Feb. 15, 1938. S. A. FARRELL 2,108,660

VARIABLE PITCH AND REVERSING PROPELLER MECHANISM

Original Filed March 1, 1935 3 Sheets-Sheet 1

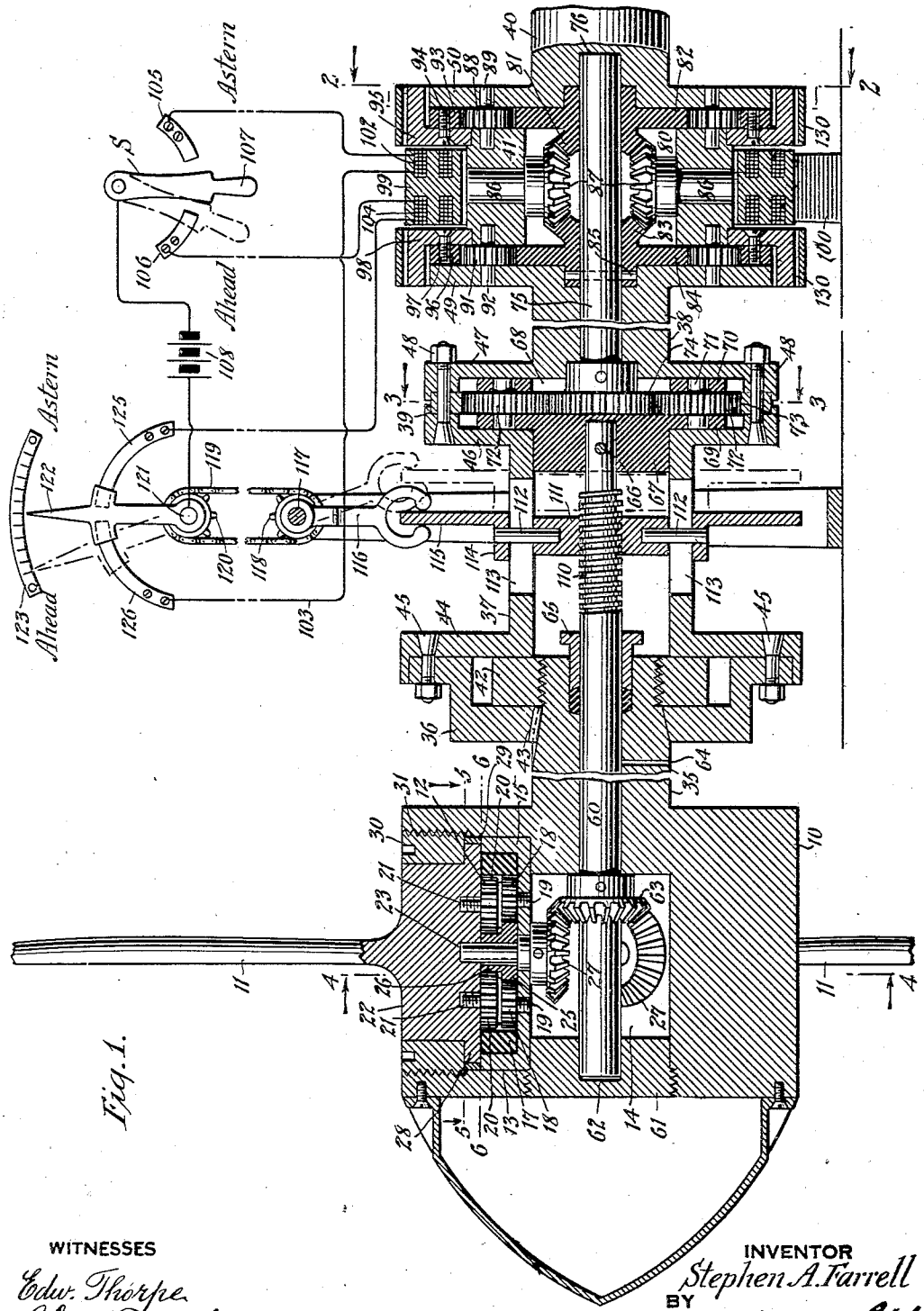


Fig. 1.

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VARIABLE PITCH AND REVERSING PROPELLER MECHANISM

Original Filed March 1, 1935 3 Sheets-Sheet 2

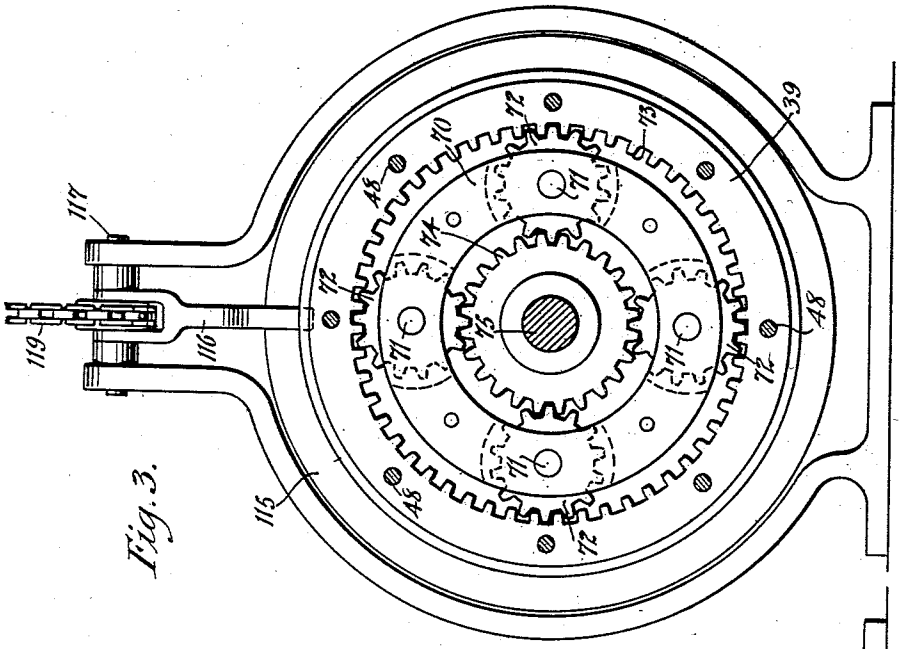


Fig. 3.

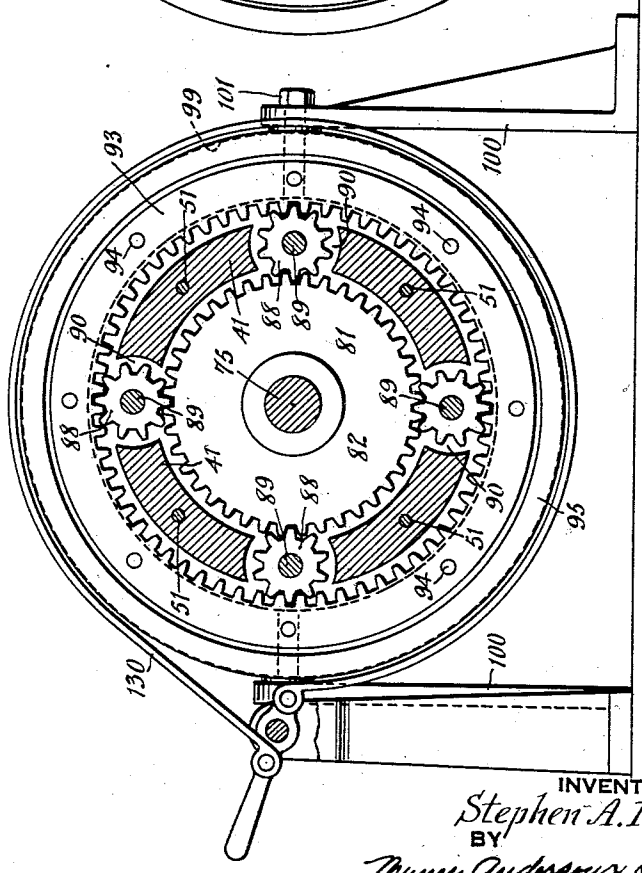


Fig. 2.

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VARIABLE PITCH AND REVERSING PROPELLER MECHANISM

Original Filed March 1, 1935 3 Sheets-Sheet 3

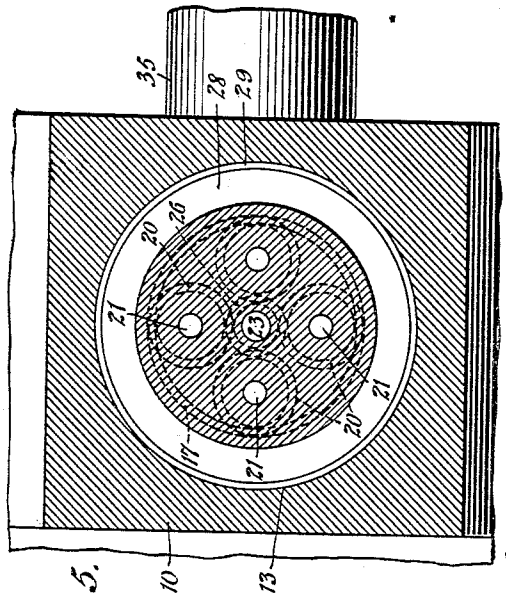


Fig. 5.

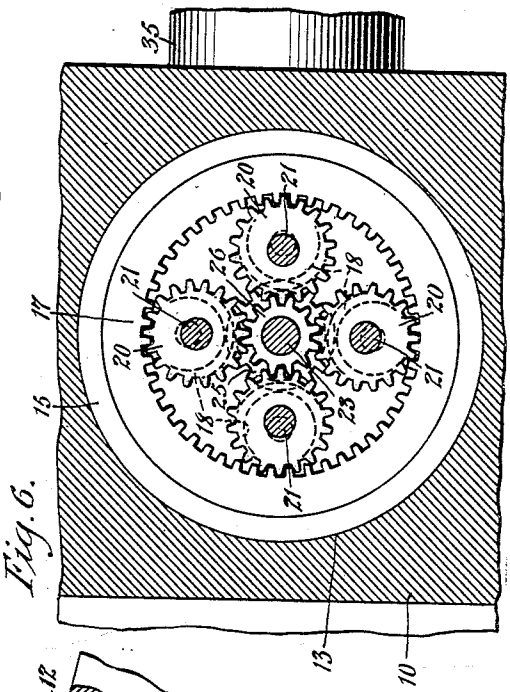


Fig. 6.

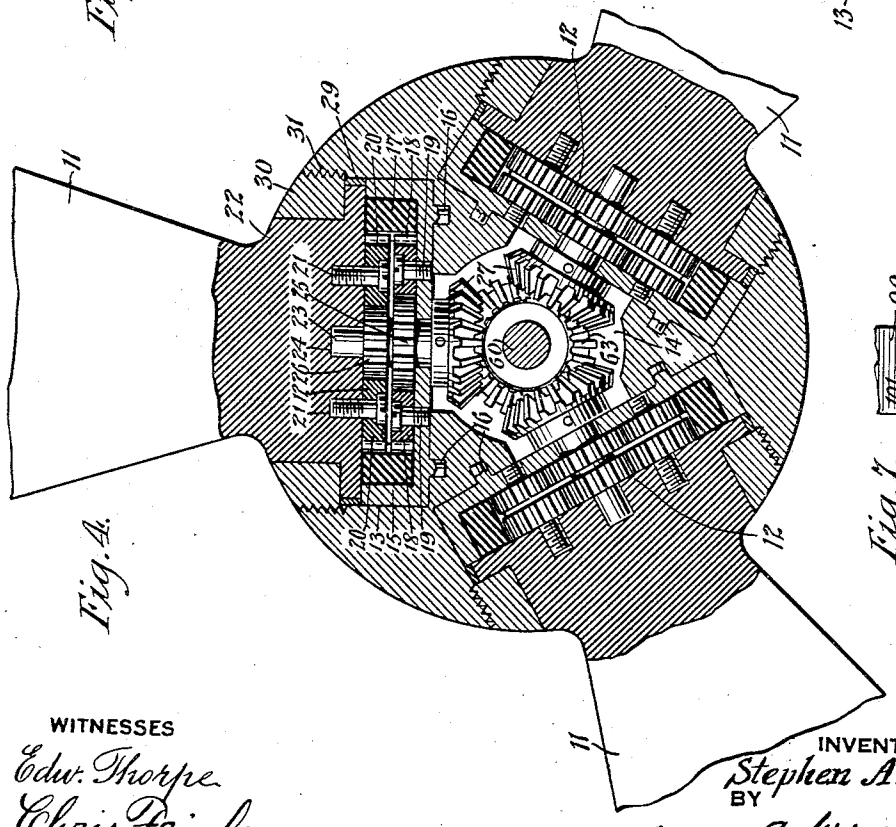


Fig. 4.

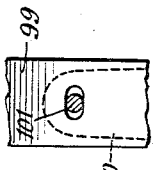


Fig. 7.

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UNITED STATES PATENT OFFICE

2,108,660

VARIABLE PITCH AND REVERSING PROPELLER MECHANISM

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Application March 1, 1935, Serial No. 8,952
Renewed October 14, 1936

3 Claims. (Cl. 74—291)

This invention relates to a variable pitch and reversing propeller mechanism which may be used advantageously with marine and other craft.

An object of the invention is the provision of a mechanism of the indicated character whereby variable direct and reverse thrust adjustment of the blades of a propeller may be accomplished from a remote point.

A further object of the invention is the provision of a mechanism of the indicated character whereby the pitch of the blades of a propeller may be varied at will to impart a direct or reverse thrust, and to make it impossible to vary the pitch of the blades beyond a maximum direct and reverse thrust value.

A further object of the invention is the provision of a propeller having angularly adjustable blades with efficient means operable to cause the simultaneous adjustment of the blades to vary the thrust thereof, and which means is automatically operable to prevent movement of the blades from their adjusted positions due to reactive pressure of the fluid medium in which the blades are operating, to the end that power transmitting means may be employed, to operate the adjusting means as well as to drive the propeller, relieved at all times of any reactive strain from said blades.

Regarding the use of the invention in marine craft, it has the following advantages. It enables a man navigating a craft, to personally vary the propeller pitch, to get any possible thrust in either direction in two seconds, and to accomplish this without shock. The prime mover, Diesel, gasoline or steam turbine may be run at a constant governed speed in the same direction at all times, and the efficiency is that of a direct drive. The prime mover may be run at an economical speed while driving the craft at reduced speeds. It enables the use of a remote control. It enables the provision of a driving mechanism which will always be in perfect mechanical and dynamic balance, simple, durable, light in weight, compact and comparatively inexpensive.

With the foregoing, other objects and advantages of the invention will appear from the embodiment thereof, which by way of example, is described in the following specification and illustrated in the accompanying drawings, in which:

Fig. 1 is a longitudinal sectional and diagrammatic view of a mechanism embodying the features, portions thereof being broken away.

Fig. 2 is an enlarged transverse section taken on the line 2—2 of Fig. 1.

Fig. 3 is an enlarged transverse section taken on the line 3—3 of Fig. 1.

Fig. 4 is an enlarged transverse section taken on the line 4—4 of Fig. 1.

Fig. 5 is an enlarged section taken on the line 5—5 of Fig. 1.

Fig. 6 is an enlarged section taken on the line 6—6 of Fig. 1.

Fig. 7 is a view of one of the details.

The mechanism of the present invention is hereinafter described by way of example, as applicable to marine craft such as large steamships, naval vessels, and also smaller craft such as motor boats and launches.

The mechanism includes a propeller generally consisting of a hub 10, blades 11, there being three blades in the present instance, and a self-locking gear set 12 carried by the hub for each of said blades and operable to rotate the blade on its own axis to angularly adjust the same, for the purpose of varying the pitch so as to obtain direct and reverse thrust, or in other words, varying the amount and direction of the propeller thrust. The hub 10 has three bores or holes 13 extending radially therein and spaced equi-distantly, and also has an axial bore 14 therein which communicates with the bores 13 and also opens through one end of the hub. Each of the bores 13 provides a cross-sectionally round recess for one of the blades 11 and also for one of the gear sets 12. Each gear set includes a circular case 15 which fits within the bore, and is held in place against movement with respect to the hub by pins 16 on the case which enter holes in the hub. The case 15 is machined to receive an internal ring gear 17 which is free to rotate in said case. The gear 17 meshes with gears 18, each of which is freely rotatable on an arbor 19 screwed into or otherwise secured to the case 15. The gear 17 also meshes with gears 20 each of which is freely rotatable on an arbor 21 screwed into or otherwise secured to the base or inner end 22 of the related blade 11. The gears 20 are larger than the gears 18. The arbors 19 and 21 are disposed so that their gears 18 and 20 respectively will rotate freely on axes perpendicular to the axis of rotation of the hub, and parallel to the axis of rotation of the blade. A stub shaft 23 is disposed axially of the related blade 11 and one end thereof is loosely received in a socket 24 in the base 22 and its other end projects through the case 15 into the bore 14. The shaft 23 has keyed fast thereto or formed integral therewith gears 25 and 26 respectively. The gear 25 is larger than the gear 26. The gear 25 meshes

with the gears 18, and the gear 26 meshes with the gears 20. The inner end of the shaft 23 has secured thereto a bevel gear 27, the same being disposed in the bore 14. The base or inner end 22 of the blade 11 is cross-sectionally round in the form of a disc and has a flange 28. A spacing ring 29 fits within the blade bore 13 and also fits around the flange 28 and rests on the case 15. The blade bore 13 is threaded to receive a locking ring 30 which is made of two parts in threading engagement with the internal threads 31 in the hub at the outer end of the bore 13. The ring 30 seats on the spacing ring 29, the ring 30 being set down hard on the ring 29 which is slightly higher than the flange 28, thereby permitting the blade 11 to rotate freely while being adjusted. In this manner the blade is positively locked in position without appreciable lost motion.

It will be apparent that each gear set 12 is of the epicyclic or planetary type. It will be obvious that when motion is transmitted to the shaft 23 of each gear set by rotating its gear 27 in one direction, the gear 25 will cause the gears 18 to rotate on their own axes, on their arbors 19, and the gears 18 in turn will cause the ring gear 17 and gear 26 to rotate, the gear 17 will cause the gears 20 to rotate on their arbors 21, and to planetate around the shaft 23, due to the difference in the size or proportion of the gears 18 and 25 compared to the gears 20 and 26. In this manner each blade 11 may be caused to rotate in one direction or the other, according to the direction in which each of the bevel gears 27 is rotated, to angularly adjust the blade the desired degree to vary the amount and direction of the propeller thrust while acting in the water.

By reason of the locking characteristics inherent in each gear set 12, its blade is prevented from movement from its adjusted position in response to the reactive pressure of the water. In this connection it is to be observed when reactive strain is imposed on each blade, this will be transmitted to the arbors 21. This will tend to cause the gears 20 to impose a strain equally on the ring gear 17 and the gear 26 and also the gear 25 which is integral therewith. The gears 17 and 25 are in mesh with the gears 18 and are tending to rotate in the same direction, consequently the gears 18 cannot rotate and the strain will be transferred through the arbors 19 to the case 15 which is held fixed with relation to the hub. In this manner each blade will always and instantly be locked in its adjusted position against reactive movement from pressure of the water while acting therein.

The flanged base 22 of each of the blades constitutes a practical mounting for the blade to support it for angular adjustment in conjunction with the gear set 12.

There is provided means for driving or rotating the propeller, and said means is connected between the hub 10 of the propeller and the prime mover such as a Diesel, gasoline or steam turbine, or other power plant. The said means comprises the components or parts 35, 36, 37, 38, 39, 40, and 41 with suitable connections completing an assembly in perfect balance and symmetry about an axis co-axial with the axis of rotation of the hub 10. The component 35 consists of a hollow shaft section of suitable length, preferably formed integral with the hub 10. The shaft section 35 carries the component 36 which consists of a dished flange secured in place by a nut 42 in threading engagement with the shaft section 35. The nut 42 bears on the flange 36, the latter being provided with a tapering opening to fit around a taper portion of the shaft section 35 and the latter being keyed to the flange 36, as at 43. The component 37 consists of a hollow shaft section having a flange 44 on one end which is secured to the flange 36 by bolts 45, and the other end has a dished flange 46. The component 38 consists of a hollow shaft section of any preferred length, and has a dished flange 47 on one end similar to the flange 46. The component 39 consists of a ring which is disposed between the flanges 46 and 47. Bolts 48 extend through the flanges 46 and 47 and the ring 39 to securely connect the shaft sections 37 and 38, and also to secure the ring 39. The other end of the shaft section 38 has a flange 49. The component 40 consists of a shaft section having a flange 50 similar to the flange 49. The component 41 consists of a ring or annulus which serves as a spacer, the same being arranged between the flanges 49 and 50. Bolts 51 extend through the flanges 49 and 50 and the annulus 41 to thus connect the shaft sections 38 and 40. The shaft section 40 will be coupled with the shaft of the prime mover of the character mentioned hereinabove. From the foregoing it will be obvious that the components 35 to 41 inclusive with the connections mentioned constitute means for transmitting rotary motion to the hub 10 to drive the propeller.

Controllable means is provided for operating the gear sets 12 simultaneously to similarly adjust the blades 11. The means consists of the following components or elements: A shaft section 60 extends through the shaft section 35 into the bore 14 in the hub 10. The bore 14 of the hub 10 is tapped to receive a round nut 61 which has a bore 62 therein to receive the outer end of the shaft section 60. In this manner the shaft section 60 is supported for rotation. Bevel gear 63 is fast on the shaft section 60 and meshes with the bevel gear 27 of each of the gear sets 12. The shaft section 35 has an oil hole 64 for the purpose of introducing lubrication into the bore 14 to lubricate the gearing. The stuffing box 65 is connected with the shaft section 35 and surrounds the shaft section 60 to prevent lubrication from leaking past the shaft section 60 when the lubricant is injected under pressure through the hole 64. The shaft section 60 is fixedly secured as at 66 to a carrier 67 loosely extending in the shaft section 38. The flanges 46 and 47 form a box or casing providing a chamber 68. The carrier 67 has a flange 69 which is disposed in the chamber 68, and the flange 69 is connected with a ring 70 also disposed within the chamber 68, the flange 69 being connected with the ring 70 in spaced relation by spacers shown in dotted lines in Fig. 3, and pins 71 are supported by the flange 69 and the ring 70, there being four pins 71 in the present instance. Each pin 71 provides an arbor for a gear 72 which is freely rotatable thereon between the flange 69 and the ring 70. Thus there are four gears 72 which rotate on axes parallel to the axis of the shaft section 60. The gears 72 mesh with teeth 73 on the ring 39. The ring 39 with its teeth 73 constitute an internal gear. The gears 72 also mesh with an external gear 74 fast on a shaft section 75. The gear 74 like the gear 72 is housed within the chamber 68. The shaft section 75 extends through the shaft section 38 into a bore 76 in the shaft section 40. The carrier 67, ring 70, pins 71, gears 72, 73, and 74 constitute a planetary speed chang-

ing gear set, the function of which is to reduce the speed of the shaft section 60 with respect to the shaft section 75, and to increase the torque between these shaft sections, and to increase the speed of the shaft section 60 with respect to the propeller driving means 35—41 while rotating in the same direction of the latter.

Another gear set as follows is provided for causing the direct and reverse rotation of the shaft section 75 in response to the direct rotation of the drive shaft section 40, and through the intervention of said speed changing gear set causing the direct and reverse rotation of the shaft section 60. The flanges 49 and 50 and the annulus 41 as bolted together form a chamber 80. A duplex gear element consisting of a bevel gear 81 and a spur gear 82 is loosely mounted on the shaft section 75 within the chamber 80. A similar duplex gear element consisting of a bevel gear 83 and spur gear 84 is keyed as at 85 to the shaft section 75 within the chamber 80. Stub shafts 86 are made fast in the annulus 41 and are disposed diametrically opposite each other to provide axes perpendicular to the axis of the shaft section 75. A bevel gear 87 is loosely mounted on each of the stub shafts 86 and meshes with the bevel gears 81 and 83. The spur gear 82 meshes with planetary gears 88 mounted on arbors 89 respectively supported by the annulus 41 and the flange 50. The annulus 41 is recessed as at 90 to receive the gears 88. The spur gear 84 meshes with planetary gears 91, similar to the gears 88, the gears 91 being mounted on arbors 92 respectively supported by the annulus 41 and flange 49, the gears 91 being disposed in recesses in the annulus similar to the recesses 90. The planetary gears 88 mesh with an internal gear 93 secured as at 94 to a ring clutch element 95 mounted for rotation on the annulus 41. The gear 93 is disposed between the flange 50 and the element 95. The planetary gears 88 mesh with an internal gear 96 similar to the gear 93, the gear 96 being secured as at 97 to a ring clutch element 98, similar to the clutch element 95. The gear 96 is disposed between the flange 49 and the clutch element 98. The clutch elements 95 and 98 are made of magnetizable metal. A ring clutch element 99 surrounds the annulus 41 between the clutch elements 95 and 98. The clutch element 99 may be made in segments of magnetizable metal. The clutch element 99 is supported by stationary brackets 100 through the intervention of means 101 preventing rotation of the element 99 but permitting a limited amount of axial movement in opposite directions with respect to the clutch elements 95 and 98. The clutch elements 95 and 98 are free to rotate with the annulus 41 at all times, except when engaged by the clutch element 99. The clutch element 99 has a plurality of coils 102 directly adjacent the clutch element 95. The coils 102 are electrically connected in an electric circuit 103. Coils 104 similar to the coils 102 are embodied by the clutch element 99 directly adjacent the clutch element 98. The coils 104 are also electrically connected in the circuit 103. A switch S consisting of arcuate contacts 105 and 106 respectively and a blade 107 is provided. The contacts 105 and 106 and the blade 107 are included in the circuit 103. The circuit 103 also includes a suitable source 108 of electrical energy. The switch S will be arranged at a remote point under the control of a navigator. When the blade 107 is moved into engagement with the contact 105, the circuit will be closed causing current to flow through the coils 102 completing a magnetic circuit between the clutch element 95 and the element 99. This will cause the element 99 to move axially into contact with the element 95 thus holding the latter fast. Likewise when the blade 107 is moved into engagement with the contact 106 the circuit will be closed causing current to flow through the coils 104, thereby completing a magnetic circuit between the clutch element 99 and the clutch element 98. This will cause the clutch element 99 to move axially in contact with the clutch element 98 holding the latter fast. The contact 105 will be designated Astern, and the contact 106 will be designated Ahead.

In order to indicate the angular adjustment of the propeller blades 11 there is provided the following means which is operated by the rotation of the control shaft section 60. The shaft section 60 has a right-hand threaded portion 110 within the shaft section 37. A nut 111 is in threading engagement with the portion 110. Pins 112 extend radially from the nut 111 diametrically opposite each other through longitudinal slots 113 respectively in the shaft section 37. The pins 112 in the slots 113 prevent rotation of the nut 111 with respect to the shaft section 37, but permit axial movement with respect thereto. The pins 112 tightly fit in holes in a circular flange 114 on a disk 115 slidable axially on the shaft section 37. The disk 115 and its flange 114 are in two half-sections secured to each other. An arm 116 is mounted for rocking movement on a shaft 117. The arm 116 is bifurcated, and the furcations thereof are disposed on opposite sides of the disk 115 normally out of contact therewith but in close proximity to the disk. A sprocket 118 is fast on the shaft 117. A chain 119 encircles the sprocket 118 and a sprocket 120 fast on a shaft 121. A pointer 122 is mounted on the shaft 121 for movement therewith. The pointer 122 moves with respect to a suitable graduated scale 123 to indicate any change in the pitch or the adjustment of the propeller blades 11. The scale 123 and its pointer 122 may be arranged near the switch S so that indications regarding the pitch or adjustment of the blades 11 will be transmitted to the navigator.

In order to automatically disengage the clutch element 99 from either the element 95 or 98, when the propeller blades 11 have reached the angle necessary for full speed, either astern as when the element 95 is held, or ahead, as when the element 98 is held, there is provided the following means. Contacts 125 and 126 respectively are arranged in relation to the pointer 122. Pointer 122 will be made of conducting material. The pointer 122 and the contacts 125 and 126 are electrically connected in the circuit 103. When the propeller blades 11 are in their neutral positions, the pointer 122 will be disposed vertically and equally in engagement with the contacts 125 and 126. Therefore when the switch blade 107 is moved into engagement with either the contact 105 or the contact 106, the circuit 103 will be closed to accordingly adjust the blades 11 for reverse thrust astern, or a direct thrust ahead. While the adjustment of the blades is taking place, the shaft section 60 will be rotating in one direction or the other according to whether the blades 11 are being adjusted for reverse thrust astern or direct thrust ahead. This will cause the movement of the nut 111, and through the intervention of the parts 116 to 121 inclusive, the pointer 122 will be

moved out of engagement with the contact 125 into engagement with the contact 126 and vice versa, thereby opening the circuit 103, causing de-energization of the coils 102 or 104 as the case may be, thereby disengaging the clutch element 99. The means are so devised that this action will take place when the blades 11 have reached their maximum thrust value either for imparting motion ahead or astern. When the propeller blades 11 have been adjusted to their maximum value for direct or reverse thrust, the circuit 103 may be closed by moving the switch blade 107 into engagement with the contact 105 while the pointer 122 is fully in engagement with the contact 126 to cause adjustment of the propeller blades 11 to impart a reverse thrust astern, whereas the switch blade 107 may be moved into engagement with the contact 106 while the pointer 122 is fully engaged with the contact 126 to cause the adjustment of the blades 11 to impart a direct thrust ahead.

The operation of the mechanism is as follows: Assume the propeller blades 11 to be in their neutral positions (zero pitch), and the pointer 122 at zero as shown in Fig. 1, with the shaft section 40 being driven in a clockwise direction looking at the same from the right-hand end. Let us further suppose that the ship is at a pier or dock, and it is desired to get out into the stream by backing. The navigator will move the switch blade 107 into engagement with the contact 105 while watching the pointer 122. This will close the circuit 103 through the coils 102 causing the clutch element 99 to engage the element 95 and hold the latter against rotation. The gear 93 being secured to the clutch element 95 will also be held against rotation. This will cause the gears 88 to rotate counter-clockwise on their own axes, while planetating clockwise, causing the gears 82 and 81 to rotate clockwise. This will cause the gears 83 and 84 to rotate counter-clockwise through the intervention of the gears 87. The gears 83 and 84 rotating counter-clockwise will cause the shaft section 75 to rotate in the same direction. The planetary gears 91 will be rotating idly on their own axes clockwise and will be planetating clockwise causing the internal gear 96 and the clutch element 98 to which it is secured to rotate idly in a clockwise direction. The rotation of the shaft section 75 in a counter-clockwise direction causes the gear 74 to rotate in the same direction. The gear 74 causes the gears 72 to rotate clockwise on their own axes and also to planetate in a counter-clockwise direction, while the carrier 67 is also caused to rotate in a counter-clockwise direction by the pins 71, at a reduced speed compared to that of the shaft section 75, but slightly faster than the means 35—41. The carrier 67 being secured fast to the shaft section 60 causes it to rotate at the reduced speed in a counter-clockwise direction. The shaft section 60 causes rotation of the gear 63 therewith, which in turn causes the simultaneous rotation of the gears 27 of the gear sets 12. This will cause the rotation of the shafts 23 and gears 25 and 26 connected therewith in a clockwise direction as viewed in Fig. 6. The gears 25 and 26 will cause rotation of the gears 18 and 20 respectively in a counter-clockwise direction. The gears 18 cause the internal gear 17 to rotate in a counter-clockwise direction. Due to the difference in the proportion of the gears 25 and 18 compared to the gears 26 and 20, the gears 20 will take purchase on the internal gear 17 and planetate in a counter-clockwise direction causing the blades 11 to move in the same direction to an angular position causing a reverse thrust astern. While this action is taking place, the nut 111 will be caused to move axially toward the hub 10 by the shaft section 60, due to the fact that the shaft sections 37 and 60 will be rotating in opposite directions. This axial movement of the nut 111 with the pins 112 will cause similar movement of the disk 115 thereby causing movement of the pointer 122 through the intervention of the parts 116 to 121 inclusive, to indicate on the scale 123, the degree of astern adjustment of the blades 11. By moving the switch blade 107 into engagement with the contact 106, the circuit 103 will be closed through the coils 104 thereby causing the clutch element 99 to contact the clutch element 98 and hold the latter against rotation. The gear 96 being secured to the element 98 will be held fast. This will cause the gears 91 to rotate counter-clockwise on their own axes while planetating in a clockwise direction, thereby causing the gears 83 and 84 to rotate in a clockwise direction and as a consequence the shaft section 75 will be caused to rotate in a clockwise direction. The gears of the speed reducing gearing will cause the shaft section 60 and its gear 63 to rotate in a clockwise direction at reduced speed compared to the speed of the shaft section 75. This will cause the operation of the gear sets 12 in a manner opposite to that hereinbefore described, thereby causing adjustment of the propeller blades 11 for a direct thrust ahead. The shaft section 60 rotating clockwise like the shaft section 37 but at a faster rate of speed, causes the nut 111 to move axially toward the carrier 67. Through the intervention of the parts 112—121, the pointer 122 will be moved to indicate on the scale 123, the ahead adjustment of the blades 11.

When the clutch element 99 is disengaged and the driving means is rotating all of the gearing is rotating about the axis of the driving means in a nascent state. The propeller will be driven at the same speed as the shaft section 40 and in the same direction which is clockwise, and at the same time the shaft sections 60 and 75 will be rotating at the same speed and in the same direction when the clutch element 99 is disengaged.

If desired an emergency brake means 130 may be employed in conjunction with each of the clutch elements 95 and 98 to hold and release the same.

It will be understood that the mechanism will automatically release the clutch when the propeller blades have reached the pitch limit, either backing or going ahead at full speed. In other words, if the switch blade 107 is put on the astern contact 105 and left there, the propeller blades will be turned on their own axes in such manner that the ship will back full speed astern, and the clutch will be automatically released at the instant the propeller blades have been adjusted for extreme thrust. The same is true if the switch blade 107 is put on the ahead contact 106. Furthermore, after the extreme pitch has been given the propeller blades in either direction, no mistake can be made regarding further changes in the pitch of the blades desired. If the navigator wishes to vary the pitch of the blades to attain changes in speed, the switch S must be closed ahead or astern, and when the indicator shows the pitch for the desired speed, the switch must be opened thereby releasing the clutch and so leaving the blades at the desired pitch.

It is to be understood that the invention is not restricted to the precise arrangement of parts shown and described, as details of construction may be modified and rearranged without departing from the spirit of the invention, the scope of which is limited only by the terms of the appended claims.

I claim:

1. In a variable pitch and reversible propeller mechanism, in combination, a rotatable shaft, an intermediate rotatable shaft in axial alinement with the first shaft, a hollow propeller driving shaft through which the first and intermediate shafts extend, speed changing means connected with all of said shafts to change the speed of the first shaft with respect to the driving shaft, and means connected with the intermediate shaft and driving shaft to operate the speed changing means, to cause the first shaft to rotate in the same direction as the driving shaft but faster, or in a reverse direction thereto, in response to the direct rotation of the driving shaft.

2. In a variable pitch and reversible propeller mechanism, in combination, a rotatable shaft, an intermediate rotatable shaft in axial alinement with the first shaft, a hollow propeller driving shaft through which the first and intermediate shafts extend, speed change means to change the speed of the first shaft with respect to the driving shaft, said means comprising a carrier fast on the first shaft, freely rotatable planetary gears on said carrier, an external gear fast on said intermediate shaft, and an internal gear fast on said driving shaft, said planetary gears meshing with said external and internal gears; and means connected with the intermediate shaft and driving shaft to operate the speed changing means, to cause the first shaft to rotate in the same direction as the driving shaft but faster, or in a reverse direction thereto, in response to the direct rotation of the driving shaft.

3. In a variable pitch and reversible propeller mechanism, in combination, a rotatable shaft, an intermediate rotatable shaft in axial alinement with the first shaft, a hollow propeller driving shaft through which the first and intermediate shafts extend, speed changing means connected with all of said shafts to change the speed of the first shaft with respect to the driving shaft, and means connected with the intermediate shaft and driving shaft to operate the speed changing means, to cause the first shaft to rotate in the same direction as the driving shaft but faster, or in a reverse direction thereto, in response to the direct rotation of the driving shaft, said last means comprising a duplex gear loose on said intermediate shaft, a duplex gear fast on said intermediate shaft, freely rotatable planetary gears carried by the driving shaft for each of said duplex gears and meshing with one series of teeth thereof, other freely rotatable planetary gears carried by said driving shaft between said duplex gears and meshing with their remaining series of teeth, an internal gear for each duplex gear meshing with said first planetary gears, and a device to hold and release said internal gears.

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