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Design of a Passenger Ship Launch Using an Air Bag System

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ABSTRACT

Ship launching is one of the stages of ship production before the ship is handed over to the owner, which marks the beginning of the ship's life. With the development of technology at this time, various launching methods have been developed, one of which is the launching method using an air bag system. Launching using air bags has many advantages compared to conventional launching methods that have been used so far. Pre-launch calculations are performed to avoid risks during the launch. Launching using air bags begins with calculating the weight plan of the ship launch and the preparation of the air bag layout. Using CB/T 3837:1998 Technological Requirements for Ship Upgrading or Launching Relying on Air Bags, Shipbuilding Industry Standard, and ISO 14409:2011 ships and marine technology-ship launching air bags, the number of air bag requirements and layout can be determined to support the ship launching process. The passenger ship, with an length overall of 62.80 metres, is planned to have a launch weight of 1058.881 tons. By using the QG6 high-bearing capacity air bag model with 6 layers of cord fabric with a diametre of one metre and a contact length between the air bag and the ship's body of ten metres, a total of 11 air bags are required in a linear arrangement to support the launch of a passenger ship. The distance between air bags is 2.07 metres to 5.736 metres, the longer the distance between air bags, the greater the load supported by each air bag.

Keywords: air bag; light ship weight; steel weight estimation; ship launching.

Introduction

Ship launching is one of the stages in the process of building a new ship or a ship that has completed the repair or refit process. Ship launching is an important and critical stage in building a new ship and can potentially cause danger if not appropriately planned [1], [2]. In general, ship launching consists of two methods: traditional or conventional methods with the help of inclinable cradles and other methods with translation system cradles [3], in principle, ship launching can be done by floating methods, launching with the help of gravitation, and by mechanical methods [4]. Ship launching consists of longitudinal or transverse directions; there are two different ways of launching: end launching and side launching [5]. Launching is a dynamic phenomenon where the ship slides into the water on an inclined launching platform [6]. Ship launching can generally be performed in longitudinal and lateral positions. In

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longitudinal ship launching, there are fewer launching structural components than in side launching [7].
Ship launching can be determined based on the type of building berth, the design of the ship's hull, and the launching weight of the ship. The launching weight of the ship dramatically affects the infrastructure and equipment that will be used. The launch weight is calculated according to the components installed on the ship. As time goes by, technology in shipbuilding is advancing, including in the ship launching process. At present, many shipyards in Indonesia use ship-launching technology with air bag systems. Several national and international standards were developed to ensure success in the launching process using air bags [8]. Ship launching with this method has many advantages, including saving time, reducing workload, having high flexibility, and not requiring a lot of maintenance that costs much money [9].
The launching process is a complex event, especially when uncommon ship structures are of particular concern in the launching process [10]. However, launching using air bags still has risks [11], one of the risks that can occur is launch failure caused by air bags not being able to withstand the launch load [9]. The launch load or weight consists of the weight of the launched vessel and the weight of the launch equipment [6]. The calculation of the launch weight depends on the weight of the ship (light weight) [5], the calculation of the ship's weight at launch can be done with the Bonjean curve [12] so the calculation of the ship's weight is carried out to avoid risks during launching with an air bag.
Pioneer passenger ships are one of the many ships circulating and sailing in Indonesian seas and are used to reach small and outer islands. In the process of building a pioneer passenger ship, the launch stage is carried out at the final stage before the seatrial. Launching using an air bag system is inseparable from the number of air bag devices needed. The calculation of the number of air bags during the construction process must be carried out to ensure that the launching process runs safely because, as the launching weight increases, it becomes necessary to focus more on the overloading of the air bags and the possibility of deformation of the ship's bottom [8]. This research will discuss launch planning using the air bag system method on pioneer passenger vessels to determine the ship's weight at launch, the pressure and type of air bag, and perform air bag stacking planning.

Methods

The article is an original article as a result of research and review. Articles can be written in English. Total article pages between 10 – 12 pages including bibliography.
In the process of building a new ship, ship launching is one of the stages that will be passed before the ship is handed over to the ship owner. Ship launching is primarily influenced by various factors, including the transfer of ship weight from the block keel, waterline, land structure, and others, which is one of the supporting factors during the ship's construction itself [7].
In this study, a pioneer-type passenger ship model with a size of 1200 GT was used. The data owned is the ship's principle dimensions, where the passenger ship's principle dimensions data can be seen in Table 1.

Table 1. Ship’s principle dimensions [13]

Dimensions	Values
Length over all (LoA)	62.80 m
Length per pendicular (Lpp)	57.36 m
Width (B)	12.00 m
Height (H)	4.00 m
Draft (T)	2.70 m
Speed (V)	12 knot
Engine Power	2 x 1000 HP

The steps taken in planning a ship launch are:

1. Selection of launching method
2. Calculation of launch weight
3. Planning or drafting the launch

In general, ships are launched with the stern end of the ship touching the water first, but some shipyards located on rivers with narrow river widths may launch ships sideways. Launching a vessel with the bow touching the water first is rarely done due to the vessel's buoyancy and moment of weight, which can cause failure and damage to the vessel's structure or construction during launching [14]. Figure 1 shows the launching scheme in the longitudinal direction of the ship, with the stern end touching the water first.

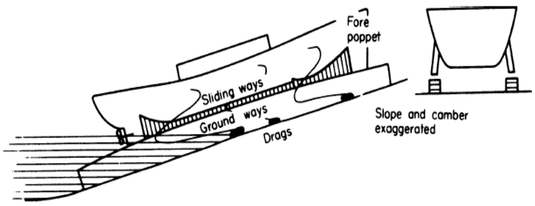

Figure 1. longitudinal's ship launch scheme [14]

Ship launching must be planned and prepared from construction until the end of construction work. Technology development at this time provides and facilitates the ship's readiness before launching. The ship launching method is selected according to the technology owned by the shipyard, the construction work process, the condition of the shipyard and other factors. There are several steps in the ship launching process including [15].

- Free - In an inclined plane under the action of gravity;
  Longitudinal ship launching and Transversal ship launching
- Surfacing - when raising the water level in the launching facilities;
  Dry Dock, Floating Dock
- Forced - mechanized.
  Launching by Cranes, Travel lifting and Ship-lift system

Launching with longitudinal and transverse methods requires a relatively expensive. Investment costs are quite expensive because the owner has to build a sliding shoe or cradle structure, while launching using graving docks and floating docks requires a costly investment. With the existing technology, launching with the air bag method was developed, which is more practical and efficient and does not require a lot of investment. Air bag method is more practical and efficient and does not require expensive investment [16]. As shown in Figure 2, ships are launched using air bags. Some of the advantages and disadvantages of using air bags include [17]:

- Advantages:
  a. Low investment cost
  b. Little labour required
  c. Utilisation of unused land
- Disadvantages:
  a. Lifetime is short
  b. Longer docking and undocking process time
  c. Higher difficulty level

In this study, a longitudinal launching method with the help of an air bag is used in the launching process. Ship launching using air bags is included in the category of free launching in an inclined plane under the action of gravity, where this launch is assisted by the force of gravity.

Figure 2. Ship's launching with air bag [18]

During free or gravity-fed ship launching, the ship slides downward due to its weight. For small vessels, the launch weight is divided into three components: structural weight, machinery weight, and equipment weight [19]. In general, the launching weight consists of the weight of the launched ship (D) and the weight of the launching equipment (P), where the weight of the launching equipment ranges from 7 to 16 % of the weight of the launched ship [6].

$$D_t = D + P \quad (1)$$

where :
Dt is launch's weight (ton)
D is ship's launch weight (ton)
P is ship's outfitting weight (ton)

The weight of the launching equipment is usually for slipway launches, where a sliding way is attached to the body of the ship that will be in contact with the ground. In ship launching using an air bag system, the launching weight is only the weight of the ship being launched (D). The weight of the ship in launching is usually only the weight of steel, the weight of machinery, and the weight of reserves, or, in other words, the weight of an

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empty ship (light weight). The launch weight calculation refers to the weight of the ship's steel when the ship is empty [20]. To get the empty ship weight of the ship, use the following equation [21].

$$W_L = W_H + W_M + R \quad (2)$$

Where :
W_H is weight of hull (ton)
W_M is weight of machinery (ton)
R is reserve (margin/tolerencae of estimations) about 2-3% (ton)
Lightship weight is the weight of the ship complete with equipment already installed and without fuel, supplies, and cargo. Some literature explains that in determining the weight of an empty ship is the sum of the weight of steel, the weight of equipment, the weight of machinery, and margins [21].

$$\text{Lightship} = \text{Steel Weight} + \text{Outfit weight} + \text{Machinery Weight} + \text{Margin} \quad (3)$$

where :

- **Steel weight (ton)**

Table 2. Steel weight estimation [22]

Ship type	Cargo	Cargo cum Passenger	Passenger	Cross Channe Pass. ferry
(100/Δ) x steel weight	20	28	30	35

For tankers, $\frac{100}{\Delta}$ x steel weight = 18

- **Outfit weight (ton)** [23]

$$W_o = K.\nabla \quad (4)$$

where, ∇ is the total 'converted volume' and K = 0.036–0.039 t/m^3.
Passenger ships with large car-transporting sections and passenger ships carrying deck passengers K = 0.04–0.05 t/m^3.
The 'converted volume' L . B . D [24]

- **Machinery weight (ton)**

Murirosmith formulae,

$$W_m = \frac{BHP}{10} + 200 \text{ tons diesel} \quad (5)$$

This includes all weights of auxiliaries within definition of m/c weight as part of light weight. Corrections may be made as follows: For twin-screw ships add 10% and For ships with large electrical load add 5 to 12%

- **Margin on Light Weight Estimation (ton)**

Table 3. Margin Weight [22]

Ship type	Margin on Wt
Cargo ships	1.5 to 2.5%
Passenger ships	2 to 3.5%
Naval ships	3.5 to 7%

In launching using an air bag system, it is necessary to calculate the number of air bags needed to support the launch. The calculation of the number of air bags required according to regulation CB/T 3837 - 1998 Technological Requirements for Ship Upgrading or Launching Relying on Air-Bags, Shipbuilding Industry Standard [25] can be calculated with the following equation:

$$N = K_1 \frac{Q.g}{C_b.R.L_d} + N_1 \quad (6)$$

Where :
N is number air bags (pieces)
K_1 is constant value, with value 1.2~1.3
Q is weight of the ship to be launched (ton)
g is gravity force (9.8 m/s^2)
C_b is coefficient block
R is allowable bearing, force per length of air bag, (kN/m), see **Error! Reference source not found.**
L_d is contact length between air bags and ship's bottom at midship section (m)
N_1 is the number of air bags that are reinstalled in connection, generally about 2~4 pieces

Based on ISO 14409-2011 standard, ships and marine technology-ship launching air bags, category of air bags divided into two, based on bearing capacity per metre in length, [26]:

1. QP-ordinary air bag;
2. QG-high-bearing capacity air bag.

Table 4. Type and models of air bag [26]

Type	Type No.	Model
QP	QP3	Ordinary air bag with 3 layers of cord fabric
	QP4	Ordinary air bag with 4 layers of cord fabric
	QP5	Ordinary air bag with 5 layers of cord fabric
QG	QG6	High-bearing capacity air bag with 6 layers of cord fabric

Specific types and models of air bags can be seen in Table 4, where for each type and model of air bag, the air bag model is influenced by the arrangement of the cord fabric layers. Cord fabric air bags are made of synthetic cord, as in tyres, which are arranged with certain ideal angles that function to withstand pressure from the inside and distribute stress evenly [27]. The diameter of the air bag in accordance with the ISO 14409-2011 standard is 0.8 m; 1.0 m; 1.2 m; 1.5 m and 1.8 m. Each diameter and type of air bag has the ability to withstand the pressure of the ship's load. Can be seen in Table 5, where each type and diameter size has its own ability to withstand existing loads.

In the arrangement between air bags, it is necessary to pay attention to the distance between the midpoints of the two adjacent air bags, where the existing distance should be in accordance with the strength of the hull construction to be launched, and avoid excessive layering of air bags. The distance between air bags can be determined using the equation below:

$$\frac{L}{N-1} \leq 6 \quad (7)$$

$$\frac{L}{N-1} \geq \frac{\pi D}{2} + 0,5 \quad (8)$$

Where :
L is the length of ship's bottom that can contact with air bag (m).
N is number of air bag, pieces
D is nominal diameter of air bag, (m)

There are three ways to arrange air bags with the longitudinal launch method: linear, staggered, and two-line arrangements. The linear arrangement can be used when the vessel width is not more than the effective length of the air bag, while if the vessel width is more than the effective length and less than the effective length of two air bags, the staggered arrangement can be used. When the vessel width is greater than the combined effective length of two air bags, or for special vessels such as HSC catamarans or barges, a two-lines arrangement should be selected. The arrangement form can be seen in Figure 3.

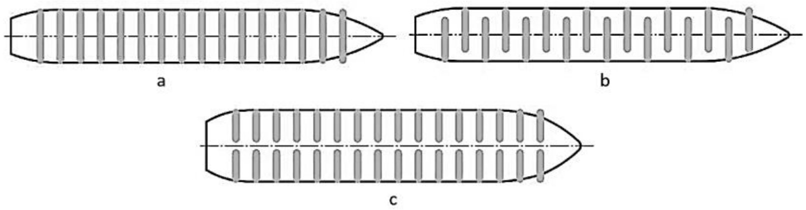

Figure 3. Arrangement type a) linear arrangement, b) staggered arrangement, c) two lines arrangement [28]

Table 5. Performance parameters of air bags [26]

Type No.	Diameter m	Initial Internal Pressure for test kPa	Related working pressure, Pe kPa	Bearing capacity per meter in length, Ph kN/m	Minimum burst pressure kPa
QP3	0.8	25	130	114	390
	1.0	18	100	110	300

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	1.2	15	85	112	260
	1.5	13	70	115	210
	1.8	11	60	118	180
	0.8	35	170	149	510
	1.0	25	130	143	390
QP4	1.2	20	110	145	330
	1.5	16	90	148	270
	1.8	14	80	158	240
	0.8	48	210	184	630
	1.0	35	170	186	510
QP5	1.2	28	140	185	420
	1.5	20	110	181	330
	1.8	16	90	178	270
	0.8	56	245	215	740
	1.0	45	200	219	600
QG6	1.2	32	165	217	490
	1.5	25	130	215	390
	1.8	20	110	218	330

Rated working pressure may deviate 5%. Compress deformation may deviate 2%

Results and Discussions

In the research, calculations and planning were carried out through several work steps. The first stage is to calculate the displacement of the ship using the equation

$$\Delta = C_B . L . B . T . \rho \ (1 + s) \text{ ton} \qquad (9)$$

Where :

s: shell plating and appendage displacement (approx 0.5 to 0.8 % of moulded displacement)

ρ: density of water (= 1.025 t/m^3 for sea water)

Since the C_B block coefficient data is unknown, the C_B value is calculated using Ayre's formula:

$$C_B = C - 1.68 \ F_n \qquad (10)$$

Where :

C is constant values, 1.08 for single screw ships and 1.09 for twin screw ships

F_n is Froude number $F_n = \frac{V}{\sqrt{g.L}}$

$$F_n = \frac{6{,}173}{\sqrt{9{,}8.57{,}36}}$$

$$F_n = 0.26$$

So, $C_B = 1.09 - 1.68 \, , 0.26$

$$C_B = 0.653$$

By entering the values, the displacement can be found, with the s value taken as 0.5.

$$\Delta = C_B . L . B . T . \rho \ (1 + s)$$

$$\Delta = 0{,}653 \, , 57{,}36 \, , 12 \ \ 2{,}7 \, , 1025 \ (1 + 0{,}5)$$

$$\Delta = 1865{,}87 \text{ ton}$$

- Steel weight

$$\text{steel weight} = 30 \text{ x} \frac{\Delta}{100}$$

$$\text{steel weight} = 30 \text{ x} \frac{1865{,}87}{100}$$

$$\text{steel weight} = 559{,}761 \text{ ton}$$

- Outfit weight

$$W_o = K . \nabla$$
$$W_o = K . L . B . D$$
$$W_o = 0.036 \, . \, 57.36 \, . \, 12 \, . \, 4$$
$$W_o = 0.036. \ 57.36 \, . \, 12 \, . \, 4$$
$$W_o = 99.12 \text{ ton}$$

- Machinery weight

$$W_m = \frac{BHP}{10} + 200 \text{ tons diesel}$$

$$W_m = \frac{2000}{10} + 200 \text{ tons diesel}$$

$$W_m = 400 \text{ tons diesel}$$

- Ship weight:

$$\text{Ship weight} = \text{Steel Weight} + \text{Outfit weight} + \text{Machinery Weight}$$
$$\text{Ship weight} = 559.761 + 99.12 + 400$$
$$\text{Ship weight} = 559.761 + 99.12 + 400$$
$$\text{ship weight} = 1058.881 \text{ ton}$$

Margin on Light Weight Estimation is 2%, so the total margin is 21.18 ton

In this study, the total weight of the ship at launch is 1080.061 tonnes, where the weight of each ship to be launched has its own weight according to the existing construction and equipment. As shown in Table 6, the calculation of the weight of a passenger ship at launch with an overall length of 68 m conducted by Sugeng et al, in 2020, resulted in a launch weight of 1074.590 tonnes. The launch weight in this case is the weight of the empty vessel, including the weight of the construction and skin plates [20].

Table 6. Ship's launching weight

Ship's Length	Launching's Weight
Loa 62 m	1080.061 ton
Loa 68 m	1074.590 ton

- Air bag's number calculations

$$N = K_1 \frac{Q.g}{C_b.R.L_d} + N_1$$

K_1, constant value, taken 1.2

Q weight of the ship to be launched, taken 1080.061 ton

G, gravity force, 9.8 m/s^2

C_b, block coefficient of the ship to be launched taken 0.653

R, allowable bearing, force per length air bag, (kN/m), taken QG6, diameter 1.0 m with R 219 kN/m

L_d contact length between air bags, taken 10 m, as shown in Figure 4 which is the contact between the air bag and the vessel body.

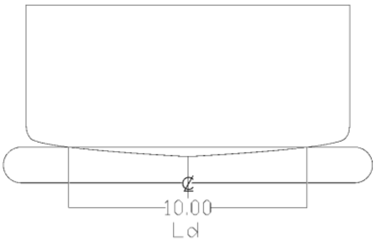

Figure 4. Air bag contact length (L_d)

N_1 the number of air bags installed in conjunction is taken as 2.

$$N = 1.2 \frac{1080.061 \,.\, 9.81}{0.653 \,.\, 219 \,.\, 10} + 2$$
$$N = 10.89$$
$$N = 11$$

The calculation of the centre distance between air bags can be done as follows:

$$\frac{L}{N-1} \leq 6$$
$$\frac{L}{N-1} \geq \frac{\pi D}{2} + 0.5$$

$$\frac{57.36}{11-1} \geq \frac{3.14 \,.\, 1}{2} + 0.5$$

$$5.736 \geq 2.07$$

So, the allowable distance between air bags is 2.07 metres to 5.736 metres per air bag. With the position of the air bags ranging from 2.07 metres to 5.736 metres in Figure 5, it can be seen that the air bag arrangements are arranged by following the determined distance. Air bag arrangements in ship construction areas with the greatest weight, such as the engine room area, must have a short distance because the massive weight will affect the construction stress that occurs. Greater stress occurs in the area under the ship, which is in direct contact with the air bags [29].

$$q = \frac{P}{s} \tag{11}$$

q = 18,84 ton/m

Next, it is required to know how much load is held by each air bag in tonnes (P1) with the formula below [29].

$$P1 = q \,.\, \text{x} \tag{12}$$

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Where q is the load distribution, and x is the distance between air bags. The arrangement of air bags in this study uses a linear arrangement with an air bag length of 12 m. So the load received by each air bag with a distance between air bags of 5.736 m is 101.283 tonnes.

Table 7. Load per air bag

Distance between airbags	Air bag load
2.070 m	38.998 ton
5.736 m	101.283 ton

In Table 7, it can be seen that the load received by the air bag is influenced by the distance between air bags, where the longer the distance between air bags, the greater the load that must be supported by each air bag. So the placement between air bags with a short distance is more recommended in the area under the engine room, which has a large construction weight compared to other constructions.

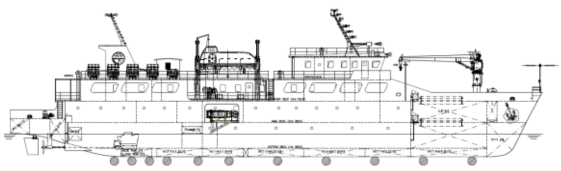

Figure 5. Air bag arrangement

In the designed launch, with a launch weight of 1058.881 tonnes, 11 airbag units are required. The requirements for the use of airbags for different types of ships are different. The difference in the use of airbags for ship types is strongly influenced by the ship's weight, the length of the keel, the shape of the ship's base and the length of contact between the airbags and the ship's base [30].

Conclusions

From the calculation and planning process of launching with the ship launching method with an air bag system, starting with calculating the launch weight, Where the launch weight is the ship in an empty state or lightship weight. The launch weight calculation will be used as a reference for calculating the number of air bags to be used. The launch planning weight of a passenger ship with an overall length of 62.80 metres is 1058.881 tonnes. Using the regulations of CB/T 3837 - 1998 and planned launch using air bag model QG6 High-bearing capacity air bag with 6 layers of cord fabric with a diameter of 1.0 metre, 11 air bags are required to support the launch of this passenger ship with a linear arrangement. The arrangement distance between air bags is between 2.07 metres to a maximum of 5.736 metres between air bags. With a short distance between air bags, the smaller the load supported by each air bag, on the other hand, the longer the distance between air bags, the greater the load supported by each air bag.

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Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by Kharis Abdullah. Writing, review, and editing by Sryang T. Sarena. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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