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Initial Maintenance Notes about the First River Ship Lock in Iran

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Abstract

Mared Dam in northern Abadan is under construction on the Karun River and it is the first ship lock in Iran. In this study, the ship's lock was examined. Every vessel must pass through this lock in order to transport water from Arvand River to Karun and vice versa. The interior dimensions of the Mared Shipping Lock are 160 meters long, 25 meters wide and 8 meters deep. Several important times are calculated for lock operation. $T$is the first time the gates open, T15 the time the initial gates remain open until the height difference between the two sides reaches 150 mm, Tfilled is the duration between the start of the opening the gates till the difference between the two ends becomes zero after T15. Finally, T is the total time required for opening or closing the gates completely. The rotational speeds of the gates range from 5 to 35 radians per minute. Numerical modeling has been used to study fluid behavior and interaction between fluid and gates in flow 3D software. Different lock maintenance scenarios have been analyzed. Important parameters such as inlet and outlet flow rate changes from gates, water depth changes at different times, stress and strain fields, hydrodynamic forces acting on different points of the lock have been calculated. Based on this, the forces acting on hydraulic jacks and gates have been calculated. The minimum time required for the safe passage of the ship through the lock is calculated.

1. Introduction

The entry of salty water from the Persian Gulf into the rivers of Khuzestan province in Iran (caused by sea tides) causes a decrease in the quality of fresh water in these rivers. This issue causes many problems in the water supply of agricultural lands in the summers of drought years. To solve this problem, three dams and three ship locks (the Bahman Shir dams at upstream and downstream of Bahman Shir River and Mared Dam). The locations of these structures indicated at the Fig. 1.

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Fig 1. (a) The Location of the Bahman Shir dam (upstream), (b) Bahman Shir dam (downstream dam) and (c) Mared Dam. Note: The borders of the countries are not exact.

Thus, salinity water penetration will be control at upstream of the Karun River. By usage of a ship lock for the dam, vessels can be pass of it. The ship lock is currently the most widely used, promising and important type of navigational structure in the world. Therefore, it is very important to evaluate the safety of ship lock operation in service Li et al. (2023). A navigation lock is a structure in a waterway provided to provide a safe navigational passage between two pools of water that are not on the same level(Dhanuka et al., 2018). The literature review show that that several studies have been conducted by researchers in connection with this structure, for example, we can referred to the studies of Liu et al. (2022), Mäck and Lorke (2014), Ables (1978); Hu et al. (2024), Iuorio (2024).

According to Moore (1950), there were structures similar to locks in the ancient Chinese (Song Dynasty empire, from 960 to 1279) and ancient Europe. Currently, there are many shipping locks in many countries of the world, especially in Europe, North America, China and Russia (Negi et al., 2024; Nogueira et al., 2024; Yang et al., 2024).

Also, a lot of research has been done to improve design, operation, performance, environmental issues, physical and mathematical models, forces on ships and vessels inside ship locks, forces on gates (sector, miter or caisson) and the other important issues.

There has been a great deal of research on every kind of ship lock design worldwide. A list of some of the design criteria for these locks, as well as some research on this, is provided in the references list. Of course, three ship locks in the upstream dam of Bahman Shir, the downstream dam of the Bahman Shir and the Mared dam of the Karun Rivers are Iran's first shipping locks. The initial study of river navigation (Mahab., 1976) and its further study (Scott_Wilson; and Piesold., 2005) have led to the design of vessel dimensions. Due to changing climate conditions, river transportation facilities in the Karun have been re-examined (Mansouri Kia and Ansari, 2008).

Many parameters needed to understand the basic concepts of locks are provided in the U.S. Army Corps of Engineers guides (Army, 1964; Dhanuka et al., 2018). For example:

Layout and Design of Lock Dimensions, Filling and Emptying Systems, Approach Walls, Lock Sills, Emergency Access, Elevators, Gates, Valves, and Bulkheads, Loads, Analysis and Design Criteria, types of Navigation Dam Structures, and many more.

Gao et al. (2013) had been considered Steady-flow Integration Approach (SIA) and VOF approach to find the time of full filling in a ship lock with simple geometry. The time of full filling was 6.3 and 12.5s respectively. Undoubtedly, VOF approach is more accurate than SIA method. The SIA is not good method for design, especially in the lock with complex geometry. Like many other researchers, they have suggested that the three-dimensional VOF method is a nice choice to find out more precisely of the filling time, velocity fields, water fluctuations and others detail in the ship lock.

Wang and Zou (2014) express owing to the size restriction of lock chamber, the shallow water and bank effects on the hydrodynamic forces acting on the ship may be remarkable and complicated. They had numerical study for “Pierre Vandamme” Lock in Zeebrugge at the model scale. Their numerical analyses show effect of speeds, water depth, eccentricities on the hydrodynamic forces. By this data an instruction for the maneuvering of ships passing through a lock will be provided. The unsteady viscous flow and hydrodynamic forces are calculated by applying an unsteady Reynolds-averaged Navier–Stokes (*RANS*) equations with a RNG k-epsilon turbulence model. User-defined function (UDF) is compiled to define the vessel or ship motion, too.

(O’Mahoney and De Loor, 2015) Showed some error occurs as a result of 3D analyzes when the geometric details of the lock are not provided in the CFD 3D CAD model. When there is a combination of salt and fresh water in the hydraulic structure, densities are different and buoyancy effects will be important. When densities are different and lock with complex or relatively complex geometry the flow field will be consequently very different. CFD method present an estimate amount of mixing between salt and fresh water.

Belzner et al. (2018) presented a simple way based on the 1D Saint-Venant equations and allows the simulation of a lock filling process to determine the forces acting on the vessel due to different hydraulic conditions. They described hydrodynamics of the lock filling process with accuracy. For 1D ship lock model their basic formulas was Saint-Venant equations. The model was setup with the physical dimensions of a lock chamber and of the ship in it. To test the accuracy of the prediction, the lock Bolzum (lock near Hannover, Germany) was used. Results showed that the longitudinal forces are depending on four important factors: the first, geometry; second, percentage of valve opening velocity; third valve discharge coefficient and forth, jet propagation. In that research, the different conditions of applying force on the ship in the different opening percentage of the water inlet valves to the lock are described.

Economic comparative study and update of river transportation in the Karun (Mansouri Kia, 2018) and dimensions of the navigation channel (Mansouri Kia, 2022; Mansouri Kia et al., 2022) have been investigated.

Considering the importance of ship lock structure, in this research, the hydraulic behavior of the structure was investigated using numerical modeling in order to find the appropriate answer to the following questions.

First: What is the time to fill or discharge of the chamber depended on upstream and downstream head changes with/without vessels inside of it?

Second: How much are the forces of the sectorial gates when they are opening or closing under operation conditions? These forces can be used to optimize the design of the sectorial gates?

Third: How much are the forces aware of the proposed vessel under any circumstances?

Fourth: Given the mechanical operational limitations, what are the best guidelines for operating locks?

Fifth: How long does it take for the ship to pass through the lock?

In this research, the main focus is to answer the fourth and fifth questions. Of course, a part of the answer to other questions is also mentioned.

In the few years past, all types of launches have been passed to the coasts of Naseri port (Ahvaz). The memories of these trips are remained between the Khuzestan people. It is a regional capacity. New research has begun to restart the Karun Navigation River with an economic vessel. Three dams are under construction. It is clear that these dams require shipping locks. This study examines the fill and discharge times of shipping locks.

For this purpose, flow Science 3D software was used for modeling. Ultimately, the purpose of this study was to answer the question of determining the time to fill and discharge lock a without any vessel inside of it. First, a description of the history of shipping locks and research on them is mentioned.

The purpose of this study was to determine the time of filling and discharge of the ship lock, considering the dimensions of these three locks in previous studies. Lockfill software is suitable for modeling filling and discharge time. This software is well in agreement with the subject of this study. It builds a two-dimensional model by combining the Orifice relationships and the low surface water equation.

- The optimum initial opening rate was 0.9 m for each gate (1.8 m for the total of two gates).

- Practically, the maximum achievable gate speed of 12.5 degrees per minute is recommended by the Hydro Mechanical Contractor. So, the primary and secondary speeds are considered equal to this value.

- The numerical model shows that the operation of opening and closing the ship's lock and its filling and discharge for the ship to pass within 40 minutes will be carried out.

2. Materials and Methods

2.1. Theory background

The Mared Dam in northern Abadan is built on the Karun River. In this study, the ship's lock was examined. You must pass through this lock in order to transport water from The Arvand River to Karun and vice versa. The interior dimensions of the Mared Shipping Lock are 160 meters long, 25 meters wide and 8 meters deep. Figure 2 and Figure 3 show the lock geometry.

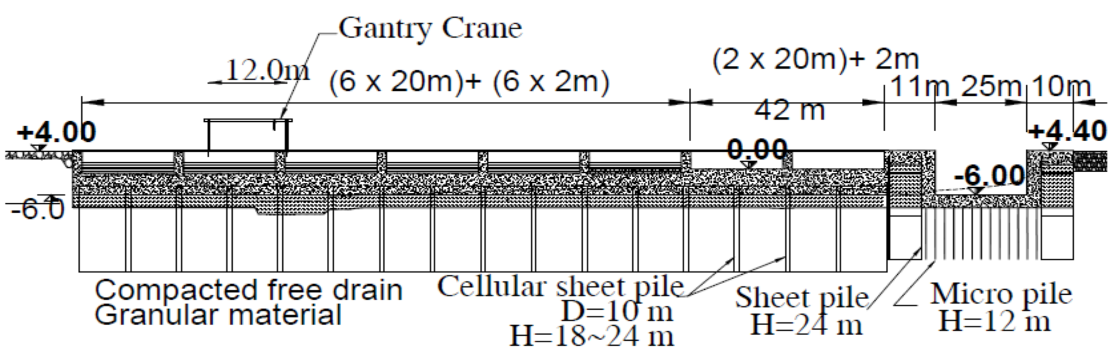

Fig 2. Longitudinal section of the Mared Dam and its ship lock.

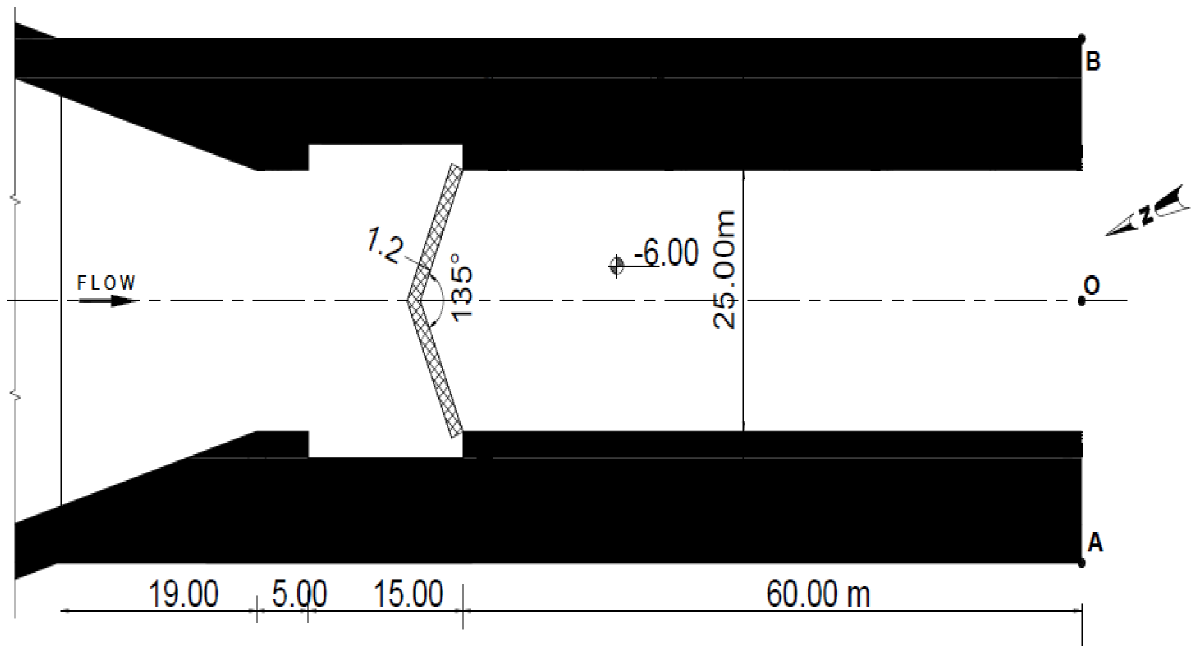

Fig 3. Sector Gate Location Plan in Ship Lock (Iranian sahel Omid Co. and Engineer, 2015).

In this study, some times that are important for ship lock operation have been determined.

The time between the lock being fully closed and its opening to a certain extent and

T is the duration time when the lock gates open from the fully closed state to an initial amount with a constant initial angular velocity., T_{15} is the duration time between the initial gates remain open until the height difference between the two-water level (inside and outside the chamber lock) reduced till 150 mm, T_{filled} is the duration time between the start the opening the gates again till difference the two-water level becomes zero after T_{15}. Other times are calculated for the operation of locks and finally T is the total time required for opening or closing the gates completely. The rotational speeds of the gates range from 5 to 35 radians per minute. For this purpose, numerical modeling has been used to study fluid behavior and the interaction between fluid and gates in the Flow 3D software. The results are:

- The result of the two-dimensional model is evaluated for constant opening speed and variable angular velocity. The range of speed variations from 5 to 35 degrees is assumed. The time required for filling is calculated.

The specific modeling module for sector gates is not public in this software and was not used. The second software tested was Ansys Fluent software.

Therefore, numerical modeling has been used to study the fluid behavior and interaction between fluid and gates in Flow 3D software. In this software, the governing equations at fluid in the VOF method are rewritten and numerically solved.

In software analysis, the continuity equation or conversation of mass as well as the conversation of moment of momentum are governed. It's easier to work with, and less time consuming. Also, in this problem, which is not too complicated, the accuracy of the answers will be acceptable.

The software input information on physical and fluid characteristics is summarized in Table 1.

Table 1. Software input information on physical fluid properties.

Parameter	Value	Unit
Chamber of roughness coefficient	3	mm
Roughness factor vessel body	5	mm
Freshwater Specific Weight (20 ° C)	1000	Kg/m3
Specific weight of saline water (20 ° C)	1030	Kg/m3
Freshwater Viscosity (20 ° C)	0.001	Kg/s
saline water viscosity (20 ° C)	0.001	Kg/s
Floating density	160	Kg/m3
Width of the Chamber	25	m
The length of the Chamber	160	m
Chamber floor elevation	-6	msl
Sector Gate Height (6 + 1.2 + 0.8)	8	m
Designing Sector gate head	8	m
Lock normal water level at upstream	1.2	msl
Lock minimum water level at upstream	1	msl
Maximum water level at upstream of lock (designing flood)	3.6	msl
Minimum water level at downstream of lock (tidal sea)	-0.37	msl
Maximum water level at downstream of ship lock (tidal sea)	+0.94	msl
Maximum water level at downstream of lock (corresponding to flood condition)	2.2 to 2.5	msl

For the definition of a hydraulic head, the idioms direct and reverse head will be used. The direct head occurs when the water level in the convex side of the gate shell is higher than its concave face. Thus, loads entering the gates are caused by the friction of the pintle and hinge, the hydraulic loads entering the bracket seal and the friction with the sealing. The reverse head occurs when the water surface level at the concave side of the gate is higher than its convex side. Thus, loads entering the gates are caused by the friction of the pintle and hinge, the hydraulic loads entering the bracket seal and vertical structural members at near the gate.

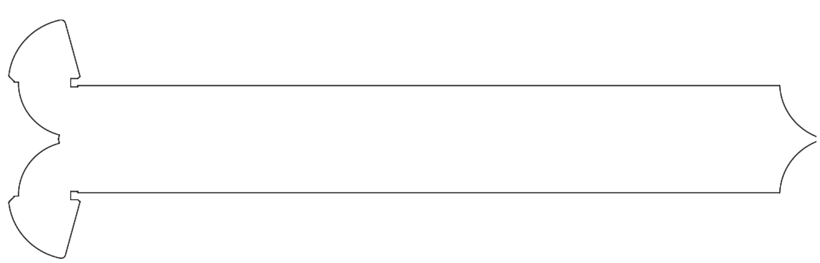

Fig 4. Wetting surface for gates opening and closing (4746 m^2).

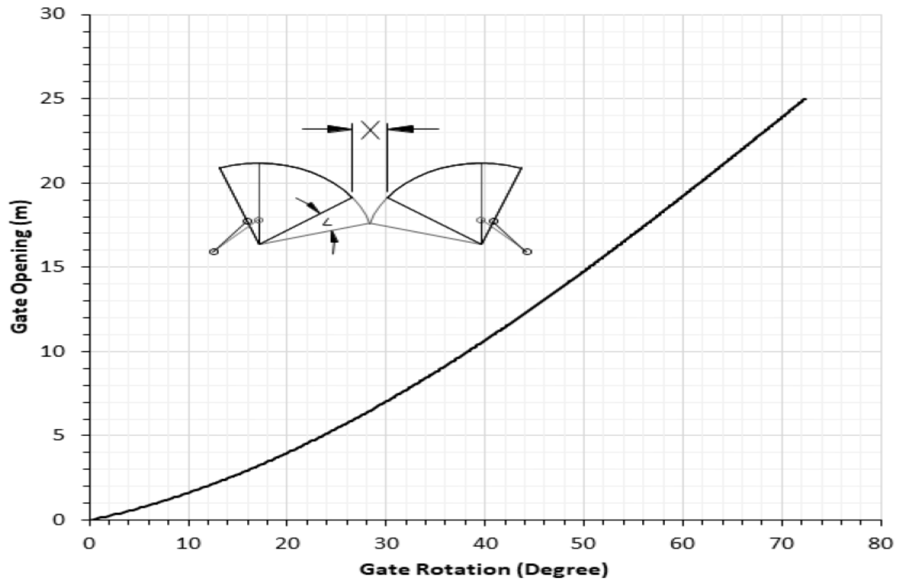

Fig 5. Total Gate Opening (m) Versus Angular Gate Rotation (degree).

2.2. The modeling and determining the most important times

2.2.1. Two-dimensional flow modeling

According to the design regulations of the United States Army Corps of Engineers hydraulic (USACE), it can use of combination of spillway orifice equation with the conservation of mass equation for Two-dimensional flow modeling. A combination of these equations time of filling or discharge of lock (chamber) will be determined. This model is used to calculate the amount of flow under different opening of gates by this equation (USACE.EM1110-2-1604, p4-10).

$$Q = cb_g h^{2/3} \tag{1}$$

Where c is the discharge coefficient in the free flow is constant and will decrease in submerged conditions related to the percent submergence rate. This can be found in Figure 6.

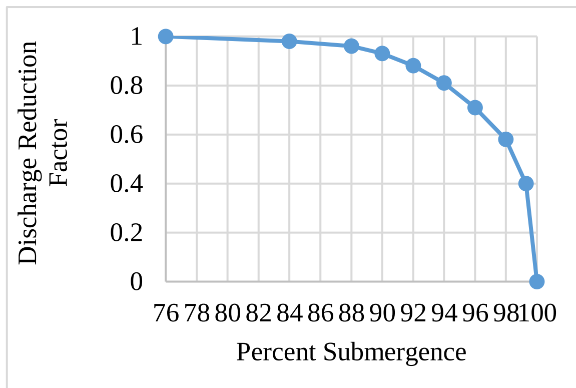

Fig 6. Determination of discharge coefficient in submerged overflow (USACE. EM 1110-2-1604, p. 4-12).

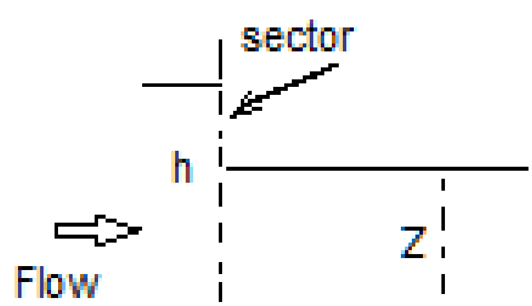

Fig 7. The parameters Definition of the flow Orifice formula (2).

$$Q = cb_g(2g(h-z))^{2/3} \quad (2)$$

In this equation, b is the effective opening of the gates, including the midline of the opening of the gates and the gap created at the sides. In cases where the flow is always submerged, the spillway Flow equation is modified to the Orifice flow equation.

In the case of the orifice, the discharge coefficient(C) is constant at 0.55. Also, the height of the water in the chamber (z) is the water depth at the inlet (h). The amount of increasing the height of the water in the chamber by considering the conversation of the mass equation is as follows:

$$Q = A_L dz/dt \quad (3)$$

A_L is the wet surface of the lock chamber in the plan. Figure 8 shows how to calculate the opening rate.

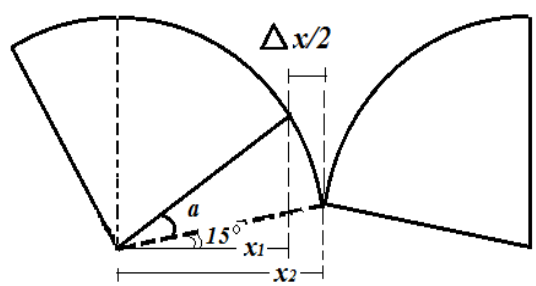

Fig 8. The following equation is used to calculate bg.

$$b_g = 2R\left(\cos\left(\frac{\pi}{12}\right) - \cos\left(\frac{\pi}{12} + \alpha\right)\right) \quad (4)$$

R is the radius of the gate and α (in radians) the amount of the gate's primary opening. For above Figure:

$$x_2 = R\cos\left(\frac{\pi}{12}\right), x_1 = R\cos\left(\frac{\pi}{12} + \alpha\right) \quad (5)$$

$$\Delta x = R\left(\cos\left(\frac{\pi}{12}\right) - \cos\left(\frac{\pi}{12} + \alpha\right)\right) \quad (6)$$

$$a = \arccos(\cos\left(\frac{\pi}{12}\right) - \Delta x/R) - \frac{\pi}{12} \quad (7)$$

$$v_x = R\sin\left(\alpha + \frac{\pi}{12}\right)v_a \quad (8)$$

$$\Delta x = 2v_a\int_{t1}^{t2}\sin(v_a t + \frac{\pi}{12})dt \quad (9)$$

$$= 2\left(\cos\left(v_a t_1 + \frac{\pi}{12}\right) - \cos\left(v_a t_2 + \frac{\pi}{12}\right)\right)$$

T_f the time required to reach the initial (primary) opening X_f is done by sorting the formula above.

$$T_f = \frac{1}{v_a}\left(arc\cos(\left(\frac{\pi}{12}\right) - \frac{\Delta X_f}{2}\right) - \frac{\pi}{12}) \quad (10)$$

According to the USACE recommendation, a two-speed gate is provided. In cases where the height difference on both sides of the gates is more than 1500 mm, the USACE regulations recommend that the average speed of the primary speed be between 1 to 6 degrees /sec and secondary speed after the height difference on both sides of the gate is about 150 mm between 25 and 35 degrees. Initial of opening for each gate at least 30 cm and max 90 cm (Middle lock opening for both gates are 180 cm) Recommended. If the water height of the lock on both gates sides is less than 1500 mm, the initial speed can also be 25 to 35 degrees per minute. In the Mared project, the height difference is 1570 mm, thus 1500 mm assumption it is possible. Therefore, it considers the lock with low bearing, so the initial speed for gates can also be considered 5 to 35 degrees per minute.

On the other hand, even after filling the gates, it must wait until the gates are fully open. In this case the ship will be allowed to pass. Therefore, the secondary speed will be much more effective than the primary speed for determining of operation ship's timing through the gate.

2.2.2. Total time for the vessel to pass through the ship lock

In Figure 9, the crossing times of the ship lock are divided into different components. The time for the vessel speed to reduce to zero in the waiting area is AB. The waiting time is BC. The time for moving in the chamber is CD. The total time the vessel passes through the locks is a function of the volume of traffic to the ship lock passage capacity (I/C). The theoretical operating capacity of the lock (C) is 12 million tons per year. The maximum number of vessels is 20 per day for passes of locks and 4000 vessels per year for 200 working days. The proposed barge unit capacity of this research is 950 tons of bulk cargo. The vessel is filled in one direction, but in the backward direction it is not filled. That is, 20% of the time, on the return path, with 50% capacity. The capacity of a return journey with a tonnage of (0.5 * 0.2 + 1) 950 =1045 will be the design for the barge unit and for the double barge 2090 tons. However, in economic calculations the average annual maximum is 2.133 million tons. Given the traffic volume of 4 million tons per year, the coefficient (I/C) will be approximately 0.33. According to Table 2, the total transit time is estimated to be approximately 25 minutes. But for a 90% confidence factor, the total crossing time is estimated to be about 40 minutes (25 multiplied by 1.6). This uses the 90% value of passage time as a measure of reliability at locks. This denotes the time it takes for 90% of vessels to pass through the lock (Brolsma and Roelse, 2011).

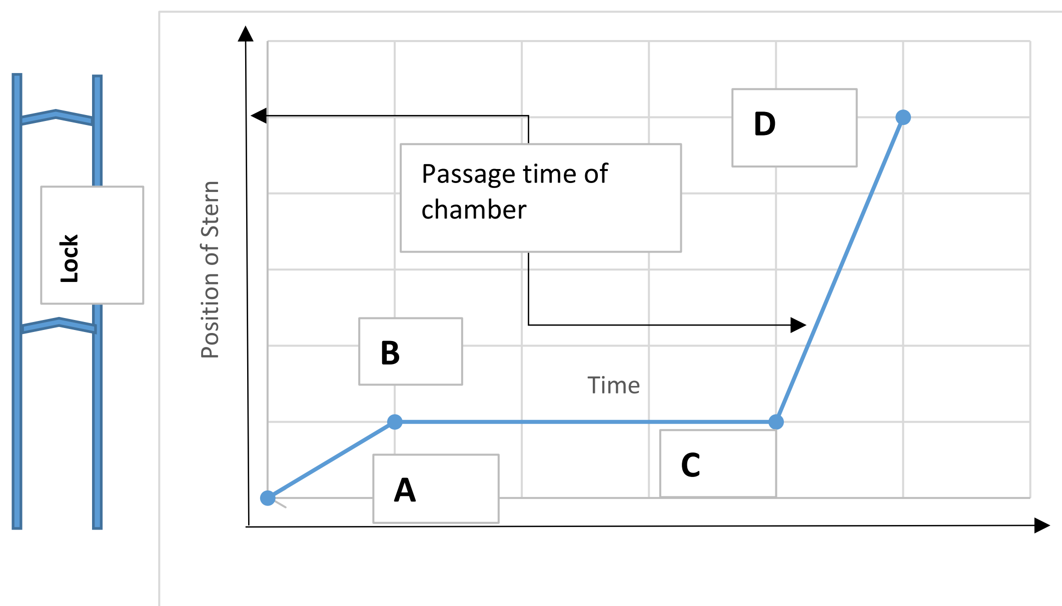

Fig 9. Shape of Time / Distance to describe the division of time into different components of a navigational crossing operation (Brolsma and Roelse, 2011).

Table 2. Estimation of vessel passing Time of lock (Brolsma and Roelse, 2011). According to the traffic volume coefficient to the pass-through capacity (I/C) realistically.

I/C	Ave. passage time (min)	90% value of passage time (min)
0.3	25	38
0.4	30	48
0.5	45	77
0.6	60	108
0.7	80	152
0.8	125	250
0.9	235	494

2.2.3. Three-dimensional flow modeling

After two-dimensional analysis, the three-dimensional analysis is performed. Software input information on physical fluid properties is presented at Table1.

3. Results and Discussion

3.1. Two-dimensional flow modeling

In this study, the primary opening of the gates starts at a speed of between 5 and 35 degrees/minute and continues to a maximum of 1.8 meters (0.9 meters per sector gate). The gates are held at the initial opening position to reach a height difference of 150 mm between the two gates. Investigations show that for the initial opening of 0.9 m (both gates are 1.8 m) and the secondary velocity of 35 degrees per minute, the minimum time required for the gates to fully open is 380 seconds and the minimum filling time for the chamber is 310 seconds. However, according to hydro-mechanical experts, the maximum acceptable speed in this project is 12.5 degrees/minute. Practically, the initial and secondary velocity will be considered equal to this value. Also, for the operating instructions, the initial opening of each gate is 0.9 meters (1.8 meters for two gates).

Table 2. Variations of the time the chamber is filled or discharged and the total time the gates open or close completely according to different parameters.

Velocity of opening (deg/s)	Parameter	***Initial opening (m)***						
		0.3	***0.4***	***0.5***	***0.6***	***0.7***	***0.8***	***0.9***
5	T_t	1612.34	1413.2	1291.46	1208.61	1148.15	1101.6	1064.51
5	T_{filled}	925.1	729.7	612.4	534.5	479.5	438.7	407.7
5	T_f	51.46	66.31	80.35	93.7	106.46	118.7	130.5
5	Max opening(m)	2.75	2.8	2.89	2.99	3.11	3.23	3.55
5	Max dis (m^3/s)	12.89	16.92	20.73	24.3	27.59	30.57	33.2
5	Max Rotation^o	15.05	15.36	15.73	16.14	16.6	17.08	17.58
10	T_t	1190.77	995.05	876.53	796.65	738.87	695.05	660.45
10	T_{filled}	877.6	683.2	566.2	488	432.2	390.4	358.1

10	T_f	25.73	33.16	40.17	46.85	53.23	59.35	65.25
10	Max opening (m)	4.03	4.09	4.16	4.23	4.33	4.42	4.53
10	Max dis (m^3/s)	13.04	17.25	21.36	25.34	29.18	32.86	36.38
10	Max Rotation°	20.12	20.34	20.6	20.87	21.2	21.54	21.92
15	T_t	1050.21	855.67	738.19	659.24	602.48	559.5	525.77
15	T_{filled}	856.4	662.5	545.8	467.8	412.1	370.2	337.7
15	T_f	17.15	22.1	26.78	31.23	35.49	39.57	43.5
15	Max opening(m)	5.09	5.14	5.2	5.27	5.35	5.43	5.53
15	Max dis (m^3/s)	13.09	17.36	21.56	25.68	29.71	33.63	37.44
15	Max Rotation°	23.86	24.03	24.22	24.46	24.72	24.99	25.3

Max opening = Maximum opening duration filling & emptying (m)

Max dis (m^3/s) = Maximum discharge (m^3/s)

Max Rotation° = Maximum rotation during filling (degree)

Communication between a variety of parameters, such as: Gates opening times, T_{15}, T_{filled}, T_s, T_T and so on are created. The patterns in Figure 10 are generated by drawing the results.

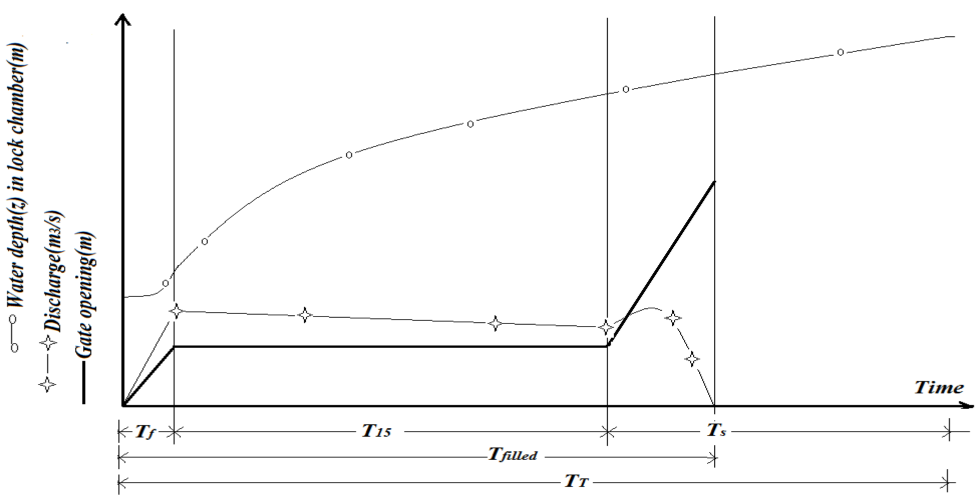

Fig 10. Shows the time variations of gate movement or surface water level displacement for different variables

T_f is gate opening time

T_{15} the duration of time that we wait those initial gates opening remains constant until the difference surface level reaches approximately 150 mm.

T_{filled} different times between the start of the secondary speed opening (surface water level between up/down gates is 150 mm until the gates were fully opened. It is between 6 and 12 minutes respect to employer requested in this project.

T_s is the difference time from surface water level between up/down gates is 150 mm until the gates were fully opened.

T_T is the total time required for gates to open or close completely.

The following figures illustrate how these parameters change with respect to each other. Figure 11 shows the time of complete closing of gates in terms of rotational speed and initial opening. Also, it shows that for the 0.9 m initial opening (both gates are 1.8 m) and the secondary velocity of 35 degrees/min, the minimum time required to open completely of the gates would be 380 seconds. Figure 12presents a time of complete filling of the chamber in terms of rotational speed and initial opening of the gates. It shows that the minimum time required for the chambers to fill is 310 seconds for the initial opening of 0.9 m (both 1.8 m) and a secondary velocity of 35°/ min. Figure 13 shows the inlet/outlet flow to the chamber at 5 degrees per minute angular velocity for the different initial openings.

Note that a saddle state occurs at the start of the secondary gates opening at the outlet/inlet discharge. Another point is that the time of filling the chamber does not mean that the ship can pass. It is necessary to wait until the gates are fully opened. That is, the time required for crossing is greater than the time shown.

Figure 14 shows the depth variations in the chamber at 5 degrees per minute angular velocity of gates for different initial openings. Figure 15 illustrates the effect of gate openings (primary and secondary) on the complete filling time of the chamber or complete emptying time it. In this figure moving the gates is under 5 degrees per minute angular velocity. These figures similar can be plotted for other numbers in Table 3.

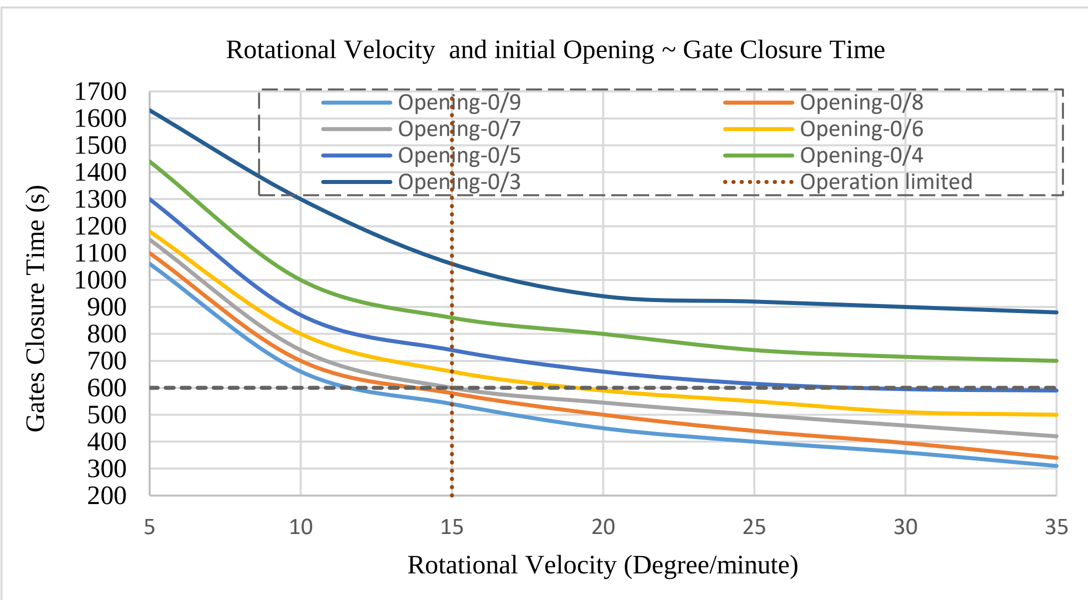

Fig 11. Time of complete closing of gates in terms of rotational speed and initial opening.

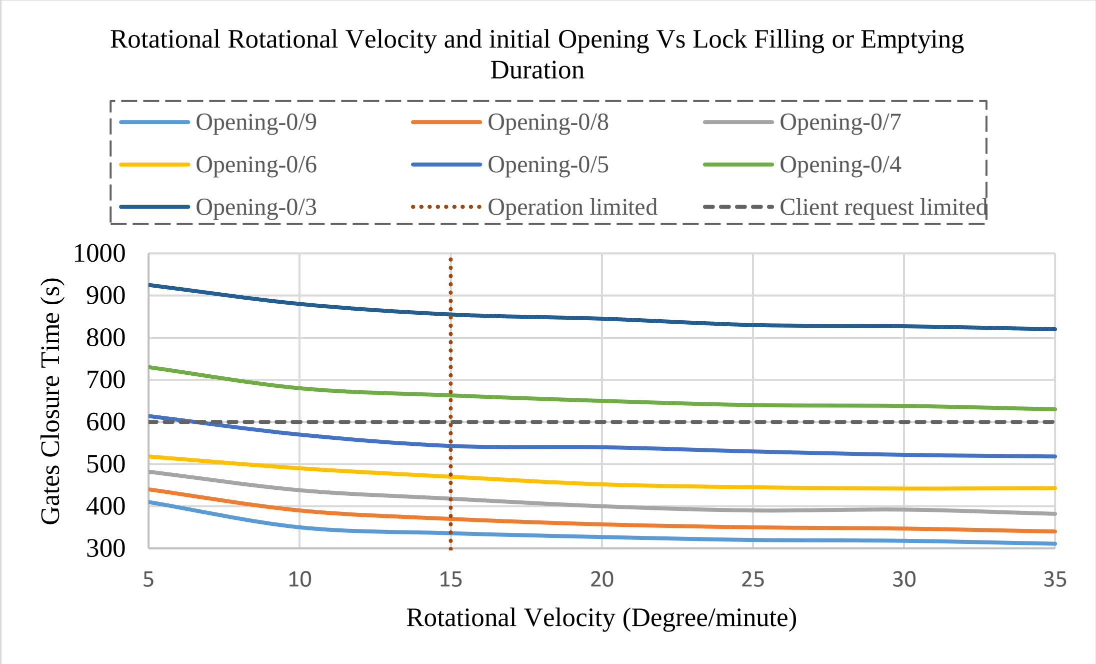

Fig 12. Time of filling/emptying of the chamber in terms of rotational speed and initial opening of the gates.

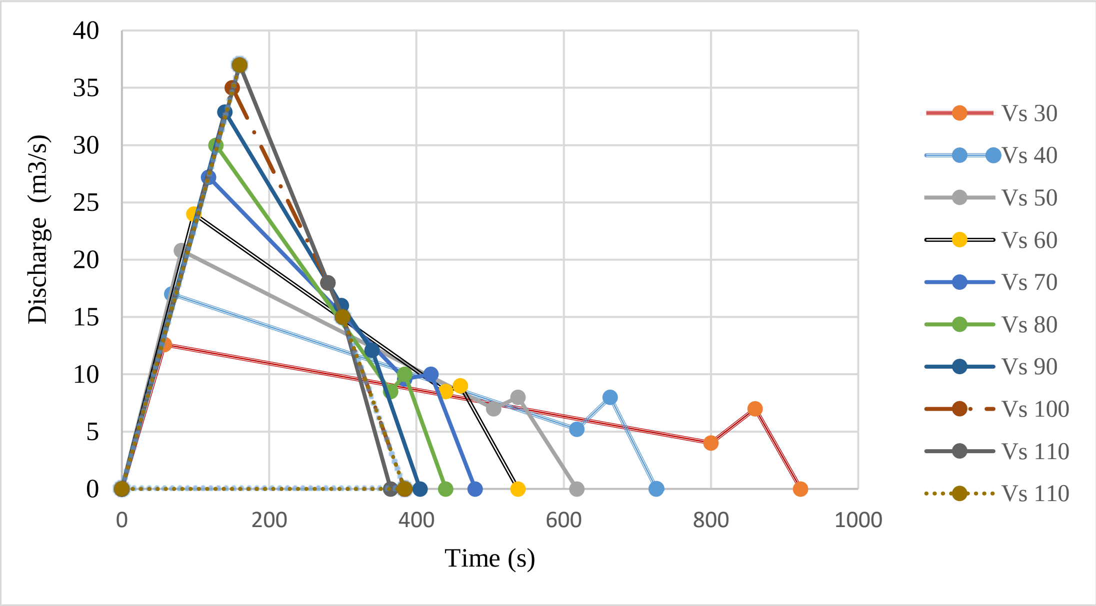

Fig 13. Inlet/outlet flow to the chamber at an angular velocity of 5 degrees per minute of gates for different initial openings.

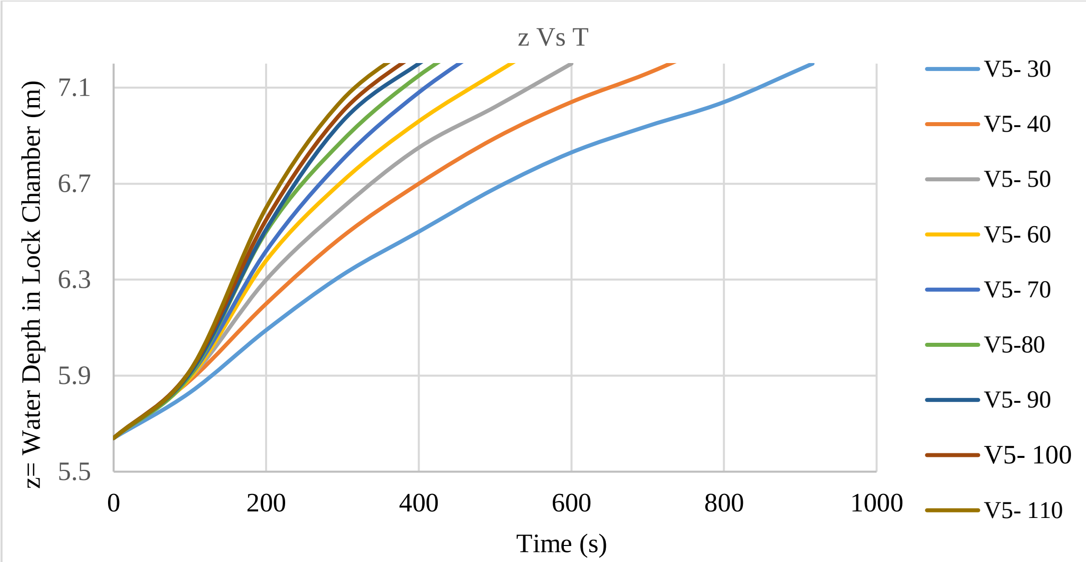

Fig 14. Depth variations in the chamber with an angular velocity of 5 degrees per minute of gates for different initial openings

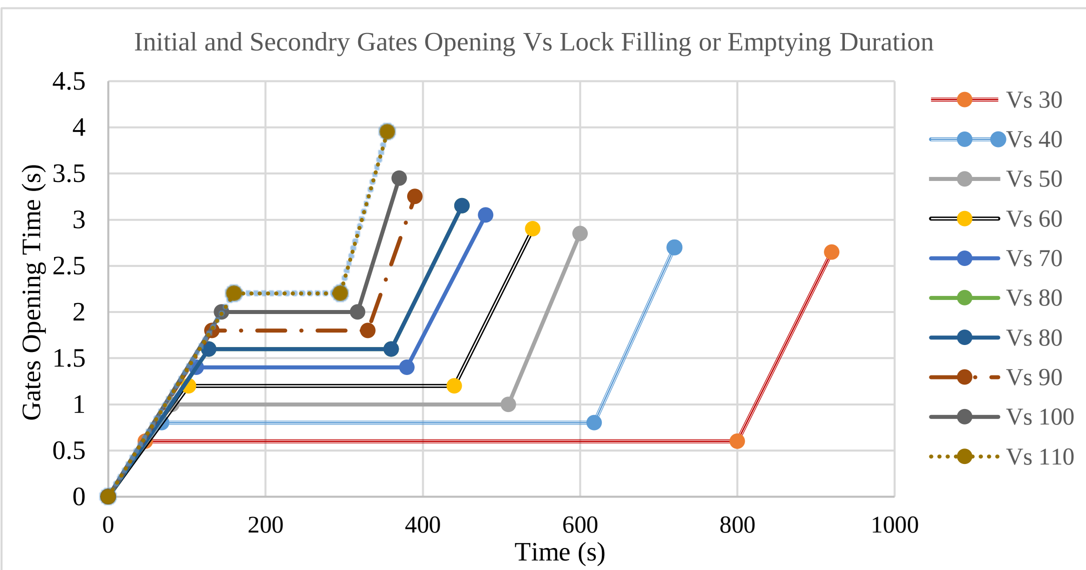

Fig15. The effect of gate openings (primary and secondary) on the complete filling time of the chamber or complete emptying time it. When moving the gates is 5 degrees per minute angular velocity

3.2. Total time for the vessel to pass through the ship lock

The theoretical operating capacity of the lock (C) is the between 12 till 18 million tons per year. The average annual capacity is from 1 till 7 million tons per year. But in the economic calculations the average annual maximum is 2.133 million tons. Given these data, estimation of vessel passing time of lock is shown in table 3. When the (I /C) ratio is lesser than 0.3, total passage time will be maximum 38 minute. This the simple sensitivity analysis shows at the realistic scenarios $(I \leq 4 \ and \ 12 \leq C \leq 18)$ the passage time is about 40 minutes.

Table 4. Estimation of vessel passing time of lock. According to the traffic volume coefficient to the pass-through capacity (I /C) realistically.

I	C	I/C	90% value of passage time (min)
1	12	0.08	Maximum 38
1	18	0.06	Maximum 38
2	12	0.17	Maximum 38
2	18	0.11	Maximum 38
3	12	0.25	44
3	18	0.17	Maximum 38
4	12	0.33	40
4	18	0.22	Maximum 38
5	12	0.42	50
5	18	0.28	Maximum 38
6	12	0.5	77
6	18	0.33	40
7	12	0.58	100
7	18	0.39	50
4	12	0.33	40

3.3. Three-dimensional flow modeling

Different scenarios have been analyzed. The results are presented in the following figures. Figure 16 shows the meshing and forces generated in a part of the lock geometry. Figure 17 shows the changes of turbulence energy at different times near the entrance gate. In another scenario, the same energy changes are presented in Figure 18. The changes of lock immersion with time are presented in Figure 19.

Figure 21 shows the changes of the turbulent energy at different times and in an assumed longitudinal of lock. Note that the internal length of the lock is 160 meters.

Figure 21 shows Stresses generated at the structural components of the gate at the fourth minute after initiation reopening with an angular rotation of 12.5°/min. Force entering the hydraulic jack depending on the rate of speed gate reopening at 12.5 degrees per minute is shown in Figure 22. By dividing the length of the shipping lock into four equal parts discharges (m^3/s) in the fourth zone in Figure 23.

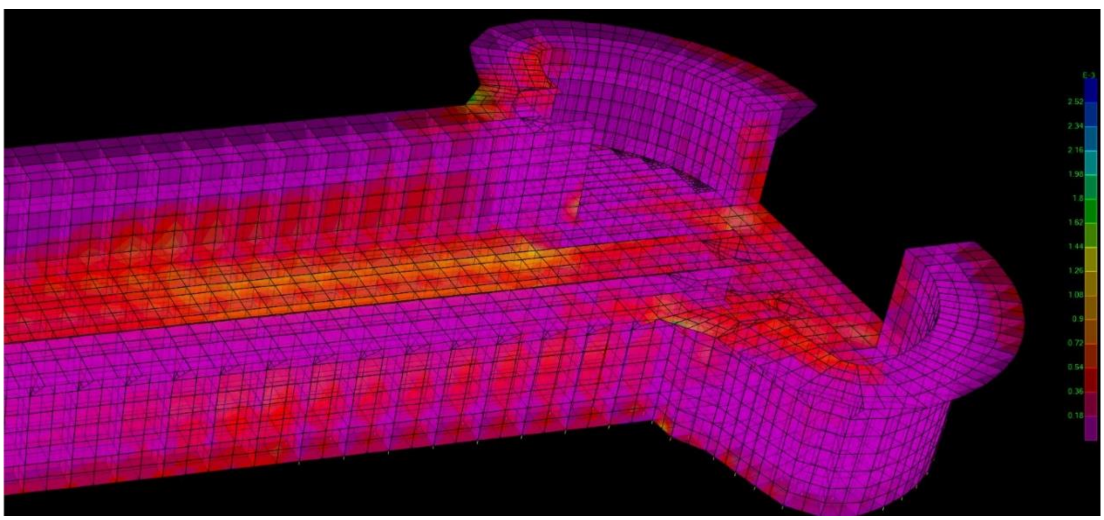

Fig 16. The meshing and forces generated in a part of the lock geometry.

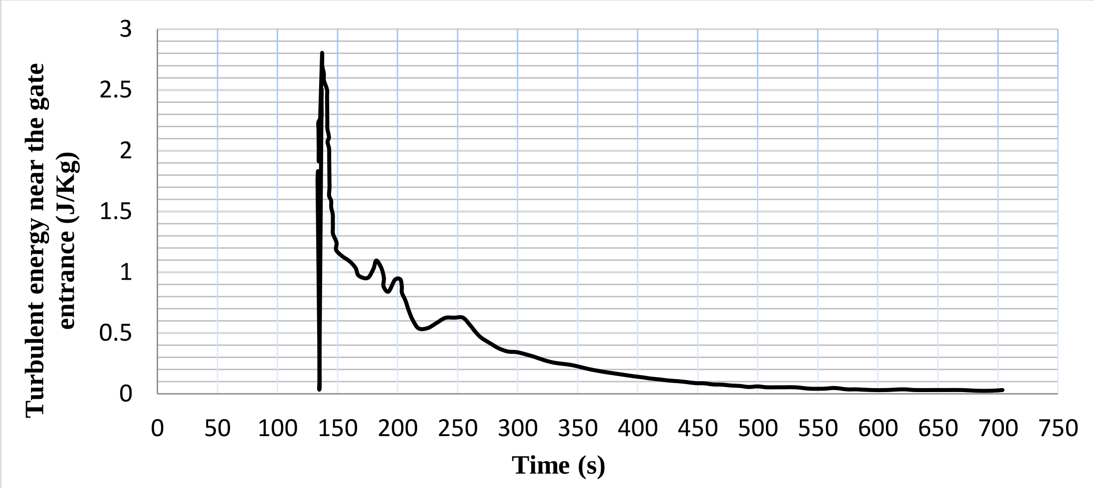

Fig 17. The changes of turbulence energy at different times near the entrance gate.

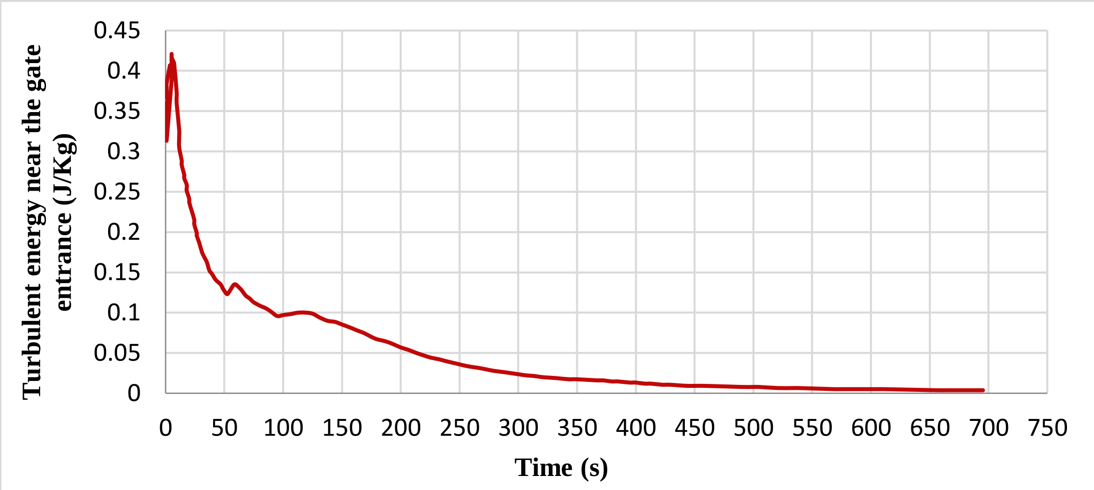

Fig 18. The changes of turbulence energy at different times near the entrance gate.

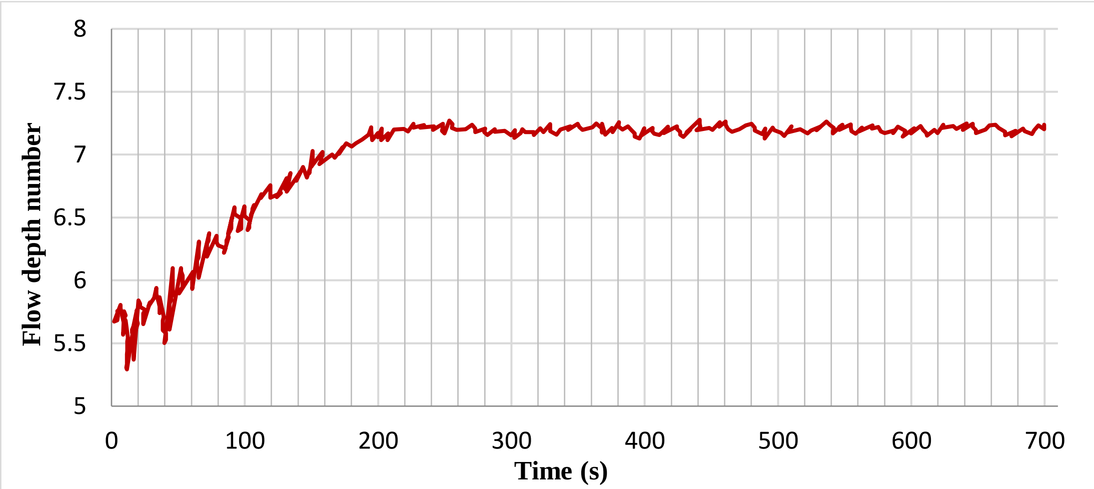

Fig 19. The changes of lock immersion vs. time. Flow depth number is the level difference between the bottom of the lock and the water level.

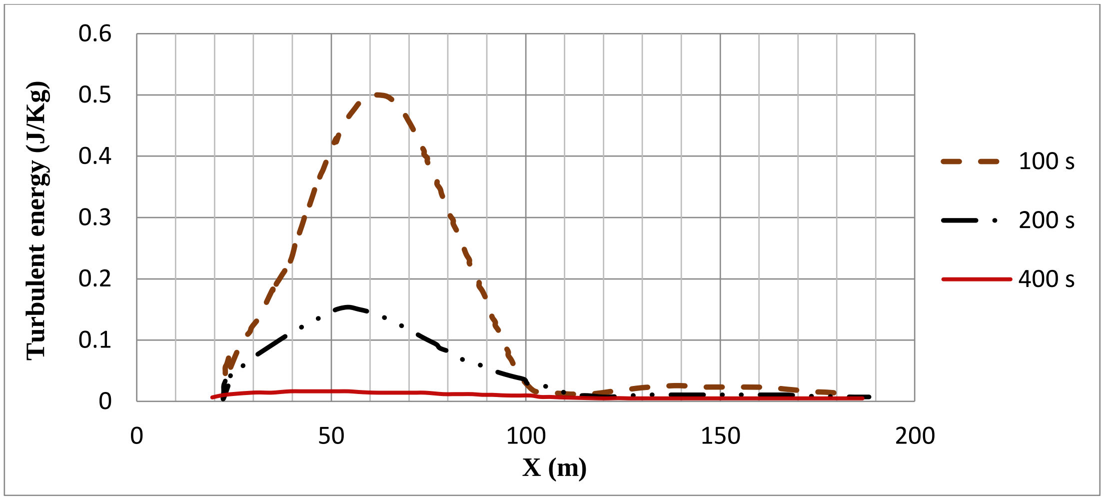

Fig 20. Variations of the turbulence energy at different longitudinal points of the lock at different times.

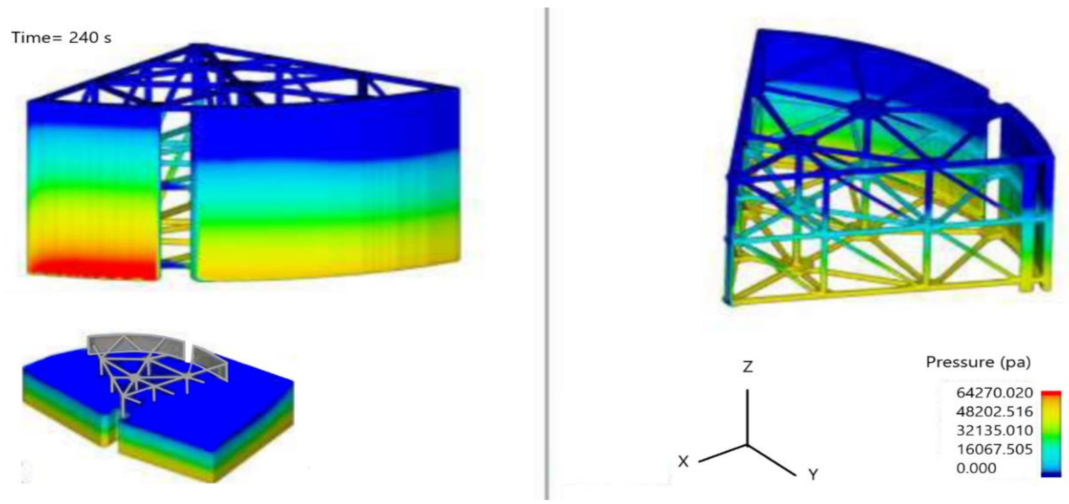

Fig 21. Stresses generated at the structural components of the gate at the fourth minute after initiation reopening with an angular rotation of 12.5°/ min.

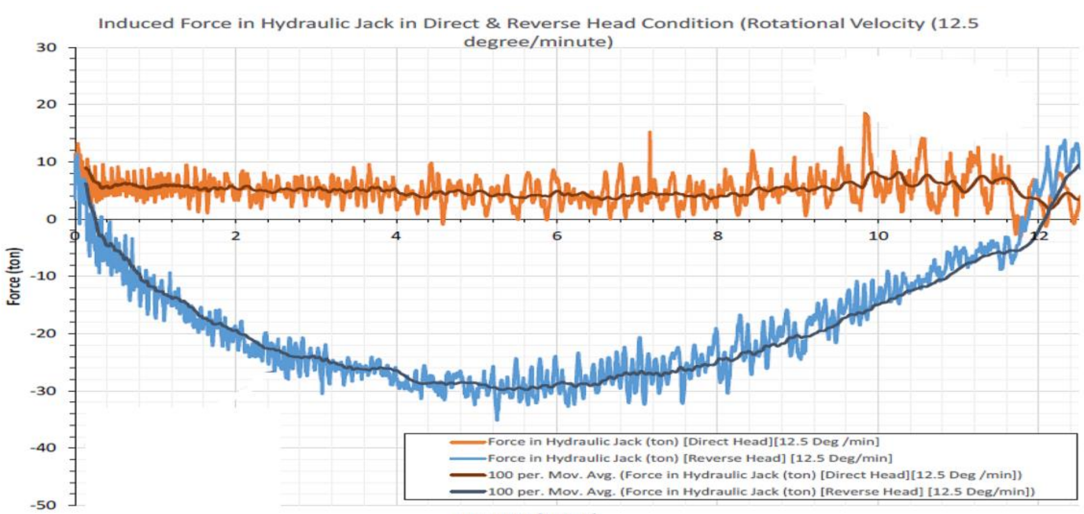

Fig 22. Force entering the hydraulic jack depended on the rate of speed gate reopening at 12.5 degrees per minute.

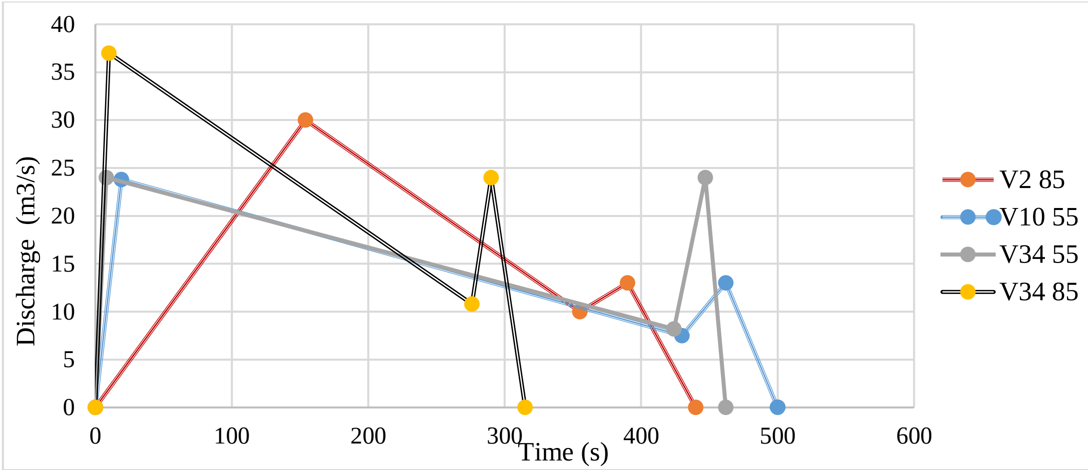

Fig 23. Discharges (m^3/s) in the main four zones (assuming the length of the shipping lock is divided into four equal parts) V2-85 presents this manner: while the angular velocity of opening/closing the gates is 2 degrees per minute, and the initial opening of the gates is 85 cm.

3.4. Validation

It is necessary to have a low level of disturbance so that the resulting waves will not cause problems for the ship. It is also necessary for the water speed to pass the ship below 1 meter per second. In Table 5, this parameter is controlled.

Table 5. Maximum water speed in look is lower than 1 m/s for vessel passing into the lock.

	Time(s)	Max V (m/s)	Result
1	50	0.59	ok
2	100	0.686	ok
3	300	0.122	ok
4	500	0.08	ok
5	700	0.08	ok

In order to verify the results, the flow rate due to the 3D model has been obtained at different times. For the same time, the gate opening value has been calculated. Therefore, the flow rate obtained from the three-dimensional model method is comparable with the flow rate obtained from the classical equation (equation 2). For example: The results show a low percentage difference between the two methods.

Table 6. Flow rate obtained from the three-dimensional model method (Q_1) is compare with the flow rate obtained from the equation number 2 (Q_2).

T (s)	Bg (m)	Z (m)	H (m)	z/h	C	Q_1	Q_2	%ΔQ
10	0.13	5.8	7.2	0.8	0.95	4.5	4.6	2.2
53.2	0.9	6.1	7.2	0.85	0.9	27	27.1	0.37
212	0.9	7.0	7.2	0.97	0.97	4	3.85	3.85

4. Conclusion

Determination of the filling and discharge times of the Karun Ship Lock for its operation. The main objective of this study is to identify the ideal maintenance condition for the first ship lock in Iran. The optimum time and speed for opening and the closing of ship lock gates are calculated. The unique results of this research include:

The result of the two-dimensional model is evaluated for constant opening speed and variable angular velocity. The range of speed variations from 5 to 35 degrees is assumed. The time required for filling is calculated. Variations of turbulent energy and the amount of applied forces in different places inside the lock have been calculated.

The optimum initial opening rate was 0.9 m for each gate (1.8 m for the total of two gates) is calculated. Practically, the maximum achievable gate speed of 12.5 degrees per minute is recommended by the Hydro Mechanical Contractor. So, the primary and secondary speeds are considered equal to this value.

The numerical model shows that the operation of opening and closing the ship's lock and filling and discharge for the ship to pass within 40 minutes will be carried out at the request of the employer. The required time to open or close of lock gates is 10 minutes.

Practically, the maximum possible speed of the gate is 12.5 degrees per minute. Thus, the primary and secondary gates' speed for open or close are equal to that considered. A comprehensive study of these results is warranted. The average time for filling the chamber is 5 minutes when the inner water level is -0.37 and the outer is +1.2

The numerical model shows that the operation of opening and closing the ship's lock and filling and discharge for the ship to maximum force on the largest mentioned vessel is 500 KN. The maximum force on the anchor and Bullard is 152 KN. Maximum torque on gate and hinge is 1000 KN-m. Maximum turbulence in 5 cm under dewatering conditions. The result of the two-dimensional model is evaluated for constant opening speed and variable angular velocity.

Data Availability

The data used to support the findings of this study is available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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