Main Diesel Engine Selection for Ships Based on Life Cycle Costing

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Keywords: Main diesel engine, Life cycle costing, Decision-making.

Abstract. In order to obtain optimum decision making in selecting main diesel engine for ships, the life cycle cost technology is proposed. The breakdown structure and calculation model of life cycle cost for main diesel engine of ships are established. Taking a specific selection for main diesel engine of one ship as the instance, the purchase cost and life cycle cost for three types of main diesel engine are compared and analyzed. The type of main diesel engine is selected based on the calculation result of life cycle cost. The instance shows that the life cycle cost technology is a powerful decision-making tool, which is worthy of popularization and application in ship design and development stages.

Introduction

In the process of ship design, main diesel engine selection is very important. Selection for main diesel engine is affected by many factors, such as the rated power, rated revolutions per minute, fuel consumption, purchase price, weight and size, life, maintenance cost, and so on. For some ship, many kinds of main diesel engines can be chosen at the beginning of the design. Some diesel engines are expensive, but they have high reliability and low fuel consumption. Some diesel engines are cheap, but they have high fuel consumption and failure rate, etc. It is proved that the life cycle cost technology is an economic powerful decision-making tool [1-7]. This paper will put forward that the main diesel engine will be chosen by life cycle cost technology. Life cycle cost model of main diesel engine is set up. The purchase cost and life cycle cost (LCC) for three types of main diesel engine are compared and analyzed for some special ship.

The LCC breakdown structure of main diesel engine for ships

According to cost breakdown method provided in the International Electro technical Standards IEC300-3 [4], the LCC breakdown structure of main diesel engine for ships is described in Fig. 1.

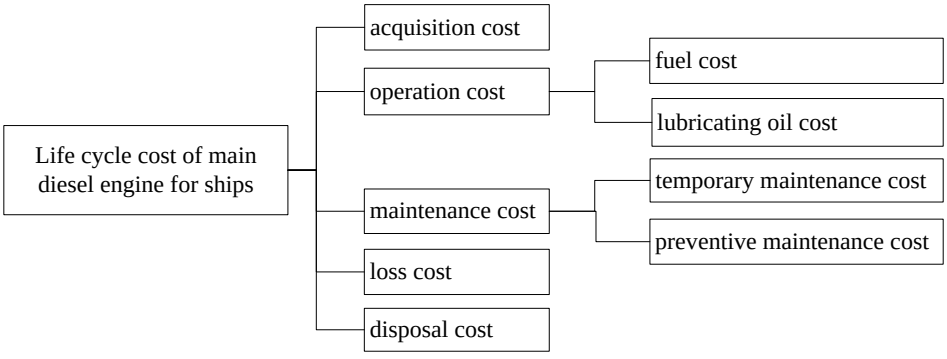

Fig. 1 The LCC breakdown structure of main diesel engine for ships

Acquisition cost C_P

Acquisition cost refers to the cost used to obtain the main diesel engine, which includes the cost of the price, transportation and installation, initial guarantee spare parts and other costs.

Operation cost C_U

Operation cost refers to the energy costs, mainly including the cost of fuel and lubricating oil costs. Fuel cost is related to the main diesel engine's oil consumption rate, working time and oil price, etc.

Maintenance cost C_M

Maintenance cost refers to the costs needed to pay for the main diesel engine to restore or improve to a specified state. Maintenance can be divided into preventive maintenance, temporary maintenance. Preventive maintenance can be divided into the dock maintenance, minor maintenance and medium maintenance. Temporary maintenance can be divided into daily temporary maintenance and emergency maintenance.

Loss cost C_L

Loss cost mainly includes loss of business caused by the failure of the main diesel engine. The preventive maintenance does not cause loss cost.

Disposal cost C_R**.**

Disposal cost refers to the cost used to deal with retired equipment. The disposal cost of the main engine system can be retrieved in 8% of the acquisition expense after retirement.

The LCC model of ship diesel engine

Assuming the annual average price index is γ, the bank average annual rate is i , annual average working hour of a ship is T, its unit is hour. The number of the main engine is K.

The LCC of the main engine is mainly composed of acquisition cost, operation cost, maintenance cost, loss cost and disposal cost. The LCC is given by

$$LCC = C_P + C_U + C_M + C_L + C_R \tag{1}$$

Where C_P is the cost used to obtain the main engines in RMB; C_U is operation cost of the main engines in RMB; C_M is maintenance cost of the main engines in RMB; C_L is loss cost caused by the failure of the main engines in RMB; C_R is disposal cost for main engines after retirement.

Operation cost C_U

The main diesel engine operation cost in a year mainly includes the fuel cost and lubricating oil cost. The main diesel engine operation cost is given by

$$C_{UY} = \frac{T \times K \times E_{\mathrm{R}} \times W}{\rho_{\mathrm{R}}} \times C_{\mathrm{R}} + \frac{T \times K \times E_{\mathrm{H}} \times W}{\rho_{\mathrm{H}}} \times C_{\mathrm{H}} \tag{2}$$

Where C_{UY} is annual average operation cost in RMB; E_{R} is average fuel consumption of single main diesel engine in kg per kilowatt; W is the power of single main diesel engine in kW; ρ_{R} is fuel density in kg per liter; C_{R} is fuel unit price in yuan per liter; E_{H} is average lubricating oil consumption of single main diesel engine in kg per kilowatt; ρ_{H} is lubricating oil density in kg per liter; C_{H} is lubricating oil unit price in yuan per liter.

Consider the price index and the time value of the funds, the operation cost in N years is given by

$$C_U = C_{UY} \times \sum_{n=0}^{N} \frac{(1+\gamma)^n}{(1+i)^n} \tag{3}$$

Where C_U is the operation cost of the main diesel engines in their life; C_{UY} ——annual average operation cost in RMB. *N* is the number of the service time.

Maintenance cost C_M

Maintenance cost mainly consists of maintenance labor cost, maintenance equipment cost and spare parts cost. It is given by

$$C_M = C_{ML} + C_{MC} \tag{4}$$

Where C_M is the maintenance cost of the main diesel engines in the whole life; C_{ML} is the temporary cost of main diesel engine throughout the life cycle; C_{MC} is the cost for an overhaul of single main diesel engine in the entire life. C_{ML} is closely related to mean maintenance cost, mean time between failures, mean equipment work time, service time, price index, and interest rates. C_{ML} is given by

$$C_{ML} = \frac{T \times K}{MTBF} \times C_F \times \sum_{n=0}^{N} \frac{(1+\gamma)^n}{(1+i)^n} \tag{5}$$

Where *MTBF* is mean time between failures of single main diesel engine in hour; C_F is the mean maintenance cost of single main diesel engine in yuan. C_{MC} is related to mean overhaul interval time of single main diesel engine, average cost of main diesel engine overhaul once. It is given by

$$C_{MC} = K \times C_{PMW} \times \sum_{n=1}^{m} \left(\frac{1+\gamma}{1+\mathrm{i}} \right)^{n_m} \tag{6}$$

Where C_{PMW} is average cost of main diesel engine overhaul once in yuan; *m* is The number of the main diesel engine needed to overhaul during the service; *n* is the index of the overhaul of main diesel engine; n_m is the service time of the main diesel engine when the overhaul index is m in year.

Loss cost C_L

If the time value of funds and the price index are considered temporarily, loss cost is given by

$$C_L = \frac{K \times T}{MTBF} \times \frac{W \times K}{0.75} \times C_{L0} \times MTTR \tag{7}$$

Where C_L is the loss cost caused by main diesel engines fault in yuan; C_{L0} is loss cost at unit time caused by the failures of main diesel engine unit power in yuan per hour, generally 10 yuan/horsepower; *W* is The power of the single main diesel engine in kW; *MTBF* is mean time between failures of single main diesel engine in hours. If one main diesel engine fails, the ship will not be able to work; *MTTR* is the time that a ship cannot work caused by the failures of main diesel engine.

Disposal cost C_R

The disposal cost of main diesel engine after retirement is given by

$$C_R = -C_P \times \frac{(1+\gamma)^N}{(1+i)^N} \times 8\% \tag{8}$$

Where C_P is the purchase cost of main diesel engine in yuan. *N* is the number of the service time.

A case of main diesel engine selection for a ship based on the LCC technology

Basic parameters

A ship has two main diesel engines. The annual work time of each diesel engine is about 2000 hours. The density of the diesel is about 0.84 kg per liter and the density of the lubricating oil is about 0.90 kg per liter. The diesel costs about 5.8 yuan per liter and lubricating oil costs of about 60 yuan per liter. The service time of the ship is 33 years. Disposal cost of main engine after 33 years is 8%. Loss cost is about 3000 yuan per hour. It is assumed that the price index is 4% and bank average annual rate is 3%.

Life profile of the ship

Main diesel engine is mainly overhauled in ship preventive maintenance time, such as in dock repair, minor maintenance, or medium maintenance, in order to reduce the loss of the ship. Life profile is the description of the usage and maintenance action of the ship from the beginning to the end of the service. The profile of the ship is shown in Figure 2. According to "dock repair - minor repair - dock repair - medium repair" mode, there are five dock maintenances, two minor maintenances and two medium maintenances. Each task time is about 30 months. Dock repair time is about 3 months; minor repair time is about 6 months, and medium maintenance time is about 12 months.

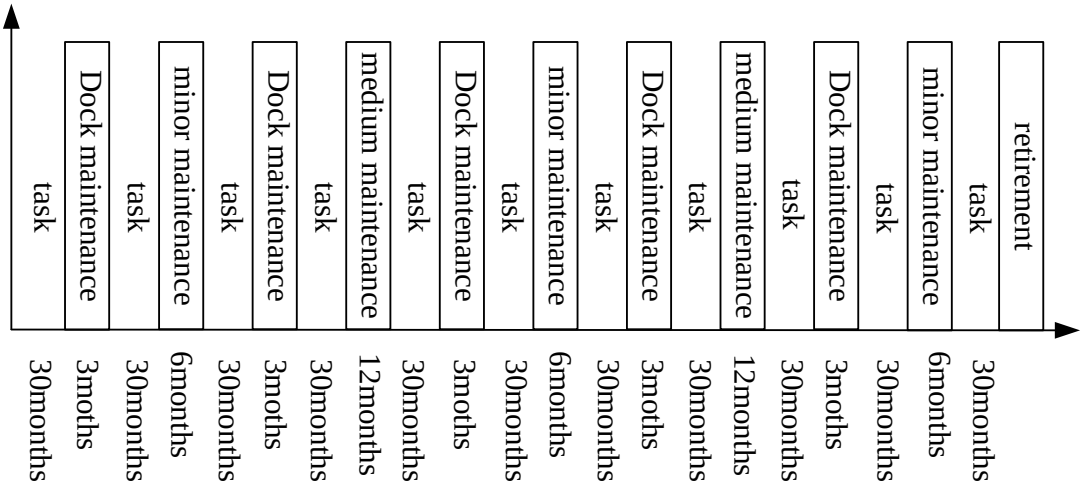

Fig.2 Life profile of the ship

Main diesel engine alternatives

The power of single main diesel engine is about 4000 horsepower, or about 3000 kilowatts. Considering the redundancy factor 10%, the power of single main diesel engine can be about 3300 kW. According to the investigation, three kinds of main engine is described in Table 1.

Tab.1 Basic parameters of main diesel engine alternatives

Parameter Name	Scheme 1	Scheme 2	Scheme 3
Maximum continuous power (kW)	3460	3300	3300
Fuel consumption rate (g/kWh)	185	188	190
Fuel consumption (g/kWh)	0.7	0.8	0.9
MTBF (h)	3000	2000	1500
The cost of the average maintenance time (yuan)	10000	8000	8000
MTTR (h)	20	20	20
The host machine overhaul interval (year)	10	8	8
Average cost of The host machine overhaul(ten thousand yuan)	46	32	35
Acquisition expenses of whole system(ten thousand yuan)	2450	2000	1800

Life cycle cost estimation results

Calculation result of three schemes is listed in Table 2.

Tab.2 Life cycle cost in three schemes

Parameter Name	Scheme 1	Scheme 2	Scheme 3
Maximum continuous power (kW)	3460	3480	3500
Fuel consumption rate (g/kWh)	185	188	190
Fuel consumption (g/kWh)	0.7	0.8	0.9
MTBF (h)	3000	2000	1500
The cost of the mean maintenance time (yuan)	10000	8000	8000
MTTR (h)	10	10	10
The main engine machine overhaul interval (year)	10	8	8
Average cost of The main engine machine overhaul(ten thousand yuan)	46	32	32
Acquisition expenses of whole system(ten thousand yuan)	2450	2000	1800
Loss cost of per hour caused by main engine down (yuan per hour)	92267	92800	93333
Annual average working time of the ship (h)	2000	2000	2000
Working cost(ten thousand yuan)	70881	72765	74292
Temporary maintenance cost(ten thousand yuan)	26	31	41
Plans to overhaul cost(ten thousand yuan)	219	224	246
The total maintenance cost(ten thousand yuan)	245	255	287
Loss cost(ten thousand yuan)	2030	3062	4106
Expenses recovery(ten thousand yuan)	-267	-218	-196
LCC(ten thousand yuan)	75339	77864	80289

In Table 2, the following conclusions can be drawn: The purchase cost in Scheme 1 is the largest, more than the purchase cost of Scheme 2 4.5 million yuan, more than the purchase cost of plan 3 6.5

million Yuan; Life cycle cost of Scheme 1 is 753.39 million yuan, less 25.25 million Yuan than Scheme 2, less 49.5 million yuan than Scheme 3. According to the estimation results, the design department sets up the main diesel engine selection scheme for ship-owners based on Scheme 1.

Summary

This paper constructed the life cycle cost model of ship's main diesel engine, and the model was applied to main diesel engine selection of one ship. The case shows that the scheme with the least initial investment is not necessarily the one with the minimum life cycle cost, and the scheme with the largest initial investment is not necessarily the scheme with the maximum life cycle cost. By life cycle cost technology, the scheme with minimum life cycle cost can be obtained. Life cycle cost technology is a powerful tool for scientific decision-making, which is worth popularizing in ship design and development stages and application.

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