United States Patent

Taniguchi et al.

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[45] **July 18, 1972**

[54] PROPELLER WITH KORT NOZZLE

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[52] **U.S. Cl.**.....**415/172,** 60/221
[51] **Int. Cl.**.....**B63h 1/16**
[58] **Field of Search**.....60/220, 221; 115/12, 12 A, 115/16, 14; 415/171, 169, 168, 109, 172

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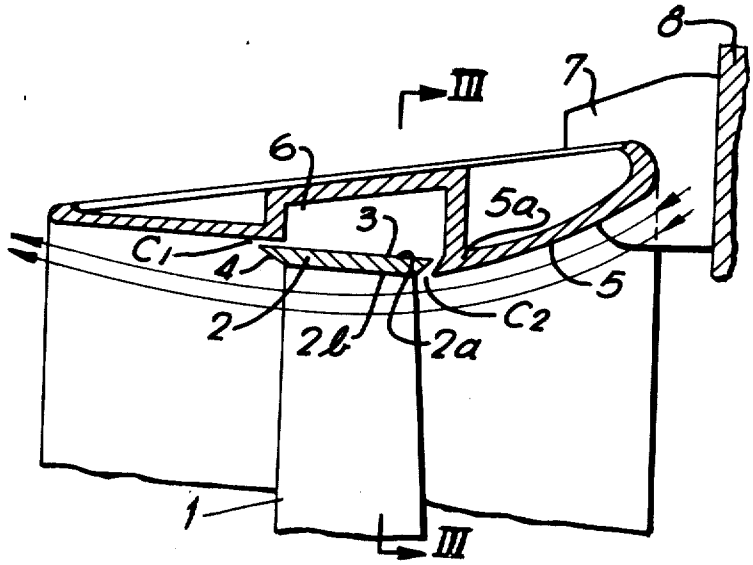
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[57] **ABSTRACT**

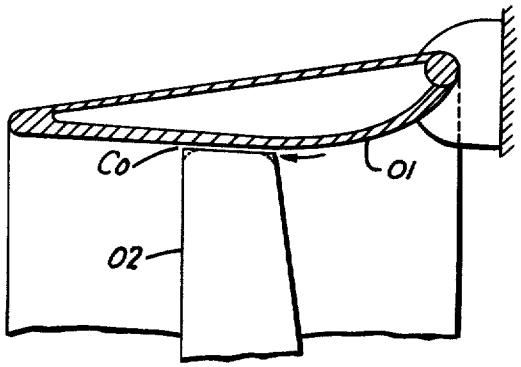
A propeller assembly including a Kort nozzle is formed of a plurality of propeller blades mounted for rotation on a shaft. The Kort nozzle circumferentially encloses the outer edge of the propeller blades and has an outwardly extending annular groove formed in its inner surface arranged opposite the outer edges of the blades. Secured to the outer edges of the blades for rotation therewith, is an annular member which forms a closure for the opening to the annular groove in the nozzle. The annular member is positioned in combination with the inner surface of the Kort nozzle to form a pair of narrow openings to the annular groove spaced apart in the propulsion direction of the propeller assembly.

3 Claims, 10 Drawing Figures



Patented July 18, 1972 3,677,660

3 Sheets-Sheet 1



(PRIOR ART)

FIG. 1

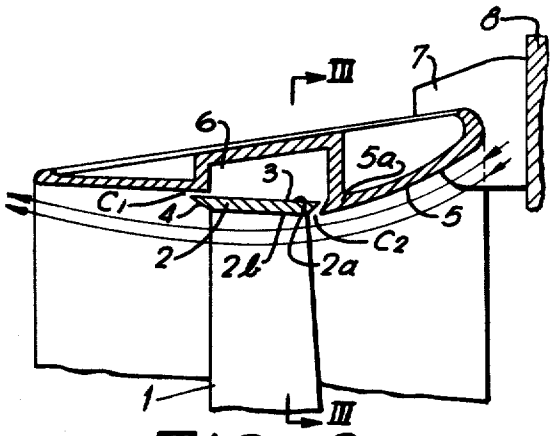


FIG. 2

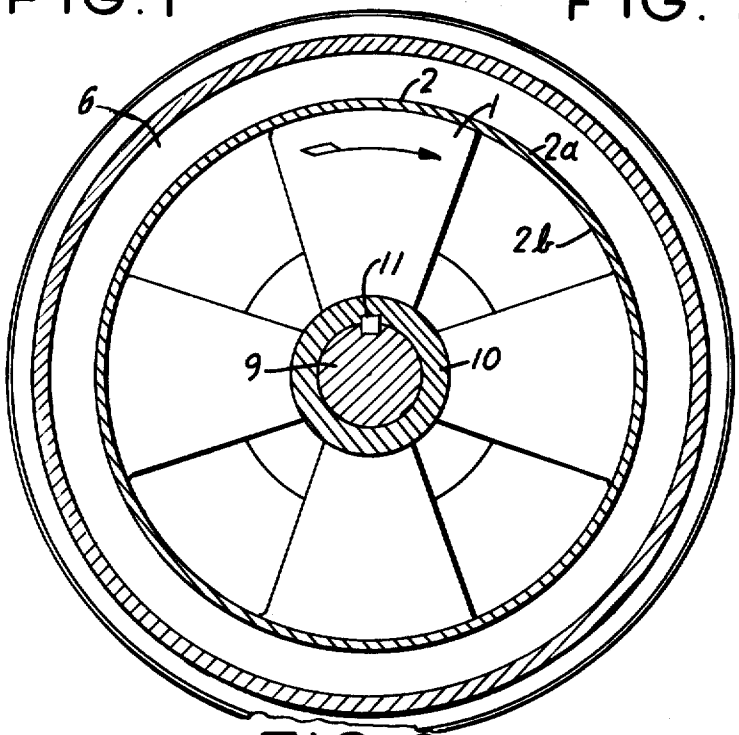


FIG. 3

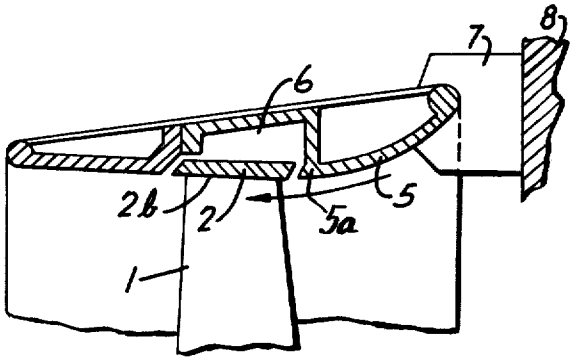


FIG. 4

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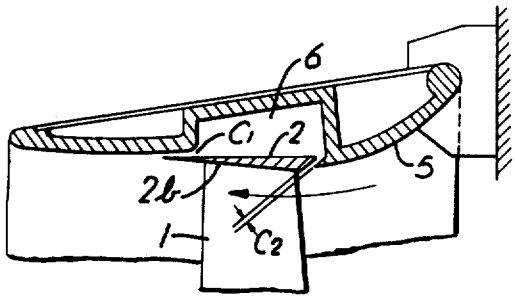


FIG. 5

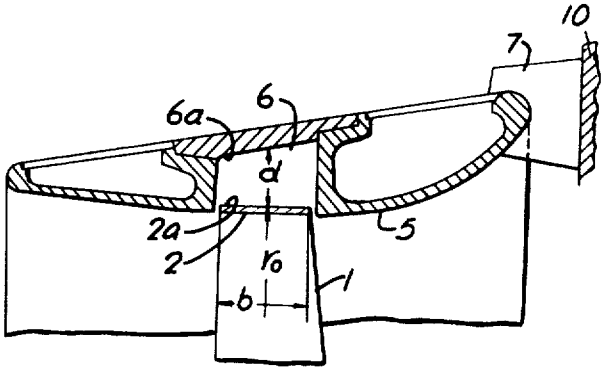


FIG. 6

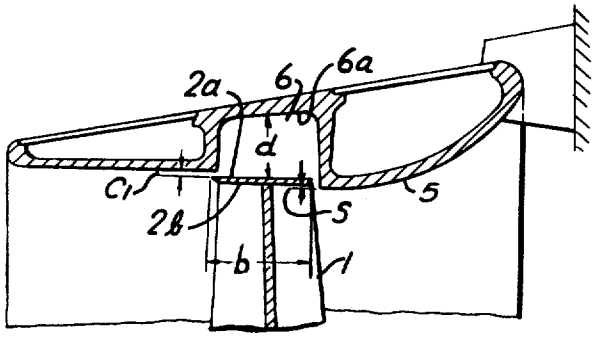


FIG. 7

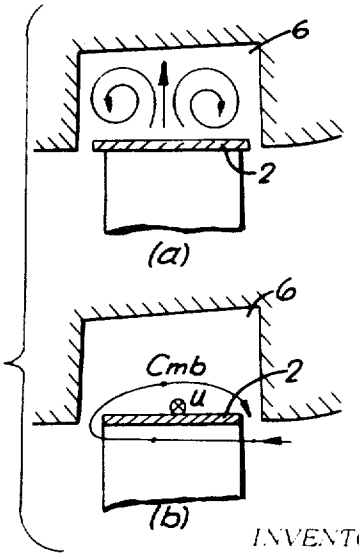


FIG. 8

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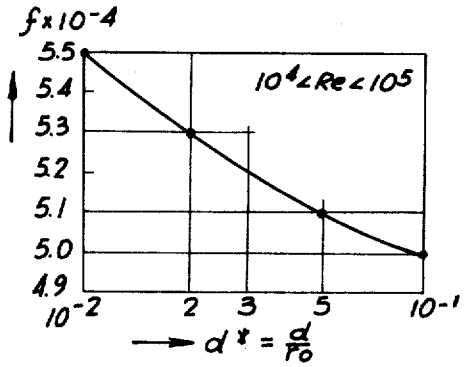


FIG. 9

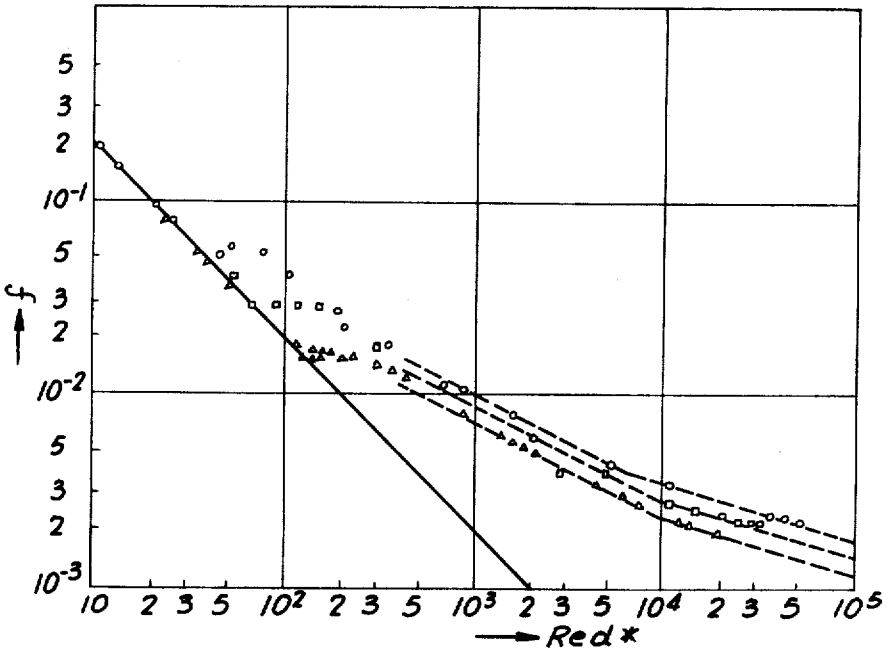


FIG. 10

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PROPELLER WITH KORT NOZZLE

BRIEF EXPLANATION OF THE DRAWINGS

FIG. 1 is a diagrammatical fragmentary cross-sectional view of a conventional propeller with Kort nozzle, showing the positional relation between the Kort nozzle and the outer end of the propeller blade; FIGS. 2 and 3 are view of an embodiment of the present invention, in which FIG. 2 is a fragmentary vertical cross-sectional view showing the positional relation between a Kort nozzle and the outer end of a propeller blade and FIG. 3 is a cross-sectional view taken on the line III-III of FIG. 2; FIGS. 4 to 7 inclusive are fragmentary cross-sectional views of other embodiments of the invention, respectively; FIGS. 8(*a*) and 8(*b*) are a set of views for explaining the secondary flow of a swirling fluid formed between the Kort nozzle and the annular member at the outer edge of the propeller blade; FIG. 9 is a graph showing the turbulent flow drag coefficient vs. Reynold's number curve obtained by a calculation according to Wendt's formula; and FIG. 10 is a graph showing the experimental values obtained by Wendt.

DETAILED DESCRIPTION OF INVENTION

The present invention relates to improvements in the Kort nozzle-incorporating propellers.

In general, a propeller with Kort nozzle provided therein produces an extremely large propulsion as compared with a propeller not provided with such a nozzle. This is attributed to the following three functions of the Kort nozzle: namely,

1. function to equalize the entering fluid;
2. function to mitigate the eddy flow occuring at the outer and end of the propeller blade by the fluid passage surface of the Kort nozzle; and
3. function to prevent contraction of the slip stream.

Owing to such functions, the pressure applied to the outside surface of the Kort nozzle becomes greater than that applied to the inside surface thereof and such pressure differential generates a propulsive force in the entire Kort nozzle, which occasionally reaches from 40 to 50 percent of the entire propulsive force of the propeller, as is well known. The application of the Kort nozzle-incorporating propeller to a tugboat, etc., brings about such and amazing advantage that a 50 percent increase can be obtained in the shore towing force, i.e. in the death pull, and a 30 percent increase can be obtained even in the self-propulsion. On the other hand, the conventional propeller provided with Kort nozzle had the following disadvantage. Namely, in the conventional propeller as shown in FIG. 1, a gap C_o exists between the Kort nozzle 01 and the outer edge of the propeller blade 02, and this gap is considerably large because it is usually designed to be about 1/100 of the radius at the throat of the Kort nozzle. Therefore, drifting wood or other solid substances in the water are frequently caught in the gap, causing breakage of the propeller blade. This not only lowers the working efficiency of the associated ship but also adds to the cost of repair, with the result that the above-mentioned merit in performance is offset. Under the circumstances, various countermeasures have been proposed and put in practice for the purpose of obviating the disadvantage. Namely, it has been proposed to exchange a broken propeller blade with a spare propeller blade, to alleviate the damage to the propeller blade by fitting a flexible material in a portion of the fluid contacting surface of the Kort nozzle or to attach a lattice-shaped guard to the front surface of the Kort nozzle to prevent intrusion of solid substances present in the water. However, any one of these measures is no more than a passive method conceived with a view to alleviating the damage to the propeller blade to the possible extent on the concept that the occurrence of such trouble is inevitable, and it cannot be said that they are the measures which fundamentally solve the problem.

The present invention has been achieved in the light of such a disadvantage of the conventional Kort nozzle-incorporating propeller as described above. Namely, it is an object of the present invention to provide a technical means which will

positively eliminate the above-described trouble or, in other words, to construct a Kort nozzle-incorporating propeller which will not permit solid substances in the water to be caught between the fluid contacting surface of the Kort nozzle and the outer edge of the propeller blade. It is also an object of the invention to minimize the power loss of a propeller driving prime mover, while simultaneously attaining the object set forth above.

According to one aspect of the present invention, there is provided a propeller assembly which comprises propeller blades, a Kort nozzle having an annular groove formed circumferentially in the inner surface thereof confronting the outer edges of said propeller blades, and an annular member fitted to the entire circumference of the outer edges of the propeller blades for rotation with said propeller blades and substantially covering said annular groove of the Kort nozzle, the surface of said annular member facing the fluid flow passage constituting a part of the inner surface of said Kort nozzle, whereby intrusion into the gap between the Kort nozzle and the outer edge of the propeller blade of the solid substances in the water can be prevented. According to another aspect of the invention there is provided a propeller assembly of the character described, wherein the shapes and dimensions of said annular groove and said annular member are so suitably selected as to decrease to the extent possible the fluid friction loss due to rotation of the annular member and thereby to decrease the power loss of a propeller driving prime mover to the extent possible.

The present invention will be described more practically hereinafter with reference to the embodiments shown in the drawings.

FIGS. 2 and 3 show an embodiment of the present invention. Referring to FIGS. 2 and 3, a suitable number of propeller blades 1 (the embodiment shown comprises four of such propeller blade) are integrally connected at their roots to a propeller boss 10 which is secured to a propeller shaft 9 by means of a key 11. An annular member 2 is fixed to the outer edges of the propeller blades 1 along the entire circumference thereof, and has a front fin 3 and a rear fin 4. A Kort nozzle 5 is provided circumferentially of the assembly of said propeller blades and said annular member and has an annular groove 6 formed in a portion of the inner surface thereof in confronting relation with the outer edges of the propeller blades 1. More specifically, the annular groove 6 is formed in a suitable width *b* and depth *d* rearwardly from the terminal end of the convergence of the fluid passage defined by the Kort nozzle 5 or the point from which said fluid passage expands outwardly forwardly or, in other words, from the leading end portion of the minimum cross-section of said Kort nozzle 5 which has previously been determined, and an annular chamber is defined by said annular groove 6 and the outer surface 2*a* of the annular member 2. Therefore, the annular groove 6 is substantially covered by the annular member 2 and the inner surface 2*b* of said annular member 2 constitutes a part of the inner surface of the Kort nozzle 5, defining the fluid passage. Gaps C_2 and C_1 are formed between the leading and trailing edges of the annular groove 6 in the Kort nozzle 5 and the front and rear fins 3 and 4 of the annular member 2 respectively, and the sizes of these gaps should be as small as possible and is preferably not larger than 1/100 of the throat radius of the Kort nozzle 5, provided that smooth rotation of the propeller blades 1 is ensured. At fin 5*a* may be provided extending rearwardly from the front lower corner of the annular groove 6 and taking a part of the front fin 3 of the annular member 2, to prevent intrusion of solid substances into the gap. The Kort nozzle of the structure described above is supported by a bracket 7 firstly fixed to a portion of the hull 8.

In the propeller assembly shown, when the propeller blades 1 are rotated by driving the propeller shaft 9, the hull is propelled by the propulsion of said propeller blades 1 and water flows through the passage defined by the Kort nozzle as indicated by the arrows. In this case, the annular member 2 fixed to the outer edges of the propeller blades 1 rotates

together with said propeller blades, while covering the annular groove 6 of the Kort nozzle 5. Further, since the inner surface 2b of the annular member 2 constitutes a part of the inner surface of the Kort nozzle 5, providing for smooth passage of the fluid through the passage, there is no fear of solid substances being caught in the gap between the outer edge of the propeller blade and the inner surface of the Kort nozzle 5. In addition, the propeller blade 1 is naturally deflected in the direction of propulsion, incident to rotation of the propeller blade, under a load imposed thereon and hence the gap C_2 is further reduced, which makes the intrusion of solid substances through the gap C_2 more difficult. Even if a small solid substance is allowed to enter the annular chamber through the gap C_2, it is readily discharged through the gap C_1 as said gap C_1 remains the same in size and is larger than the gap C_2. Thus, the annular member 2 is protected against damage.

Because of such construction and function, the propeller assembly described above demonstrates the effects of the Kort nozzle-incorporating propeller as such and has the advantage that it is entirely free of accident caused by solid substances floating in the water.

Another embodiment of the present invention is shown in FIG. 4. This embodiment is different from the preceding embodiment in that the rear half portion of the Kort nozzle 5 is removable so that the annular member 2 fixed to the propeller blades 1 may be received in the annular groove 6 of the Kort nozzle and further in that the inner surface 2b of the annular member is made substantially flush with the inner surface of the Kort nozzle 5 to define the flow passage.

Still another embodiment of the invention is shown in FIG. 5. This embodiment differs from the first-described embodiment in that the annular member 2 is shaped into a substantially wing-like configuration and its streamlined inner surface 2b of a contour approximating that of the streamlined inner surface of the Kort nozzle 5 is made flush with the inner surface of said Kort nozzle to define the flow passage. In the second and third embodiments, the inner surface of the Kort nozzle 5 and the inner surface 2b of the annular member 2 are substantially flush with each other to provide a smooth surface of flow passage as stated above. It will, therefore, be obvious that these embodiments achieve the same effects as those of the first embodiment, without substantially reducing the propulsion of the propeller assembly.

The fourth embodiment of the invention shown in FIG. 6 is distinguishable from the preceding three embodiments in that the distance d between the outer surface 2a of the annular member 2 and the bottom surface 6a of the annular groove 6 of the Kort nozzle 5 is made as large as possible within the range tolerated by the structural strength of the Kort nozzle 5. The fifth embodiment of the invention shown in FIG. 7 differs from the respective embodiments described above in that the distance d is made large as in the case of the preceding fourth embodiment and also in that the width b of the annular member 2 is reduced and the forward end portion of the inner surface 2b of the annular member 2 is stepped up by a distance S relative to the inner surface of the Kort nozzle 5.

Considering the fluid friction loss due to rotation of the annular members in the fourth and fifth embodiments, the friction loss of the annular member 6 may be regarded as sort of friction loss of a rotating cylinder. In obtaining the friction loss of a rotating cylinder, a dimensionless number of $d = d/r_o$ is employed wherein d is the depth of the annular groove 6 and r_o is the radius of the propeller blade in FIG. 6. It is well known that with regard to the relationship between the turbulent flow drag coefficient f and the Reynolds' number Red, Wendt obtained the experimental values indicated by the markings ○, □ and △ in FIG. 10 when the values of d^* is 0.470, 0.176 and 0.0691 respectively, and that based on the experimental values the relationship between the turbulent flow drag coefficient and the Reynolds' number Red* is given by the formula

$$F = 0.073[d^*(1+d^*)]^{1/4}\, Re^{-0.3}$$

within the range of $10^4 < Re < 10^5$. The values of f and d^*, calculated from the above formula are in such relation thAt the former becomes smaller as the latter becomes larger, as shown in FIG. 9. Further, although it is not certain from the graph of FIG. 10 whether the value of f becomes further smaller or remains substantially the same in the range of $10^5 < Re < 10^6$ in the proximity of the normal r.p.m. of the Kort nozzle-incorporating propeller, the friction loss due to a symmetrical eddy as shown in FIG. 8(a) (which is produced secondarily by the centrifugal force created in the fluid by the rotation of the annular member 2 and the boundary of the vertical walls of the annular chamber) is included in the turbulent flow drag coefficient f and is so small as will not pose a practical problem. It will thus be seen that in order to minimize the friction loss due to rotation of the annular member 2, it is preferable to make the value of d as large as possible as in the fourth and fifth embodiments. Now, considering the circulation of fluid around the annular member 2 as shown in FIG. 8 (b), the pressure coefficient ϕ which is a dimensionless value of pressure rise is

$$\phi = \Delta p / \tfrac{1}{2}\rho u^2 = 0.5$$

wherein u is the peripheral speed of the propeller blade. Therefore, in no case will the velocity Cmb of the circulating fluid exceed the value which is considered to result when the static pressure rise of the propeller is entirely converted into dynamic pressure, namely $(Cmb/u) \leqq \sqrt{\phi} = 0.7$. In practice, however, the fluid passing through the propeller flows at a consistent velocity as a whole, as a result of branching, confluence, curving and sudden expansion of cross-sectional area of the flow passage, occurring in the vicinity of the gaps C_1 and C_2, and it is possible to consider that $Cmb/u << 1.0$. Nevertheless, the fear of small solid substances entering the annular chamber through the gap C_1 at the trailing end of the annular member 2 cannot definitely be denied, insofar as the above-mentioned circulating flow exists, no matter how minor it may be. Therefore, according to the present invention the rear fin 4 of the annular member 2 is extended slightly rearwardly from the rear lower corner of the annular groove 6 of the Kort nozzle 5 while maintaining the gap C_1 between it and the inner surface of the Kort nozzle 5, as shown in FIGS. 2, 5 and 7, whereby the circulating flow can be minimized and hence the fear of solid substances entering the annular chamber through the gap C_1 can be eliminated, by letting the solid substances by carried downstream along with the fluid. Therefore, it will be obvious that the rear fin 4 is preferably formed as described above.

The width b of the annular member 2 should be made as small as possible as shown in FIGS. 6 and 7, because it has a direct influence on the friction loss.

In the fifth embodiment shown in FIG. 7, the inner surface 2b of the annular member 2 is stepped up by a distance S relative to the inner surface of the Kort nozzle 5. Therefore, the fluid friction loss due to rotation of the annular member can be further decreased.

As will be clearly understood from the foregoing practical descriptions on various embodiments, the present invention brings about the advantages that the drawbacks of the conventional Kort nozzle-incorporating propellers can completely be eliminated and that the power loss due to rotation of the annular member can be minimized, and, therefore, is of great industrial advantage.

Although the present invention has been described and illustrated with reference to specific embodiments thereof, it should be understood that the invention is not restricted only to the embodiments shown but many changes and modifications are possible within the scope of the invention defined in the appended claims.

What is claimed is:

1. A propeller assembly comprising a rotatable shaft, a plurality of propeller blades secured to and disposed in angularly spaced relationship on said shaft for rotation therewith, said

propeller blades extending outwardly from said shaft, said propeller blades extending in the propulsion direction of the assembly and having a leading surface facing in the propulsion direction and a trailing surface facing in the opposite direction, a Kort nozzle circumferentially enclosing the outer edges of said propeller blades and said Kort nozzle extending forwardly of the leading surface of said propeller blades and rearwardly from the trailing surface of said propeller blades, the inner surface of said Kort nozzle intermediate its leading edge and trailing edge forms an annular groove aligned opposite and spaced outwardly from the outer edges of said propeller blades, and an annular member secured to the outer edges of said propeller blades for rotation therewith and disposed opposite said annular groove, the dimension of said annular member in the propulsion direction being sufficient to form a covering substantially closing the opening to said annular groove and arranged to provide a narrow circumferentially extending opening to said annular groove along its leading and trailing edges, the inner surface of said annular member being arranged in general alignment with the inner surface of said Kort nozzle, said leading edge of said annular member sloping from its inner surface to its outer surface in the propulsion direction and the juxtaposed surface of said Kort member at the inner edge of said annular groove is closely spaced from and slopes in the same direction as the leading edge of said annular member forming the opening to the leading end of said annular groove, and the trailing edge of said annular member extends in the direction opposite to the propulsion direction so that it is spaced outwardly from and coextends for a portion of the inner surface of said Kort nozzle extending from said annular groove toward the trailing edge thereof and provides the opening therebetween for the trailing end of said annular groove.

2. A propeller assembly comprising a rotatable shaft, a plurality of propeller blades secured to and disposed in angularly spaced relationship on said shaft for rotation therewith, said propeller blades extending outwardly from said shaft, said propeller blades extending in the propulsion direction of the assembly and having a leading surface facing in the propulsion direction and a trailing surface facing in the opposite direction, a Kort nozzle circumferentially enclosing the outer edges of said propeller blades and said Kort nozzle extending forwardly of the leading surface of said propeller blades and rearwardly from the trailing surface of said propeller blades, the inner surface of said Kort nozzle intermediate its leading edge and trailing edge forms an annular groove aligned opposite and spaced outwardly from the outer edges of said propeller blades, and an annular member secured to the outer edges of said propeller blades for rotation therewith and disposed opposite said annular groove, the dimension of said annular member in the propulsion direction being sufficient to form a covering substantially closing the opening to said annular groove and arranged to provide a narrow circumferentially extending opening to said annular groove along its leading and trailing edges, the inner surface of said annular member being arranged in general alignment with the inner surface of said Kort nozzle, said leading edge of said annular member sloping from its inner surface to its outer surface in the propulsion direction and the juxtaposed surface of said Kort nozzle at the inner edge of said annular groove is closely spaced from and slopes in the same direction as the leading edge of said annular member forming the opening to the leading end of said annular groove, and the inner and outer surfaces of said annular member tapered to and meet in an apex at the trailing edge thereof, and the trailing edge extends in the direction opposite to the propulsion direction so that it is closely spaced inwardly from and coextends for a portion of the inner surface of said Kort nozzle extending from said annular groove toward the trailing edge thereof and provides the opening therebetween from the trailing end of said annular groove.

3. A propeller assembly comprising a rotatable shaft, a plurality of propeller blades secured to and disposed in angularly spaced relationship on said shaft for rotation therewith, said propeller blades extending outwardly from said shaft, said propeller blades extending in the propulsion direction of the assembly and having a leading surface facing in the propulsion direction and a trailing surface facing in the opposite direction, a Kort nozzle circumferentially enclosing the outer edges of said propeller blades and said Kort nozzle extending forwardly of the leading surface of said propeller blades and rearwardly from the trailing surface of said propeller blades, the inner surface of said Kort nozzle intermediate its leading edge and trailing edge forms an annular groove aligned opposite and spaced outwardly from the outer edges of said propeller blades, and an annular member secured to the outer edges of said propeller blades for rotation therewith and disposed opposite said annular groove, the dimension of said annular member in the propulsion direction being sufficient to form a covering substantially closing the opening to said annular groove and arranged to provide a narrow circumferentially extending opening to said annular groove along its leading and trailing edges, the inner surface of said annular member being arranged in general alignment with the inner surface of said Kort nozzle, said inner leading edge of said annular groove is spaced radially inwardly relative to the trailing edge of said annular groove, the leading edge inner surface of said annular member is spaced closely outwardly from the adjacent inner surface of said Kort nozzle and the trailing edge of the inner surface of said annular member extends in the direction opposite to the propulsion direction rearwardly beyond the trailing edge of said annular groove and is spaced closedly inwardly from the inner surface of the portion of said Kort nozzle extending from said annular groove to the trailing edge thereof so that the opening to the trailing end of said annular groove is positioned between the outer trailing edge surface of said annular member and the juxtaposed inner surface of said Kort nozzle extending rearwardly from the inner trailing edge of said annular groove.

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