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INLAND NAVIGATION AND ADAPTATION TO CHANGING HYDROLOGICAL CONDITIONS
AN ECONOMICAL AND TECHNICAL POINT OF VIEW

Importance of the inland navigation

Inland navigation is a very important and reliable backbone of the support with goods and merchandises in Middle Europe. Two major river systems, the Rhine Area including the Netherlands, Belgium, Germany, France and Switzerland is linked to the Danube Area going from Germany via Austria, Slovak Republic, Hungary, Serbia, Romania, Bulgaria, Moldavia and Ukraine to the Black Sea. Rivers and canals connect Luxemburg, Poland and the Czech Republic into these systems. With Central France having rivers leading to the see and little canals linking them together into the European Waterway System, a great deal of Europe's economical force is relying on inland waterway transport from the North and East to the Black Sea.

In 2005, the inland waterway sector in Germany transported 237 Mio tons on around 7,500 km of waterways. At the same time railway was carrying 317 Mio tons on almost 35,000 km and road transport did 1.153 Mio tons on a street system of 232,000 km. Thereby it is important to know that a great deal of the road transport volume is short distance. This part does not compete with the two other modes. In the Netherlands, the amount of goods transported in barges is almost as much as by trucks.

It is easy to recognize from these figures that the inland waterway sector plays a very important role in Middle Europe as a supplier of industries and private households.

Influence of climate conditions

The supply over waterways is generally very reliable and calculable. The possibility of communicating directly with the crew and thus always being in the position to receive detailed information about the actual position and the status of the transport, enables a more exact planning of the cargo handling as well as the production supply.

Climate and weather-conditioned disturbances however remain a magnitude of influence since the beginning of commercial shipping some 2,000 years ago. Ice drift commonly occurring on the Rhine in former winter times is today only occasionally a problem on some canals and tributaries.

On the other hand floods and low water are a raising climatic conditioned phenomena which can obstruct transportation on waterways substantially. High water levels become a crucial problem for the inland navigation in the very moment they occur if navigation is stopped because of reaching certain water level marks. Since no way around exists on the German part of the Rhine a ship is condemned to idle time if she is being caught behind a high water barrier. In the event of longer persisting floods, like the one at the end of the 90's this may lead to serious economical endangering of the ship owner.

Fortunately longer persisting flood periods are very seldom. Shorter periods of high water levels on the Rhine however have to be taken into account more often.

Much more crucial could become the contrary - the low water risk. The year 2003 showed us the effects of a long continuing low water period on the Rhine quite dramatically. At a water level of somewhat less than 40 cm at Kaub water gauge the navigation was not yet ceased, but due to the higher empty draught and the stern trim, larger and especially heavier double hull tankers were no longer able to pass the shallow river parts unloaded. Additionally, the ships, which were able to carry on, only conveyed rather small quantities in comparison with the volumes at full loading capacity.

The minor shipping volumes led to a drastic decrease of the entire inland navigation cargo volume in the Rhine area, and not only there. The Danube area had to fight with the same problems. The attempt to change over to the other bulk traffic carrier, the railway, could not solve the problem of the insufficient ship capacities. Bernd Malmström, at that time CEO of Deutsche Bahn Cargo AG, justified in November 2003 in an interview with the DVZ the delay in delivery and the bad service of the Deutsche Bahn among other things with „the low water of the rivers, which claimed all free reserves available at short notice".

Economical Consequences of water levels

For the view on economical aspects I would like to choose the tanker sector with its so called Reuters tariff for the transportation of gas oil and gasoline between Rotterdam and Basel. PJK International B.V., an independent information centre in the Netherlands, determines a daily overview of the freight charges by a continuous questioning of the shippers and charterer respectively ship owners starting from Rotterdam to five ports of destination along the Rhine. These freight rates serve as orientation aid for the negotiation of the spot freight rates respectively form the basis for the freight bill of long-term transportation contracts.

Like all market prices, the spot freight rates for tank transportation are formed via the interaction of supply and demand. The short term demand e.g. for fuel oil or gasoline as well as their transport, depends on numerous criteria, like the expected trend in price for the product, available warehouse storage capacities as well as actual or expected consumption, just to name a few of the total spectrum. The short-term disposability of suitable tanker shipping volume is fixed regarding the number of ships and their dimensions; their capacity, however, depends strongly on the water level.

In order to be able to demonstrate the influence of the water level on the development of the freight rates during a longer period, in this chart, covering the time span 1995 to 2004, I drew a comparison between the annual average values of the Reuters tariff for gas oil and the water level Kaub. A certain correlation is distinguishable. In 1995, the average water level at Kaub of 2.88 m faced an average Reuters' rate of € 6.40. A year later the water level fell to an average of 1.88 m and the Reuters' rate rose to € 8.89. For the subsequent years, the trends can be reconstructed likewise, only with different values. The year 2001 constitutes an exception. A Reuters' average rate of € 13.56 was reached at a relatively high water level. Induced by refinery losses because of conversions of the production on lowsulphur fuels and because of panic-like product purchases as a consequence of the terror-attacks on September 11th, there was a keen demand for the available overall tanker volume most of the year.

In 2003 the average water level showed the lowest position in these years. To explain the enormous level of the average freight we have to consider the extreme low positions that the water level did reach and the long time it stayed on low levels.

The relation between limited barge capacity due to low water levels and raising freight costs is obvious. In the tanker barge sector another factor has to be added. To achieve a higher safety in the transport of dangerous goods the sector has to change the existing single hull ship volume as fast as possible into double hull tonnage.

Double hull means another steel hull inside the ship's sizes. In addition, this again means an extra load of between 120 T and 300 T of ship weight plus the loss of cargo volume by distance between the 2 hulls. Especially in low water conditions, double hull tankers easily loose 50 to 60 % of the capacity that a comparable single hull tanker still has to offer.

Archimedes' principle

Please allow me to take a look onto a physical principle for a necessary understanding of our basic problem.

The Greek mathematician Archimedes, who lived from 287 b. C. until 212 b. C., received the order from King Hiero of Syracuse to examine whether his crown, which was manufactured very filigree, really was wrought of solid gold. Since he was told not to damage the crown, he had to find another procedure for the solution.

It is said that Archimedes found the solution for the crown-problem when he took a bath. This was the moment of discovery of the basic hydrostatic principle. When he stepped into the tub, he realized that his body partly immersed in the water displaced a mass of the fluid equal to the mass of his body. The crown and the gold weighed the same in the air but he knew that an alloy of a lighter metal, such as silver, would increase the bulk of the crown. He applied his discovery by putting a weight of pure gold equivalent to the crown into a vessel filled with water. Then he transferred the crown into the vessel and, because of the lighter specific gravity of silver, the crown displaced more water, it weighed less, showing that its volume was larger. A legend was born and his test proved that the goldsmith manufacturing the crown cheated King Hiero.

The Archimedes' principle, named after his discoverer, states that a body immersed in a fluid is buoyed up by a force equal to the weight of the displaced fluid.

A ship will float if its weight is equalled by the weight of displaced water. The relative density or weight per unit of volume of the body compared to the fluid determines the buoyant force. Consequently, the buoyant force depends upon the volume of the object and the volume of the object and not the weight determines the buoyant force. Buoyant force is the weight of the volume of fluid displaced.

In case the ship's weight will be increased by more cargo, either the volume of the ship and thus its dimensions has to become larger. Which naturally means that for a ship made of iron more iron has to be processed, involving a further increase of the ship' deadweight and thus an increase of the ship s' immersing respectively its empty draught and so on. Or the weight of the ship itself has to be reduced without any modification of the volume for example by using lighter materials.

All this may now sound like „the little shipbuilder, lesson one". But with the continuous demand that the ship has to suit the river, not the river the ship, I thought to know some basic physics could help understand the situation and possibilities.

Study of DST / VBD

The German Federal Ministry of Transport tried to bring clarity into the hydrostatic, hydrodynamic and economic connections in 2004. The DST Development Centre for Ship Technology and Transport Systems in Duisburg was ordered to make a study for „technical and economical concepts for river-adapted inland navigation ships".

Unfortunately, this study does not offer a simple solution for negative water level developments on the Rhine. Against the background of the discoveries of the ancient Greek from Syracuse however this result is also not astonishing. Let us deal a little more with the discoveries of the DST.

A generally well-known fact, but nevertheless worth mentioning, is that the waterways in Europe each permit different maximum dimensions. The present restrictions of the Rhine as the most important waterway in Western Europe are a maximum length of 135 m for a motor barge and a maximum width of 22.90 m. Convoys of coupled barges may be between 183 m and 269 m long. With 9.10 m over the highest navigable water level, the passage heights of the bridges between Rotterdam and Karlsruhe do not represent any restriction for inland barges.

If one however deviates from the Rhine to tributaries and canals, ships have to adapt to lock-conditioned restrictions of a width between 9.50 m to 11.45 m and a length of sometimes less than 100 m. Sometimes bridges do not allow the ship to be higher than 4.30 m.

The new mega barges with a length of 135 m and width of about 17 m primarily aim at the low-priced and effective supply of refineries with raw materials or for a highly effective container transport. These mega barges built for the Rhine can by no means sails on tributaries. Is a barge intended for transportation tasks reaching such loading or discharging berths willing or not the barge has to be content with the smaller maximum dimensions for these destinations - and thus for a ship's lifespan of 40 to 50 years.

The result of the study of the DST was that the enlargement of the barge dimensions well also enlarge the load capacity. But for the preservation of stability with the same load capacity any enlargement of the ship's dimensions requires the increase of the firmness of the hull. This is only possible by using more steel. However using more steel increases the weight of the empty ship. With reference to the discoveries „of the ancient Greek" 2,500 years ago this means that the ship immerses more.

According to the findings of the DST the load capacity increases congruent with the length. However if the possible draught of an extended barge is reduced by low water, the corresponding gain in loading capacity lessens too until it becomes zero with reaching of the empty weight draught. The widening of the ships dimensions only results in an increase of the loading capacity to 70% of the widening rate. Thus, the widening of the ships dimensions causes a stronger increase of the empty draught than the extension of the barge dimensions.

Regarding tanker barges the aspect of safety makes the situation even more difficult. Compared with single-hull tank barges double-hull tank barges have a clearly higher empty weight. According to the experiences of our company with the reconstruction of ships, these differences of weight result in differences between 130 t and 300 t for current types of ships depending on their size and version. This means double hull tankers immerse around 20 to 30 cm more than a comparable single hull tanker.

Thus, the enlargement of ship dimensions lead to the enlargement of the capacity and effectiveness of a ship, but only, if it is possible to use the gained draught on a river deep enough. That way a solution for the low water problem cannot be obtained. The conversion of the tanker fleet from single-hull into double-hull ships will lead to an even further enlargement of the problem.

New technical concepts

Futura Carrier

On April 5, 2005, Germany’s former Federal Minister for the Environment Jürgen Trittin has awarded a € 2.2 mill support package to the developers of the newly designed “Futura Carrier”. He praised it as a new environmentally friendly inland waterway ship, where “the ship was made to suit the rivers and not the other way around”. A second one, an inland waterway tanker is being constructed at present with a similar subsidy.

The first one named “RMS Kiel” is swimming now. It is a river-going coaster having been built according to Rhine and Sea Rules. With a draft of about 4.20 m at a maximum loading capacity of between 3,000 and 3,500 t (the final figure is not yet clear) she is not at all a ship made to suit rivers. When she immerses 2.50 m she is expected to be able to carry about 1,400 t, probably even considerably less due to necessary ballast. A regular modern river tanker with a size of 110 m by 11.45 m and a heavy double hull can still load between 1,650 t and 1,750 t at the same draft, which is 250 t to 350 t more.

Also the idea of shaping the hull differently for example like a catamaran or a trimaran does not help at all with the necessary draft. Remember the ancient Greek Archimedes – the shape of a floating body does not have any influence upon its draft.

The interesting part of this concept is in fact its new type of machinery and the way they are positioned on the ship. Four engines, two in the front, two in the aft with four times 600 kW, a total of 2.400 kW. The engines are said to be very low on emissions and low on fuel consumptions. Unfortunately, the first Futura Carrier is still not operating due to a lot of problems with the engine concept so we cannot see these promises coming true.

Design of ship hull form is varied

A decrease of a ship's empty draught respectively of the draught with an unchanged dead-weight capacity can obviously only be reached by reducing the empty weight of the ship. This may naturally not be to the debit of the hull's stability. Likewise, the collision firmness of the ship may not be worsened particularly in case of tankers. The present trend to build double hull ships as the ADNR plans for type C tankers is combined with a substantial increase of the ships weight. Since Archimedes, we also know that without any modification of the external dimensions the loading capacity thereby decreases correspondingly.

On the one hand, the solution can only exist in a different method of building the hull, which obtains the same strength with a smaller amount of steel. But so far no methods are on the market, which offer an acceptable result at justifiable costs. On the other hand, one can reach the weight reduction by using lighter materials. Exotic metals exclude themselves by their equally exotic costs. Due to higher costs and because of security doubts with tankers aluminium also did not yet offer itself as solution. Similar to synthetic materials aluminium so far only found a greater significance in the building of yachts as well as within the military range.

SPS Sandwich Plated Steel

The only promising solution at the moment is offered by the combination of steel and polyurethane with the name "Sandwich Plated Steel". Developed by the near London based company Intelligent Engineering a layer of polyurethane is placed in between two layers of regular ship building steel. It is more or less a compact double hull. This mixed material has shown an enormous strength in test.

This SPS material has been successfully implemented in the repair of ships and bridges and in military applications. Its advantage in shipbuilding is that because of its strength most of the regular stiffeners can be left away without loosing the necessary constructional force of a ship's body. This saves weight and makes a ship sink less with the same amount of cargo. Especially for tankers it is expected that SPS may be at least as protective as the double hull used today. A recently finished study about the use of SPS overlay technology for offshore installations in comparison with a conventional double hull has shown promising results. In case of a high impact collision, SPS is even stronger than a double hull.

But there is still some way to go. Classification societies and authorities are cautious and there is more research to do to prove the possibilities of SPS or to develop alternatives.

Nevertheless all foreseeable technical development in shipbuilding will not be able to cope with extremely low water levels. If this will happen too often in the future we will have to consider further adaptations of our waterway infrastructure for example by building locks. And this will also be in favour of preserving the river landscape of today.

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