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(56) References cited :
DE-C- 606 119
FR-A- 820 738
GB-A- 7 889
JP-A- 5 311 490
JP-A-60 222 391
JP-A-61 146 699
JP-A-63 154 494
US-A- 1 386 835
US-A- 2 199 823
US-A- 2 474 562

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Description

TECHNICAL FIELD

The present invention relates to a device for propelling ships.

BACKGROUND ART

Ship propelling devices include a tandem propeller device comprising at least two propellers mounted on a propeller shaft and spaced apart longitudinally of the shaft (Unexamined Japanese Patent Publication SHO 57-205297), a tandem propeller device comprising front and rear propellers which are different in diameter (Unexamined Japanese Utility Model Publication SHO 56-30195 and SHO 57-139500), finned propeller boss cap (Unexamined Japanese Patent Publication SHO 63-154494), etc.

With the above-mentioned tandem propeller devices, the velocity induced by the front propeller is in such a direction as to accelerates the water flowing rearwardly of the propeller and also moves the water in the same direction as the rotation of the propeller, consequently giving a lower efficiency to the rear propeller which operates in the rearward flow produced by the front propeller. It has therefore been difficult to improve the propeller efficiency of the tandem propeller device.

The tandem propeller device will be described generally with reference to FIGS. 9 to 11 and FIGS. 30 and 31.

FIG. 9 is a diagram showing a propeller blade as it is seen from the rudder side. In FIG. 9, R is the radius of the propeller, and r is an optional radial position.

FIG. 10 shows the propeller blade in section taken along a cylinder with the radius r and developed to a plane. The propeller blade has a pitch like screws and a pitch angle θ with respect to the direction of rotation. (The pitch surface is defined by the so-called nose-tail line through the leading edge of the blade and the trailing edge thereof.) Further the blade has a camber forwardly of the propeller as seen in the cross section of FIG. 11.

When the propeller rotates to advance, the water follows in the direction of βi with respect to the direction of rotation. (The term "velocity induced by propeller" in FIG. 10 refers to the flow of water induced by the rotation and advance of the propeller. The water is drawn into the propeller and moves in the direction of rotation of the propeller.) The greater the difference between θ and βi, i.e., the attack angle θ - βi, and the greater the camber of the blade, the greater is the lift L acting on the blade.

The lift L acts perpendicular to the direction of inflow of water, and the component thereof in the direction of advance is a thrust T, and the component thereof in the direction of the rotation is a rotation resistance force F.

$$\left.\begin{aligned} T &= L\cos\beta i \\ F &= L\sin\beta i \end{aligned}\right\} \qquad \text{Expression (1)}$$

The pitch and the camber are so determined that the rotational torque delivered from the engine is in balance with the rotation resistance torque Q = F x r. The greater the ratio of the thrust to the rotation resistance force, T/F, the higher is the propeller efficiency ηo.

$$\eta o \alpha T/F = \cot \beta i \qquad \text{Expression (2)}$$

Next, the tandem propeller will be discussed. In the case of the tandem propeller, the front propeller is positioned in front of the rear propeller and is therefore subjected to the velocity induced by the rear propeller, so that βi is slightly greater, i.e., βi' as shown in FIG. 30. As a result, as will be apparent from Expression (2), ηo becomes smaller, hence a lower propeller efficiency.

Similarly, the rear propeller, which is positioned in the rearward flow from the front propeller, is subjected to the velocity induced by the front propeller (the propeller-induced velocity increases due to acceleration as the water flows rearward) and further to the velocity induced by the rear propeller itself, with the result that βi becomes greater, i.e., βi" as shown in FIG. 31. The rotational torque delivered from the engine may be absorbed by the combination of the front and rear propellers, while the diameter, pitch, etc. of the front and rear propellers are variable. Accordingly, although some conclusion as to the improvement of efficiency can not be obtained only from the above explanation, it is apparent that the induced velocities of the front and rear propellers adversely affect each other to make it difficult to achieve an improved propeller efficiency.

Next, the relationship between the propeller efficiency and the propeller-induced velocity, especially the propeller-induced velocity in a ship stern wake, will be discussed with reference to calculation examples based on the propeller lifting surface theory and the propeller theory of infinite number of blades. The propeller-induced velocity varies with the position with respect to the radial direction or front-rear direction of the propeller. As an example, FIGS. 20 and 21, solid curves represent the values obtained according to the propeller lifting surface theory and the propeller theory of infinite number of blades for a propeller designed for ships of medium speeds when the propeller is in rotation in a uniform flow. FIG. 20 shows a distribution of propeller-induced velocities at the position of the propeller along the radial direction thereof. FIG. 21 shows a distribution of propeller-induced velocities in the front direction at r/R = 0.3. In these diagrams, Wx is the velocity of a propeller-induced flow which is drawn into the propeller and forced out rearwardly thereof, and Wθ is the velocity of a propeller-induced flow which is produced in the same direction as the propeller rotation. It is seen that both Wx and Wθ increase greatly at the position of the propeller.

In actually, the propeller operates in a complex stern flow of water, and the propeller-induced velocity therefore varies. The flow at the position of the propeller in the stern will be considered. Since the water has viscosity, the water near the surface of the hull is dragged by the ship, so that the flow at the position of propeller has a velocity Vs(l - W) which is slightly smaller than the velocity Vs of the ship. Vs·W is the velocity of water dragged along by the ship. This flow is termed a "wake," and W is termed a "wake coefficient." The wake has an uneven distribution in the disk of propeller. (This distribution is termed "wake distribution.") FIG. 22 shows the wake distribution of ships of medium speed. Generally, with common merchant ships, the wake is great and the flow into the propeller has a low velocity at the central portion but the wake diminishes toward the outer ends of blades with increasing the velocity of the flow into the propeller as shown in FIG. 22. FIGS. 20 and 21, broken curves represent calculated propeller-induced velocities when the propeller is in rotation in the wake. It is seen that over the r/R range of 0.2 to 0.6 in which the wake is great, the propeller-induced velocity is much higher in the wake than in the uniform flow.

The propeller-induced velocity results in a lower propeller thrust and an increased rotation resistance torque, i.e., a lower propeller efficiency. FIGS. 23 and 24 show the radial distributions of decreases in the thrust and increases in the rotation resistance torque, respectively, corresponding to the propeller-induced velocities of FIG. 20 (as calculated based on the propeller lifting surface theory). The solid line represents the result in the uniform flow, and the broken line the result in the wake. The decrease in the thrust due to the propeller-induced velocity is 4% of the propeller thrust in the uniform flow but is as great as 10% of the thrust in the wake. The increase in the rotation resistance torque due to the induced velocity is 21% of the whole in the uniform flow but is as great as 28% in the wake. FIGS. 23 and 24 indicate that the decrease and increase concentrically occur in the r/R range of 0.2 to 0.6 where the wake is great.

The finned propeller boss cap (hereinafter referred to briefly as "PBCF") disclosed in Unexamined Japanese Patent Publication SHO 63-154494 comprises a propeller boss cap having fins. The fins act as plates for guiding the water flow in the rear of the propeller boss cap toward such a direction as to inhibit hub vortices, diffusing hub vortices to decrease the drag induced by vortices on the propeller blades. However, the propeller efficiency is dependent on the propeller-induced velocity, especially that in the uneven stern wake, as already stated. Accordingly, the effect expected of the PBCF can not be fully achieved unless the problem associated with the induced velocity is solved.

A first object of the present invention which has been accomplished to solve the foregoing problems of the prior art is to provide turbine blades in the rear of propeller blades to realize an improved propeller efficiency and a reduced torque.

The propeller basically differs from the turbine in that the former is a device for giving energy to a fluid to obtain a propelling force from the resulting reaction, whereas the latter is a device for obtaining a rotational torque from the energy possessed by a fluid. The velocities induced by the two devices are in exactly opposite directions to each other. We have attained the above first object directing attention to this basic difference.

A second object of the present invention is to provide a ship propelling device comprising turbine blades disposed in the rear of propeller blades, the turbine blades being prepared separately from a propeller boss and a propeller cap and removably provided on the propeller boss or between the boss and the propeller cap, the propelling device therefore being so adapted that an existing cap is usable as it is for an existing propeller.

DISCLOSURE OF THE INVENTION

To fulfill the first object, the present invention provides the following technical means.

More specifically, the present invention provides a ship propelling device having mounted on a propeller shaft 1 propeller blades 2 and turbine blades 3, the device being characterized in that the propeller blades 2 are arranged at a front position with the turbine blades arranged at a rear position, the axial distance ℓ between both the blades 2, 3 being at least 6%, the number of turbine blades 3 being the number of propeller blades 2 multiplied by an integer, the diameter of the turbine blades 3 being 33 to 60% of the diameter of the propeller blades 2.

The axial distance ℓ is a value (%) obtained by dividing the distance between the center lines of the respective blades 2, 3 by the diameter of the propeller.

Further according to a preferred embodiment of the present invention, the pitch angle θ_P of the propeller blades 2 and the pitch angle θ_T of the turbine blades 3 satisfy the relation of $\theta_T \leqq \theta_P + 20°$ at a position of $0.3 \leqq r/R \leqq 0.6$, whereby the first object is achieved.

To fulfill the second object, the present invention provides according to a further preferred embodiment the following technical means.

More specifically, the device is characterized in that the turbine blades 3 disposed in the rear of the propeller blades 2 each have a flange 13A at the base portion thereof, the flange 13A being removably fastened to the outer periphery of a propeller boss 2A with screws. Alternatively, the device is characterized in that the turbine blades 3 disposed in the rear of the propeller blades 2 have a ring 3A at their base portions, the ring 3A being removably fixedly interposed between a propeller boss 2A and a propeller cap 4 in the rear of the boss 2A. The device is further characterized in that the turbine blades 3 are formed integrally with the ring 3A. Alternatively, the device is characterized in that the turbine blades 3 are removably fixed to the ring 3A by screw fastening means. Further alternatively, the device is characterized in that the turbine blades 3 are each removably fitted in a dovetail groove 3B formed in the outer periphery of the ring 3A axially thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a front view showing an embodiment of the invention;
FIG. 2 is a side elevation of the same;
FIG. 3 is a diagram of flow into the blade section of front propeller of the embodiment;
FIG. 4 is a diagram of flow into the turbine blade section of the embodiment;
FIG. 5 is a diagram illustrating the position of the propeller blade and the turbine blade relative to each other with respect to the front-rear direction;
FIG. 6 is a graph showing the relationship between the increase in propeller efficiency and the position of turbine blades;
FIG. 7 is a graph showing the relationship between the increase in propeller efficiency and the number of turbine blades;
FIG. 8 is a graph showing the relationship between the increase in propeller efficiency and the turbine blade diameter;
FIG. 9 is a front view of one propeller blade;
FIG. 10 is a diagram of flow into a blade section;
FIG. 11 is a sectional view showing the camber of the propeller blade;
FIGS. 12 and 13 are fragmentary side elevations showing two embodiments of the invention wherein turbine blades are interposed between a propeller boss and a propeller cap;
FIGS. 14 to 16 are front views showing three examples of how to attach the turbine blades to a ring;
FIG. 17 is a fragmentary side elevation showing the turbine blade as attached to the propeller boss by a flange;
FIG. 18 is a side elevation of the flanged turbine blade;
FIG. 19 is a plan view of the same;
FIG. 20 is a graph showing a radial distribution of propeller-induced velocities (at the position of propeller);
FIG. 21 is a graph showing a distribution of propeller-induced velocities in the front-rear direction ($r/R = 0.3$);
FIG. 22 is a diagram illustrating a wake distribution of medium- speed ships;
FIG. 23 is a graph showing a radial distribution of decreases in thrust due to propeller-induced velocities;
FIG. 24 is a graph showing a radial distribution of increases in rotation resistance torque due to propeller-induced velocities;
FIG. 25 is a comparative graph showing θ_P and β_{Ti} in a uniform flow of a propeller for medium- speed ships;
FIG. 26 is a comparative graph showing θ_p and β_{Ti} in a wake of the propeller for medium- speed ships;
FIG. 27 is a comparative graph showing θ_P and β_{Ti} in wake of another propeller for medium- speed ships;
FIG. 28 is a comparative graph showing θ_P and β_{Ti} in a wake of a propeller for high- speed ships;
FIG. 29 is a graph showing the relationship between zero lift angle and the camber ratio;
FIG. 30 is a diagram of flow into the blade section of front propeller of a conventional tandem propeller device; and

FIG. 31 is a diagram of flow into the blade section of rear propeller of the same.

BEST MODE OF CARRYING OUT THE INVENTION

Embodiments of the present invention and the operation thereof will be described below with reference to the drawings.

FIGS. 1 and 2 show a ship propelling device having mounted on a propeller shaft 1 propeller blades 2 at a front position (with respect to the direction of advance or toward the hull side) and turbine blades 3 at a rear position, the axial distance ℓ (see FIG. 5) between both the blades 2, 3 being at least 6%, the number of turbine blades 3 being the number of propeller blades 2 multiplied by an integer, the diameter of the turbine blades 3 being 33 to 60% of the diameter of the propeller blades 2. In FIG. 2, indicated at 2A is a propeller boss, and at 4 a cap.

The axial distance ℓ is a value (%) obtained by driving the distance between the center lines of the respective blades 2, 3 by the diameter of the propeller (see FIG. 5).

The geometric configuration of the propeller blade 2 and the turbine blade 3 are so designed that the pitch and the camber of the propeller blade satisfy the expression

$$\theta + \alpha 0 - \beta i > 0 \qquad \text{Expression (3)}$$

and that those of the turbine blade satisfy the expression

$$\theta + \alpha 0 - \beta i < 0 \qquad \text{Expression (4)}$$

In the expressions, $\alpha 0$ is the zero lift angle of the blade section (i.e. the angle the direction of inflow of water makes with the pitch surface when the lift is zero). It is positive when the camber is directed forward, is negative when the camber is directed rearward, or is zero when the camber is zero.

The propeller basically differs from the turbine in that the former (propeller) is a device for giving energy to a fluid to obtain a propelling force from the resulting reaction, whereas the latter (turbine) is a device for obtaining a rotational torque from the energy possessed by a fluid

FIGS. 3 and 4 are diagrams of flow into the front propeller blade section and into the rear turbine blade section, respectively, of the propeller having turbine blades. With the propeller blade shown in FIG. 3, a rotational torque corresponding to a rotation resistance force F_p' is given to obtain a thrust T_p', whereas with the turbine blade shown in FIG. 4, the thrust acts as a rearward resistance force $-T_T$", while the rotation resistance force acts as a force $-F_T$" to reduce the force. The propeller produces a thrust, whereas the turbine blade obtains energy from a rearward flow from the propeller to serve only as an auxiliary blade to reduce the rotation resistance torque. In this respect, the propeller provided with the turbine blades is a device entirely different from the tandem propeller device.

The direction of the velocity induced by turbine blades is exactly opposite to the direction of the velocity induced by the propeller. The flow induced by the propeller is drawn into the propeller and also follows the direction of rotation of the propeller, but the velocity induced by the turbine blades forces the flow forward and rotates the flow in a direction opposite to the direction of rotation of the propeller.

The efficiency of the propeller having the turbine blades will be considered. With respect to the front propeller, β_{Pi} decreases to β'_{Pi} owing to the velocity induced by the turbine blades, consequently improving the efficiency of the front propeller. With respect to the rear turbine blades, the greater β_i, the higher is the efficiency since the direction of the force produced is opposite to that of the propeller. A still higher efficiency can be achieved if it is possible to design the turbine blades so that β_{Ti} of the turbine blades has the following relationship with β_{Pi} of the propeller blades.

$$\beta_{Pi} < \beta_{Ti} \qquad \text{Expression (5)}$$

In the front side of the propeller, β_{Ti} is small, but if the turbine blades are provided in the rear of the propeller, the propeller-induced velocity is accelerated to give an increased β_{Ti} value, hence an advantage. Further when the rearward flow from propeller impinges on the turbine blade surfaces, the turbine blades act as solid walls and will produce an effect to block the flow. Especially if positioned in the rearward flow from propeller which is given an accelerated propeller-induced velocity, the turbine blades will presumably produce an enhanced blocking effect.

The foregoing relationship between propeller-induced velocity in the stern wake and the propeller efficiency appears to indicate that the propeller having the turbine blades produces an increased effect in the wake and that it is desirable to select the turbine blade diameter from a range wherein the wake is great.

Based on the above discussion and the propeller lifting surface theory, calculations were made of the efficiency in the wake of a four-blade propeller equipped with turbine blades in the rear of the propeller and designed for use with high- speed ships, the calculations being made for different numbers and different diameters of turbine blades. The position of the turbine blades with respect to the front-rear direction or axial direction of the propeller is expressed in terms of a value ℓ (%) which is obtained by dividing the distance from the center line of the propeller to the center line of the turbine blade as measured on the boss surface by the diameter of the propeller. The position of the turbine blades as disposed in the rear of the propeller is positive (see FIG. 5). The diameter of turbine blades (blade assembly) is expressed in percentage based on the diameter of the propeller.

Table 1 and FIG. 6 show the results of calculations obtained for turbine blades which are 4 in number and 45% of the propeller diameter in diameter, as disposed at varying positions of 0%, 13% and 20%. In the table, K_T is a thrust coefficient (= $T/\rho n^2 D_P^4$; T: thrust, ρ: density of water, n: number of revolutions of propeller, D_P: propeller diameter), K_Q is a torque coefficient (=$Q/\rho n^2 D_P^5$; Q: torque), and $\Delta\eta o$ is an increase (%) in efficiency based on the the propeller efficiency. The table and the graph reveal that an increased propeller efficiency can be achieved when the turbine blades are disposed rearward from the position of ℓ = 1%. When efficiency increases of at least 1.8% are to be attained in view of the design and the manufacturing cost of the turbine blades, ℓ is in the following range.

$$\ell > 6\% \qquad \text{Expression (6)}$$

Table 1

Turbine blade position	Properties			
	K_T	K_Q	ηo	$\Delta\eta o$ (%)
0%	0.157	0.0296	0.723	-0.3
13%	0.158	0.0289	0.744	2.6
20%	0.158	0.0289	0.745	2.7
Propeller only	0.161	0.0302	0.725	–

Table 2 and FIG. 7 show the results obtained for turbine blades which are disposed at the position of ℓ = 13%, have diameter of 45% of the propeller diameter and are 4, 8 or 12 in number. The table and the graph reveal that an efficiency increase of at least 1.8% can be achieved when the number of turbine blades is the number of propeller blades multiplied by an integer (one to three times the latter).

Table 2

Number of turbine blades	Properties			
	K_T	K_Q	ηo	$\Delta\eta o$ (%)
4	0.158	0.0289	0.744	2.6
8	0.154	0.0282	0.744	2.7
12	0.151	0.0277	0.741	2.2
Propeller only	0.161	0.0302	0.725	–

Table 3 and FIG. 8 show the results obtained for turbine blades which are disposed at the position of ℓ = 13% and 4 in number and have a diameter of 25%, 35%, 45%, 55% or 65% of the propeller diameter. The table and the graph show that an increase in the turbine blade diameter results in a greater increase in efficiency, whereas an excessive increase in the diameter conversely decreases the efficiency, indicating that efficiency increases of at least 1.8% can be achieved when the turbine blade diameter is in the following range.

$$33\%\ D_P < \text{turbine blade diameter} < 60\%\ D_P \qquad \text{Expression (7)}$$

Table 3

Turbine blade diameter	Properties			
	K_T	K_Q	ηo	$\Delta \eta o$ (%)
25%	0.162	0.0301	0.730	0.7
35%	0.161	0.0297	0.739	2.0
45%	0.158	0.0289	0.744	2.6
55%	0.151	0.0276	0.742	2.3
65%	0.134	0.0249	0.732	1.0
Propeller only	0.161	0.0302	0.725	–

Next, the correlation between the pitch angle of the front propeller and the pitch angle of the rear turbine was checked. Basically, if the pitch and the camber of the rear blades are so determined as to satisfy Expression (4), the blades serve as turbine blades. Using some symbols in FIG. 4, Expression (4) can be rewritten as:

$$\theta_T + \alpha_{T0} - \beta'_{Ti} < 0 \qquad \text{Expression (4)'}$$

where α_{T0}: zero lift angle of rear turbine blades. Now suppose the camber of the rear blades is zero, that is, the blades are flat plates. α_{T0} is then zero, and Expression (4)' becomes:

$$\theta_T - \beta'_{Ti} < 0 \qquad \text{Expression (8)}$$

Further if the pitch angle θ_T of the rear blades are made to coincide with the direction β_{Ti} of the rearward flow from the propeller, the velocity induced by the rear blades becomes zero, and β'_{Ti} equals β_{Ti}. Thus when the pitch angle of the rear blades which are in the form of flat plates satisfies the relation:

$$\theta_T < \beta_{Ti} \qquad \text{Expression (9)}$$

the rear blades serve as turbine blades.

Accordingly, β_{Ti} was calculated based on the propeller lifting surface theory and the propeller theory of infinite number of blades, for comparison with the pitch θ_P of propellers. FIGS. 25 to 28 show the results of comparison. FIG. 25 shows the results in a uniform flow of a propeller for medium- speed ships, FIG. 26 shows results in a wake of the same propeller as in FIG. 25, FIG. 27 shows the results in a wake of other propeller for medium- speed ships, and FIG. 28 shows the results in a wake of a propeller for high-speed ships. In these graphs, $\beta_{Ti}(0)$, $\beta_{Ti}(10)$ and $\beta_{Ti}(20)$ mean β_{Ti} at ℓ of 0%, 10% and 20%, respectively.

These results indicate that

$$\beta_{Ti} \simeq \theta_P \text{ for } 0.3 \leqq r/R \leqq 0.6 \qquad \text{Expression (10)}$$

at a position of $\ell > 6\%$ although the flows into the propellers are different or the propellers are different. When the expression is substituted in Expression (9),

$$\theta_T < \theta_P \text{ for } 0.3 \leqq r/R \leqq 0.6 \qquad \text{Expression (11)}$$

Expression (11) is for flat plates. When the plates are cambered, we obtain:

$$\theta_T < \theta_P - \alpha_{T0} \text{ for } 0.3 \leqq r/R \leqq 0.6 \qquad \text{Expression (12)}$$

FIG. 29 shows an example of relationship between the camber ratio (i.e. camber/blade width) and $\alpha 0$. It is seen from FIG. 29 that a 1% variation in the camber ratio alters the zero lift angle by about 1°. When the turbine blades are given a camber rearward and if the camber ratio is up to 20% if highest, Expression (12) becomes:

$$\theta_T \leqq \theta_P + 20° \text{ for } 0.3 \leqq r/R \leqq 0.6 \qquad \text{Expression (13)}$$

(In Expressions (10) to (13), R is the radius of the propeller.) when the pitch angle of the rear blades is so determined as to satisfy Expression (13) at a position of 0.3 to 0.6 in r/R, the blades serve as turbine blades, of which the foregoing advantages is expected.

At a position of $r/R < 0.3$, β_{Ti} markedly increases, and even if θ_T is a considerably great value, the blades act as turbine blades, so that no specific limit is given herein. Further even when θ_T is so determined as not to satisfy Expression (13) in a portion of the r/R range of from 0.3 to 0.6, the overall blade assembly can be so designed as to function as turbine blades, whereas the above-mentioned advantage will then diminishes.

FIGS. 12 to 19 show some embodiments of means for installing the turbine blades 3 in place.

With reference to FIGS. 12 and 13, the turbine blades 3 are provided at their base portions with a ring 3A, which is interposed between a propeller boss 2A and a propeller cap 4 in the rear of the boss, fitted around a propeller shaft 1 and removably fixed in position with bolts 5, 6, 7. With the embodiment shown in FIG. 12, the propeller boss 2A, ring 3A and cap 4 are fastened together with bolts 5. In the case of FIG. 13, the ring 3A is fastened to the propeller boss 2A with bolts 6, and the cap 4 is fastened to the ring 3A with bolts 7. As seen in FIGS. 14 to 16, the bolts 5, 6, 7 are inserted through bolt holes 3C formed in the ring 3A axially thereof in a radial arrangement for fastening.

FIGS. 17 to 19 show embodiments wherein the turbine blades 3 are removably fixed to the outer periphery of the propeller boss 2A with screw fastening means. Each turbine blade 3 is provided at its base portion with a flange 13A in the form of a flat plate and having fastening holes 13B. With the flange 13A placed on the outer periphery of the propeller boss 2A, bolts 13C are inserted through the respective fastening holes 13B and driven into female screws formed in the boss.

FIGS. 14 to 16 show relationships between the ring 3A and the turbine blades 3. The ring 3A of FIG. 14 is formed in its outer periphery with axial dovetail grooves 3B in a radial arrangement. With the end face of base portion of each turbine blade 3 placed on the outer periphery of the ring 3A, a dovetail 3D formed at the base portion of the turbine blade 3 is axially fitted into the dovetail groove 3B. The dovetail 3D is axially restrained by the propeller boss 2A and cap 4.

With the embodiment of FIG. 15, the turbine blades 3 and the ring 3A are integrally formed by casting, welding or the like. Incidentally with the embodiment of FIGS. 17 to 19, the turbine blade 3 and the flange 13A are similarly made integrally.

FIG. 16 shows an embodiment wherein the ring 3A has attaching holes 3E in a radial arrangement, and a projection 3D having a threaded portion is inserted through the hole 3E and fastened with a nut 8.

The ring 3A of some of the above embodiments can be in the form of a divided ring. The turbine blades 3 can be provided with means for adjusting the angle of the blade as attached.

The turbine blades 3, and the ring 3A or flanges 13A can be made of the same material as the propeller (e.g., copper alloy), or of FRP or like composite material.

According to the present invention described above, turbine blades are provided in the rear of propeller blades, so that the device produces a greater effect when the velocity induced by the propeller is higher, that is, when the rearward flow from the propeller has a higher velocity and also when the flow following the direction of rotation is greater, hence an improved propeller efficiency.

When the propellers of ships in service become no longer rotable lightly (efficiently) owing to the staining or degradation of the hull or to an overage machine, the turbine blades which assure a reduced torque can be attached to the propeller to render the propeller rotatable lightly.

The turbine blades are provided at their base portions with flanges or a ring, and the flanges are removably attached to the outer periphery of the propeller boss or the ring is removably provided between the boss and the propeller cap. This arrangement makes it possible to use an existing cap as it is for an existing propeller to provide a propelling device having the turbine blades at a low cost. When the ring is given a suitable wall thickness, the turbine blades can be attached thereto is integral members, or by welding, fitting or fastening with bolts, with considerably great freedom, hence facilitated design and manufacture.

INDUSTRIAL APPLICATION

The present invention can be utilized for ship propelling devices having propeller blades and turbine blades mounted on a propeller shaft.

Claims

1. A ship propelling device having mounted on a propeller shaft (1) propeller blades (2) and turbine blades (3), the device being characterized in that the propeller blades (2) are arranged at a front position with the turbine blades (3) arranged at a rear position, the axial distance ℓ between both the blades (2), (3) being at least 6%, the number of turbine blades (3) being the number of propeller blades (2) multiplied by an integer, the diameter of the turbine blades (3) being 33 to 60 % of the diameter of the propeller blades (2), the axial distance ℓ being a value (%) obtained by dividing the distance between the center lines of the respective blades (2), (3) by the diameter of the propeller blades.

2. A ship propelling device as defined in claim 1 wherein the pitch angle (θ_P) of the propeller blades (2) and the pitch angle (θ_T) of the turbine blades (3) satisfy the relation of $\theta_T \leqq \theta_P + 20°$ at a position of $0.3 \leqq r/R$

$\leqq$ 0.6 wherein R is the radius of the propeller blades, and r is an optional radial position.

3. A ship propelling device as defined in claim 1 wherein the turbine blades (3) disposed in the rear of the propeller blades (2) each have a flange (13A) at the base portion thereof, the flange (13A) being removably fastened to the outer periphery of a propeller boss (2A) with screws.

4. A ship propelling device as defined in claim 1 wherein the turbine blades (3) disposed in the rear of the propeller blades (2) have a ring (3A) at their base portions, the ring (3A) being removably fixedly interposed between a propeller boss (2A) and a propeller cap (4) in the rear of the boss (2A).

5. A ship propelling device as defined in claim 4 wherein the turbine blades (3) are formed integrally with the ring (3A).

6. A ship propelling device as defined in claim 4 wherein the turbine blades (3) are removably fixed to the ring (3A) by screw fastening means.

7. A ship propelling device as defined in claim 4 wherein the turbine blades (3) are each removably fitted in a dovetail groove (3B) formed in the outer periphery of the ring (3A) axially thereof.

Patentansprüche

1. Schiffsantriebvorrichtung, bei der Propellerblätter (2) und Turbinenblätter (3) an einer Propellerwelle (1) montiert sind, die Vorrichtung ist dadurch gekennzeichnet, daß die Propellerblätter (2) an einer vorwärtigen Position bei an einer rückwärtigen Position angeordneten Turbinenblättern (3) angeordnet sind, der axiale Abstand ℓ zwischen den Blättern (2), (3) wenigstens 6% beträgt, die Anzahl der Turbinenblätter (3) die mit einer ganzen Zahl multiplizierte Anzahl der Propellerblätter (2) ist und der Durchmesser der Turbinenblätter (3) 33 bis 60% des Durchmessers der Propellerblätter (2) beträgt, wobei der axiale Abstand ℓ ein Wert (%) ist, der durch Dividieren des Abstandes zwischen den Mittellinien der jeweiligen Blätter (2), (3) mit dem Durchmesser der Propellerblätter erhalten wird.

2. Schiffsantriebvorrichtung, wie im Anspruch 1 definiert, in welcher der Anstellwinkel (θ_P) der Propellerblätter (2) und der Anstellwinkel (θ_T) der Turbinenblätter (3) die Beziehung $\theta_T \leqq \theta_P + 20°$ an einer Position 0,3 $\leqq r/R \leqq$ 0,6 erfüllen, worin R der Radius der Propellerblätter und r eine fakultative radiale Position sind.

3. Schiffsantriebvorrichtung, wie im Anspruch 1 definiert, in welcher jedes der hinter den Propellerblättern (2) angeordneten Turbinenblätter (3) an seinem Basisteil einen Flansch (13A) hat, wobei der Flansch (13A) lösbar am Außenumfang einer Propellernabe (2A) durch Schrauben befestigt ist.

4. Schiffsantriebvorrichtung, wie im Anspruch 1 definiert, in welcher die hinter den Propellerblättern (2) angeordneten Turbinenblätter (3) einen Ring (3A) an ihren Basisteilen besitzen, wobei der Ring (3A) lösbar ortsfest zwischen eine Propellernabe (2A) und eine Propellerkappe (4) hinter der Nabe (2A) eingesetzt ist.

5. Schiffsantriebvorrichtung, wie in Anspruch 4 definiert, in welcher die Turbinenblätter (3) einstückig mit dem Ring (3A) ausgebildet sind.

6. Schiffsantriebvorrichtung, wie in Anspruch 4 definiert, in welcher die Turbinenblätter (3) lösbar am Ring (3A) durch Schraubverbindungsmittel befestigt sind.

7. Schiffsantriebvorrichtung, wie in Anspruch 4 definiert, in welcher jedes der Turbinenblätter (3) lösbar in eine Schwalbenschwanznut (3B), die in der Außenumfangsfläche des Ringes (3A) in dessen axialer Richtung ausgebildet ist, eingebaut ist.

Revendications

1. Dispositif de propulsion de navires dans lequel sont montés sur un arbre porte-hélices (1) des pales d'hélices (2) et des pales de turbines (3), le dispositif étant caractérisé en ce que les pales d'hélices (2) sont

situées à une position antérieure aux pales de turbines (3), situées à une position postérieure, la distance axiale l entre les pales (2), (3) étant au moins de 6%, le nombre de pales de turbines (3) étant égal au nombre de pales d'hélices (2) que multiplie un nombre entier, le diamètre des pales de turbines (3) étant de 33% à 60% du diamètre des pales d'hélices (2), la distance axiale l étant une valeur (%) obtenue en divisant la distance entre les axes des pales respectives (2), (3) par le diamètre des pales d'hélices.

2. Dispositif de propulsion de navires comme défini dans la revendication 1, dans lequel l'angle de calage (θ_P) des pales d'hélices (2) et l'angle de calage (θ_T) des pales de turbines (3) satisfont à la relation $\theta_T \leqq \theta_P + 20°$ quand $0{,}3 \leqq r/R \leqq 0{,}6$, où R est le rayon des pales d'hélices, et r est une position radiale optionnelle.

3. Dispositif de propulsion de navires comme défini dans la revendication 1, dans lequel les pales de turbines (3) situées à l'arrière des pales d'hélices (2) ont chacune une bride (13A) à leurs portions de base, la bride (13A) étant amoviblement attachée à la périphérie externe de moyeux d'hélices (2A) par des vis.

4. Dispositif de propulsion de navires comme défini dans la revendication 1, dans lequel les pales de turbines (3) situées à l'arrière des pales d'hélices (2) ont un anneau (3A) à leurs portions de base, l'anneau (3A) étant amoviblement attaché, et interposé entre un moyeu d'hélices (2A) et un carénage d'hélices (4) à l'arrière du moyeu (2A).

5. Dispositif de propulsion de navires comme défini dans la revendication 4, dans lequel les pales de turbines (3) sont façonnées d'une pièce avec l'anneau (3A).

6. Dispositif de propulsion de navires comme défini dans la revendication 4, dans lequel les pales de turbines (3) sont fixées amoviblement à l'anneau (3A) par des moyens de fixation à vis.

7. Dispositif de propulsion de navires comme défini dans la revendication 4, dans lequel les pales de turbines (3) sont ajustées chacune amoviblement dans une rainure en forme de queue d'arronde (3B), découpée dans la périphérie externe de l'anneau (3A) selon un axe parallèle à celui de l'anneau.

FIG. 1

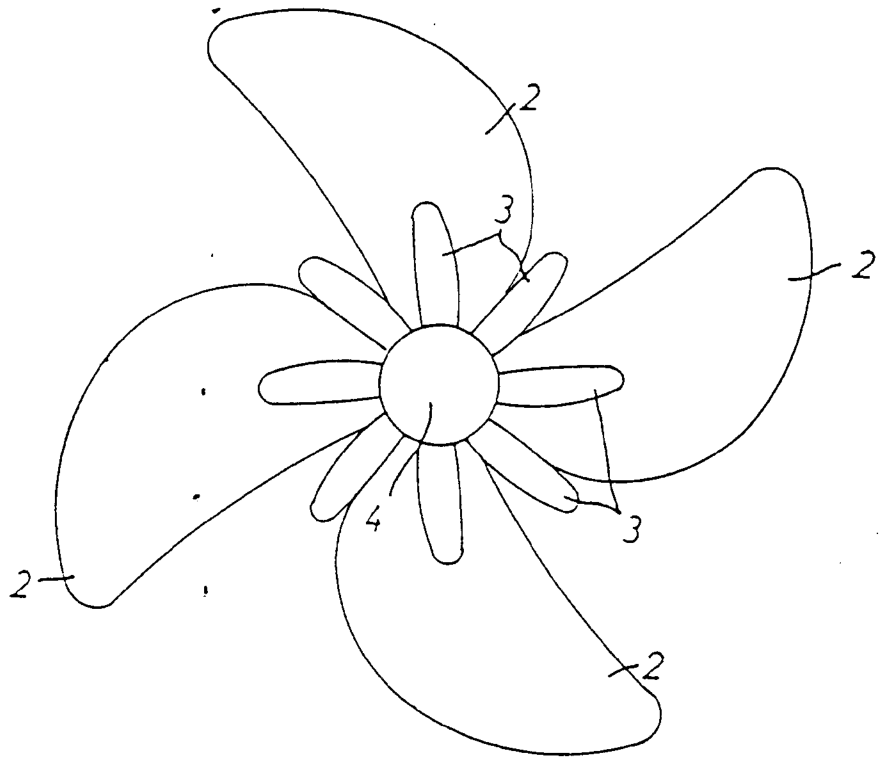


FIG.2

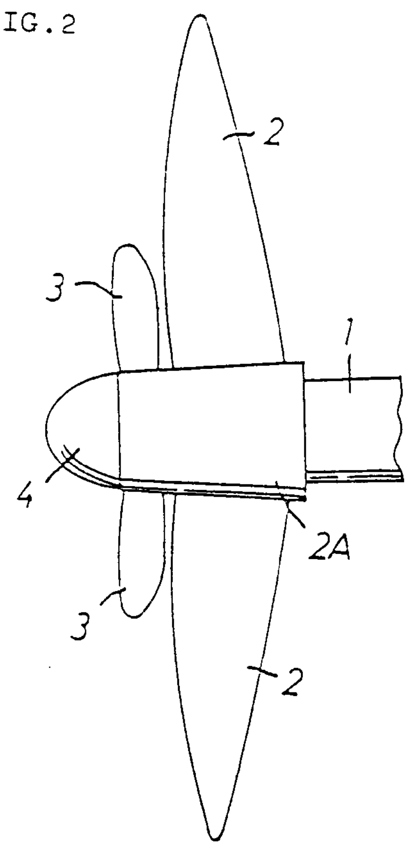


FIG. 3

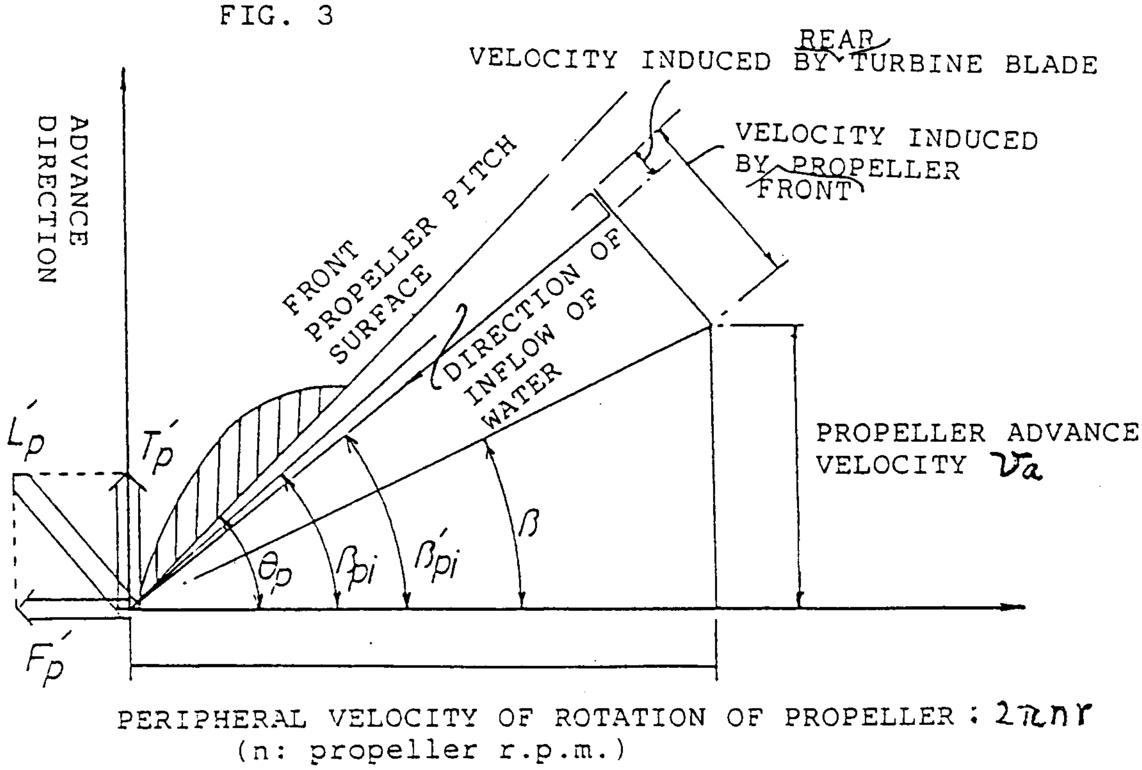

VELOCITY INDUCED BY REAR TURBINE BLADE
VELOCITY INDUCED BY FRONT PROPELLER
ADVANCE DIRECTION
FRONT PROPELLER PITCH SURFACE
DIRECTION OF INFLOW OF WATER
PROPELLER ADVANCE VELOCITY Va
L'p
T'p
F'p
θp
βpi
β'pi
β
PERIPHERAL VELOCITY OF ROTATION OF PROPELLER : 2πnr
(n: propeller r.p.m.)

FIG. 4

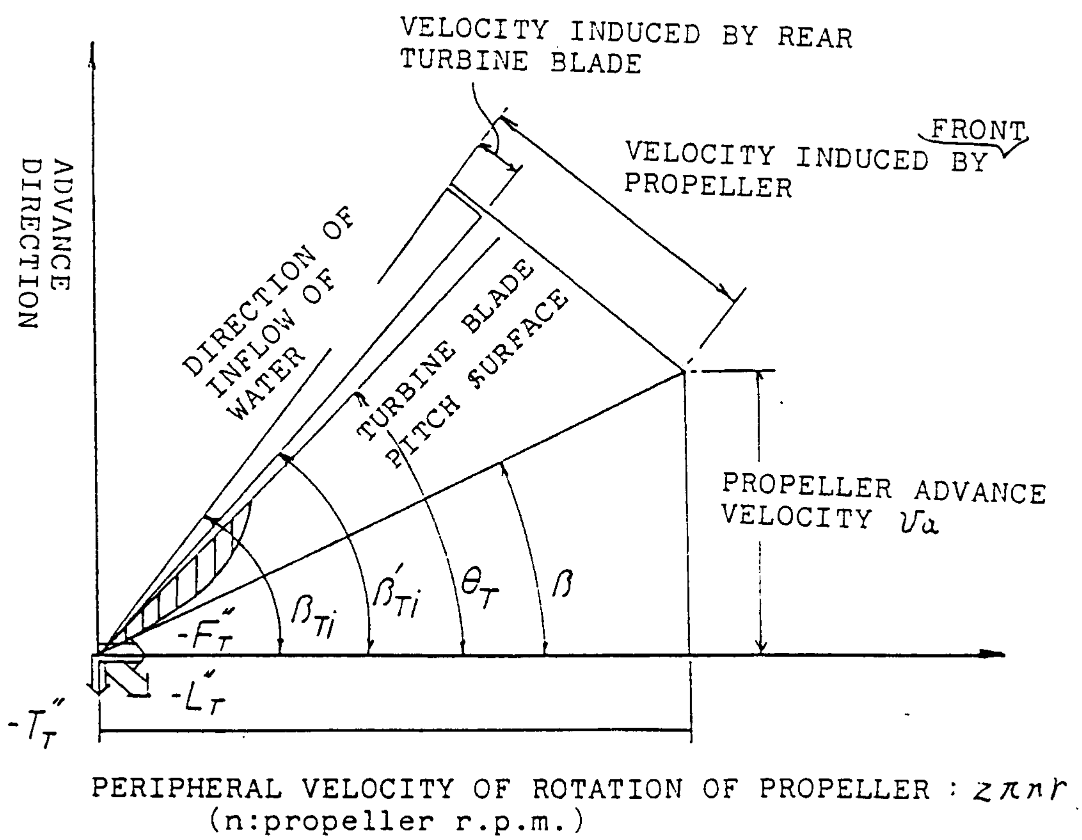

VELOCITY INDUCED BY REAR TURBINE BLADE
VELOCITY INDUCED BY FRONT PROPELLER
ADVANCE DIRECTION
DIRECTION OF INFLOW OF WATER
TURBINE BLADE PITCH SURFACE
PROPELLER ADVANCE VELOCITY Va
βTi
β'Ti
θT
β
-F"T
-L"T
-T"T
PERIPHERAL VELOCITY OF ROTATION OF PROPELLER : 2πnr
(n:propeller r.p.m.)

FIG.5

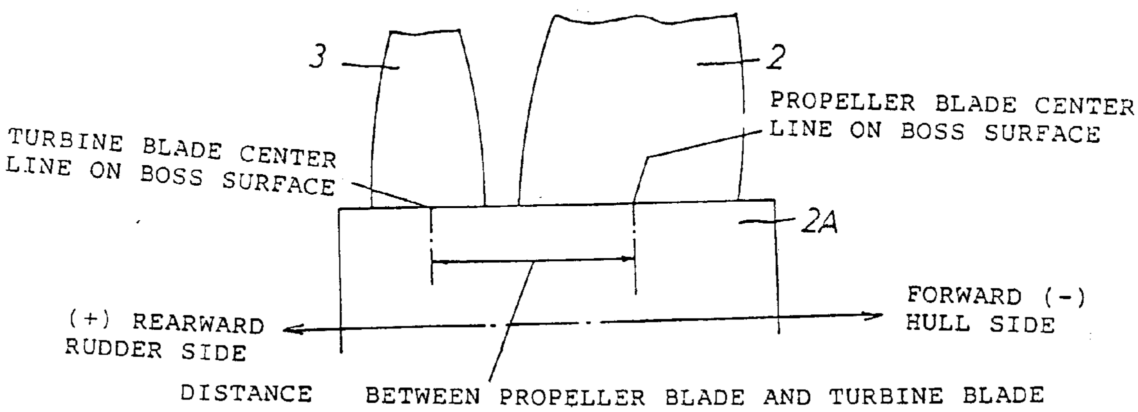


FIG.6

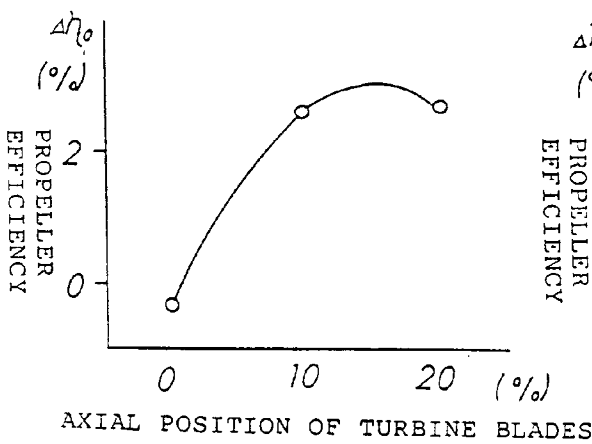


FIG. 7

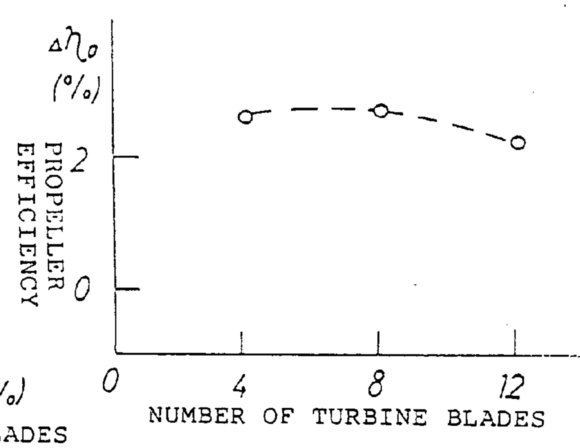


FIG. 8

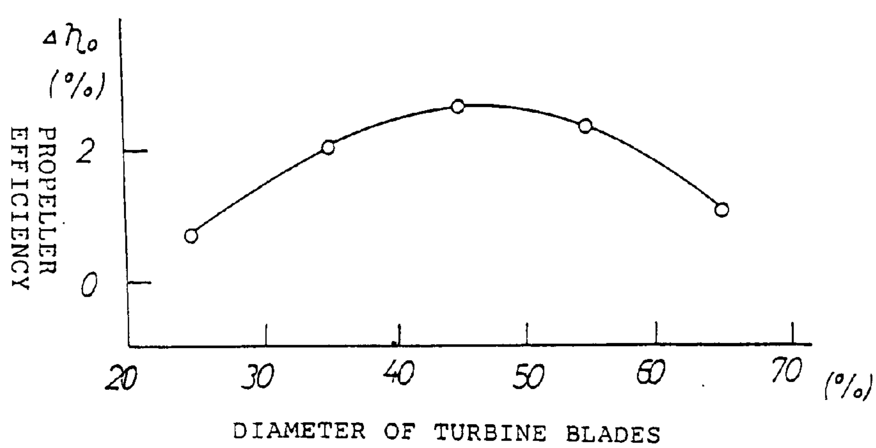


FIG. 9

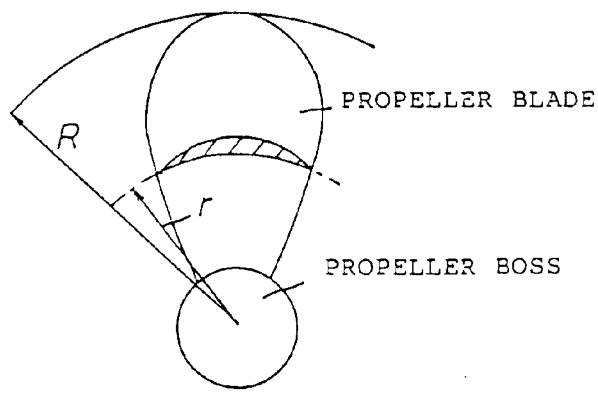


FIG.10

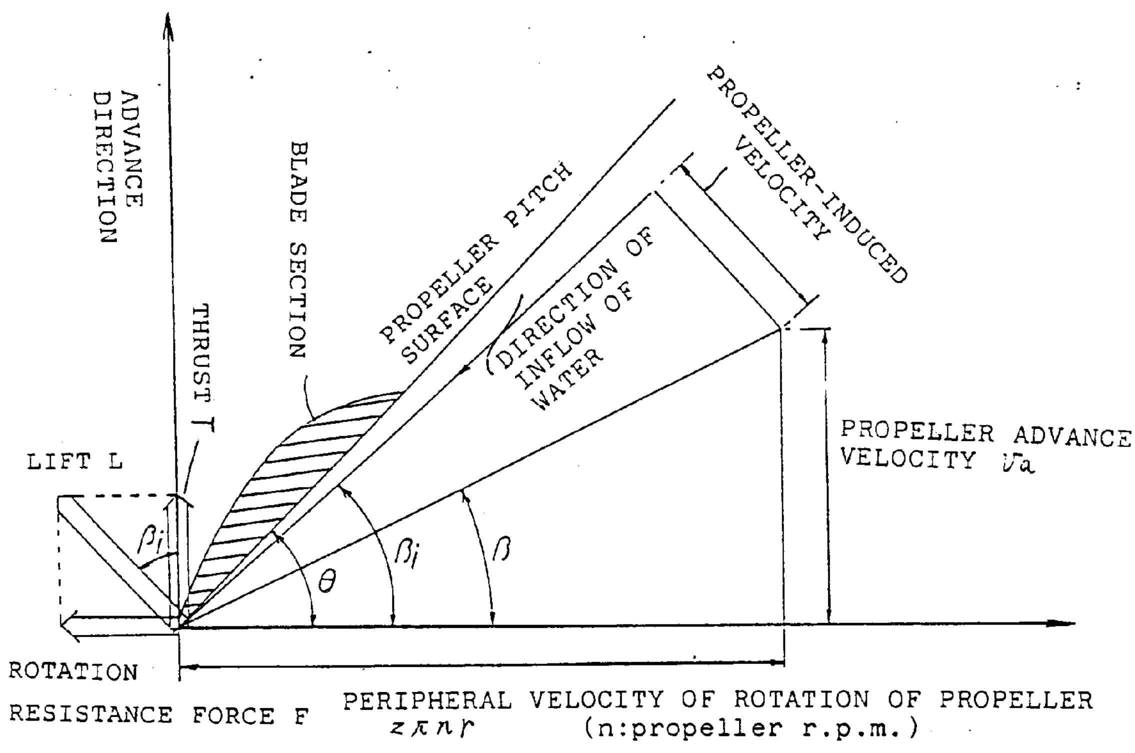


FIG. 11

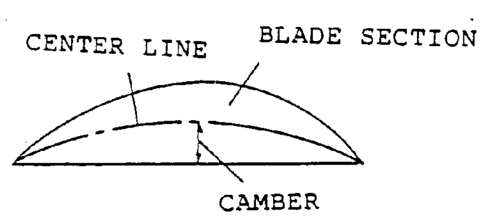


FIG.12

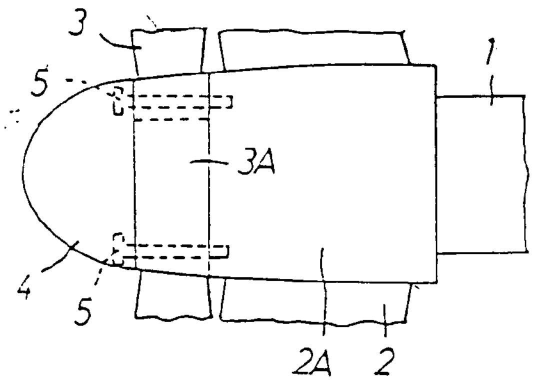


FIG.13

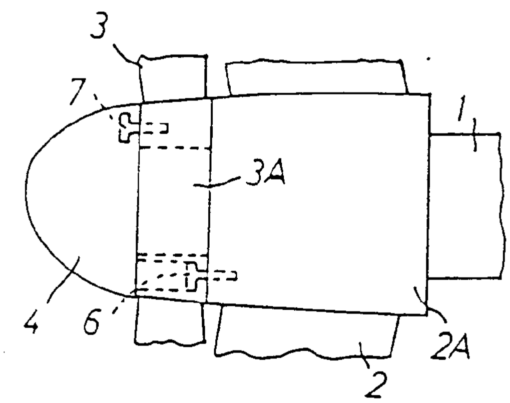


FIG.14

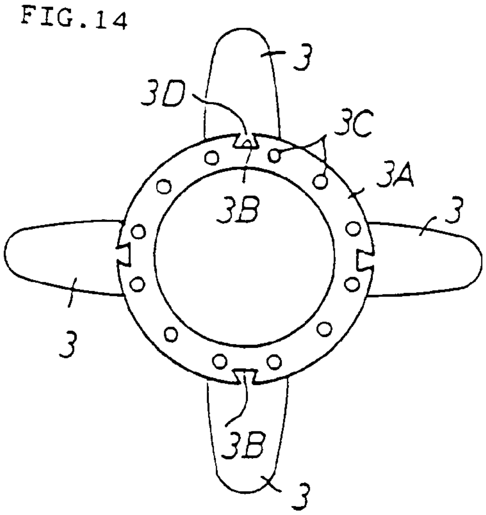


FIG.15

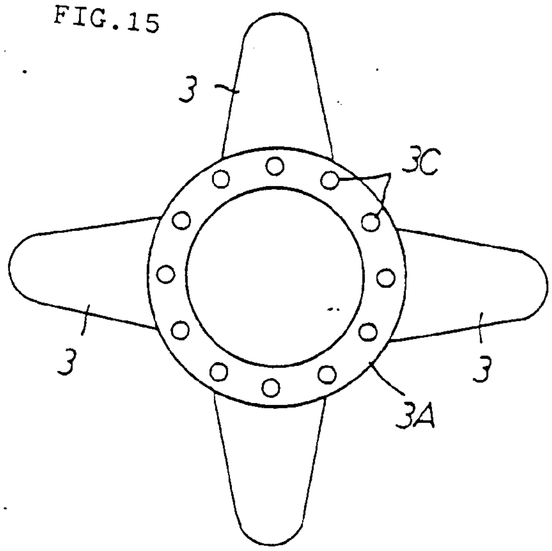


FIG.16

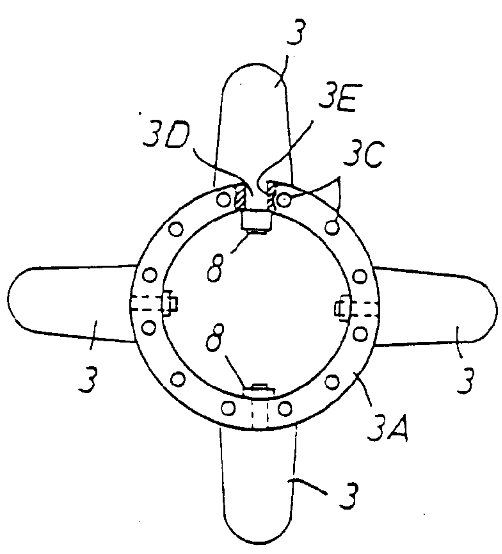


FIG.17

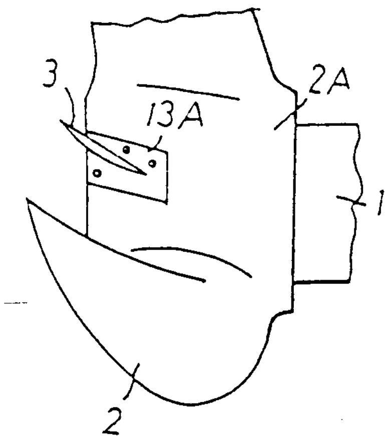


FIG.18

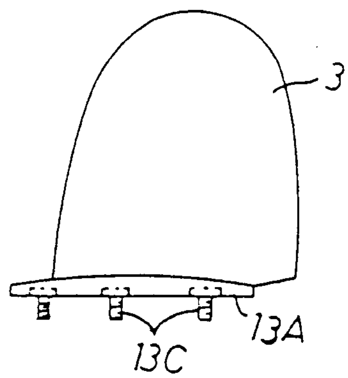


FIG.19

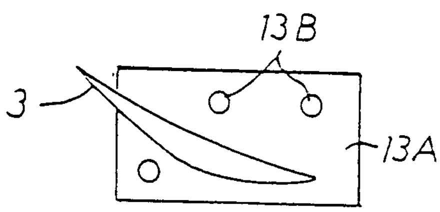


FIG.20

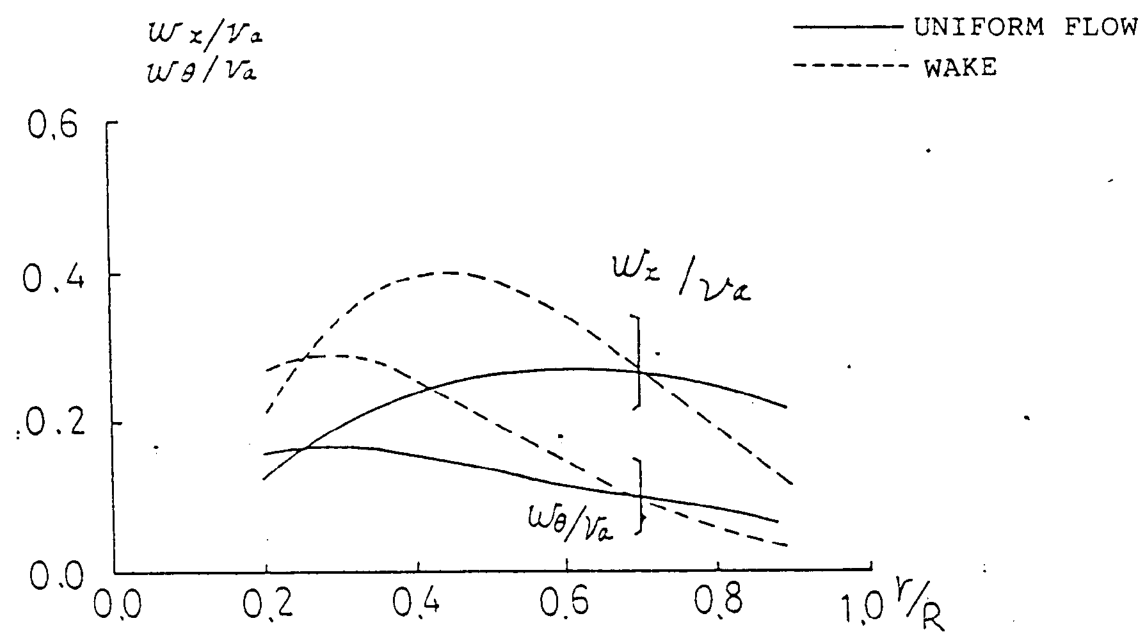

Wx/Va
Wθ/Va
UNIFORM FLOW
WAKE
0.6
0.4
0.2
0.0
Wx/Va
Wθ/Va
0.0
0.2
0.4
0.6
0.8
1.0
r/R

FIG.21

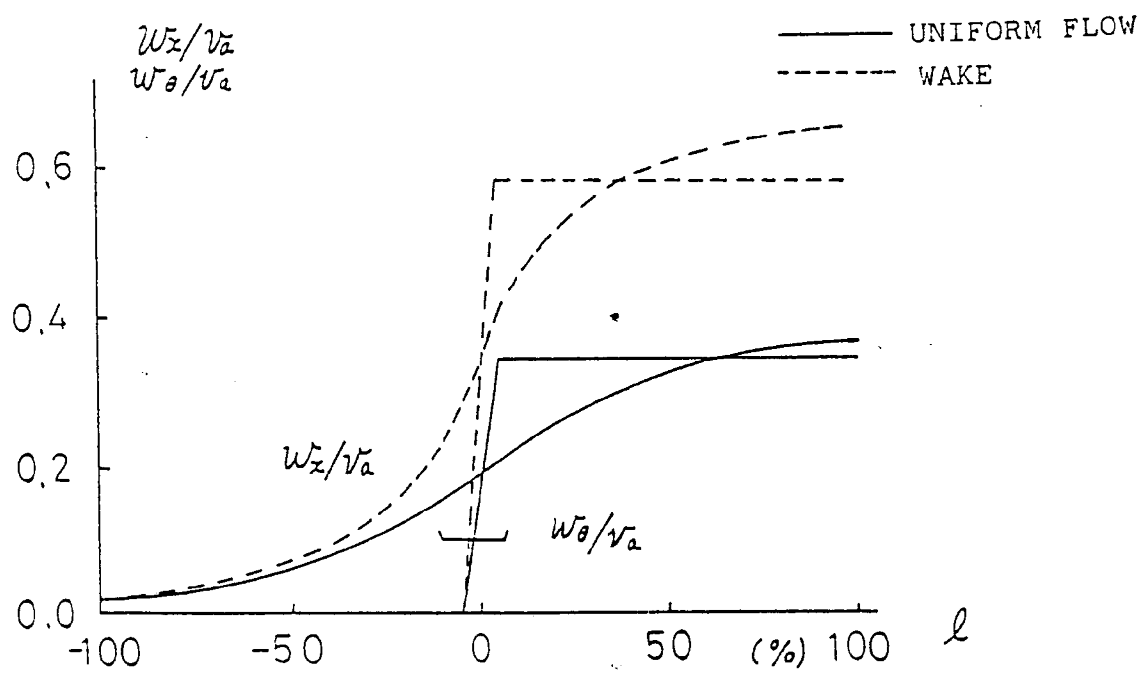

Wx/Va
Wθ/Va
UNIFORM FLOW
WAKE
0.6
0.4
0.2
0.0
Wx/Va
Wθ/Va
-100
-50
0
50
(%)
100
ℓ

FIG.22

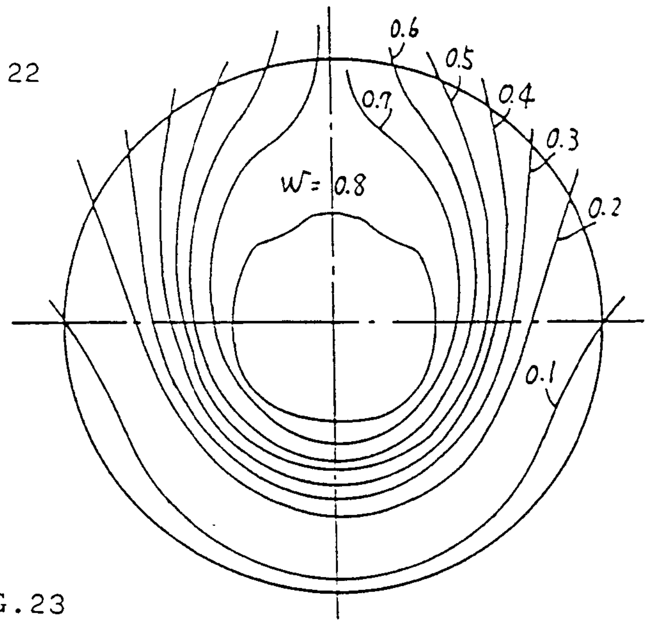


FIG.23

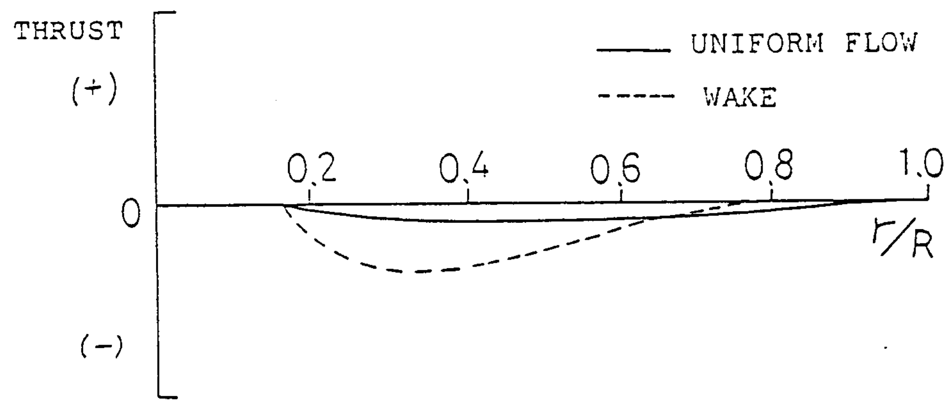


FIG.24

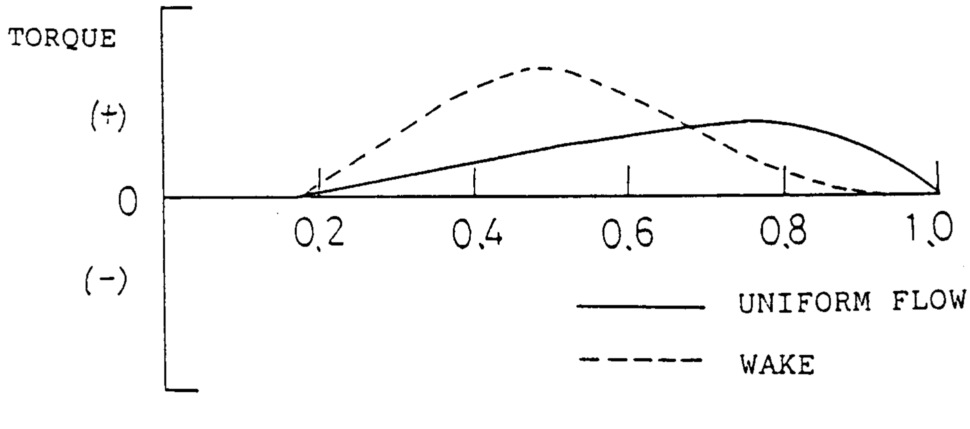


FIG.25

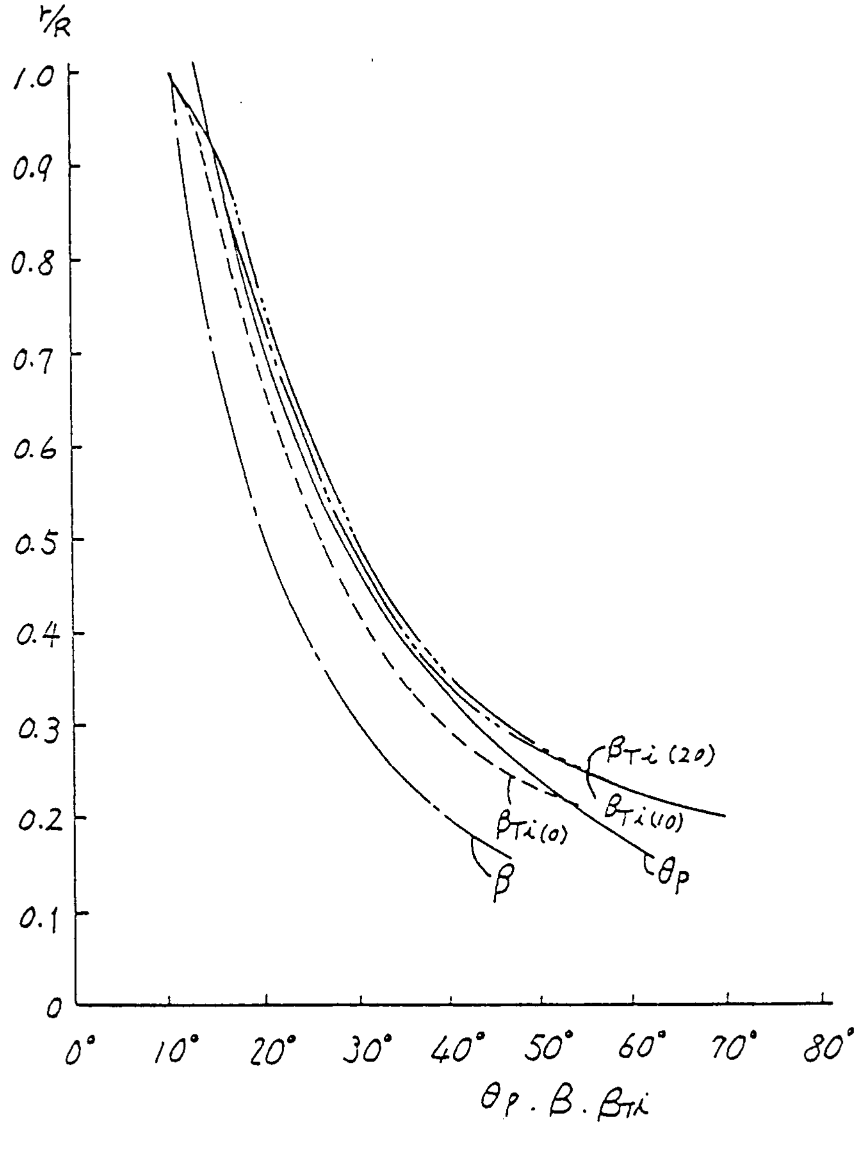

r/R
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0°
10°
20°
30°
40°
50°
60°
70°
80°
θp . β . βTi
βTi (20)
βTi (10)
βTi (0)
θp
β

FIG.26

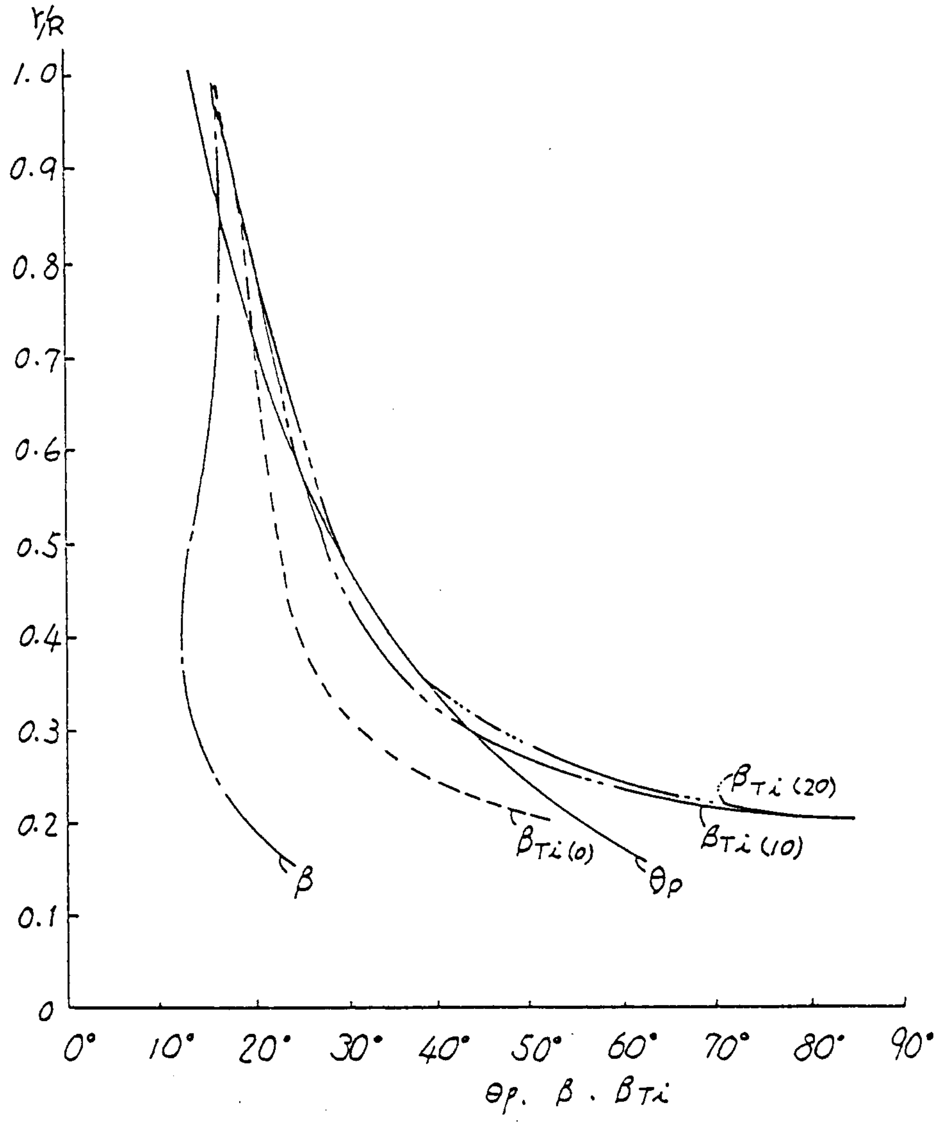

r/R
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
θp. β . βTi
β
βTi(0)
θp
βTi(10)
βTi(20)

FIG.27

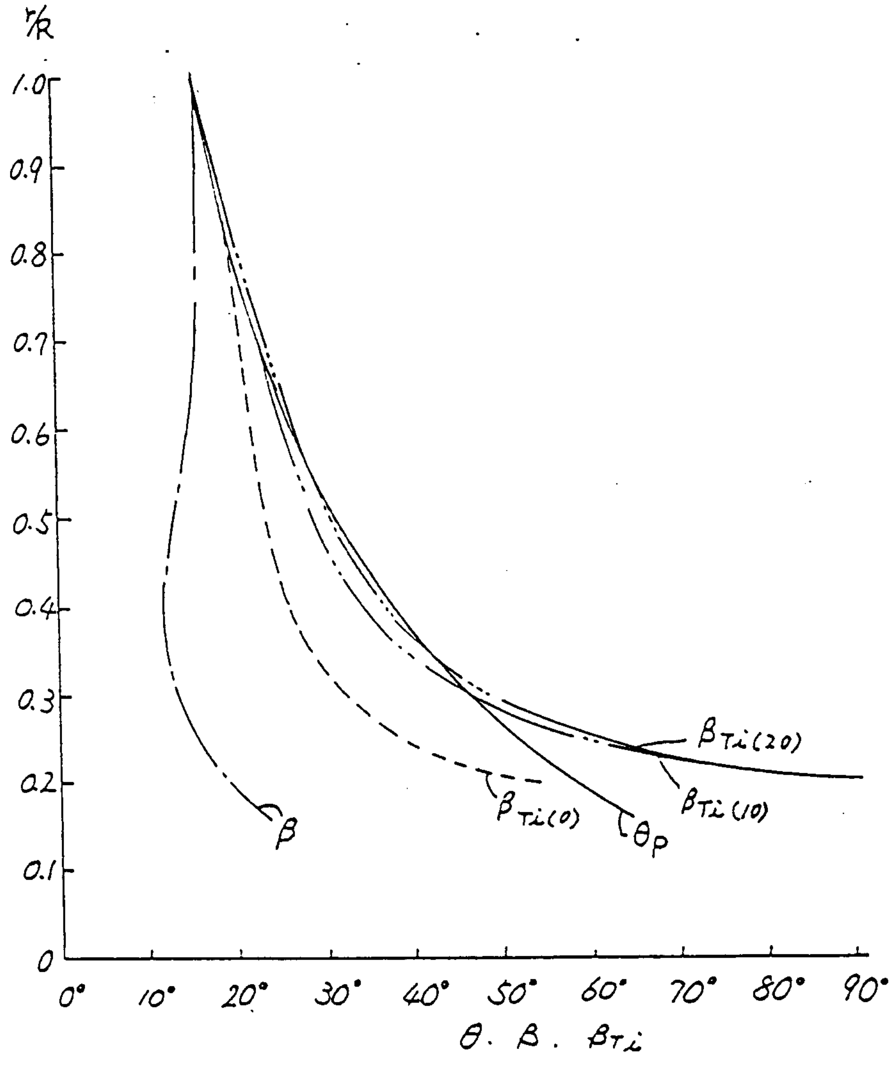

r/R
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
θ. β. βTi
β
βTi(0)
θp
βTi(10)
βTi(20)

FIG.28

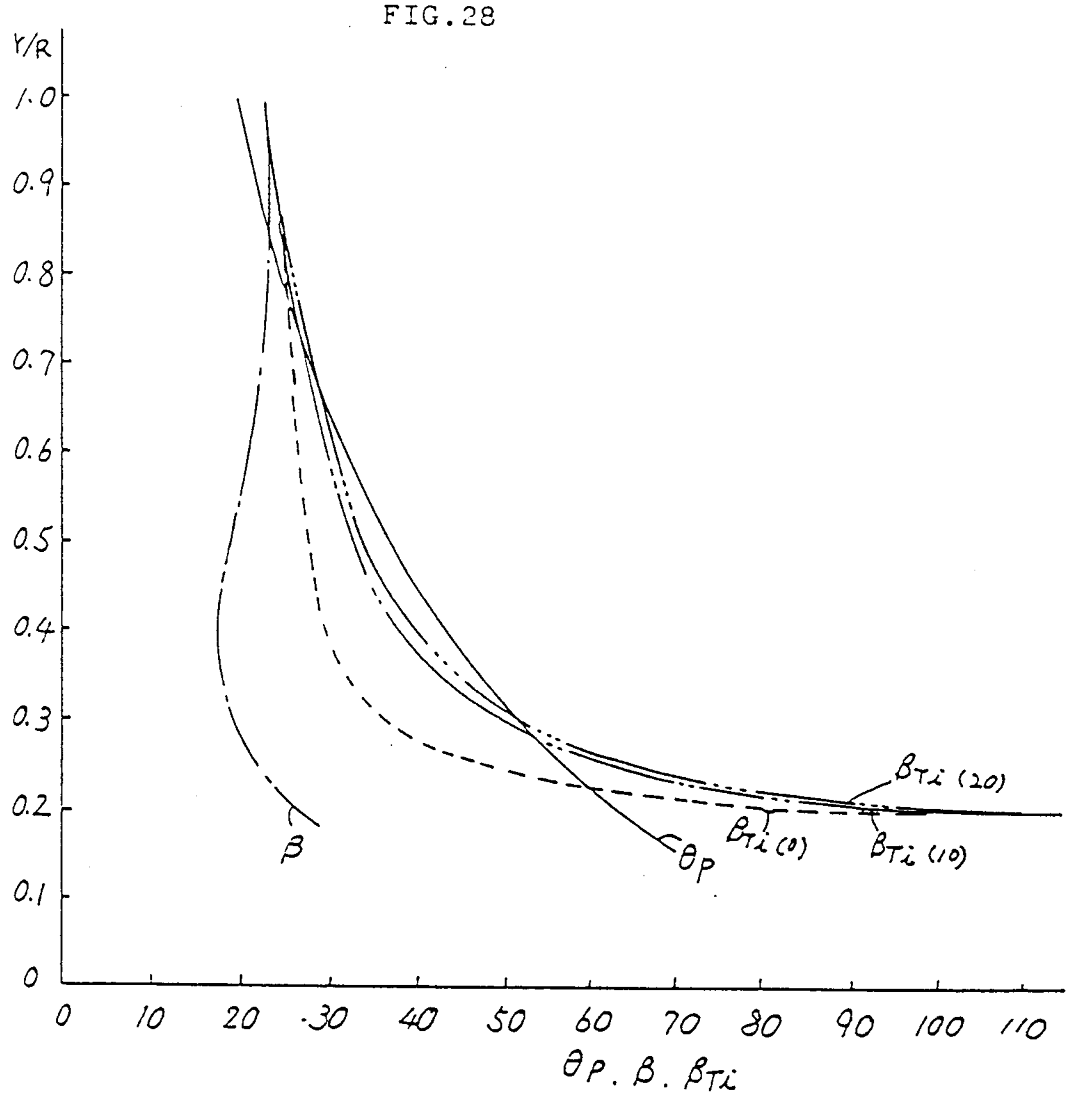

r/R
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
70
80
90
100
110
θP . β . βTi
β
θP
βTi (0)
βTi (10)
βTi (20)

FIG.29

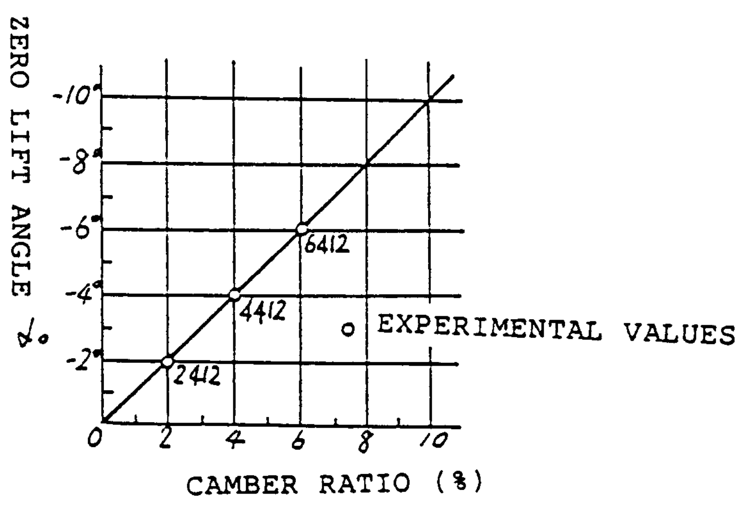

ZERO LIFT ANGLE α₀
-10°
-8°
-6°
-4°
-2°
0
2
4
6
8
10
6412
4412
2412
o EXPERIMENTAL VALUES
CAMBER RATIO (%)

FIG.30

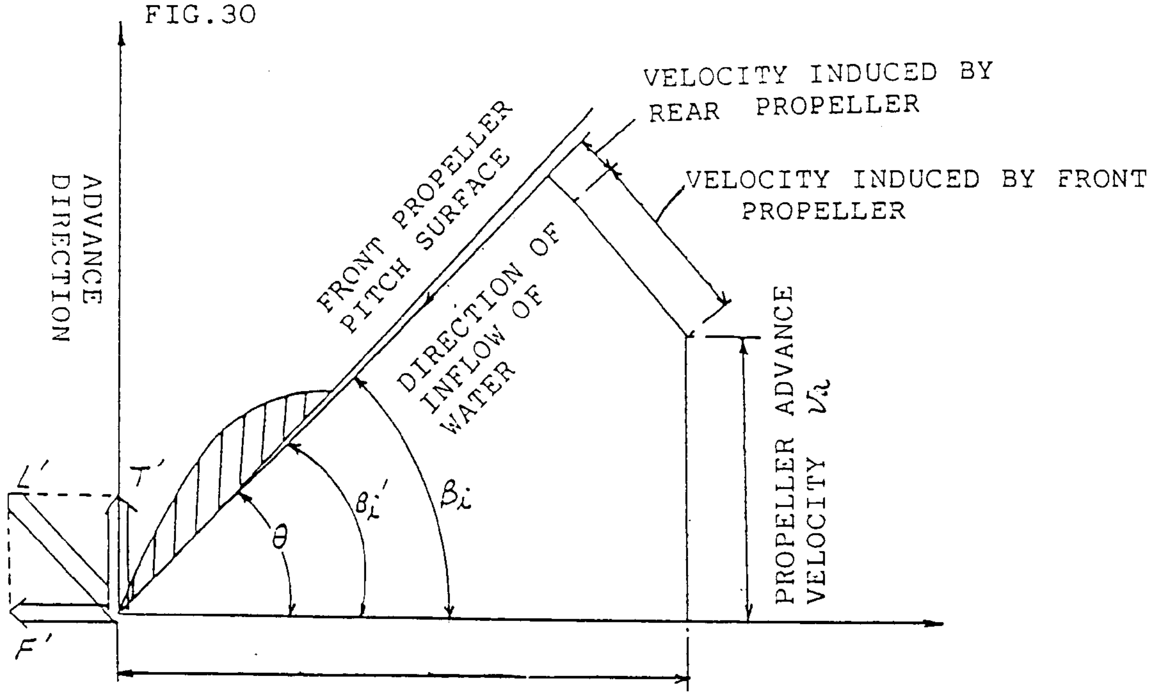
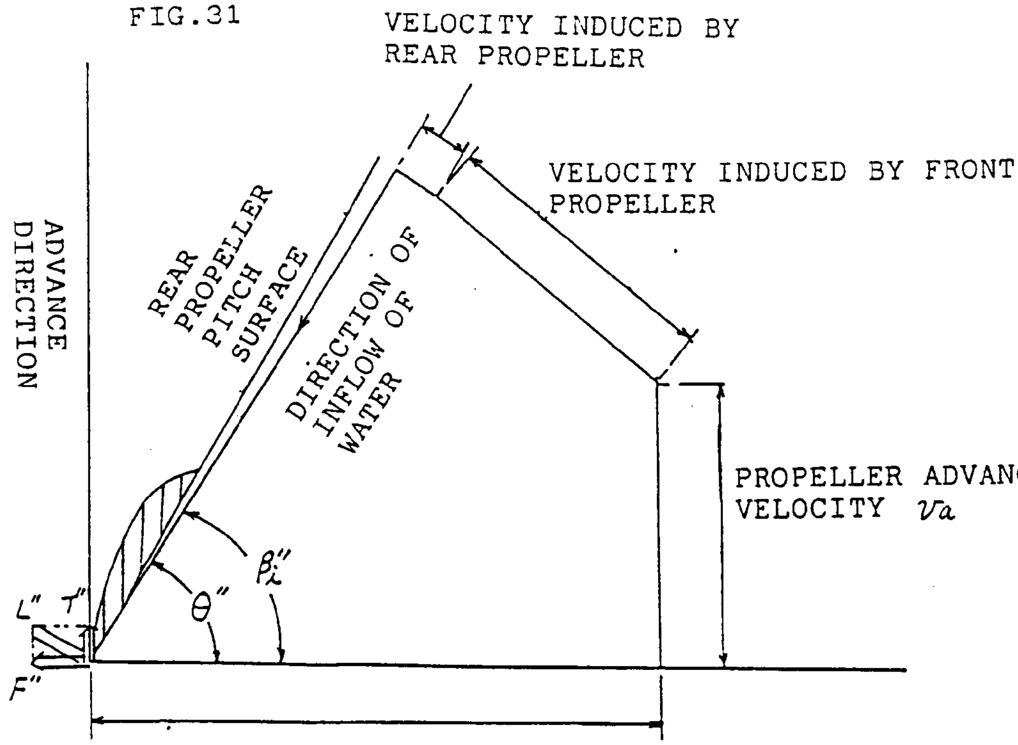

VELOCITY INDUCED BY REAR PROPELLER
VELOCITY INDUCED BY FRONT PROPELLER
ADVANCE DIRECTION
FRONT PROPELLER PITCH SURFACE
DIRECTION OF INFLOW OF WATER
PROPELLER ADVANCE VELOCITY v_i
L'
T'
F'
θ
β_i'
β_i
PERIPHERAL VELOCITY OF ROTATION OF PROPELLER : $2\pi nr$
(n:propeller r.p.m.)

FIG.31


VELOCITY INDUCED BY REAR PROPELLER
VELOCITY INDUCED BY FRONT PROPELLER
ADVANCE DIRECTION
REAR PROPELLER PITCH SURFACE
DIRECTION OF INFLOW OF WATER
PROPELLER ADVANCE VELOCITY v_a
L"
T"
F"
θ''
β_i''
PERIPHERAL VELOCITY OF ROTATION OF PROPELLER : $2\pi nr$
(n:propeller r.p.m.)

1	PROPELLER SHAFT
2	PROPELLER BLADES
2A	PROPELLER BOSS
3	TURBINE BLADES
3A	RING
4	PROPELLER CAP