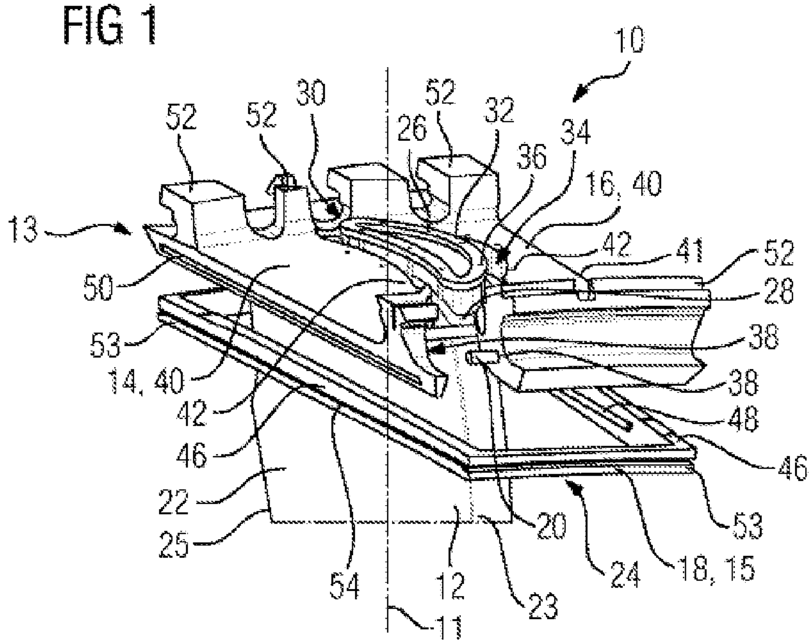
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FIG 2

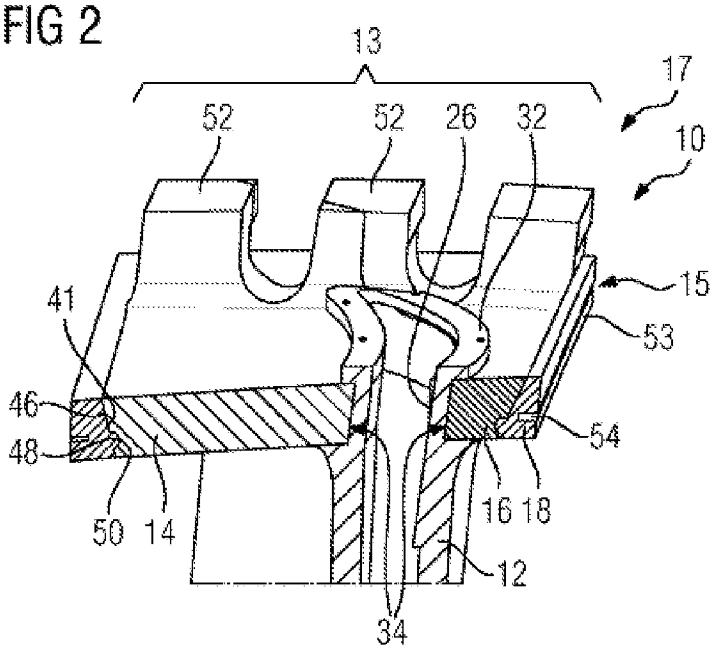
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FIG 3

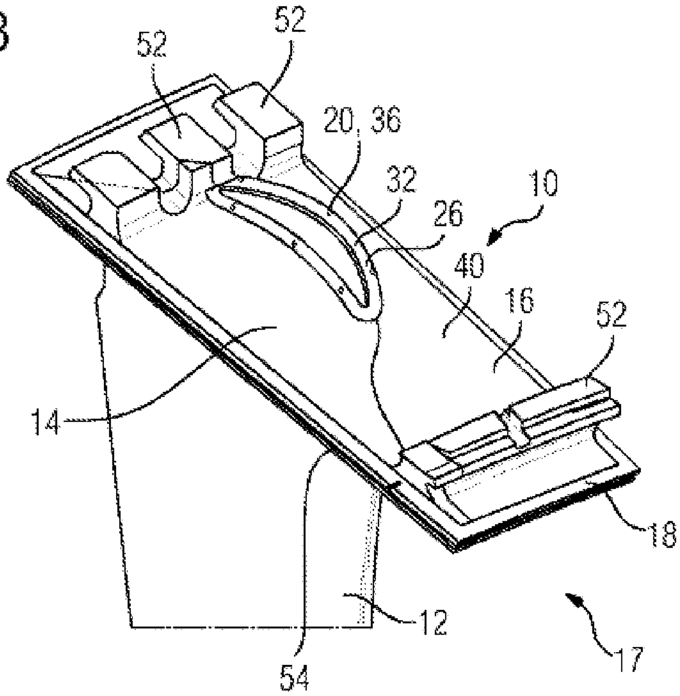
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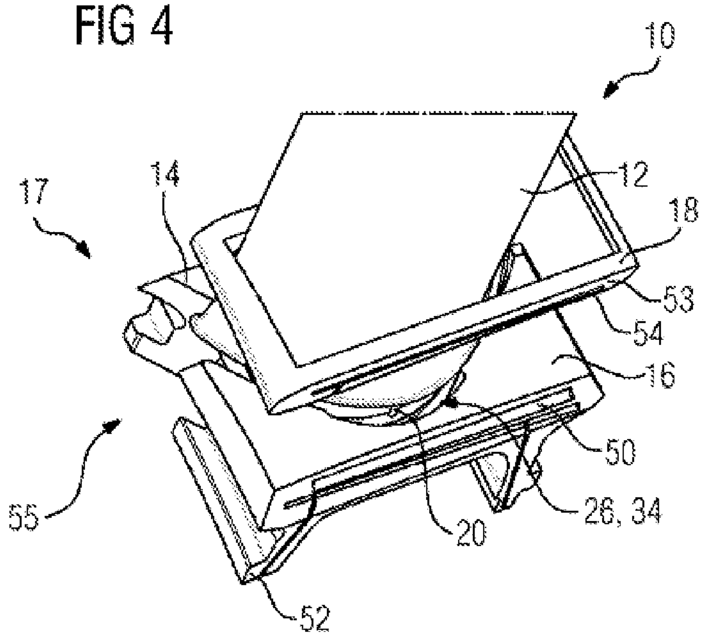
FIG 4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TURBINE BLADE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is the US National Stage of International Application No. PCT/EP2013/056652 filed Mar. 28, 2013, and claims the benefit thereof. The International Application claims the benefit of European Application No. EP12162106 filed Mar. 29, 2012. All of the applications are incorporated by reference herein in their entirety.

FIELD OF INVENTION

[0002] The invention relates to a turbine blade having a platform and a blade airfoil in direct succession along a longitudinal axis of the turbine blade.

BACKGROUND OF INVENTION

[0003] A great many types of turbine blades and methods for manufacturing turbine blades are known from the extensive available prior art. For example, turbine blades for gas turbines are often manufactured by casting. In casting, the blade root, platform and blade airfoil are simultaneously formed from the casting material, such that turbine blades of this type are one-piece. Subsequently, those surfaces which are exposed to the hot gas of the turbine are also provided with a corrosion protection layer and a thermal protection layer in order to increase the service life of the turbine blade. Cast turbine blades are also generally hollow in order that a coolant for cooling the blade material can flow inside. Turbine blades of steam machines are generally milled from solid or are forged.

[0004] Turbine blades used in static turbomachines are subjected, in operation, to a multiplicity of loads which cause the turbine blades to age and wear both in foreseeable and non-foreseeable ways.

[0005] Specifically, both low-cyclic and higher-cyclic fatigue loads and also thermomechanical loads arise. In addition, turbine blades have to be protected from oxidation and from creep. The loads mentioned previously affect in particular those surfaces and components of the turbine blades which are directly exposed to the hot gas or hot steam. On the attachment side, turbine blades are also exposed to what are termed “bearing loads” and “frictional loads”. In light of these various loads and requirements, the material of one-piece turbine blades must be chosen such that, as far as possible, a multiplicity if not all of the loads are taken up by the material without premature ageing or a premature end of the service life of the turbine blade being reached. With respect to the thermal load and with respect to the corrosion load, it is for example known to equip turbine blades of gas turbines with a layer system which protects the material of the turbine blade both from corrosion and from an excessive introduction of heat.

[0006] Nonetheless, wear phenomena such as cracks can appear in various regions of the turbine blade and endanger the operation of the turbomachine. For this reason, it is known to check turbine blades for such defects after a predetermined service period and, if one of these is discovered, to replace or recondition the affected turbine blades.

[0007] Furthermore, modular turbine blades, in which the blade airfoil and the platform are separately manufactured components which are assembled with the aid of various constructions or joined connections to form a turbine blade, are known from the prior art. Examples of such modular turbine blades are for example disclosed in documents US 2010/054932 A1, JP 92 041902 A, EP 2 213 839 A2, US 2011/0142639 A1, U.S. Pat. No. 4,650,399, DE 103 46 240 A1 and FR 2463 849 A1. Various solutions are described for securing the components which, in part, are made from different materials. These range from bracing by means of tie rods (JP 92 041902 A) to screwed connections (US 2010/054932 A1) or pin connections (U.S. Pat. No. 4,650,399 A1) to soldering or welding (DE 103 46 240 A1). Modular turbine blades are thus often very onerous in terms of construction and finishing.

[0008] A further disadvantage may for example reside in a service life which is shorter in comparison with a monolithic turbine blade, which arises on account of a construction and/or connection of the individual components which is only of limited reliability.

SUMMARY OF INVENTION

[0009] It is an object of the invention to provide a modular turbine blade which is constructed and assembled in a particularly simple and yet most reliable fashion.

[0010] The object concerning the turbine blade is achieved by means of one such blade according to the features of the claims.

[0011] According to aspects of the invention, the turbine blade comprises at least one platform and a blade airfoil in direct succession along a longitudinal axis of the turbine blade—corresponding to the radial direction of a turbomachine—wherein the blade airfoil has a projection in the longitudinal direction and the platform comprises—in radial relation to the longitudinal axis—an outer platform part and an at least two-part inner platform part, wherein the inner platform part bears laterally against the projection of the blade airfoil and the outer platform part is formed as an endless platform frame which grips around the outer edge of the inner platform part. The main components of the inner platform part are here respectively labeled as platform elements.

[0012] Aspects of the invention are based on the knowledge that separately manufactured platform elements of a turbine blade can be particularly simply attached to a separately manufactured blade airfoil if these are placed laterally against and end-side extension of the blade airfoil, what is termed a projection, and the two platform elements are pressed against the projection of the blade airfoil with the aid of a clamp. For example, a first platform element can be arranged on the suction side of the projection of the blade airfoil, and a second platform element can be arranged on the pressure side. The clamp is configured as an endless circumferential platform frame. The platform frame can, by virtue of its annular—endless—form, clamp around the platform elements in a shrink fit, such that it is no longer strictly necessary to further secure the platform frame against any losses.

[0013] The projection of the blade airfoil is set back with respect to the pressure-side and suction-side blade airfoil surface by means of a step, such that the platform elements bearing against the step cannot move parallel to the longitudinal axis of the turbine blade.

[0014] The cross section of the platform frame can have various shapes. Preference is given, however, to such shapes as bring about a form fit with the rim of the inner platform part. For example, the cross section may be lozenge-shaped or

C-shaped. In that context, the rim of the inner platform part is always embodied in corresponding fashion to the cross section shape.

[0015] A particular advantage of the turbine blade according to aspects of the invention is that, in particular, two different materials may also be used for the platform elements, the blade airfoil and for the platform frame. It is thus in addition possible to take into account the different local loads, which can lead to an extended service life of the turbine blade.

[0016] A further advantage of the turbine blade according to aspects of the invention is the increased precision with respect to the outer dimensions of the platform since these are easier to bring about when manufacturing the platform frame than when casting a purely monolithic turbine blade.

[0017] Various methods can be used for the durable connection of the platform frame to the platform elements. Since the platform frame is configured as an endless frame, shrink-fitting the platform frame onto the circumferential rim of the inner platform part is preferred. Before shrink-fitting, the platform frame may be heated and/or the platform elements may be cooled. After assembling the platform frame and the platform elements and after a subsequent temperature equalization, the platform frame is then seated securely on the circumferential rim of the inner platform part. Spot-welding and—soldering, and welding or soldering along the connection line from the rim of the inner platform part and platform frame, are also possible.

[0018] Of particular advantage is that development in which a collar is formed at the free end of the projection of the blade airfoil, which collar provides, in conjunction with the step, a groove which is endless in the circumferential direction of the profile of the blade airfoil, into which groove the platform elements of the inner platform part are inserted in form-fitting fashion. The platform elements then have, close to the projection, a wall thickness which corresponds substantially to the width of the groove.

[0019] The particular feature of the proposed turbine blade is that the platform elements are placed against the projection by means of a movement perpendicular to the longitudinal axis, and their securing element against a return movement, in the form of the platform frame, is placed over the platform elements with a movement transverse thereto—that is to say parallel to the longitudinal axis. Thereafter, it is simply necessary to ensure that only the platform frame is secured against releasing. A displacement of the platform, comprising the platform elements and the platform frame, parallel to the longitudinal axis is also blocked on account of the step between the actual blade airfoil and the projection, and on account of the collar on the projection.

[0020] The inner platform part expediently comprises two platform elements, although more platform elements may also be provided.

[0021] The construction according to aspects of the invention permits the use of different materials for the various components of the turbine blade. It is thus possible, for example, for the blade airfoil and the platform elements to be made from different materials which are adapted to the respective local requirements and loads, as described in the introduction. The platform frame may also be made of a material which is best suited to its purposes. It is thus possible for various alloys and casting materials to be used within one turbine blade.

[0022] The turbine blade may be equipped both at its first blade airfoil end and at a second end, opposite the first end, with an above-described platform having an inner platform part with a plurality of platform elements and an outer platform part formed from a platform frame. In this case, the blade airfoil has on both sides in each case one above-described projection.

[0023] According to one advantageous development, the plurality of platform elements may be coupled to one another and/or one platform element, a plurality of platform elements or all the platform elements may be coupled to the blade airfoil by means of bolts. For example, when only two platform elements which grip around the projection of the blade airfoil are provided, both platform elements may have mutually opposite aligned bores into which a bolt is inserted. This improves the mechanical coupling between the two platform elements and increases the strength of the turbine blade assembled from individual components.

[0024] Furthermore, the platform elements may have through holes and/or blind holes which extend parallel to the longitudinal axis and into which are inserted bolts that are also seated in openings extending through the collar of the projection. Such a bolted connection of the projection of the blade airfoil to the platform elements prevents the platform elements detaching from the blade airfoil, even when the platform frame is not present. In addition to easier assembly, this measure also increases the strength of the turbine blade and the operational reliability of the turbine blade for the unlikely event of the platform frame tearing.

[0025] In order to prevent the platform frame moving off the inner platform part, the inner platform part and the outer platform part may be coupled by means of a tongue-and-groove connection.

[0026] According to a first advantageous development, the platform frame bears areally against the inner platform part, wherein the contact surface at least partially encloses, with the longitudinal axis, an angle greater than 0° and smaller than 90°. Such an arrangement prevents, at least in one direction, a parallel displacement of the platform frame along the longitudinal axis, which is of particular advantage if the invention is applied to turbine rotor blades. In this case, the centrifugal force acting on the platform frame while the turbomachine is in operation is also transmitted into the inner platform part by a form fit on account of the contact surface which is inclined with respect to the longitudinal axis. This reliably prevents loss of the platform frame due to the centrifugal force.

[0027] The angle is preferably between 15° and 35°, for example the angle is 20°.

[0028] According to a further advantageous development, the platform frame has, on at least one laterally outward-facing surface, a slot for receiving a sealing element. Such a configuration presents the advantage that, in the event of wear of slots present in the platform rim due to the sheet-like sealing elements seated therein, the invention presented here provides a simple and reliable possibility of also reconditioning such operationally loaded turbine blades. In addition, such slots may be produced more cost-effectively than in the case of purely monolithic turbine blades.

[0029] The turbine blade may expediently be formed both as a guide vane and as a rotor blade.

[0030] In order that the turbine blade may be inserted with the inner platform part and the outer platform part into the form of the endless platform frame gripping around the inner platform part, even in the case of high-temperature uses, it is advantageous if the inner platform part and the platform frame are coated in one coating procedure. It is thus possible to apply a seamless protective coating to both platform parts.

[0031] The above-described invention is described further below with reference to the description of the figures. Further advantages and features of the invention will emerge with reference to the represented exemplary embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] In the figures:

[0033] FIG. **1** shows a turbine blade in a type of exploded representation, comprising a blade airfoil having a projection, a two-part inner platform part and an outer platform part,

[0034] FIG. **2** shows, in cross section, the turbine blade from FIG. **1** in the assembled state,

[0035] FIG. **3** shows, in perspective representation, the plan view of the turbine blade from FIG. **2**, and

[0036] FIG. **4** shows the turbine blade from FIG. **1** with a modular platform arranged on the tip side.

DETAILED DESCRIPTION OF INVENTION

[0037] In all figures, identical features are provided with identical reference signs.

[0038] FIG. **1** shows part of a turbine blade **10** in the manner of an exploded drawing. The turbine blade **10** is of modular configuration and, according to this exemplary embodiment, therefore comprises as separately manufactured components a blade airfoil **12**, two platform elements **14**, **16** and a platform frame **18** and a plurality of bolts **20** connecting these to one another.

[0039] Moreover, the turbine blade **10** comprises a virtual longitudinal axis **11**.

[0040] The blade airfoil **12** is curved aerodynamically and has, as is known, a pressure side **22** and a suction side **24**. The pressure side **22** and the suction side **24** connect at a leading edge **23** and at a trailing edge **25**. During designated use within a turbomachine, a working medium flows from the leading edge **23** to the trailing edge **25**.

[0041] At the upper end, shown in FIG. **1**, of the blade airfoil **12**, there is provided a projection **26** which is formed in one piece with the profile of the blade airfoil **12**. Laterally, the projection **26** is curved aerodynamically in similar fashion to the pressure side **22** and the suction side **24**. However, the projection **26** is formed substantially smaller in its dimensions than the profile of the blade airfoil **12** given by the blade airfoil walls **22**, **24**, such that the projection adjoins the blade airfoil **12** via a step **28**. The projection **26** comprises, at its free end **30**, a collar **32**. This collar **32** extends perpendicular to the longitudinal axis **11** and along the entire circumference of the profile, whereby it forms, with the step **28**, a circumferential groove **34**.

[0042] In the exemplary embodiment represented, three through holes **36** are provided in both the suction side and the pressure side of the collar **32** of the projection **26**, which holes open into one of the side walls of the groove **34**. Two platform elements **14**, **16** are fastened to the side of the projection **26**, with it also being possible to provide a larger number of platform elements.

[0043] The platform elements **14**, **16** have a platform material thickness which substantially corresponds to the width of the groove **34**. The platform elements **14**, **16** have, upstream of the leading edge **23** or, respectively, downstream of the trailing edge **25**, in each case one or more blind holes **38** into which bolts **20** are partially inserted. The orientation of the blind holes **38** is on one hand perpendicular to the longitudinal axis **11** and on the other hand chosen such that, when the bolts are inserted, the two platform elements **14**, **16** can be pushed toward one another until both platform elements **14**, **16**, seated in the groove **34**, bear against the projection **26**. In addition, the platform elements **14**, **16** have, on their side facing toward the working medium, hereafter called the rear side **40**, blind holes **42** which, once the platform elements **14**, **16** are seated in the groove **34**, are aligned with the relevant through holes **36** in the collar **32**. Accordingly, pin-like bolts may be pushed into the mutually aligned holes **36**, **42**, whereby the platform elements **14**, **16** are first securely connected to the blade airfoil **12**.

[0044] Next, the platform frame **18** is pushed parallel to the longitudinal axis **11** of the turbine blade **10** until it clamps around the two platform elements **14**, **16**. Preference is given in this context to the platform frame **18** being shrink-fitted. With the clamping, the two platform elements **14**, **16** are on one hand firmly pressed against one another and on the other hand pressed into the groove **34** such that, on account of the resulting form fit, they can no longer move along the longitudinal axis **11**. The two platform elements **14**, **16** then form an inner platform part **13** of the turbine blade **10** and the platform frame **18** forms an outer platform part **15** of the turbine blade **10**. The inner platform part **13** and the outer platform part **15** form the platform **17** (FIG. **2**).

[0045] In order to prevent the platform frame **18** from detaching from the two platform elements **14**, **16**, one tongue-and-groove connection is formed on each of the two longitudinal edges **41** of the inner platform part **13** and on each of the two longitudinal struts **46** of the platform frame **18**. In FIG. **1**, a tongue **48** belonging to the longitudinal strut **46** is represented on an inner side of the latter and a groove **50** belonging to the platform element **14** is represented on the longitudinal edge of the latter. Of course, in addition to or instead of this, a tongue-and-groove connection can in each case be provided on the transverse edges and/or transverse struts.

[0046] On the rear side **40** of the platform elements **14**, **16**, one or more hooks **52** are provided both on the leading edge side and on the trailing edge side, in order to push the turbine blade **10** into a turbine guide vane support and attach it thereto. Accordingly, the turbine blade **10** represented in FIG. **1** is formed as a guide vane.

[0047] Where the turbine blade **10** is formed as a rotor blade, those means of the turbine blade **10** which are provided for attachment are preferably formed monolithically on the projection **26** such that the means designated as the blade root is then integrally connected to the projection **26** and to the blade airfoil **12**. A circumferential groove **34** for the platform elements **14**, **16** is also provided in the case of the rotor blade.

[0048] FIG. **2** shows, schematically, a partial perspective section view of the turbine blade **10** from FIG. **1** in the assembled final state. However, FIG. **2** shows neither the holes arranged in the collar **32** nor the bolts seated therein. By contrast, the division of the inner platform part **13** into the pressure-side platform element **14** and the suction-side platform element **16**, as shown in the perspective representation in FIG. **3**, can be seen.

[0049] In the case of the turbine blades shown in FIGS. **1**, **2** and **3**, the platform **17** attached radially outward and thus on the root side of the blade airfoil **12**—when in its operating position within an axial turbomachine—is configured according to the invention. By contrast, FIG. **4** shows the turbine blade **10** with its tip-side end **55**, which can have, by analogy with the root-side end, a modular platform **17** comprising two platform elements **14**, **16** and the platform frame **18**. The tip-side end **55** differs here from the root-side end only with respect to that side of the platform **17** which faces the working medium. As is conventional, in the case of turbine guide vanes **10** used in static gas turbines, what are termed U-rings are attached at the tip-side end **55** and couple and connect together, at the tip side, the guide vanes arranged in a ring. In addition, FIG. **4** shows a slot **54** on a lateral, outward-facing surface **53** of the platform frame **18**. The slot **54** serves to accommodate sheet-like sealing elements which can be provided between mutually adjacent guide vanes in order to seal the gap present therebetween.

[0050] In all, the invention relates to a turbine blade **10** comprising a blade airfoil **12** and a modular platform **17** therefor, in succession along a longitudinal axis **11** of the turbine blade **10**. In order to provide a modular turbine blade **10**, which on one hand is of particularly simple construction and on the other hand ensures a particularly reliable, long-lived and durable connection between the individual components, it is proposed that the blade airfoil **12** comprise a projection **26** and the platform **17** comprise an outer platform part **15** and an at least two-part—in radial relation to the longitudinal axis **11**—inner platform part **13** which bear laterally against the projection **26** of the blade airfoil **12** and wherein the outer platform part **15** is formed as an endless platform frame **18** which grips around the outer rim of the inner platform part **13**.

1.-**13**. (canceled)

14. A modular turbine blade comprising:

a platform and a blade airfoil in succession along a longitudinal axis of the turbine blade,

wherein the blade airfoil has, at a first end, a projection in the longitudinal direction and

wherein the platform comprises, in radial relation to the longitudinal axis, an outer platform part and an inner platform part having at least two platform elements, which platform elements bear laterally against the projection of the blade airfoil and wherein the outer platform part is formed as an annular, endless, platform frame which grips around the outer edge of the inner platform part, wherein the platform frame, the inner platform part and the blade airfoil having the projection are each formed as separately produced components.

15. The turbine blade as claimed in claim **14**,

wherein the inner platform part comprises two, three or four platform elements.

16. The turbine blade as claimed in claim **15**,

wherein the platform elements are connected form-fittingly to the projection of the blade airfoil with respect to the longitudinal axis, in that a collar is formed at the free end of the projection, which collar provides, in conjunction with the step, a groove which is endless in the circumferential direction of the profile of the blade airfoil, into which groove the platform elements of the inner platform part are inserted in form-fitting fashion.

17. The turbine blade as claimed in claim **15**,

wherein the plurality of platform elements are coupled to one another and/or one platform element, a plurality of platform elements or all the platform elements are coupled to the blade airfoil by means of bolts seated in holes.

18. The turbine blade as claimed in claim **14**,

comprising, at said first and second end of the blade airfoil, a corresponding platform.

19. The turbine blade as claimed in claim **17**,

comprising, at said first and second end of the blade airfoil, a corresponding platform.

20. The turbine blade as claimed in claim **14**,

wherein the inner platform part and the platform frame has at least one tongue-and-groove connection.

21. The turbine blade as claimed in claim **17**,

wherein the inner platform part and the platform frame has at least one tongue-and-groove connection.

22. The turbine blade as claimed in claim **18**,

wherein the inner platform part and the platform frame has at least one tongue-and-groove connection.

23. The turbine blade as claimed in claim **14**,

wherein the platform frame bears laterally areally against the inner platform part and the bearing surface at least partially encloses, with the longitudinal axis, an angle greater than 0° and smaller than 90°.

24. The turbine blade as claimed in claim **17**,

wherein the platform frame bears laterally areally against the inner platform part and the bearing surface at least partially encloses, with the longitudinal axis, an angle greater than 0° and smaller than 90°.

25. The turbine blade as claimed in claim **18**,

wherein the platform frame bears laterally areally against the inner platform part and the bearing surface at least partially encloses, with the longitudinal axis, an angle greater than 0° and smaller than 90°.

26. The turbine blade as claimed in claim **20**,

wherein the platform frame bears laterally areally against the inner platform part and the bearing surface at least partially encloses, with the longitudinal axis, an angle greater than 0° and smaller than 90°.

27. The turbine blade as claimed in claim **24**,

wherein the angle is between 10° and 35°.

28. The turbine blade as claimed in claim **23**,

wherein the angle is between 10° and 35°.

29. The turbine blade as claimed in claim **14**,

wherein the platform frame has, on at least one outward-facing surface, a slot for receiving a sealing element.

30. The turbine blade as claimed in claim **14**,

wherein the platform frame is shrink-fitted onto the inner platform part and/or is soldered and/or welded thereto.

31. The turbine blade as claimed in claim **17**,

wherein the platform frame is shrink-fitted onto the inner platform part and/or is soldered and/or welded thereto.

32. The turbine blade as claimed in claim **18**,

wherein the platform frame is shrink-fitted onto the inner platform part and/or is soldered and/or welded thereto.

33. The turbine blade as claimed in claim **20**,

wherein the platform frame is shrink-fitted onto the inner platform part and/or is soldered and/or welded thereto.

34. The turbine blade as claimed in claim **23**,

wherein the platform frame is shrink-fitted onto the inner platform part and/or is soldered and/or welded thereto.

35. The turbine blade as claimed in claim **14**,

either formed as a turbine guide vane, wherein its attachment means is in each case arranged in monolithic fashion on at least one of the platform elements, or

formed as a turbine rotor blade, wherein its attachment means is in each case arranged in monolithic fashion on the projection of the blade airfoil.

36. The turbine blade as claimed in claim **17**,
either formed as a turbine guide vane, wherein its attachment means is in each case arranged in monolithic fashion on at least one of the platform elements, or
formed as a turbine rotor blade, wherein its attachment means is in each case arranged in monolithic fashion on the projection of the blade airfoil.

37. The turbine blade as claimed in claim **18**,
either formed as a turbine guide vane, wherein its attachment means is in each case arranged in monolithic fashion on at least one of the platform elements, or
formed as a turbine rotor blade, wherein its attachment means is in each case arranged in monolithic fashion on the projection of the blade airfoil.

38. The turbine blade as claimed in claim **20**,
either formed as a turbine guide vane, wherein its attachment means is in each case arranged in monolithic fashion on at least one of the platform elements, or
formed as a turbine rotor blade, wherein its attachment means is in each case arranged in monolithic fashion on the projection of the blade airfoil.

39. The turbine blade as claimed in claim **23**,
either formed as a turbine guide vane, wherein its attachment means is in each case arranged in monolithic fashion on at least one of the platform elements, or
formed as a turbine rotor blade, wherein its attachment means is in each case arranged in monolithic fashion on the projection of the blade airfoil.

40. The turbine blade as claimed in claim **30**,
either formed as a turbine guide vane, wherein its attachment means is in each case arranged in monolithic fashion on at least one of the platform elements, or
formed as a turbine rotor blade, wherein its attachment means is in each case arranged in monolithic fashion on the projection of the blade airfoil.

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