# Flow adapted rudder geometry for energy efficiency improvement on fishing vessels


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## I. INTRODUCTION

A scenario with oil not cheaper than $ 200 a barrel should make us think on the best way to adapt our economy and industries to this situation, that will probably be a reality in a few years.

This scenario has a huge impact on the industry but particularly affects maritime transport and fisheries sectors in which the cost of fuel is the most significant expenditure having a direct impact on the income statement. Every ship owner is nowadays interested on every technology able to reduce the fuel bill, devices providing small improvements in performance and which were despised a few years ago became now very interesting.

Since the construction of the first ships, they have always been equipped with mobile devices for the government, having evolved from primitive paddles arranged on the sides of the ship to the conventional blades attached to a rotating vertical shaft located on the ship's stern. Stern propellers are the most common propulsive solution nowadays; this arrangement creates a flow of water at high speed, which impacts on the rudder surface, improving this way its manoeuvring response.

As the efficiency of a typical propeller can be about 60%, we wonder whether it is possible to increase the propulsive performance of the ship trying to recover some of the energy lost in the propeller so as to improve its interaction with the rudder.

The use of CFD tools together with towing tank testing opens up new possibilities in the study of complex hydrodynamic phenomena occurring in the stern of the ship and in particular between the propeller and rudder; this type of analysis assist the design process of devices like rudders, not only for improved manoeuvring (which is its main role), but also for achieving a maximum energy recovery in the service condition.

## II. STATE OF THE ART.

For the rudder we are located downstream of the propeller so our goal is to increase the recovery energy ratio from the propeller loses. We can say that three are the main sources of propeller losses; frictional losses, axial losses and rotational losses. Whenever we put a rudder downstream the propeller we are recovering rotational losses. This is easy to understand taking into account the force diagram exposed in Fig. 1. so generally we must minimize the value of the ruder drag or maximize it when it points forward. To do this we can act on the rudder in many different ways; one could be modifying the geometry of each horizontal profile of our rudder, adapting it to the velocity field. Other solutions could use devices as Costa bulb, or employ transversal fins.

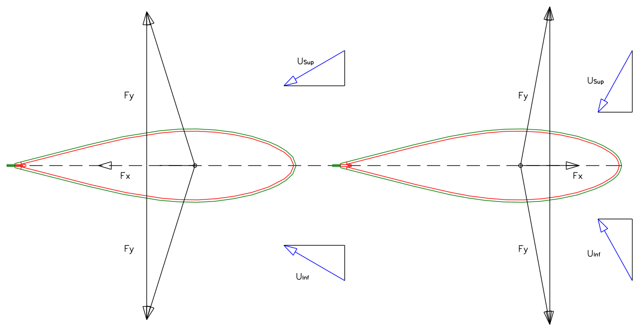


Fig. 1. Force distribution on rudder profiles.

## III. DESIGN METHODOLOGY.

Three different approximated models have been employed for our CFD calculations:

- RANSE for propeller and rudder w/o free surface.
- Potential flow for propeller and RANSE for rudder.
- Potential flow for propeller and rudder.

Beyond the mathematical model we must discuss the numerical methods employed for our calculations. For the solution of the potential equations, the numerical method employed was a Boundary Element Method. For RANSE equations the method was a Finite Volume Method.

As previously stated, the first stage of our calculations was the propeller operating behind the hull. The water velocities were taken mainly from two different sources, a CFD simulation of the hull or from towing tank measurements. The velocities taken from either of these two sources are used as boundary values for our calculations

In Fig. 2 we can see the velocities distribution downstream the propeller and the pressures on the rudder surface. In this pictures black colour is for higher pressure and white for lower pressure. As can be seen this pressure distribution is motivated by the velocity field and of course it is an asymmetric pressure distribution.

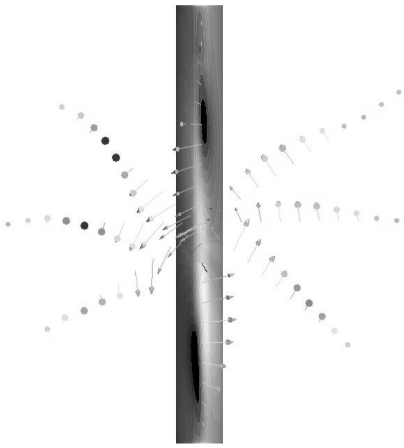

Fig. 2. Velocities upstream the rudder and pressure distribution.

In Figs. 3 and 4 it can be seen the pressure distributions in two different cases that correspond with the rudders of the second of the towing tank data, calculated with the RANSE propeller-rudder approximation without free surface.

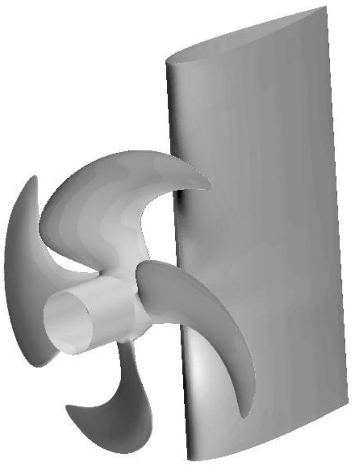

Fig. 3. Pressure distribution.

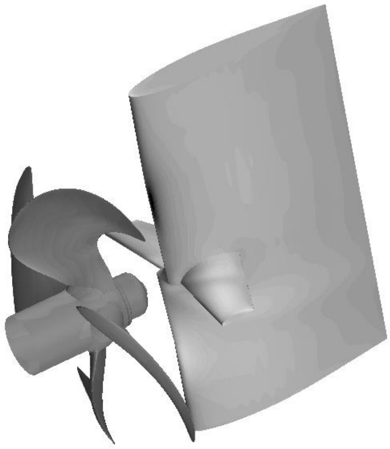

Fig. 4. Pressure distribution.

There is a fact to be considered when these CFD simulations are carried out: as the simulation is performed with the modified rudder and the energy recovery increases, the rpm of the propeller must decrease to achieve the same ship velocity. The magnitude to be checked is the sum of propeller thrust and rudder longitudinal force. Another important aspect to be considered is the scale effect, since model and ship scale simulations were performed. The calculations for full scale showed that there are scale effects not taken into account by the ITTC method for the extrapolation of the model test results. This means that the recovery percentage for a well designed rudder is higher for the full scale ship than for the model scale one. For example, for rudders in figures 3 and 4, the expected improvement employing towing tank data is around 3% for full scale, while employing CFD it can be seen that the improvement is around 5%. This is due to the existence of local Rn higher than the Rn during the towing tank experiments.

## IV. TOWING TANK TESTS I.

Towing tank testing performed with a 70 m tuna purse seiner with two different rudder geometries are described. The first of the geometries corresponds to a conventional rudder, a NACA 20 profile rudder. The second one is a wake adapted ruder with a Costa bulb, designed employing the methodology described before. In Fig. 5. the geometry of the twisted rudder with a Costa bulb is showed below.

The next graphs correspond to self-propulsion tests conducted with the two rudders. It can be seen in Fig. 6. there is a reduction in delivered power between 3% and 4%.


Fig. 5. Twisted rudder designed by VICUSdt fitted on a vessel.

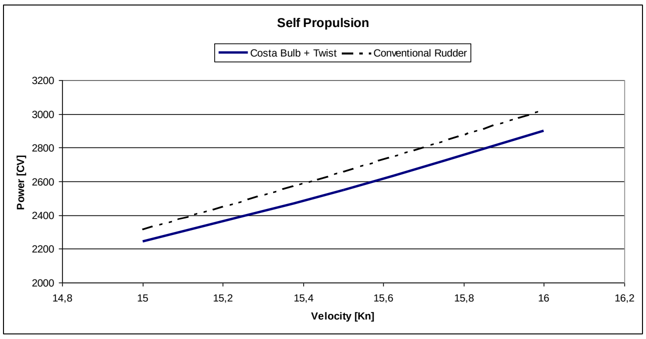


Fig. 6. Self propulsion delivered power.

Fig. 7. and Fig.8. show the values of Cl and Cd of both rudders at different angles.

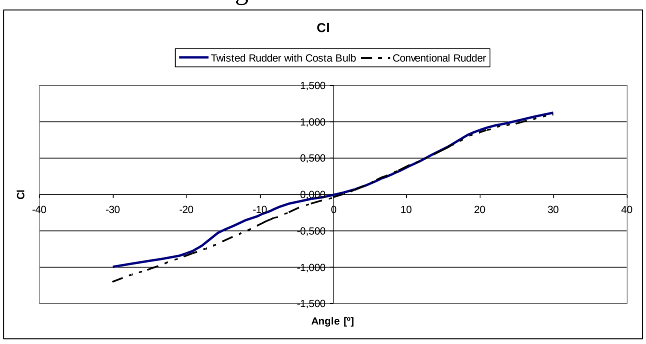


Fig. 7. Self propulsion rudderstock Cl measurement.

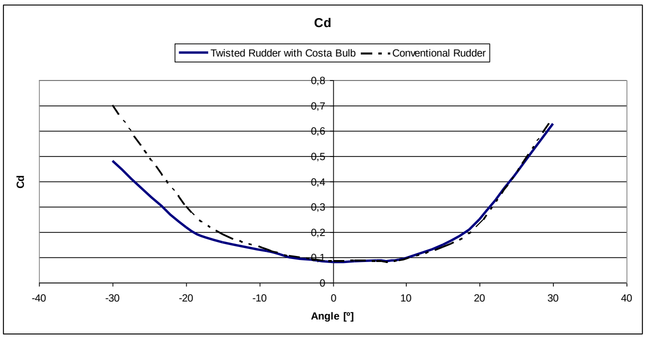


Fig. 8. Self propulsion rudderstock Cd measurement.

As it was expected, the forces for the twisted rudder are worse turning starboard than for the conventional rudder at port side turning. Even so the difference is not so big.

## V. TOWING TANK TESTS II.

Below, the comparison of towing tank data of another tuna purse seiner with two different rudder geometries is shown. The first one is a conventional rudder and the second one is a twisted rudder with two horizontal fins (one on each side).

After this, the newly designed rudders are fitted, conventional and twisted one, and the towing force for both cases is measured. The goal is to measure the improvement achieved with the twisted rudder so in Fig. 9. the improvement percentage of the twisted rudder over the conventional one is showed.

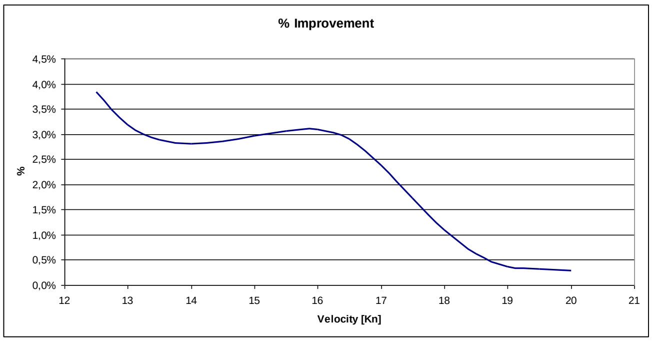


Fig. 9. Improvement for twisted rudder

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The improvement for a range of velocities from 15 to 17 kn, is between 3% and 2%. Inside this improvement there is a reduction on the drag force of the rudder and also transversal forces are lower, a fact which indicates a better response of our rudder reducing the corrections carried out by the automatic pilot. In Fig. 10 a photo of the second rudder can be seen.

Fig. 10. Towing tank model photo.

## VI. IMPACT ON THE FISHING FLEET.

For the impact study on the actual tuna fleet, we are going to make an estimate of the fuel cost reduction using this kind of devices for the second of the analyzed cases. The ship is a tuna purse seiner with a length between perpendiculars of 74 m, a beam of 14,2 m and a displacement of 4200 t. Typical service conditions for this vessel; assuming an average velocity of 15,5 kn working for 5000 h/year. Besides this we are going to take into account the effect of the generation equipment which consuming around 800 kW is taken into account Based on the towing tank data for this case it can be checked that the power required for the ship equipped with the conventional rudder is 2500 kW.

With a fuel price of about 750 $ / t, the annual fuel cost for the ship can be estimated around 1.700.000 $. Taking into account the efficiency improvement achieved by the twisted rudder, annual fuel savings of 39,000 $ can be expected. The return of investment for the rudder change, based on the figures above, is below two years.

The previous estimation was made taking into account the expected improvement from the traditional extrapolation from the towing tank data. The calculations, as explained before, show that the scale effect depends not only on friction causes but also on the geometry of the flow; the efficiency improvement will be higher than the value resulting if the ITTC extrapolation methods are employed to extrapolate the results to full scale.

Taking our calculations as basis, the annual fuel savings would be bigger, around 60,000$.

## VII. CONCLUDING REMARKS.

This study is concerned with the development of new rudder geometries to achieve better energy efficiency on fishing vessels. A few mathematical models, with pros and cons, have been presented to be solved employing numerical methods. CFD is presented as a useful tool for the design of these devices as it is possible to make an evaluation of many design alternatives before manufacturing the final design. Towing tank data have been also presented and analyzed for the assessment of the calculations and the applicability of these devices to real ships. We want to thank the Spanish Ministry of Science and Innovation for their support in developing the present research.

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