Comparative of Feasibility Study Between Diesel Mechanical Propulsion System and Combination of Diesel Engine and Electric Motor Propulsion System on Offshore Patrol Vessel (OPV) 80 m

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Abstract. The modern offshore patrol vessel is designed to carry out various missions in the management of economic exclusion zones, thus having some speed of service. For example, the speed for slow patrol is 10 knots, regular patrols 18 knots and chasing 22 knots. This condition requires a flexible propulsion system, which is combination of mechanical and electrical propulsion system. The application of this propulsion system to the OPV can increase the load factor of the propulsion system, resulting in lower fuel consumption than when using a mechanical propulsion system. Based on feasibility analysis results, the choice of combination of mechanical and electrical propulsion system is more advantageous than mechanical propulsion system, although investment and maintenance cost is higher. Therefore, patrol boats should use combination of mechanical and electrical propulsion system.

1 Introduction

Offshore patrol vessels (OPV) have multiple functions, namely military and civilian. Therefore, OPV's weapon system is not as sophisticated as the KCR ship. In the framework of development of Minimum Essential Force (MEF II), the government plans to build 2 OPV vessels of 80 m. The type of OPV vessel propulsion offered by Dutch DAMEN and French DNCS uses a mechanical propulsion system. [1]

The OPV vessel has operational areas in the exclusive economic zone (EEZ) to monitor illegal activities, such as infiltration of foreign troops, illegal fishing, pirate handling, smuggling, and illegal immigrants, handling of marine accidents / oil spills, border controls and other similar activities [2]. Based on this function, the OPV vessel operates under various speed conditions, i.e. surveillance (10 knots), patrols (18 knots), and interception (22 knots).

The CODAE propulsion system is a dynamic combination of diesel mechanic propulsion (DMP) system and diesel electric propulsion (DEP) systems. This system has four propulsion modes: shaft motor, shaft generator, mechanical, and booster modes [3-9]. These various propulsion modes could adapt to meet the requirement of the various OPV 80 m's operation condition. Such propulsion system is worth considering to be applied to the OPV 80 m due the operational flexibility it offers.

This paper presents a configuration layout and specification of the CODAE propulsion system applied as well as the comparison between the DMP and CODAE systems in terms of both technical and economic aspects.

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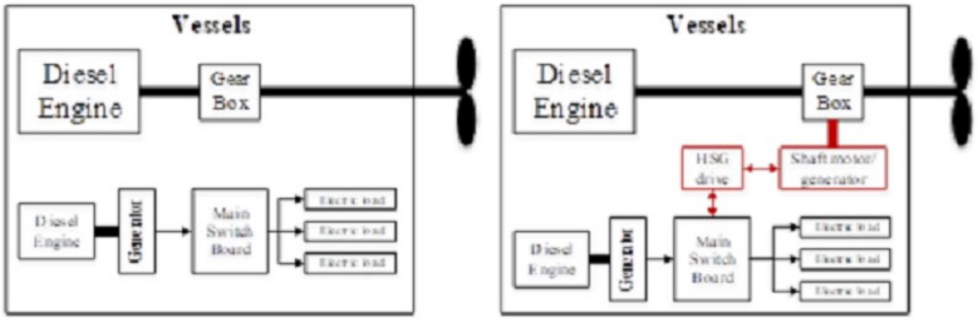
2 The CODAE Propulsion System

Basically, the propulsion system used on ships can be classified into three types, namely mechanical, electrical and combination of them. A propulsion system is a combination of mechanical and electrical propulsion systems, that is called by hybrid propulsion system or combination of diesel mechanic or electric (CODAE) propulsion system. Therefore, the CODAE system can operate as a mechanical, electrical or mechanical and electrical combination system [3-9]. Selection of operating mode on a CODAE propulsion system is adjusted to the existing propulsion power requirement, so that it can maintain to operate at optimal conditions.

A CODAE propulsion system that also uses shaft generator is referred to as a CODAE propulsion system, therefore the system has four operational modes. The four operational modes are electric, power take off/shaft generator, mechanic and hybrid (CODAE) modes. Where the selection of suitable mode is based by fluctuations in the propulsion power and electric power are needed.[4] Figure 1 shows the difference between the mechanical propulsion system and CODAE propulsion system, where the difference lies in the shaft generator / motor and hybrid shaft generator (HSG) drive.



a. Diesel Mechanical Propulsion system b. CODAE propulsion system

Fig 1. DMP and CODAE propulsion system [6]

In general, OPV patrol boats use diesel mechanical propulsion systems, due to their simplicity and reliability. Since OPV ship missions have been increasingly variable, the conventional propulsion system is less suitable. Therefore, the CODAE propulsion system is one of the replacement candidates, in addition to the electrical propulsion system. As mentioned in the above paragraph, the mechanical propulsion system can be a CODAE propulsion system in the presence of a generator / motor shaft and HSG controller.

3 The Feasibility Study of Ship Propulsion System

The feasibility study is a major study to decide whether a project is implemented, suspended or terminated. The review is conducted by reviewing various aspects, such as legality aspect, technical aspect, marketing, social economy, economics and management and finance. In this paper, the comparison of feasibility analysis between the use of mechanical propulsion system and CODAE on the OPV patrol boat is only viewed from the technical and economic aspect. The purpose of the technical aspect is determination of propulsion and electric system configuration for both DMP and CODAE for the OPV 80 m. The economic aspect includes comparing total investment cost, fuel consumption cost, and maintenance cost between the use of both propulsion systems. The result of comparison is a break even point (break event point).

Tables 1. Operational Profile of OPV 80 m

No.	Operation conditions	Vs [knot]	Propulsion Power (kW)	Electrical Power (kW)	Duration [hour/year]
1	*At port*	-	0	873	3504
2	Loitering	10	645	1021	1577
3	Patrol	18	3921	1110	2102
4	Interception	22	7637	1129	1577

3.1 Technical Aspect

The configuration of OPV's propulsion system is obtained based on OPVs' operational profile. The OPV's operation profile is as shown in Table 1, there are four operation conditions with different speed. In accordance with the need for propulsion power and electrical power under each operating condition of the vessel, the engine propeller matching (EPM) analysis, and generator capacity analysis are performed. There are three main purposes of EPM analysis, first, the full power of the main engine can be developed or almost full power. Secondly, the propulsion plant will function satisfactorily in all designs and design conditions. Third, the main engine operates on the best fuel consumption. The result of both analyses for DMP and CODAE propulsion system is presented in Table 2.

Tables 2. Component of DM and CODAE Propulsion System

No	Component	DM Propulsion Systems	CODAE Propulsion System
1	Main Engine	**2** MTU 20V4000 M93L, 4300kW, 2100 rpm	**2** MTU 20V4000 M73L, 3600kW, 2050 rpm
2	Auxiliary Engine	**4** CAT C18 ACERT, 450 kWe, 1500 rpm, 380VAC.	**4** KOHLER KD800-YF, 720 kWe/900 Kva, 1500 rpm, 400VAC.
3	Propeller	**2** Wageningen B4.65, D=1,83 m, P/D 0.852, η_0=0.569	**2** CPP B 4.55, ∅ 1,6 m, *P/D* 0,5-1,4
4	Gear box	**2** Single input & output, ratio 3:1	**2** ZF 24060 D PTI, 4615 kW/2050 rpm, single input & double output (1:1 & 2.577:1). 2650 kg
5	Shaft motor/ generator		**2** ABB M3BP 355 SMC4, 400 VAC, 616 A, 355 kW, 50 Hz, 1487 rpm, 2280 Nm
6	HSG drive		**2** ABB ACS850-04-650A-5, 3 phase, 355 kW, 380~500 VAC, 650 A

3.2 Economic Aspect

3.2.1 Investment Cost

The investment cost of a propulsion ship system OPV 60 m is the cost that must be incurred by the ship owner to build or modify the ship's propulsion system. This cost includes the components of the configuration of each type of propulsion system. The components of the mechanical propulsion system and CODAE refer to Table 2, which consists of main engine, auxiliary engine, propeller, gear box, generator shaft / motor and HSG drive.

Generally, the investment cost of each component of the ship propulsion system is based on the power capacity. For investment cost of diesel engine as main driver of ship besides influenced by big power factor, hence congress type conguration and bore size also have an effect. For example, the investment cost of an inline diesel engine is higher than that of a V-line diesel engine. In addition, the investment cost of V-line diesel engines decreased along with the increase in bore size. Table 3 summarizes the prices of ship propulsion system components.

Tables 3. Comparasion of investment cost between DMP and CODAE Propulsion System

No	Component	DMP Propulsion Systems	CODAE Propulsion System
1	Main Engine	€ 2.924.000,-	€ 2.448.000,-
2	Auxiliary Engine	€ 720.000,-	€ 1.152.000,-
3	Propeller	€ 860.000,-	€ 791.000,-
4	Gear box	€ 598.000,-	€ 609.500,-
5	Shaft motor/generator		€ 95.850,-
6	HSG drive		€ 56.000,-
Total of investment cost		€ 5.102.000,-	€ 5.133.720,-

3.2 Fuel Consumption Cost

In general, the largest component of ship operating costs is fuel costs (Wijayanto, 2011). One of the factors affecting the fuel cost of a ship is load factor of main engine and auxiliary engine. Operation of main engines and auxiliary engines at high load factor conditions have lower SFOC than operating at low load factor. OPV vessels operate at some service speed according to their mission, so the load factor varies. The comparison of fuel consumption between the application of mechanical propulsion system and CODAE according to the operational profile of OPV 80 m in Table 4.

Tables 4. Fuel consumption based on OPV profile

Operation mission	Speed (knot)	Duration (hour/year)	DMP propulsion system		CODAE propulsion system	
			Main engine	Aux engine	Main engine	Aux engine
Harbouring	-	3500	-	998 ton	-	645 ton
Surveillance	10	1550	288 ton	445 ton	-	571 ton
Patroling	18	2100	1836 ton	593 ton	2040 ton	245 ton
Chasing	22	1550	2212 ton	445 ton	2204 ton	605 ton
Total of fuel consumption			6817 ton/year		6309 ton/year	

3.3 Maintenance Cost

The cost of maintaining a patrol boat propulsion system includes all costs incurred for maintenance and repair of the propulsion system, including maintenance costs of the main engine, diesel generator set, CPP, gearbox, frequency converter, and generator / motor shaft. Maintenance cost of each component is primary data obtained through direct interview with the expert from the engine distribution's company, shipyard, and shipping company as owner and / or ship operator. The result of interview may be tabulated in Table 5 and Table 6.

Table 5. Maintenance and spare part replacement cost of diesel motor

Diesel motor	Type of maintenance	Maintenance cost	Replacement cost of spare part
Main engine: 3440 kW, 2100 rpm	Top Overhaul	Rp 960.000.000,-	Rp 3.602.000.000,-
	General Overhaul	Rp 1.601.000.000,-	Rp 6.003.000.000,-
Diesel generator: 565 kW, 1500 rpm	Top Overhaul	Rp 143.000.000,-	Rp 792.000.000,-
	General Overhaul	Rp 187.000.000,-	Rp 1.322.000.000,-
Diesel generator: 846 kW, 1500 rpm	Top Overhaul	Rp 175.000.000,-	Rp 1.189.000.000,-
	General Overhaul	Rp 292.000.000,-	Rp 1.983.000.000,-

Tabel 6. Maintenance cost of electric motor based on spesification and the level

Spesification of electric motor	Level	Hour operating	Recondition cost
400 kW; 400 Volt; 1500 rpm; 50 Hz;	L1	10.000	Rp 6.500.000,-
	L2	20.000	Rp 6.500.000,-
	L3	40.000	Rp 36.000.000,-
	L4	80.000	Rp 68.000.000,-
700 kWe; 400 Volt; 1500 rpm; 50 Hz;	L1	10.000	Rp 9.500.000,-
	L2	20.000	Rp 9.500.000,-
	L3	40.000	Rp 57.000.000,-
	L4	80.000	Rp 89.000.000,-

The amount of labor honor for the maintenance of one unit of perporosan system based on field data in a shipyard in Surabaya is Rp. 23.343.750, -. In general, shaft system maintenance should replace three packings, where the price per unit is Rp 2.500.000, -. This replacement is done when the ship does General Overhaul 5 years.

4 Break Event Point

Break Even Point (BEP) between mechanical and hybrid propulsion systems is a point where the sum of investment costs and operational costs are both the same. The length of time to reach Break Even Point can be used to make changes to the ship propulsion system or not. Break Even Point calculations require basic calculation components such as the following:

1. Fixed Cost. In the ship propulsion system investment, this component is a fixed or constant cost.
2. Variable Cost. In the ship propulsion system investment, the dynamic cost components depend on the ship's operational profile. If the ship's operational length and speed increase, then the variable cost increases. Examples of these costs are the cost of fuel consumption, maintenance costs and replacement cost of spare parts.
3. Selling Price. This component in the ship propulsion system changes is an advantage that can be obtained due to changes in the propulsion system.

In this analysis, there are only two component of BEP to be considered, that is fixed and variable costs. The fixed cost is investment cost of the propulsion system. The investment cost includes purchasing and installation costs of components of both the propulsion systems. Variable cost includes fuel consumption costs dan all maintenance cost , both costs are time dependent. Figure 2 is the result of BEP analysis, where the BEP can be reach less than one year.

Conclusions

As shown in Table 2, the main differences between DMP and CODAE for OPV's 80 are reductions of main engine power and increase the diesel generator power capacity. The use of electric motors as the propulsion of ships under surveillance conditions can reduce the fuel consumption is very large. Operation of diesel motors on low load factors (15%) results in high fuel consumption (300 gr/kWh). The difference in investment cost between DMP and CODAE propulsion system is not much different, compared to when using electric propulsion system. Therefore, the BEP between using a mechanical propulsion system into a CODAE propulsion system can be achieved in less than a year. Therefore, in the future, the use of CODAE propulsion systems on patrol boats is highly recommended.

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References

[1] A. D. Firmansyah, et al.,"Perancangan*controllable pitch propeller* pada kapal *offshore patrol vessel* 80 (OPV80)," Jurnal Teknik ITS, vol. 1, no. 1, pp. G230 – G231, Sept. 2012.
[2] M. J. Underwood, "Patrol boats: aworldmarket overview,"Marine Technology, vol. 33, no. 2, pp. 101 – 107, Apr. 1996
[3] Koenhardono, E.S., "Neural Network-Based Engine Propeller Matching (NN-EPM) for Trimaran Patrol Ship", in Applied Mechanics and Materials Vol. 493 (2014) pp 388-394.
[4] D. Wahyudi, "Hybrid Propulsion Sistem (DMP & DEP) for Trimaran Type Fast Patrol Boat", SENTA Conference, Surabaya 2009.
[5] Koenhardono, E.S., "Perencanaan Konfigurasi Sistem Propulsi Hybrid Pada Kapal Patroli Trimaran", SENTA Conference, Surabaya 2012.
[6] B. Kwasieckyj,"Hybrid propulsion systems: efficiency analysis and design methodology of hybrid propulsion systems," TU Delft, SDPO.13.008.m, March 2013.
[7] Koenhardono, E.S., "Selection of propulsion systems for naval patrol trimaran vessels between the hybrid shaft generator and mechanical propulsion system", SENTA International Conferenece, Surabaya, 2016.
[8] Koenhardono, E.S., "Applications of Hybrid Propulsion System on Trimaran Tourist Vessels that Reliable and Environmental Friendly", SENTA International Conference, Surabaya 2017.
[9] Koenhardono, E.S., "The Study of the Application of Hybrid Propulsion System on OPV with Controllable Pitch Propellers", IJMEIR, Vol. 1(4), Sept. 2017. 346-354.