DYNAMIC POSITIONING CONFERENCE
October 13-14, 2015

THRUSTERS

Steerable Nozzle for DP Operation

By Henning Steffen

Becker Marine Systems

Introduction

The correct main propulsion system for DP operating vessels is essential to fulfil the high requirements for DP operation. Vessels today are equipped with wide variety of propulsion systems such as azimuth drives, propeller-rudders drives or conventional shaft arrangement.

The well-known combination of a CPP propeller in a nozzle in combination with a high lift rudder provides excellent vessel operation and has very good performance in bollard pull, response time, and cruise behaviour. Nevertheless, to fulfil the redundancy requirement for DP2, this system still requires 2 aft tunnel thrusters to get system approval. The side force which can be produced by high lift rudder in this configuration is limited to a certain point and is not sufficient to adequately keep the vessel in position.

The newly developed Becker Steerable Nozzle (BSN) showed excellent performance during the development in CFD and model tests. In comparison to a high lift flap rudder, the BSN is able to produce the same side force with only half the engine power on the propeller. These results raised the questions whether it is possible to fulfil the high requirements from DP2 with only 1 aft tunnel thruster when using the Becker Steerable Nozzle. To prove this assumption a complete DP2 study at HSVA[1] was performed with a PSV design from a Singapore ship designer.

The Becker Steerable Nozzle

The idea of the BSN is not new. In the 1970s and 80s the Becker Kort-Nozzle was a well-known rudder concept for tug boats and fishing vessels. The product combines the propeller nozzle with the rudder and at the trailing edge of the nozzle is either a moveable flap or a fixed fin to improve the manoeuvrability. The nozzle itself will be turned around the propeller (± 35°) and acts like a rudder. Figure 1 shows this design of a Kort-Nozzle application on a small fishing vessel.

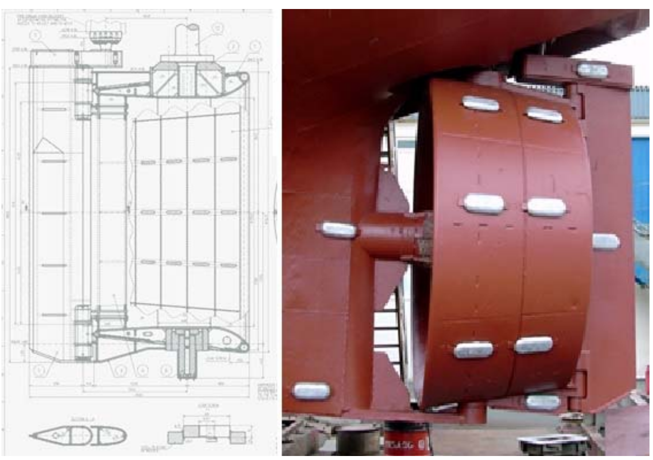

Figure 1 Kort-Nozzle with heel pintle bearing (Becker 2015)

This old design of the Kort-Nozzle incorporated a heel pintle bearing[2] which made the product uninteresting for twin screw applications and also caused difficulties for the integration in the hull structure. A full spade design was available as well but due to the high bearing loads, the moveable flap was replaced by a fixed fin to reduce the rudder forces and consequentially the bearing loads.

[1] Hamburgische Schiffbau-Versuchsanstalt
[2] Third bearing at the bottom of the nozzle

Becker's idea was to develop a new design without the heel pintle bearing and with a movable flap to be able to use the BSN for twin screw application without the drawback from the fixed fin. In this new design the bollard pull performance of the nozzle should be improved by a new nozzle profile which should be specially designed for a nozzle which is turned around the propeller. In this regard the SVA[3] in Potsdam was contracted to develop the new nozzle profile whilst Becker took care of the new bearing design.

The new nozzle profile from SVA shows a significantly improvement in bollard pull and the profile has a special inner shape in the way of the propeller tip see Figure 4.

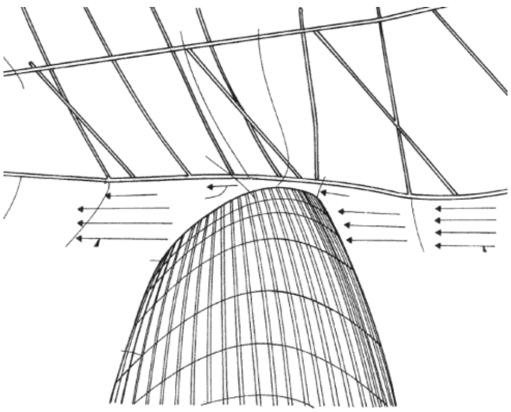

Figure 2 Inner nozzle shape of new profile (Becker 2015)

This spherical shape provides a constant gap between the propeller tip and inner nozzle profile at rudder angle of ± 8. Without the special shape, the tip clearance would increase significantly and the bollard pull performance would decrease. With this shape the BSN provides a constant bollard pull at smaller rudder angles which improves towing operations. The overall bollard pull performance was increased by approximately 8% in comparison to the former 19A nozzle profile (see Figure 3).

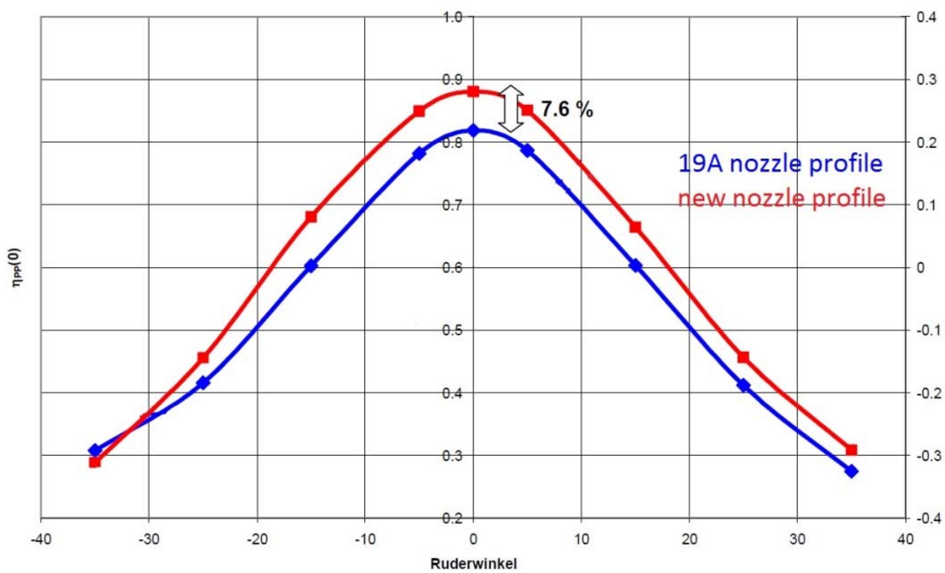

Figure 3: Bollard pull comparison of nozzle profiles (SVA / Schulz 2012)

[3] Schiffbau-Versuchsanstalt Potsdam

After profile optimization, a new bearing design followed which allows the BSN to be fitted without a heel pintle bearing and makes the product more attractive for all twin screw working boats. A special rudder stock pipe with a large diameter was developed to reduce the high loads on the bearing and to eliminate the pintle bearing. The large diameter also reduced the risk of vibration generated by the overlapping natural frequencies from the nozzle body and the propeller. For the flap bearing, a special synthetic material was used called HP-super[4]. This material provides excellent reliability and wear and tear resistance. After finding a suitable reference project the new BSN design was modelled in SolidWorks[5] and a FEM[6] study was conducted to prove the strength and reliability of the new full spade design as shown in Figure 4.

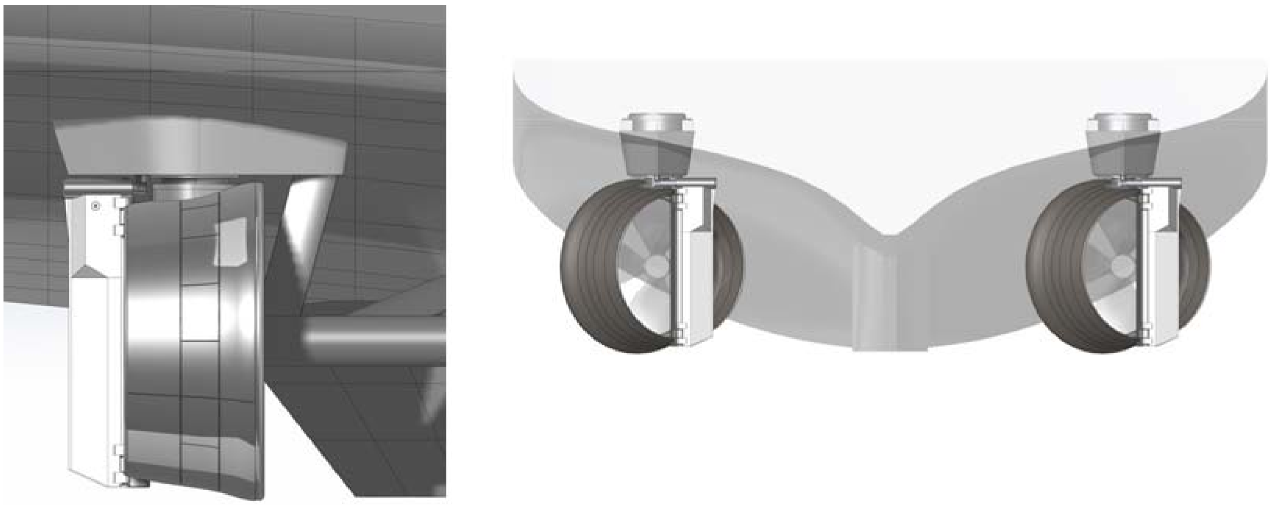

Figure 4 New BSN design (Becker 2015)

The strength calculation did not reveal any areas of concern and validated the new design's reliability and durability. The new system can be used on all kind of twin- and single screw vessels, such as AHTS, Tug Boat and fishing vessels. The improved nozzle profile and the moveable flap are included to provide excellent manoeuvrability and bollard pull performance.

CFD Calculation

After the completing the profile optimization and design of the new nozzle arrangement, a series of CFD[7] calculations were executed to show the advantage of the BSN against a standard flap rudder arrangement. The focus was on the station keeping performance in bollard pull condition, which is similar to a DP operation.

A comparison of the relation between propeller thrust rudder side forces is shown in Figure 5 and it clearly shows a substantial potential for improved station keeping performance with BSN.

[4] HP-Super is bearing material developed by Becker Marine Systems
[5] 3D Computer Aided Design (CAD) program
[6] Finite Element Method
[7] Computational Fluid Dynamics

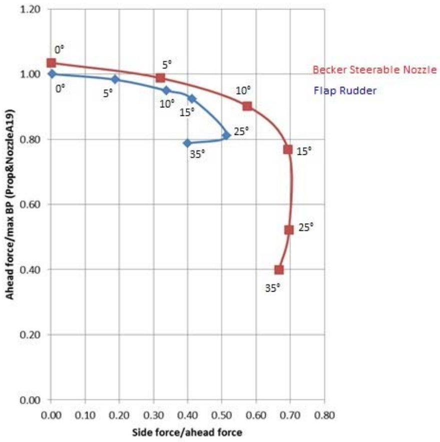

Figure 5 comparison of side forces from BSN and flap rudder (Becker 2015)

To improve the station keeping performance even more, the idea was to be able to delete or reduce the stern thruster in the aft ship and use the side force from the BSN for side movement. Unfortunately, the DP 2 rules require 2 aft thrusters for redundancy. To prove the CFD results and to show that a vessel is able to perform DP 2 operations with only one aft thruster when using the BSN, a model test in a towing tank was necessary. Fortunately a PSV hull design from a Singaporean ship designer was available at HSVA and it was permitted by ship designer to use the existing ship model for the tests.

The Model Test

The model tests at HSVA included station keeping analysis and propulsion test comparing the Becker Steerable Nozzle with a conventional flap rudder. For both propulsion systems two 2800 mm CPP propeller models were used. The main particulars from the vessel are shown in Table 1

Length between perpendiculars	64.70 m
Breadth, moulded	21.00 m
Draught, aft	5.2 m
Draught, mean	5.2 m
Draught, fore	5.2 m
Displacement, moulded	5595.2 m^3
Block coefficient	0.7919
Centre of buoyancy from AP	31.276

Table 1 Main vessel dimensions (HSVA / Dr. Ing. Henning Weede 2015)

A propulsion test which compared the flap rudder, BSN and azimuth drives was performed as well. The results from the azimuth drive were available from the original tests for this particular hull design.

Although the BSN is designed for high bollard pull and not optimized for propulsion efficiency, the test showed no disadvantage for the BSN compared to the other propulsion concepts (see Figure 6) in this area. The BSN and the flap rudder are in the same range whilst the azimuth drive needs considerably more power compared to the traditional shaft arrangement units.

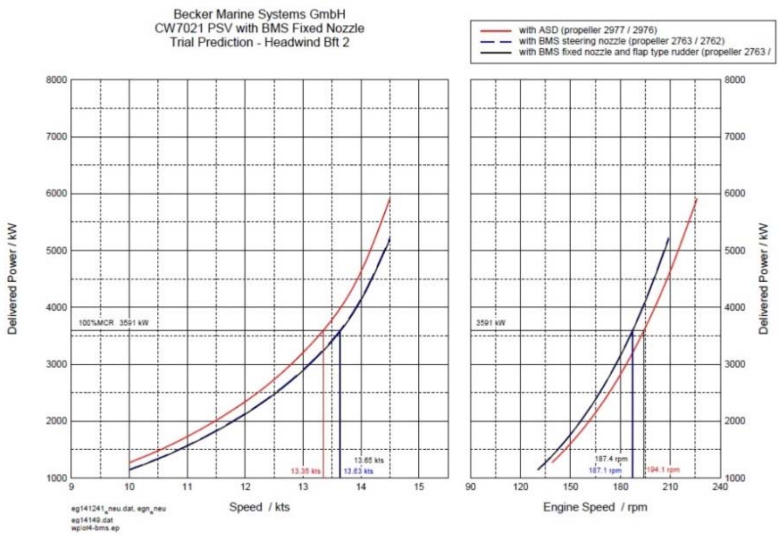

Figure 6 Power Comparison (HSVA / Jan Lassen 2015)

After finishing the propulsion test the ship model was prepared for the upcoming DP test see Figure 7.

Figure 7 Becker Steerable Nozzle model and flap rudder at ship hull

Both systems (BSN and flap rudder) were tested and HSVA investigated if it's possible to maintain position with only one aft thruster with the following boundary conditions (HSVA / Dr. Ing. Henning Weede 2015):

- Installed power for each propeller (100% MCR) 1000 kW
- 15 m/s wind speed
- 2m wave height
- 1m/s current
- 1400 kW on each bow tunnel thruster
- 400 kW on the stern tunnel thruster

The results showed that the flap rudder arrangement was not able to maintain position without a second thruster. In Figure 8 you can see the different propulsion units and the corresponding power requirements in kW for each failure mode:

- Intact mode
- Stb. propeller failed
- Stern tunnel thruster failed
- Fwd. bow tunnel thruster failed

	port propeller	starboard propeller	stern tunnel thruster	each bow tunnel thruster
intact	96	96	376	85
stb. propeller failed	249	-	389	87
stern tunnel thruster failed	1000	1000	-	120
forward bow tunnel thruster failed	96	96	366	249

Figure 8 Results for flap rudder in DP operation (HSVA / Dr. Ing. Henning Weede 2015)

In the failure mode "stern thruster failed" it can be seen that both propeller / rudder need 1000 kW on each propeller to maintain position. Since the boundary conditions were set with 1000 kW for each propeller it can be anticipated that the required engine power is higher than 1000 kW since the calculation didn't consider higher engine loads as mentioned in the boundary conditions. This failure mode shows that the main propulsion units with flap rudder cannot produce enough forces to fulfil the DP 2 requirements. In the intact mode the complete system – both propeller / rudder, 1 stern thruster and 2 bow thruster- needed roughly 740 kW.

The results for the BSN were much better and the arrangement proved that it's possible to maintain position without an aft tunnel thruster under given boundary conditions (see Figure 9).

	port Becker nozzle	starboard Becker nozzle	aft tunnel thruster	each bow tunnel thruster
intact	117 kW	104 kW	232 kW	85 kW
Stb. Becker nozzle failed	251 kW	-	270 kW	88 kW
aft tunnel thruster failed	497 kW	508 kW	-	100 kW
forward bow tunnel thruster failed	104 kW	104 kW	224 kW	250 kW

Figure 9 Results for BSN in DP operation (HSVA / Dr. Ing. Henning Weede 2015)

In the important failure mode, each propeller with BSN needed approximately 500 kW to produce the required side forces. This is around half of the available propeller power which confirms that even with slightly tougher environmental conditions the BSN is still able to fulfill the DP 2 requirements. When comparing the overall needed power for the intact mode it can be seen that the BSN station keeping operation needs 120 kW less engine power to maintain position (740kW for the rudder arrangement vs. 620 kW for the BSN arrangement). This leads to less fuel consumption for the same operation in the same environmental conditions.
Taking all the investigations and model test into account you can sum up the advantages of the BSN compared to flap rudder arrangement as follows:

- Reduced space needed
- simplifies the aft ship arrangement and construction,
- Fewer stern thrusters or less stern thruster power required for station keeping
- More powerful aft ship for manoeuvring

- Max. -/+35deg steering gear required only
- Improved overall manoeuvrability
- Improved DP-performance at zero speed
- Increased bollard pull

The vessels types which would benefit from this system would be all boats which tow and push something such as AHTS, Seismic Vessel, Fishing Vessel and Tug Boats. But due to the remarkable station keeping performance the BSN is also interesting for vessels which are not necessarily equipped with a propeller nozzle. Platform supply vessels for example are often equipped with a conventional shafting arrangement and open propeller, but due to their operation profile and the low bollard pull requirements they don't need a propeller nozzle. But when using the BSN, these vessels would be able to maneuver more precisely, keep position more efficient and the safety for crew and vessel will be increased.

Conclusion

The model tests and CFD investigations showed the potential for Becker Steerable Nozzle for DP operating vessels. The performance of such vessels can be improved by the addition of the BSN and either reducing the number of tunnel thrusters in the aft ship or reducing the engine power for the aft tunnel thrusters and meanwhile keeping the same DP notation. The Becker Steerable Nozzle provides increased DP performance compared to a flap rudder arrangement which is not only important in regard to operational efficiency, but also with regard to safety. A more powerful aft ship provides safer maneuvering in tough weather conditions and can protect the crew and the vessel against dangerous situations.

References

HSVA/ Jan Lassen 2015:	Model test report report WP 151/14
HSVA / Dr. Ing. Henning Weede 2015:	Model test report report MAN 331/14
Becker 2015:	Becker Nozzle Presentation Becker Marine Systems 2015, Hamburg
SVA / Schulz 2012	Model test report 3814.1