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Bilge System Design on 500 GT Ferry for Bulukumba–Selayar Route

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Abstract. A piping system is the main part of a system that connects the point where the fluid is stored to the point of accessing the pipe. Both pipe strength and pump capacity must be carefully considered because the safety of a ship will depend on the piping arrangement as well as on other ship equipment. The main function of the bilge pipe system is the drainage system in case of flooding in the compartment due to grounding or collision. Another function is the drainage system in the event of leaks on the welding root, condensation on the side shell leaks on the piping system (particularly in the engine room), and discharge water due to water-splash over the hatch. This study aimed to design a bilge piping system design using Autopipe Software with ASME B31.3 standard for the piping process. The design phase of the system is collecting data, then determining the load case. After that, selecting components needed for the construction of the system. The following step, making 3-dimensional modeling on Autopipe by entering input based on the determining components. Finally, validating the model, and proceed with the running model according to the specified load case. The result of the running model is the pipe stress level which is described in the stress code in the Autopipe. The final results are 3-dimensional drawings of the system and the number of components needed for constructing the system under Indonesian Classification Bureau (BKI) rules and ASME B31.3 standards for the piping process.

1. Introduction

Bulukumba-Selayar route, which is located in South Sulawesi Province, Indonesia, has a crossing port of the Bira Port (Bulukumba) -Pamatata Port (Selayar), whose existence has a very important role in the development of the surrounding area which is separated by water. The development Bira-Pamatata crossing has become an important issue considering that ferry is still a transportation mode that is widely used by the local community.

The project of the 500 GT Ferry for the Selayar-Bulukumba route consists of hull construction and in-ship system plannings. The shipbuilding construction planning aims to determine the ship shape [1], while the in-ship system is a system planning that supports all performance in ship operations [2]. One of the planning systems is the piping system. The piping system is defined as a system that connects the point where the fluid is stored to the point where discharged [2]. To flow the fluid, the piping system should be designed carefully because it affects the domestic needs and safety of the ship.

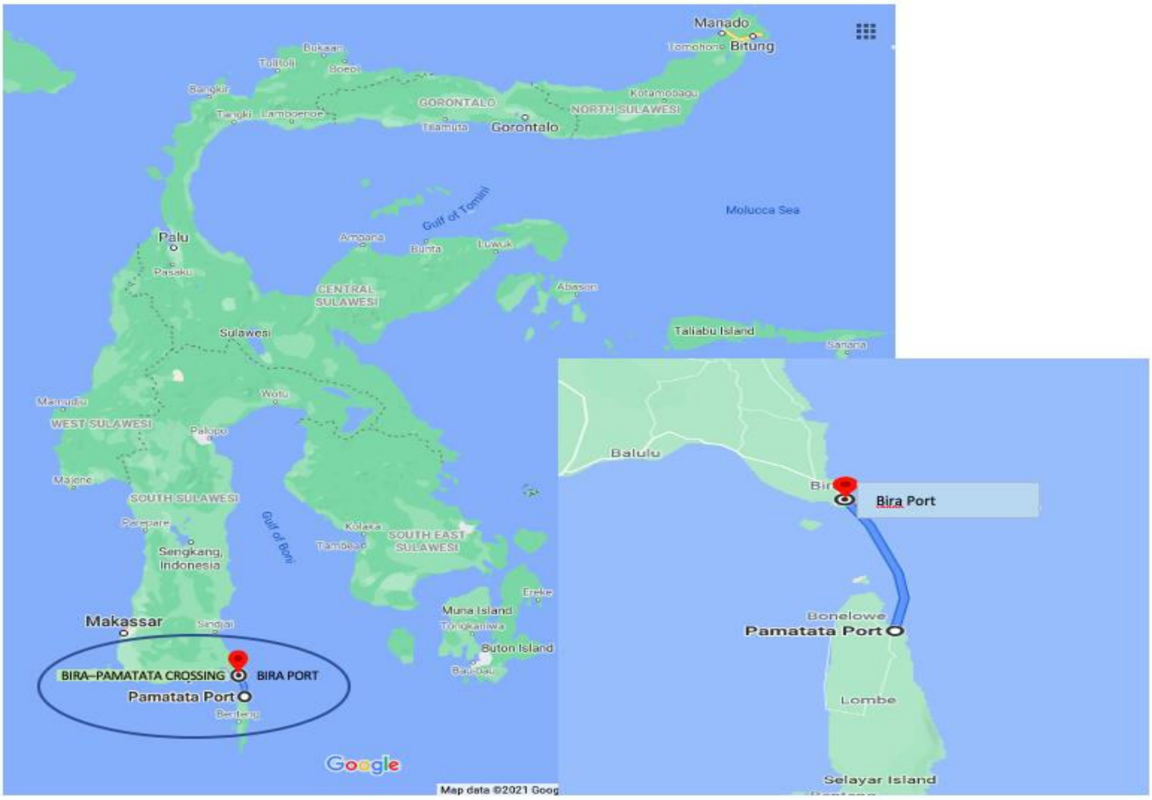

Figure 1. Bulukumba-Selayar route [3]

When a ship experiences a leak caused by grounding or collision, a bilge system is needed to discharge water quickly from the inside to the outside of the ship. The bilge system has the main function to drain due to water penetrating the ship, the system also accommodates various liquids in the well which are then pumped in using a bilge pump to be discharged from the ship via the overboard [3]. The liquid that is scattered in the engine room will be accommodated in the bilge well which is located under the engine room, it will then be separated between water and lubricating liquid using a separator, here water can be directly discharged through the overboard, while the lubricating liquid will be accommodated on the sludge tank.

The bilge system should have a proper design so that the number of pipe components and supports could be determined, and pump capacity could be estimated. In designing a system, it is necessary to design a drawing that can assist in the design process of the system, it can be easily interpreted to minimize errors in the ship construction. Autopipe is 3-dimensional design software that can produce output such as static load, dynamic load, and the necessity of pipe components [4]. Therefore this study aims to design the bilge system on the 500 GT ferry for the Selayar-Bulukumba route, South Sulawesi, Indonesia, that comply with BKI and ASME B31.3 standards for the process piping using Autopipe.

2. Literature Review

2.1. Piping System

The piping system is a complex system that should be designed as effectively and efficiently as possible to meet the ship provision, crew, cargo, and maintain ship safety both while sailing or anchoring. The piping system can be defined as the main part of a system that links the storing point to the discharging point for either transferring power or pumping, it must be considered carefully because the safety of a ship will depend on the piping arrangement and other ship equipment [2].

Pipe is a hollow and tubular body that is used to transport or flow a commodity that has flow characteristics such as liquids, gases, vapors, and fine powders. Pipe is one part of the piping system, the piping system includes pipes, flanges, fittings, bolts, gaskets, valves that are connected together [5].

2.2. Pipe components

The piping installation system includes pipes, flanges, valves, separator attachments. The system is expected to produce an efficient system in terms of position and safety which comply with the rules of the classification and the specifications of the installation guide of the machinery support system [6].

2.3. Bilge System

Based on BKI 2021 vol. 3 section 11, calculation of the bilge pipe diameter as follows [7].

$$d_H = 1.68\sqrt{LxBxH} + 25 \ (mm) \quad (1)$$

The equation for the calculation of the pipe diameter above is based on BKI Sec 11, where d_H is the inner diameter of the main pipe, L is the length of the ship, B (beam) is the breadth of the ship and H (depth) is the height. Then the equation for the calculation of the branch pipe is as follows.

$$d_Z = 2.15\ (\sqrt{l(B+H)}) + 25\ mm \quad (2)$$

Where d_Z the inner diameter of the branch pipe, and *l* is the length of the watertight compartment. After that determine the thickness of the pipe with the following equation.

$$S = So + c + b \ (mm) \quad (3)$$

The equation for calculating the pipe thickness above is based on BKI Sec.11, where S is the minimum thickness, So is the calculation of the thickness as follows.

$$So = \frac{(da\ x\ PR)}{(20\ x\ \sigma\ perm\ x\ V) + PR} \quad (4)$$

Where *da* is the outer diameter, *PR* is the pressure requirement, *σperm* is the max stress tolerance, V is the efficiency factor, C is the seawater lines' corrosion factor, b is the curvature allowance. Then the calculation of the bilge pump capacity can be calculated using the following equation.

$$Q1 = 10^{-3} x\ {d_H}^2 \quad (5)$$

The equation above is based on BKI Sec. 11 where *Q1* is the minimum capacity and d_H is the inner diameter of the main pipe.

2.4. Pipe

The division of pipe classes is regulated by BKI which is based on the working pressure and temperature. The piping system should be carried out as practically as possible with welded or brazed bends and joints to the extent possible with flanges or joints which can be removed if necessary, all pipes are to be protected in such a way as to avoid mechanical damage and must be supported/clamped in such a way as to avoid vibration.

2.5. Gate Valve

Gate valve is a valve with a working mechanism which is a system of opening and closing the gate component to regulate the fluid flowing in it. The gate valve can work in both directions so that it can flow from left to right or the other way around [8].

2.6. Slip On Flange

This type of flange has no holes and is used at the end of pipes or fittings in a piping installation. This is similar in shape to the lap joint flange type. The two types of the flange are the same as inserting the main pipe into the flange, the difference is that if the slip on the pipe does not come out of the flange, while the lap joint type, there is a side of the pipe that comes out of the flange, and the side inside the flange is usually radial. In slip-on, the flange is only partially inserted, the outside and inside will be welded. Because the pipe enters the flange, the inside diameter of the slip-on must be greater than the outside diameter of the pipe [9].

2.7. Blind Flange

Blind flange is a type of flange that functions to close the flow, like a cap in a fitting. This type of flange is flat, there are no other components because it serves to close [9].

2.8. Autopipe

Autopipe is a computer program used to analyze and calculate stresses in pipes, flange analysis, support analysis, displacement, and stress code in static and dynamic conditions. Autopipe can analyze the effect caused by the thermal load throughout the piping system. with modeling, loading, and analysis, it will produced output stress, deflection, force, and moment to achieve the design goal of the piping system in a safe and proper condition..

2.9. Model Validation

In Autopipe, there are three validation steps, the first validation is consistency check which can display a warning message for load cases that are entered unanalyzed or do not match the combined load code, or combination load code that includes unanalyzed loading.

The second validation is the coincident node check which checks the maximum distance used to determine the proximity of a point from another given point. This criterion is used to identify nodes that are "coincident" but not connected. After the tolerance distance is set, a coincident node check can be run.

The third validation is a design check which scans and reports such as scanning the model regarding the pipe structure and the use of fittings on the pipe and then issues a warning if an error occurs in the modeling.

2.10. Stress Code

It is a stress code visualization using Autopipe which displays a color-coded plot of the stress ratio between piping points for the associated load combination so that it can help show which points have a stress level that exceeds a predetermined standard..

3. Research Methodology

3.1. Data

The main dimensions of the ship can be seen in Table 1 and pump capacity in Table 2. A list of the prices of the selected pipe components used in the input process in designing the system can be seen in Table 3.

To find out how the process of moving fluid from one compartment to another compartment can be seen from the ballast bilge pipe diagram which was taken from PT. Industri Kapal Indonesia Persero (https://www.ikishipyard.co.id/). The ship has two bilge tanks, each located at the port side and starboard which has a sounding pipe with a self-closing device, as shown in Figure 2.

For the design of the bilge pipe system in a 3-dimensional form on the Autopipe, a base drawing is needed which can be seen in Figure 3, from the double-bottom drawing, it is obtained the shape of the bilge pipe construction which serves as a reference in the drawing process on the Autopipe.

Table 1. Main dimensions

Dimensions	Value	Units
Length overall (*Loa*)	46.80	m
Length between perpendiculars (*Lpp*)	41.86	m
Beam	12.00	m
Depth	3.70	m
Draft	2.60	m
Service Speed at 85% MCR	12.00	Knot
Trial Speed at 100% MCR	13.00	Knot

Table 2. Pump capacity

Pumps	Capacity
General service/fire pump (*self priming*)	50 m^3/h * 40 m Head
Bilge pump (*self priming*)	40 m^3/h * 25 m Head
Ballast pump	40 m^3/h * 25 m Head
Enmergency Bilge Pump	25 m^3/j * 20 m Head

Table 3. List of the prices

Name	NPS (inch)	*Class*	Price per pcs (IDR)
ASTM Pipe grade B length 6m	2	-	907,000
	3	-	1,316,000
Slip on flange-carbon steel	2	150	111,000
	3	150	197,500
Pipe support	2	-	32,000
	3	-	45,000
Bellmouth-galvanized steel	2 to 3	-	105,000
Strainer-carbon steel	2	150	1,050,000
Blind flange-carbon steel	3	150	283,000
Tee branch-stainless	2	150	159,000
Gate valve	2	150	1,882,400

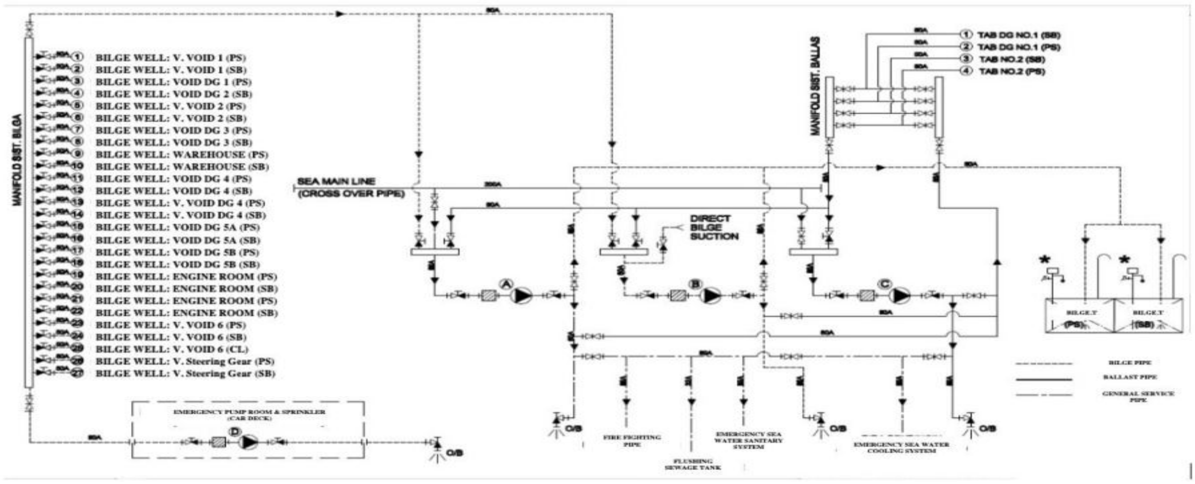

Figure 2. Ballast and Bilge Piping Diagrams

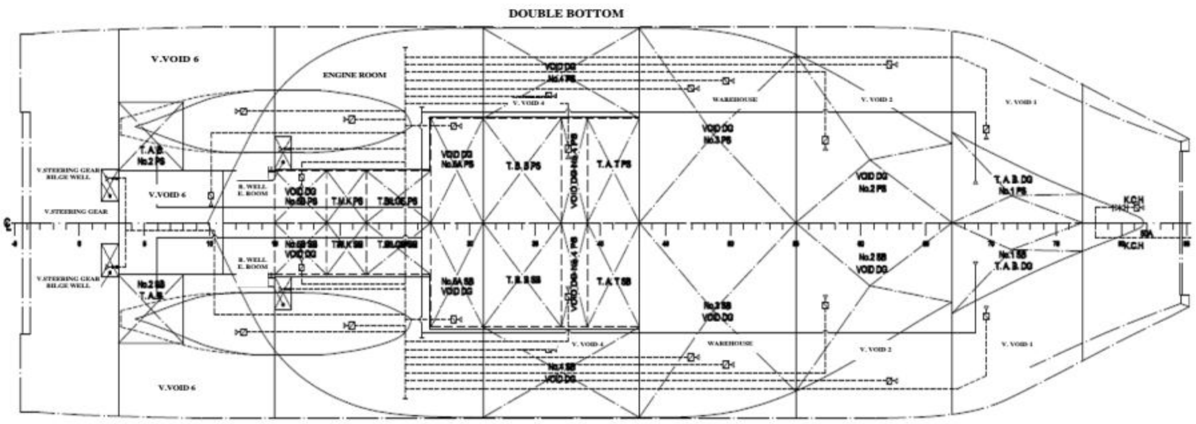

Figure 3. Double Bottom

From the calculations according to equation (1), the d_H as the main bilge pipe diameter is 67.91, using equation (2) the d_Z value as the branch pipe diameter is 49.09. Then adjusting to the nominal pipe size of the pipes sold in the market, the main pipe diameter is 80 A and the branch pipe diameter is 50 A. The material chosen for the main and branch pipe is A53 grade b which is low carbon steel. Tensile strength and yield strength for bilge pipes can be seen in Table 4.

It is known that if a pipe system construction does not have the correct pipe support system it is the cause of the construction failure due to the uneven loading system. Therefore it is important to lay pipe supports, for the distance between the pipe supports itself, which can be seen in Table 5.

Adjusting the used bilge pipe material, the ASTM group 2-1.1 class for the flange pressure-temperature ratings data for low carbon steel can be seen in Table 6.

Table 4. Mechanical properties of main and branch pipes [10]

	Grade		Units
	A	**B**	
Tensile strength	48000	60000	Psi
	330	415	Mpa
Yield strength	30000	35000	psi
	205	240	Mpa

Table 5. Spacing of vertical support [11]

NPS (inch)	Water service (ft)	Steam, gas, or air service (ft)
1	7	9
2	10	13
3	12	15
4	14	17
6	17	21
8	19	24
12	23	30
16	27	35

Table 6. flange pressure-temperature ratings for ASTM group 2-1.1 [12]

Working pressure (bar)							
ASTM				***Class***			
Temperature (°C)	150	300	400	600	900	1500	2500
-19 – 38	19.6	51.1	66.1	102.1	153.2	255.3	425.5
50	19.2	50.1	66.8	100.2	150.4	250.6	417.7
100	17.7	46.6	62.1	93.2	139.8	233	388.3
150	15.8	45.1	60.1	90.2	135.2	225.4	375.6

3.2. Loading

The planning of loading in the system uses a PR design pressure of 2.5 bar equal to the head of the bilge pump which is converted in international units to 0.25 N / mm^2, then all fluids flowing in the system are considered sea water so that the operating temperature is used is 30° C taken from the calculation of the kinematic viscosity of seawater.

4. Results and Discussion

4.1. Model Validation

The bilge pipe system that has been validated by the validation model which is no failures is shown in Figure 4.

4.2. The Effect of Pipe Support Placement on Displacement

The displacement change analysis can help see how the bilge pipe system installed on the ship. It can be seen that the displacement changes when the pipe support placement does not comply with the standard which can be seen in Figure 5.

Then the completed bilge pipe system modeling which uses pipe support to minimize displacement caused by the load of the pipe component itself can be seen in Figure 6.

4.3. Stress Code

The visualization of the system stress code on the ship using Autopipe is displayed with a color-coded plot of the stress ratio between piping points for the associated load combination which can be seen in Figure 7.

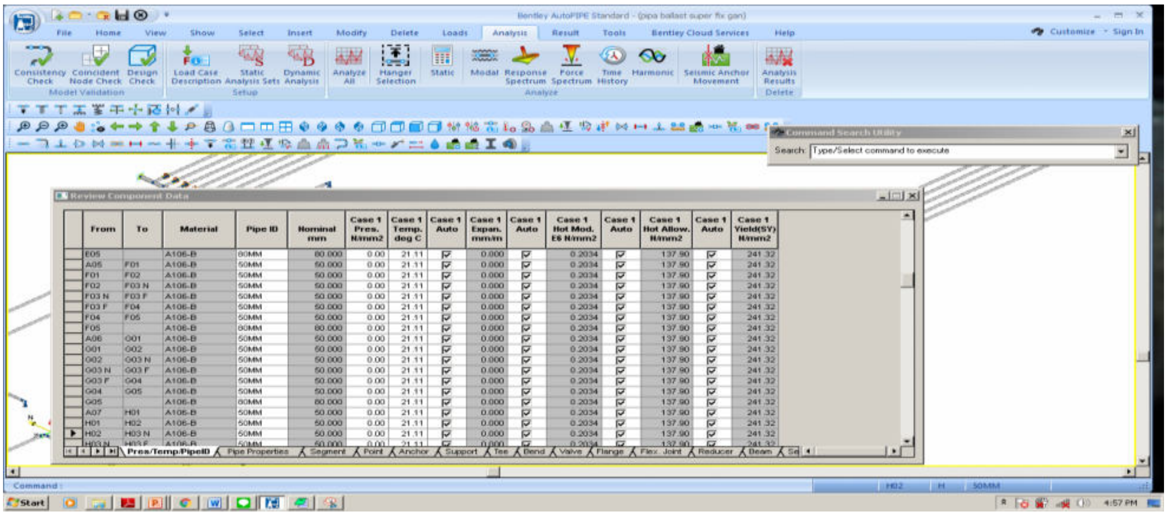

Figure 4. Model Validation

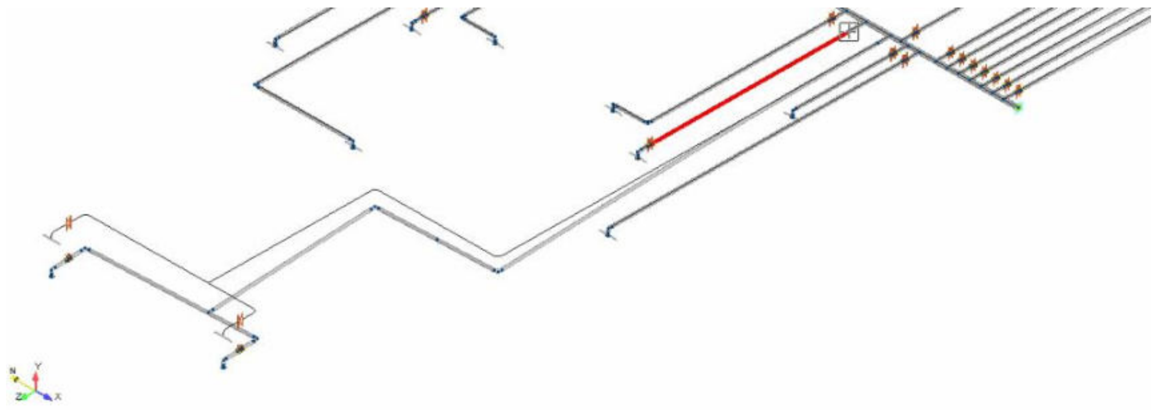

Figure 5. Bilge pipe system with inappropriate distance between pipe supports

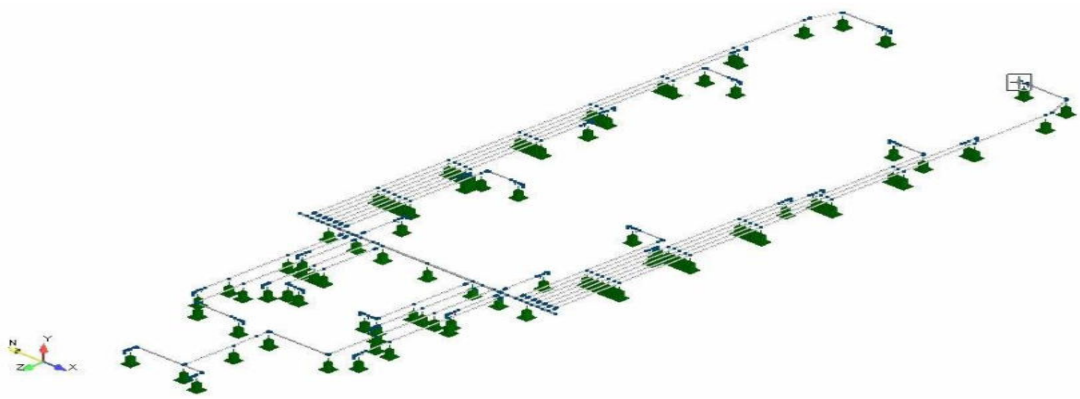

Figure 6. Bilge pipe system with suitable distance between pipe supports

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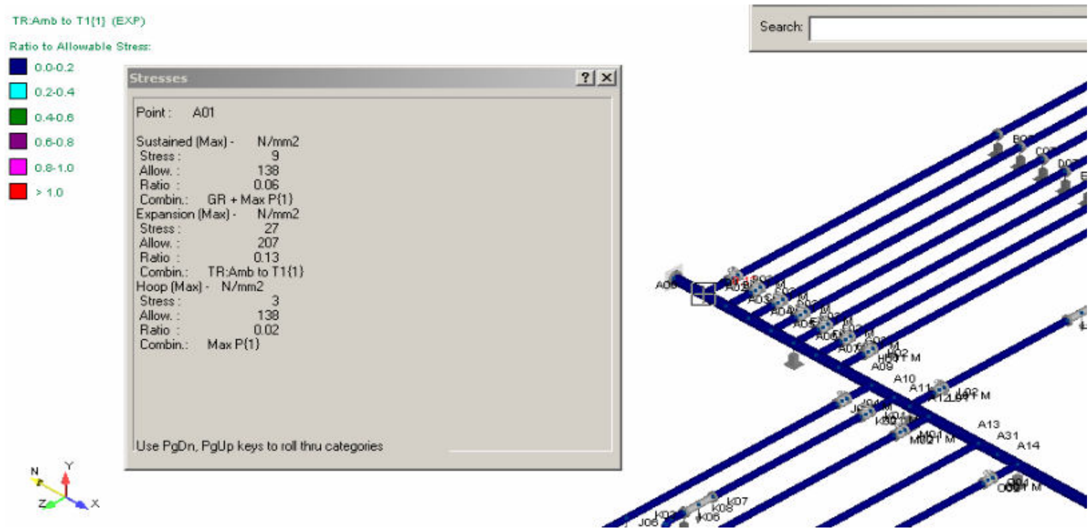

Figure 7. Stress Code

It can be seen in Figure 7 that the placement of the pipe support is correct and does not have a ratio to allowance stress of more than 1. For the largest value, it is found in the V (Void) 1 pipeline which can be seen in table 7. For continue stress, expansion stress, and hoop stress each stress does not exceed the standard. It is known that the allowable stress for A53 grade b pipe is 138 N / mm2, in the Autopipe, the formula for hoop moment is the same as the allowable stress for pipes with straight lines, this is because the bending moment value is not large due to the pressure and the working temperature is low. Then for the stress expansion formula is as follows.

$$Sa = f(1.25Sc + 0.25Sh) \quad (6)$$

Where Sa is the expansion stress, Sc is the allowable stress of 138 Mpa, f is the stress range factor where the value is 1 because Sc and Sh have a value at the maximum limit of 138 Mpa. For Sh is hoop stress where the value is equal to the allowable stress. So that after the calculation, the Sa value is 138 N / mm2.

Table 7. Stress code

***Pipe size* (in)**	***Sustained* (N/ mm^2)**			***Expansion* (N/ mm^2)**			***Hoop* (N/ mm^2)**		
	Stress	*Allow*	*Ratio*	*Stress*	*Allow*	*Ratio*	*Stress*	*Allow*	*Ratio*
Main	3	138	0.02	21	207	0.10	3	138	0.02
V1	9	138	0.06	27	207	0.13	3	138	0.02
V2	7	138	0.05	27	207	0.13	3	138	0.02
VDG2	5	138	0.03	27	207	0.13	3	138	0.02
Warehouse	1	138	0.01	27	207	0.13	3	138	0.02
VDG3	6	138	0.05	27	207	0.13	3	138	0.02
V4	3	138	0.02	27	207	0.13	3	138	0.02
VDG4	6	138	0.04	27	207	0.13	3	138	0.02
V6	8	138	0.05	27	207	0.13	3	138	0.02
ER	4	138	0.03	27	207	0.13	3	138	0.02
VDG5a	4	138	0.03	27	207	0.13	3	138	0.02
K6T	5	138	0.03	27	207	0.13	3	138	0.02
ER.K	3	138	0.02	27	207	0.13	3	138	0.02
BW	2	138	0.01	27	207	0.13	3	138	0.02

VDG5b	2	138	0.01	27	207	0.13	3	138	0.02

Table 8. Material used for bilge pipe system component

Main Bilge Pipe				
Material		**NPS (inch)**	**Length (m)**	**Number (pcs)**
A53 grade B		**3**	**6 m**	**2**
Branch Bilge pipe				
Compartment name	**Material**	**NPS (inch)**	**Length (m)**	**Number (pcs)**
Bilge well: Void 1 (PS)	A53 grade B	2	6	4
Bilge well: Void 1 (SB)	A53 grade B	2	6	4
Bilge well: Void 2 (PS)	A53 grade B	2	6	3
Bilge well: Void 2 (SB)	A53 grade B	2	6	3
Bilge well: Void 4 (PS)	A53 grade B	2	6	1
Bilge well : Void 4 (SB)	A53 grade B	2	6	1
Bilge well: Void 6 (PS)	A53 grade B	2	6	1
Bilge well: Void 6 (SB)	A53 grade B	2	6	1
Bilge well: Void 6 (CL)	A53 grade B	2	6	2
Bilge well: Void DG 2 (PS)	A53 grade B	2	6	3
Bilge well: Void DG 2 (SB)	A53 grade B	2	6	3
Bilge well: Void DG 3 (PS)	A53 grade B	2	6	2
Bilge well: Void DG 3 (SB)	A53 grade B	2	6	2
Bilge well: Void DG 4 (PS)	A53 grade B	2	4	2
Bilge well: Void DG 4 (SB)	A53 grade B	2	4	2
Bilge well: Void DG 5A (PS)	A53 grade B	2	2	1
Bilge well: Void DG 5A (SB)	A53 grade B	2	2	1
Bilge well: Void DG 5B (PS)	A53 grade B	2	6	1
Bilge well: Void DG 5B (SB)	A53 grade B	2	6	1
Bilge well: warehouse (PS)	A53 grade B	2	6	2
Bilge well: warehouse (SB)	A53 grade B	2	6	2
Bilge well: Engine Room (PS)	A53 grade B	2	2	1
Bilge well: Engine Room (SB)	A53 grade B	2	2	1
Bilge well: Engine Room (PS)	A53 grade B	2	6	1
Bilge well: Engine Room (SB)	A53 grade B	2	6	1
Bilge well: Steering Gear Room (PS) and Steering Gear Room (SB)	A53 grade B	2	6	3
Slip on flange				
Material		NPS (inch)	Class	Number (pcs)
Carbon steel		2	150	174
Carbon steel		3	150	2
Blind flange				
Material		NPS	Class	Number
Carbon steel		3	150	2
Pipe support				
Material		NPS	Class	Number
Cast iron		2	-	9
Cast iron		3	-	44
Gate valve				
Material		NPS	Class	Number
Cast steel		2	150	27
Strainer				
Material		NPS	Class	Number
Carbon steel		2	150	23
Tee				
Material		NPS	Class	Number
Carbon steel		2	150	1
Bellmouth				
Material		NPS	Class	Number
Carbon steel		2 to 3	150	27

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4.4. *Number of Components Used For Designing Bilge Pipe Systems*

After the design has been completed and meets the standards applicable to the Autopipe, the next step is to calculate the required number of bilge pipe system components according Autopipe. The total of the components is shown in Table 8

4.5. *Cost Estimation of Bilge Pipe Systems*

Table 9 is the calculation of the cost of the required bilge pipe components, the calculations are based on the price list shown in Table 3. Based on the results, the total cost estimation is IDR 141,964,800 (one hundred forty-one million nine hundred sixty-four thousand eight hundred rupiah).

Table 9. Cost estimation of bilge pipe system component

Components	NPS (inch)	Number (pcs)	Price per pcs (IDR)		Total price (IDR)
Pipa ASTM grade B length 6m	2	45	907,000		40,815,000
	3	2	1,316,000		2,632,000
Slip on flange-carbon steel	2	174	111,000		19,314,000
	3	2	197,500		395,000
Pipe support	2	44	32,000		1,408,000
	3	9	45,000		405,000
Bellmouth-galvanized steel	2 to 3	27	105,000		1,296,000
Strainer-carbon steel	2	23	1,050,000		24,150,000
Blind flange-carbon steel	3	2	283,000		566,000
Tee branch-stainless	2	1	159,000		159,000
Gate valve	2	27	1,882,400		50,824,800
			Σ Total Price	=	141,964,800

5. Conclusion

Based on the design of the bilge pipeline system with Autopipe , a 3-dimensional design of the 500 GT ferry bilge pipe system using a design pressure of 2.5 bar adjusts the bilge pump head and all the fluid flowing in the bilge pipe is considered seawater so based on the kinematic viscosity of seawater, the design temperature value used is 30 ° C. The stress generated from the designed system does not exceed the allowable stress value so that it can be concluded that the system is safe. This is in accordance with the input process of all materials and the given load comply with the standard which is ASME B31.3 for the piping process. Allowable hoop stress is considered the same as allowable stress because the working temperature and pressure have a low value. In the stress code V1, the stress value is 9 N / mm2 that is the greatest working stress, the maximum working stress of the hoop is 3 N / mm^2. The allowable expansion stress value is obtained from the calculation of 207 N / mm2 and the working expansion stress is 27 N / mm^2. The number of components needed in the design of the system are; (1) 80A main bilge pipe with a length of 6m has a total requirement of 2 pcs, (2) 50A branch bilge pipe with a length of 6m has a total pipe requirement of 45pcs. Finally, the total estimated cost of the bilge system design is IDR 141,964,800 (one hundred forty-one million nine hundred and sixty-four thousand eight hundred rupiah).

References

[1] Hidayat T and M B 2016 Analysis of Increasing Content of Local Components in Development of New Domestic Ships *J. Wave* **10** 61–6 [In Bahasa]

[2] Windyandari A and Janah J I 2013 Piping System Design on Km. Nusantara *Kapal J. Ilmu Pengetah. dan Teknol. Kelaut.* **10** 154–63 [In Bahasa]

[3] Anon *Pamatata Port to Bira Port - Google Maps*
[4] Anon Piping Design And Pipe Stress Analysis Software - AutoPIPE
[5] Zahra A K, Supomo H and Baihaqi I 2019 Technical and Economic Analysis of the Application of Pipe Piece Family Manufacturing (PPFM) in Piping System Installation of 17,500 DWT Tanker *Tek. ITS* **8** [In Bahasa]
[6] Pramono S and Kurniawan R D *Piping System of Ship with 2655 HP Engine* [In Bahasa]
[7] Klasifikasi Indonesia B 2021 *Rules For Classification And Construction Part 1 Seagoing Ships Volume III RULES FOR MACHINERY INSTALLATIONS Consolidated Edition 2021*
[8] Zikri Z and Al Huda M 2019 Determination of Appropriate Welding Process Parameters to Eliminate Linear Indication Defects in Gate Valve Products *J. Teknol.* **9** [In Bahasa]
[9] Azka Roby A and Bahari R 2016 Design of 2 Phase Mini Vertical Separator on Fluid Sampling Activities (Review of Economic Aspects) in PT. Pertamina EP Asset 2 Field Limau *J. Tek. Patra Akad.* **Vol 7.** [In Bahasa]
[10] Anon ASTM S/A 53 Carbon Steel Pipe & Tube | A53 Carbon Steel Pipe | FedSteel.com
[11] Becht IV C 2009 B31.3 Process Piping *Companion Guide to the ASME Boiler and Pressure Vessel Code, Volume 1, Third Edition* vol 1, ed K R Rao (ASME Press) p 0
[12] Anon Flanges General - Pressure-temperature ratings ASTM and ASME

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