Evaluation of water flushing effect on icebreaking operation of "Shirase" by analysis of Japanese Antarctic Research Expedition voyage data

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Lützow-Holm Bay is sometimes coverd with very thick multiyear landfast ice. The Japanese Antarctic research icebreaker "Shirase II" has to break these thick ice to reach the Syowa Station. Shirase has a water flushing system in order to improve icebreaking performance.The aim of water flushing system is to decrease the frectional resistance between ship hull and dry snow. Table 1 shows the friction coefficients between steel, sea ice, and snow(Yamauchi et. al., 2011; Yamauchi, 2013). It has been shown that frectional resistance can be reduced by watering from ship bow in ice tank model test. It is not necessarily clear, however, that the same fact can be said for a full-scale ship in actual ice conditions.

Table 1 friction coefficients between steel, sea ice, and snow

Sea ice	Dry snow	Wet snow
0.04~0.06	0.21~0.28	0.09~0.22

In this study, we analyze the data of actual icebreaking voyage of Shirase in Japanese Antarctic Research Expedition 60th (JARE60) and compare ship resistance in continuous icebreaking mode with and without watering.

Shirase's navigation data is recorded using a ship-monitoring system (SMS) that records basic navigation data such as ship ship speed, propeller shaft thrust, ship motions and GPS locations. We estimated the icebreaking resistance in continuous icebreaking by the following formula:

$$R_{total} = (T_r + T_l)(1 - t_p) - Ma \times 10^{-3}$$

The R_{total} is estimated icebreaking resistance. T_r and T_l are right and left shaft thrusts. a is acceleration of the ship. M is mass of Shirase, 17760×10^3 [kg]. Figure 1 shows ship speed, thrust, and icebreaking resistance of Shirase in one sequence of continuous icebreaking. 23 sequences of continuous icebraking were conducted in JARE60 icebreaking test. We calculated average icebraking resistance 0 to 30 seconds before starting watering and 10 to 30 seconds after starting watering. Figure 2 shows the defference of average resistance in each sequence. We compare the average resistance before-watering with after-watering in all sequences, and it is shown that icebreaking resistance decreases about 3.7% by watering. Table 2 shows average of icebreaking resistance with and without water flushing. Calculation of the t-test confirms that the defference of resistance is significant.

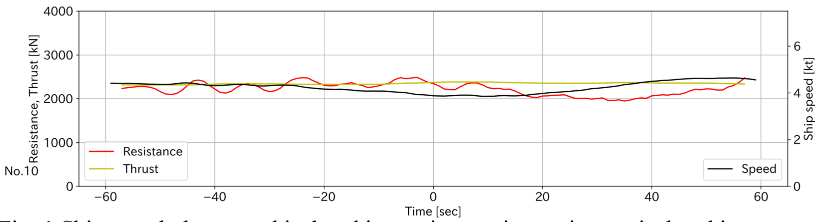

Fig. 1 Ship speed, thrust, and icebreaking resistance in continuous icebreaking

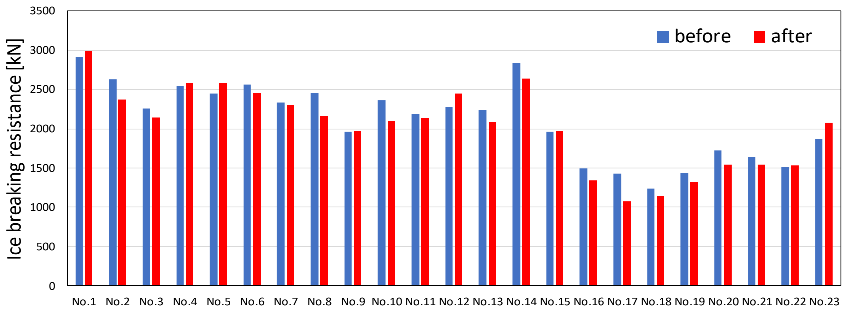

Fig. 2 Comparison of icebreaking resistance between with and without water flushing

Table 2 Average of icebreaking resistance with and without water flushing

Resistance before watering [kN]	Resistance after watering[kN]	Difference [kN]	Rate of change [%]
2102.48	2023.12	-78.36	-3.7

References

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