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CONCEPT AND OPERATION MODE OF THE ADVANCED ELECTRONIC CONTROL SYSTEM OF THE AZIMUTH PROPELLERS IN TUGS

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ABSTRACT:

"The remote control of azimuth propellers in tugs from the bridge (speed, thrust direction and clutch) is electronic and each manufacturer has his characteristic model, although the control system and the arrangement of the propellers to achieve the expected thrust are similar.

In this article, we analyse the remote electronic control devices in the bridge from the tug azimuth propellers in general, especially its performance and operation mode, without making any distinction between those located forward (tractor Z) or aft (ASD), since their foundation is similar and the only difference is the horizontal propeller position and consequently the direction of the remote controls from the bridge to achieve the expected thrust direction and speed".

Keywords: Tugs, Omnidirectional Propulsion, Azimuth propellers, thrust direction, *rpm* and clutch remote control system.

INTRODUCTION

Although the azimuth thruster concept is an innovation dating back more than fifty years ago, nowadays it still remains a novelty to many ship owners and operators. The basic idea behind an azimuth thruster is that the propeller can rotate 360 degrees round a vertical axis providing omni-directional controlled thrust. This

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means superior manoeuvrability for vessels equipped with azimuth thrusters. It also eliminates the need for a rudder and a reverse gear (i.e. the azimuth thruster itself also functions as a reduction gear[1]). Unlike the cicloidal propellers where Voith Turbo Marine is the only manufacturer -from that the generic name of *Voith propellers*-, the azimuth thrusters are manufactured by different firms and have been referred to under different names e.g. *Z-drives*, *rudder propellers*, *rotable propulsion units*, *omnidirectional thrusters,* although the brand name of a manufacturer like *Shottel*, *Ulstein Rolls-Royce*, *Steerprop*, *Niigata, Duckpeller* etc. is often used as a generic label for all azimuth thrusters.

The system consists of several different devices: azimuth thrusters, steering and control unit levers and shaft lines. As a whole, they might well be more accurately referred to as a "*propulsion and steering system*".

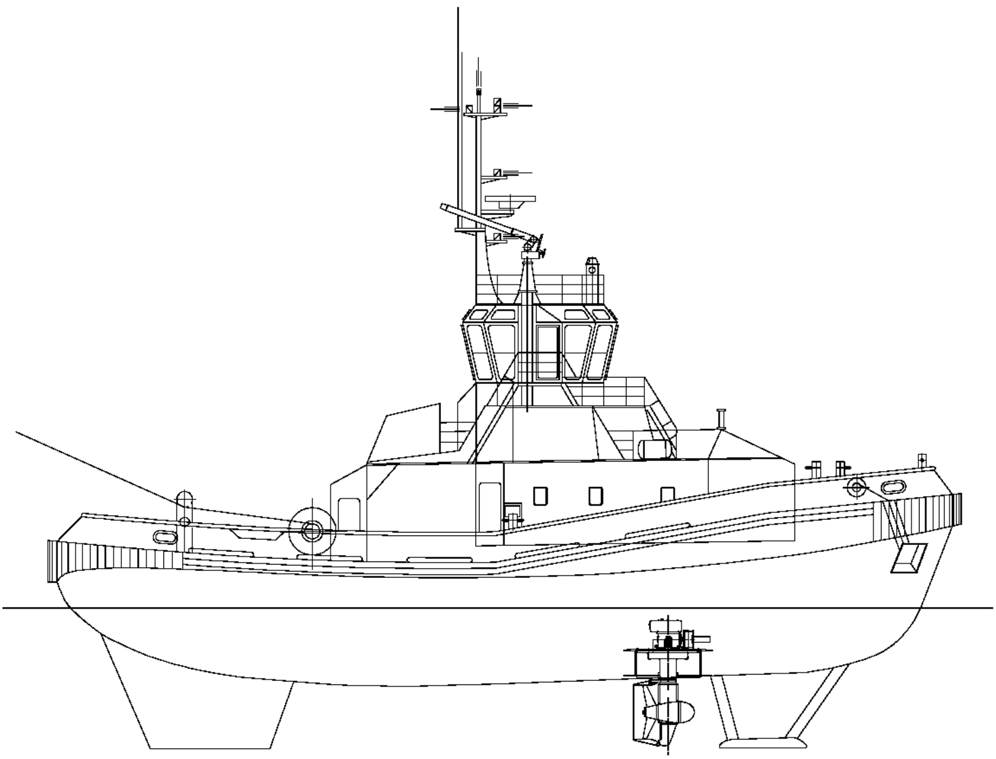


Figure 1. Tractor Z Tug. Drawing: author

1 Thanks to the fact that the reduction gear system is located in the propeller unit, every part in the high-torque power transmission has also been moved into the unit itself.

In Spain, the tugs with this type of propellers are the tractor *Z*[2] (its propellers are mounted in the forepart of the tug´s hull, the same as the *tractor Voith*) and the *Azimuth Stern Drive (ASD)* whose propellers are located aft, the same as conventional tugs[3].

The remote control of these propellers from the bridge (speed and thrust direction) is electronic and each manufacturer has his own characteristic model, although the control system and the arrangement of the propellers to achieve the expected thrust are very similar.

In this article, the remote electronic control devices in the bridge from the tug azimuth propellers are analysed in general, especially their performance and operation mode, without making any distinction between those placed forward (*tractor Z*) or aft (*ASD*), since their basis is similar and the only difference is the horizontal propeller position and consequently the position of the remote controls from the bridge in order to achieve the expected thrust direction.

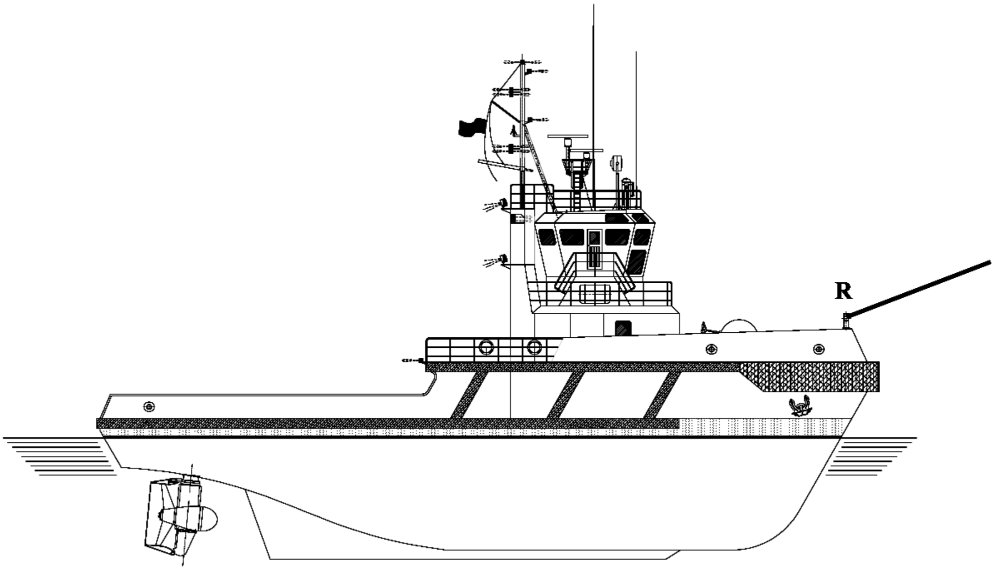


Figure 2. ASD Tug. Drawing: author

[2] So called because of the configuration of the drive shaft.

[3] There are two new states of the art tugs that also have this type of propellers, they are the *Ship Docking Module (SDM)* now rechristened in Europe –for contractual reasons– as *Asymmetric Tractor Tug (ATT)* which are "*Salvador Dalí*" and "*Ramón Casas*" recently delivered to the Spanish operator *Reyser, S.L.* for its own operations in the harbour of Barcelona and the *Rotor Tug* , a revolutionary concept characterised as an enhanced tractor tug with two propellers forward and where the large skeg aft is replaced by an azimuthing propulsion unit; but for the time being, this type of tugs are not working in Spanish harbours.

AN INDEPENDENT ELECTRONIC CONTROL SYSTEM FOR EACH AZIMUTH PROPELLER

General description

Generally, a control of this type for the azimuth propeller[4] of a tug consists of a follow-up remote control system from the bridge, which is independent for the control of each propeller.

The basic operation unit of the system is the control head, which has got different denominations according to the manufacturer. It basically consists of a single lever which can rotate 90º vertically and 360º horizontally for the thruster functions (steering, *rpm* and clutch). Thus, each thruster has its own independent control system, allowing all the azimuth propeller controls in only one hand:

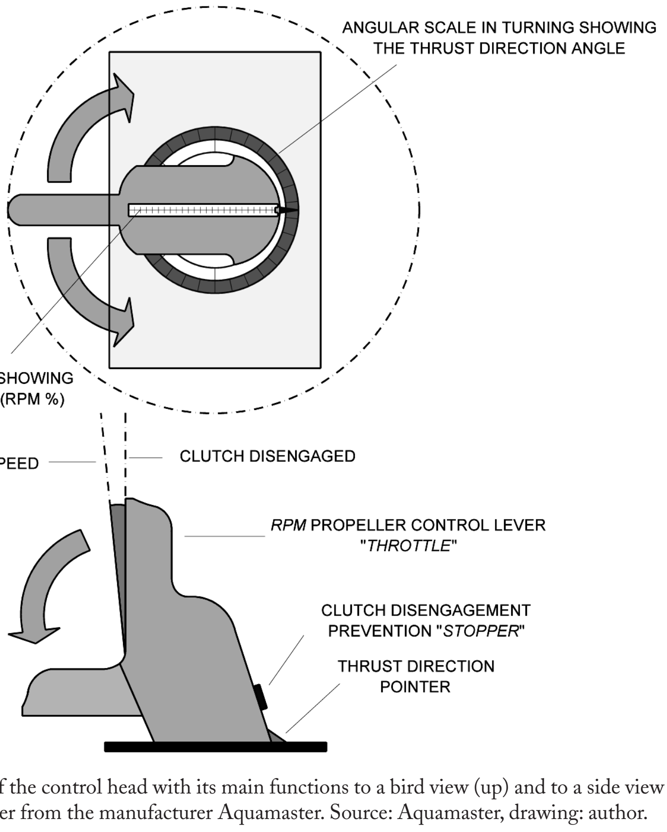


Figure 3. Drawing in ACAD of the control head with its main functions to a bird view (up) and to a side view (down) of an azimuth propeller from the manufacturer Aquamaster. Source: Aquamaster, drawing: author.

[4] Although their functionality is very similar, as well as its design, its denomination varies depending on the manufacturer; thus, *Schottel* denominates it *Copilot*, Aquamaster denominates it *Aquamaster Control Head* and Ulstein denominates it *Combilever*.

— Continuous horizontal control of the thrust direction (steering) throughout the 360º.

— Clutch control: the clutch remains disengaged when the lever is in vertical position with a tilting angle of between 0º and 5º, in which case, the propeller does not rotate (the highest number of degrees from the vertical position depends on each manufacturer). From this point, the power increases by tilting the lever further. When the lever is in 90º position, full power (*rpm*) is in use.

— Main engine speed control (*rpm* control): the prime mover´speed is controlled by tilting the control lever "*throttle*" in the vertical direction. The prime mover *rpm* of the two engines does not necessarily have to be adjusted. It is possible to stop and hold the ship in its place by thrust orientation only.

— Some manufacturers, as Aquamaster, incorporate clutch disengagement prevention by means of the "*stopper*". A "*stopper*" button blocks the return of the lever to the upright position to keep the clutch engaged while the engine idles.

The azimuth propeller follows the movements of the control head in the bridge with a certain delay "*follow-up control*", in such a way that the operator can concentrate on the real operation of the ship, as this control acts in a logical way.

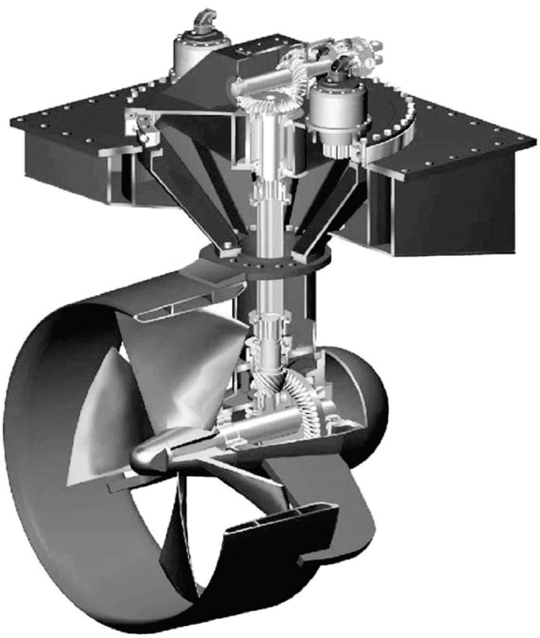


Figure 4. Diagram depicting the "Z" drive configuration of a typical azimuthing propulsion unit (in this case from the manufacturer Thrustmaster), cut away to show the drive shafts and gears. The steering gear, which turns the entire centre portion and propeller through 360º, is omitted for clarity reasons. Source: Thrustmaster.

The control statio

It usually consists of a small console provided with at least the following units:

—The control head, a single lever for the operation of the thruster functions –steering, *rpm* and cluth.

—A thrust direction indicator.

—A control panel of the propeller with different indicators.

Some manufacturers as *Duckpeller* and *Niigata* do not have the three functions in a single lever, but rather they have:

— a single control lever for both propellers named *unilever*, a kind of *joystick* which is a single control lever on the wheelhouse console that is used to control the direction of the tug as well as the speed for a given *throttle* setting.

— two levers named "*throttles*" for the *rpm* control of the main engines of each propeller.

The angle that the propellers make with the forward and aft line is controlled by the *unilever*.

The general principle is that the tug will go in the direction where the *unilever* is placed, with a combination of rotational and translational movements, made possible by the control system vectoring the propeller thrusts in various ways. With the *unilever* forward or aft in the centreline, the propellers drive the tug directly ahead or astern.

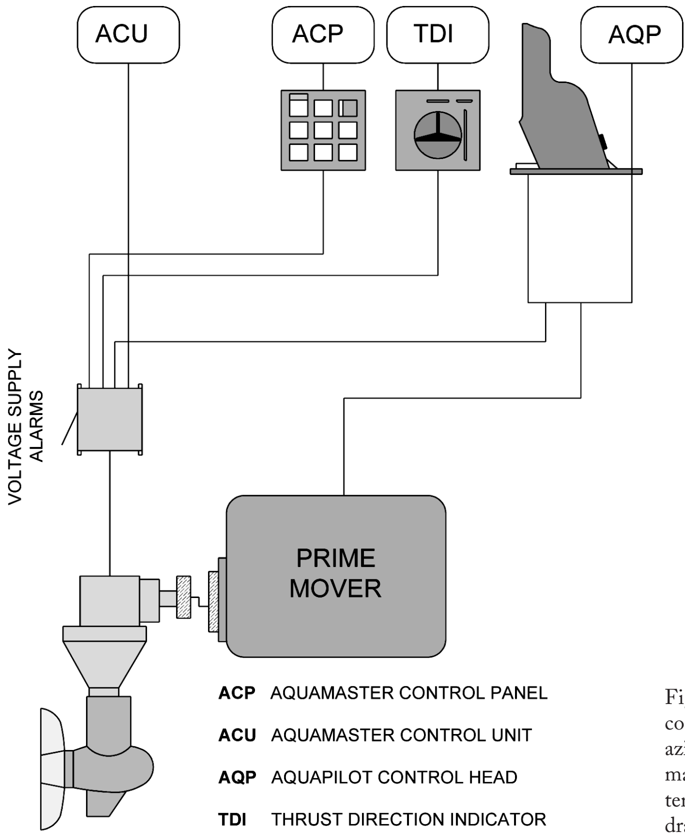


Figure 5. Diagram of a control system of an azimuth propeller by the manufacturer Aquamaster. Source: Aquamaster, drawing: author.

With the *unilever* placed off the centreline, a control system rotates the propeller units, so that the tug travels in the direction where the lever is placed.

Main engines are controlled by two *throttle* levers, while directional or steering control is carried out by means of only one *unilever*, in such a way that the electronic control system adjusts the thrust direction of the two *Z-pellers* in order to move the tug in the direction that the *unilever* is moved. With the *unilever* in the vertical or neutral position, the thrust of the two *Z-pellers* is at right angles to the vessel´s centre line on each side, thus holding the vessel stationary. Speed control, and thus propeller thrust, is also independent for each main engine.

There are combined clutch and engine speed control levers named *throttles,* located on the wheelhouse console adjacent to the *unilever*.

The tug's manoeuvrability may be further improved by the tug master by varying the speed of each engine in combination with the various *unilever* settings.

The secondary steering system: backup control system

The control system of the propellers includes a secondary *non follow-up* dependent back-up system usually known in the tug slang as secondary steering, although considering its function (thought more to be used mainly in case of the "*follow up control*" failure), we could denominate it more properly as emergency steering.

This back-up system is made up of some push-buttons which have a direct and independent electric connection with the propeller unit by electronic circuits, i.e. they are directly connected to each propeller.

Figure 6. Control Head of one of the two Aquamaster propellers (named Aquamaster Control Head) of the ASD tug "Sertosa Treinta y dos" working-based at La Coruña harbour. To the right of this control, the two push-buttons that constitute the secondary steering system can be appreciated. Photograph: author.

The thrust direction control

The control head of the azimuth propeller controls the turning of the propulsion unit. All the controls of the different manufacturers have some specific characteristics, but in general, their functions are very similar. Taking as an example that of the manufacturer Aquamaster, when the control lever is rotated horizontally an angle bigger than 0,7º, the propeller turning controller (*Aquamaster Turning Controller - ATC-)* senses the deviation angle and turns the propeller to the desired direction by controlling the hydraulic system and adjusting the turning speed, according to some preset values[5]. The horizontal turning speed of the propeller is partially proportional to the deviation angle between the actual direction of the propeller and the value settled down by the control head. When the deviation is more than 23º, the turning speed is higher; when it is smaller than this angle, the turning speed is proportional to the angle difference. The steering lever includes a circular scale where the thrust direction is shown in degrees.

The thrust direction indicator is electrically independent from the control system. The propeller speed indication is usually integrated to the thrust direction indicator connected to the propulsion unit.

The speed control

The main engine speed is controlled by tilting the propeller control lever vertically. Generally, the idling *rpm* range is 0º- 5º; from this point, the power increases by tilting the lever further towards full power *rpm* at 90º. The main engine speed does not necessarily have to be adjusted. It is possible to stop and keep position by only thrust orientation.

The clutch control

The propeller built-in clutch is controlled by tilting the propeller control lever through five degrees from the upright position. A microswitch, driven by the propeller, controls the thruster clutch. A *stopper* button usually blocks the return of the lever to the upright position inside the propeller control lever to keep the clutch engaged while the engine idles. For security reasons, starting the main engine is only possible when the clutch is disengaged. A clutch engaged bright and a clutch engaged prevention indicators with a warning light are all located on the propeller control panel.

Electronics in azimuth propellers

The hydraulic steering function system of the propeller is electronically controlled. The turning control is an intelligent, microprocessor-based unit with an

5 This guarantees smooth steering without pressure shocks in the hydraulic system.

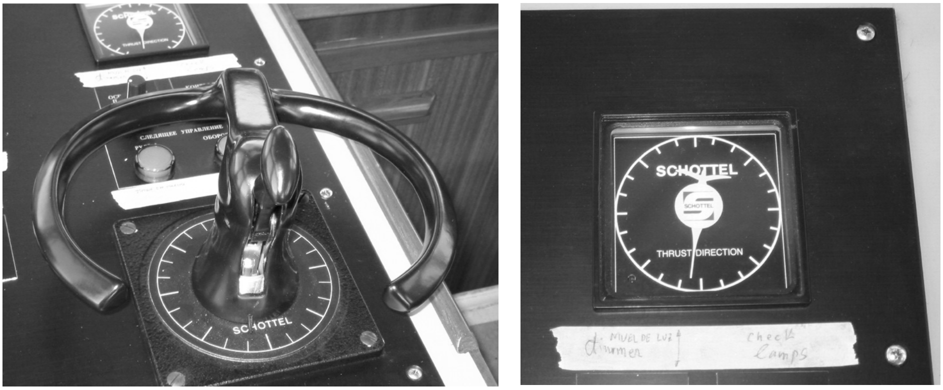


Figure 7. Left: Control Head of one of the two Schottel propellers (entitled Copilot) of the tug ASD "Bravyy" recently built by a Spanish shipyard to a Russian owner. Right: the thrust direction indicator of the propeller. Photographs: author.

automatic adjustment system and self-monitoring. All its settings are electrical and have a self-diagnostic display system in the propeller control unit which ensures the propeller´s smooth turning and shock-free steering at low hydraulic steering pressures, as well as a constant turning speed.

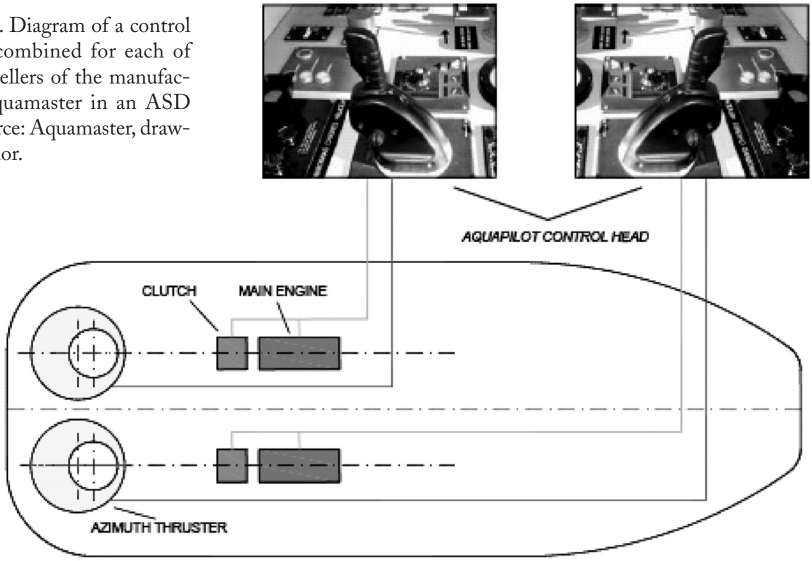
In figure 7 a control head of a *Schottel* azimuth propeller can be appreciated. This control consists of a horizontal wheel which controls the propeller thrust direction (the wheel has a pointer at console level that points the propeller direction exactly), and a small lever "*throttle*" from which the thrust of the propeller is controlled, modifying the *rpm* of the motor that drive it from the vertical to the horizontal position where full power (*rpm*) is in use.

The propeller lever synchronizing when there is more than one control station on the bridge

The state of the art wheelhouse´s designs of *tractor* and *ASD* tugs has good outside visibility close to 360º from the operating position[6], and consequently in general, the optimum solution is to have only one central steering position. So, at present, it is strange to see a bridge equipped with more than one control station. However, in case there is more than one control station in the bridge, each propeller lever control per propeller unit is synchronized with the same ones in another control station. Then, all the control levers will move together and any station can take control of the propeller by means of a push button control; in that case, the selection

[6] The *ASD* always with their bow towards the assisted ship "*bow first*" and the *tractor Z* with their stern towards the assisted ship "*stern* or *skeg first*."

Figure 8. Diagram of a control system combined for each of the propellers of the manufacturer Aquamaster in an ASD tug. Source: Aquamaster, drawing: author.



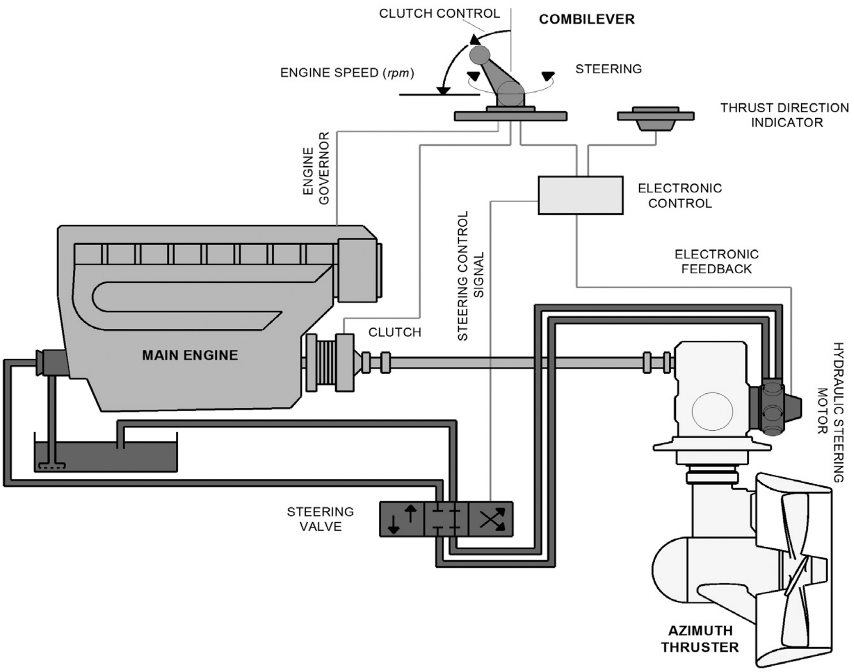


Figure 9. Detail of the control system of one of the two azimuth propellers of the manufacturer Ulstein in an ASD tug. In the diagram, a direct shaft line can be appreciated. Actually, at present and due to the new designs of the ASD tugs, the propellers are higher than their motors and the shaft line does not adopt such a simple disposition. Source Ulstein, drawing: author.

is indicated with a light, whereas the other control stations are now passive and will follow the one in command (now they are in slave mode).

In this case, the propeller control lever has the lever syncronizing unit which lets an alarm sound if the lever in the slave mode does not follow the lever in command. In the same way, the alarm is triggered (with indication and contact), when the operator turns or tilts the lever in the slave mode.

THE UNIQUE COMBINED CONTROL SYSTEM FOR THE TWO PROPELLERS

The manufacturers of the different azimuth propellers usually offer the option of installing a combined control (a kind of a *joystick*[7]), designed to control the movements of a ship equipped with several propellers (normally with up to four) by means of a single three-axis *joystick* which simultaneously controls all propulsion units.

The control programme is individually prepared for each vessel according to their individual hydrodynamic characteristics and steering performance.

There are already quite a number of different *joysticks* on the market[8] for the control of azimuth propeller tugs and, in short, they consist of a micro-computer controlled device for vessels equipped with more than one azimuth propeller. Through an input gear (a combination of a lever and horizontal wheel), the desired side-stepping direction and rotary motion of the vessel as well as the force of the movement are continuously fed at a set value for each *joystick* position. The direction of motion is indicated by the direction of the lever and the force of motion by the deflection of the lever[9].

Although it is not very common, there are tugs with this option; but it is necessary to point out two things: on the one hand, this is not suitable for a harbour tug because although the manoeuvre is simpler, its controls options are restricted to predeterminated parameters by the manufacturer as mentioned, following the client´s indications. On the other hand, the Clasification Societies demand that the tug has the possibility of individually controlling each propeller although a unique combined control system is installed. This is made not only as a security measure in case of a possible failure of the combined system, but also so that the tug Captain has the option to use all the functionality of an omnidirectional propulsion system which, otherwise, would be reduced if it only had the possibility of using the combined control system.

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[7] The word "*joystick*" is a term used in aviation and has its origin in the simple tiller and whipstaff for steering a boat or ship.t

[8] For example, Aquamaster denominates it "*Micropilot Control System*", while Schottel denominates it "*Master Pilot Control System*."

[9] For example, while the Aquamaster design constitutes a true *joystick* (this is a small lever that in the case of the *ASD tugs* controls the two azimuth propellers, but in the case of other types of ships it can control up to four azimuth propellers); in the case of Schottel, the design is similar to the independent control of each propeller (*copilot*).

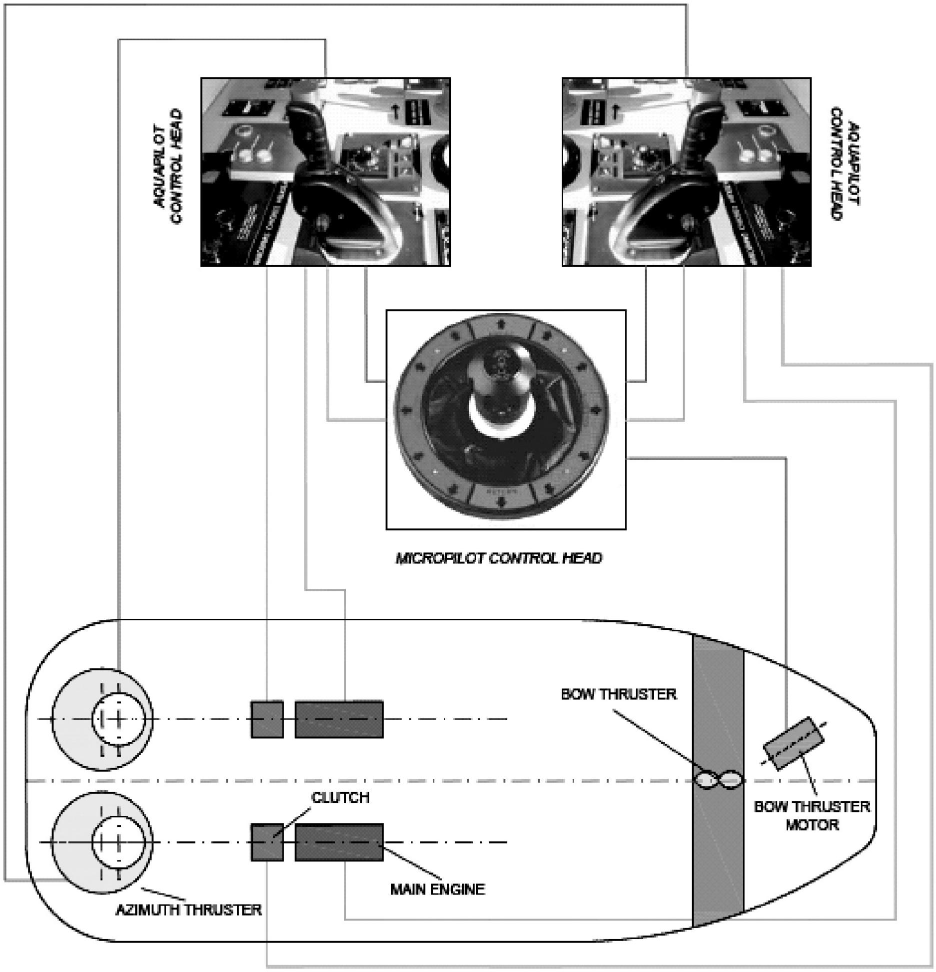

Figure 10. A typical Integrated Bridge System in an ASD Tug with an Aquamaster Micropilot Control System for two azimuth propellers and a bow thruster which controls every propulsion unit simultaneously. Source: Aquamaster, drawing: author

In conclusion, the Captain of an *ASD* or a *tractor Z* harbour tug with the necessary skill and with a combined control system should not use it to carry out the harbour assisting manoeuvres. On the contrary, he should use the independent electronic control system for each propeller. As a consequence, he gets a higher versatility which will improve the performance, especially the most difficult ones.

In figure 10 there is a diagram showing a combined control system by the manufacturer Aquamaster which controls all the propulsion units simultaneously[10]. As it can be appreciated, the lines that go to the propellers, which control the orientation of the thrust, and those that go to the respective motors that drive each one of them, control the *rpm*. In the case of the figure, an *ASD* tug with its two typical azimuth propellers aft and a tunnel bow thruster is represented, being able to control them all by means of the named *Micropilot Control System*.

CONCLUSIONS

The tugs with Azimuth propellers have got a remote electronic control from the bridge which controls both their orientation and *rpm* in their engines and the clutch.

In order to carry out the assistance manoeuvres with the best possible security, it is thought that the option of a combined control of the two Azimuth propellers in only one control, which some manufacturers offer, does not seem a recommendable solution in the case of the tugs as it restricts its manoeuvre capability. It limits the endless combinations of orientation and azimuth thrust to the parametres previously defined by the manufacturer in order to get the expected movement.

This electronic control system of the Azimuth propellers has been shown less hard and reliable compared with the mechanic control of the cicloidal propellers of the Tractor Voith tugs, although lately the azimuth propeller manufacturers are doing great efforts to improve its reliability. However, there are two disadvantages which are very difficult to overcome compared with the Voith mechanic control: on the one hand, higher keeping manteinance costs and on the other, in case of damage or breakdown, it may need more out-of-order time, as the manufacturer technical assistance is practically essential.

[10] In the state of the art tug denominated Rotor Tug which is endowed with two azimuthal propellers forward (the same as a *tractor Z*) and a third azimuth propeller aft in substitution of the skeg of the genuine tractor tugs, the manufacturer *Schottel* that has been the only one that has mounted the azimuth propellers in this type of tugs at the moment, has designed a system of combined control that controls the three propellers, denominated *Master Pilot Control System*. As it is the most natural thing, the tug is also equipped with an independent control for each one -denominated *Copilot*- which is not only advisable to give bigger versatility to the tug, but also obligatory, as the Classification Societies demand it.

REFERENCES

Blank, John (1989). *Modern Towing,* Cornell Maritime Press, Centreville, Maryland, pp. 607.

Brandner, P.A. (1995). *Performance and effectiveness of omni-directional stern drive tugs.* PhD thesis, University of Tasmania.

Gaston, M.J. (1996). *Tugs & towing,* MBI Publishing Company, London.

Gollar, G.H. (1994) "Operational considerations influencing the choice of modern tug propulsion systems", *Ship & Boat International,* Abril, pp. 5-9.

Hensen, Henk (2003). *Tug Use in Port. A practical guide,* The Nautical Institute, London.

Reid, George H. (1994). *Primer of Towing,* Cornell Maritime Press, Centreville, Maryland.

Reid, George H. (1986). *Shiphandling with tugs,* Cornell Maritime Press, Centreville, Maryland.

CONCEPTO Y MODO DE OPERACIÓN DEL SISTEMA DE CONTROL ELECTRÓNICO DE LOS REMOLCADORES DOTADOS DE HÉLICES ACIMUTALES

INTRODUCCIÓN

Aunque el concepto de hélice acimutal es una innovación que data de hace más de cincuenta años, aún hoy en día constituye una novedad para muchos armadores y operadores de buque. La idea básica que subyace detrás de una hélice acimutal es que puede girar 360º en torno a un eje vertical generando un empuje controlado omnidireccional en sentido horizontal, lo que significa una superior maniobrabilidad para los buques equipados con este sistema de propulsión suprimiendo al mismo tiempo la necesidad de un timón, de un sistema de inversión del sentido de giro de la hélice o de una reductora (la propia unidad de la hélice acimutal incorpora el sistema reductor de las rpm a las que gira el motor principal que le suministra potencia). A diferencia de las hélices cicloidales cuyo único fabricante es Voith Turbo Marine, de ahí el nombre genérico de hélices Voith con el que se les conoce; las hélices acimutales se fabrican por diferentes firmas motivo por el que se les conoce bajo diversos nombres tales como Z-drives, rudderpropellers, rotatable propulsion units, omnidirectional thrusters aunque en ocasiones el nombre de sus fabricantes como Shottel, Ulstein Rolls-Royce, Steerprop, Niigata, Duckpeller etc. se emplean como un término genérico aplicable para describir a todas las hélices acimutales.

Este sistema de propulsión se compone de diferentes dispositivos: las propias hélices acimutales, las unidades de gobierno y control de las mismas y las líneas de ejes. El sistema quizá podría denominarse en su conjunto con más propiedad como un “*sistema de propulsión y gobierno*”.

En España, los remolcadores que están equipados con este tipo de hélices son el tractor Z (sus hélices van en la parte de proa de casco al igual que los remolcadores *tractor Voith*) y los *Azimuth Stern Drive (ASD)* cuyas hélices van ubicadas a popa al igual que los remolcadores convencionales.

El control remoto de estas hélices desde el puente (velocidad y dirección del empuje) es electrónico y cada fabricante tiene su propio diseño, aunque el sistema de control y la disposición combinada de las hélices para conseguir el empuje en una determinada dirección es muy similar.

En este artículo se analizan en general los dispositivos de control electrónico remoto desde el puente de las hélices acimutales, especialmente su funcionamiento y modo de operación, sin hacer distinción entre aquéllas que van ubicadas a proa (*tractor Z*) o a popa (*ASD*), ya que su fundamento es similar y la diferencia radica en la orientación de la hélice y consecuentemente en la posición de los controles remotos desde el puente para conseguir el empuje que se pretende.

UN SISTEMA DE CONTROL ELECTRÓNICO INDEPENDIENTE PARA CADA HÉLICE ACIMUTAL

Se aborda inicialmente el estudio del típico sistema de control independendiente para cada hélice acimutal que generalmente consiste en un sistema seguimiento "*follow-up remote control system*" mediante control remoto desde el puente y que es independiente para el control de cada una de las dos hélices que montan estos remolcadores. La unidad básica de operación es la unidad de control principal, que recibe diferentes denominaciones según el fabricante de las hélices y que en general consiste básicamente en una simple palanca que se puede girar 90º en sentido vertical y 360 en sentido horizontal con lo que se consigue el control de la orientación, las *rpm* y el embrague de la hélice.

El sistema de control de las hélices incluye adicionalmente un sistema secundario sin seguimiento "*non follow-up*" generalmente conocido en el argot de los remolcadores como gobierno secundario, aunque en vista de su función (pensado para emplearse principalmente en caso de un fallo del sistema de seguimiento "*follow-up*" visto anteriormente), podríamos denominarlo más propiamente como un gobierno de emergencia en caso de fallo del sistema principal.

Este sistema alternativo de gobierno consiste en dos pulsadores que tienen una conexión eléctrica directa e independiente con cada una de las hélices en forma de circuitos electrónicos, esto es, están conectados directamente a cada hélice.

Aunque en los remolcadores de última generación no es normal, en el caso de que exista más de una consola de control en el puente, cada palanca de control de cada hélice se sincroniza con la palanca correspondiente que exista en cualquier otra estación de control, actuando de *esclava* la que no tiene el control de mando transferido.

EL SISTEMA DE CONTROL COMBINADO DE TODOS LOS SISTEMAS DE PROPULSIÓN DEL REMOLCADOR

Las fabricantes de las diferentes hélices acimutales, generalmente ofertan la opción de instalar adicionalmente un control combinado y simultáneo de todas las unidades propulsoras (una especie de *joystick*), diseñado para controlar los movimientos de un buque equipado con varias hélices (normalmente hasta cuatro) por medio de un único *joystick* que controla simultáneamente todas las unidades propulsoras.

El programa de control se prepara individualmente para cada buque, de acuerdo con sus características hidrodinámicas y capacidad de gobierno.

En el caso de los remolcadores existen diferentes *joysticks* en el mercado que comercializan los fabricantes de sus hélices y que en resumen consisten en un dispositivo compuesto de una microcomputadora controlada que está pensada para buques equipados con más de una hélice acimutal. La dirección del movimiento del buque se genera mediante la dirección de la palanca del *joystick* y la fuerza de ese movimiento mediante la desviación de dicha palanca con relación a la vertical.

CONCLUSIONES

Los remolcadores dotados de hélices acimutales van dotados de un sistema de control electrónico remoto desde el puente que controla tanto la orientación de las mismas, como las *rpm* de sus motores y el embrague.

Con el fin llevar a cabo las maniobras de asistencia con la mayor seguridad posible, se estima que la opción de un control combinado de las dos hélices acimutales en un solo mando que ofertan algunos fabricantes y que suelen instalarse en otro tipo de buques, no parece una solución muy recomendable en el caso de los remolcadores por cuanto restringe su capacidad de maniobra al limitar las infinitas combinaciones de orientación y empuje de sus hélices a los parámetros definidos previamente por el fabricante para conseguir el movimiento que se pretende.

Este sistema de control electrónico de las hélices acimutales se ha revelado desde su implantación algo menos robusto y fiable si lo comparamos con el control mecánico de las hélices cicloidales de los remolcadores *tractor Voith*, si bien es verdad que en los últimos años, los distintos fabricantes de hélices acimutales están haciendo grandes esfuerzos para mejorar su fiabilidad, aunque probablemente se mantengan dos desventajas difíciles de superar si se compara con el control mecánico de *Voith* y que son de una parte, unos mayores costes de mantenimiento y de otra, que en caso de avería, puede ocasionar unos períodos mayores fuera de servicio, al resultar prácticamente imprescindible la asistencia técnica del fabricante.