Air System Analysis in Engineering Roomof the Vessel Ship

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Abstract – After post repowering Vessel Ship, in its operation, the engine room temperature conditions change which causes an uncomfortable and dangerous atmosphere for the operation of all equipment in the engine room, especially for the engine controller and other auxiliary control systems, for which a The aim of this study was to determine the amount of heat load caused by heat generated to determine the right blower capacity for the vessel ship engine room, in this study using mathematical calculations based on the theory of air conditioning theory from the calculation of heat load in the vessel ship engine room, calculation of losses in the ducting system and with the presence of friction resistance in the ducting system, as for the results of the research carried out can be concluded that there is a need to replace the blower following the results of the calculation given that the blower is insufficient the air needed

Keywords – Air System, Engineering Room.

I. Introduction

The increase in temperature in the engine room can affect the performance of equipment and machinery operators. With high temperatures, the air in the engine room expands, causing the oxygen content in the air to thin out. If the oxygen content in the air needed as a mixture of fuel in the combustion process is less, then incomplete combustion will occur. Incomplete combustion causes the power released by the engine to decrease (Susilo et al, 2017).

1.2. Formulation of the problem.

This Final Project can formulate several problems as follows:

a. The amount of heat load that occurs in the SHIP 354 engine room
b. Is the installed capacity of the blower still able to maintain engine room temperature in ideal conditions?

1.3. Research purposes

a. What is the amount of heat load that occurs in the engine room using ISO 8861 and calculation of loss in the ship 354 Engine Room ducting system after repowering.
b. Is the old air duct system capable of supplying air needs in the engine room.
c. Is the installed blower capacity still able to maintain engine room temperature in ideal conditions.

II. Materials And Methods

2.1 Airflow Calculations.

To find out the calculation of airflow in the Machine Room can be known by using calculations on the ISO 8861 method. In it is explained that the outside ambient temperature used is + 35° C. Changes in temperature from the Air Intake leading to the Engine Room to enter the ducting inlet maximum 12.5 ℃. The capacity of the ventilation system that is fulfilled can make the working space comfortable in the engine room, provide adequate combustion air for the main engine, boiler and also prevent sensitive heat apparatus from overheating (Suharjo, 2019).

To find out the total amount of air in the engine room below, namely:

Q = qc + qh ....(2.1)
Q = 1.5 x qc .... (2.2)

Where :
Q = total airflow for the engine room
qc = total airflow for motorbikes
qh = the total airflow needed for heat evacuation from the combustion motor
qc = qdp + qdg + qb .... (2.3)

Where:

qdp = airflow for main engine restriction
qdg = airflow for combustion in an electric generator diesel motor
qb = airflow for combustion in the boiler

To find out the value of airflow for combustion of diesel engines the main driver can be used with the following formula (Wilbert, 1996):

$$q_{dp} = \frac{P_{dp} \times m_{ad}}{\rho} \quad ....(2.4)$$

Where :

Pdp = power on the main engine
mad = air requirement for combustion in main engine
= 0.0023 kg / kW s (2 steps)
= 0.0020 kg / kW s (4 steps)
P = air density
= 1.13 kg / m3 (ρudara at +350 C, 70% RH and 101.3 kPa)

To find out the value of airflow for combustion of diesel generator engines, it can be used with the following formula:

$$q_{dg} = \frac{P_{dg} \times m_{ad}}{\rho} \quad ....(2.5)$$

Where :

Pdg = power on diesel engines for electric generators
mad = air requirement for diesel engine combustion for electric generators

= 0.0023 kg / kW s (2 steps)
= 0.0020 kg / kW s (4 steps)

To find out the value of combustion airflow in a qb boiler, it can be used with the following formula:

$$q_b = \frac{m_s \times m_{fs} \times m_{af}}{\rho} ......(2.6)$$

The amount of airflow is very important for qh heat evacuation. To find out the qh price can be calculated using the formula below

$$q_h = \frac{\phi_{dp} + \phi_{dg} + \phi_b + \phi_{el} + \phi_{ep} + \phi_t + \phi_p + \phi_0}{\rho \times c \times \Delta T} - 0.4(q_{dp} + q_{dg}) - q_b \,........(2.7)$$

Where :

ϕ_{dp} = heat emission from an air drive diesel engine (kilowatt)ϕ
ϕ_{dg} = heat emission from an electric generator engine (kilowatt)ϕ
ϕ_b = heat emissions from boilers and thermal fluid heaters (kilowatts)ϕ
ϕ_p = heat emission from steam and condensate pipe (kilowatt)ϕ
ϕ_{el} = heat emission from electrical installations (kilowatts)ϕ
ϕ_{el} = heat emission from the exhaust pipe including the gas waste burning boiler (kilowatt)
ϕ_t = heat emissions from hot tanks (kilowatts)ϕ
ϕ_t = heat emission from other components (kilowatts)ϕ
qdp = airflow for main drive diesel engine (m3 / s)
qdg = airflow for combustion diesel generator (m3 / s)
qb = airflow for boiler combustion (m3 / s)

c = 1.01 kJ / (kg. K) (heat air specific capacity)
ΔT = 1.25 K or 0 C

(difference in the increase in engine room air temperature, for example, the difference between measurements of inlet and outlet temperature during initial design conditions (Harington, 1991). The external outlet temperature is measured from the engine room to the funnel without installation-sensitive heat).

The value of heat emission from the main engine can be known by using the formula below (ISO 8861, 1998):

$$\phi_{dp} = P_{dp} \frac{\Delta h_d}{100} \,......(2.9)$$

the value of heat emission from a diesel generator

$$\phi_{dg} = P_{dg} \frac{\Delta h_d}{100} \dots\dots(2.10)$$

Where :

Pdg = Standard Power / Diesel service power when the maximum continuous rating (kW)
Δ hd = heat loss from the diesel generator in percentage

The value of heat emission from the boiler uses the formula below

$$\phi_b = Q \; x \; \frac{\Delta h_b}{100} \; x \; B_1 \dots\dots(2.11)$$

Q = Maximum continuous rating on the boiler, in kilowatts
Δhb = heat loss from the boiler when the maximum continuous rating is in percentage
B1 = Constants used in the location of boilers and other heat exchangers in the engine room.

The value of heat emission from the condensate pipe used in the boiler system can be known using the formula:

$$\phi_p = m_{sc}\ x\ \frac{\Delta h_p}{100} \ldots\ldots (2.12)$$

Where :

msc = Total steam consumption, in kW (1 kW ~ 1.6 kg / h steam)

Δhp = Heat loss from steam and condensate pipe, in the percentage of steam consumption,

The value of heat emission from the electric generator can be calculated using the formula:

$$\phi_g = Pg\ x\ \left(1 - \frac{\eta}{100}\right) \ \ldots\ldots (2.13)$$

Where :

Pg = Power (power) owned by the generator with an air cooling system, in kW (Generators in stand-by position can be ignored)

η = generator efficiency, in percentage

2.2. Loss of Airway System Pressure.

This calculation can be formulated as follows

$$P_t = \Delta Pf + \Delta Pd + \Delta P \ \ldots\ldots (2.14)$$

Where:

Pt = total pressure loss (kg / m2 or mm H2O)
ΔPf = pressure loss due to friction resistance on the pipe.
ΔPd = pressure loss due to local flow resistance.
ΔPv = pressure loss due to changes in flow velocity.
Straight pipe friction resistance can use the Darcy-Weisbach equation

$$\Delta Pf = \lambda \times \frac{l}{De} \times \frac{\gamma}{2g} \times V^2$$

Where:

λ = coefficient of friction from the pipe
V = average air velocity in the channel (m / s)
L = straight pipe length (m)
γ = air specific gravity (kg / m3)
g = gravity acceleration (m / s2)
De = equivalent diameter of pipe (m)

For rectangular channels

$$De = \frac{4 \times ab}{2(a+b)}$$

Local flow resistance from the channel can be expressed by pressure losses caused by changes in flow ΔPd

$$\Delta Pd = \zeta_T \times \frac{\gamma}{2g} \times V_1^2 = \zeta'_T \times \frac{\gamma}{2g} \times V_2^2$$

Where :

ζ_T = local resistance coefficient for upstream conditions where the air velocity is V1 (m / s) and at the total pressure.

ζ'_T = local resistance coefficient for downstream conditions where the air velocity is V2 (m / s) and at the total pressure concerned

III. Result And Discussion

a. Formulation

Q = q_c + q_h
q_c = q_{dp} + q_{dg} + q_b
q_{dp} = (P_{dp} × m_{ad}) /ρ……. .. (2.4)
q_{dp} = (5346 (2) x 0.0020) /1.13
q_{dp} = 18,924 m³ / s
P_{dp}= 5346 kW (multiplied by 2 because there are 2 main engine units)
Mad = 0.0020 kg / kW s for playing the 4-stroke engine
ρ = 1.13 kg / m3 (air density at +350 C, 70% RH and 101.3 kPa)

$$q_{dp} = \frac{P_{dp} \times m_{ad}}{\rho}$$

$$q_{dp} = \frac{5346\ (2)\ x\ 0.0020}{1.13}$$

$$q_{dp} = 18.924\ \text{m}^3/\text{s}$$

For the amount of heat produced by the diesel engine for electricity generator q_{dg} and boiler q_b there is no because in the engine room there is no Diesel Generator or boiler so the price of $q_{dg} = q_b = 0$

q_c = **q_{dp}** = 18,924 m³ / s

b. For the amount of heat produced by the diesel engine for electricity generator q_{dg} and boiler q_b there is 0 because in the engine room there is no Diesel Generator or boiler so the price of **$q_{dg} = q_b = 0$**, To find out the number of emissions from the Main engine because the engine used is a 4-step engine, the calculation is as follows:

$$\phi_{dp} = 0.396\ x\ P^{0.70}$$

The percentage of heat loss Δh not found in technical data, so that the calculation using the formula

$$\phi_{dp} = 0.396\ x\ P^{0.70}$$
$$\phi_{dp} = 0.396\ x\ 5346^{\ 0.70}$$

ϕ_{dp} = 161.18 kW(multiplied by 2 because there are 2 main engines), so

$$\phi_{dp} = 322.36 \text{ kW}$$

c. Emissions from Diesel Generator ϕ_{dg} = 0 there is no Diesel in the engine room

d. Emisi dari boiler ϕ_b = 0because there is no boiler so the price

$$\phi_{dp} = \phi_b = 0$$

e. Emissions from the condensate pipe ϕ_p = 0 because there is no steam boiler

f. Emissions from the electric generator ϕ_g = 0 because there are no electric generator□

g. Emissions from electrical installations. Several engines operate there when the ship sails, here is a power usage table when the ship sails

$$\phi_{el} = 20\ \%\ \text{x P use at sea}$$

Table 1. Total Power of Engineering Room

No	Electric Installation	Amount	Power (kw)	Total Power (kW)
1	Air starting Compressor Panel	2	0.02	0.04
2	High-Pressure Compressor	2	0.03	0.06
3	LCP for Main Engine	2	0.48	0.96
4	ME Ht FW. Preheating Electric Pump	2	3.50	7
5	ME HT Electrical Water Heater	2	4.00	8
6	TL Lamp	16	0.025	0.4
	Total power (kW)	**10954.6**		

h. Emissions from exhaust pipes. from the data in the field obtained :

a = 1.255 m
b = 1.255 m

$$De = \frac{4 \times ab}{2(a+b)}$$

$$De = \frac{4 \times (1.255 \times 1.255)}{2(1.255 + 1.255)}$$

$$De = 1.255 \text{ m}$$

Δt = 350 K and diameter = 1,255 m because of the 4 stroke drive then ϕ_{ep} = 0.11 kW

i. Emissions from other components $_o$n kW: 10954 kW.

So that the total for heat emission q_h is obtained as follows

$$= \frac{\phi_{dp} + \phi_{dg} + \phi_b + \phi_g + \phi_{el} + \phi_{ep} + \phi_t + \phi_p + \phi_o}{\rho \times c \times \Delta T} - 0.4(q_{dp} + q_{dg}) - q_b$$

$$= \frac{78 + 3.94 + 0 + 9.456 + 39.4 + 0 + 0.234 + 0 + 0}{1.13 \times 1.01 \times 12.5} - 0.4(7.938 + 0.4) - 0$$

$$q_h = 5.85 m^3/s$$
$$Q = q_c + q_h$$
$$Q = 8.339 + 5.85$$
$$Q = 14.2\ m^3/s$$
$$Q = 30088.09\ cfm$$

Then the air demand obtained after calculating using ISO 8861 is 14.2 m3 / s or around 30088.09 cfm

Calculation of Losses in Ducting Systems.

$P_t = \Delta Pf + \Delta Pd + \Delta Pv$

Where:

ΔPf = pressure loss due to friction resistance in the straight pipe.
ΔPd = pressure loss due to local flow resistance.
ΔPv = pressure loss due to changes in flow velocity.
Pressure losses due to friction resistance (ΔPf) for rectangular section channels with a cross-section size of 860 mm x 1135 mm. Channel length = 7 m.

$$Re = \frac{Vd}{v}$$

d = pipe diameter (m)
v = air dynamic viscosity (m²/s) 16,425 m²/s

$$De = \frac{4 \times ab}{2(a+b)}$$

$$= \frac{4 \times 0{,}76 \times 1{,}285}{2 \times (0{,}76 + 1{,}285)}$$

= 0,955 m

$$Re = \frac{10 \times 0{,}955}{16{,}425 \times 10^{-6}}$$

= 581.497,73 ⟶ $Re \geq 10.000$

$$\lambda = 0{,}0055\left[1 + \left(20000\frac{\varepsilon}{d} + \frac{10^6}{\mathrm{Re}}\right)^{\frac{1}{3}}\right]$$

= 0,100986

$$Pf = 0{,}100986 \text{ x } \left(\frac{7}{0{,}955}\right) \text{ x } \left(\frac{1{,}2}{2 \times 9{,}8}\right) \text{ x } 10^2 \text{ kg/m}^2 = 4{,}532 \text{ kg/m}^2$$

for two rectangular section channels with a cross section size of 1,033 mm x 254 mm. Channel length = 2.0 m

$$De = \frac{4 \times ab}{2(a+b)}$$

$$= \frac{4 \times 0{,}254 \times 1{,}033}{2 \times (0{,}254 + 1{,}033)}$$

= 0,3313 m

$$Re = \frac{10 \times 0{,}3313}{16{,}425 \times 10^{-6}}$$

= 159.745,51 ⟶ $Re \geq 10.000$

$$\lambda = 0{,}0055\left[1 + \left(20000\frac{\varepsilon}{d} + \frac{10^6}{\mathrm{Re}}\right)^{\frac{1}{3}}\right]$$

= 0,141394

$$Pf = 0{,}141394 \text{ x } \left(\frac{2{,}0}{0{,}3313}\right) \text{ x } \left(\frac{1{,}2}{2 \times 9{,}8}\right) \text{ x } 10^2 \text{ kg/m}^2 = 5{,}226 \text{ kg/m}^2$$

So that the total pressure loss due to friction resistance is:

ΔPf = 4,532 + 5,226 = 9,758 (kg/m² atau mmH_2O)

Pressure losses due to the presence of local flow resistance (ΔPd) for rectangular section channel connections with a cross-section size of 760 mm x 1,285 mm (Ahmadi et al, 2019)

- there are three curved elbow connections (90⁰):

$$Pd = \lambda \times \frac{le}{d} \times \frac{\gamma}{2g} \times V^2$$

$$= 0{,}100986 \times 4{,}5 \times \frac{1{,}2}{2 \times 9{,}8} \times 10^2 \text{ kg/m}^2$$

= 2,782 kg/m² x 3
= 8,346 kg/m²

- There are four branch line connections that have decreased flow:

$$Pd = \zeta \times \frac{\gamma}{2g} \times V^2$$

$$= 0{,}2 \times \frac{1{,}2}{2 \times 9{,}8} \times 10^2 \text{ kg/m}^2$$

= 1,224 kg/m² x 4
= 4,896 kg/m²

-there is one connection to merge branch channels

$$Pd = \zeta \times \frac{\gamma}{2g} \times V^2$$

$$= 0{,}1 \times \frac{1{,}2}{2 \times 9{,}8} \times 10^2 \ \text{kg/m}^2$$

$= 0{,}612\ \text{kg/m}^2$

So that the total pressure loss is due to local flow resistance:

$\Delta Pd = 8{,}346 + 4{,}896 + 0{,}612\ \text{kg/m}^2$
$= 13{,}854\ (\text{kg/m}^2 \text{ or mm } H_2O)$

Losses due to changes in flow speed(ΔPv):

$$\Delta Pv = \frac{V^2}{2g} \times \gamma$$

$$= \frac{10^2}{2 \times 9{,}8} \times 1{,}2\ \text{kg/m}^2$$

$= 6{,}122\ (\text{kg/m}^2 \text{ or mm } H_2O)$

So that the total pressure loss / ducting losses (Pt) design:

$Pt = \Delta Pf + \Delta Pd + \Delta Pv$
$Pt = 9{,}758 + 13{,}854 + 6{,}122 = \mathbf{29{,}734\ mm\ H_2O}$

Blower Specification Requirements

The amount of power needed by the air fan is calculated by the equation: Power of the driving motor (ASHRAE Handbook)

$$(\text{kW}) = \frac{Q \times Pt}{6120\ \ \eta}$$

Where :

Q = supply air capacity, (m3 / minute)
Pt = total pressure, (kg / m2 or mm H2O), standard 50 kg / m2
η = air fan efficiency

Driving motor power (kW)

$$\frac{585{,}9755\ \left(\text{m}^3/\text{menit}\right) \times 50\ \left(\text{kg/m}^2\right)}{6120 \times 0{,}8} = 5{,}984\text{kW} = 8.023\ \text{HP}$$

IV. Conclusion

From the calculation above, the data for the selection of blowers with a capacity of = 35,158.5 m3 / hour (20,693.5 cfm) is obtained. Because it is planned to use two blowers installed parallel to meet this capacity, a blower with capacity and power capacity of 17,579.2 m3 / hour (10,346.77 cfm) and 4 Horsepower is needed.

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