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THE SHIP WITH LOWEST OVERALL OPERATING COSTS

BROD NAJNIŽIH UKUPNIH TROŠKOVA KORIŠTENJA

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Review
Pregledni članak

Abstract

In any ship design development, tankers included, economic transport principles have to be taken into consideration. It means that a designer has to anticipate the environmental conditions of the ship exploitation. The best tanker design would be chosen in accordance with both technical and economic criteria.

In order to be able to perform economic analysis of the design, it is necessary to define technical limitations which will define areas of feasibility. Technical criteria ensure technical feasibility of the design solution, and evaluation is guided by economic criteria.

All elements of ship design are closely related to the ship exploitation, which is in turn dependent upon the state of the freight market. Considering a long period of the ship exploitation and instability of the transport market, the ship will surely pass through several cycles. The instability of the transport market will affect the ship income.

The criterion of the required freight has been chosen as the economic criterion for the choice of the optimal design because, in that case, the influence of the freight market instability on the achieved result can be neglected.

Features of the applied technical and economic model will be shown on the example of an oil tanker.

Sažetak

Pri razvijanju svakog projekta broda, pa tako i tankera u obzir treba uzeti i ekonomske principe prijevoza. To za projektanta znači poznavanje okolišnih uvjeta pri kojima će brod poslovati kao i predviđanje istih. Najpovoljniji projekt tankera bio bi izabran vodeći računa i o tehničkim i ekonomskim kriterijima.

Kako bi se moglo pristupiti ekonomskoj analizi projekta potrebno je definirati tehničke elemente projekta, kao i tehnička ograničenja koja će definirati područja izvedivosti. Tehnički kriteriji osiguravaju tehničku izvedivost rješenja, a ocjenu daju ekonomski kriteriji.

Svi elementi osnivanja broda usko su povezani s korištenjem broda, koje je pak zavisno o stanju na tržištu vozarina. S obzirom na dugo razdoblje korištenja broda i nestalnost tržišta transporta, sigurno je da će brod proći kroz nekoliko ciklusa. Ova nestalnost reflektirat će se i na dohodak broda.

Kao ekonomski kriterij izbora najpovoljnijeg projekta izabran je kriterij zahtjevane vozarine jer se njime utjecaj nestalnosti na tržištu vozarina na dobiveni rezultat zanemaruje.

Na primjeru tankera za sirovu naftu i prerađevine bit će pokazane značajke primijenjenog tehničko-ekonomskog modela.

Introduction

Uvod

A standard procedure of ship design takes into account technical limitations as well as conditions of design requirement. The latter include the ship deadweight, its speed, description of the cargo and

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the range of voyage. A ship design must satisfy the requirements made by the ship owner as well as regulations of the register and the international maritime authorities.

In the process of ship design, it is necessary to decide upon the best technical and economic solutions after having analyzed all possible variants of the design. This choice is called optimization for given predicted conditions. Analysis of total operating costs is carried out by means of calculation and prediction, i.e. by means of the process of voyage simulation. The suggested comprehensive technical and economic analysis can only result in a complete optimal solution of the task in particular voyage conditions. In order to get a flexible ship design solution, several ship variants should be considered, as well as several routes at different speeds of ships in exploitation. Hence, it is clear that technical and economic optimization of the ship design, which is always optimal for particular conditions, would not be optimal at the same time for different routes and different speeds.

The aim of this paper is to present the treatment in calculations as well as possibilities of adjustment to the overall optimal solution of the task. The practice so far has been to separate the ship designers' work on defining the ship design in the shipyard from the work of the shipowner's consultants. The oil tanker has been chosen as a typical example to describe the simulation of the ship exploitation with optimal solution of technical and economic ship design.

1. The choice of the ship design features
Izbor tehničkih značajki broda

A review and prediction of oil and oil products production by regions, as well as the transported quantities on particular lines give an insight into the employment of particular ship sectors and a prediction of the development trend of the tanker fleet size. One of the groups with similar deadweights is the group of oil tankers with the deadweight of approximately 71,000 tdw (on the summer draught). This group is often referred to as Panamax (tankers intended for passing through Panama canal). The average speed in service for these ships is about 14.5 knots for a ship on the summer draught at approximately 82% of the contracted maximum continuous rating. For the purpose of an analysis we use the basic ship design for the tankers having the above mentioned features of deadweight and speed. The ship in question was built in 1999 in accordance with the regulations in force at the time. A modern technical solution guarantees the reliability of the existing data for the propulsion device and the machinery, gives the weight of the light ship as well as its classification, and enables a quality calculation of the ship building price.

The main features of the basic ship:

L_{pp} = 220.0 m
B = 32.2 m
T_d = 12.572 m
$Disp$ = 76773 t (on draught T_d)
C_B = 0.84
$CMCR$ = 12000 kW
$V_{SERVICE}$ = 14.55 kn
$P_{B\ SERVICE}$ = 9800 kW

In addition to the basic ship, two variants with the following main measurements, i.e. the fine lined ship and the full ship, have been considered.

L_{pp} = 238.5 m
B = 32.2 m
T = 12.572 m
$Disp$ = 77289 t
C_B = 0.78
$CMCR$ = 12000 kW
$V_{SERVICE}$ = 15.0 kn
$P_{B\ SERVICE}$ = 9800 kW

L_{pp} = 212.0 m
B = 32.2 m
T = 12.572 m
$Disp$ = 75598 t
C_B = 0.86
$CMCR$ = 12000 kW
$V_{SERVICE}$ = 14.0 kn
$P_{B\ SERVICE}$ = 9800 kW

Following the same principle, these two variants have retained optimal technical solutions in the same way as the basic ship.

2. Economic considerations applied in the analysis
Ekonomski elementi korišteni u analizi

A cost analysis following the generally accepted scheme in the shipping industry will be carried out for the purpose of comparing the design variants. The economic analysis of the ship business operation comprises costs per year. The total annual operating costs of the ship can be divided into capital costs, operating costs and voyage costs (expenses for fuel, ports, passages through canals). Operating costs can be further divided into manning

costs, insurance costs, maintenance and repair costs, service costs and administration costs. These are daily running costs incurred whether the ship is at sea or in port.

2.1. Capital costs
Troškovi kapitala

Capital costs are related to the purchase of the newbuilding and they are a function of the contracted price of the ship and a financial arrangement.

The first element is the newbuilding cost calculation for the ship. For the basic ship the calculation was based upon data of weight classification of the light ship in the way that the price of the steel was divided into the weight of the ship plates and the weight of the profiles and into unit price, separately for ship plates and for profiles. Subsequently, working hours for steel, equipment and machinery were calculated. The unit price for equipment was added to this sum, while the price of machinery compartment was divided into main elements such as main engine, shafting, boiler and several auxiliary engines, and all the rest in the machinery room has the same unit price. Finally, total overhead costs of the shipyard were added. The calculation procedure for the price of newbuilding was repeated for the fine lined ship and for the full ship.

Prices for newbuilding follow market cycles of freight and demand. The main factor influencing the cost of newbuilding is a demand for a particular ship type and size. This demand is in turn related to the freight market, but to a lesser degree than it is the case with the secondhand ships.

For most shipowners the sum of money needed for the purchase of a ship is beyond their immediate cash resources. In the case of using borrowed funds, the costs of debt service should be added to capital costs. In the capital cost calculation it was assumed that 75% of the newbuilding price is covered by a 12 year loan with the interest of 5% per year, while the remaining 25% is covered by cash paid by the shipowner, which also represents capital cost. Capital cost is then calculated into the annual capital cost expressed in US$ per year.

2.2. Manning costs
Troškovi posade

Manning costs include:

- direct costs (wages for the crew, paid vacation, travels, overtime, food, pension insurance) and
- indirect costs (health insurance, employment agency fees, trade union fees, training, sick leave,...)

Manning costs depend primarily on the number of crew members, which in turn depends upon the ship size and the automation level. Technical improvements of engines and equipment have resulted in less watch-keeping and less maintenance with a direct consequence of reduced crew numbers. However, determining the crew numbers requires a serious approach, as there is a possibility of increase in indirect maintenance costs in case of excessive reduction of the crew.

This group of costs was reduced during the 1970s and 1980s when recession in the shipping industry brought about the employment of cheaper manpower from the countries such as Philippines, the Indian subcontinent, China, Eastern Europe. At the same time, other costs were also reduced by the elimination of pension insurance. But the age distribution of seamen points to the disturbing fact that we could be confronted with the shortage of experienced and skillful seamen in the near future and with an increased demand for better educated manpower. The present status of the employed seamen discourages many potential candidates who are considering taking a job aboard a ship. Consequently, an increase in manning costs is expected soon.

Manning costs are based on the total crew of 25 persons; among them there are 10 officers and 15 sailors. The crew members are of three nationalities; senior officers are Europeans, younger officers come from less developed countries, while sailors come from the Far East. It is estimated that the total manning costs are 67,000 US$ per month. This amount does not include overtime costs, travels to and from the ship, different indirect costs for the crew such as trade union fees, employment agency fees, working clothes costs, costs for training and education, etc.

2.3. Risk insurance costs
Troškovi osiguranja rizika

Risk insurance costs are divided into two groups:

- insurance of hull, equipment and machinery (H & M)
- insurance of the cargo, the crew and indemnity (Protection and Indemnity., i. e. P & I)

H&M insurance covers the ship hull, equipment and machinery, in which the shipowner has a direct insurable interest.

P&I insurance covers the claims from third parties in cases such as, for example, oil pollution of the sea, or claims in cases of injuries to employees. These risks tend not to be covered by direct placement on the insurance market as, more usually, this business is covered by mutual insurance between shipowners under the auspices of the P&I clubs.

2.4. Repairs and maintenance costs
Troškovi popravka i održavanja

This group of costs comprises direct and indirect costs. Direct costs include the price of work in ship maintenance interventions and the cost of the expended material. Indirect maintenance costs refer to all other expenses of the ship when it is not in operation.

Expenditure on repairs and maintenance depends upon the class requirements related to the quality of the ship arrangement, upon the freight market, the ship age, its type and size, voyage patterns, and the shipowner's strategy. Prediction of costs depending upon some of these parameters is precarious due to the repair shipyard market.

2.5. Other operating costs
Troškovi službe i administracije

Other operating costs include the expenses for operating supplies (spares, paints, chemical substances, lubricating oils, stores,...), provisions, administration and other expenses related to general management of the ship.

A large share of these costs is related to the costs for lubricating oils. The total consumption of lubricating oils, consequently the expenditure on lubes, to a large extent depends upon the size, age and technology of the ship equipment and machinery, as well as upon the efficiency of maintenance.

Costs for provisions depend upon the crew numbers, costs for operating supplies depend upon the ship deadweight, while other expenses for management depend upon the organization and the size of the shipping company.

2.6. Expenses for fuel
Troškovi goriva

The annual expenses for fuel are calculated from voyage simulation of the ship and the specific consumption of diesel oil and heavy fuel oil in ship exploitation and in port respectively. The price of fuel moves in line with the price of crude oil and varies according to the routes or to the port of fuel loading.

Features of the ship exploitation define the range of voyage, the time required for the ship loading/unloading and the annual rate of the ship exploitation. Calculation of these features is the basis for the calculation of the voyage costs and the cargo handling costs. Depending on the features of the ship exploitation, the share of a particular group of costs varies.

In this analysis, cost of bunkers depends on the ship design variant and on the chosen route (which is described in the following chapters). Daily heavy fuel oil consumption in ship exploitation is calculated according to the speed in service and the required power, and according to the assumed fuel consumption for low-speed diesel engines Warsila-Sulzer RTA-U.

Overall annual expenses are among major expenses in total operating costs of the ship.

2.7. Port costs and canal charges
Troškovi luka i kanala

Port costs as a part of voyage costs are variable depending on the part of the world and the position of ports, and they are beyond any comparison. In recent years, these costs have increased in order to meet more rigorous requirements regarding safety and environment protection. They include charges for entering the port and pilotage costs, towing costs, mooring costs, agency fees, customs duty, etc.

Bearing all this in mind, it is expected that these costs will be the highest in the ports of Japan and Europe.

Port costs and canal charges depend upon the ship size, draughts, and loading/unloading conditions. Canal charges (Suez canal, Panama canal) are standardized according to the ship tonnage and draughts.

This group of costs will be calculated according to the round voyage.

3. Choice and simulation of voyage
Izbor i simulacija plovidbe

For the tanker design, the following typical round voyages have been chosen:

- The Mediterranean (Bizerta-Rijeka)
- Loading from the Arabian Gulf (Ras Tanura-Suez-Rotterdam)
- Yokahama-Suez-London

In calculation of the ship voyage simulation, the speed of voyage for both the loaded ship and the ship in ballast, as well as the time at the terminal and the time needed for passage through canals are determined. The total number of hours/days of a round voyage is calculated from the distance between the given ports and the time spent in voyage, and from the time spent at terminals.

The ship is in exploitation 350 days a year, so it is possible to calculate the number of round voyages per year.

Voyage costs, i.e. port costs and canal charges and expenses for fuel, depend upon the number of round voyages. An additional calculation only for the voyage Ras-Tanura-Suez-Rotterdam, with reduced propulsion power of 53% MCR, has been carried out for the purpose of voyage simulation. The procedure of voyage simulation encompasses all annual ship operating costs of ship exploitation shown in tables 1, 2 and 3.

4. Economic evaluation
Ekonomska ocjena

A ship is a subject on the market where it makes an income, i.e. the freight expressed in US$/t. This amount varies depending on the route and the cargo volume. It is quite clear that profit is the difference between the ship income and the ship expenses.

The required freight will be calculated as a ratio of the total annual ship operating costs and the ship annual transport capacity. The annual transport capacity of the ship is the volume (expressed in tons) of cargo transported in a year, and by definition it is a function of the ship size, speed, a particular round voyage distance and the time spent in ports.

In our case, the resulting freight should be considered only as a definition of minimum expenses. Bearing in mind that neither inflation nor taxes have been taken into account, the conclusion that the shipowner who achieves this amount is at the break-even point is not valid.

The most acceptable ship design is chosen according to the criterion of required freight rate, which means that the design variant which covers its operating costs with minimum freight rate is the optimum.

5. Conclusion
Zaključak

Three ship designs considered in this paper, i.e. the basic ship, the ship with a finer value of C_B and the full ship, have been ranked according to their acceptability in tabl.1, tabl.2, and tabl.3. The tables also show additional analysis of 3 round voyages with different distances.

The tables give the calculated required freight rates for these three round voyages, without profit and taxes. The lowest calculated required freight rate represents the optimal design for a given round voyage.

So, for example, the required freight rate is the lowest for the full ship design, and for the medium round voyage of 12,700 nm it amounts to 18.24 US$/t.

The medium freight rate without profit and without taxes, increased by 25%, is used for all three ship designs without any alterations.

The annual profit from transported cargo for a chosen round voyage and a chosen ship design is calculated by subtracting the total annual expenses from the total income from freights.

The resulting sum expressing profit shows that the best profit is achieved for the chosen short round voyage.

Further on, for the chosen medium and long round voyage, the basic ship design gives maximum profit. For the chosen short round voyage, the full ship design gives best profit.

In addition to three round voyages covering different distances, the fourth voyage variant has been made, i.e. the variant of a round voyage with reduced power, namely 53% MCR and the adequate reduced speed. This variant was very promising at the times of abrupt rises in fuel prices. The benefit of using the reduced power has not been noted; i.e. the required freight rate for all three ship design is increased. The profit is the best for the full ship design.

The results of this analysis show that three ship designs considered are different in building process and in operation in the conditions enforced by the prices of newbuilding, steel, working hours, interest etc., as well as in the conditions imposed by the ship operating costs, i.e. manning costs, insurance costs, etc. Immediately after price conditions change in a larger or a lesser degree, the results of the ship acceptability as a means of transport change too.

From this work follows that the ship design optimization performed by designers in shipyards in technical and economic scope is the basic task, but it should be accompanied by the analysis of technical and economic elements in the process of making a decision on the building of a ship on the part of the shipowner/consultant.

It would be desirable and justified to carry out the process of the ship design optimization simultaneously with the process of optimization of the annual ship exploitation.

The ship with the lowest overall operating costs would be a result of the proposed technical and economic analysis, and would be the optimal solution.

References/*Literatura*

[1] TANKER MARKET PROSPECTS TO 2005: Profitability And Instability?, DREWRY SHIPPING CONSULTANTS LTD., 1998.

[2] SHIP COSTS: The Economics Of Acquisition And Operation, DREWRY SHIPPING CONSULTANTS LTD., 1997.

[3] M. VUKIČEVIĆ, OPTIMALIZACIJA PROJEKTNOG ZAHTJEVA BRODA, doktorska dizertacija, FSB ZAGREB, 1982.

[4] M. JAZVIĆ-MIOKOVIĆ, IZBOR NAJPOVOLJNIJEG PROJEKTA TANKERA PREMA TEHNIČKO-EKONOMSKIM KRITERIJIMA, magistarski rad, FSB ZAGREB, 2000.

Table 1. The basic ship design with technical features and economic indicators
Tablica 1. Temeljni projekt s tehničkim značajkama i ekonomskim pokazateljima

Lpp = 220.0 m B = 32.2 m T = 12.572 m $Displ$ = 76 773 t C_B = 0.84	$P_{B\,MCR}$ = 12000 kW V_{SERV} = 14.55 kn (loaded) $V_{BALSERV}$ = 15.55 kn (ballast) $P_{B\,SERV}$ = 9800 kW			
Newbuilding price, [US$]	31,500,000.0			
Capital costs, [US$]	50,302,100.0			
Annual capital costs, [US$/y]	4,191,842.0			
Operating costs, [US$/y]	2,350,000.0			
Round voyage range, [nm]	1756	12700	12700 (53% MCR)	22000
Cost of bunkers, [US$/y]	1,356,912	1,626,962	1,122,509	1,654,834
Port costs and canal charges, [US$/y]	2,508,503	1,544,647	1,387,663	888,247
Total annual costs, [US$/y]	10,407,260	9,713,451	9,052,014	9,084,922
Required freight rate, [US$/t]	3.83	18.29	18.97	29.75
Annual transport capacity, [t/y]	2,717,545	531,043	477,072	305,375
Expected freight rate, [US$/t]	4.80	22.90	22.90	37.20
Annual profit, [US$/y]	2,636,957	2,447,423	1,872,935	2,275,032

Table 2. The fine ship design with technical features and economic indicators
Tablica 2. Projekt finijeg broda s tehničkim značajkama i ekonomskim pokazateljima

Lpp = 238.5 m B = 32.2 m T = 12.572 m $Displ$ = 77 289 t C_B = 0.78	$P_{B\,MCR}$ = 12000 kW V_{SERV} = 15.0 kn (loaded) $V_{BALSERV}$ = 16.0 kn (ballast) $P_{B\,SERV}$ = 9800 kW			
Newbuilding price, [US$]	33,819,000.0			
Capital costs, [US$]	54,005,250.0			
Annual capital costs, [US$/y]	4,500,400.0			
Operating costs, [US$/y]	2,350,000.0			
Round voyage range, [nm]	1756	12700	12700 (53% MCR)	22000
Cost of bunkers, [US$/y]	1,350,644	1,625,217	1,122,245	1,653,834
Port costs and canal charges, [US$/y]	2,555,351	1,585,734	1,401,465	911,780
Total annual costs, [US$/y]	10,756,400	10,061,350	9,374,110	9,416,014
Required freight rate, [US$/t]	3.89	18.45	19.45	30.04
Annual transport capacity, [t/y]	2,768,297	545,168	481,817	313,466
Expected freight rate, [US$/t]	4.80	22.90	22.90	37.20
Annual profit, [US$/y]	2,531,429	2,422,997	1,659,501	2,244,914

Table 3. The full ship design with technical features and economic indicators
Tablica 3. Projekt punijeg broda s tehničkim značajkama i ekonomskim pokazateljima

Lpp = 212.0 m B = 32.2 m T = 12.572 m $Displ$ = 75 598 t C_B = 0.86		$P_{B\,MCR}$ = 12000 kW V_{SERV} = 14.0 kn (loaded) $V_{BALSERV}$ = 15.0 kn (ballast) $P_{B\,SERV}$ = 9800 kW		
Newbuiding price, [US$]	29,175,000.0			
Capital costs, [US$]	46,589,350.0			
Annual capital costs, [US$/y]	3,882,446.0			
Operating costs, [US$/y]	2,350,000.0			
Round voyage range, [nm]	1756	12700	12700 (53% MCR)	22000
Cost of bunkers, [US$/y]	1,365,136	1,629,210	1,122,863	1,656,122
Port costs and canal charges, [US$/y]	2,447,039	1,491,694	1,369,188	857,909
Total annual costs, [US$/y]	10,044,620	9,353,350	8,724,496	8,746,477
Required freight rate, [US$/t]	3.79	18.24	18.53	29.65
Annual transport capacity, [t/y]	2,650,959	512,838	470,720	294,945
Expected freight rate, [US$/t]	4.80	22.90	22.90	37.20
Annual profit, [US$/y]	2,679,983	2,390,630	2,055,002	2,225,489

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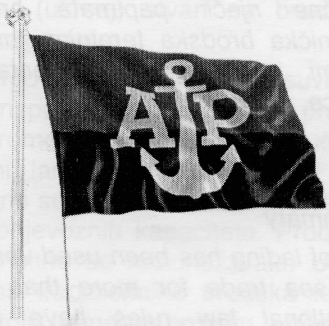

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