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(54) **Propeller combination with non-cupped blades for a boat propeller unit.**

(57) The invention relates to a boat propeller unit with double, counter-rotating propellers. The forward propeller is designed to function without cavitation, while the after-propeller is at least partially cavitating, being non-cupped, and being made with a blade width of between 60% and 75% of the blade width of the forward propeller.

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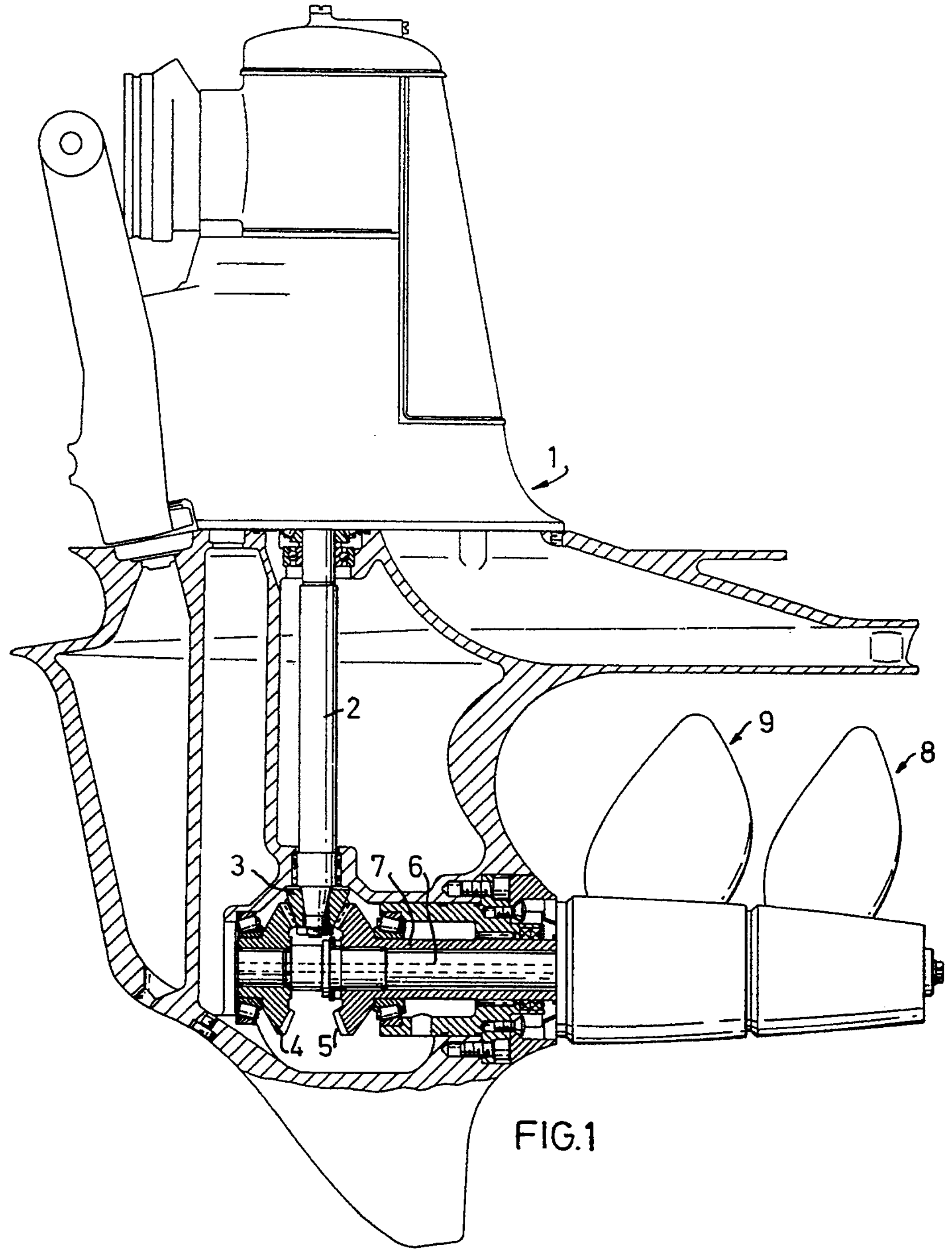

FIG.1

Background of the Invention

The present invention relates to a propeller combination for a boat propeller unit, comprising a forward propeller and an after-propeller intended to rotate in opposite directions about a common rotational axis.

Such a propeller combination is shown in my prior U.S. Patent No. 4,619,584, in which both the propellers are designed for optimum cavitation-free operation. This gives the propellers a "firm-grip" in the water which is an advantage for heavy boats, since it provides good maneuverability and good control of the boat's movement in the water.

However, if increased engine power is used in a lighter boat for higher speeds, the propeller grip can affect the behavior of the boat during sudden turns with extreme rotation of the steering wheel. For example, for a fast boat (35 to 45 knots) with a deep V-bottom, the long, deep V will track the boat even in turns. If the steering wheel is turned sharply, the boat can be forced into such a sharp turn that the V will suddenly lose its grip and the after-portion skid. At precisely this moment when the skidding occurs, there arises a counter-acting, transverse force on the propeller in the propeller's plane of rotation. The water strives to counter-act the subsequent displacement of the propeller, the counter-acting forces being proportional both to the pull of the propeller and its displacement speed.

The suddenly arising (and short-lived) force makes the propeller "stick" in the water for an instant, and if the boat speed is quite high and one makes a hard, rapid turn of the wheel the boat may make a short, outwardly directed tipping movement, which can be unexpected for the boat's passengers. This sudden phenomenon is not particularly connected with double propeller units but applies generally to non-cavitating propellers.

In my prior U.S. Patent No. 4,670,714, I disclosed a propeller combination which appreciably reduces the propeller transverse forces which can arise when skidding (especially in boats with a deep V-bottom) not only to increase safety but also to provide a softer, more comfortable movement when turning.

This was achieved by designing the forward propeller to function without cavitation, while the after-propeller functions with either partial or optimum cavitation, has cupped blades, and has a total blade area of between 1/3 and 2/3 of the total blade area of the forward propeller.

The following general principles apply to cavitation:

A propeller blade cuts through the water with a speed which is a combination of the boat speed and the rotational speed of the blade. At the representation radius of 70%, the velocity is normally 60 to 70 knots. The velocity is high and the blade must therefore be thin and long, so that the water will have time to fill up the cavity which tends to form when the blade cuts through the water. At 60 knots for example, the blade may have a thickness of at most 8% of the blade width and at 70 knots at most 6%.

In addition to the blade thickness, the water is affected by a pressure difference over the blades, corresponding to the pulling force of the propeller. This creates a suction side and a pressure side, to which pressure the effect of the blade thickness is added. The required blade area per kW of engine power can be calculated by known methods for a propeller which is to transmit maximum power without cavitating. For the propeller drive unit described in U.S. Patent No. 4,619,584 the target value is about 10 cm^2 per kW. By dimensioning the after-propeller with "too little" area, a cavitating propeller is obtained.

A propeller having a thick profile produces a large cavitation bubble but yields low friction in the water. Conversely, a propeller having a thin profile must have a longer blade and therefore yields higher friction in the water while producing a smaller cavitation bubble. There is an optimum where the relation between profile thickness and blade length (cavitation and friction) gives maximum propeller efficiency. This is the point of optimum cavitation. If the propeller is designed to cavitate but not to produce maximum efficiency, it operates with partial cavitation.

When the propeller combination disclosed in U.S. Patent No. 4,670,741 was invented, it was thought that a cupped profile was necessary to prevent collapse of the cavitation bubble on the blade. The after-propeller in that combination was therefore designed to be cupped, i.e., the blade is provided with a sharp curvature at the rear edge to produce a pressure field on the suction side of the blade with pressure decreasing from the nose to the rear edge of the blade. The result is that the cavitation bubble begins at or near the rear edge and is small.

Although the efficiency of the cupped, cavitating after propeller is somewhat lower than for a conventional propeller, it is possible to reduce the steering forces by up to 50%.

Summary of the Invention

It has now been discovered that it is not necessary for the after propeller to be cupped. The advantages of the combination disclosed in U.S. Patent No. 4,671,740 can be achieved by having a non-cavitating forward propeller and a counter-rotating, partially cavitating after propeller, whether or not the after propeller is cupped. Collapse of the cavitation bubble on the blade can be prevented by making the blade profile more symmetric or with a sharper front edge.

The invention will be described below with reference to examples shown in the accompanying drawings.

Brief Description of the Drawings

Fig. 1 shows in partial section a side view of a propeller combination according to the invention;
Fig. 2 shows a cross section through a forward propeller blade; and
Fig. 3 shows a cross section through an after-propeller blade.

Detailed Description

The propeller drive unit generally designated 1 in Fig. 1 is a so-called inboard/outboard drive unit, designed to be mounted on a boat transom and be coupled to the output shaft of an engine (not shown). The drive unit contains a reversing mechanism, with an output shaft 2 having a conical gear 3 in constant engagement with two conical gears 4 and 5. Gear 4 drives one propeller shaft 6 and gear 5 drives a hollow shaft 7 journalled concentrically to shaft 6. Shaft 6 carriers propeller 8 and shaft 7 carriers propeller 9. This arrangement makes the propeller shafts rotate in opposite directions.

The forward propeller 9 shown in section in Fig. 2 is shaped so that the propeller will function without cavitation, while the after-propeller shown in section in Fig. 3 is shaped so that the propeller will have a partial, less-than-optimum cavitation. For this purpose the propeller 8 is made with a section, the chord of which in the example shown is reduced by about 30% in relation to the forward propeller 8. To provide partial cavitation for the after-propeller the total blade area must be between 1/3 and 2/3 of the total blade area of the forward propeller.

As shown in Fig. 3, the thickness of the blades of the after-propeller is increased about 14% in relation to the forward propeller so as not to reduce the strength of the blade due to the reduced blade width.

Tests and analyses have demonstrated that the forward propeller 9 should have three blades (possibly four blades) and be non-cavitating (i.e. have conventional shape) and that the after-propeller 8 to cavitate partially should have a blade width of between 60% and 75% of the width of the forward propeller and preferably have the same number of blades as the forward propeller. The optimum diameter will then be 4-6% less due to the blade shape, and an additional 5-10% less due to the increased flow-through speed caused by the forward propeller. This agrees exactly with the diameter desired in order to lie just within the flow tube from the forward propeller. One blade less would tend to result in a propeller with too large a diameter. When using an after-propeller with one blade more, i.e., a four-bladed propeller, the diameter of the after-propeller should be between 75% and 95% of the diameter of the forward propeller and its pitch ratio (pitch/diameter) should be between 1.1 and 1.3 times that of the forward propeller.

To avoid collapse of the cavitation bubble on the blade, the profile of the after propeller can be made nearly symmetric, or with a sharper front edge, or by giving it a relatively high angle of attack. In contrast to a propeller combination having a cupped after propeller designed for optimum cavitation, which is particularly adapted for high speed, the propeller of the present invention, which is designed for at least partial cavitation but not necessarily optimum cavitation, is adapted for lower speeds.

Claims

1. A propeller combination for a steerable boat propeller unit comprising a forward propeller and an after propeller intended to rotate in opposite directions about a common rotational axis, the forward propeller having a predetermined number of blades and a total blade area, and being shaped so as to function without cavitating and the after propeller having a predetermined number of non-cupped blades, and being shaped so as to function with at least partial cavitation, the after propeller having a total blade area of between 1/3 and 2/3 of the total blade area of the forward propeller.

2. A propeller combination according to claim 1, in which the blade width of the after propeller is between 60% and 75% of the blade width of the forward propeller.

3. A propeller combination according to claim 1, in which the propellers have the same number of blades.

4. A propeller combination according to claim 1, in which the after propeller has one more blade than the forward propeller.

5. A propeller combination according to claim 4, in which the diameter of the after propeller is between 75% and 95% of the diameter of the forward propeller.

6. A steerable propeller drive unit comprising:
   a. an output shaft;
   b. a first conical gear secured to the output shaft; i) a second conical gear in constant engagement with the first conical gear such that the first conical gear drives the second conical gear in a first direction;
   c. a propeller shaft secured to and driven by the second conical gear;
   d. a third conical gear in constant engagement with the first conical gear such that the conical gear drives the third conical gear in a second

direction which is opposite the first direction;
e. a hollow propeller shaft secured to and driven by the third conical gear, the hollow propeller shaft being journaled concentrically to the propeller shaft;
f. a forward propeller secured to one of the propeller shaft and the hollow propeller shaft;
g. an after propeller secured to the other of the propeller shaft and the hollow propeller shaft such that the forward and after propellers rotate in opposite directions,

the forward propeller having a predetermined number of blades, each blade having a predetermined chord, a predetermined width and a predetermined thickness, the predetermined thickness being no more than 0.08 times the predetermined blade width and the blade being shaped so that the forward propeller functions without cavitating; the after propeller having a predetermined number of non-cupped blades, each blade having a predetermined chord, a predetermined width and a predetermined thickness, the predetermined chord of the after propeller being less than or equal to 0.70 times the predetermined chord of the forward propeller and the after propeller being shaped for at least partial cavitation.

7. A steerable propeller drive unit comprising:
a. an output shaft;
b. a first conical gear secured to the output shaft;
c. a second conical gear in constant engagement with the first conical gear such that the first conical gear drives the second conical gear in a first direction;
d. a propeller shaft secured to and driven by the second conical gear;
e. a third conical gear in constant engagement with the first conical gear such that the first conical gear drives the third conical gear in a second direction which is opposite the first direction;
f. a hollow propeller shaft secured to and driven by the third conical gear, the hollow propeller shaft being journaled concentrically to the propeller shaft;
g. a forward propeller secured to one of the propeller shaft and the hollow propeller shaft, the forward propeller having a predetermined number of blades having a total blade area, each blade having a predetermined chord, a predetermined width and a predetermined thickness, the forward propeller being shaped so as to function without cavitating; and
h. an after propeller secured to the other of the propeller shaft and the hollow propeller shaft such that the forward and after propellers rotate in opposite directions,

the after propeller having a predetermined number of non-cupped blades, each blade having a predetermined width and a predetermined thickness, the blades of the after propeller having a total blade area which is between 1/3 and 2/3 of the total blade area of the blades of the forward propeller and the blades being shaped so as to function with at least partial cavitation.

8. The propeller drive unit of claim 7 in which the forward propeller and the after propeller have the same number of blades and the predetermined width of the blades of the after propeller is between 60% and 75% of the predetermined width of the blades of the forward propeller.

9. The propeller drive unit of claim 7 in which the after propeller has one more blade than the forward propeller and the diameter of the after propeller is between 75% and 95% of the diameter of the forward propeller.

10. The propeller drive unit of claim 7 wherein the thickness of each of the blades of the forward propeller is less than or equal to 8% of the blade width of the blades of the forward propeller.

11. A steerable propeller drive unit comprising:
a. first and second propeller shafts intended to rotate in opposite directions about a common rotational axis,
b. a forward propeller secured to the first shaft for rotation therewith; and
c. an after propeller secured to the second propeller shaft for rotation therewith,

the forward propeller having a predetermined number of blades and a total blade area, and being shaped so as to function without cavitating and the after propeller having a number of non-cupped blades, and being shaped so as to function with at least partial cavitation, the after propeller having a total blade are of between 1/3 and 2/3 of the total blade area of the forward propeller.

12. A propeller combination according to claim 11, in which the blade width of the after propeller is between 60% and 75% of the blade width of the forward propeller.

13. A propeller combination according to claim 11, in which the propellers have the same number of blades.

14. A propeller combination according to claim 11, in which the after propeller has one more blade than the forward propeller.

15. A propeller combination according to claim 11, in which the diameter of the after propeller is between 75% and 95% of the diameter of the forward propeller.

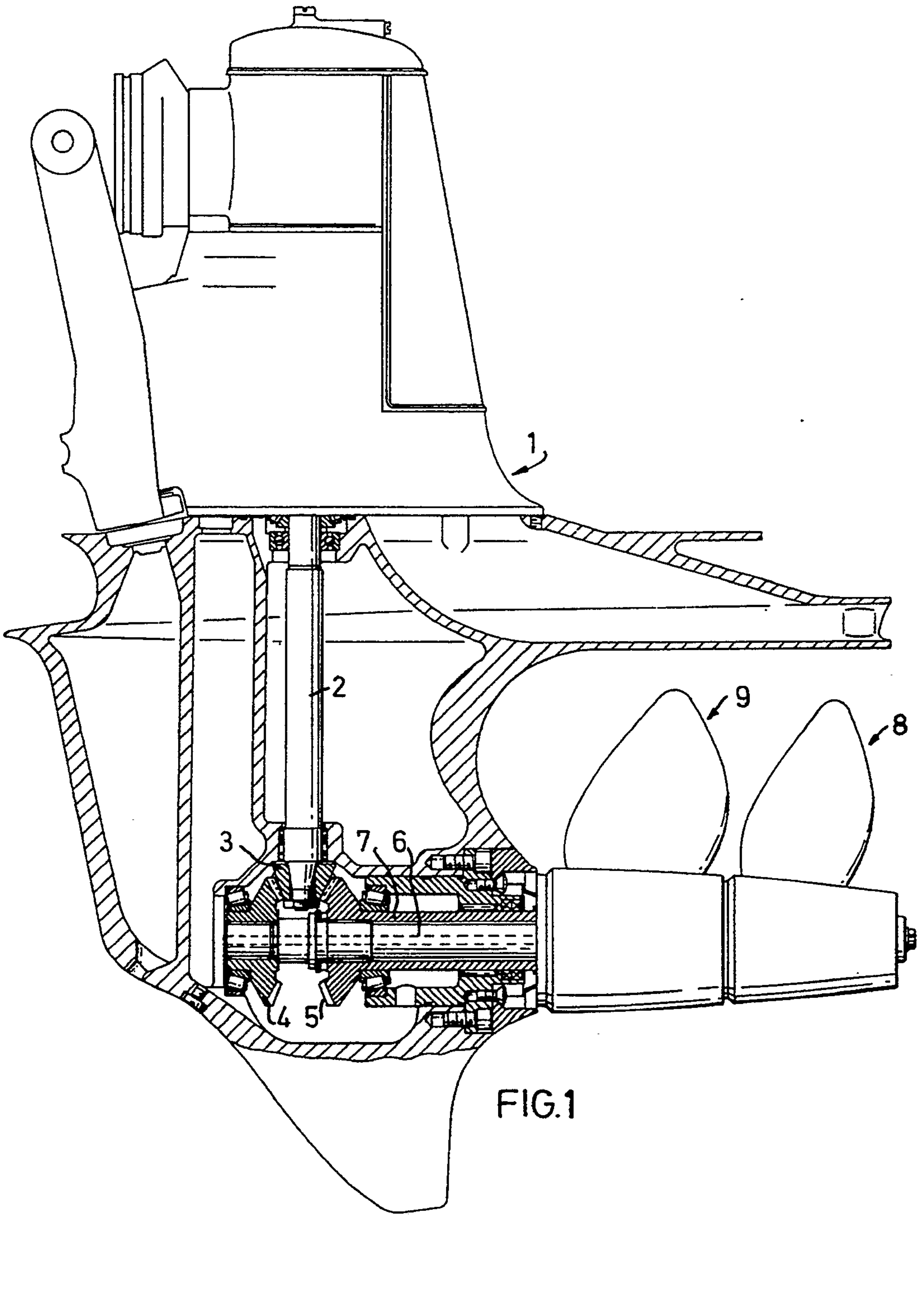

FIG.1

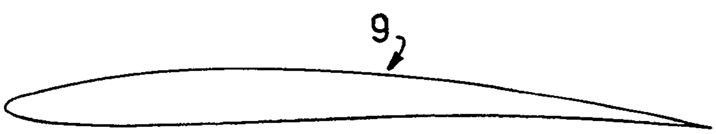

FIG. 2

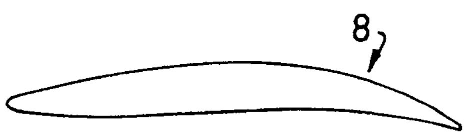

FIG. 3

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EUROPEAN SEARCH REPORT

Application Number

EP 91 85 0124

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X A	EP-A-215758 (AB VOLVO PENTA) * the whole document *	1-5, 11-15 6-9	B63H5/10
D,A	US-A-4619584 (AB VOLVO PENTA) * the whole document *	1, 6, 7, 11	
A	GB-A-2066371 (BRUNSWICK CORPORATION) * figures 4-7 *	1, 6, 7, 11	
A	US-A-4293280 (B.YIM) * column 4, lines 35 - 54; figures 1-6 *	1, 6, 7, 11	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)
B63H

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	27 AUGUST 1991	CZAJKOWSKI A.R.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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