Model tests with and without Mewis Duct® at BSHC and other towing tanks

by

Friedrich Mewis, MSH, Mewis Ship Hydrodynamics, Dresden, Germany
Olaf Zimmermann, OZMARE, Olaf Zimmermann Maritime Engineering, Hamburg, Germany

Abstract

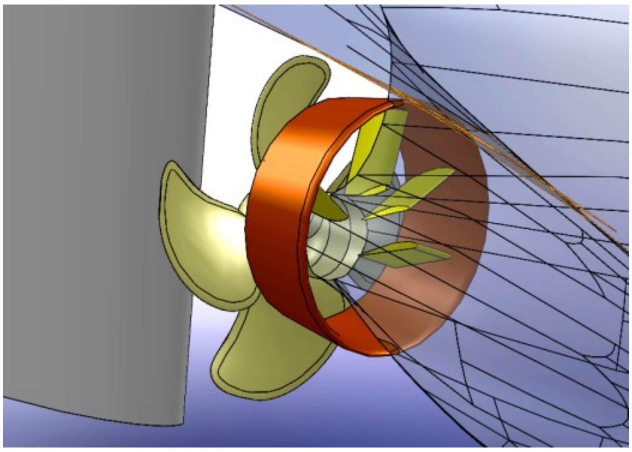
Since its introduction in 2008, the Mewis Duct® (MD), a hydrodynamic Energy-Saving Device (ESD) for full form vessels, has experienced extraordinary success. To date about 900 have been delivered, with about 1100 on order.
Many model tests for the Mewis Duct® have shown an average power saving of 6.3 per cent. Measurements at full scale confirm the power savings measured at model scale. The design of the MD is largely based on CFD-methods with model tests remaining a core element of the overall process. Becker Marine Systems (BMS), Hamburg, guarantees the power reduction with the certification from model tests; no cure – no pay.
Until now more than 200 MD projects have been designed and then model-tested at 13 different towing tanks worldwide. With 38 test series carried at BSHC in Varna, the Bulgarian Ship Hydrodynamics Centre is in this matter one of the most frequented towing tanks and one of the tanks with the most stable results.
The Mewis Duct® has been developed in co-operation with Becker Marine Systems, Hamburg, who also exclusively market and sell the product.

Introduction

Hydrodynamic Energy-Saving Devices are stationary flow-directing devices positioned near the propeller. These can be positioned either ahead of the propeller fixed to the ship's hull, or behind, fixed either to the rudder or the propeller itself.
Energy-Saving Devices that improve propulsion efficiency have been in use for over 100 years, for example in 1927 Wagner [1] details 25 years of experience with the Contra-Propeller Principle.

Some well-known devices for reducing wake losses include the WED (Wake Equalising Duct), see Schneekluth, 1986 [2] and the SILD (Sumitomo Integrated Lammeren Duct) as detailed by Sasaki and Aono in1997 [3]. These devices are based on an original idea of Van Lammeren in 1949 [4].

It is clear that there exist many ESDs on the market, each with extensive in-service and model testing experience. It would therefore appear impossible to develop an absolutely new solution to the problem. However by combining two or more components of already established principles new developments are possible. This approach offers even more possibilities by targeting a combination of different types of flow losses.



The Mewis Duct®, described for the first time by Mewis in 2008 [5] is such a combination, which is based on two fully independent working ESD-principles:

- The Contra-Rotating Propeller Principle, well known for more than 100 years, see [1]

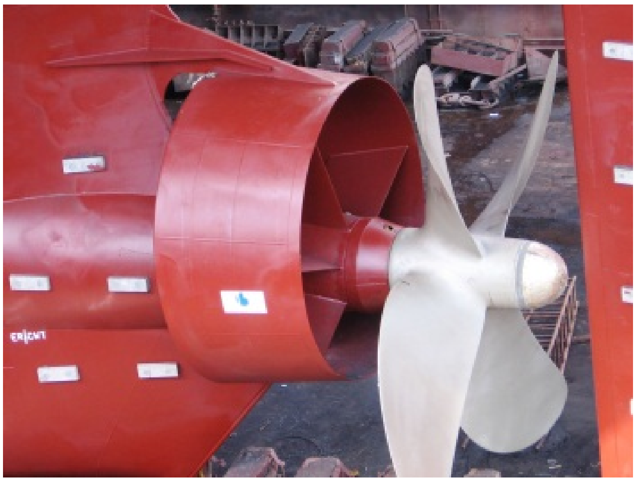
and

- The Pre Duct Principle first published in 1949 by Van Lammeren [4].

Figure 1 The Mewis Duct® arranged at the ship's aft body

More detailed description of the development of the Mewis Duct® are published by the author and others in 2009 [6], 2011 [7], 2013 [8] and 2014 [9].

The Mewis Duct®



The Mewis Duct® is suited for full-form slower ships like tankers and bulker carriers. It allows either a significant fuel saving at given speed or alternatively for the vessel to travel faster for a given power level. The MD consists of two hydrodynamic effective components, the nozzle (duct), positioned ahead the propeller with an integrated asymmetric fin system located inside the nozzle, see Figure 1 and 2. The MD has no moving parts and it is constructed very simply, for both structural and cost reasons.

Figure 2 First installed full scale Mewis Duct®, STAR ISTIND, 54,000 DWT MPC, 2009

The design goal of the MD in comparison with other ESDs is to improve two fully independent loss sources, namely:

- Losses in the ship's wake via the duct
- Rotational losses in the slipstream via the fins

The key advantage of the Mewis Duct® is to improve three components of the propeller flow:

- Equalisation of the propeller inflow by positioning the duct ahead of the propeller. The duct axis is positioned vertically above the propeller shaft axis, with the duct diameter smaller than the propeller diameter.
- Reduction of rotational losses in the slipstream by integrating an asymmetrical pre-swirl fin system within the duct. The chord length of the fin profiles is smaller than the duct chord length, with the fins positioned towards the aft end of the duct.
- An additional small improvement of the propulsion efficiency is obtained from higher inflow speed generated at the inner radii of the propeller which leads to a reduction of the propeller hub vortex losses.

In addition, the installation of the MD leads to small positive effects with propeller cavitation, yaw stability and rpm-stability in a seaway.

The realistic overall possible power reduction lies between 3 % and 8 %, see also Table 1 and Figures 4 and 5.

Table 1 Mewis Duct®, possible power reductions by their components

Possible power reductions by MD-components		
Component	Dependency	**Possible power reduction %**
Pre duct	on the wake field	**1 to 6**
Fin system	less	**2 to 4**
Hub vortex	less	**0 to 1**
Possible power reduction, total		**3 to 11**
Realistic possible power reduction, total		**3 to 8**

The Mewis Duct® has now been on the market for almost 8 years and has developed into a very successful product, see Figure 3.

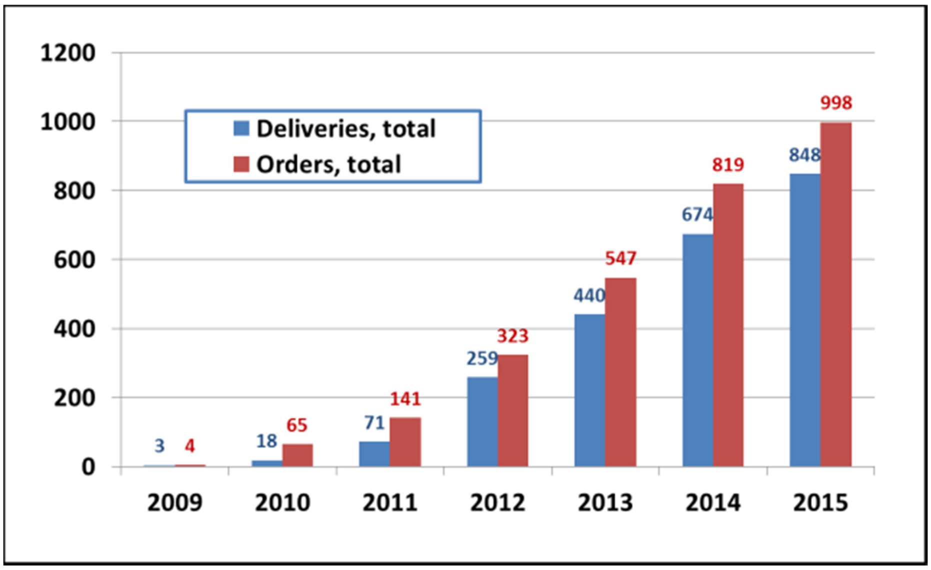


Figure 3 Mewis Duct®, orders and deliveries since 2009

Five key reasons are responsible for this success:

- The oil price has been relatively stable at a high level for 6 years (2008 to 2014)
- The achieved power reduction is stable and high for different draughts and independent of the ship's speed.
- The return on investment is about two years with the today's oil prices.
- The MD can be retrofitted easily because the rpm-reduction by the MD tends to be in the region of just 1 %.
- The MD is simple and robust.

Model tests and full-scale measurements with and without Mewis Duct®

The hydrodynamic design and optimisation of Energy-Saving Devices is in general based on four tools:

- Basic design based on human experience
- Optimisation by CFD-methods
- Checking and optimisation of the ESD-behaviour by model tests
- Checking the ESD-effect via full scale measurements and observations

Model tests for estimation of the power demand or alternatively the ship's achievable speed with the available installed power, estimation of manoeuvring behaviour and checking of cavitation performance are generally accepted methods for examination of the most important hydrodynamic characteristics at an early design stage of the vessel. They allow assessment of the vessel's hydrodynamic characteristics before the ship is built, and also optimisation of ship lines and propulsion system at relatively little cost.

Therefore model tests offer a very well-suited method to estimate differences between the model fitted with and without a hydrodynamic Energy-Saving Device such as the Mewis Duct®. Such tests, however, require a very high level of measurement accuracy.

Since it is in general assumed that the measured model-scale results correspond to the full scale case, model tests play an important role in the development and optimisation of Energy Saving Devices and in the ship design process in general.

Full-scale measurements are not possible before the ship manufacture is however there is a need for results from full-scale measurements for the calibration of the CFD- and model test results. Three methods for comparison of full-scale measurements are typically used:

- The best method is to undertake trial trips without and with Mewis Duct® fitted on a newbuilding, directly one after the other. In such cases there should be only 3 to 5 days difference between both sets of measurements, the only uncertainties being the weather and sea conditions and the existing uncertainty of the measuring process itself.
- A second method is the comparison of long-time measurements (best: full docking periods) without and with MD fitted to the same ship. Such an approach is only possible for MD retrofit cases.

- If the Mewis Duct® is to be installed on several ships of a large ship series, and that series has a mix of "with" and "without" the MD fitted, there is a possibility to compare continuous power measurements To reach reliable results at least 3 identical ships each fitted with and without MD are required.

The comparison of one ship fitted with a MD with another ship without a MD can lead to incorrect conclusions; see Table 4 and the comment to this table.

After seven years with MDs in service, full-scale measurement results with and without Mewis Duct® for all three methods are available, with the main conclusion that they correspond in general with the model test results. Overall, it can be concluded that model tests results agree well with the measured full-scale data.

Self-propulsion tests with and without Mewis Duct®

The self-propulsion tests are the most frequently used model tests for MDs since the results can be used for optimisation of the Mewis Duct® design and for estimation of the achieved power reduction. At the time of writing more than 200 separate MD projects have been designed and tested by model tests at 13 different towing tanks worldwide. With 38 test series carried at BSHC in Varna, the Bulgarian Ship Hydrodynamics Centre is in this matter one of the most frequented towing tanks and one of the tanks with the most stable results.

Becker Marine Systems (BMS), Hamburg, guarantees the power reduction with the certification from model tests; no cure – no pay. It makes the model tests to a very important part of the contractual process.

The model tests serve mainly to determine the net power saving achieved with the respective Mewis Duct® design. Additionally, the model tests are used for the final optimisation of the fin pitch angles and as validation data for the CFD-calculations. Additional special tests with different duct shapes or self-propulsion and resistance tests with only the duct fitted reveal important information of the MD performance at model scale.

In order to ensure satisfactory performance of the Mewis Duct® at full scale, the final MD with the final optimised fin settings from the model tests is calculated in both full and model scale. If large differences are observed the fin settings are sometimes slightly adjusted to compensate.

For the most ESDs the achievable power reductions depend on the ship's speed and the propeller thrust coefficient C_{Th}:

$$C_{Th} = \frac{T}{\frac{1}{2}\rho \cdot V_A^2 \cdot D^2 \cdot \pi/4},$$

where ρ is the water density, V_A the advanced velocity, D the propeller diameter and T the propeller thrust.

The best possibilities for improvement occur where C_{Th} is high, it results mainly from too small propeller diameters and low speeds.

Figure 4 shows the results of self-propulsion tests for 81 projects (as at December 2012) with and without MD fitted from 10 different towing tanks around the world, plotted with respect to the thrust loading coefficient C_{Th}. The average power reduction is 6.3 %; in design draught 5.7 % and in ballast draught 7.3 %.

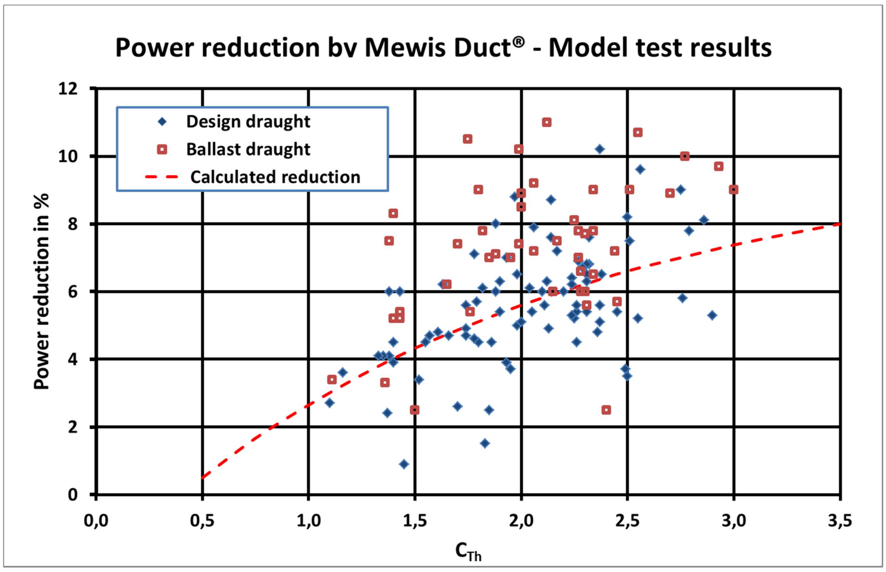


Figure 4 Power reductions by Mewis Duct®, model test results 2008 – 2012, average measured power reduction: 6.3 %

The dotted red line in Figure 4 and 5 represents the theoretical calculated possible power reduction of the Mewis Duct®. The real possibilities depends on more realistic conditions, such as the wake field of the ship (representing the ship's hull form), the propeller design, the quality of the MD design itself and the measuring accuracy of the towing tank.

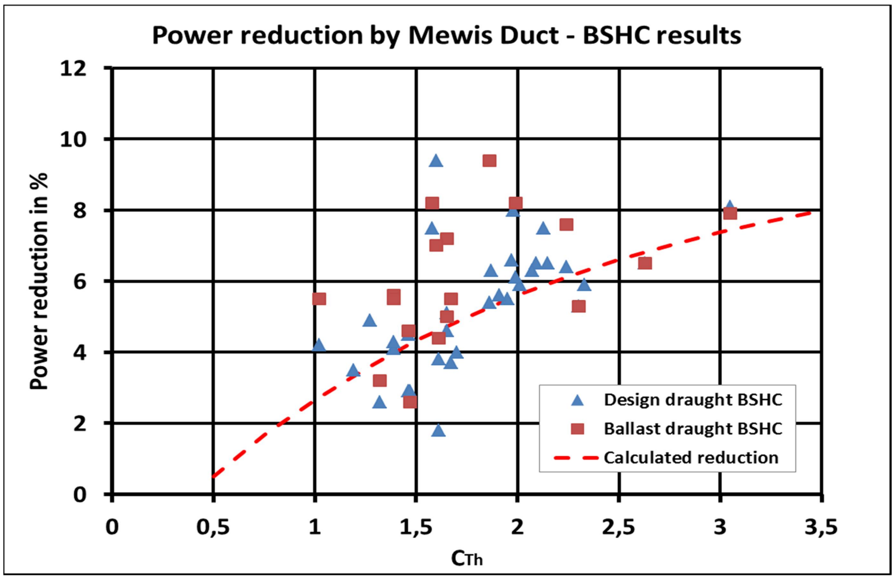


Figure 5 Power reductions by Mewis Duct®, model test results at BSHC, average measured power reduction: 5.6 %

Cavitation tests with and without Mewis Duct®

Model tests for estimation of the influence of Mewis Duct® on the cavitation behaviour and pressure pulse excitement have been carried for several different ship types at two different towing tanks (SSPA and HSVA). The test results are very similar.
Figures 6 and 7 show measured pressure pulses for a model of a 158,000 DWT bulk carrier both with and without MD. In this case the model tests were performed at HSVA with 15 pressure tapping holes in the model surface positioned directly above the propeller. The visual comparison of the graphs shows the significant decrease of the pressure pulses resulting from the MD. The first blade frequency is reduced by 15 %, the second by 68 % and all higher frequencies by more than 80 %. These measurements are in line with the full scale observations regarding lower vibration levels. Furthermore, it has been observed that propeller blade tip cavitation can be significantly reduced when the MD is fitted.

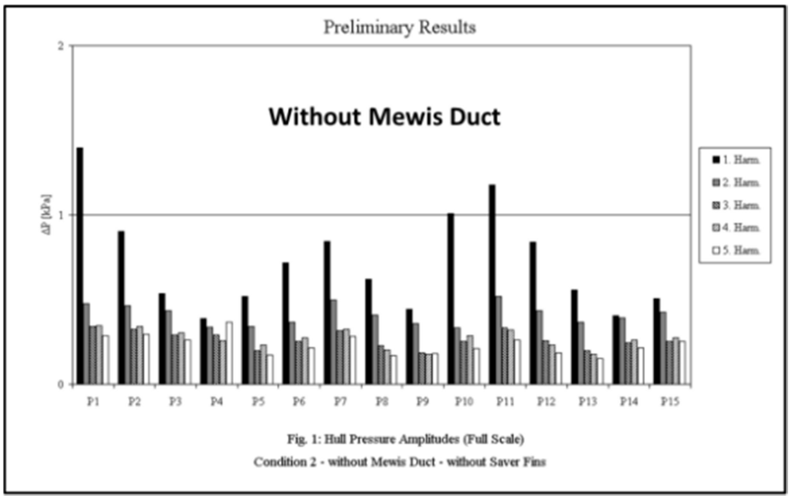


Figure 6 Measured pressure pulses above the propeller without Mewis Duct® 158,000 DWT Bulk Carrier, HSVA

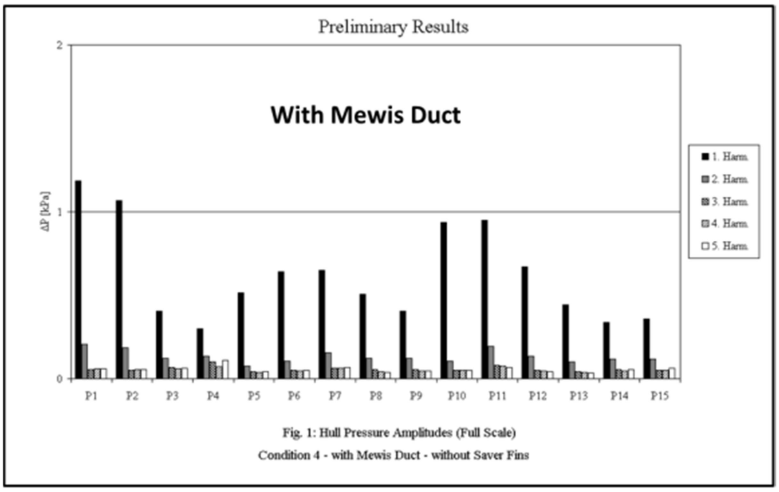


Figure 7 Measured pressure pulses above the propeller with Mewis Duct®, 158,000 DWT Bulk Carrier, HSVA

Manoeuvring tests with and without Mewis Duct®

Model tests with and without Mewis Duct® were carried out at SSPA for a 46,000 DWT tanker. The ship without MD is slightly unstable in yaw. In this case fitting a MD lead to a remarkable and unexpected improvement of the yaw stability. The first overshoot angle at the standardized Zig-Zag-Tests 10°/10° was reduced by 15 % and the second overshoot by 23 %, the tactical diameter increased by only 3 %. In this special case the IMO-criteria were fulfilled with the MD installed, see also Table 2.

Full scale results are available for a 163,000 DWT Bulk Carrier; the results are very similar to those at model scale.

Table 2 Zig-Zag-Tests 10°/10°, with and without Mewis Duct® in model and full scale

Zig-Zag-Tests 10°/10°	IMO - Criterion	w/o MD	with MD	with/without
Model tests	46,000 DWT Tanker, SSPA			
1st overshoot (°)	17,2	17,0	14,5	**-15%**
2nd overshoot (°)	31,8	40,6	31,4	**-23%**
Tactical diameter/Lpp	5,00	2,75	2,84	**3%**
Full scale trial	163,00 DWT Bulk Carrier			
1st overshoot (°)	20,0	10,5	9,0	**-14%**
2nd overshoot (°)	35,0	26,9	22,0	**-18%**

Mewis Duct® in combination with other ESDs

For customers it is often of interest to know how the Mewis Duct® performs in combination with other Energy-Saving Devices, whether there is installed another ESD at the ship or the ship owner plans to install it at a future date.

In spite of combining ESD's, flow losses can only be minimized once.

Of the entire MD model tests so far performed there are 7 in which the MD has been fitted in combination with other ESDs, the results of which are shown in table 6. The following main findings can be concluded from these results:

- The PBCF behind MD is working only partially.
- The Hybrid Fins (at rudder) behind the MD are working badly, without MD fitted they work well.
- Saver Fins forward of the MD tend to work well.
- The Rudder bulb behind the MD is working only partially.
- The Tandem Fins forward to the MD are working only partially.
- The twisted rudder behind the MD tends to work well.

It has to be taken into account that in a few cases the results depend on the order of the test series or the results are incomplete since not all possible variations were investigated.

Table 3 Model test results, Mewis Duct® in combination with other ESDs

Typ	Towing tank	Power reduction
MD + PBCF (Japan)		
80k BC	MARIN, Wageningen	
MD only PBCF only MD + PBCF	Source: Dang at all, 2011, [11]	**6.0%** **2.0%** **7.0%**
115k Tanker	SSPA, Gothenburg	
MD only MD + PBCF		**4.1%** **4.1%**
MD + Hybrid Fins, Fukudam, Japan		
61k BC	SRC, Tokyo	
MD only HF only MD + HF		**6.1%** **3.5%** **6.8%**
MD + Saver-Fin, Samsung, Korea		
158 k Tanker	HSVA, Hamburg, 2010	
Saver-Fins only MD only SF + MD		**1.6%** **2.1%** **3.8%**
158 k T. new MD design	HRBI, Zagreb, 2014	
all tests with Saver-Fins MD only (additional)		**4.7%**
MD + Sanoyas Tandem Fins, Japan		
89 k BC	SRC, Tokyo	
MD only MD + Rudder Bulb MD + RB + Sanoyas TF		**7.1%** **8.0%** **9.5%**
MD + Becker Twisted Rudder (TLKSR)		
110 k COT	SSPA, Gothenburg	
MD only		**7.0%**

MD + Tw. Rudder		**9.1%**

The tests MD + Saver Fins shows the development of the design quality from 2010 to 2014, while 2010 the MD shows a power reduction of 2.2 %, the new (2014) designed MD shows 4.7 % gain for the nearly identical ship with identical Saver Fins.

Full scale measurements, speed and power, with and without Mewis Duct®

A very important question is the confirmation that the Mewis Duct® works correctly at full scale. The CFD calculations show a small improvement in power reduction at full scale relative to the results at model scale. This is objectively based on the higher Reynolds Numbers at full scale, which leads to smaller inflow angles and reduced likelihood of flow separation.

During the last few years some high-quality full scale measurements have been made. They show that, in general, the projected full scale power savings extrapolated from the model scale measurements are valid. The problem here is more the inadequate accuracy of single full scale measurements. For that reason it is better to use measurements over a longer time period or with several sister vessels.

Table 4 Full scale trial measurements without and with Mewis Duct® fitted to an 118,000 DWT Bulk Carrier, courtesy of HSVA

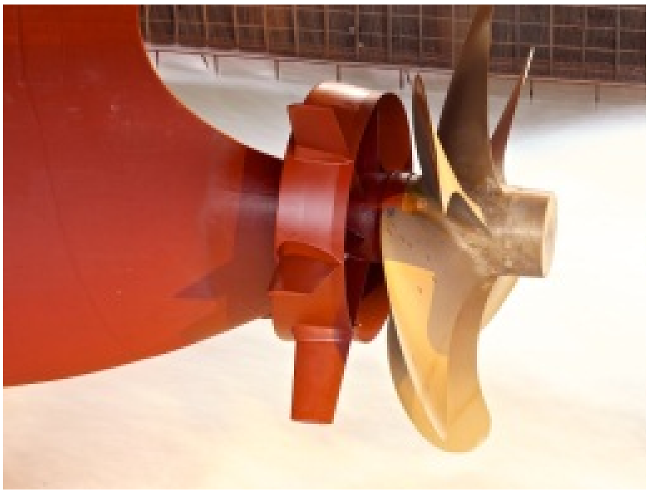
Trial speed		**HSVA - model test**	
Vessels w/o Mewis Duct®			
ship 1	15.38 kts		
ship 2	15.37 kts		
ship 3	15.12 kts		
		from model test	
Trial average:	**15.29 kts**	**predicted speed:**	**15.26 kts**
Vessels with Mewis Duct®			
ship 4	15.52 kts		
ship 5	15.44 kts		
ship 6	15.59 kts		
ship 7	15.56 kts		
ship 8	15.55 kts		
ship 9	15.54 kts		
ship 10	15.48 kts		
		from model test	
Trial average:	**15.53 kts**	**predicted speed:**	**15.48 kts**

The trial results for a number of sister ships with and without Mewis Duct®, see Table 4, show on average virtually identical results to the model tests, the measured speed gain is 0.24 kts at full scale and 0.22 kts in model scale, with 7.5 % achieved power reduction at full scale, and a measured 6.9 % at model scale. However, by comparing only two individual ships it can be concluded that the gain is very small (for example ship 1 with ship 5: ΔV=0.06 kts) or more than twice that of the model test results (ship 3 with ship 6: ΔV=0.47 kts).

These results clearly show the high levels of uncertainty and possible error when comparing individual vessels; instead any comparisons should ideally be made over as many ships and as long a time period as possible.

Mewis Duct® Twisted

The Mewis Duct® has proved to be very successful for large and slow speed ships like bulkers and tankers. The design principle, from both structural and cost reasons, is very simple, with straight and untwisted fins and a robust nozzle. All parts are fixed and immovable. For speeds higher 19 kts and C_{Th} -values lower 1.3 the power reduction is too low for economical use. For such cases the risk of cavitation is also increased. Instead, the Becker Mewis Duct® Twisted (BMDT), formerly known as Becker Twisted Fin® (BTF), see Figure 8, was developed for faster ships as container vessels.



Like the Mewis Duct®, the Becker Mewis Duct® Twisted has no movable parts, is also installed in front of the propeller and generates a pre-swirl. The nozzle ring is significantly smaller than that of the Mewis Duct® and has specially-developed thinner profiles which significantly reduced drag. The fins familiar from the MD on the inside of the nozzle ring extend outwards beyond the nozzle. The fins are both tapered and twisted with modifications to the free outer fin tips. By these measures the cavitation risk has been minimised.

Figure 8 First installed full scale Becker Mewis Duct® Twisted, MS SANTA CATARINA, 7090 TEU CV, December 2012

Computational Fluid Dynamics (CFD) calculations, model tests and full scale operation have shown fuel savings averaging about 3 % for container ships.

To date (July 2016) 53 Becker Mewis Duct® Twisted have been delivered with total 65 on order.

Summary

Since its introduction in 2008 the Mewis Duct® has proved worldwide to be one of the most successful hydrodynamic Energy-Saving Devices available. The main hydrodynamic effect of the Mewis Duct® is the reduction of two completely independent energy losses around the running

propeller behind the ship, namely the reduction of ship-based wake losses and also the reduction of propeller-based rotational losses in the slipstream.
The Mewis Duct® has been developed in co-operation with Becker Marine Systems, Hamburg, who also exclusively market and sell the product. To date about 900 have been delivered, with about 1100 on order. Overall, model tests for the Mewis Duct® have shown average achieved power savings of 6 %. Measurements at full scale confirm these model scale results. The Mewis Duct® has a small positive effect on both the cavitation behaviour of the propeller and the yaw stability of the ship.
The design of the Mewis Duct® is largely based on CFD-methods with model testing remaining a core element of the overall process.
The present paper shows further model test results of projects with Mewis Duct® in combination with other ESDs.
The Becker Mewis Duct® Twisted, a development of the Mewis Duct® for faster ships such as container vessels has recently been successfully introduced, to date 53 BMDTs have been delivered with total 65 on order.

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After nearly 8 years of very successful collaboration with my colleagues from Becker Marine Systems (BMS) in Hamburg and IBMV in Rostock I would like to express my thanks to all colleagues who have been involved in the development, optimisation, marketing and realisation of the "Mewis Duct" project.
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Also special thanks go to my colleagues at IBMV Rostock, Steve Leonard, head of the R&D at IBMV, and Thomas Guiard who has been responsible for the MD design and optimisation for over four years.

References

[1] Wagner, R. (1929). 'Rückblick und Ausblick auf die Entwicklung des Contrapropellers', Jahrbuch der Schiffbautechnischen Gesellschaft, 30. Band, pp. 195 – 256, Berlin, Germany.

[2] Schneekluth, H. (1986). 'Wake Equalising Ducts', The Naval Architect, London, UK.

[3] Sasaki, N., Aono, T. (1997). 'Energy Saving Device "SILD"', Journal of Shipbuilding Vol. 45, No. 135, Japan.

[4 Van Lammeren, W.P.A. (1949). 'Enkele Constructies ter Verbetering van het Rendement van de Voorstuwing', Ship en Werf van 1 April 1949 No.7, Rotterdam, the Netherlands.

[5] Mewis, F. (2008). 'Development of a novel power-saving device for full-form vessels', HANSA 145. Jahrgang, Hamburg November 2008.

[6] Mewis, F. (2009). 'A Novel Power-Saving Device for Full-Form Vessels', First International Symposium on Marine Propulsors, SMP'09, Trondheim, Norway.

[7] Mewis, F., Guiard, T. (2011). 'Mewis Duct® – New Developments, Solutions and Conclusions', Second International Symposium on Marine Propulsors, SMP'11, Hamburg, Germany.

[8] Guiard, T., Leonard, S., Mewis, F. (2013). 'The Becker Mewis Duct® – Challenges in Full-Scale Design and new Developments for Fast Ships', Third International Symposium on Marine Propulsors, SMP'13, Launceston, Australia.

[9] Mewis, F. (2014). "Six Years Mewis Duct® - Six Years of Hydrodynamic Development", Jahrbuch der Schiffbautechnischen Gesellschaft108. Band 2014, pp 157-164, Hamburg, Germany.

[10] Dyne, G. (1983). 'Ship propulsion improvement – principles and a survey of alternative propulsion systems', Eight WEGEMT School 'SHIP DESIGN AND FUEL ECONOMY', Gothenburg 1983.

[11] Dang, J., Chen, H., Dong, G., Ploeg, A., Hallmann, R. & Mauro, F. (2011). 'An Exploratory Study on the Working Principles of Energy Saving Devices (ESDs)', Proceedings of the Symposium on Green Ship Technology (Greenship'2011), Wuxi, China.