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FEASIBILITY ANALYSIS OF REPOWERING LANDING PLATFORM DOCK CLASS WITH ELECTRIC PROPULSION MOTORS

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ABSTRACT

The Indonesian Naval War Ship of Landing Platform Dock (LPD) class is a ship that has the main task as a base ship and personnel carriers, combat vehicles, tactical vehicles, helicopters and limited medical evacuation as elements of the Navy in maintaining and upholding the sovereignty of the Republic of Indonesia. To support this, of course, LPD vessels must have reliable and strong performance and capabilities. One effort to achieve this is by repowering the propulsion system on the ship using an azipod type propulsion electric motor (PEM), so as to increase the effectiveness and efficiency of ship operations, because the use of the PEM system is a sophisticated and modern propulsion system, fuel efficient, environmentally friendly (low emissions), low noise, and low vibration. This is an important requirement to realize the LPD Indonesian Naval War Ship which is superior in carrying out operations. In this study, the author will take a case study on Indonesian Naval War Ship Banjarmasin-592 by carrying out resistance calculations, calculating total electrical power requirements, selecting prime movers, selecting diesel generators, calculating the comparison of specific fuel oil consumption (SFOC) and emissions between PEM and PDE, selection of propulsor (azipod), and redesign of engine room layout after using PEM. Based on the results of the analysis, it is known that fuel consumption and emissions from the PEM system on LPD ships for one year of operation can save fuel by 3.7% and reduce emissions by 38.5%, so as to increase endurance in carrying out shipping and reduce air pollution. In addition, in terms of room space, the application of the azipod-type PEM system is 10% more efficient and profitable because there is an elimination of several existing components of the PDE system. The planning for repowering the propulsion system is expected to be a consideration in the development of the next LPD / SSV class Indonesian Naval War Ship, as well as the PEM system can be implemented in the construction of other class Indonesian Naval War Ship.

Keywords: *Azipod, LPD, PEM, Repowering, SFOC.*

1. INTRODUCTION

The Navy Ship Landing Platform Dock (LPD) type is a support ship or support in the implementation of a military operation. This LPD ship has the function to support Landing Platform Dock (LPD) / Landing Ship Dock (LSD) operations, Amphibious Operation / Amphibious Assault Vessel, Operation Manouver From The Sea (OMFTS), Tank Troop Carrier (Ferry Role), Primary Casualty Receiving Ship (PCRS), Disaster Relief Operation (DRO) / Civic Mission, and Helicopter Platform. In addition, this LPD ship has the main task of being a base ship and personnel carrier, combat vehicles, tactical vehicles, helicopters and limited medical evacuations that have Docking Undocking capabilities to project power from sea to land through the Landing Craft Utility (LCU) floating vehicle. as an element of the Navy in maintaining and upholding the sovereignty of the Republic of Indonesia. To support these main functions and tasks, as well as efforts to maintain national defense stability, of course, LPD ships owned by the Indonesian Navy must have reliable and strong performance and capabilities. Therefore, one of the efforts to improve the reliability and toughness of LPD ships is to improve the performance of the propulsion system on the ship, so that the ship can operate at the expected speed (Mochamad Guruh GS, 2016). In an effort to improve the efficiency of the LPD ship propulsion system, the author will plan repowering the ship's propulsion system which in this case is a case study on Indonesian Naval War Ship Banjarmasin-592 using Propulsion Electric Motor (PEM).

Propulsion Electric Motor (PEM) is a type of ship propulsion system that utilizes electrical energy from a diesel generator to rotate an electric motor, so that it can move the propulsion system or propeller on the ship. In today's modern era, PEM is widely used in the maritime/shipping technology industry, especially in military technology in this case

Volume 14, Number 03, pp.71-86
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warships. In its application, PEM provides many advantages, such as ease and suitability in setting the propeller rotation speed and direction of rotation, the control system can be controlled remotely by the operator, the redundancy of power engine production is doubled to generate power in this case the electric power supply. flowed continuously and together by several generator sets so that variations in power can be generated faster, the flexibility of the engine room design that allows to separate the propulsion motor from the main drive so that it saves more on dimensions (size, space and weight) in laying components, fuel efficiency due to the high and uniform loading of electric propulsion results in this system producing better performance for heat recovery and the engine working at the most optimum point of fuel efficiency, low noise and vibration levels due to t without a main engine and gearbox as well as a good layout of engine components, lower pollution impacts due to reduced exhaust emissions from the main engine, more efficient distribution of power efficiency.

2. LITERATURE REVIEW

2.1 AC Electric Motor

AC Electric Motor is an electric motor that uses an AC power source to rotate the rotor on the motor. An AC electric motor has two main electrical parts, namely the stator and the rotor. The stator is a component of static electricity. The rotor is a rotating electrical component to rotate the motor shaft. One of the disadvantages of AC motors is that the speed of the motor is more difficult to control. To overcome this disadvantage, AC electric motors can be equipped with variable frequency drives to increase speed control while reducing power (Riasty Purwandari, 2010). In use, unlike DC electric motors which require a rectifier, this AC electric motor can function immediately. In ship operation, the use of an AC electric motor for PEM uses a variable frequency in speed regulation. In today's modern era, there are technological innovations in regulating these frequencies including the following:

a. Stadt Lean Drive is the latest technological innovation where the speed regulation of the AC electric motor does not use electric pulses as in the DC PWM Converter, but directly uses the AC sine wave setting by paying attention to the incoming voltage and current.

b. Pulse Width Modulation (PWM) is a variable frequency setting by changing the waveform of an AC power source, so that it can affect the speed of an AC electric motor. In its use, this PWM uses DC power assistance which is used to supply the converter.

2.2. PEM of Azipod Type

This PEM of azipod type is almost the same as the azimuth thruster type electric motor propulsion system, that is, there is an azimuth podded vertical position to move the propeller. The difference is that the position of the electric motor on the azipod is inside the propeller pod construction and the axis becomes one with the propeller, so that the electric motor is outside the hull of the ship. While the position of the electric motor on the azimuth thruster is in the hull of the ship. In addition, the azipod type does not use a horizontal shaft. In this azipod, as with the azimuth thruster, the propeller can rotate 360° around the vertical axis, so it has superior maneuverability in terms of ship maneuvers. The schematic of the PEM of azipod type system can be seen in Figure 1 below.

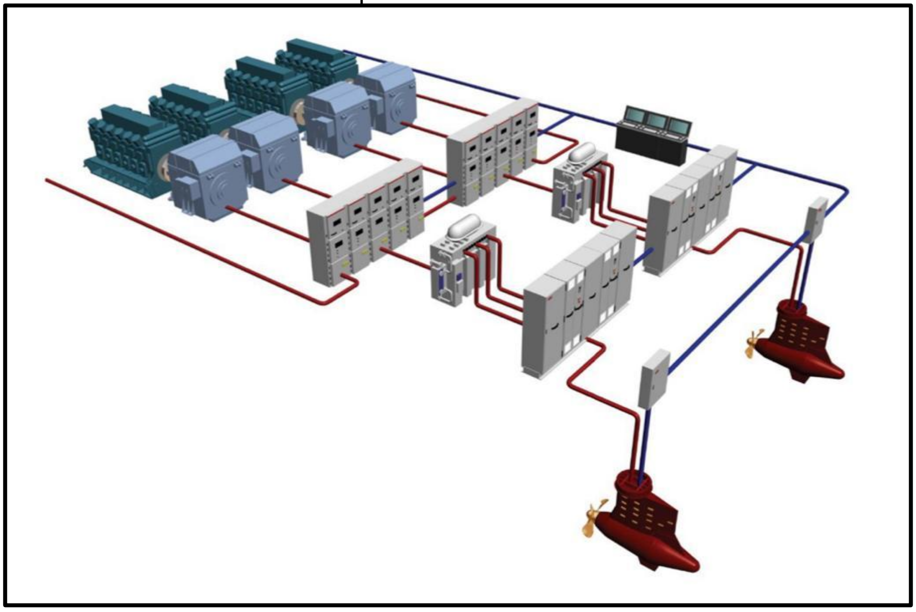

Figure 1. PEM of Azipod Type

Volume 14, Number 03, pp.71-86
ISSN: 2460-7037
E-ISSN: 2722-5763

2.3. Ship Hydrostatic

Hydrostatic ship is one element that is needed in planning ship design. Ship hydrostatics are generally depicted in the form of hydrostatic curves to full draft and do not apply to trim ship conditions. This hydrostatic curve diagram shows and explains the shape and characteristic properties of the hull below the waterline for each increase in draft or until full load (Amirul Karman, 2018). There are many curves in the hydrostatic curve diagram which are the hydrostatic parameters. The hydrostatic parameters are as follows :

- Volume Displacement (m^3)
- Ton Displacement (ton)
- Water Area (Aw) (m^2)
- Midship Area (Am) (m^2)
- Ton per Centimeter (TPC)
- Coefficient of Block (Cb)
- Coefficient of Prismatik (Cp)
- Coefficient of Vertical Prismatic (Cvp)
- Coefficient of Waterplane (Cw)
- Coefficient of Midship (Cm)
- Longitudinal Centre Buoyancy (LCB)

2.4 The Guldhammer-Harvald Method of Ship Resistance

The ship's resistance is a force that prevents the ship from moving through a fluid in the opposite direction to the ship's motion. The value of the ship's resistance force is needed to calculate the thrust required by the ship to pass the fluid at the desired speed. In calculating the ship's resistance and power, there are several methods, one of which is the Guldhammer-Harvald method. This method is a commonly used method in calculating ship resistance and power. In calculating ship resistance using this method, one of the things that must be considered is the sea margin. Where this sea margin serves as an interpretation of the condition of the ship while at sea (service). There are several sea margins from this method, namely, among others, North Atlantic shipping lanes to the East (15% summer and 20% winter), North Atlantic shipping lanes (20% summer and 30% winter), Pacific shipping lanes (15-30%), South Atlantic and Australian shipping lanes (12-18%), East Asian shipping lanes (10-20%), and Southeast Asian shipping lanes (10-15%).

In the Guldhammer-Harvald method, the total resistance of the ship is broken down into several components or types of resistance, namely frictional resistance, wave resistance, additional resistance (appendage resistance, air resistance, steering resistance), residual resistance, and other prisoners. To calculate the total resistance, the coefficient of total resistance and wet surface area must be calculated first using the following equation (Sv. Aa. Harvald, 1983).

$$C_t = C_r + C_f + C_A + C_{AA} + C_{AS}$$

$$S = 1{,}025\, L\, (\,\delta \times B + 1{,}7\, T\,)$$

$$R_{total} = \tfrac{1}{2}\, \rho C_t\, S V^2$$

Where;

ρ = Density of seawater (Kg/m2)
V = Ship speed (m/s)
C_t = Total resistance coefficient
S = Wet surface area (m^2).

2.5 Main Propulsion of Ship

Electric Motor use the same principle in calculating the ship's power and performance of the propulsion engine, because both use the same energy source and working principle of the engine. The thing that distinguishes the two is the media in the propulsion system such as the shafting arrangement, which of course makes the performance value of the propulsion engine different.

a. Effective Horse Power (EHP)

EHP is the power needed to move the ship at a certain speed in a state of the hull that is not completely smooth or ideal for fluid friction.

$$EHP = R_T\, Vs$$

b. Delivered Horse Power (DHP)

DHP is the power that has been absorbed by the propeller through the shaft which will then be used by the propeller to generate thrust.

$$DHP = EHP / P_C$$

The value of Pc (propulsion coefficient) can be calculated by multiplying hull efficiency, rotative relative efficiency, and propeller efficiency in open water test (open water efficiency).

$$Pc = \eta H \times \eta rr \times \eta Po$$

c. Thrust Horse Power (THP)

THP is the thrust of the propeller against the water.

$$THP = EHP / \eta H$$

d. Shaft Horse Power (SHP)

SHP is the driving force of a shaft on the ship.

$$SHP = DHP / \eta s \eta b$$

e. Break Horse Power (BHP)

BHP-scr is the power value of the motor drive in a continuous service rating condition which in this case relates to the gear reduction used. Ships that use reduction gear, will have losses in the transmission gear system (ηG) determined at 2%. If the ship does not have a reduction gear, the losses are considered to be 0%.

$$BHP_{scr} = SHP / \eta G$$

BHP-mcr is the maximum output power of the driving motor which in this case is assumed to be 80-85% of the BHP-scr.

$$BHP_{mcr} = BHP_{scr} / 0{,}85.$$

Volume 14, Number 03, pp.71-86
ISSN: 2460-7037
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2.6 Specific Fuel Oil Consumption (SFOC)

International agreements are one of the SFOC is the amount of fuel mass required by an engine for each unit of power and time at a certain load and rotation.

$SFOC = m_{bb}/(Ne \times t)$ (kg/kWh)

SFOC = Spesifik fuel oil consumption (kg/kWh)

$〖Ne〗_{msn}$ = engine power (kW)

t = time (detik)

m_{bb} = amount of fuel (kg) = Vg x ρ.

2.7 Electric Motor Propeller Matching (EPM)

A comprehensive discussion of human rights is propeller and electric motor have been obtained. At this stage, the electric motor and propeller will then be matched to obtain the optimum electric motor power selected for the propeller. In other cases, if the propeller and electric motor do not match, then the optimum power of the electric motor will not be able to be utilized optimally by the propeller.

In this calculation, known data such as Speed of Advanced, propeller rotation, propeller dimensions, and other related data, will later be used to calculate several variables related to the EPM calculation. For example, to calculate the coefficient , to read the KT KQ J diagram, and to find the final propeller power and RPM after matching.

2.8 Software Maxsurf

Maxsurf software is software that is used to analyze hydrodynamic phenomena that occur in the ship's hull. The tests that can be done on this Maxsurf software include testing ship resistance, ship hydrostatics, ship stability and ship motion.

a. Maxsurf Modeler

Maxsurf modeler is part of the maxsurf software which is used to design the ship's hull and set the direction of the planned line position on the ship and determine the distance. The output of the hull design process in the maxsurf modeler is in the form of a hull shape with a surface msd format, where from this surface the hydrostatic characteristics of the ship can be known such as ship draft, displacement, hull coefficient, and submerged area. Maxsurf software is a special software for ship design and analysis.

b. Maxsurf Resistance

Maxsurf resistance is part of the maxsurf software which is specifically used to analyze the value of the resistance of a ship based on the planned speed and draft. The output of this maxsurf resistance is in the form of the value of the ship's froude number, the value of the ship's resistance and the estimated ship power requirement (effective horse power) used to move the ship according to the desired ship speedt.

3. RESEARCH METHODS

The design in this study uses a mixed type of qualitative and quantitative research with case study methods, where the authors want to know the results of the design and analysis of repowering using the PEM system which is implemented on the LPD class Indonesian Naval War Ship based on ship speed parameters, including the value of fuel consumption and design. engine room layout in accordance with the characteristics of the PEM system to determine the efficiency of space in the engine room. Then the results of the numerical calculation analysis will be validated and compared with existing ship data and laboratory scale test results.

4. RESULTS AND DISCUSSION

4.1. Making LPD Hull Model Using Maxsurf Modeler

In the process of making the LPD hull model, there are several steps or stages that must be carried out. These stages are closely related and cannot be separated from each other. Making this model is done by paying attention to the step by step, which starts from determining the coordinates obtained from the initial data in the form of a Indonesian Naval War Ship lines plan for LPD / SSV class. The initial stage to process the initial data into a three-dimensional model that is ready to be tested is by redrawing the lines plan using the Maxsurf modeler software. The line plan image of the Indonesian Naval War Ship LPD / SSV class can be seen in Figure 2 below.

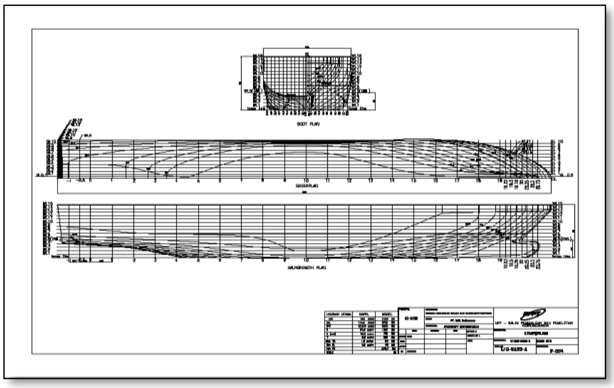

Figure 2. Lines Plan of Indonesian Naval War Ship LPD / SSV Class

Volume 14, Number 03, pp.71-86
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By redrawing using the maxsurf modeler software in accordance with the ship's lines plan data that has been obtained, it is hoped that the three-dimensional LPD hull model created using the maxsurf modeler software will be the same as the original ship. In the maxsurf modeler software, 4 models of the LPD ship design images that have been created will be displayed, namely profile, plan, bodyplan and perspective views. The general description of the maxsurf modeler software display from the LPD hull model is shown in Figure 3 below.

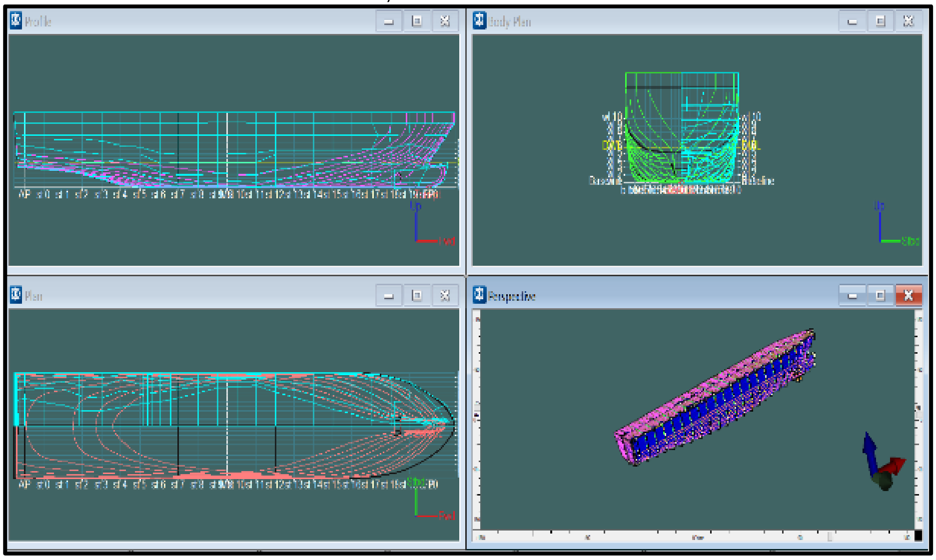

Figure 3. Hull Model LPD

4.2 LPD Ship Resistance Analysis Using Maxsurf Resistance

The calculation of ship resistance using maxsurf resistance software has been widely used in the shipping world. Maxsurf resistance software is one of the facilities from maxsurf that can be used to predict and estimate ship resistance. Several regression-based methods and one analytical method were used to predict the hull shape resistance. Maxsurf resistance can calculate the component of ship resistance in the form of coefficients, but not all components of ship resistance are available. This is because the method used is different, so it will be different to the applied formulation. In this study, the maxsurf resistance software used to carry out the analysis of LPD ship resistance is using the Holtrop method. Because in this Holtrop method, there is a specific formula that is more detailed in dividing the types of ship resistance. The division of ship resistance contained in the Holtrop method is the frictional resistance of the hull submerged in water, wave resistance, air resistance, and residual resistance.

The initial stage in the process of calculating the ship's resistance is entering the LPD hull model data that has been made on the maxsurf modeler into the maxsurf resistance, then the running process is carried out. In this running process, the speed simulation parameters used are several speed variables, namely at economical speed, cruising speed and maximum speed of LPD ships, which range from 12 to 16 knots fast. The running process and the resulting graph in calculating the total ship resistance using the maxsurf resistance software can be shown in Figures 4 and 5 below.

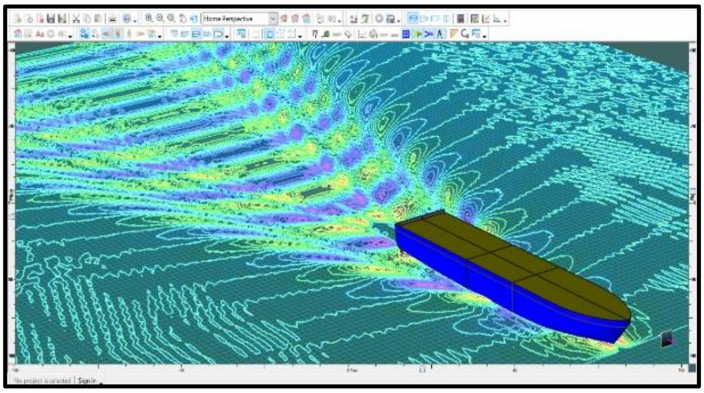

Figure 4. Maxsurf Resistance Running Process

Volume 14, Number 03, pp.71-86
ISSN: 2460-7037
E-ISSN: 2722-5763

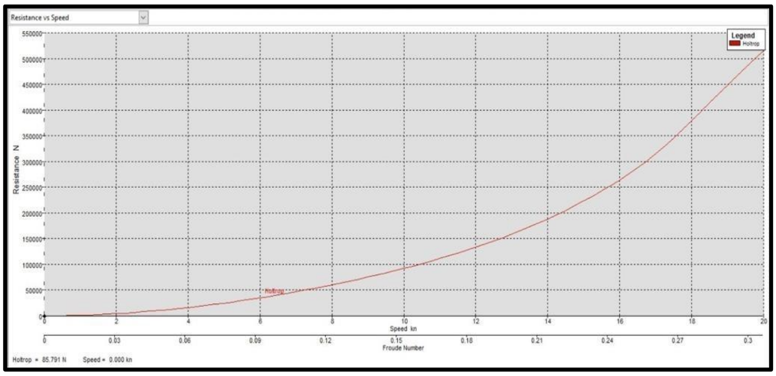

Figure 5. Graphics of Maxsurf Resistance

The results of the calculation of the total resistance of the LPD ship using maxsurf resistance on several speed variables are as follows.

Table 1. LPD Ship Resistance Value Using Maxsurf Resistance

Speed (Vs)	***Maxsurf Resistance* (*Holtrop*)**
(knot)	***Resistance* (kN)**
12 (Economical)	133,3
12,5	145,4
13	158,6
13,5	172,8
14 (Cruise)	188,3
14,5	205,1
15	223,3
15,5	242,8
16 (Maximum)	264,1
16,5	288
17	314,9
17,5	345,3
18	378,6

4.3 LPD Ship Resistance Analysis Using Numerical Calculations Guldhammer-Harvald Method

The following is an analysis of the calculation of LPD ship resistance using the PEM of azipod type system with the Guldhammer-Harvald method.

Calculation of displacement volume (▼) :

It is known that the general data of LPD ships are:

Lwl = 114,6 m
B = 21,8 m
T = 5 m
Cb = 0,809

Vol. disp. = Lwl×B×T×Cb
= 114,6 m×21,8 m×5 m×0,809
= 10105,5426 m^3

Calculation of displacement (Δ) :

Density of seawater (ρ) = 1,025 ton/m^3

Volume displacement (▼) = 10105,5426 m^3

Disp. = ▼ ×ρ air laut
= 10105,5426 m^3×1,025 ton/m^3
= 10358,1812 ton

Calculation of wet surface area (ς) :

It is known that the general data of LPD ships are:

Lpp = 107,49 m
B = 21,8 m
T = 5 m
Cb = 0,809

ς = ρ seawater×Lpp [(Cb×B) + (1,7 ×T)]
=1,025 ton/m^3 ×107,49 m [(0,809×21,8 m) + (1,7×5 m)]
= 3070,089 m^2

Determination of the Froude number coefficient (Fn) :

Where;

Volume 14, Number 03, pp.71-86
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Max. speed (Vs) = 16 knot = 8,23104 m/s (1 knot = 0,51444 m/s)
Gravitational acceleration (g) = 9,8 m/s^2
Lwl = 114,6 m
Fn = Vs⁄(g×Lwl)^0,5
= (8,23104 m/s)⁄〖(9,8 m/s^2 ×114,6 m)〗^0,5
= 0,24561188

Determination of the Reynolds number coefficient (Rn) :
Φ = 0,000001188 (kinematic viscosity of seawater at 15°C)
Rn = (Vs×Lwl)⁄Φ
= (8,23104 m/s×114,6 m)⁄0,000001188
= 794004363,63636

Determination of residual resistance coefficient (C_R) :
In determining the value of C_R (coefficient of residual resistance) from the Guldhammer-Harvald diagram, the coefficient of residual resistance is expressed as a function of the Froude number.
Where;
Lwl = 114,6 m
Volume disp. (▼) = 10105,5426 m^3
L/▼^(1⁄3) = (114,6 m)/(〖10.105,5426〗^(1⁄3) m^3) = 5,30
Prismatic coefficient determination (φ) :
ϕ = Cb⁄β
Where β = (0,08×Cb)+0,93 = (0,08×0,809)+0,93 = 0,9947
So that φ = 0,809⁄0,9947 = 0,813
ϕ = 0,813 and Fn = 0,246 is used to find C_R in the residual resistance coefficient diagram.
Where is the C_R value of L⁄▼^(1⁄3) = 5,0 (0,000880) and L⁄▼^(1⁄3) = 5,5 (0,0008) is obtained with reference to Fn and φ on the Guldhammer-Harvald diagram of the coefficient of residual resistance, as well as being the lower and upper limits of the results of the C_R determination. Meanwhile, the C_R value of L⁄▼^(1⁄3) = 5,3 is obtained by interpolation. The calculation of the interpolation ofC_R value of L⁄▼^(1⁄3) = 5,3 is as follows.
C_R (interpolation) = [1b+(2a-1a)×(3b-1b)]/((3a-1a))
= [0,00088+(5,3-5)×(0,0008-0,00088)]/((5,5-5))
= 0,00083
Due to the Guldhammer-Harvald diagram the coefficient of residual resistance is based on the ratio between the width (B) and draft (T) of the ship, namely B/T = 2,5. Then there is a correction to the C_R value, where B = 21,8 m and T = 5 m, so B/T = 4,36. C_R value for vessels that have a width-to-load ratio greater or less than that price must be corrected.
10^3 C_R=10^3 C_R(B/T=2,5) +0,16(B/T-2,5)
10^3C_R= 〖(10〗^3×0,00083)+0,16(4,36-2,5)
C_R=0,001129492

Determination of C_R value correction to LCB, namely:
LCB = e %×Ldisp
= 0,00654×114,6
= 0,749484
LCB in % = 0,007
Lwl = 114,6 m
LCB standart = LCB in %×Lwl
= 0,007×114,6 m
= 0,8022
Δ LCB = LCB-LCB standart
= 0,749484-0,8022
= -0,0527

Determination of the C_R correction caused by the ship's hull:
There is a boss propeller, so C_R is increased by 3-5%. In this calculation the maximum is taken namely 5%, so that:
C_R = (1+X%) C_R
= (1+5%)0,001129492
= 0,001185966
There are brackets and propeller shafts, so that C_R is increased by 5 – 8%. In this calculation, because the azipod propulsion system does not use brackets and propeller shafts, but there is a propeller pod whose position is vertical, the minimum is 5%, so that:
C_R = (1+X%) C_R
= (1+5%)0,001129492
= 0,001245264

Determination of frictional resistance coefficient (C_F) :
R_n = 794004363,63636
log⁡〖R_n 〗 = 8,8998229
C_F = 0,075/(log⁡〖R_n 〗-2)2
= 0,075/(8,8998229-2)2
= 0,00157538 (this C_F value applies at seawater temperature of 15°C)
As for the shipping area of Southeast Asia and its surroundings, the sea water temperature is 18°C, so the coefficient of frictional resistance is:
C_F = C_F standart×[1+0,0043(15℃-t)]
= 0,00157538×[1+0,0043(15℃-18℃)]
= 0,001555058

Determination of additional resistance coefficient (C_A) :
Additional resistance coefficient for LPD ship model correction, namely:
Lwl ≤ 100 m, 10^3 C_A = 0,4
then C_A = 〖0,4/10〗^3 = 0,0004
Lwl = 150 m, 10^3 C_A = 0,2
then C_A = 〖0,2/10〗^3 = 0,0002
While Lwl LPD ship= 114,6 m
So that the interpolation calculation is carried out: 10^3 C_A=0,4+[(Lwl-100m)×(0,2-0,4)/(150m-100m)]
= 0,4+[(114,6m-100m)×(0,2-0,4)/(150m-100m)]
= 0,0003416

Volume 14, Number 03, pp.71-86
ISSN: 2460-7037
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Determination of air resistance (C_AA) and steering resistance coefficient (C_AS):

C_AA = 0,006×(Lwl+100)^(-0,16)-0,00205
= 0,006×(114,6+100)^(-0,16)-0,00205
= 0,000491502

C_AS = 0,04×10^(-3) = 0,00004

Calculation of total resistance (R_T) :

Total resistance coef.(C_T) = (C_R+C_F+C_A+C_AS)

C_T = (0,001245264+0,001555058+0,0003416+0,00004)

So to calculate the total resistance of the ship (R_T), it must first know the air resistance (R_AA) and wave resistance (R_W) which are as follows:

R_AA = C_AA×0,5×ρ air× 〖Vs〗 ^2×Compart.
= 0,000491502×0,5×1,223kg/m^3 × 〖8,23104〗 ^2 m/s×(21,8 m×2,5×3)
= 3,329270923

R_W = C_T×0,5×ρ seawater× 〖Vs〗 ^2×ς
= 0,003181922×0,5×1,025 ton/m^3 × 〖8,23104〗 ^2 m/s×3070,089 m^2
= 339190,5786

R_T = R_W+R_AA
= 339190,5786 +3,329270923
= 339193,9078 N = 339,19 kN

Based on numerical calculations using the Guldhammer-Harvald method which has been carried out at economic, cruising and maximum speed variables, namely between 12 knots to 16 knots, the calculated value of LPD ship resistance using the PEM of azipod type system is as follows.

Table 2. Value of LPD Ship Resistance Guldhammer-Harvald Method

Speed (Vs)	*Guldhammer-Harvald*
(Knot)	***Resistance* (kN)**
12 (Echonomical)	168,35
12,5	184,99
13	199,52
13,5	219,61
14 (Cruise)	238,28
14,5	261,74
15	284,44
15,5	310,99
16 (Maximum)	339,19
16,5	361,04
17	382,56
17,5	404,68
18	427,40

4.4 Comparison and Validation of LPD Ship Resistance Calculation Results

From several calculation and testing methods on the LPD ship model, several data have been obtained from the analysis of the total ship resistance calculation using the Guldhammer-Harvald numerical calculation method as well as software assistance and analysis programs from the Maxsurf resistance software which in the data processing and calculations use the Holtrop method. To find out whether the numerical calculation results from the two methods are appropriate and valid, it is necessary to implement a data comparison method and validation of the total resistance value of the LPD vessel from the resistance test in the hydrodynamics laboratory / BTH-BPPT. From the comparative analysis of the total resistance of the ship, it is hoped that the percentage of margin of error and the value of the difference in the total resistance of LPD vessels obtained from each calculation result of these methods will be known. So that the validation of the results of the calculation of the total resistance value can be declared valid and appropriate, where the percentage margin of error should not be more than 3%. Comparison of data from the three methods can be shown in the data table below.

Volume 14, Number 03, pp.71-86
ISSN: 2460-7037
E-ISSN: 2722-5763

Table 3. Comparison and Validation of LPD Ship Resistance Values

Speed (Vs)	***Guldhammer-Harvald***	***Maxsurf Resistance* (*Holtrop*)**	**BTH-BPPT (*Towing Tank*)**
(Knot)	***Resistance* (kN)**	***Resistance* (kN)**	***Resistance* (kN)**
1	2	3	4
12	168,35	133,3	168
12.5	184,99	145,4	184
13	199,52	158,6	200
13.5	219,61	172,8	218
14	238,28	188,3	238
14.5	261,74	205,1	260
15	284,44	223,3	284
15.5	310,99	242,8	311
16	339,19	264,1	339
16.5	361,04	288	370
17	382,56	314,9	405
17.5	404,68	345,3	446
18	427,40	378,6	491

Based on the table above, it can be seen that the calculation of the total resistance value of LPD vessels using the Guldhammer-Harvald method is close to the total resistance value of the towing tank method in BTH-BPPT which is the basis for validation, namely with an average margin of error of 2.5%. , while the calculation using the software maxsurf resistance the average value of the margin of error is quite far, which is 21.6%, so the results of the resistance are less accurate. The results of the comparison and validation show that the total resistance value calculated from the Guldhammer-Harvald method is valid and appropriate, namely the percentage value of the margin of error is below 3%. In this study, the method used as the basis and reference for calculating the value of the power required for the LPD ship is based on the value of the ship's resistance with the Guldhammer-Harvald method.

4.6 Determination of Total Electrical Power Requirement for LPD Ship

Based on the results of the previous electric motor power calculation, the power for the electric motor propulsion system is 5680,04 KW. For the LPD ship's electrical power needs, the largest is at the time of departure and arrival (rear front role), which is 1301,4 KW. So that in these conditions, which will be added to the electrical power requirement for the propulsion system, the calculation results are obtained as follows:

Total electrical power requirement = 5680,04 KW + 1301,4 KW = 6981,44 KW.

Based on the calculation and analysis of the total electrical power requirement of the previous ship, a value of 6981.44 KW was obtained which then this value will be distributed to several diesel generators that will be installed on the LPD ship. Judging from the current condition of the engine room of the LPD ship, in planning the number of diesel generators is divided into 4 units. Where the 4 diesel generator units consist of 2 diesel generator units with a large capacity (main diesel generator) and 2 diesel generator units with a smaller capacity (auxiliary diesel engine).

Main DG cap.= total electric pwr requirement / 3

= 6981,44 KW / 3

= 2327,15 KW (prime power rating)

100% cap. = prime power rating + engine margin

= 2327,15 KW + (2327,15 KW x 15%)

= 2327,15 KW + 349,07 KW

= 2676,22 KW (standby power rating)

Aux DG cap. = 1 unit Main DG capacity / 2

= 2327,15 KW / 2

= 1163,58 KW (prime power rating)

100% cap. = prime power rating + engine margin

= 1163,58 KW + (1163,58 KW x 15%)

= 1163,58 KW + 174,54 KW

= 1338,12 KW (standby power rating).

Volume 14, Number 03, pp.71-86
ISSN: 2460-7037
E-ISSN: 2722-5763

4.7 Selection of Azipod Type Electric Motor

From several brands of PEM azipod type, ABB Azipod DO 1100A was chosen which will be used in repowering LPD ships in this research plan. The technical data and an overview of the ABB azipod DO 1100A are shown in Figure 7 below.

Propeller diameter	: 2,95 m
Output power	: 2700 KW
Shaft speed	: 272 rpm
Torque	: 95 kNm
Ship speed	: 16 knot
Main motor supply volt.	: 660 V
Weight	: 37.240 kg

Figure 6. ABB Azipod DO 1100A

4.8 EPM determination

After selecting the azipod brand and knowing the technical specifications of the azipod to be used, the next step is to analyze the electric motor propeller matching (EPM). In the azipod propulsion between the electric motor and the propeller, it is included as one of the characteristics of the manufacturer's product, so to determine the performance of the electric motor and propeller (EPM) it can be seen from the technical specification data in the manufacturer's catalog. Based on the azipod catalog produced by ABB Marine, data is obtained as shown in Figure 8 below, where the graph shows the characteristics of the propeller on the azipod and the relationship between the speed of the propeller and the power of the electric motor of the azipod.

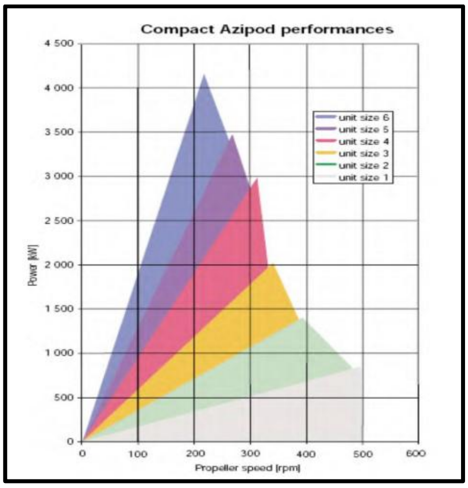

Figure 7. Compact Azipod Performances Graphics

Volume 14, Number 03, pp.71-86
ISSN: 2460-7037
E-ISSN: 2722-5763

4.9 Diesel Generator Selection

Caterpilar brand diesel generator was chosen to be used in planning this research. Based on the analysis of determining the number and capacity as well as the selection of diesel generators that have been carried out previously, the Caterpilar brand diesel generators that will be selected and used to support repowering on this LPD ship are CAT diesel generator types 3512C and C280-8. The technical data of the two diesel generators are as follows.

a. Technical data DG CAT 3512C :

Type : Vee 12, 4-stroke-cycle diesel

Aspiration : TTA

Bore x stroke : 170 x 215 mm

Frequency : 60 Hz

Power rating min : 1550 eKW / 1937 kVA

Power rating max : 1700 eKW / 2125 kVA

Voltage : 440 V

Speed : 1800 rpm

Fuel consumption : 386,8 ltr/h

Emissions : EPA T2C - IMO II - EU NC

Dimensions

Length : 5085,3 mm

Width : 2142,1 mm

Height : 2131,1 mm

Weight : 12762 kg

b. Technical data DG CAT C280-8 :

Type : In-line 8, 4-stroke-cycle diesel

Power rating min : 2300 eKW

Power rating max : 2710 eKW

Speed : 900 rpm

Output voltage : 480 V

Emission : IMO Tier II/EPA Marine Tier 2

Aspiration : TA

Stroke : 300 mm

Bore : 280 mm

Dimensions

Length : 8140 mm

Width : 2326 mm

Height : 3406 mm

Weight : 22.226,03 kg

4.10. Comparison of SFOC and Emissions LPD Ship Using PEM and PDE systems

The calculation of the SFOC value and emissions from LPD ships using the PDE system are as follows.

It is assumed that in 1 year the ship operates 3 times with the main engine and diesel generator operating simultaneously (assumed operating time is 720 hours of rotation / 1 month).

So that ME and DG operational time in 1 year:

Load factor (Lf) = number of ops. x operating time / 12 months

= 3 x 1 month / 12 months

= 0,25

SFOC (ME) = 2 x SFOC (ltr/h) x 24 h x 365 x Lf

= 2 x 520 ltr/h x 24 h x 365 x 0,25

= 2277,6 KL/year

SFOC (DG) = 2 x SFOC (ltr/h) x 24 h x 365 x Lf

= 2 x 135 ltr/h x 24 h x 365 x 0,25

= 591,3 KL/year

Total SFOC = SFOC (ME) + SFOC (DG)

= 2277,6 KL/year + 591,3 KL/year

= 2868,9 KL/year

Total emission (PDE) for 1 year:

Emissions ME = 2 x Emissions (g/KWh) x power ME x 24 x 365 x Lf

= 2 x 22 g/KWh x 2205 KW x 24 x 365 x 0,25

= 212,48 ton/year

Emissions DG = 3 x Emissions (g/KWh) x power DG x 24 x 365 x Lf

= 3 x 12,38 g/KWh x 500 KW x 24 x 365 x 0,25

= 40,67 ton/year

So that the total emissions produced by LPD ships with PDE are:

Total emissions ME and DG = 212,48 + 40,67

= 253,15 ton/year

The calculation of the SFOC value and emissions from LPD ships using the PEM system are as follows.

Electric power normal service mode = (2 x 2414,02 KW) + 562 KW = 5390,03 KW

Volume 14, Number 03, pp.71-86
ISSN: 2460-7037
E-ISSN: 2722-5763

It is known that the Main DG used is 2 x 2710 KW and the Auxiliary DG used is 2 x 1550 KW.

So that the DG used to support the normal service mode is 2 x 2710 KW (main DG).

SFOC (main DG) = 2 x SFOC (ltr/h) x 24 h x 365 x Lf

= 2 x 631 ltr/h x 24 h x 365 x 0,25

= 2763,78 KL/year

Total emission (PEM) for 1 year:

Emissions Main DG = 2 x Emissions (g/KWh) x power DG x 24 x 365 x Lf

= 2 x 8,58 g/KWh x 2710 KW x 24 x 365 x 0,25

= 101,84 ton/year

Emissions Aux DG = 2 x Emissions (g/KWh) x power DG x 24 x 365 x Lf

= 2 x 7,94 g/KWh x 1550 KW x 24 x 365 x 0,25

= 53,91 ton/year

So that the total emissions produced by LPD ships with PEM are:

Total emissions Main DG and Aux DG = 101,84 + 53,91 = 155,75 ton/year

4.11 Redesign Engine Room Layout of LPD Ships After Using PEM System

In this study, planning for repowering using an azipod-type PEM system requires several new components that function to support and support the operation of the system. The new components include the following.

a. Diesel generator
b. Azipod
c. MSB
d. Transformer
e. Frequency converter

In addition to requiring new components, in planning the repowering of LPD ships using the PEM system, there are several components of aircraft and equipment from the existing system that must be eliminated. This is because these components are not used in the azipod type PEM system. Some components of aircraft and equipment in the existing system that are not used are as follows.

a. Main engine
b. Diesel generator
c. Gear box
d. Shaft
e. Propeller
f. Steering gear
g. MSB

In the redesign of the engine room, the placement of new equipment components will be arranged, where the layout and position of the equipment components are adjusted to the conditions of the LPD ship engine room and equipment / aircraft components from the existing system. The following is an overview of the engine room layout of the existing LPD ship and the redesign of the engine room layout of the LPD ship that already uses the PEM system as shown in Figure 8-11 below:

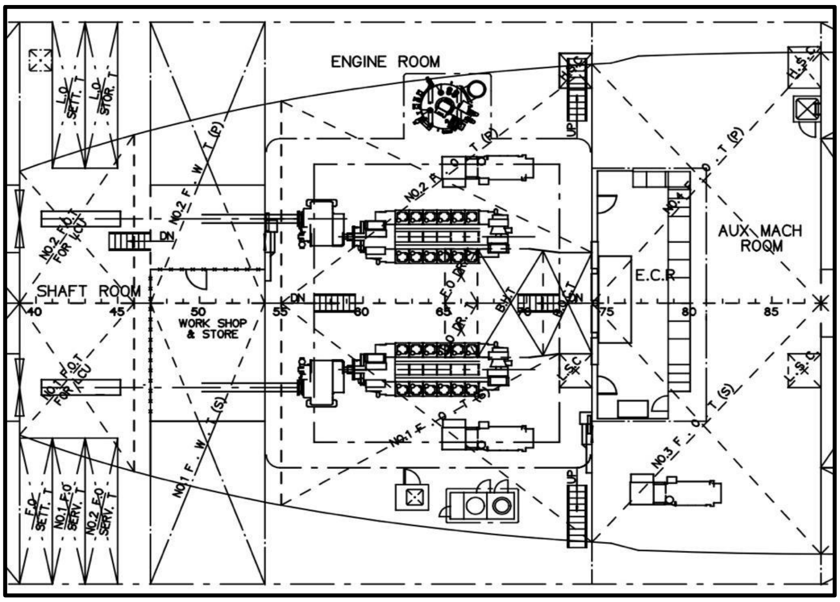

Figure 8. Engine Room Layout Existing LPD

Volume 14, Number 03, pp.71-86
ISSN: 2460-7037
E-ISSN: 2722-5763

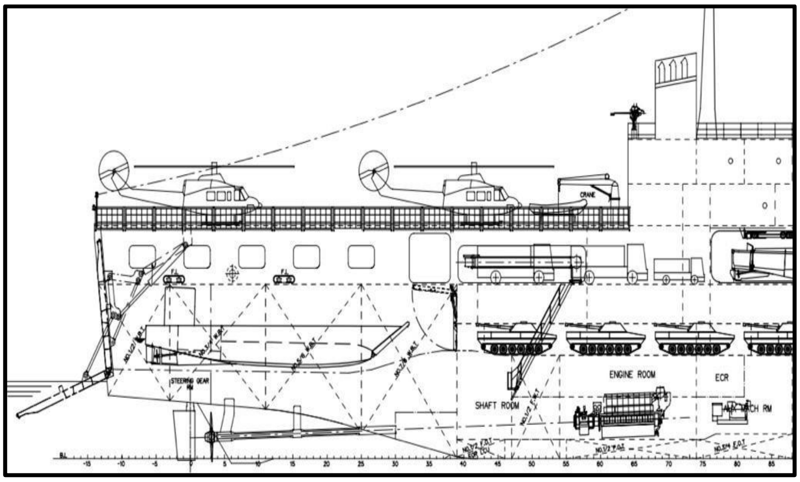

Figure 9. LPD with Existing PDE System

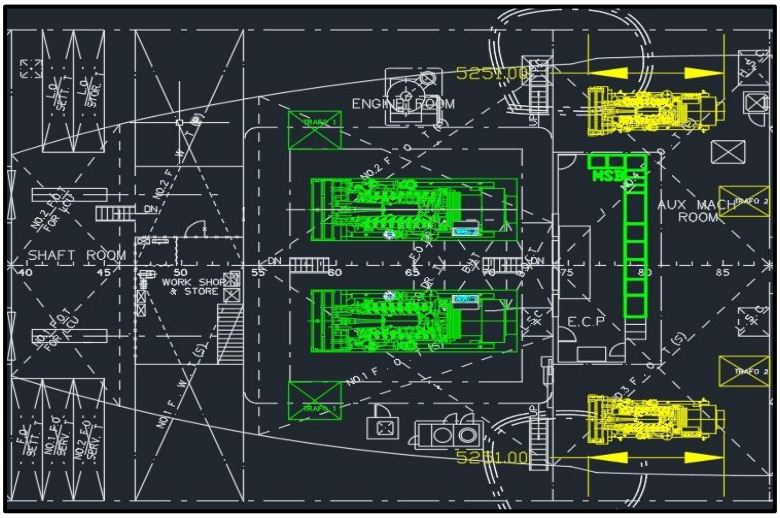

Figure 10. Engine Room Layout LPD Using PEM System

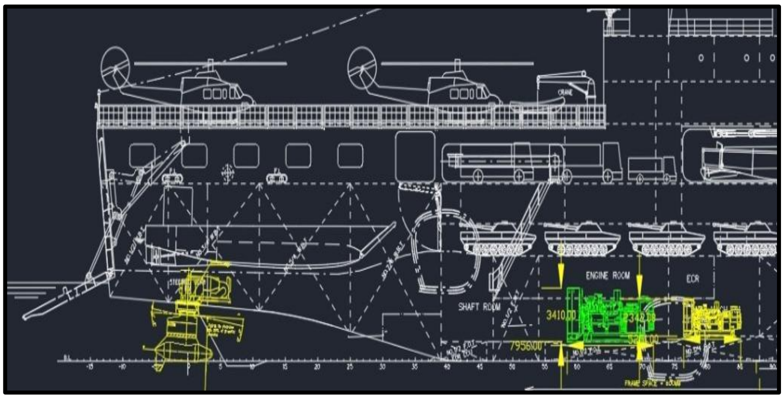

Figure 11. LPD with PEM (Azipod) System

From setting the location of the components in the process of redesigning the engine room layout, then calculating the efficiency of space space in the engine room after using the PEM system components. This calculation is done by calculating the total area of each component using AutoCAD software. The component area of the PDE system in the engine room is 1.00 m2 and the component area of the PEM system in the engine room is 0.90 m2, so that in terms of room space the PEM system is 10% more efficient than the PDE system.

5. CONCLUSION AND SUGGESTIONS

From the results of the analysis and discussion that have been carried out previously, the following conclusions can be drawn.

a. Based on the numerical calculation of ship resistance using the Guldhammer-Harvald method

Volume 14, Number 03, pp.71-86
ISSN: 2460-7037
E-ISSN: 2722-5763

and has been validated with the results of the laboratory resistance test from BTH-BPPT, the comparison value with an average error margin of 2.5% is obtained. From the results of this analysis, it was concluded that the results of the numerical calculation of the LPD ship resistance value were appropriate and valid.

b. Based on the calculation of fuel consumption (SFOC) and emissions from LPD vessels with PDE and PEM systems within a period of 1 year, the SFOC values obtained from LPDs with PDE are 2868.9 KL/year and LPD with PEM are 2763.78 KL/ year. In addition, the value of emissions from LPD with PDE of 253.15 tons/year and LPD with PEM of 155.75 tons/year is also obtained. From the results of the analysis, it is concluded that LPD with PEM is more efficient in fuel consumption and more environmentally friendly than LPD with PDE. This can be seen from the difference in SFOC which is 105.12 KL/year and the difference in emissions is 97.4 tons/year, so with PEM it can save fuel by 3.7% and reduce emissions by 38.5% if compared to PDE.

c. PEM system in the engine room, a redesign of the engine room layout was carried out by adjusting the location and position of these components. From the arrangement of the location of these components, the room space efficiency for the PEM system components is 10% compared to the PDE system. From the results of this analysis, it is concluded that LPD with PEM is more efficient in terms of space for components than LPD with PDE.

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