

PROPELLER INTEGRATION BETWEEN HUB AND CARBON FIBRE REINFORCED
POLYMER BLADE IN A PROPELLER

FIELD OF THE INVENTION

5 The present invention relates to propeller comprising a hub and a plurality of blades made at least partly from a fibre reinforced polymer and each having a tip and a root, each of the plurality of blades extends from the hub in a radial direction. For each of the blades a tenon is provided at the root, which tenon is received in a mortise provided in the hub together with a bonding material.

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BACKGROUND OF THE INVENTION

Propellers for propulsion of a vessel are found in numerous sizes and varieties, such as an open propeller, where the propeller is arranged and rotated by a shaft connected to a machinery, and electromagnetic thrusters, where blades are
15 arranged in a rotor configuration comprising magnets and a stator with electrical coils rotates the rotor. The propel blades are at their roots connected to a hub. In some situations, the tips of the blades are also connected to an outer tubular element, such as in thrusters, e.g. azimuth thrusters.

20 The propeller blades generate due to their hydrodynamic shaping a thrust which propels the vessel. However, the blades experiences during generation of the thrust, larger hydrodynamic generated forces, which generate high stresses through-out the blade. Further, high stresses are also generated at the root and tip (if connected to a tubular element) sections due to e.g. a bending moment at
25 the roots and tips generated by the hydrodynamic forces.

Traditionally, propeller blades are made from metal or a metal alloy since the material properties of the metal or metal alloy, such as toughness and ductility, are attractive in an attempt to avoid cracking formation e.g. at the root and/or
30 tip, where the blades are connected.

While propeller blades made from metal or a metal alloy are well functioning for a long service time, there are some drawbacks regarding producing propeller blades from metal or metal alloy. One such important drawback is the substantive
35 weight of the blades made from metal or a metal alloy. Since the blades rotates,

the moment of inertia (which is correlated with the weight) is substantial. While this is of less importance for a propeller operating at constant rotations speed, a substantial moment of inertia has a negative effect on propellers operating at varying speed as a response time is prolonged and power used to change the
5 operating speed is substantial.

Accordingly, it could be advantageous to reduce the "rotating mass" of a propeller and in particular reduce the weight of the blades.

10 It may be tempting to produce the blades from a fibre reinforced polymer, as such blades are relatively lighter than metal or metal alloys blades. Further, the blades need to be attached to a hub in order to provide rotation and the thrust produced is to be conveyed by the hub to the vessel. During this, blades connected to the hub will be exposed to both tensile and compressive stresses of typical time
15 varying magnitude especially at points or regions where the blades are connected to the hub, or the tips are connected to a tubular element. Accordingly, attempting to use blade made from a fibre reinforced polymer automatically leads to technical problems relating to how to attach the blade to a hub.

20 Accordingly, it could be advantageous to use blades made from fibre reinforced polymer in a propeller configuration.

OBJECT OF THE INVENTION

It is an object of the invention to provide a propeller where the blades are made
25 from fibre reinforced polymer

It is a further object of the present invention to provide an alternative to the prior art.

30 In particular, it may be seen as an object of the present invention to provide a propeller having blades made from fibre reinforced polymer that solves or at least mitigates the above-mentioned problems.

SUMMARY OF THE INVENTION

Thus, the above-described object and several other objects are intended to be obtained in a first aspect of the invention by providing a propeller comprising

- a hub, and
 - a plurality of blades made at least partly from a fibre reinforced polymer and
- 5 each having a tip and a root, each of said plurality of blades extends from said hub in a radial direction,
- wherein for each of said blades
- a tenon is provided at said root, which tenon is received in a mortise provided in said hub together with a bonding material,
- 10 • an interlocking joint is provided between said tenon and said mortise by
- at least a section of said tenon has increasing width in an inward radial direction of said propeller, and
 - at least a section of said mortise has decreasing width in an outward radial direction of said propeller,
- 15 ○ said widths are dimensioned with a smallest width of said mortise being smaller than a largest width of said tenon.

“*made at least partly from a fibre reinforced polymer*” may refer to that the blade may be made, preferably essentially entirely, from fibre reinforced polymer, or the

20 parts or sections of the blade may be made from fibre reinforced polymer. The latter may be achieved by e.g. a shell construction, where the blade comprises a shell, which may or may not comprise a core material, such as a foam, e.g. a polyurethane foam. In preferred embodiments, the entire outer shape of the blade is provided by fibre reinforced polymer. Hence, in such embodiments, a trailing

25 edge, a leading edge and regions connecting the leading edge and trailing edge are provided by fibre reinforced polymer.

A propeller may in preferred embodiments be an open propeller and may in other embodiments be a ring propeller.

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A *ring propeller* is a propeller where blades are connected to the hub at their roots and the tips of the blades are connected to a tubular element, which often is referred to as a ring, hence the naming “ring propeller”. An embodiment of a ring propeller is illustrated in Fig. 1A and B.

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An *open propeller* is a propeller where blades are connected to the hub at their roots and the tips of the blades are not connected to a support structure, such as a tubular element. It is noted that a tip of blade in an open propeller often is rounded, whereby a tip of a blade of open propeller may essentially be the outer
5 most point or section of the blade. An embodiment of an open propeller is illustrated in Fig. 2A and B.

In preferred embodiments, a propeller, such as an open propeller or a ring propeller, is a propeller for a vessel, such as a waterborne vessel, such as a boat,
10 a ship, a hover craft, a planning vessel, a submissible vessel or a submarine. In such embodiments, the propeller may be configured and used for propelling the vessel by rotating the propeller. Vessel typically refers to a vehicle designed for travel across or through a body of water.

15 "Bonding material" preferably refers to a polymer. Which polymer to choose for a given application may typically depend on the geometries of the parts and on the expected loads and deformations during use. A particular used polymer can be determined as part of the design process by use of computer simulations and/or experiments. In some embodiments, the bonding material provides an adhesive
20 bond. The bonding material may be a flexible bonding material. The polymer is preferably a settable, such as curable polymer having flexibility in the set, such as in the cured state.

BRIEF DESCRIPTION OF THE FIGURES

25 The present invention and in particular preferred embodiments thereof will now be disclosed in more details with regard to the accompanying figures. The figures show ways of implementing the present invention and are not to be construed as being limiting to other possible embodiments falling within the scope of the attached claim set.

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Fig. 1A and B schematically illustrates a first embodiment of a propeller, being a ring propeller. In Fig. 1A the propeller is illustrated in a 3-dimensional view and in Fig. 1B, the propeller is illustrated in cross sectional 3-dimensional view.

Fig. 2A and B schematically illustrate second embodiment of a propeller, being an open propeller. In Fig. 2A the propeller is illustrated in a 3-dimensional view and in Fig. 2B, the propeller is illustrated in cross sectional 3-dimensional view;

- 5 Figs. 3A-D schematically illustrate details of the preferred embodiment of Fig. 1A and B; Fig. 3A schematically illustrates in a 3-dimensional cross section view a connection between a blade, a hub and a tubular element; Fig. 3B, Fig. 3C and Fig. 3D are close-ups of Fig. 3A;
- 10 Fig. 4 schematically illustrate the propeller of Figs. 1A and B in a partial exploded-view wherein the lock ring is axially disposed

Fig. 5 schematically illustrates the propeller of Figs. 1A and B configured for use in a permanent magnet thruster by having permanent magnets arranged on the
15 tubular element; the magnets are encapsulated in a cover and thereby not visible as such in Fig. 5.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Reference is made to Figs. 1A and B schematically illustrating a propeller and to
20 Figs. 3A-D illustrating details of the propeller shown in Figs. 1A and B. As illustrated, the propeller 1 comprises a hub 2 which, when installed on a vessel, is rotatable mounted. The propeller has a plurality of blades 5 which are made from a fibre reinforced polymer. The number of blades and the hydrodynamic shape of the blades, together with size, are typically selected in accordance with a specific
25 requirement as to produced thrust.

The propeller illustrated in Figs. 2A and B shares many features of the embodiment of Figs. 1A and B, namely the way the roots of the blades are connected to the hub as will be detailed in the following. Accordingly, the open
30 propeller of Fig. 1B may preferably be considered as a ring propeller without the tubular element to which the tips of the blades are connected. However, the tips of the blades in an open propeller is typically rounded – as shown in Fig. 1B – to provide a desired hydrodynamic characteristic of the propeller.

Reference is now made to Figs. 3A-D schematically illustrating details of the propeller of Figs. 1A and B. Each of the blades 5 has a tip 6 and a root 7, where the tip 6 is positioned distant from the hub 2 and the root 7 is positioned at the hub 5. As illustrated, each of the blades 5 extends from the hub 2 in a radial direction. The blades may be forward-swept or backward-swept (relative to a rotational direction), or may be none-swept.

The propeller blades 5 are each connected to the hub 2 in the following manner. Each of the blades 5 has a tenon 9 provided at the root 7 and a tenon 9 of a blade 10 is received in a mortise 8 provided in the hub 2. As will be apparent from the following, the tenons 9 and the mortices 8 are mutually shaped to allow for the presence of a bonding material so that a tenon 9 is received in a corresponding mortice 8 together with a bonding material 10.

15 Further, the tenons 9 and the mortices 8 are mutually shaped so that an interlocking joint is provided between a tenon 9 and a mortise 8, when the tenon 9 is received in the mortice 8. Such an interlocking joint is provided by at least a section of tenon 9 has increasing width w_1 in an inward radial direction of the propeller 1, and at least a section of said mortise 8 has decreasing width w_2 in an 20 outward radial direction of said propeller 1.

As "interlocking joint" typically refers to a situation where a tenon 9 of a blade 5 cannot be pulled out from the mortice 8 in radial direction of the propeller (without destroying the tenon and/or mortice), preferably the widths w_1 , w_2 are 25 dimensioned with a smallest width of said mortice 8 being smaller than a largest width of said tenon 9.

By the interlocking joint, the blades are prevented from being pulled away from the hub by a centrifugal force acting in radial direction during rotation of the 30 propeller. However, as the blades 5 are made from fibre reinforced polymer, such as carbon fibre and resin, some fibre reinforced polymer-based blades 5 may be considered being brittle at least to some extent. While the bonding material 10 at least assist in providing the interlocking joint, the bonding material also provide flexibility to the joint, as will be detailed in the following. A flexibility may 35 advantageous be provided not only in a radial direction but also in tangential

direction and different configurations of the tenon and mortices may provide flexibility in one or both directions.

In the embodiment illustrated in Figs. 1A and B, as seen in Fig. 3A, the tenon 9 and mortice 8 each has a section with trapezoid cross section whereby the tenon 9 and the mortice 8 form a dovetail joint. However, the invention is not limited to such a dovetail joint, as other configurations of tenon and mortice are within the scope of the invention.

As perhaps most clearly visible in Fig. 3B, the mortise 8 and the tenon 9 are mutually dimensioned so as to provide a first clearance $\delta 1$ between facing side surfaces 1 of the mortise 8 and the tenon 9. The facing surfaces in the illustrated embodiment are the surfaces extending in radial direction although with a slope relative to the radial direction. Thus, in the illustrated embodiments, there are two such clearances, one on either side of the tenon 9, and these clearances are occupied essentially by the bonding material 10. By occupying the first clearances $\delta 1$ by the bonding material, a radial and at least to some extent also a tangential flexibility is provided to the interlocking joint.

The mortice 8 and the tenon 9 are in the illustrated embodiments also mutually dimensioned so as to provide a second clearance $\delta 2$ between facing lower surfaces 13 of the mortise 8 and the tenon 9. In the illustrated embodiment, the facing lower surfaces are surfaces between a bottom of the mortice 8 and a lower surface of the tenon 9. This second clearance $\delta 2$ is also occupied by bonding material 10. By occupying the second clearance $\delta 2$ with bonding material the radial flexibility and the tangential flexibilities are increased.

It is noted that the first and the second clearance $\delta 1$ and $\delta 2$ may not need both to be provide and occupied by the bonding material. However, if larger flexibilities are aimed at, the presence of both clearances may be advantageous.

The bonding material in combination with the first $\delta 1$ and/or the second clearances $\delta 2$ and/or a third clearance $\delta 3$ (as disclosed below) besides adding flexibility to the joint may also prevent direct contact between the surfaces of the

tenons 9 and the surfaces of the mortices 8, which could otherwise deteriorate the surfaces due to abrasion.

During rotation of the propeller, the propeller blade may have a tendency to bent
5 in radial and/or tangential direction and such bending may provide a stress concentration in the root area of the blade. Such a stress concentration may be increased if the root section of a blade 5 abuts an edge of the hub formed in hard material, such as stainless steel. This may potentially occur at an outer edge of the mortice 8. To alleviate such potential stress concentration, the mortise 8 and
10 the tenon 9 are mutually dimensioned to provide a third clearance $\delta 3$ between facing side surfaces 12 of the mortise 8 and the tenon 9. This third clearance $\delta 3$ is provided at an upper end 14 of the mortise and extends in a radial direction of the propeller to an outer surface 15 of the hub 2. Preferably, the third clearance has an increasing width in the radial direction. By this, the blade may bend at the root
15 section, without direct contact between the hub 2 and the blade 5 at the root section of the blade. This third clearance $\delta 3$ may also be occupied by the bonding material 10.

In the illustrated embodiment, the tenons 9 are introduced into corresponding
20 mortices by moving the tenons 9 into the mortices 8 in an axial direction. This is rendered possible by each of the mortises 8 has an opening 16 facing in an axial direction of the propeller, and the opening 16 is dimensioned for insertion of a tenon 9 into the mortise 8. The opening 16 is illustrated in Fig. 3C showing a mortice 8 without a tenon 9 introduced therein.

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To prevent the blade 5 to travel in axial direction beyond a desired position, each of the mortises 8 has a dead end 18. This dead end 18 is provided at an end of the mortise 8 being opposite to the opening 16 through which the tenon 9 is introduced into the mortice 8. A clearance between the dead end 18 and the
30 tenon occupied by the bonding material may be provided.

While the bonding material may bond the tenon 9 firmly to the mortice 8 it may be preferred to make sure that the tenons 9 cannot moved out of the mortices 8 through the openings 16. To accomplish this, the propeller may further comprise a
35 lock ring 17 arranged at the hub 2 to cover the openings 16 of the mortises 8

facing in the axial direction. The lock ring 17 may be more clearly visible in Fig. 4, wherein the lock ring 17 is illustrated axially disposed relatively to its position in an assembled propeller. Fig. 4 also illustrates that the tenons 9 protrude from the hub 2 and that the lock ring 17 comprises depressions 24 which mate the shape of protruding parts of the tenons 9.

While such a lock ring is preferred, the openings may alternatively be covered e.g. by separate cover element. Further, a clearance occupied by the bonding material 10 may be provided in between the lock ring and the tenon 9. The lock ring 17 is – or separate cover elements are – preferably fastened to the hub 2 by screws.

The forces acting on a propeller blade 5 during using is often relatively high at the root e.g. due to a bending moment. As the blades are made from fibre reinforced polymer, it has been found advantageous that each of said blades 5 comprising a transition root section 9 at the root 7 which may be considered as a thickening of the blade 5 at the root 7 to allow the blade 5 to better take-up the forces acting at the root 7. The transition root section 19 extends a distance in a radial direction of the propeller from above the mortise 8 to a section of the blade 5 being shaped to provide thrust upon rotation.

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An abrupt change in geometry in a stressed object may provide a local stress concentration. To alleviate such effect in embodiments comprising a transition root section, a transition region 20 located where said transition root section 19 runs into the section of the blade 5 being shaped to provide thrust proceed with a curvature, preferably a continuous curvature. Such a smooth change in geometry has the potential to avoid local stress concentration.

Often blades are twisted in the sense that the evolution of the chord along the length of the blades turns. This often means that the chord line at the root of the blade is angled relatively to the axial direction of the propeller. In preferred embodiments, this is accounted for by aligning the mortice 8 and tenon 9 with the orientation of a chord line at the root of the blade 5.

In many preferred embodiments, the fibre reinforced polymer is a carbon fibre reinforced polymer, although other fibres, such as Kevlar, glass fibres or even

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combinations thereof are used in other embodiments. It is further noted that blades 5 may not be made massively or entirely from fibre reinforced polymer, as the blades may be a core structure, e.g. with a hollow core.

- 5 As illustrated in Figs. 1A and B, and in Fig. 3A, a preferred embodiment of a propeller may further comprise a tubular element 4 arranged co-axially with the hub 2 and the tip 6 of each of the blades 5 is connected tubular element 4. In the illustrated embodiment the tubular element 4 has a width so that no blades protrude beyond the tubular element in axial direction at the position where the
- 10 blade tips 6 are connected to the tubular element 4. Such a tubular element 4 may serve a number of purposes such as increasing the structural integrity of the propeller, increasing the thrust produced by the impeller and/or serving as a surface carrying magnets if the propeller is used in and electromagnetic thruster.
- 15 Preferably, each tip 6 is connected to the tubular element 4 by being received in a groove 22 provided in the tubular element 4. As disclosed in connection with the mortices 8 and tenons 9, clearance(s) may also be provided in grooved connection (combination of groove 22 and tip 6) and preferably also occupied by a bonding material.
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- The tip 6 may comprise at an outermost position of the blade 5 a connecting section 25. Such a connection section typically has a larger width w_c than a thickness t_b of the blade 6 measured immediately inward of the connection section 23. Such a connection section 25 is disclosed in Fig. 3D. At least a section of said
- 25 connection section 25 is received in the groove 22 preferably together with the bonding material.

In some embodiments, the propeller is used in an open propeller device, which has a propeller according to an embodiment of the invention. By open propeller is

30 typically meant a propeller not having the tubular element 4 (e.g. as illustrated in Fig. 2A and B) and that the hub of the propeller is arranged on a shaft rotatable by motor, such as an electrical motor, a hydraulic motor, a combustion engine, such an Otto engine or a Diesel engine.

- 35 In preferred embodiments, the bonding material is a polymer.

In preferred embodiments, the hub 2 may be made from metallic material, such as stainless steel. And, in embodiment comprising the tubular element 4, the tubular element may be made from fibre-reinforced polymer composite or metallic material, such as stainless steel.

In preferred embodiments, the invention relates to a permanent magnet thruster having a propeller according to a preferred embodiment of the invention. An embodiment of a propeller for a permanent magnet thruster is illustrated in Fig. 5. In such embodiments, the propeller comprises the tubular element 4 and a plurality of permanent magnets 23 are provided on or at a lateral surface of said tubular element 4. In the embodiment shown in Fig. 5, the magnets are encapsulated in a cover, whereby the magnets are not exposed to water during use. Accordingly, the magnets 23 are not visible in Fig. 5 although the cover is visible as a tubular part arranged on the outside of the tubular element 4.

The permanent magnet thruster also has a stator yoke (not illustrated) arranged outside the tubular element 4, the magnets 23 and the cover. The stator yoke has a plurality of stator coils being magnetizable by an electrical current. The plurality of permanent magnets 23 and the plurality of stator coils are mutually configured so that when the plurality of stator coils are magnetized, the stator yoke rotates the propeller 1.

For embodiments like the one illustrated in Fig. 1A and B, the tenons 9 are introduced into corresponding mortices 8 by moving the tenons 9 into the mortices 8 in an axial direction, as disclosed above. Further, tips 6 are each received in a groove 22 provided in an inner surface of the tubular element 4. Fig. 3A illustrates blade for which the tenon 9 is received in the mortice 8 and the tip 6 is received in the groove 22.

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When a propeller blade has twist (as in Fig. 1A and B), the orientation of the tip 6 is different from the orientation of the root 7. To allow for assembly of the propeller, that is introducing the tenons 9 into the mortices 8 and at the same time introduce the tips 6 into the grooves 9, the second clearances $\delta 2$ are dimensioned so that the tenons 9 can be displaced radially inward to an extent

providing the tubular element 4 to be arranged in a position encircling the tips 6. This typically means that the size of the second clearance δ_2 is larger than or substantial equal to the depth of the groove 22. With the blades 6 and the tubular element 4 so arranged, the blades 6 are moved radially outwardly so that the tips 5 6 are introduced into the grooves 22. This movement may advantageously be provided by one or more jacking screws (not illustrated) extending from the inside of the hub and into the mortices 8. By tightening such jacking screws, the end of the jacking screws abut undersides of the tenons 9, whereby the blades are forced radially outwardly introducing the tips 6 into the grooves 22. The grooves 22 are, 10 preferably, pre-filled with a bonding material to fixate that tips 6 in the grooves 22, preferably in a flexible manner.

With the tips 6 positioned in the grooves 22, a bonding material is applied into the mortices 8 to fill the clearances δ_1 , δ_2 and, if provided, also δ_3 . The bonding 15 material may advantageously be filled into the clearances under elevated pressure to avoid formation of voids in the bonding material. When the bonding material has set, the jacking screws can safely be removed.

Although the present invention has been described in connection with the 20 specified embodiments, it should not be construed as being in any way limited to the presented examples. The scope of the present invention is set out by the accompanying claim set. In the context of the claims, the terms "comprising" or "comprises" do not exclude other possible elements or steps. Also, the mentioning of references such as "a" or "an" etc. should not be construed as excluding a 25 plurality. The use of reference signs in the claims with respect to elements indicated in the figures shall also not be construed as limiting the scope of the invention. Furthermore, individual features mentioned in different claims, may possibly be advantageously combined, and the mentioning of these features in different claims does not exclude that a combination of features is not possible 30 and advantageous.

List of reference symbols used:

- 1 Propeller
- 2 Hub
- 35 3 Shaft

	4	Tubular element
	5	Blade
	6	Tip
	7	Root
5	8	Mortise
	9	Tenon
	10	Bonding material
	11	First section of mortise
	12	Facing side surfaces
10	13	Facing lower surfaces
	14	Upper end (of mortise)
	15	Outer surface
	16	Opening
	17	Lock ring
15	18	Dead end
	19	Transition root section
	20	Transition region
	21	Cord angle
	22	Groove
20	23	Magnet
	24	Depression
	25	Connecting section
	δ1	First clearance
	δ2	Second clearance
25	δ3	Third clearance

CLAIMS

1. A propeller (1) comprising
- a hub (2), and
 - a plurality of blades (5) made at least partly from a fibre reinforced polymer
- 5 and each having a tip (6) and a root (7), each of said plurality of blades (5) extends from said hub (2) in a radial direction,
- wherein for each of said blades (5)
- a tenon (9) is provided at said root (7), which tenon (9) is received in a mortise (8) provided in said hub (2) together with a bonding material (10),
- 10 • an interlocking joint is provided between said tenon (9) and said mortise (8) by
- at least a section of said tenon (9) has increasing width (w_1) in an inward radial direction of said propeller (1), and
 - at least a section of said mortise (8) has decreasing width (w_2) in an
- 15 outward radial direction of said propeller (1),
- said widths (w_1 , w_2) are dimensioned with a smallest width of said mortise (8) being smaller than a largest width of said tenon (9).
2. A propeller according to claim 1, wherein for each blade said tenon (9) and said
- 20 mortise (8) each has a section with trapezoid cross section whereby said tenon (9) and said mortise (8) form a dovetail joint.
3. A propeller according to claim 1 or 2, wherein for each blade (2) said mortise (8) and said tenon (9) dimensioned to provide a first clearance (δ_1) between
- 25 facing side surfaces (12) of said mortise (8) and said tenon (9), and a second clearance (δ_2) between facing lower surfaces (13) of said mortise (8) and said tenon (9), wherein said bonding material (10) is provided to substantially fill said first and second clearances (δ_1 , δ_2).
- 30 4. A propeller according to any one of the preceding claims, wherein for each blade (2) said mortise (8) and said tenon (9) are dimensioned to provide a third clearance (δ_3) between facing side surfaces (12) of said mortise (8) and said tenon (9), said third clearance (δ_3) being provided at an upper end (14) of said mortise and extends in a radial direction of said propeller to an outer surface (15)

of said hub (2), preferably said third clearance has an increasing width in said radial direction.

5. A propeller according to any one of the preceding claims, wherein for each
5 blade said mortise (8) has an opening (16) facing in an axial direction of said propeller, wherein said opening is dimensioned for insertion of said tenon (9) into said mortise (8).

6. A propeller according to claim 5, wherein for each blade said mortise (8) has a
10 dead end (18) at an end of the mortise (8) opposite to said opening (16).

7. A propeller according to claims 5 or 6, further comprising a lock ring (17) arranged at said hub (2) to cover said openings (16) of the mortises (8) facing in said axial direction.

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8. A propeller according to any one of the preceding claims, wherein each of said blades (5) comprising a transition root section (19) at said root (7), said transition root section (19) extends a distance in a radial direction of said propeller from above said mortise (8) to a section of the blade (5) being shaped to provide thrust
20 upon rotation.

9. A propeller according to claim 8, wherein a transition region (20) located where said transition root section (19) runs into said section of the blade (5) being shaped to provide thrust proceed with a curvature, preferably a continuous
25 curvature, to reduce stress concentration in the transition region (20).

10. A propeller according to any one of the preceding claims, wherein for each of said blades (5), said mortice (8) and tenon (9) are aligned with an orientation of a chord line at the root of said blade (5).

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11. A propeller according to any one of the preceding claims, wherein the fibre reinforced polymer is a carbon fibre reinforced polymer.

12. A propeller according to any one of the preceding claims, further comprising a tubular element (4) arranged co-axially with said hub (2), wherein said tip (6) of each of said blades (5) is connected said tubular element (4).

5 13. A propeller according to claim 12, wherein for each blade said tip (6) is connected to said tubular element (4) by being received in a groove (22) provided in said tubular element (4) preferably together with a bonding material.

14. A propeller according to claim 13, wherein for each blade said tip (6)
10 comprising at an outermost position of the blade a connecting section (25), said connecting has a larger width (w_c) than a thickness (t_b) of said blade (6) measured immediately inward of said connection section (25), and wherein at least a section of said connection section (25) is received in said groove (22), preferably together with said bonding material.

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15. An open propeller device comprising a propeller according to any one of the preceding claims, wherein said propeller is arranged on a shaft rotatable by motor, such as an electrical motor, a hydraulic motor, a combustion engine, such an Otto engine or a Diesel engine.

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16. A propeller according to any one of the preceding claims, wherein said bonding material is a polymer.

17. A propeller according to any one of the preceding claims, wherein said hub is
25 made from metallic material, such as stainless steel and/or, when dependant on claim 12, said tubular element is made from fibre-reinforced polymer composite or metallic material, such as stainless steel.

18. A propeller according to any one preceding claims, wherein said propeller is a
30 propeller for a waterborne vessel, such as a boat, a ship, a hover craft, a planning vessel, a submissible vessel or a submarine.

19. A permanent magnet thruster comprising a propeller (1) according to any one of claims 12-14, comprising

- a plurality of permanent magnets (23) provided on or at a lateral surface (5) of said tubular element (4);
- a stator yoke (15) arranged outside said tubular element (4) and comprising a plurality of stator coils (16) being magnetizable by an electrical current,

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- said plurality of permanent magnets (23) and the plurality of stator coils (16) are mutually configured so that when said plurality of stator coils (16) are magnetized, the stator yoke (15) rotates said propeller (1).