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Study on the Rudder Characteristics of Ultimate Rudder by Numerical Calculation

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Abstract. The authors invented Ultimate Rudder3) as the rudder with bulb. The authors calculated the rudder characteristics of the normal rudder and Ultimate Rudder by CFD at several steering angles and compared these values. The result showed that regardless of the presence or absence of the bulb, signs of separation appear on the control surface with a steering angle of 20 deg. to 30 deg. and regarding the steering torque coefficient, it was found that the steering torque coefficient of Ultimate Rudder is larger than the normal Rudder when the steering angle is less than 20 deg. and also the steering torque coefficient can be decreased by changing the shape of the rudder bulb.

1 INTRODUCTION

Since EEDI was applied, the demand of Energy Saving Devices (ESD) has been increased. NAKASHIMA PROPELLER developed ECO-Cap1) 2) as the cap with fin and Ultimate Rudder as the rudder with bulb so far. In particular, the rudder with bulb at fore side of rudder has a long history and has been equipped on many vessels. Many studies about propulsive performance of rudder with bulb have been carried out. On the other hand, steering performance is also required for rudder, but there are not many studies about the steering performance of the rudder with bulb. The rudder characteristics are defined by lift-drag characteristics at each angle. In this paper, the rudder characteristics of the rudder both with and without bulb at aft side of propeller were calculated by CFD.

2 CALCULATION BY CFD

2 rudders were compared in this paper. One is a normal rudder without bulb. Another is Ultimate Rudder. And then these rudders and 6 blades propeller were designed for mega container vessel. The propeller particulars are shown in Table 1 and over views of rudders are shown in Fig.1.

The scale ratio is 39.58. The chord length of rudder center is 163.4mm, the height is

257.68mm. The clearance between bulb and cap is 2.5mm in model scale. These compared rudders have same rudder section.

In this paper, the authors calculated rudder characteristics by SOFTWARE CRADLE "SCRYU/Tetra Ver.10" which is commercial CFD code. The number of mesh was about 21 million. k-kl-ω model was applied for turbulent model. The analyzed model is shown in Fig.2. The rudder is settled after the propeller same as actual vessel. This calculation was analyzed in model scale. The propeller was rotated in 8rps. 1.44m/s non-uniform wake flow was given at inlet boundary. Lift, drag, and steering torque coefficients were calculated at each rudder angle, and these were compared between normal rudder and Ultimate Rudder. Fig.3 shows the coordinate system.

Table 1: Principal particulars of propeller

	MPNO.1
Number of blades	6
Diameter (m)	0.240
Pitch ratio at 0.7R	1.0326
Expanded area ratio	0.7695
Boss ratio	0.1789
Skew angle (deg.)	34

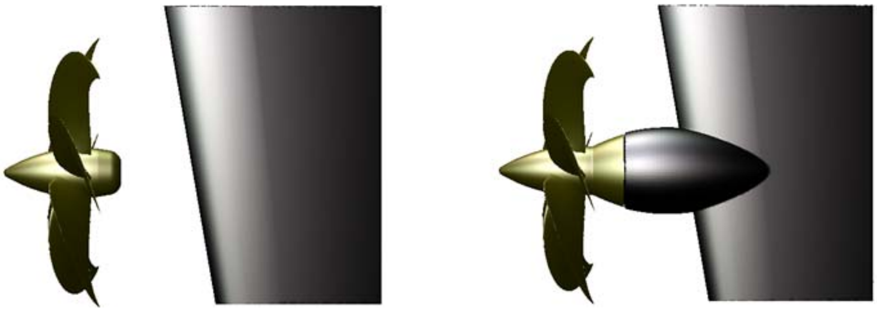


Fig.1 Profile of propeller and rudder

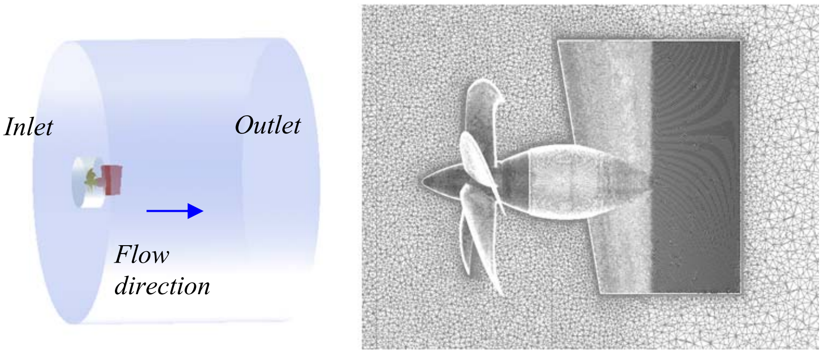


Fig.2 Analysis region of propeller and rudder with bulb

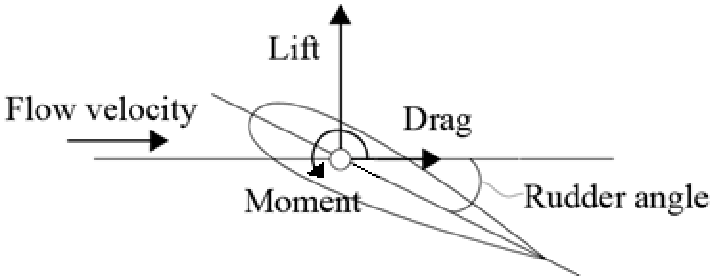


Fig.3 Coordinate system

3 CALCULATION RESULTS

3.1 Comparison of lift and drag coefficient

Fig.4 shows lift and drag coefficients for normal rudder and Ultimate Rudder by CFD calculation.

Lift coefficient of normal rudder increases from 0deg. to 20deg. And it is almost same level from 20 deg. to 30deg. In contrast, lift coefficient of Ultimate Rudder tends to increase slightly even the range between 20deg. and 30deg. There is little difference between normal rudder and Ultimate Rudder from 0deg. to 20deg. but the difference is bigger at 30deg.

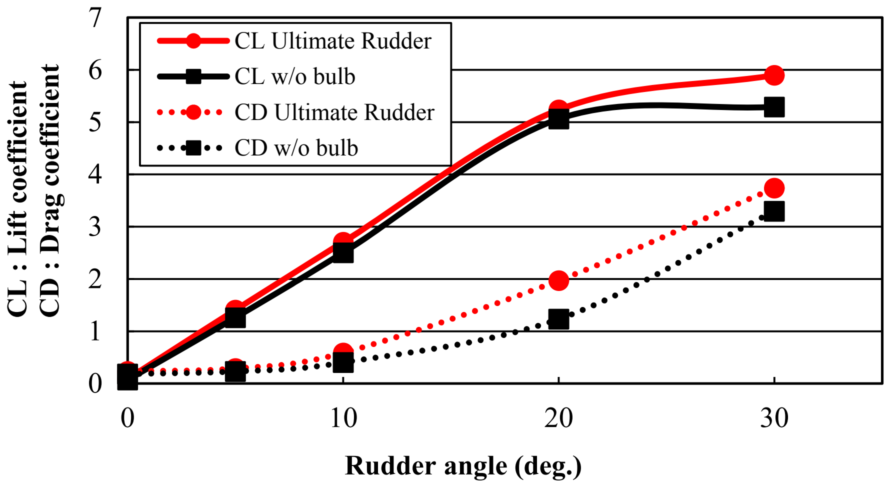


Fig.4 Lift and drag coefficient by CFD

Next, Fig. 5 to 8 show the pressure distribution and the stream line at the steering center cross section of Ultimate Rudder and the normal rudder every 10 deg. from 0 deg. to 30 deg.

With both the normal rudder and Ultimate Rudder, signs of separation appear on the control surface at 20 deg. Further, at 30 deg., a large separation region can be confirmed in both rudders. About Ultimate Rudder in fig. 8, it seems that the low pressure range spreads to the starboard side of the rudder by the bulb.

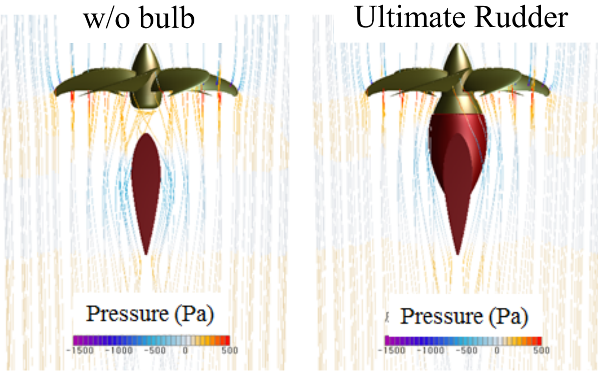
In order to investigate the influence of the pressure distribution on the rudder surface on the lift and drag, the direction and strength of the pressure are obtained by multiplying the pressure of the rudder surface and the normal vector, the lift direction component is P_L, the drag direction component is P_D.

Fig. 9 and 10 show the distributions of P_D and P_L on the starboard side of Ultimate Rudder and the normal rudder and the limiting stream line at 30 deg. The lower value of P_D means greater drag, and the higher value of P_L means greater lift force.

As shown in Fig. 9, lower range of P_D of the normal rudder spreads to the upper side of the rudder, but lower range of P_D of Ultimate Rudder is relatively widely distributed downward from the bulb. Also, it can be seen that there is lowest point of P_D in the lower part of the bulb body. Both of them tend to have a tendency for P_D to be lower at the part where the limiting streamlines are disturbed. It is considered that drag was generated by separation of flow.

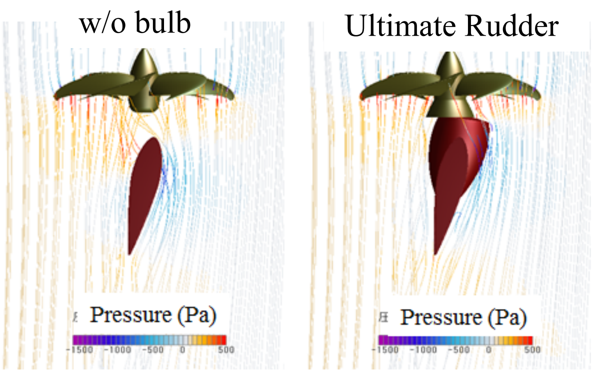
Regarding the lift force, as shown in Fig. 10, a high range of P_L is generated near the front edge of Ultimate Rudder and the normal rudder. Especially, there is a high value of P_L at the front edge of the rudder lowering the turbulence of the limiting streamline, but it was confirmed that the bulb rudder has higher P_L than the normal rudder.

From the calculation result of 30 deg., it was found that lift force and drag force occurred in the bulb part with the bulb rudder, which affects the lift coefficient and drag coefficient of the entire rudder.


w/o bulb

Ultimate Rudder

Fig.5 Pressure distribution and streamline at 0 deg.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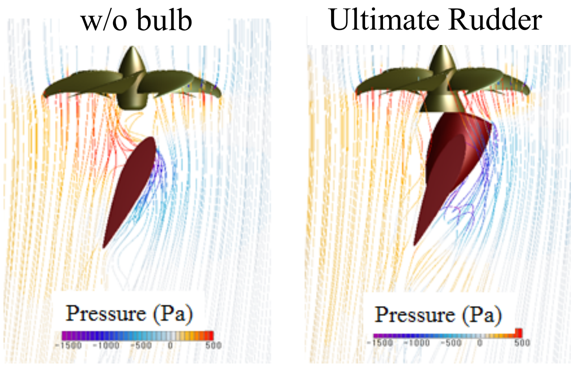
Ultimate Rudder

Fig.6 Pressure distribution and streamline at 10 deg.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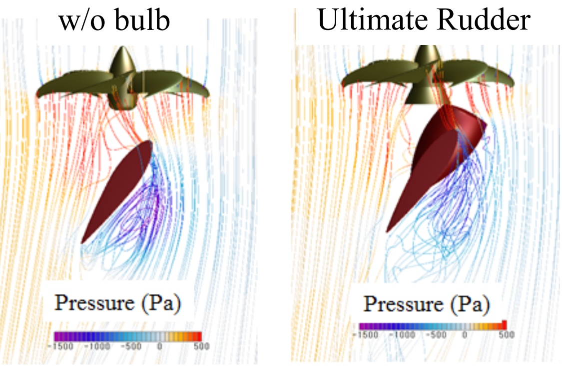
Ultimate Rudder

Fig.7 Pressure distribution and streamline at 20 deg.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Ultimate Rudder

Fig.8 Pressure distribution and streamline at 30 deg.

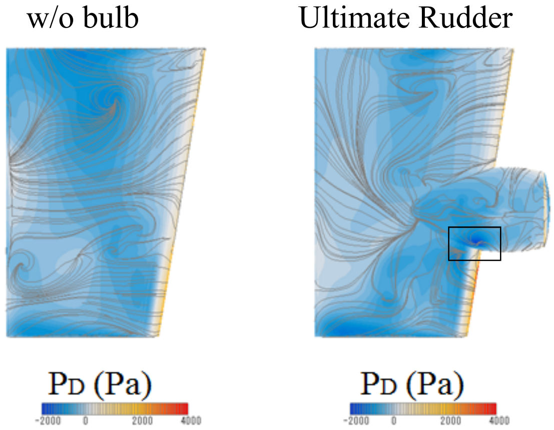

Fig.9 PD distribution and limiting streamline at 30 deg.

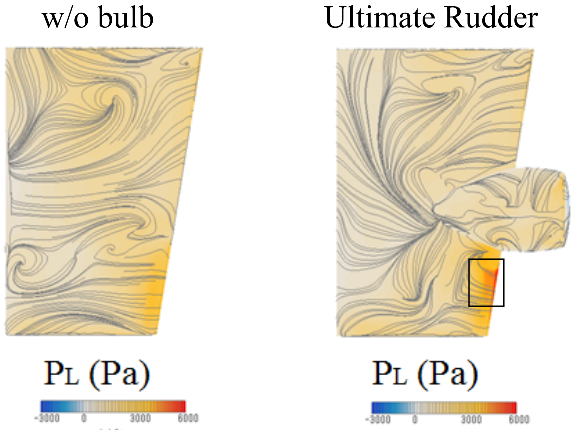

Fig.10 PL distribution and limiting streamline at 30 deg.

3.2 Comparison of steering torque coefficient

Fig. 11 shows the steering torque coefficient at each steering angle of Ultimate Rudder and the normal rudder. Regarding Ultimate Rudder, the calculation was also carried out in a shape with 20 mm clearance between the propeller cap and the bulb. Regarding the adjustment of the clearance, length of the bulb is shortened without changing the position of the rudder main body.

From Fig. 11, it was found that a large steering torque in the minus direction is generated in a range where the steering angle is small with Ultimate Rudder with 2.5 mm clearance. Although the direction is different at 30 deg., almost same steering torque coefficient is generated for Ultimate Rudder and the normal rudder.

Regarding Ultimate Rudder with 20 mm clearance, the steering torque coefficient is smaller in the whole area than in the case of 2.5 mm clearance. This is probably because the bulb is shorter and the distance between the center of the rudder shaft and the leading edge of the bulb is shorter. At the steering angle of 30 deg., the steering torque coefficient is smaller than that of the normal rudder.

From the above, it was confirmed that by changing the clearance and by shortening the total length of the propeller cap and the rudder bulb, the steering torque coefficient can be adjusted.

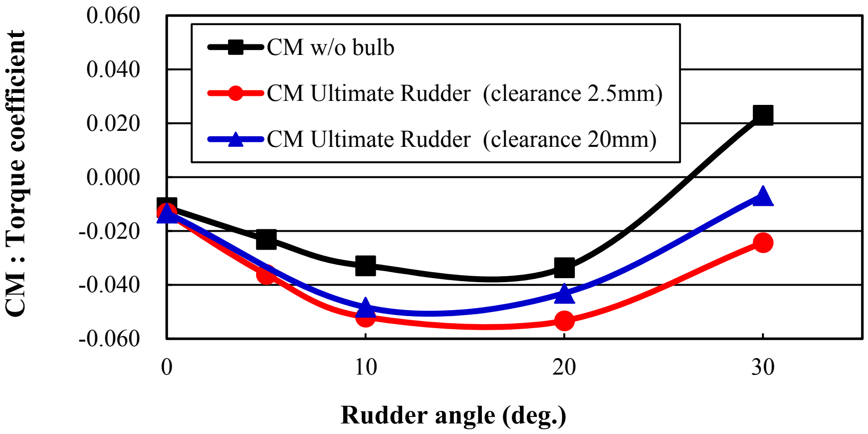

Fig.11 Rudder torque coefficient by CFD

4. Conclusion

About the propeller, Ultimate Rudder, and the normal rudder designed for mega container vessel, authors calculated the lift, drag, and the steering torque coefficient by CFD in the model scale and these values were compared. As a result, regardless of the presence or absence of the bulb, signs of separation appear on the control surface at 20 deg. and separation regions could be confirmed at 30 deg. However it was found that Ultimate Rudder does not suddenly decrease the lift coefficient even after stalling, but conversely increases slightly. This is thought to be the effect of lift and drag on the bulb body.

Regarding the steering torque coefficient, it was found that the steering torque coefficient of Ultimate Rudder is larger than the normal Rudder when the steering angle is less than 20 deg. The steering torque generating direction is different but the values are almost same when the steering angle is 30 deg. Moreover, it was confirmed that the clearance of the propeller cap and the bulb was expanded from 2.5 mm to 20 mm, the steering torque coefficient became smaller. In other words, it can be said that the steering torque coefficient can be decreased by changing the shape of the rudder bulb.

REFERENCES

[1] K. Katayama et.al. : Optimization of the Propeller with ECO-Cap by CFD, SMP’15, 2015.
[2] M. Okazaki et.al. : Scale Effect Analysis of ECO-Cap by CFD, NuTTS2015, 2015.
[3] Y. Okada et.al. : The development of “Ultimate Rudder” for EEDI, MARINE2015, 2015.
[4] A. Fujii et.al. : Mitsui Integrated Propeller Boss (MIPB), ISME Yokohama’95, 1995.
[5] Claus D. Simonsen, Christian Klimt Nielsen :CFD based estimation of potential power saving for ships with fuel saving rudder-propeller device, www.dcmt.dk.