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STUDY ON THE POSITION OF THE BOW SPRAY RAIL OF A PATROL VESSEL

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ABSTRACT

Modern patrol ships characterised by an 'axe bow' shape allows the placement of an anti-spray rail. These not only reduce drag but also minimize the wave height generated by the ship's bow. This article will present the effect of positioning of an anti-spray rail at various heights on the ship's bow to reduce drag resistance. The most favorable placement scenario will be determined through the results of numerical simulations conducted by using the commercial software Fidelity Fine Marine.

Keywords: anti-spray rail, patrol vessels, CFD.

1. INTRODUCTION

The meaning of the high performance has changed over time and could be equally applied to wind-powered vessels as well as motor-propelled boats. Speed is an important factor, although it is normally combined with the ability to cut through waves as smoothly as possible.

Any ship in motion encounters hydro-aerodynamic forces from the fluids through which it moves. The projection of the resulted hydro-aerodynamic forces is referred to as drag or total resistance [5].

The determination of the total resistance is one of the major challenges in naval hydrodynamics, because this phenomenon is extremely difficult to analytically express in terms of the factors that generate it. The carried out theoretical studies until now, have not led to exact results, due to the difficulties found in the mathematical formulation of the interaction between the ship's hull, the fluid and the mathematical formulation of the water turbulence phenomenon.

The practical solution of the problem regardoing the total resistance was achieved through experimental tests on ship models. The obtained results were satisfactory for solving the problems of dimensioning the ship's propulsion system. However, these experimental tests required expensive equipment and a considerable amount of time to prepare the experiment. As a solution to these problems, numerical methods appeared to be more cost-effective and provide detailed information about the relevant variables for the respective process, even in the areas inaccessible to experimental tests.

Modern patrol vessels have adopted a proven geometric design, an axe bow type that allows safe navigation at high speeds, even in Beaufort 6 sea conditions. At the same time, this new and modern concept ensures a reduced total resistance, as well as a reduction in fuel consumption compared to conventional ships by approximately 20%.

2. THE ANTY SPRAY RAIL

The past two decades, there has been a consistent increase in the speed of patrol vessels. Therefore, designers and shipyards were increasingly confronted with the impact of speed on stability and resistance characteristics.

The spray rail is defined as a prominent, step-shaped surface on the hull of a vessel (or its floats), which ensures their sliding on the water with a reduced resistance, as illustrated in Figure 1.

The use of anti-spray rail is a popular method to improve the performance of patrol vessels by reducing the total resistance and wave height generated by the vessel at high speeds.

Fig. 1. Anti-spray rail

Modern patrol vessels, especially those with axe bow bows which enable safe navigation at high speeds, include redanes placed along bow line known as anti-spray redans. These spray rail are simple in shape and can be designed either during the construction of the hull or added after construction (Figure 2).

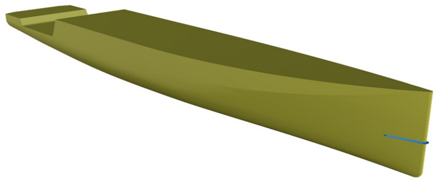

Fig. 2. Anti-spray rail positioned at the patrol vessel's bow

3. TOTAL RESISTANCE OF THE PATROL VESSELS

In the military industry, the ship's hull has continued to be refined to increase the efficiency of rapid intervantion missions. The total resistance of patrol vessels is estimated similarly to any monohull type vessel. [1]

The total resistance of the patrol vessel is the sum of all the different forces acting against the direction of navigation. This is divided into components according to the different sources of resistance, so that the total resistance can be estimated or calculated more easily. The speed at which the ship is sailing will also be analyzed to determine the total resistance.

The overall resistance components of the patrol vessel are influenced and depend on varios factors such as hull shapes, appendages or superstructure. The air affects the upper part of the hull and superstructure of the patrol vessel, causing the appearance of aerodynamic resistance, while water affects the lower part of the body and the appendages of the patrol vessel, causing hydrodynamic resistance [2].

Another set of components that influence total resistance are the weather conditions during navigation, such as wind force, wind direction, and the sea state, and will therefore be taken into account by the corresponding components.

Due to the difficulty in measuring other components of, defining residual resistance plays an important role. Residual resistance includes all components that depend on the Froude number, including the form component of the frictional resistance, that actually depends on the Reynolds number [2].

The total resistance can be represented as the effect of an external flow around a body in a fluid, determined from the form resistance resulting from the pressure distribution on the lateral surface (R_P), and the frictional resistance that manifests only at the boundary layer level (R_F) [3].

Frictional resistance represents 80-85% of the total resistance for slow ships, and 50% for high-speed ships [3].

Pressure forces are the forces acting in a direction normal to the body, while frictional forces are the forces acting parallel to the ship's hull. When these forces are integrated over the entire surface, with their components in the direction of motion, the results are pressure resistance and frictional resistance. These resistance values are positive when opposed to the ship's direction of motion [2].

4. NUMERICAL SIMULATION OF THE FLOW AROUND THE HULL OF THE PATROL VESSEL

To study the flow around the patrol vessel, the commercial code Fidelity Fine Marine was used. The solver integrates the Reynolds averaged Navier-Stokes equations using the finite volume method which involves the spatial discretization of the transport equations. The k-ω SST turbulence model with the use of wall functions was used to model the Reynolds stresses. The treatment of the free surface is based on a "surface capturing" method using the volume of fluid method [4].

The surface of the patrol vessel, on which the studies presented below were carried out is presented in Figure 3.

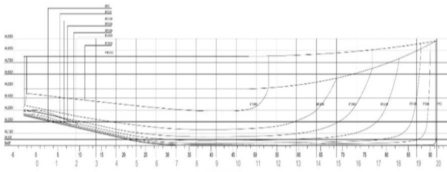

Fig. 3. Sheer plan of the patrol vessel

Table 1 . Main dimensions for the patrol vessel

Main Features	Symbol	Value
Length at waterline	L_{WL}	66 [m]
Length between perpendiculars	L_{pp}	64.05 [m]
Maximum beam	B	10.25 [m]
Maximum draft	T	3.2 [m]
Construction height	H	4.75 [m]

The surface of the patrol vessel was generated in Rhinocerus 5 (Figure 4) with the main dimensions illustrated in Table 1.

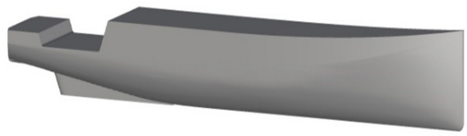

Fig. 4. The surface of the patrol vessel

The anti-spray rail surface used in this study was generated in Rhinocerus 5 (Figure 5) with the main dimensions illustrated in Table 2.

Table 2. Main dimensions for the spray rail

Main Features	Symbol	Value
Length	L	3.57 [m]
Beam	B	0.20 [m]
Height	H	0.20 [m]

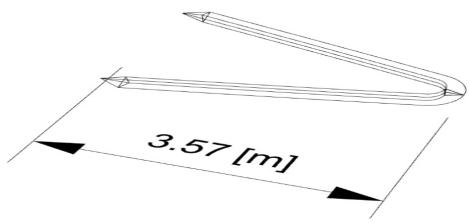

Fig. 5. Anti-spray rail surface

4.1 STUDY OF THE PATROL VESSEL BARE HULL

The first set of calculations was performed for the hull of the patrol vessel without the spray rail, to analyze the flow around it and determine the total resistance. The calculations were performed for six speeds corresponding to Froude numbers between 0.24 and 0.42 (Figure 6).

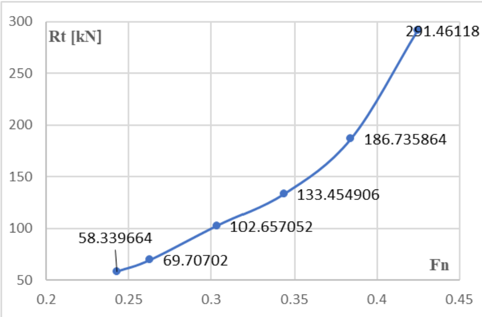

Fig. 6. Total resistance curve of the bare hull

In addition to the values of the total resistance, the profile of the bow wave (Figure 7) and the mass fraction ploted on the hull (Figure 8) were also illustrated.

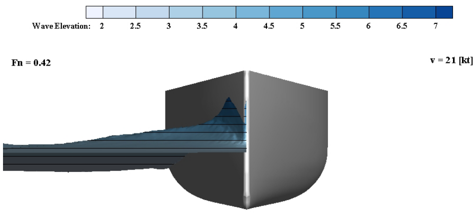

Fig. 7. The wave profile developed by the bare hull for Fn= 0.42

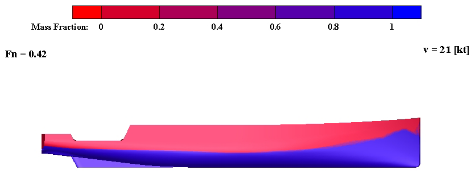

Fig. 8. The mass fraction on the bare hull

4.2 THE EFFECT OF ANTI-SPRAY REDAN ON SHIP RESISTANCE

After performing the numerical simulations for the hull without spray rail and after analyzing the obtained results, the next set of calculation were focused on analyzing the effect of positioning the "anti-spray" at different heights on the "axe-bow" (Figure 9) to quantify the influence on the total resistance and on the wave generated by the bow of the patrol vessel.

Thus, in this study case, a number of seven numerical simulations were carried out for each spray rail position, as depicted in Figure 9, at six speeds corresponding to Froude numbers between 0.24 and 0.42.

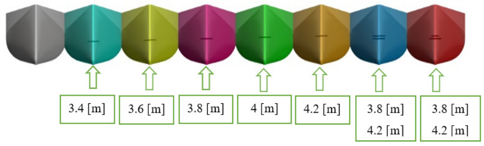

Fig. 9. Anti-spray rail positions at different heights located in the bow of the ship

As in the case of the ship without spray rail, in these seven study cases the values of the total resistance were calculated, as well as the illustration of the development of the bow wave in front view (Figure 10) and side view (Figure 11).

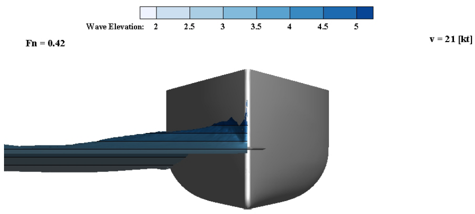

Fig. 10. The wave profile developed by the hull with the anti-spray rail at 3,8 m for Fn= 0.42

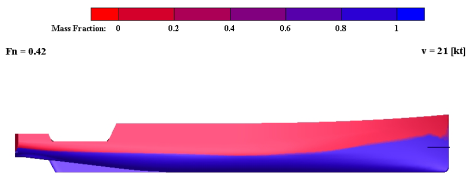

Fig. 11. The mass fraction on the hull with the anti-spray rail at 3,8 m, for Fn= 0.42

The effects of the anti-spray rail differ in all the previously analyzed cases, it being influenced both by the height (Hr) at which it is placed and by the speed at which the patrol vessel sails. In order to analyze the effect of the spray rail position on the six velocities analyzed, some comparative graphs (Figures 12-16) are presented below, taking as a reference the results of the total resistance obtained in the previously analyzed numerical simulations.

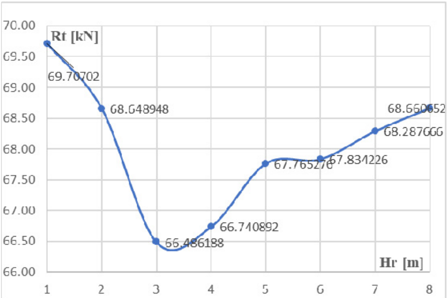

Fig. 12. Effect of anty-spray rail on total resistance at speed v = 13 [kt]

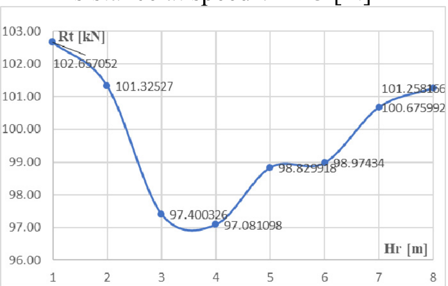

Fig. 13. Effect of anty-spray rail on total resistance at speed v = 15 [kt]

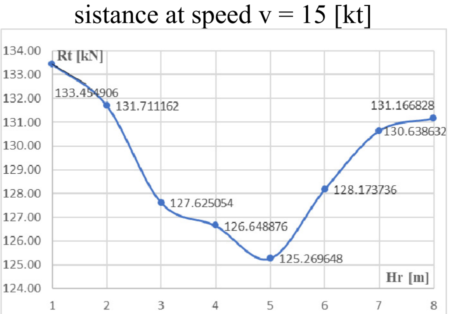

Fig. 14. Effect of anty-spray rail on total resistance at speed v = 17 [kt]

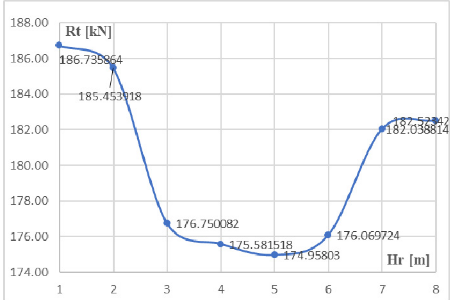

Fig. 15. Effect of anty-spray rail on total resistance at speed v = 19 [kt]

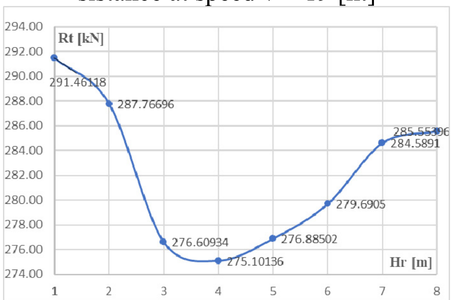

Fig. 16. Effect of anty-spray rail on total resistance at speed v = 21 [kt]

Previously presented, the results obtained for patrol vessel without spray rail represent the reference in relation to which the study of the effect of spray rail on the total resistance was carried out. Table 3 shows the relative variations in total resistance. Graph were drawn to illustrate the variations in the coefficients of total drag (Figure 17).

Table 3. Relative values of total resistance variation

	R_T[%]				
Rail at	13 [kt]	15 [kt]	17 [kt]	19 [kt]	21 [kt]
3.4 [m]	-1.52	-1.30	-1.31	-0.69	-1.27
3.6 [m]	-4.62	-5.12	-4.37	-5.35	-5.10
3.8 [m]	-4.26	-5.43	-5.10	-5.97	-5.61
4.0 [m]	-2.79	-3.73	-6.13	-6.31	-5.00
4.2 [m]	-2.69	-3.59	-3.96	-5.71	-4.04
3.8 & 4.2 [m]	-2.04	-1.93	-2.11	-2.52	-2.36
3.8 & 4.2 [m]	-1.50	-1.36	-1.71	-2.26	-2.03

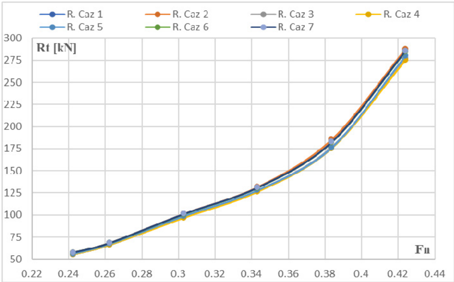

Fig. 17. The curves of the total resistance for each case of location of the spry rail analyzed

5. CONCLUDING REMARKS

The effect of the anti-spray rail on the hydrodynamic parameters of the patrol vessel was studied by comparing with the results obtained for the patrol vessel without spray rail. Thus, the total wave and viscous resistances were calculated for each case of anti-spray rail positioning. Following the numerical simulations, it was found that the spray rail effect reduces the total resistance of the ship in all 7 analyzed cases. The performance of the spray rail on total resistance increases from case 1 (Ship with spray rail located at the height of 3.4 [m]) to cases 3 and 4 (Ship with spray rail located at the height of 3.8 [m] and ship with spray rail located at 4 [m]) where the percentage decrease reaches its maximum point, followed by a decrease in performances in cases 5, 6 and 7 (ship with the spray rail located at the height of 4.2 [m] and ships with 2 spray rail located at the heights of 3.8 [m] and 4.2 [m].

Following the results of the cases analyzed at speeds corresponding to Froude numbers 0.24 – 0.42, it was found that for the minimum speed of 12 [kt], case number 2 with the spray rail positioned at Hr = 3.6 [m] reduces the total drag by 5.04%, for cruise speed v = 17 [kt] case number 4 with spray rail positioned at Hr = 4 [m] reduces total drag by 6.13 % and for maximum speed v = 21 [kt] case number 3 with the spray rail positioned at Hr = 3.8 [m] reduces drag total by 5.61 %.

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