

NEW INLAND CONTAINER VESSELS FOR TRANSPORT TO THE HINTERLAND

by



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Large container vessel, propulsion, water depth, draught, ship's speed

MOTS-CLEFS

Grand porte-conteneurs, propulsion, mouillage, tirant d'eau, vitesse du bateau

1. INTRODUCTION

Present developments in the field of container transport on both inland and maritime waterways show that the rise in transport volume coincides with the increase in ship size. While within maritime shipping first of all port entrances and transshipment facilities have to be technically upgraded to cope with this increase in size, the situation for inland navigation is much more complicated. For fairways with restricted depth and width the interaction phenomena between ship and waterway as well as during passing-

model no. M 1699 – scale 1:16

ship dimensions:

				draught [m]			
				3.50	2.80	1.70	1.60
length	L	[m]	135.00				
breadth	B	[m]	20.00				
displacement	∇	[m ³]	8148	6411	3762	3527	

propeller data:

outer propeller	2 x Wageningen B 4.70 with nozzle 19a		
diameter	D	[m]	1.76
pitch ratio	P/D	[--]	1.00
area ratio	A_E/A_0	[--]	0.60
number of blades	Z	[--]	4

middle propeller	1 x Wageningen B 4.60 with nozzle 19a		
diameter	D	[m]	1.60
pitch ratio	P/D	[--]	1.05
area ratio	A_E/A_0	[--]	0.60
number of blades	Z	[--]	4

Fig. 1: Data large container vessel

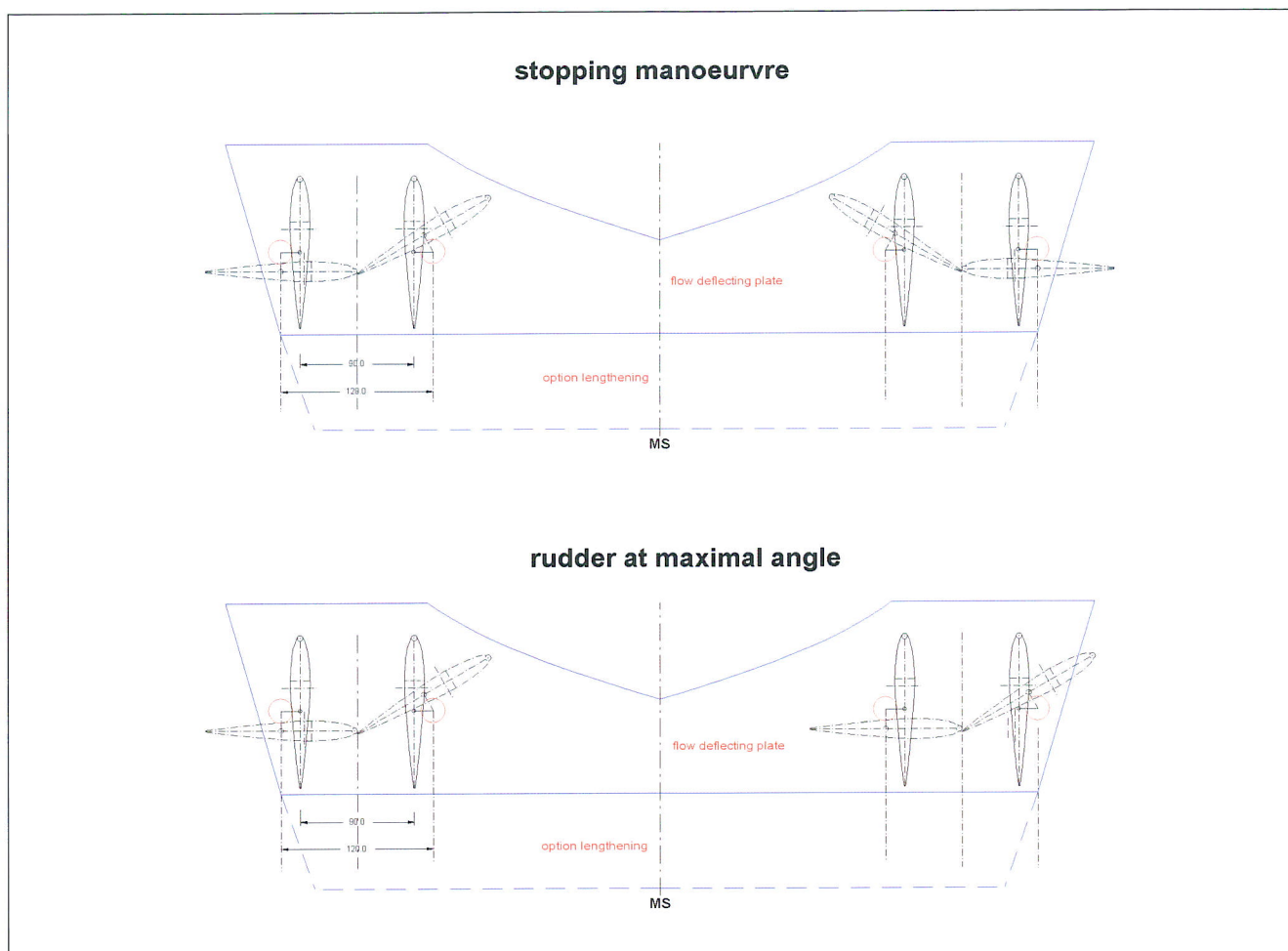


Fig. 2: Rudder according to „Székffy” patent

by and overtaking manoeuvres gain more and more in importance as a result of this rise in size, and should be taken into account when drawing up suitable ship designs. A new large container vessel to be planned is going to be compared with inland ships being in operation today. Thanks to the promotion on the part of the Federal Ministry of Labour, Social Affairs, Qualification and Technology of the Federal State of North-Rhine-Westphalia this study could be carried out.

2. NEW DEVELOPMENT JOWI-PLUS

Based on the new developments and optimisations of inland vessels as well as detailed analyses in the 1990's a big container ship oversized in length with 135 m and width with 16.84 m has been designed. This study which also dealt with the economic situation resulted in the construction of the large container vessels JOWI and AMISTADE. Up to now they have proved to be a very good solution and are trend-setting for waterborne container transport.

Following these experiences a large container vessel with a length of 135 m and a breadth enlarged to 20 m will be the focus of another study. The ship's main dimensions can be taken from figure 1 on the previous page.

The new breadth allowing the stowage of an additional row of containers simultaneously changes the flow around the after body of the ship. Therefore, it was intended to fit out the vessel with a 2- or if necessary even 3 screw propulsion unit. In addition, the influence of a flow deflecting plate mounted above the propeller should be analysed, as in some cases it has proved to improve the propulsion.

The propulsion arrangement consisted of outer twin screws with $D_p = 1.76$ m and two nozzles. The propeller with $D_p = 1.60$ m with nozzle was taken as additional centre propulsion.

Concerning the outer propeller a twin area rudder - according to the patent of the Hungarian Géza Székffy - was foreseen. This arrangement is steered eccentrically and enables at a maximal rudder angle a closed skeleton line of both blades (figure 2).

The ship's forepart has a classical stem bow with a length of 30 m. A 4-canal-bow thruster is outlined by recesses in outer shell. The after body of the vessel is designed as twin-screw with tunnel and has a length of 40 m. This form allows the installation of a third screw in order to reduce possible separation tendencies in the centre-line plane.

The design of this ship type was to be tested for different draughts and water depths.

3. PROPULSION

At first the ship ran at a medium water depth of 5.00 m as twin-screw (figure 3). The total output of $P_D = 2000$ kW resulted in a speed of 14.6 km/h at a draught of 3.5 m. The immersion at the centre-line rises to about 0.5 m. The installation of an additional centre propeller increases the engine output to $P_D = 2800$ kW. The speed goes up to 15.4 km/h at an immersion of approx. 0.7 m.

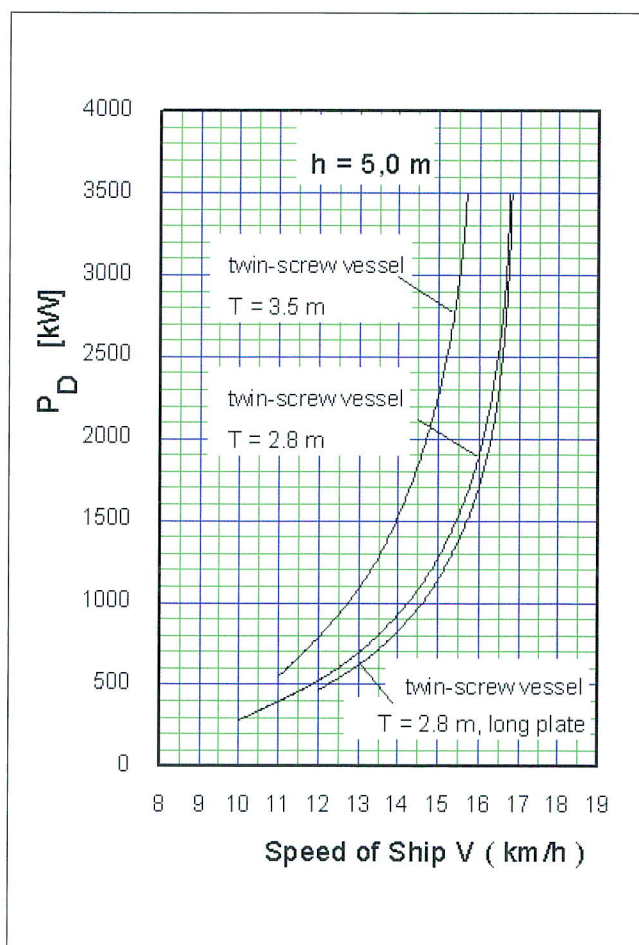


Fig. 3: Propulsion, water depth $h = 5.00$ m

At a draught of 2.8 m the engine output of 2000 kW leads to 16.3 km/h and 2800 kW result in 16.6 km/h. The immersion grows to 0.7 and 0.8 m.

This increase in output apparently produces a rise in speed at larger water depths. The installation of a sheet for descending current purposes close to the nozzle exit results in a speed increase of up to the Froude depth number of $F_{nh} \approx 0.72$.



Fig. 4: Wave pattern, $h = 5.0$ m, $T = 2.8$ m, $V_s = 15.5$ km/h

The generation of waves along the ship's hull can be described as unobtrusive and supports the chosen fineness of fore- and aftship. Figure 4 shows a small local wave trough of about 0.2 m at frame no. 3 at a speed equal to $F_{nh} \approx 0.67$.

The underwater pictures reveal a good flow. Typically for a shallow water vessel the direction of the flow at the aftship (figure 5) between the screws is directed forward.

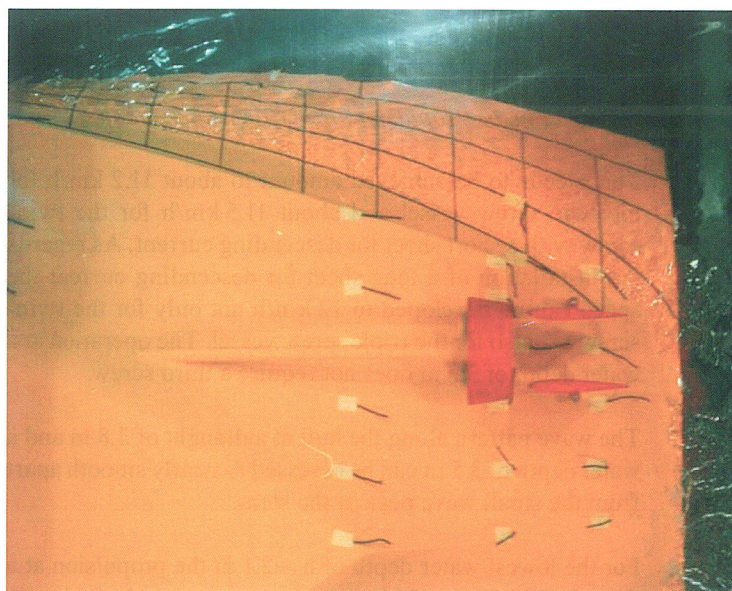


Fig. 5: Flow around the ship, $h = 5.0$ m, $t = 2.8$ m, $V_s = 15.5$ km/h

Starting at a draught of 1.6 m the ship can run ahead in ballast condition. However, some spare time should be considered concerning the venting of the tunnel until the screws produce their utmost thrust.

At a lower water depth of $h = 3.5$ m the power input of the ship immersing by 2.8 m is limited to about 1500 kW (figure 6).

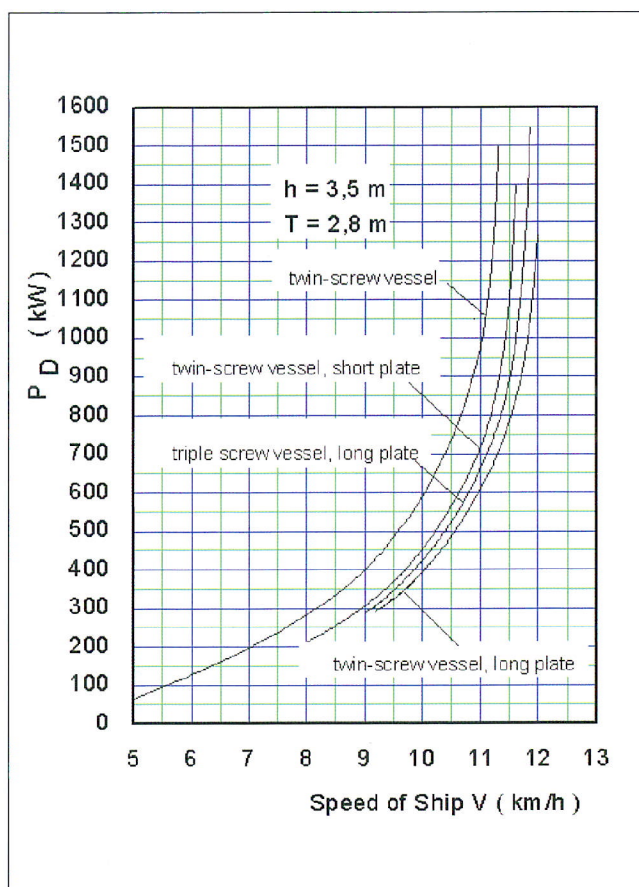


Fig. 6: Propulsion, water depth $h = 3.5$ m

The speeds to be achieved amount to about 11.2 km/h for the twin-screw vessel and about 11.5 km/h for the twin-screw with a short sheet for descending current. As regards the installation of a long sheet for descending current the speed can be developed to 12 km/h not only for the twin-screw but also for the triple screw vessel. The operation at a water depth of 3.5 m does not require a third screw.

The wave pattern along the hull at a draught of 2.8 m and a water depth of 3.5 m can be assessed as nearly smooth apart from the small wave peak at the stem.

For the lowest water depth of $h = 2.1$ m the propulsion at a draught of 1.7 m could be proven up to a speed of 8 km/h. On these conditions however, water and consequently also air are already being sucked in from astern.

4. STOPPING

According to the Inspection Regulations for Vessels on the Rhine (RheinSchUO), chapter 5, ships and coupling units have to be able to stop in time. Regarding the vehicle being discussed here with the dimensions of 135 m x 20 m the stopping distance in still water must not exceed 350 m. In addition, a speed astern of at least 6.5 km/h has to be guaranteed.

At a draught of 3.5 m and a water depth of 5.0 m the large twin-screw container vessel has a stopping distance of 345 m in loaded condition. The speed astern amounts to 7.0 km/h.

With regard to the lower water depth of 2.1 m and a draught of 1.7 m stopping distances of 375 m and speeds astern of 2.2 km/h were measured. The problems concerning air being sucked in during propulsion at a draught of 1.7 m will increase during stopping. The use of a modern bow thruster with a jet aiming on wards can however solve this problem.

5. EVASIVE MANOEUVRE

The Inspection Regulations for Vessels on the Rhine (RheinSchUO) demand to verify a manoeuvring behaviour in form of an avoiding manoeuvre. In doing so the vehicle has to, for instance at a rudder angle of 20° , develop a certain turning speed, achieve the same turning speed at a contra-rudder angle of 20° and support this movement with a zero turning speed.

The present ship belongs to the class of pushing trains with 4 barges and must provide evidence of the previously described manoeuvre at a controlled turning speed within 180 seconds. In reality, this manoeuvre could be proven within 50 seconds.

When classifying this large container vessel to the so called coupling units the avoiding manoeuvre has to take place at $12^\circ/\text{min}$. Actually, only 58 seconds were needed. This gives emphasis to the excellent manoeuvring qualities of this vessel.

6. TAKING OVER MANOEUVRE

Within this project captive taking over manoeuvres were carried out with the second towing carriage. The large model was kept by the main carriage and a standard self-propelled motor vessel with the dimensions 110 m x 11.45 m by the small carriage. The smaller vessel played the part of the vehicle which was taking over. Forces as well as trim and immersion of the large container vessel models were determined depending on the longitudinal position of both

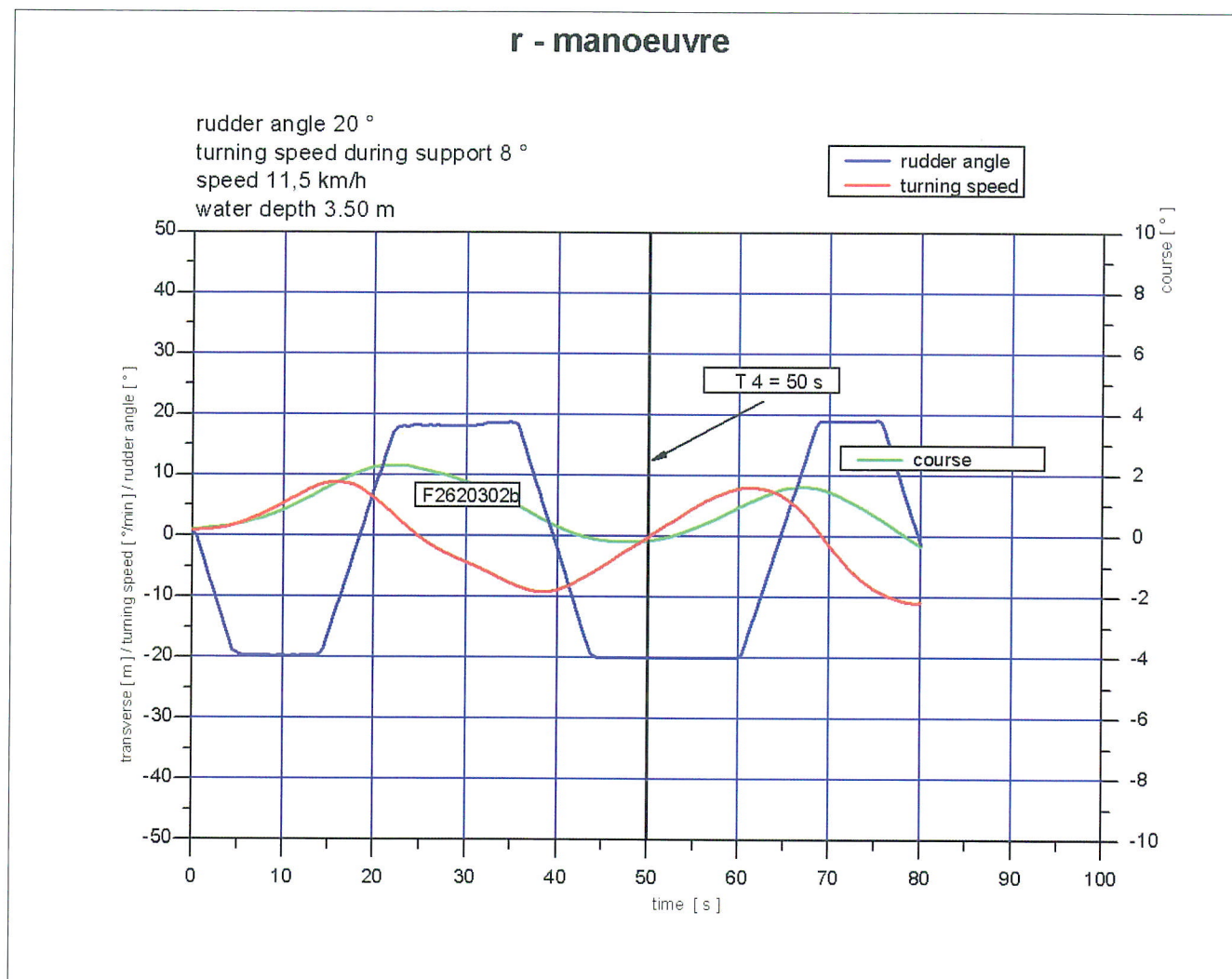


Fig. 7: Evasive manoeuvre

ships towards each other. The outboard distance between the ships was 20 m.

The speeds of the large container vessel at a draught of 2.8 m and a water depth of 5.0 m varied between 11.0 and 14.4 km/h. The vessel taking over ran at between 12.0 and 16.0 km/h.

The peak of the transverse force during the captive taking over manoeuvre rose to 30 kN.

As regards taking over manoeuvres which were run freely the large container vessel has to compensate the transversal force by adjusting the drift angle. Also this manoeuvre was carried out as model test. During this test the vessel that was taking over was led in a captive manner and the large container vessel was steered manually. The transverse force caused by the taking over vessel had been compensated by the drift angle of the large ship starting with 6 degrees and then reaching gradually 1 degree.

7. INFLUENCES ON THE ENVIRONMENT

In the course of the development regarding ship size the question for the effects on the bottom of the fairway arises.

Thus, during propulsion tests the pressure distribution was measured under and the wave height alongside the ship. At a water depth of 5.0 m and a draught of 3.5 m (figure 8 on the next page) there appears a wave through of 0.6 m at the bow area moving to the fore shoulder with a negative pressure of minus 1 m water column. Along the remaining ship's length this underpressure keeps a value of approx. minus 0.5 m water column until it reaches the suction area of the screw. There it goes up to minus 0.8 m water column and after having passed the lower stern to reach a small wave through of 0.3 m. At the lower water depths of 3.5 m and 2.8 m these pressure peaks are not that significant.

Druckhöhen aus Bodendruck- und Wellenaufmessungen

von MS bis 32 m Druck- ab 32 m Wellenaufmessungen

VBD-Modell-Nr. M1699
Länge [m] 135,0
Breite [m] 20,0
Tiefgang [m] 3,5

Fahrt 1520207
Breite des Gerinnes [m] 160,0
Wassertiefe [m] 5,0
Geschwindigkeit ü. Grund [km/h] 15,5

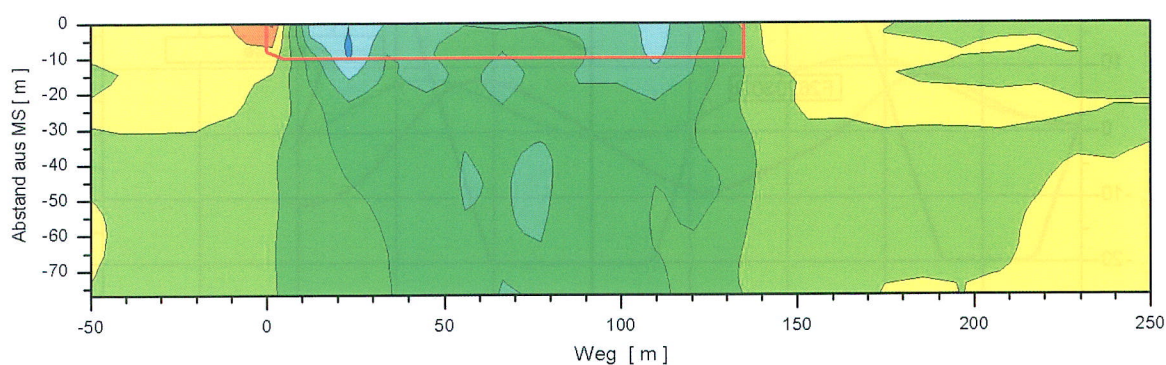
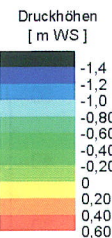


Fig. 8: Pressure distribution, water depth $h = 5.0$ m

Druckhöhen aus Bodendruck- und Wellenaufmessungen

von MS bis 32 m Druck- ab 32 m Wellenaufmessungen

VBD-Modell-Nr. M1699
Länge [m] 135,0
Breite [m] 20,0
Tiefgang [m] 1,7

Fahrt 1640205
Breite des Gerinnes [m] 160,0
Wassertiefe [m] 2,1
Geschwindigkeit ü. Grund [km/h] 8,0

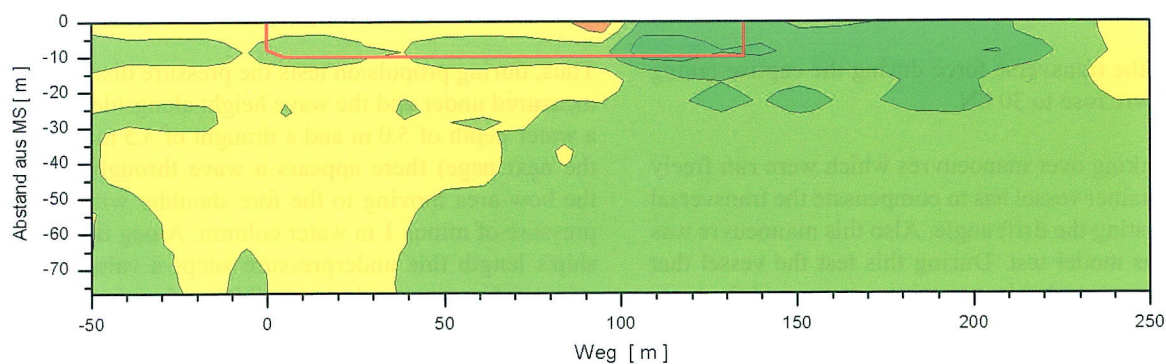
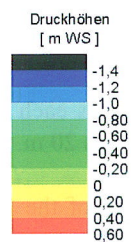


Fig. 9: Pressure distribution, water depth $h = 2.1$ m

The lowest analysed water depth of 2.1 m and the draught of 1.7 m (figure 9) do not reveal any pressure peak within the fore ship area. At that the flow around the bilge is clearly visible. At the after body a negative pressure turns up stretching far behind the vessel.

When comparing the recorded values of the large container vessel and the conventional coupling or pushing trains evidence is given that the order of magnitude is nearly identical.

8. COMPARISON WITH OTHER VESSELS

The following ships are taken from the DST database for comparison purposes:

Johann Welker

single-screw ship with the main dimensions
86.0 m x 9.5 m x 3.0 m, ∇ 2146 m³

large self-propelled vessel

single-screw ship with the main dimensions
110.0 m x 11.4 m x 3.0 m, ∇ 3333 m³

lengthened large self-propelled vessel

twin-screw ship with the main dimensions
135.0 m x 11.4 m x 3.0 m, ∇ 4188 m³

coupling train

twin-screw ship plus barge
186.0 m x 11.4 m x 3.0 m, ∇ 5732 m³

JOWI-type

triple-screw ship with the main dimensions 135.0 m x 16.8 m x 3.0 m, ∇ 5783 m³

Hereinafter the displacement-specific outputs of those vessels mentioned above will be compared at a water depth of 5.0 m and a draught of 3.0 m.

It is obvious that while in shallow water the ship's breadth is raising, the max attainable speed drops as the immersion increases (figure 10) due to the higher hindering effect.

The displacement-specific output graphs of the conventional vessels Johann Welker, 110 m self-propelled ship, 135 m self-propelled ship and even JOWI-type run in a narrow range.

The coupling train and the large container vessel have a higher specific output. Concerning the coupling train this can be explained by the open coupling between pushing vehicle and the one to be pushed, causing a high resistance. As regards the large container vessel the obstruction or immersion will raise the resistance while the ship is speeding up.

The aforementioned results refer to propulsion, i.e. the fuel consumption of vessels.

Basically, the thesis "length is running" is underlined.

Besides, there are other important aspects like staff costs, building costs, loading and unloading times as well as port-specific requirements justifying in recent years the operation of larger and broader vessels.

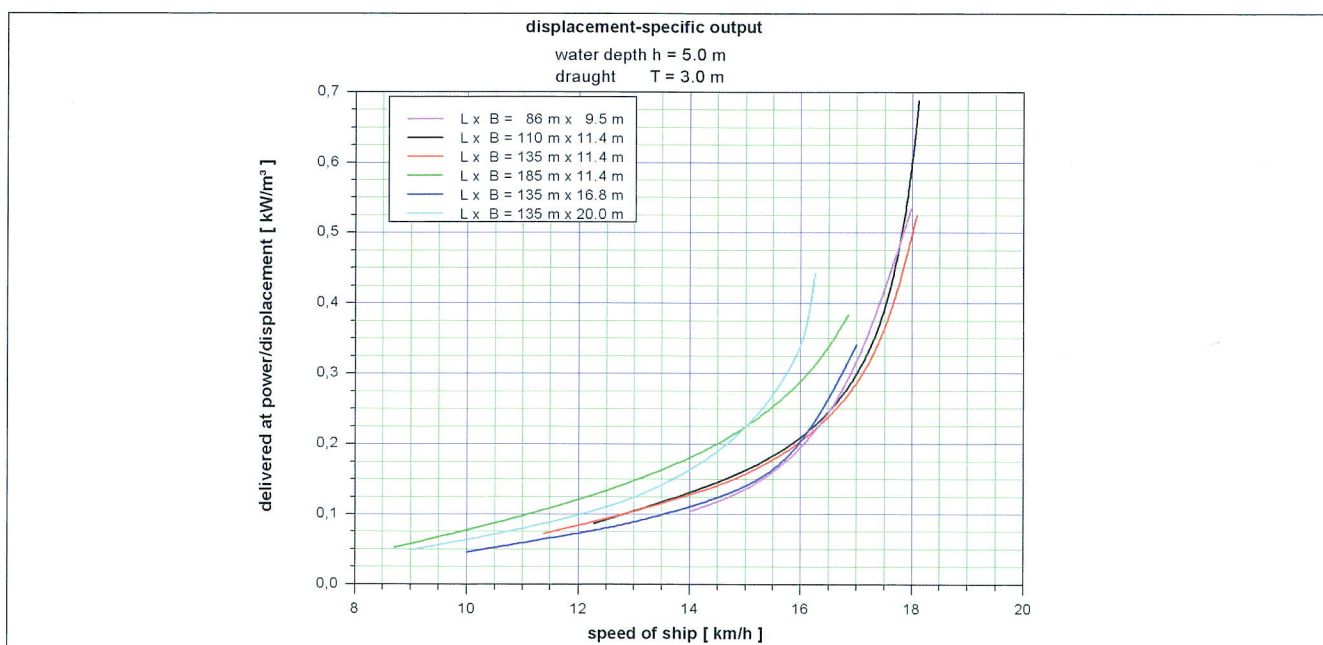


Fig. 10: Comparison of output

SUMMARY

During the past decades container transport has worldwide been rising ever more. Significant further increases are to be expected in future. As regards maritime shipping this trend for quite a while has triggered discussions concerning building ships with a TEU capacity up to 10,000 as well as the realization and adjustment of deep sea ports suitable for those jumbo vessels to call at.

In hinterland traffic these containers are transported between the sea ports and their origins or destinations, respectively, so that an appropriate growth rate can be

expected here too. In particular, the Rhine corridor plays a decisive role in managing these container quantities keeping in mind however that due to the forecasted higher shares a further increase should be considered.

Apart from the present ship size in operation with a length of 110 m and a breadth of 11.45 m, the employment of bigger vessels for more than 400 TEU seems to be trend setting. Such a vehicle has been analysed by means of model tests regarding its propulsion demand as well as transport safety.

RÉSUMÉ

Dans les dernières décennies le transport de conteneurs s'est développé toujours plus vite dans le monde entier. On peut s'attendre à ce que cette évolution se poursuive à l'avenir. Pour ce qui concerne le transport maritime, cette tendance provoque depuis un bon moment des discussions sur des navires d'une capacité allant jusqu'à 10.000 EVP ainsi que sur la construction et l'adaptation des ports en eau profonde pour accueillir ces navires géants.

Dans l'hinterland, ces conteneurs sont transportés entre les ports maritimes et leur lieu de départ ou de destination respectivement, de sorte qu'on peut là aussi s'attendre à

un taux de croissance important. En particulier, le couloir rhénan joue un rôle décisif pour la gestion de ces conteneurs, sans oublier qu'en raison de l'accroissement prévu de sa part modale, on doit prendre en compte une croissance encore plus forte du transport fluvial.

En plus des unités actuellement en service, de longueur 110 m et de largeur 11,45 m, l'utilisation de bateaux plus grands emportant plus de 400 EVP semble être la tendance. Nous avons analysé le comportement d'une telle unité grâce à des essais sur modèle physique portant sur sa propulsion et sur la sécurité de la navigation.

ZUSAMMENFASSUNG

In den vergangenen Jahrzehnten hat der weltweite Containertransport ständig zugenommen. Auch für die Zukunft werden weitere, deutliche Steigerungen prognostiziert. Dies hat in der Seeschifffahrt bereits dazu geführt, daß seit einiger Zeit über den Bau von Containerschiffen in einer Größenordnung von bis zu 10.000 TEU und die Errichtung beziehungsweise Anpassung geeigneter Tiefwasserhäfen für derartige Schiffe intensiv diskutiert wird.

Im Hinterlandverkehr werden diese Container zwischen den Seehäfen und den Quell beziehungsweise Zielorten transportiert, so daß auch hier von einem entsprechenden

Wachstum auszugehen ist. Insbesondere im Rheinkorridor spielt die Binnenschifffahrt bei der Bewältigung der Containermengen eine entscheidende Rolle, wobei zukünftig aufgrund der prognostizierten Anteilsgewinne mit zusätzlichen Wachstumsimpulsen zu rechnen ist.

Neben den bereits aktuell verwendeten Schiffsgrößen von 110 m Länge und 11,45 m Breite erscheint der Einsatz von großen Schiffen mit mehr als 400 Stellplätzen als zukunftsweisend. Dieses Fahrzeug wurde in Modellversuchen hinsichtlich seines Antriebsleistungsbedarfs sowie seiner Verkehrssicherheit überprüft.