Schiffbautechnische Gesellschaft
Fachausschuß Schiffshydrodynamik
Sprechtag "Energy-Saving Devices"
Hamburg, den 9. Oktober 2014

Version 2014-10-27

Six Years Mewis Duct® - Six Years of Hydrodynamic Development

Friedrich Mewis
Mewis Ship Hydrodynamics (MSH), Dresden, Germany

Abstract

As a result of the extreme increase of the fuel prices within the last few decades, the need for energy efficiency in ship design and operation has been continuously increasing, particularly over the last ten years. Consequently there is a growing interest in hydrodynamic Energy-Saving Devices (ESDs) which aim to improve overall ship propulsive efficiency. The Mewis Duct® (MD) is such an ESD. The main effect of the Mewis Duct® is the reduction of energy losses around the running propeller behind the ship.
The Mewis Duct® is suited for full-block low-speed vessels such as tankers and bulker carriers.
Since its introduction in 2008, the Mewis Duct® power saving device has experienced extraordinary success. To date over 600 have been delivered, with about 800 on order.
Many model tests for the Mewis Duct® have shown an average power saving of 6.3 per cent. The design of the Mewis Duct® is largely based on CFD-methods with model tests remaining a core element of the overall process. Measurements at full scale confirm the power savings measured in model scale.
The Mewis Duct® has been developed in co-operation with Becker Marine Systems, Hamburg, who also exclusively market and sell the product.

Zusammenfassung

Im Ergebnis des extremen Anstieges der Treibstoffpreise in den letzten Jahrzehnten ist die Energie-Effizienz im Schiffsdesign und –betrieb wieder in den Mittelpunkt gerückt. So ist auch das Interesse an „Energy-Saving Devices (ESDs)“ gestiegen, durch welche Leistungseinsparungen beim Schiffsantrieb erzielt werden können. Die Mewis Duct® (MD) ist eine solche ESD. Der Haupteffekt der MD ist die Verringerung der Strömungsverluste um den am Schiff arbeitenden Propeller.
Die Mewis Duct® ist für völlige langsame Schiffe wie Tanker und Bulker geeignet.
Seit ihrer Einführung 2008 hat die MD einen außerordentlichen Erfolg erzielt. Zur Zeit (Sept. 2014) sind mehr als 600 ausgeliefert und etwa 800 bestellt.
Eine Vielzahl von Modellversuchen hat eine durchschnittliche Leistungseinsparung von 6,3 % ergeben. Der Entwurf der Mewis Duct® ist geprägt durch den Einsatz von modernsten CFD-Methoden mit Modellversuchen als Hauptelement der Validierung des gesamten Entwurfsprozesses. Messungen in der Großausführung bestätigen die Modellversuchs Ergebnisse weitgehend.
Die Mewis Duct® wurde in Zusammenarbeit mit Becker Marine Systems (BMS), Hamburg, entwickelt und wird ausschließlich von BMS verkauft.

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 (Wagner, 1929) 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) and the SILD (Sumitomo Integrated Lammeren Duct) as detailed in (Sasaki and Aono, 1997). These devices are based on an original idea of Van Lammeren (Van Lammeren, 1949).

It is clear that there exist many Energy-Saving Devices 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.

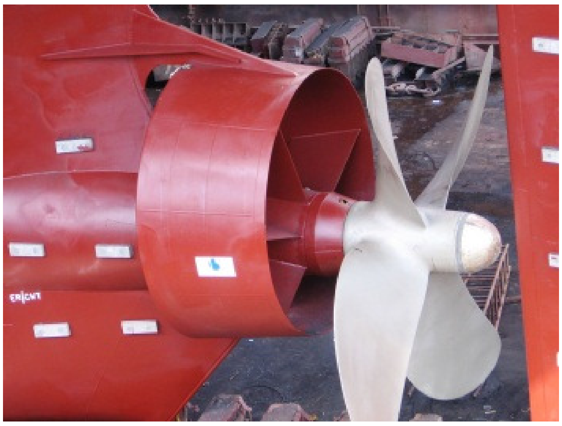

Figure 1 First installed full scale Mewis Duct®, STAR ISTIND, 54,000 DWT MPC, September 2009

The Mewis Duct®, described for the first time at STG (Mewis, 2009), 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 (Wagner, 1929) and
- The Pre Duct Principle first published in 1949 by Van Lammeren.

Loss analysis around working propeller

To understand the working principles of ESDs it is necessary to understand the losses around running propeller behind ship.

Dyne (1983) published a complete overview of these losses and of potential measures towards its minimization.

There are three areas of influential losses around the rotating propeller: the inflow, the propeller itself and the resulting slipstream (propeller race), see Figure 2.

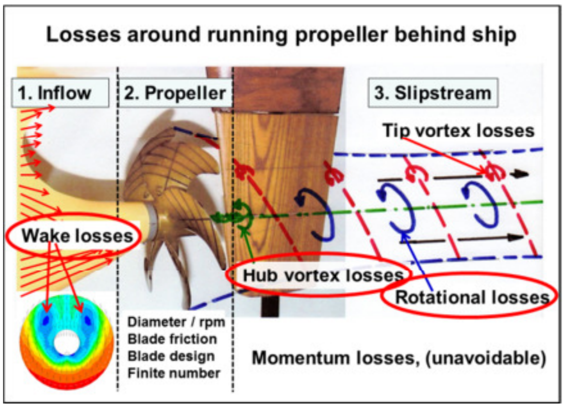

Figure 2 Losses associated with rotating propeller. Red denotes losses which are reduced by the Mewis Duct®

The following list gives an overview of improvable elements of the propeller flow and several possibilities for improving the propulsion efficiency, in other words improving the power saving.

1. Inflow
   - Ship's wake; can be improved by better ship lines
   - Unequalised inflow; can be improved by pre ducts, such as WED, SILD, MD
   - Pre-rotation; can reduce the rotational losses, can be produced by pre-swirl fins, such as SVA, PSS, MD

2. Propeller
   - Blade friction losses, can be improved with smaller blades, lower levels of surface roughness
   - Tip vortices; can be improved by fences at the blade tips, Kappel-Propeller, Gomez-Propeller
   - Rotational losses can be improved by better radial load distribution

- Hub vortex; can be reduced by PBCF, MD
- Contra-rotating propellers see 3. Slipstream

3. Slipstream

- Larger Propeller can reduce the momentum losses
- Rudder, twisted and untwisted, can reduce the rotational losses
- Rudder fins; can reduce the rotational losses
- Rudder bulb, can reduce the hub vortex losses
- Contra-Rotating Propellers and devices such as the Grim Vane Wheel can improve several losses in the slipstream

Table 1 shows an overview of the recoverable losses for an example of a large Bulk Carrier with a CTh-value of 2.3. All numbers are valid for a so-called optimum propeller and nearly optimum hull lines design.
With a well-designed Energy-Saving Device is it possible to avoid about 2/3 of the recoverable losses as stated in Table 1.

Table 1 Recoverable losses around working propeller, Large Bulk Carrier, CTh = 2.3

Losses around working propeller behind ship		
Example: Bulk Carrier, V=15 kts, CTh = 2.3		
Type of loss	recoverable losses %	Remark
frictional in the wake	0 to 10	depends very on hull lines
rotation in slipstream	5 to 7	less dependence
propeller tip vortex	1 to 3	depends on load distribution
propeller hub vortex	1 to 3	depends on load distribution and hub diameter

Energy-Saving Devices on the market

Table 2 gives an overview of the Energy-Saving Devices currently on the market. The stated power savings are valid for full-block ships such as tankers and bulk carriers with nearly optimum propellers and nearly optimum hull lines. If the power reductions of an ESD (in the last column) are higher than 2/3 of the recoverable losses according to Table 1, there is an additional improving effect by other unidentified sources.

Table 2 Possible power reductions of Energy-Saving Devices current on the market

Possible power reductions by differnt Energy Saving Devices							
No	Name	Company/ Inventor	Country	Typ of device	Location of device	Main sorces for improvement	power reduction %
One Component Devices							
1	SAVER-Fins	Samsung	Korea	forward pre-fins	far forward to propeller	using energy of ships wake	0 - 3
2	Tandem Fins	Sanoyas	Japan	forward pre-fins	far forward to propeller	using energy of ships wake	0 - 5
3	WED	Schneekluth	Germany	pre-duct	next forward to propeller	equilising of propeller inflow	0 - 4
4	SILD	Sumitomo	Japan	pre-duct	next forward to propeller	equilising of propeller inflow	1 - 6
5	SVA-Fin-System	SVA	Germany	pre-fins	next forward to propeller	reduction slipstream rotation	2 - 3
6	Pre-Swirl-System	DSME	Korea	pre-fins	next forward to propeller	reduction slipstream rotation	2 - 5
7	PBCF	Ochi	Japan	fins at propeller hub	aft end of the hub	reduction propeller hub vortex	1 - 3
8	Rudder Bulb	Costa	Swizerland	rudder bulb	rudder	reduction propeller hub vortex	0 - 3
9	Hybrid-fins	Fukudam	Japan	rudder-fins	rudder	reduction slipstream rotation reduction propeller hub vortex	2 - 4
10	Twisted rudder	BMS	Germany	rudder, leading edge twisted	rudder	reduction rudder resistance reduction slipstream rotation	0 - 2
Multi Component Devices							
11	ENERGOPAC	Wärtsilä	Finland	integrated rudder-propeller hub	propeller and rudder	reduction propeller hub vortex reduction propeller loading	2 - 6
12	PROMAS	Rolls Royce	Sweden	integrated rudder-propeller hub	propeller and rudder	reduction propeller hub vortex reduction propeller loading	2 - 6
13	CRP	Erikson	-	two contra rotating propellers	second propeller direct behind first propeller	reduction slipstream rotation reduction propeller loading	5 - 14
14	Grim Vane Wheel	Grim	Germany	additional vane turbine behind propeller	vane wheel direct behind propeller	reduction propeller loading reduction slipstream rotation	5 - 12
15	Mewis Duct®	BMS	Germany	pre-duct with integrated pre-fin system	next forward to propeller	equilising of propeller inflow reduction slipstream rotation reduction propeller hub vortex	3 - 8
Note: No 11, 12, 13, 14 are no real ESDs in the sens of extern devices, these are new rudders, propellers or combinations which has to be replaced							

For the most ESDs the achievable power reductions depend on the 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 relatively low speeds see also Figure 3.

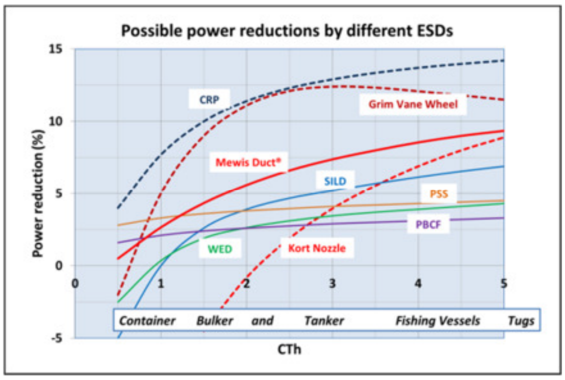

Figure 3 Possible power reductions by different ESDs, depending on the propeller loading

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 hydrodynamically effective components, the nozzle (duct), positioned ahead the propeller with an integrated asymmetric fin system located inside the nozzle, see Figure 4. The MD has no moving parts and it is constructed very simply, for both structural and cost reasons.

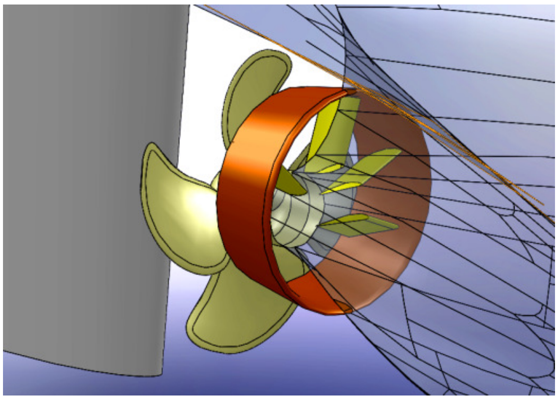

Figure 4 The Mewis Duct® arranged at the ship's aft body

The design goal of the Mewis Duct® 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 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 3 and Figure 7.

Table 3 Mewis Duct®, possible power reductions by the components

Possible power reductions by the 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 6 years and has developed into a very successful product, see Figure 5.

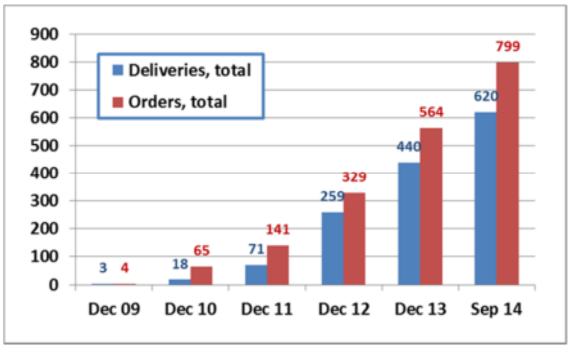

Figure 5 Mewis Duct®, Orders and deliveries since 2009

Five key reasons are responsible for this success:

- The oil price has been relatively stable at a high level for 4 years, see Figure 6.
- The achieved power reduction is stable and high for different draughts and independent of the ship’s speed.
- The return on investment is less than one year 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.

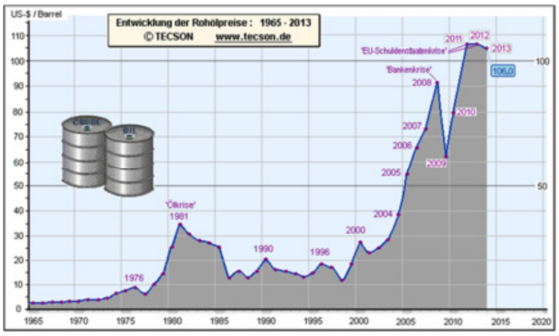

Figure 6 Oil price, yearly average, since 1965, source “www.tecson.de”, 2014

Some further reasons contributing to the successful development of the MD include:

- The company Becker Marine Systems (BMS), Hamburg is worldwide the best suited company for marketing ESDs.
- BMS guarantees the contracted power reduction with the certification from model tests, no cure no pay.
- The MD design and construction has been of a very high and stable level from the outset, due primarily to the careful use of personal and in-house experience as well as successful implementation of CFD-based design and optimisation methods
- The small company IBMV, Rostock, a daughter company of BMS, has reached a high level of hydrodynamic MD-design through a combination of in-house optimisation tools, use of leading commercial CFD solvers and continuing regression analysis of model test results

Figure 7 shows the results of self-propulsion tests for 81 projects (as at December 2012) with and without Mewis Duct® fitted from 10 different towing tanks around the world, plotted with respect to the thrust loading coefficient CTh. The average power reduction is 6.3 %; in design draught 5.7 % and in ballast draught 7.3 %.
At the time of writing (Sept. 2014) about 160 Mewis Duct® projects have been designed and tested by model tests. There is a clear improvement of the design quality over the years: the first 30 projects (2008 – 2011) shows an average gain at design draught of

5.7 % and the last 30 projects in 2014 shows an average gain of 6.3 % at design draught too.

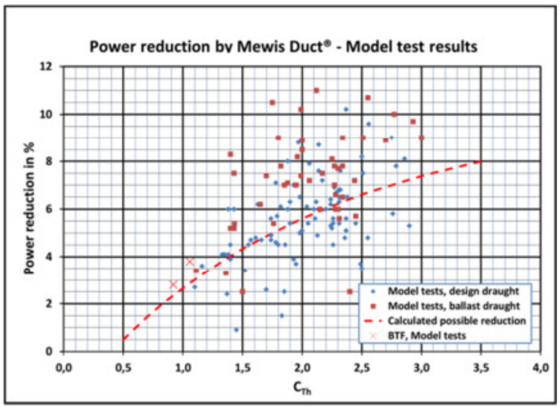

Figure 7 Power reductions by Mewis Duct®, model test results 2008 – 2012, average measured power reduction: 6.3 %

The dotted red line in Figure 7 represents the theoretical calculated possible power reduction of the Mewis Duct®. The real possibilities depend 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 Mewis Duct® design itself and the measuring accuracy of the towing tank.

Design, optimisation and development of the Mewis Duct®

For every new ship project to which the Mewis Duct® is applied, an individually designed and optimised Mewis Duct® is developed. This process is largely based on CFD-calculations in combination with model tests.
The objective of the optimisation is to adjust the MD to the particular hull shape and wake characteristics, and to select a MD design that provides the highest possible power saving for the considered vessel. CFD-tools are ideally suited for this type of work because almost every flow detail that helps in the decisions of the design process can be relatively easily extracted from the simulations in a consistent manner.
The CFD-calculations are performed by solving RANS equations on unstructured finite volume meshes. For the flow simulations the ship hull, rudder, propeller and MD are all modelled explicitly. Therefore, in order to design a Mewis Duct® for a given ship, it is necessary that geometry information for the ship's hull and propeller, as well as self-propulsion data and, if possible, the measured wake field for the contractually agreed design point, is made available.
Many questions to the design of the Mewis Duct®, such as number of fins, see Figure 8, profile type and pitch angles of duct and fins, the location of MD at the ship can be reliably answered by using the results of CFD-calculations.

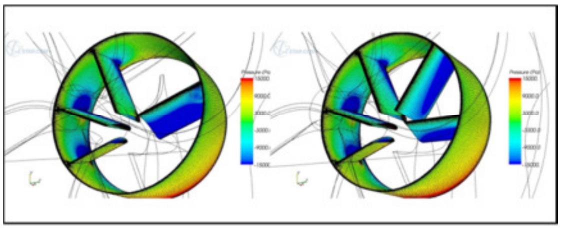

Figure 8 Mewis Duct®, example design with 4 and 5 fins, CFD-result, pressure distribution at the surface of all MD elements

Over the six years of development the general Mewis Duct® design itself has been evolved:

- The duct diameter has been increased (DD > 0.55*DP),
- The duct profiles are now shorter (LD < 0.5*DD),
- Nowadays 5 fins are used for most designs, principally for vibration reduction reasons.

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 the 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.

Becker Twisted Fin® (BTF)

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 CTh-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 Twisted Fin® (BTF), see Figure 9, was developed for faster ships as container vessels.

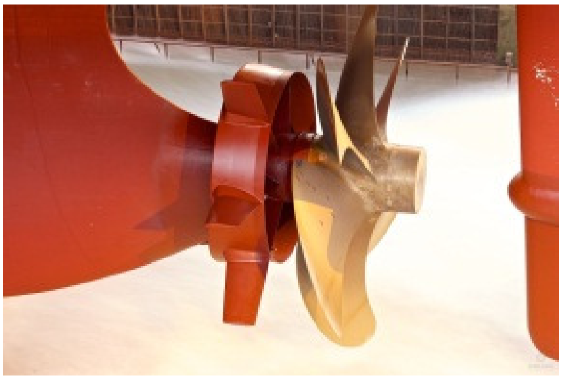

Figure 9 First installed full scale Becker Twisted Fin®, MS SANTA CATARINA, 7090 TEU CV, December 2012

Like the Mewis Duct®, the Becker Twisted Fin® 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 reduce 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.
Computational Fluid Dynamics (CFD) calculations, model tests and full scale operation have shown fuel savings averaging about 3% for container ships.

To date 19 BTFs have been delivered with another 36 on order.

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

Vessel w/o Mewis Duct®	**Trial speed**	**ship 1: 15.38 kts**
		ship 2: 15.37 kts
HSVA-model test		**ship 3: 15.12 kts**
predicted speed: 15.26 kts		**Trial average: 15.29 kts**
Vessel with Mewis Duct®	**Trial speed**	**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
HSVA-model tests		**ship 10: 15.48 kts**
predicted speed: 15.48 kts		**Trial average: 15.53 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.

Cavitation test results 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 two different ship types at two different towing tanks (SSPA and HSVA). The test results are very similar.
Figures 10 and 11 show measured pressure pulses for a model of a 158,000 DWT bulk carrier both with and without Mewis Duct®. 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.

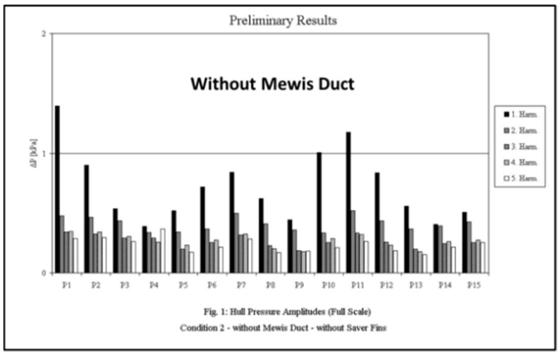

Figure 10 Measured pressure pulses above the propeller without Mewis Duct® 158,000 DWT Bulk Carrier, HSVA

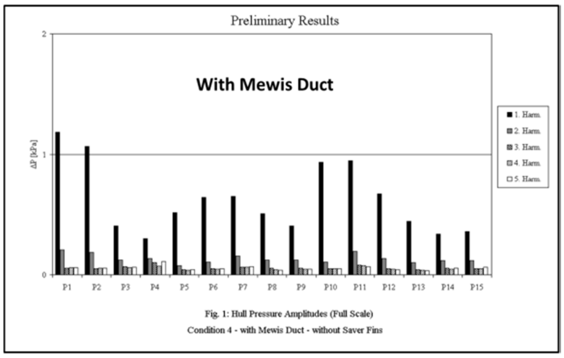

Figure 11 Measured pressure pulses above the propeller with Mewis Duct®, 158,000 DWT Bulk Carrier, HSVA

Manoeuvring test results 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 5.
Full scale results are available for a 163,000 DWT Bulk Carrier; the results are very similar to those at model scale.

Table 5 Zig-Zag-Tests 10°/10°, with and without Mewis Duct® in model and full scale

Zig-Zag-Test 10°/10°	IMO-Criterion	w/o MD	with MD	MD/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%
Tacticel 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 6 Model test results, Mewis Duct® in combination with other ESDs

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

Summary

Since its introduction, the Mewis Duct® has proved worldwide to be one of the most successful hydrodynamic Energy-Saving Devices of the last decade. The main hydrodynamic effect of the Mewis Duct® is the reduction of two complete independent energy losses around the running propeller behind the ship, namely the reduction of ship-based wake losses and also 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.
Since its launch in 2008, the Mewis Duct® energy saving device has experienced

extraordinary success. To date over 600 have been delivered, with about 800 on order. Overall, model tests for the Mewis Duct® have shown average achieved power savings of 6.3 %. 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 summarises the development of the MD-design over the last 6 years, and gives a comparison with other successful ESDs on the market. The design and optimisation philosophy behind the product has been explained. Model test results of projects with Mewis Duct® in combination with other ESDs have also been shown and discussed.
The Becker Twisted Fin®, a development of the Mewis Duct® for faster ships such as container vessels has recently been successfully introduced.

Acknowledgements

After six 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.
Special thanks go to the managing director of BMS, Mr Dirk Lehmann and Mr Frank Petersen, who was all time responsible for the "Mewis Duct" team.
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 three years.
It was a great pleasure for me to work after my retirement close together with so many young and enthusiastic naval architects.

References

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.

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

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

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

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.

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

Own publications to Mewis Duct® used for the present paper

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

Mewis, F. (2009). 'Leistungseinsparungen durch eine neuartige hydrodynamische Vordralldüse', Jahrbuch der Schiffbautechnischen Gesellschaft, 103. Band, pp. 421-431, Hamburg, Germany

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

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

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.