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Characteristics of Lateral Acceleration and Vertical Acceleration of the Position of the Vehicle on the Ferry Ro-Ro Car Deck

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***Abstract*- Ferry accidents in Indonesia happen not just once or twice, but more than that. This is reinforced by statistical data on shipping transportation accidents. Shifting or overturning of the vehicle to the side of the ro-ro ferry has a big hand in causing the ship to capsize, and eventually an accident occurs. This purpose to determine the characteristics of the lateral and vertical acceleration of vehicles based on their location on the car deck under the influence of side waves. With the use of the Maxurf program and the B-spiline mathematical equation, the method is strip theory. The results of the study detected that vehicle positioning on the ro-ro ferry car deck significantly affects the value of vertical acceleration and lateral acceleration due to rolling motion. This is one of the parameters that can cause a vehicle to roll over.**

Keywords-lateral acceleration, vertical acceleration, feri ro-ro, RAO, Ship motion.

I. INTRODUCTION

Many shipping accidents in 2021 will be caused by human factors. The fact is that there was a significant increase from the previous year of 179.55% [1]. The following year, it decreased by 31.58%, with ships sinking and catching fire as the most frequent shipping accidents [2].

According to the KNKT, the types of ships that were the object of accidents were dominated by passenger ships [3]. According to the Republic of Indonesia's Minister of Transportation, a passenger ship is any vessel transporting more than twelve passengers [4]. A ro-ro ferry is a type of passenger ship used to carry passengers, vehicles, goods (in trucks and sometimes unpowered shipping containers), and even rail cars. The handling of this type of cargo on board a ro-ro ferry is different because it is related to the distribution of loads on board, which has implications for ship stability, ship strength, and ship safety. Ferry accidents in Indonesia happen not once or twice, but more than that [5]. This can be seen from the shipping accident statistics. Domestically built ferries have a large width-to-draft ratio, which implies that the maximum stability arm occurs at a roll angle of less than 25 degrees [6]. According to the IMO, ships that have a large width-to-draft ratio tend not to meet one of the stability criteria [7]. Research on ferries has been carried out covering stability, construction strength, and maneuverability with the aim of ensuring the safety of ferries. Hasbullah et al. (2017) examined the effect of the operational environment on the maneuverability characteristics of ferries [8].

The event of shifting or overturning the vehicle to the side of the ro-ro ferry has a big hand in creating the initial tilt and immediately makes the ship lose stability, so it sinks [9]. This condition is prone to occurring during unfriendly shipping weather conditions [10].

The Ministry of Transportation's regulations regarding vehicle fastening systems on ships regulate in detail the technicalities of fastening types of vehicles as well as suitable materials used as fastenings. Likewise, the layout has been set [11][12]. However, its application in the field is less effective on short tracks. On the other hand, the force and moment imposed on the vehicle have a significant impact on the fastening system's performance. Therefore, a vehicle that is already bound can also shift or roll over due to an ineffective binding system or binding strength that is unable to withstand the forces and moments that occur. This is the basis for reviewing the opportunities for shifting or overturning vehicles to minimize shifting and overturning events.

In addition, the regulations do not take into account the details of the size of the vehicle and its implications for the chance of shifting and overturning the vehicle. The transverse shift of an object depends on the geometry of the object and its center of gravity relative to the baseline [13] [14]. Likewise with the types of vehicles and their respective geometric sizes that will be transported by ro-ro ferries. This research will produce potential shifts in objects on the ship.

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II. METHOD

Several studies that have been carried out previously regarding the possibility of shifting or overturning vehicles on ro-ro ferries include the analysis of lateral acceleration due to ship motion as a function of the position on board [15], testing of models to predict lateral acceleration based on IMO second generation stability criteria [16]. As a continuation of this research, the influence of ship motion on the vehicle fastening system on ro-ro ferries will be analyzed, which will then be used to design a vehicle fastening system so that accidents due to shifting or overturning of vehicles can be minimized in the future.

The first stage of this research is data collection, consisting of ship data, vehicle data (trucks and buses), and ship operating environment data. Ship data includes ship geometry, line plans, general plans, and vehicle fastening system data. Vehicle data consists of vehicle size, including the types of goods that are often transported by trucks, while operating environment data includes wave and wind data. Vehicle data and vehicle loading conditions were taken through field surveys at the Balikpapan - North Penajam Paser Crossing (ASDP Kariangau Branch). Wave and wind data are taken at the Meteorology, Climatology, and Geophysics Agency [17]. For the verification and validation stage of the results of the binding system design, data collection is carried out on other crossing routes, such as the Bira-Pamatata crossing and the Mamuju-Balikpapan route.

The second stage is modeling the ship's hull for numerical simulation using Maxurf software. In this simulation, the weight distribution, which is strongly influenced by the vehicle layout, is approximated by the radius of gyration coefficient for each motion response, assuming the ship is fully loaded. The simulation is carried out with variations in the direction of arrival as well as wave height and length, so that the influence of each wave parameter on the response characteristics of the ship's motion can be known. Modeling of the forces and moments operating on the vehicle as a result of the motion response as the primary cause of shifting and overturning of the vehicle is then performed based on the ship's motion response. The forces and moments that occur are viewed in the transversal and vertical directions, while the moments resulting from motion will be viewed in the transversal direction. These forces and moments will then be used to analyze the shift and rollover of the vehicle.

III. RESULTS AND DISCUSSION

A. Data Collection of Ro-Ro Ferry Crossing Tracks

The ship used as the sample in this study is a ferry with the following sizes [18]:

LOA = 54.5 m
B= 13.00 m
H= 3.45 m
T= 2.45 m

The ship has a stowage plan on the car deck, namely 15 trucks and 6 sedans, which, in addition to carrying passengers, are shown in Figure 1.

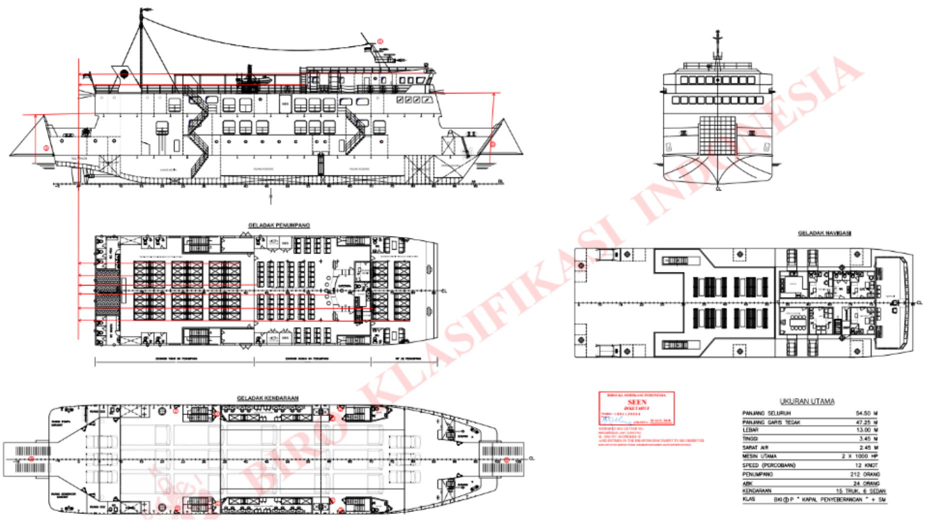

Figure 1. General Arragement Car Deck Feri

B. Ship hull modeling and stowage plan on the car deck.

After obtaining data on ships operating on the Balikpapan-Penajam Paser Utara route, modeling was then carried out using Maxurf software. This is done to determine the weight distribution on the car deck and positioning for each vehicle, as shown in Figure 2.

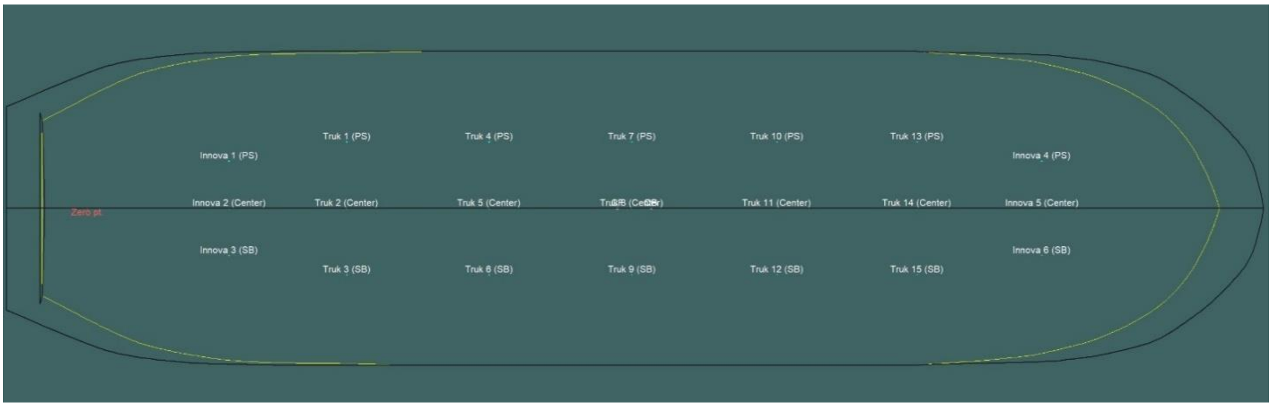

Figure 2. Stowage Plan on Car Deck Feri

Figure 2 shows the ferry car deck along with the location of each vehicle, which consists of 3 rows: the left side row, the right-side row, and the middle row. The location and size of the vehicle affect the weight distribution [19]. In addition, the vehicle positioning must be equipped with the center of gravity of each vehicle, which is measured from the after-perpendicular, center line, and bus line, as shown in Table 1.

TABLE 1.
COORDINATE THE LOCATION OF EACH VEHICLE.

No	Vehicle of type	Long Pos	Offset meters	Height
1	Innova 1 (PS)	6,31	2,10	0,88
2	Innova 2 (Center)	6,31	0,00	0,88
3	Innova 3 (SB)	6,31	-2,10	0,88
4	Truck 1 (PS)	11,55	2,96	1,13
5	Truck 2 (Center)	11,55	0,00	1,13
6	Truck 3 (SB)	11,55	-2,96	1,13
7	Truck 4 (PS)	17,91	2,96	1,13
8	Truck 5 (Center)	17,91	0,00	1,13
9	Truck 6 (SB)	17,91	-2,96	1,13
10	Truck 7 (PS)	24,27	2,96	1,13
11	Truck 8 (Center)	24,27	0,00	1,13
12	Truck 9 (SB)	24,27	-2,96	1,13
13	Truck 10 (PS)	30,75	2,96	1,13
14	Truck 11 (Center)	30,75	0,00	1,13
15	Truck 12 (SB)	30,75	-2,96	1,13
16	Truck 13 (PS)	37,00	2,96	1,13
17	Truck 14 (Center)	37,00	0,00	1,13
18	Truck 15 (SB)	37,00	-2,96	1,13
19	Innova 4 (PS)	42,57	2,10	0,88
20	Innova 5 (Center)	42,57	0,00	0,88
21	Innova 6 (SB)	42,57	-2,10	0,88

C. Simulating the Ship's Motion in Relation to Wave Direction

The next step is to simulate the motion response using strip theory. This method produces three characteristics of ship motion: heave, pitching, and rolling. When the ship is fully loaded, waves are simulating coming from the side, or beam sea. Wave data is taken from Makassar Strait water data according to the ship's operational area. [17]. The wave height is also varied so that a motion response is obtained for each condition during sailing. Some of the simulated wave heights are 2.1 and 2.8 meters, respectively. The height of this wave will have implications for the lateral acceleration and vertical acceleration values for each vehicle, apart from vehicle positioning [20]. The response amplitude operator (RAO) of the ferry when it gets waves from the side is shown in Figure 3.

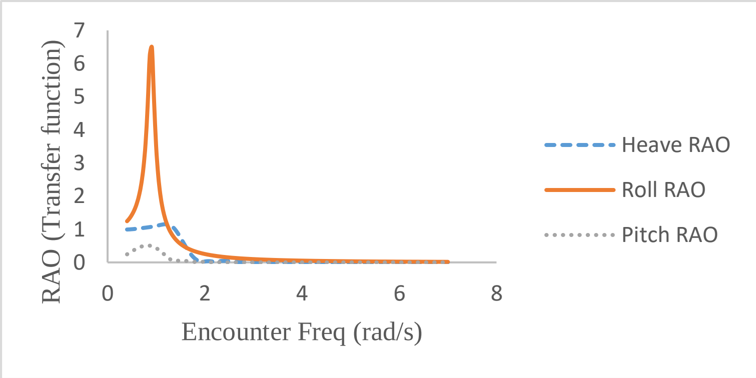

Figure 3. Response Amplitude Operator (RAO)

Figure 3 shows the RAO of the ship being operated at full load by getting waves from the side. From the RAO calculation, we can then determine the influence of the positioning of the vehicle on the car deck on the lateral acceleration and vertical acceleration values.

D. Analysis of Lateral Acceleration and Vertical Acceleration Values for Wave Height.

After obtaining the RAO value, we then observed the acceleration value laterally and vertically in the case of each wave height variation. Only a few vehicle samples were taken as representatives of each vehicle's position, which significantly affected when it received a side wave. The vehicle samples are Innova 1 representing the rear left side, Truck 4 representing the center left side, and Innova 7 representing the front left side. The lateral and vertical acceleration values for each sample vehicle at a certain wave height are shown in Figures 4 and 5.

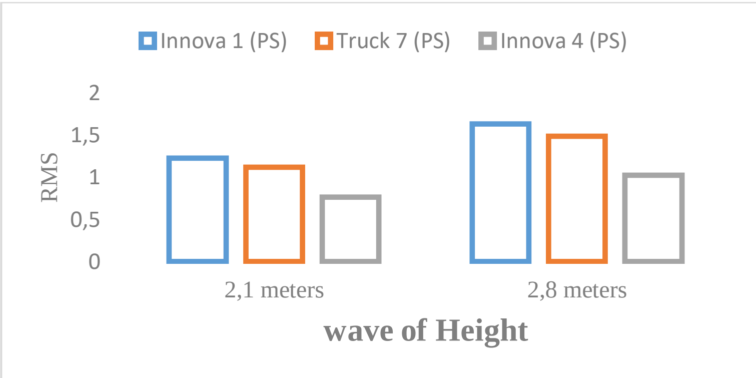

Figure 4. Vertical Acceleration

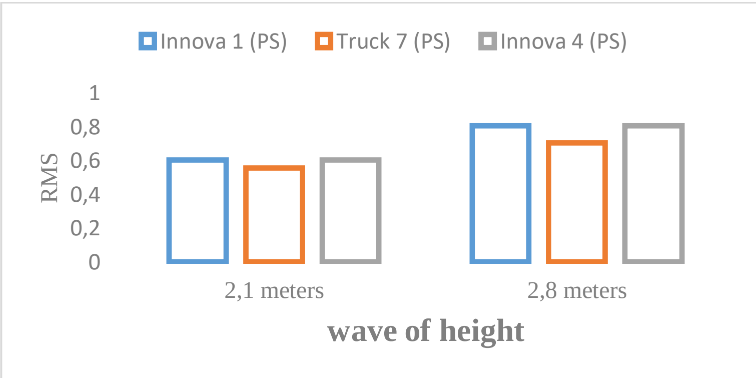

Figure 5. Lateral Acceleration

Figure 4 shows the vertical acceleration characteristics for each vehicle location, where the highest is Innova 1 (PS), which is located on the rear left side, followed by Truck 7 (PS), which is located on the middle left side, and the last is the Innova 4 vehicle (PS), which is located on the front left side. Figure 5 shows the lateral acceleration characteristics for each vehicle location, where the highest is owned by Innova 1 (PS) and Innova 4 (PS), which represent the front and rear left sides of the vehicle. Then followed Truck 7, which represents the location of the vehicle on the left side of the center.

IV. CONCLUSION

The conclusion that can be drawn from the analysis of the lateral and vertical acceleration characteristics for each vehicle is that the value of the vehicle's vertical acceleration significantly increases from the vehicle located at the front to the vehicle located behind. Vehicles located at the rear have a greater vertical acceleration value than those at the front. While vehicles located in the middle have a lower lateral acceleration value compared to vehicles located in front and behind. The lateral acceleration values of vehicles located at the front and behind tend to be the same. In further research, it will be examined in relation to the lateral and vertical acceleration of the vehicle, the magnitude of the moment of force, and the maximum acceleration that can be generated.

REFERENCES

[1] S. Sadya, Ada 19 Kecelakaan Pelayaran di Indonesia pada 2021 [Internet]. DataIndonesia.id, editor. 2022 [cited 2023 April 07]. Avalaible from: https://dataindonesia.id/sektor-riil/detail/ada-19-kecelakaan-pelayaran-di-indonesia-pada-2021.

[2] R. Mustajab, Terdapat 13 Kecelakaan Pelayaran di Indonesia pada 2022 [Internet]. DataIndonesia.id, editor 2023. [cited 2023 April 07]. Avalaible from: https://dataindonesia.id/sektor-riil/detail/terdapat-13-kecelakaan-pelayaran-di-indonesia-pada-2022.

[3] AS. Hasugian, AAIS. Wahyuni, M. Rahmawati, Pemetaan Karakteristik Kecelakaan Kapal di Perairan Indonesia Berdasarkan Investigasi KNKT. War. Penelit. Perhub. 2017;29(2):229–240.

[4] Kementrian Perhubungan Republik Indonesia. Peraturan Menteri Perhubungan Republik Indonesia Nomor PM 26 Tahun 2022 Tentang Pengawakan Kapal Niaga. 2022.

[5] KNKT. Laporan Statistik Investigasi Kecelakaan Transportasi 2022 Semester 1. Jakarta; 2022.

[6] D. Paroka, "Karakteristik Geometri dan Pengaruhnya Terhadap Stabilitas Kapal Ferry Ro-Ro Indonesia," *KAPAL J. Mar. Sci. Technol.*, vol. 15, no. 1, pp. 1–8, 2018, [Online]. Available: https://ejournal.undip.ac.id/index.php/kapal/article/view/17272/12620.

[7] IMO. International Code on Intact Stability 2008- Part A. 2008..

[8] M. Hasbullah, D. Paroka, Hanisa. The Effect of Waves on the Maneuvering Characteristics of Ferry Vessel. J. Penelit. Enj. 2017;21(1):11–22.

[9] KNKT. Investigasi Kecelakaan Pelayaran: Tenggelamnya KMP. Munawar Ferry Perairan Selat Alas, 4 Nautical Mile Timur Pelabuhan Kayangan Lombok Timur, Nusa Tenggara Barat. Jakarta; 2014..

[10] Balitribun. Gelombang Tinggi Hantam Selat Lombok, KMP Primera Oleng, Truk Tronton Terguling [Internet]. editor 2019. [cited 2023 April 07]. Available from: https://balitribune.co.id/content/gelombang-tinggi-hantam-selat-lombok-kmp-primera-oleng-truk-tronton-terguling.

[11] Kementrian Perhubungan Republik Indonesia. Peraturan Menteri Perhubungan Republlk Indonesia Nomor PM 30 Tahun 2016 Tentang Kewajiban Pengikatan Kendaraan Pada Kapal Angkutan Penyeberangan. 2016.

[12] Kementrian Perhubungan Republik Indonesia. Peraturan Menteri Perhubungan Republik Indonesia Nomor PM 115 Tahun 2016 Tentang Tata Cara Pengangkutan Kendaraan Di Atas Kapal. 2016.

[13] K. Crossland, P. Rich, A Method for Deriving MII Criteria Transaction of RINA Intern. 2000..

[14] AE. Baitis, FD. Holcombe, SL. Conwell, P. Crossland, J. Colwell, JH. Pattison. 1991 – 1992 Motion Induced Interuption (MII) and Motion Induced Fatigue (MIF) Experiments at the Naval Biodynamics Laboratory. 1995.

[15] D. Paroka, AH. Muhammad, S. Rahman, FM. Assidiq, Vulnerability of Ship with a Large Breadth to Draught Ratio Against Excessive Acceleration Criteria. In: The 7th International Conference on Marine Technology (SENTA 2022). 2023. p.1-10..

[16] D. Paroka, AH. Muhammad, S. Rahman, FM. Assidiq. Vulnerability Assessment for Excessive Acceleration Failure Mode of an Indonesian Ro-Ro Ferry by Model Experiment. Int. J. Technol. Accept. Publ. 2023.

[17] BMKG. Pusat Metereologi Maritim, 2023. Available online : [https://maritim.bmkg.go.id/].

[18] Kemenhub. Rencana Umum Kapal Penyebrangan Penumpang ro-Ro 600 GT. 2018..

[19] Alamsyah, Z. Zulkarnaen, Suardi. "The Stability Analyze of KM. Rejeki Baru Kharisma of Tarakan – Tanjung Selor Route," *TEKNIK*, vol. 42, no. 1, pp. 52–62, 2021, [Online]. Available: https://ejournal.undip.ac.id/index.php/teknik/article/view/31283/19397.

[20] Alamsyah, A. Hidayatullah, Suardi, W. Setiawan, Habibi, S.D. Nurcholik "Motion Response on The Water Ambulance Ship," *IJMEIR*, vol. 8, no. 1, pp. 1–7, 2023.