A rim driven thruster comprises an annular housing, a propulsor assembly, a magnetic rotor assembly and a stator assembly. The annular housing defines a flow path extending along an axis. The propulsor assembly is supported within the housing and comprises propeller blades extending radially from the axis of the flow path. The propeller blades are configured to rotate about the axis. The magnetic rotor assembly is mounted to radially outer ends of the propeller blades. The stator assembly comprises spaced propeller drive modules mounted to an inner circumferential surface of the annular housing. The propeller drive modules are configured to provide electromagnetic torque to the magnetic rotor assembly.
Fig. 4
RIM DRIVEN THRUSTER HAVING PROPELLER DRIVE MODULES

BACKGROUND

[0001] The present invention is directed generally to rim driven thrusters (RDT) used as propulsion systems for watercraft and the like. More particularly, the present invention relates to permanent magnet brushless motors for RDTs.

[0002] In rim driven thrusters, an electro-magnetic motor is integrated with propeller blade propulsors. In typical RDTs, a rotor assembly is integrated at outer diameter ends of the propeller blades and a stator assembly is integrated into a stationary annular housing surrounding the propeller blades. The stator assembly electro-magnetically causes the rotor assembly to rotate and generate propulsive thrust with the propeller blades. The housing is connected to the vessel through a ratchet that rotates about a vertical axis so that the RDT is able to provide propulsion and steering in a single unit.

[0003] RDTs are advantageous for submerged operation because the electro-magnetic motor is removed from the center of the propulsor. In such a configuration, electrically active components of the stator assembly are positioned within the housing so as to be easily insulated. Moreover, the motor is positioned so as to minimize hydraulic drag. Specifically, the stator assembly is positioned within the annular housing and the rotor assembly is positioned in close proximity to the housing at the outer diameter of the blades. The stator and rotor assemblies are, however, still exposed to hydraulic drag when submerged. Thus, it becomes desirable to reduce the thickness of the rotor and stator assemblies to further minimize hydrodynamic losses.

[0004] Typical RDTs utilize conventional slotted stator cores in the stator assembly. In these designs, however, it is difficult to accommodate multiple windings in the narrow and shallow slots that are needed to achieve favorable thickness dimensions. Another proposal for reducing stator core thickness has included the use of a slot-less stator winding and spiral wound stator core laminations. This stator assembly design is expensive, difficult to manufacture and suitable only for small motors. There is, therefore, a need for a permanent magnet motor configuration having favorable hydraulic drag properties in an easily and inexpensively manufactured configuration.

SUMMARY

[0005] The present invention is directed to a rim driven thruster having propeller drive modules. The rim driven thruster comprises an annular housing, a propulsor assembly, a magnetic rotor assembly and a stator assembly. The annular housing defines a flow path extending along an axis. The propulsor assembly is supported within the housing and comprises propeller blades extending radially from the axis of the flow path. The propeller blades are configured to rotate about the axis. The magnetic rotor assembly is mounted to radially outer ends of the propeller blades. The stator assembly comprises spaced propeller drive modules mounted to an inner circumferential surface of the annular housing. The propeller drive modules are configured to provide electromagnetic torque to the magnetic rotor assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. 1 is a perspective view of a rim driven thruster (RDT) connected to a hull of a waterborne vessel.

[0007] FIG. 2 is an aft view of the rim driven thruster of FIG. 1, as taken at section 2-2, showing propeller drive modules comprising a plurality of electro-magnetic stator studs.

[0008] FIG. 3 is a side cross-sectional view of the rim driven thruster of FIG. 2, as taken at section 3-3, showing rotor cores and stator cores of the plurality of electro-magnet stator studs.

[0009] FIG. 4 is an alternate aft view of the rim driven thruster of FIG. 1, as taken at section 2-2, showing propeller drive modules comprising a plurality of linear driven actuators.

[0010] FIG. 5 is a side cross-sectional view of the rim driven thruster of FIG. 4, as taken at section 5-5, showing a rotor core and a stator core of a linear driven actuator.

DETAILED DESCRIPTION

[0011] FIG. 1 is a perspective view of rim driven thruster (RDT) 10 connected to the stern of waterborne vessel 12. Waterborne vessel 12 may comprise any conventional watercraft, such as a floating ship or underwater submarine. In the embodiment shown, vessel 12 comprises a hull of a ship having transom 14 and keel 16. In operation, vessel 12 is positioned such that keel 16 is submerged and transom 14 is partially submerged in water, or any other fluid, so as to fully submerge RDT 10. RDT 10 is mounted to the hull of vessel 12 by pylons 18 and transom 14 and aft of keel 16. RDT 10 includes housing 20, propellers 22, hub 24, rim 26 and forward and aft fairings 28A and 28B. RDT 10 may also be referred to as an integrated motor propeller (IMP).

[0012] RDT 10 provides propulsive power to vessel 12 by rotation of propellers 22. RDT 10 swivels about pylon 18 behind keel 16 to steer vessel 12. RDT 10 rotates on pylon 18 under an external power source such as provided from within vessel 12. Propellers 22 are rotated by an electro-magnetic motor integrated into rim 26 and housing 20. A stator core is mounted within housing 20 and receives electric power from vessel 12 through pylon 18. Magnetic forces from the stator core are transmitted to a rotor core mounted on rim 26. Rim 26 drives propellers to rotate on hub 24 within housing 20. Forward fairing 28A and aft fairing 28B provide hydrodynamic shields for housing 20, rim 26, the stator core and the rotor core.

[0013] RDT 10 provides hydrodynamic advantages to vessel 12 because the electro-magnetic motor is moved out of the center of the flow path provided within housing 20. As such, the effect of hub 24 on hydrodynamic drag within housing 20 is minimized. It is also desirable to reduce the hydrodynamic drag of housing 20. RDT 10 of the present invention utilizes propeller drive modules in the stator core that are spaced around the rotor core between rim 26 and housing 20 to reduce the cross-sectional area of the stator core. The spaced propeller drive modules form channels that reduce hydrodynamic drag produced by RDT 10.

[0014] FIG. 2 is an aft view of rim driven thruster (RDT) 10 of FIG. 1, as taken at section 2-2, showing a stator assembly comprising propeller drive modules 30A-30D and rotor assembly 32. FIG. 2 corresponds to a view of RDT 10 with aft fairing 28B removed. In the embodiment of FIG. 2, propeller drive modules 30A-30D comprise electro-magnet stator studs. RDT 10 also includes housing 20, propellers 22, hub 24 and rim 26. Housing 20 extends axially along centerline CL to form a flow path for water driven by propellers 22. Rim 26 is supported within housing 20 by bearings in various configurations, as discussed with reference to FIGS. 3 and 5. Hub 24
is supported by propellers 22 within rim 26 so as to be co-axial with centerline CL. Propellers 22 extend radially from hub 24 across the flow path to rim 26. Propellers 22 comprise hydrofoils or blades shaped to accelerate water as they rotate about centerline CL, as is known in the art. Rim 26 comprises a continuous support ring integrally mounted to the tips, or radially outermost portion, of propellers 22. Rotor assembly 32 is affixed to a radially outer surface of rim 26 and comprises an array of permanent magnet pole pairs and a ferromagnetic core. Propeller drive modules 30A-30D are mounted to a radially inner surface of housing 20 and each comprises a ferromagnetic core and a coil winding. Forward fairing 28A and aft fairing 28B (FIG. 1) are connected to forward and aft ends of housing 20, respectively, to cover housing 20. stator assembly 30, rotor assembly 32 and rim 26.

In other embodiments of the invention, other numbers of propeller drive modules can be used in place of the four propeller drive modules 30A-30D shown.

Housing 20 circumscribes rotor assembly 32 to form gap G. Gap G comprises a flow space through which water or fluid in which RDT 10 is submerged is able to flow. As such, in other embodiments, forward fairing 28A and aft fairing 28B may be omitted during operation of RDT 10. The thicknesses of gap G, as well as rim 26, rotor assembly 32, propeller drive modules 30A-30D and housing 20 are not drawn to proportion in FIG. 2. Propeller drive modules 30A-30D are mounted to an inner circumferential surface of housing 20 so as to occupy a portion of the flow space. Propeller drive modules 30A-30D are intermittently dispersed or spaced within the flow space to permit water to flow between the modules in channels 33A-33D. The presence of channels 33A-33D reduces hydrodynamic drag, as described in greater detail with reference to FIG. 3.

FIG. 3 is a side cross-sectional view of a rim driven thruster 10 of FIG. 2, as taken at section 3-3, showing bearings assemblies 34A and 34B supporting propulsor assembly 36A at rim 26. RDT 10 includes pylon 18, housing 20, forward fairing 28A, aft fairing 28B, propeller drive module 30A, propeller drive module 30C, rotor assembly 32 and propulsor assembly 36A. Propulsor assembly 36A comprises propellers 22, hub 24, rim 26, bearing assemblies 34A and 34B, support brackets 38A-38D, shaft 39 and support rings 40A and 40B. Rotor assembly 32 comprises rotor core 42 and permanent magnet 44. Propeller drive modules 30A and 30C comprise stator cores 50A and 50C and coil windings 52A and 52C, respectively.

Annular housing 20 is connected to vessel 12 (FIG. 1) by pylon 18. Pylon 18 rotates about vertical axis VA, which causes RDT 10 to adjust the yaw of vessel 12 when propellers 22 are rotating. Annular housing 20 defines a cylindrical flow path through which center line CL axially extends. Propellers 22 extend radially with respect to center line CL between hub 24 and rim 26. The center of hub 24 extends co-axially along center line CL such that rim 26 of propulsor assembly 36A is supported concentrically within housing 20 by bearing assemblies 34A and 34B.

Forward fairing 28A and aft fairing 28B are connected to housing 20 to provide hydrodynamic surfaces to RDT 10. Forward fairing 28A is connected to housing 20 at a forward end using any suitable attachment means, such as fasteners. Alternatively, forward fairing 28A may be integrated with housing 20. Forward fairing 28A is shaped to smoothly direct flow of water over RDT 10, while allowing water to enter housing 20 to engage propulsor assembly 36A.

Aft fairing 28A is connected to housing 20 at an aft end using any suitable attachment means, such as fasteners. Aft fairing 28A is removable from housing 20 to provide access to propeller drive modules 30A and 30C and rotor assembly 32. Although, in other embodiments, aft fairing 28A may be integrated with housing 20 if access is provided elsewhere.

Housing 20 is spaced a distance away from rim 26 to form gap G, which forms a flow path in which fluid is able to flow. As shown in FIG. 1 and FIG. 5, aft fairing 28B may be configured to cover gap G. However, as shown in FIG. 3, aft fairing 28B may be configured to permit fluid to flow into gap G so as to be able to flow through channels 33A-33D (FIG. 2) formed between propeller drive modules 30A-30D. Flow of water within gap G provides cooling to propeller drive modules 30A-30D and reduced hydrodynamic losses.

Support brackets 38A and 38B extend radially inward from aft fairing 28B straight towards support ring 40A and across gap G. Support brackets 38A and 38B comprise two of three support brackets (the third not seen in the cross-section of FIG. 3) spaced one-hundred-twenty degrees apart within aft fairing 28B. Support brackets 38C and 38D extend radially inward from forward fairing 28A straight towards support ring 40B and across gap G. Support brackets 38C and 38D comprise two of three support brackets (the third not seen in the cross-section of FIG. 3) spaced one-hundred-twenty degrees apart within forward fairing 28A. In other embodiments, support brackets 38A-38D extend directly from housing 20, rather than rearings 28A and 28B. Support brackets 38A-38D provide structure for supporting shaft 39 with support rings 40A and 40B. Bearing assemblies 34A and 34B are fitted within support rings 40A and 40B, respectively. Bearing assemblies 34A and 34B receive opposite ends of shaft 39. Shaft 39 extends from bearing assembly 34A, through hub 24 and into bearing assembly 34B. Hub 24 is fitted around shaft 39, such as with a force fit, so that hub 24 and shaft 39 rotate in unison. As such, propellers 22 are permitted to rotate about centerline CL as shaft 39 rotates in bearing assemblies 34A and 34B when torque is applied to rotor assembly 32 by propeller drive modules 30A and 30C.

Propeller drive modules 30A and 30C are mounted to a radially inward facing surface of housing 20. Specifically, stator cores 50A and 50C are joined to housing 20 by any suitable means. Stator cores 50A and 50C comprise ferromagnetic material that is fashioned in the form of studs or blocks that protrude from housing 20. In the tangential, or circumferential, direction, stator cores 50A and 50C are spaced equally along housing 20 with open space being provided between to form channels 33A-33D (FIG. 2). In other embodiments, stator cores 50A and 50C are non-uniformly distributed along housing 20. Coil windings 52A and 52C are wrapped around the studs of stator cores 50A and 50C such that the windings form coils having loops that extend in the axial and tangential directions. Coil windings 52A and 52C comprise any suitable conducting material such as copper.

Rotor assembly 32 is mounted to a radially outward facing surface of rim 26. Specifically, rotor core 42 is joined to rim 26 by any suitable means. Rotor core 42 comprises ferromagnetic material that is fashioned in the form of an annular ring that circumscribes rim 26. Rotor core 42 is positioned on rim 26 to align with stator cores 50A and 50C. Permanent magnet 44 is mounted to a radially outward face of rotor core 42 in a surface-mount configuration. In other embodiments, permanent magnet 44 may be mounted in a buried configuration. In yet another embodiment, rim 26 is
omitted from propulsor assembly 36A and rotor core 42 is
mounted directly to tips of propellers 22. The orientation of
the magnetic poles of permanent magnet is in the circumfer-
ential direction.

[0023] Arranged as such within RDT 10, propeller drive
modules 30A and 30C and rotor assembly 32 form a magneto-
electric motor. Alternating electrical current is supplied
directly to coil windings 52A and 52C such as from a power
source in vessel 12 (FIG. 1). Current within coil windings
52A and 52C causes magnetic flux to flow through stator
cores 50A and 50C. The oppositely oriented magnetic poles
of permanent magnet 44 causes magnetic flux to travel
through rotor assembly 32, which travels through rotor core
42. The magnetic flux of propeller drive modules 30A and
30C interacts with the magnetic flux of permanent magnet 44
to apply a torque to rim 26. Bearing assemblies 34A and 34B
permit rim 26 and rotor assembly 36A to rotate smoothly
about center line CL. As discussed with reference to FIGS.
4 and 5, RDT 10 may use propeller drive modules of other
configurations that are mounted within housing 20 with other
bearing configurations.

[0024] FIG. 4 is an alternate aft view of rim driven thrust
er (RDT) 10 of FIG. 1, as taken at section 2-2, showing a stator
assembly comprising propeller drive modules 54A and 54B
and rotor assembly 32. In the embodiment of FIG. 2, propeller
drive modules 54A and 54B comprise linear driven actuator
stators. As with the embodiment of FIG. 2, RDT 10 also
includes housing 20, propellers 22, hub 24, rim 26, fairings
28A and 28B (FIG. 1) and rotor assembly 32. Propeller drive
modules 54A and 54B are mounted to a radially inner surface
of housing 20 and comprises pairs of ferromagnetic cores and
coil windings. Housing 20 circumnavigates rotor assembly 32
to form gap G. Gap G comprises a flow space through which
water or fluid in which RDT 10 is submerged is able to flow.
The thicknesses of gap G, as well as rim 26, rotor assembly
32, propeller drive modules 54A and 54B and housing 20 are
drawn not to proportion in FIG. 4. Propeller drive modules
54A and 54B are mounted to an inner circumferential surface
of housing 20 so as to occupy a portion of the flow space.
Propeller drive modules 54A and 54B are intermittently dis-
spersed or spaced within the flow space to permit water to flow
between the modules in channels 56A and 56B. The presence
of channels 56A and 56B reduces hydrodynamic drag, as
described in greater detail with reference to FIG. 5. In the
embodiment shown, propeller drive modules 54A and 54B
are configured similar to primary units of arc-shaped linear
motors, as is known in the art.

[0025] FIG. 5 is a side cross-sectional view of rim driven
thrust er 10 of FIG. 4, as taken section 5-5, showing bear-
ings assemblies 34C and 34D supporting propulsor assembly
36B at rim 26. RDT 10 includes housing 20, forward fairing
28A, aft fairing 28B, propeller drive module 54A, rotor
assembly 32 and propulsor assembly 36B. Propulsor assembly
36B comprises propellers 22, hub 24, rim 26, bearing
assemblies 34C and 34D, bearing pads 58A and 58B, and
bearing rings 60A and 60B. Rotor assembly 32 comprises
rotor core 42 and permanent magnet 44, which comprise the
same structure as described with reference to FIG. 3. As such,
discussion of rotor assembly 32 with reference to FIG. 5
is omitted for brevity. Propeller drive module 54A comprises
stator core 62A and coil winding 64A.

[0026] Forward fairing 28A includes bearing pad 58B
located at an aft end so as to be positioned near rim 60B. Aft
fairing 28B includes bearing pad 58A located at a forward end
so as to be positioned near rim 60A. Aft fairing 28B also
includes shield 66, which extends radially inward past bear-
ing assembly 34C and alongside bearing rim 60A. Shield 66
protects bearing assembly 34C and provides a hydrodynamic
surface. In other embodiments, shield 66 may be omitted
from aft fairing 28B, as shown in FIG. 3, to allow water to
directly enter bearing assemblies 34C and 34D. Propeller
drive modules 54A and 54B and rotor assembly 32 for cool-
ing purposes, and into channels 56A and 56B for drag-reduc-
tion purposes.

[0027] Rim 26 is supported by bearing assemblies 34C and
34D at bearing rims 60A and 60B. Bearing rings 60A and 60B
comprise forward and aft axial extensions, respectively, of
rim 26. Bearing rims 60A and 60B may be integral with rim
26 or separate components fastened to rim 26. Bearing rims
60A and 60B increase the available surface of rim 26 not used
to support rotor assembly 32. Bearing rims 60A and 60B
extend axially beyond propeller drive module 54A such that a
radially outer surface faces towards forward fairing 28A and
aft fairing 28B, respectively. Bearing rims 60A and 60B thus
comprise annular rings against which bearing assemblies 34C
and 34D engage.

[0028] Forward fairing 28A includes bearing pad 58B, and
aft fairing 28B includes bearing pad 58A. Bearing pad 58A
is integrally formed with forward fairing 28A, and bearing pad
58A is integrally formed with aft fairing 28B. In other
embodiments, bearing pads 58A and 58B may comprise sepa-
rate components or may be formed as part of housing 20. In
any embodiment, bearing pads 58A and 58B comprise annular
surfaces or lands against which bearing assemblies 34C
and 34D engage. Thus, bearing assemblies 34C and 34D are
positioned concentrically between rims 60A and 60B and
pads 58A and 58B to permit propulsor assembly 36B to rotate
within housing 20 when propeller drive module 54A is acti-
vated by rotor assembly 32. Specifically, propeller drive mod-
ule 54A applies an electro-magnetic force to rotor assembly
32 to produce rotational movement of propellers 22 about
center line CL.

[0029] Stator core 62A of propeller drive module 54A com-
prises a ferromagnetic core block that includes an arcuate
surface that facing rotor assembly 32. A plurality of axial slots
extend along the arcuate surface to provide spaces for coil
windings. For example, coil winding 64A extends axially
along stator core 62A. Thus, propeller drive module included
a plurality of circumferentially spaced slots and associated
coil windings as shown in FIG. 4. As such, propeller drive
module 54A and rotor assembly 32 function as a conventional
linear driven actuator, as is known in the art. In the present
invention, however, propeller drive module 54A and rotor
assembly 32 are curved or arced to follow the generally cylin-
drical profile of housing 20.

[0030] Arranged as such within RDT 10, propeller drive
module 54A and rotor assembly 32 form a magneto-electric
motor in the form of a linear actuator. Alternating electrical
current is supplied directly to coil winding 64A such as from
a power source in vessel 12 (FIG. 1). Current within coil
winding 64A causes magnetic flux to flow through stator core
62A. The oppositely oriented magnetic poles of permanent
magnet 44 cause magnetic flux to travel through rotor assem-
bly 32, which travels through rotor core 42. The magnetic flux
of propeller drive module 54A interacts with the magnetic
flux of permanent magnet 44 to apply a torque to rim 26. In
other embodiments, stator core 62A is non-ferromagnetic and
electrical flux within coil winding 64A interacts with the
magnetic flux of rotor assembly 32, as is known in the art. Bearing assemblies 34C and 34D permit rim 26 and rotor assembly 36B to rotate smoothly about center line CL. [0031] Construction and performance of RDT 10 benefits from propeller drive modules 30A-30D (FIG. 2) and propeller drive modules 54A and 54B (FIG. 4). Propeller drive modules 30A-30D and 54A-54B are easily mounted to housing 20 in configurations advantageous to operation of RDT 10. For example, propeller drive modules 30A-30D and 54A-54B can be manufactured as individual units or modules that can subsequently be attached to housing 20. Each module is identical, reducing the number of components and associated manufacturing costs. The modular configuration produces channels 33A-33D (FIG. 2) and channels 56A and 56B (FIG. 4) that provide hydrodynamic performance improvements. For example, propeller drive modules 30A-30D collectively occupy less than fifty percent of the flow space formed by gap G. With this space unobstructed, fluid is free to flow between rim 26 and housing 20. With modules 30A-30D and modules 54A-54B being mounted to the exterior of housing 20, rather than being inside housing 20, the thickness of housing 20 can be reduced to very thin dimensions, which also reduces the hydraulic drag produced by RDT 10. Additionally, gap G is sufficiently large so as to be able to provide corrosion protection layers to modules 30A-30D and modules 54A-54B without sacrificing magneto-electric performance. [0032] While the invention has been described with reference to an exemplary embodiment(s), it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment(s) disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.

1. A rim driven thruster comprising:
   an annular housing defining a flow path extending along an axis;
   a propulsor assembly supported within the annular housing, the propulsor assembly comprising propeller blades extending radially from the axis of the flow path and configured to rotate about the axis;
   a magnetic rotor assembly mounted to radially outer ends of the propeller blades; and
   a stator assembly comprising spaced propeller drive modules mounted to an inner circumferential surface of the annular housing and configured to provide electromagnetic torque to the magnetic rotor assembly.

2. The rim driven thruster of claim 1 wherein:
   the magnetic rotor assembly and the annular housing define a flow space within the rim driven thruster; and
   the spaced propeller drive modules form a plurality of channels within the flow space.

3. The rim driven thruster of claim 2 wherein the spaced propeller drive modules occupy less than half of the flow space.

4. The rim driven thruster of claim 1 wherein the spaced propeller drive modules are spaced equally around the inner circumference of the annular housing.

5. The rim driven thruster of claim 1 wherein the spaced propeller drive modules are spaced non-uniformly around the inner circumference of the annular housing.

6. The rim driven thruster of claim 1 wherein the spaced propeller drive modules comprise:
   a plurality of electro-magnets spaced about a circumference of the stator assembly.

7. The rim driven thruster of claim 2 wherein each of the electro-magnets comprises:
   a ferromagnetic core stud projecting from the annular housing; and
   a coil winding wrapped around the ferromagnetic core stud so as to extend in both axial and tangential directions.

8. The rim driven thruster of claim 1 wherein the spaced propeller drive modules comprise:
   a plurality of arc shaped linear actuators spaced about a circumference of the stator assembly.

9. The rim driven thruster of claim 8 wherein each of the plurality of arc shaped linear actuators comprises:
   a ferromagnetic core block comprising:
   an arcuate surface facing the rotor assembly; and
   a plurality of axially extending slots disposed in the arcuate surface; and
   a plurality of axially extending coils disposed in the plurality of axially extending slots.

10. The rim driven thruster of claim 1 wherein the propulsor assembly further comprises:
    a hub from which the propeller blades extend;
    a shaft extending through the hub;
    support brackets extending from the annular housing toward the shaft to support the propulsor assembly; and
    bearings positioned between the shaft and the support brackets.

11. The rim driven thruster of claim 1 wherein the propulsor assembly further comprises:
    a hub from which the propeller blades extend;
    a support rim surrounding the propeller blades within the annular housing; and
    bearings supporting the propulsor assembly between the support rim and the annular housing.

12. A rim driven thruster comprising:
    an annular housing defining an axial flow path;
    a propulsor assembly comprising:
    a hub mounted co-axially within the annular housing; and
    a plurality of propeller blades extending radially out from the hub;
    a rotor assembly comprising:
    an annular rotor core connected to the plurality of propeller blades, wherein the annular rotor core and the annular housing define a flow path; and
    a plurality of permanent magnets disposed about the annular rotor core within the flow path; and
    a stator assembly comprising:
    a first propeller drive module connected to the annular housing in the flow path; and
    a second propeller drive module connected to the annular housing in the flow path to define a channel between the first and second propeller drive modules.

13. The rim driven thruster of claim 12 wherein the spaced propeller drive modules comprise:
    a plurality of electro-magnets spaced about a circumference of the stator assembly.

14. The rim driven thruster of claim 13 wherein each of the electro-magnets comprises:
    a ferromagnetic core stud projecting from the annular housing; and
a coil winding wrapped around the ferromagnetic core stud so as to extend in both axial and tangential directions.

15. The rim driven thruster of claim 12 wherein the spaced propeller drive modules comprise:
a plurality of arc shaped linear motor spaced about a circumference of the stator assembly.

16. The rim driven thruster of claim 15 wherein each of the plurality of arc shaped linear motor comprises:
a ferromagnetic core block comprising:
an arcuate surface facing the rotor assembly; and
a plurality of axially extending slots disposed in the arcuate surface; and
a plurality of axially extending coils disposed in the plurality of axially extending slots.

17. The rim driven thruster of claim 12 wherein the spaced propeller drive modules are spaced equally within the flow path.

18. The rim driven thruster of claim 12 wherein the spaced propeller drive modules are spaced non-uniformly within the flow path.

19. The rim driven thruster of claim 12 wherein the propulsor assembly further comprises:
a shaft extending through the hub;
support brackets extending from the annular housing toward the shaft to support the propulsor assembly; and
bearings positioned between the shaft and the support brackets.

20. The rim driven thruster of claim 12 wherein the propulsor assembly further comprises:
a support rim surrounding the propulsor blades within the annular housing; and
bearings supporting the propulsor assembly between the support rim and the annular housing.

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