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Hydraulic Design for Mashi Hydropower Station Lock Expansion Using a 1:25 Scale Physical Model

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Abstract

This study aligns with key documents outlining the expansion of inland waterway facilities in the Xijiang River Water System, focusing on reconstructing the locks at the Mashi Hydropower Station to accommodate a 2 × 1000-ton push fleet and 1500-ton single ships. The project proposes lock chamber dimensions of 190m × 23m × 4.8m, a maximum design head of 22m, and an annual downstream throughput capacity of 780 million tons. A 1:25 scale physical model was used to analyze hydraulic characteristics of lock filling and drainage, ship berthing conditions, and flow patterns within the water conveyance system. Results indicate that with a 7-minute continuous valve opening (tv = 7min), the water transfer time meets design requirements. Energy dissipation was enhanced by adding a 0.8cm dissipation can spaced 1.2m from the branch hole, ensuring maximum bollard forces (16.96 kN longitudinal, 11.20 kN transverse) remain within limits. Pressure tests revealed the lowest instantaneous pressure near the valve gate was 1.25 m water column, and at the slope rise, it was -0.26 m water column, meeting corridor specifications. Adjustments to the inlet elevation and area eliminated adverse hydraulic phenomena under maximum head conditions, while vortex issues at the lowest navigable water levels were mitigated by extending valve opening to 8 minutes. Recommendations include operating the valve at 7 minutes under maximum head conditions and at 8 minutes under low water levels. These findings provide optimized parameters for efficient navigation and enhanced waterway infrastructure.

Keywords: Ship lock, Filling and emptying system, Inland waterway transportation, Liujiang River Basin, Navigation infrastructure

CHAPTER 1:

INTRODUCTION

1.1 Research background and meaning

In the middle of the Rongjiang River, the Guangxi Mashi Hydropower Station is crucial to the region's energy infrastructure. Found 32km from Rongan District and 150km from Liuzhou City, this hydroelectric office is filled as a foundation for the power age while offering subordinate advantages, such as route. The origin of the Mashi Hydropower Station traces back to the mid-1970s when site studies and choices were started. By 1973, the venture saw critical improvement with the launch of the fifth floodgate for water capacity, finishing in September 1976 when all units started powering simultaneously. At first, bragging an all-out introduced limit of 100MW, the Mashi Power Station changed in 2011, expanding its ability to 108.5MW through a setup of 2×36MW and an extra 36.5MW unit. Spreading over a controlled watershed area of 19,940 km^2, the Mashi Hydropower Station includes a significant repository with a complete stockpiling limit of 288 million m^3. Working as an everyday controlled repository, it keeps a typical Water stockpiling level of 134.00m, with a dead water level set at 130.00m. In addition, the station's design flood level is 136.88m (P=2 per cent), while the check flood level is 140.72m (P=0.2 per cent). This complex water executives' framework guarantees the ideal use of assets while relieving the gamble of flooding occasions. The center point of the Mashi Hydropower Station's work contains different necessary parts, each assuming an urgent part in its activity. Among these features are a left-bank joint gravity dam, a riverbed powerhouse, an overflow dam, a right-bank joint gravity dam, a ship lock, a right-bank joint thorn wall dam, and the joint earth dam that goes with it. Of specific importance is the ship lock, which works with route and transportation along the Rongjiang Stream. Situated on the right bank of the power station, the current ship lock at Mashi Power Station fills in as an imperative channel for sea traffic. Its essential area interfaces the earth dam and bank slant on the right half of the boat lock head, while the left side borders the gravity dam segment, connected to the No. 13 flood dam. Intended to oblige a 60-ton engine barge or two pontoons estimating 20m×6m (length × width) each, the boat lock brags drafts 0.9m and 0.7m, respectively. The successful size of the ship lock chamber is 1.1m×8.0m×40.5m (water profundity above sill×width×length), giving more than adequate space to vessels to cross the dam easily. In outline, the Guangxi Mashi Hydropower Station demonstrates the resourcefulness and designing ability of its planners and developers. Its double spotlight on power age and route addresses an essential pinion in the locale's energy and transportation foundation. As the station advances and adjusts to satisfy the developing needs of the current culture, its importance as a driver of monetary turn of events and progress stays unrivalled. (Zhou, 2020).

1.2 Outline of Research

Previous studies focused on the Rongjiang Mashi Hydropower Station project in the Liujiang River Basin, which have yielded significant insights into various parts of the ship lock reconstruction project and its associated water-powered frameworks. This exploration, embraced by our unit and dispatched by the Guangxi Transportation Configuration Gathering Co., Ltd., intended to enhance the plan and functional effectiveness of the ship lock and its water movement framework. The primary results and discoveries from these examinations are summed up as follows: Optimization of the Design of the Filling and Emptying System: The research concentrated on Option 1 and Option 2 as the two design options for the filling and emptying system. Option 1 proposed an energy-dissipating water conveyance framework with double open ditches in the side parts of the in-chamber longitudinal culvert; in contrast, Option 2 recommended a solitary open ditch energy dissipation framework. Using one-dimensional numerical models, the review examined the hydraulic characteristics of the lock chamber and assessed the valve opening and shutting techniques. The examination planned to improve the proficiency and viability of the water conveyance framework to guarantee smooth activity of the ship lock. Pressure characteristics of the Lock Chamber: The review dove into the pressure-driven attributes of the lock chamber, including the water-filling water-

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driven trademark bend, three-dimensional flow field conveyance, and energy dissipation impacts.

By laying out three-dimensional flow numerical models for both plan choices, the exploration was meant to advance the format of the water conveyance framework and prescribe upgrades to the plan. Examination of Water Conveyance Framework Working Circumstances: The exploration additionally broke down the functioning states of the water conveyance framework, zeroing in on the flow characteristics in the valve port entry area and the appropriation of field and strain fields. This investigation gave important experiences into the functional elements of the water conveyance framework and featured regions for advancement and improvement. Navigation Flow Conditions Study: One more part of the exploration included concentrating on the channel flow states of the by and large Water-powered model of the Rongjiang Mashi Ship lock Development Task Center. This included assessing the flow conditions for the upstream and downstream entrance regions under different working circumstances and examining berthing conditions in the approach channel berthing regions during lock filling and emptying tasks. The examination is expected to propose advancements to improve navigation flow conditions and guarantee a safe route through the lock. Comprehensive Hydraulic Model Tests: In May 2019, comprehensive hydraulic model tests were carried out to examine the flow conditions of navigable Water at various flow rates. The results showed that the changed and advanced enhancement plan improved navigation flow conditions and met the safety guidelines for longitudinal, cross-over, and return flow speeds. The exploration discoveries gave important insights into the viability of the proposed advancement plans and their effect on maritime safety. In synopsis, past examination endeavors have given significant knowledge into the ship lock's plan, activity, advancement, and related pressure-driven frameworks at the Rongjiang Mashi Hydropower Station project. These discoveries will establish additional innovative work endeavors to improve the ship lock reproduction project's productivity, safety, and supportability. (A, 2020).

1.3 Parts of the Filling and Exhausting Framework

After the ship enters or exits the lock chamber, Water is sourced from the higher level, and discharge occurs at the lower level. Entryways at the two closures of the lock chamber direct the progression of Water, permitting controlled filling and emptying. Valves control water delivery or admission, and siphons might be utilized to speed up the cycle. The filling and emptying system is essential to ship locks because it regulates the water level in the lock chamber to make it easier for boats to pass through. This section examines the complex elements that make up the filling and emptying structure, which is necessary for ship locks to function properly. High-level frameworks computerize the interaction, utilizing sensors and criticism systems to screen water levels. Drain systems, bypass channels, and emergency systems deal with unforeseen circumstances to keep vessels safe (Van de Vooren, 2021).

The filling and emptying system's primary function is to raise or lower the water levels in the lock chamber to the desired elevation for ship passage. Control valves are the primary means of regulating water flow into and out of the lock chamber. These valves are strategically placed along the lock structure, allowing operators to modulate the volume of Water entering or leaving. Precision in valve control is essential to prevent sudden changes in water levels, which could compromise the stability of vessels navigating through the lock. Gates, typically positioned at the entrances and exits of the lock, work in tandem with valves to provide additional control. They act as physical barriers that can be raised or lowered to facilitate or impede water flow. The activity includes shutting the entryways, permitting the chamber to fill or purge, and paving the way for letting the boat continue. Energy conservation and environmental responsibility are central to today's ship lock systems. A few locks integrate water-saving measures, reusing frameworks, and, surprisingly, using sustainable power sources to limit their natural effect. Automation and sophisticated control systems are frequently included in modern ship lock systems to improve accuracy and safety. Lock operations can be carried out more effectively with automated control valves since they can be remotely operated or programmed to adhere to predetermined protocols.

Furthermore, real-time data on water levels, pressure, and flow rates are provided via sensor systems, allowing for prompt valve position modifications in response to changing circumstances. These developments make control valves and gates in ship locks more responsive and dependable overall, enabling them to adjust to various operational situations. In conclusion, control valves and gates play a crucial role in the ship lock filling

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and emptying system, offering the control and accuracy required for a reliable and safe experience navigating waterways. These elements are always being improved by technology; therefore, ship lock systems are always changing to keep up with the needs of the contemporary transportation infrastructure. Cost-effectiveness and a smaller environmental footprint are aided by this efficiency focus (Tanaka, 2022).

1.4 Research status and development dynamics

A significant project aimed at increasing the region's water transportation capacity and effectiveness is the expansion of the ship locks at the Mashi Hydropower Station. Determined to oblige bigger vessels and expand throughput limit, broad preparation and exploration have been embraced to foster a hearty plan plot for the ship lock reproduction project. This part will dive into the primer work necessities, plan determinations, and exploration discoveries relevant to this task. Starter Work Prerequisites and Venture Outline The preparation and development of public government assistance water transportation projects from 2020 to 2022 have laid the basis for extending the ship locks at the Mashi Hydropower Station. The primary objective of the ship lock reconstruction project is to make it possible for larger vessels, such as a push fleet of 2× 1000 tons and a single ship of 1500 tons, to navigate. To accomplish this, the powerful elements of the lock chamber have been determined as 190m×23m×4.8m (length×width×threshold water profundity), with a planned greatest water head of 22m. The projected one-way plan yearly throughput limit downstream is 7.8 million tons. The fundamental parts of the project incorporate the primary body of the ship lock (lock head, lock chamber), upstream and downstream approach channel guide walls, berthing dolphins, baffle walls, slope retaining, holding up haven regions, on-location traffic framework, and homing aid and subordinate facility. These components add to the protected and effective activity of the extended ship locks and back the expanded volume of waterborne traffic expected upon fruition. Configuration Plan Advancement and Exploration Suggestions Beginning exploration led between September 2017 and May 2019 zeroed in on the plan transport sort of the Stone remaking and development project, which was delegated to the 500-ton class, with thought given to 1000-ton class single boats. However, subsequent modifications to the design scheme have resulted in the use of larger vessels, such as push-pull fleets of 2 ×1000 tons and

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single ships of 1500 tons. As a direct consequence, adjustments were made to the lock chamber's size, now 190 meters by 23 meters by 4.8 meters. These improvements highlight the significance of ceaseless examination and research to guarantee that the plan plot aligns with advancing task prerequisites and industry principles. The design of ship locks is daunting, requiring careful consideration of several elements, including vessel size, navigational elements, and functional capabilities. Specialized examination and exploration suggestions to offer specialized help for improving a "serviceable" plan for the ship lock recreation project and itemized investigation and examination are fundamental. This incorporates an appraisal of the lock chamber's pressure-driven attributes, assessing navigation flow conditions, and improving functional boundaries. By leading exhaustive investigations, architects and organizers can distinguish likely difficulties and open doors related to the extended ship locks, illuminating navigation and plan refinement. In conclusion, the Mashi hydropower station's ship locks will be expanded in multiple ways to increase water transportation capacity and efficiency. By sticking to starter work prerequisites, consolidating configuration plot updates, and directing intensive investigation and exploration, partners can guarantee the fruitful execution of the ship lock remaking project. This task addresses a huge interest in the locale's framework, with the possibility of working with monetary development, further developing the network, and backing maintainable turn of events. (Liu, 2021).

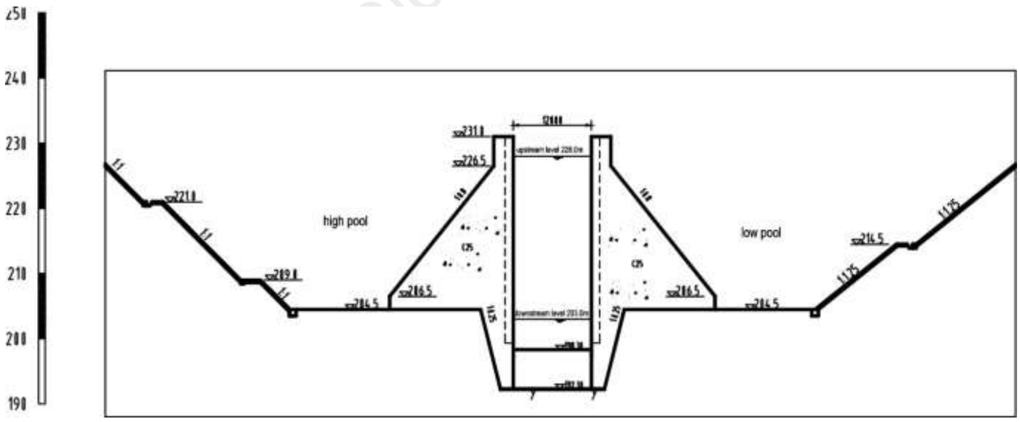

Figure1: Systems for locking ships today

The field of hydraulic engineering has become a prominent focus of research. Researchers are investigating new hydraulic technologies that streamline filling and emptying procedures, improving their environmental sustainability and energy

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efficiency. Furthermore, developments in fluid dynamics have been essential in improving the accuracy of water level control in lock chambers, which has resulted in more seamless vessel transfers (Congresses., 2020).

A prominent pattern in the ongoing status of ship lock frameworks is the rising accentuation on energy productivity. Transport locks are fundamental to stream transportation, and their energy utilization greatly impacts maintainability. A few locks have embraced sustainable power sources and creative water-saving measures to address this.

Environmentally friendly power sources, like sunlight-based and hydroelectric power, are being coordinated into the activity of ship locks to lessen their dependence on traditional energy matrices. The utilization of the sun by solar panels on lock structures to generate electricity contributes to a power supply that is both cleaner and more long-lasting. Essentially, hydroelectric power, created by the development of Water through turbines, is outfitted to control lock activities, further diminishing the natural impression. (Fossati, 2020)

Creative water-saving estimates are critical in limiting ship lock frameworks' effect on nearby environments. Procedures, for example, water reusing and effective Water the board add to preservation endeavours. Recycling systems capture and treat Water in lock operations to ensure it can be reused, lowering the lock system's overall water consumption.

The natural effect of ship lock frameworks has been a subject of concern, inciting the execution of measures to moderate unfriendly impacts. Past energy-productive practices and creative arrangements are being investigated to limit the natural impression of lock tasks.

For example, thorough natural effect evaluations are directed before the development or redesign of lock frameworks. These appraisals consider territory disturbance, water quality, and environmental well-being. The discoveries guide the plan and execution of ship lock activities to limit unfortunate results on the general climate.

In addition, there is a growing focus on preserving habitat and restoring ecosystems in and around lock areas. Wetland rebuilding projects and making fish entries are among the drives toward saving biodiversity and guaranteeing the natural well-being of streams associated with transport locks (Chanson, 2022).

While the ongoing status of ship lock frameworks reflects huge advancements in innovation, energy effectiveness, and ecological contemplations, challenges endure. Maturing frameworks, expanded traffic, and advancing ecological guidelines keep melding the ship lock advancement scene.

Future improvements in transport lock frameworks should focus on beating these difficulties by proceeding with mechanical development and manageable practices. Cutting-edge technologies, materials, and improved engineering designs will likely shape the next generation of ship locks. Ship lock systems will continue to advance due to national and international collaborative research efforts.

The state of ship lock systems demonstrates technological prowess, energy efficiency initiatives, and eco-friendly practices. The combination of Robotization, environmentally friendly power sources, and water-saving estimates denotes a positive direction toward more manageable and proficient stream transportation foundation. In conclusion, there is a dedication to developing technology for safe, effective, and sustainable water transportation, as evidenced by the research status and development dynamics in ship lock systems. The future of ship lock operations is still shaped by ongoing research, which supports international trade, economic growth, and ecological sustainability. The future of ship lock systems promises further innovation and harmonious coexistence with the ecosystems they traverse as technology advances and environmental awareness grows (Anderson, 2021).

1.5 Characteristics and Importance of Water Levels in Ship Lock

1.5.1 Infrastructure

The water levels of the primary ship lock configuration highlight critical boundaries that impact the protected and effective activity of the lock framework. The navigation infrastructure must be planned, designed, and managed with an understanding of these typical water levels. In this segment, we will dive into the fundamental data concerning the trademark water levels of the stone ship lock reproduction and extension project. 1. Upstream Trademark Water Levels 1.1 Designed Maximum Water Level for Navigation Upstream: The planned greatest route water level upstream of the ship lock is 134m. This level addresses the most noteworthy water level and is considered a safe route. Ordinary Water Stockpiling Level: The typical water stockpiling level of the centre point concurs with the planned most extreme route water level, which is additionally at 134m. The hub's dead water level, which is 130 meters high, is the lowest navigation water level upstream. This level shows the base water level expected for route activities to be practical. 2. Downstream Trademark Water Levels 2.1 Planned Greatest Route Water Level Downstream: The planned greatest route water level downstream of the ship lock is 127.17m. Flow rates and operational requirements are considered when determining this level, which is essential for downstream navigation. Least Route Water Level: the base route water level is downstream, 112m. This level addresses the least admissible water level for a safe route downstream of the ship lock.

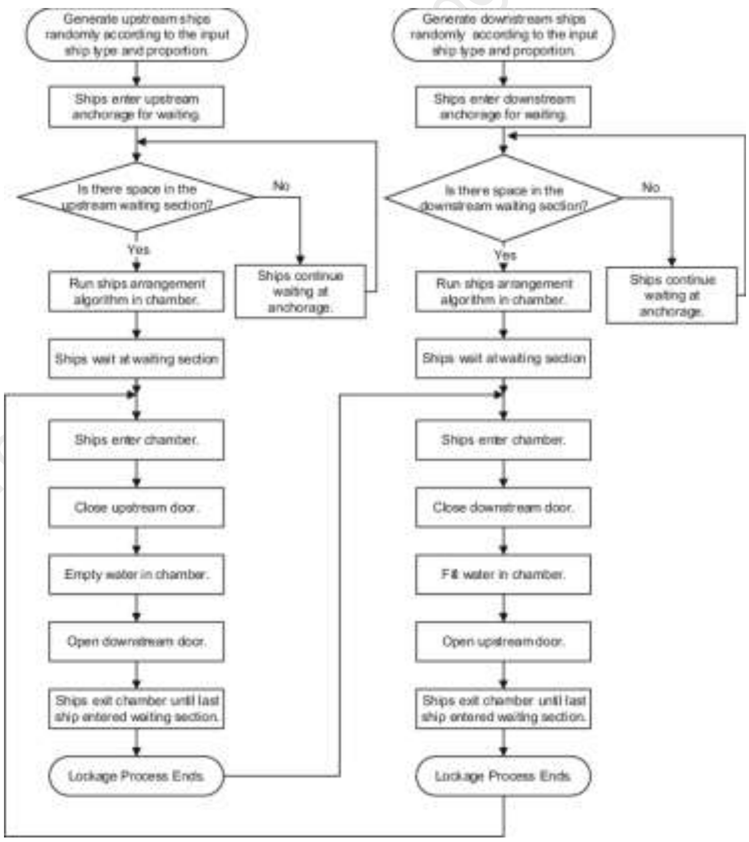

Figure 1.2Transport lock frameworks

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Table 1.1 Water level table of main features of the design of the Mashi ship lock reconstruction and expansion

serial number	Part name		Elevation (m)	Remark
1	Reservoir normal water level/dead water level		134.00 130.00	
2	highest navigable water level	upstream	134.00	normal water level
		downstream	127.17	P=10% (downstream flow Q=13800m3/s)
3	lowest navigable water level	upstream	130.00	Dead water level of Mashi Power Station
		downstream	112.00	The water level downstream of the dam site is 113.27m when the flow rate of the granite guarantee rate is 95% (79m3/s) and is included in the undercutting of the river bed.
4	Maintenance water level	upstream	134.00	Normal water storage level of the same reservoir
		downstream	115.50	In the dry season (December to February of the following year), when P=20% flood flow (927 m3/s), the corresponding downstream water level
5	design flood level	upstream	136.88	P=2% (flow rate Q=19500m3/s)
		downstream	131.00	P=2% (flow rate Q=19500m3/s)
6	Check flood levels	upstream	140.72	P=0.2% (flow rate Q=27500m3/s)
		downstream	135.55	P=0.2% (flow rate Q=27500m3/s)
7	Water storage level of downstream pumice hub		113	

Key Water Level Blends in Ship Lock Activities" Different water level blends are pivotal in working with the protected and productive section of vessels in transport lock tasks. These blends, portrayed underneath, delineate the powerful interchange among upstream and downstream water levels, characterizing the functional boundaries of the

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ship lock: Most extreme Working Head: Upstream Water Stockpiling Level: 134m 112m is the minimum water level for downstream navigation. Water Level Distinction: 22m Middle Water Head: Level of Water Storage Upstream: 134m; Level of Water Storage at Next Step: 113m Water Head: 21m Moderate Head of Water: Upstream Least Traversable Water Level: 130m Downstream Least Traversable Water Level: 112m Water Head: 18m Moderate Head of Water: Upstream Water Stockpiling Level: 134m. The highest navigable level downstream is 127.17 meters. Head of Water: 6.83 m Negligible Water Head: Upstream Least Traversable Water Level: 130m the highest navigable level downstream is 127.17 meters. Water Head: 2.83m. These characterized water level blends frame basic situations experienced during transport lock activities, impacting route, security, and effectiveness.

1.5.2 Design Ship Size Specifications for the Mashi ship lock"

The design specifications of the vessels that pass through ship locks significantly impact how effectively and safely they operate. In the case of the Mashi ship lock, which is a crucial part of the Mashi Hydropower Station, the ship types used in the design have been carefully considered to make sure they work well. This article investigates the planned transport size details for the Stone Ship lock, zeroing in on two essential vessel types: 1500t inland waterway ships and 2×1000t push armada. Configuration Boat Types and Particulars: Ships in the Inland River of 1500 tons: Length: 68 meters, Width: 11 meters, Designed Draft: 2.9 meters. The 1500t inland waterway ships address a typical vessel exploring through the Stone Ship lock. These boats are intended to convey a payload of as much as 1500 tons and are used for inland waterway transportation. The determinations of these boats, including their length, width, and Designed draft, are custom-made to guarantee similarity with the lock chamber aspects and work with smooth entry through the lock. Two 1000-ton Push Fleets: Length: 160 meters, Width: 10.8 meters, Designed Draft: 2 meters. The 2×1000t push armada design includes two vessels, each fit for conveying payloads of as much as 1000 tons. These push armadas are usually used to ship merchandise and materials along streams, especially when bigger freight volumes should be moved effectively. The plan details, including formed length, moulded width, and designed draft, are improved to guarantee mobility and strength during the route through the ship lock. Meaning of Configuration Boat Size Details: The

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plan transport size determinations illustrated above are critical for the viable activity of the Stone Ship lock. By sticking to these details, vessel administrators can guarantee that their boats can securely cross through the lock chamber without experiencing layered requirements or navigational difficulties. Besides, adjusting vessel aspects to lock chamber aspects enhances lock use and limits the gamble of clogs or postpones in the lock entry process. Conclusion: All in all, the details of the planned transport size for the Stone Ship lock are crucial for a consistent route and effective activity. By precisely characterizing the elements of 1500t inland waterway ships and 2×1000t push armadas, partners can guarantee the similarity of vessels with lock chamber aspects, subsequently improving security and functional adequacy. These determinations act as fundamental rules for vessel plan, activity, and upkeep, adding to the smooth working of the inland waterway transportation foundation.

Test Results and Analysis

4.1 Test conditions:

The test conditions of this project include the combination of maximum water head and minimum navigation water level. The valve opening time covers 5, 6, 7, and 8 minutes. The valve operation mode includes unilateral and bilateral door opening conditions. Due to the common water head conditions and maximum head, the working conditions only differ by 1m, so the hydraulic characteristic values of common water heads can be referred to as maximum head working conditions; please see Table 3 for specific working conditions.

Table 3: Test conditions

Water delivery method	Valve operation mode	Upstream water level (m)	Downstream water level (m)	Valve opening time tv(min)	Remark
Filled with water	bilateral	134	112	5, 6, 7, 8	maximum head

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		130	112	5, 6, 7, 8	Minimum navigation water level combination
	unilateral	134	112	5, 6, 7, 8	maximum head
Drain water	bilateral	134	112	5, 6, 7, 8	maximum head
		130	112	5, 6, 7, 8	Minimum navigation water level combination
	unilateral	134	112	5, 6, 7, 8	maximum head

4.5 Resistance coefficient and flow coefficient of water delivery system

According to the constant flow test, the measured flow coefficient results of the valve fully open after the inlet optimization are shown in Table 7. It can be seen from the table that the water-filling flow coefficient of the valve when it is opened on both sides is 0.74, and the water-filling flow coefficient of the valve when it is opened on one side is 0.74. Water flow coefficient is 0.87; the flow coefficient of water released when the valve is opened bilaterally is 0.64, and the water release coefficient when the valve is opened unilaterally is 0.67. See Table 3.5 for the resistance coefficient and flow coefficient of the water delivery system.

Table7: Measured values of resistance coefficient and flow coefficient of Mashi ship lock valve fully open.

Operation mode	Bilateral water filling	One side water filling	Bilateral drainage	Unilateral drainage

Flow Coefficient	0.74	0.87	0.64	0.67
OK	1.81	1.34	2.43	2.22

4.6 Lock chamber ship berthing conditions

The test conditions for ship berthing conditions in the lock chamber are based on the maximum stress condition of the ship in the lock chamber - the maximum design head water-filled operation state. The test ships mainly use 1500t inland river ships and a 2×1000t push fleet, and the 1500t ship size is 68m×11m×2.9m (length×width×design draft); the size of the 2×1000t pusher fleet is 160m×10.8m×2m (length×width×design draft). In the 1500t inland river ship test, the ships were placed in the lock chamber's upper, middle, and lower parts for testing. The water delivery valve opening time was 6 to 8 minutes, and the operation mode was considered bilateral and unilateral; the 2×1000t push fleet test will be arranged longitudinally and upstream of the lock chamber. The opening time of the water delivery valve is also 6 to 8 minutes. In addition to the bilateral operation mode, the operation mode also considers the unilateral operation mode. The main test conditions are shown in Table 8.

Table8: Lock chamber ship berthing conditions test conditions.

	Valve operation mode	ship(t)	Valve opening time tv(min)	water level combination	Ship docking location
Lock chamber ship berthing conditions	bilateral	1500	6, 7, 8	maximum head	The upper part of the lock chamber
			6, 7, 8	maximum head	middle part of the lock chamber
			6, 7, 8	maximum head	The lower part of the lock chamber
	unilateral	1500	6, 7, 8	maximum head	The upper part of the lock chamber

			6, 7, 8	maximum head	middle part of the lock chamber
			6, 7, 8	maximum head	The lower part of the lock chamber
	bilateral	2×1000t fleet	6, 7, 8	maximum head	The upper part of the lock chamber
	unilateral	2×1001t fleet	6, 7, 8	maximum head	The upper part of the lock chamber

Since there is no allowable mooring force corresponding to a 1500t ship in the specification, and using the standard value of 2000t mooring force is too dangerous, the allowable value of the mooring force for the 1500t ship is fitted by the standard value, as shown in Figures 3.9~3.10, and the fitting result is 1500t The mooring cable values are: 18.5 kN in the transverse direction and 36.9 kN in the longitudinal direction.

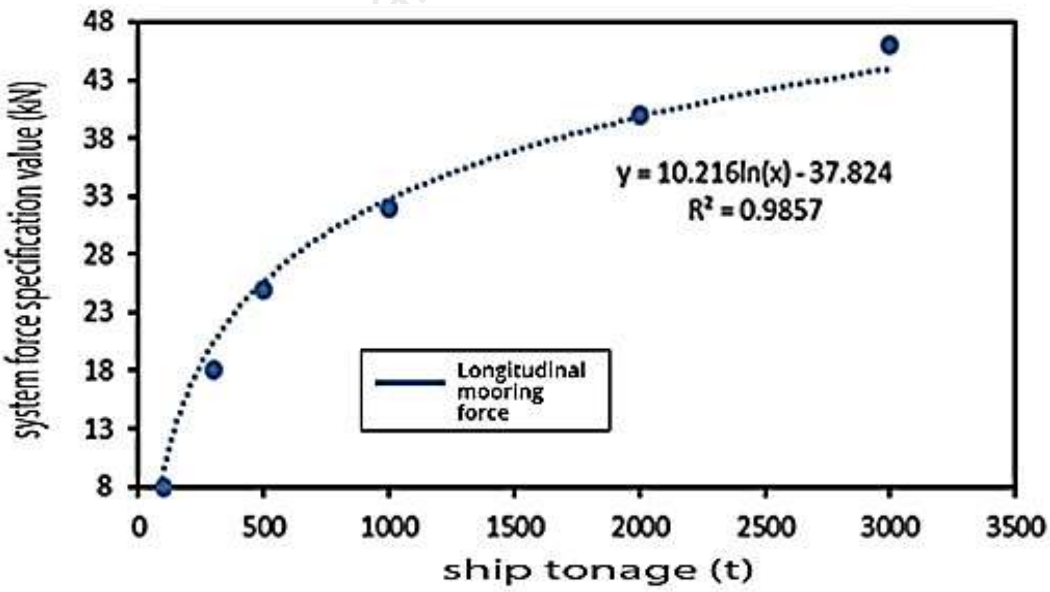

Figure 4.9 Transverse mooring force fitting

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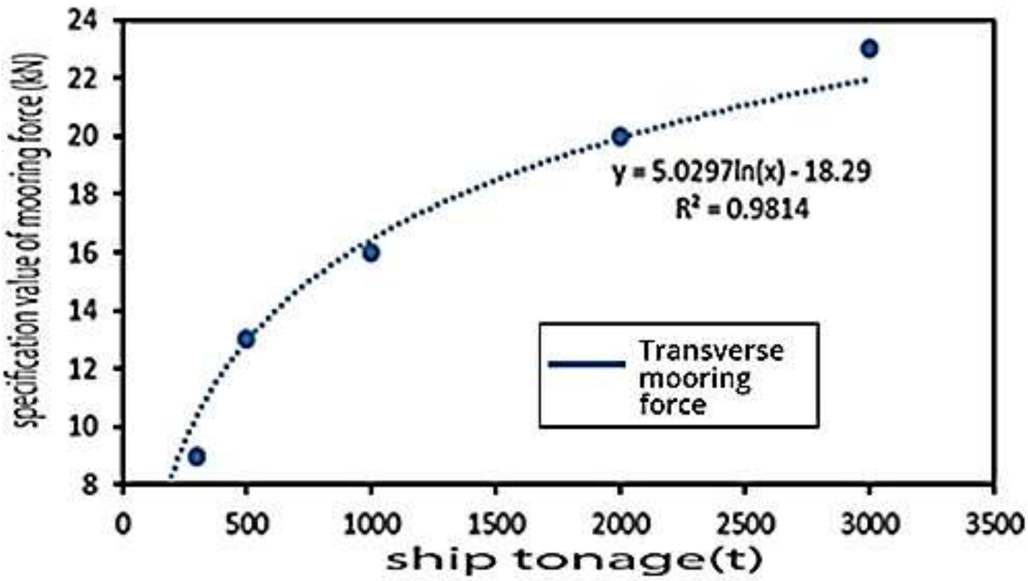

Figure 4.10 Transverse mooring force fitting

When testing the mooring force of a 1500t ship, when the valve opening time is less than 8 minutes, the ship's transverse mooring force exceeds the fitted specification value. Even if the door is opened for 8 minutes, the transverse mooring force is close to the specification value. The test results before optimization are shown in Table 9. Therefore, the model was optimized to solve the problem of excessive lateral mooring force during water transportation, and a deadening sill was added in the open ditch, as shown in Figure 3.11. The chart values given in subsequent chapters are test results after optimization.

Table 9: Maximum mooring force value of a 1500t ship before adding dead sill (before optimization)

Stop location	Valve operation mode	Valve opening time	portrait (kN)	Horizontal 1 (kN) (Bow, the same below)	Horizontal 2 (kN) (Stern, the same below)
middle part of the lock chamber	Bilateral water filling	5	22.51	12.04	24.48
			-17.65	-15.46	-12.25
		6	24.13	8.84	23.12
			-18.64	-15.96	-12.13
		7	21.65	11.64	21.74

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			-20.92	-13.49	-11.30
		8	15.00	10.08	18.43
			-22.48	-12.41	-10.39
	Bilateral drainage	5	12.70	2.07	2.14
			-10.97	-2.83	-2.94
		6	6.50	14.55	16.59
			-31.03	-15.84	-20.81
		7	24.55	10.69	11.86
			-33.60	-12.49	-10.58
		8	13.28	8.75	10.23
			-25.74	-9.25	-10.89

4.6.1(1) 1500t ship

Under the maximum design water head condition, Table 10 shows the maximum value of the ship's mooring force in the lock chamber under different valve bilateral opening speeds, and Figures show the change process line of the ship's mooring force.

It can be seen from the chart that when the bilateral valves are running, when the water-filled valve opening time tv = 7 minutes, when the bilateral valves are open, the maximum longitudinal mooring force of a 1500t single ship when berthed in the upper part of the lock chamber is 16.96kN, and the maximum lateral force is 11.20kN. , the maximum longitudinal mooring force when the 1500t single ship is berthed in the middle of the lock chamber is 15.52kN, and the maximum lateral force is 11.75kN. The maximum longitudinal mooring force when the 1500t single ship is berthed in the lower part of the lock chamber is designed to be -18.53kN and the maximum lateral force is -18.53 kN. The lateral force is 11.28 kN. The above mooring force values meet the specification requirements. During the water discharge process, the mooring force values are small and are not a control condition for ship berthing conditions.

The test results show that when the bilateral valves are filled and discharged, there is no obvious longitudinal or transverse flow in the lock chamber, the water flow in the lock chamber is less turbulent, and the water surface is stable. When the water filling

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valve opening time TV is between 6 min and 8 min, the design of a single ship with a capacity of 1500t can meet the specification requirements for both the longitudinal and transverse mooring forces.

Table10: Maximum mooring force value of 1500t ship (bilateral operation, H=22m)

Stop location	Valve operation mode	Valve opening time	Longitudinal (kN)	Horizontal 1 (kN)	Horizontal 2 (kN)
The upper part of the lock chamber	Bilateral water filling	6	23.24	9.32	9.63
			-13.37	-5.84	-14.44
		7	16.96	9.31	7.59
			-14.60	-7.31	-11.20
		8	20.16	9.09	10.91
			-11.99	-7.55	-13.04
	Bilateral drainage	6	6.64	3.51	3.77
			-10.09	-13.63	-3.71
		7	5.63	3.13	4.49
			-8.87	-15.29	-4.27
		8	8.27	9.70	11.37
			-15.48	-11.42	-10.53
middle part of the lock chamber	Bilateral water filling	6	15.19	9.38	7.07
			-10.42	-14.00	-13.42
		7	15.52	7.71	5.48
			-13.04	-10.33	-11.75
		8	14.71	8.79	5.08
			-10.59	-11.08	-12.11
	Bilateral drainage	6	6.22	1.35	0.98
			-6.70	-3.25	-1.80
		7	6.79	0.79	0.84
			-6.30	-1.66	-1.41
		8	6.29	1.17	0.89

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			-4.42	-1.84	-1.54
The lower part of the lock chamber	Bilateral water filling	6	9.27	11.48	8.06
			-18.16	-10.53	-5.10
		7	11.76	11.28	8.28
			-18.53	-9.22	-4.83
		8	9.90	8.84	6.08
			-18.85	-7.86	-4.15
	Bilateral drainage	6	5.82	1.21	1.11
			-4.86	-1.02	-1.14
		7	4.88	1.21	0.77
			-5.29	-0.97	-1.18
		8	4.20	1.20	0.87
			-6.16	-1.48	-1.44

Note: Facing downstream, the ship is docked on the right side of the lock chamber. A positive value of the longitudinal mooring force means that the direction of the mooring force is upstream, and a positive value of the transverse mooring force means that the direction of the mooring force is to the left.

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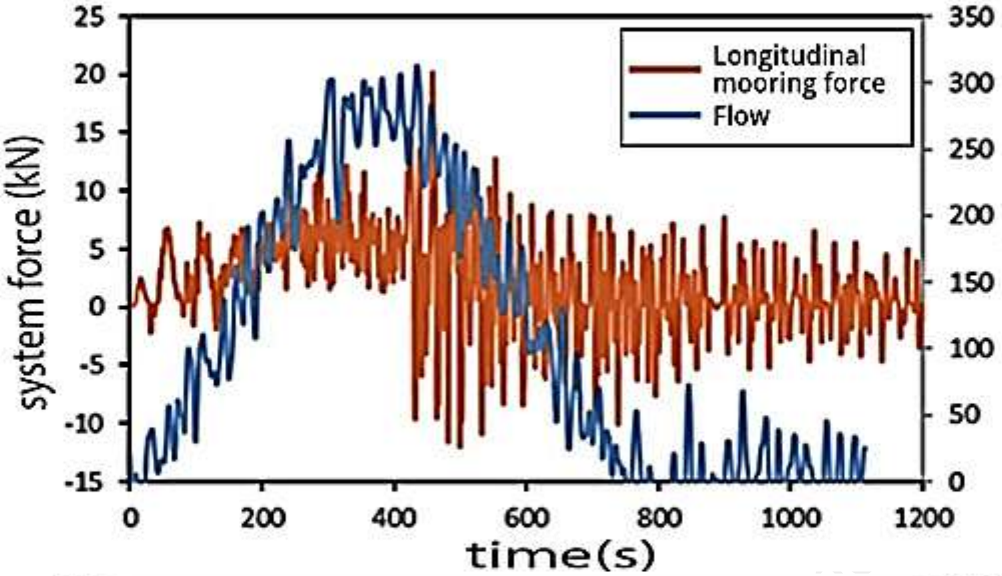

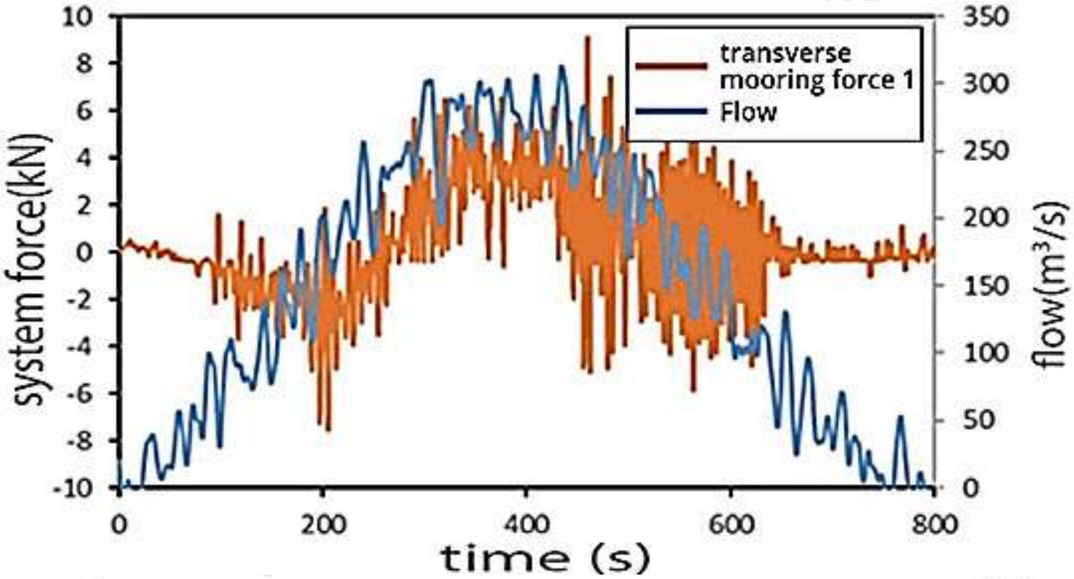

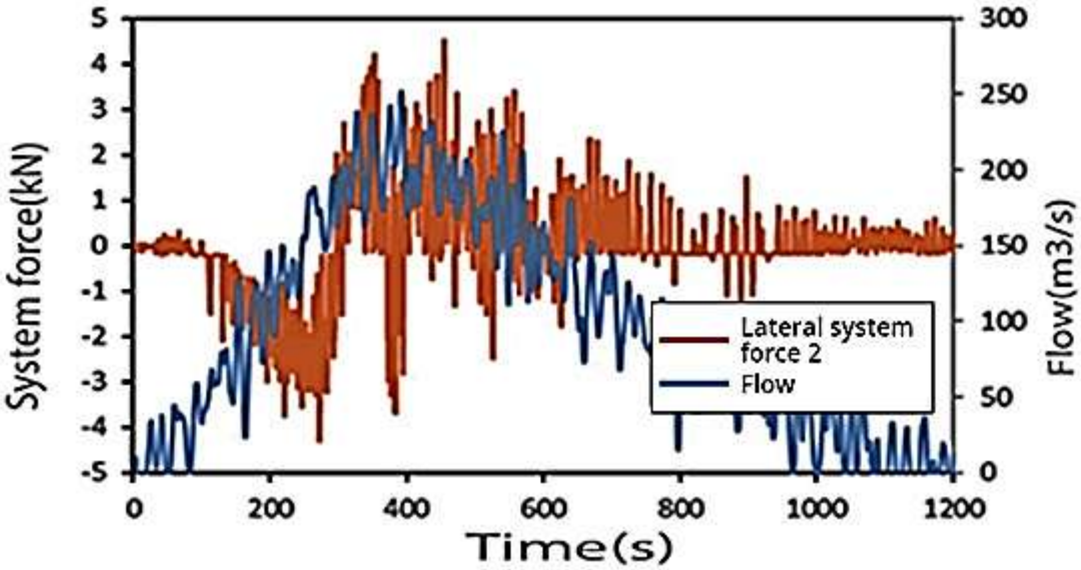

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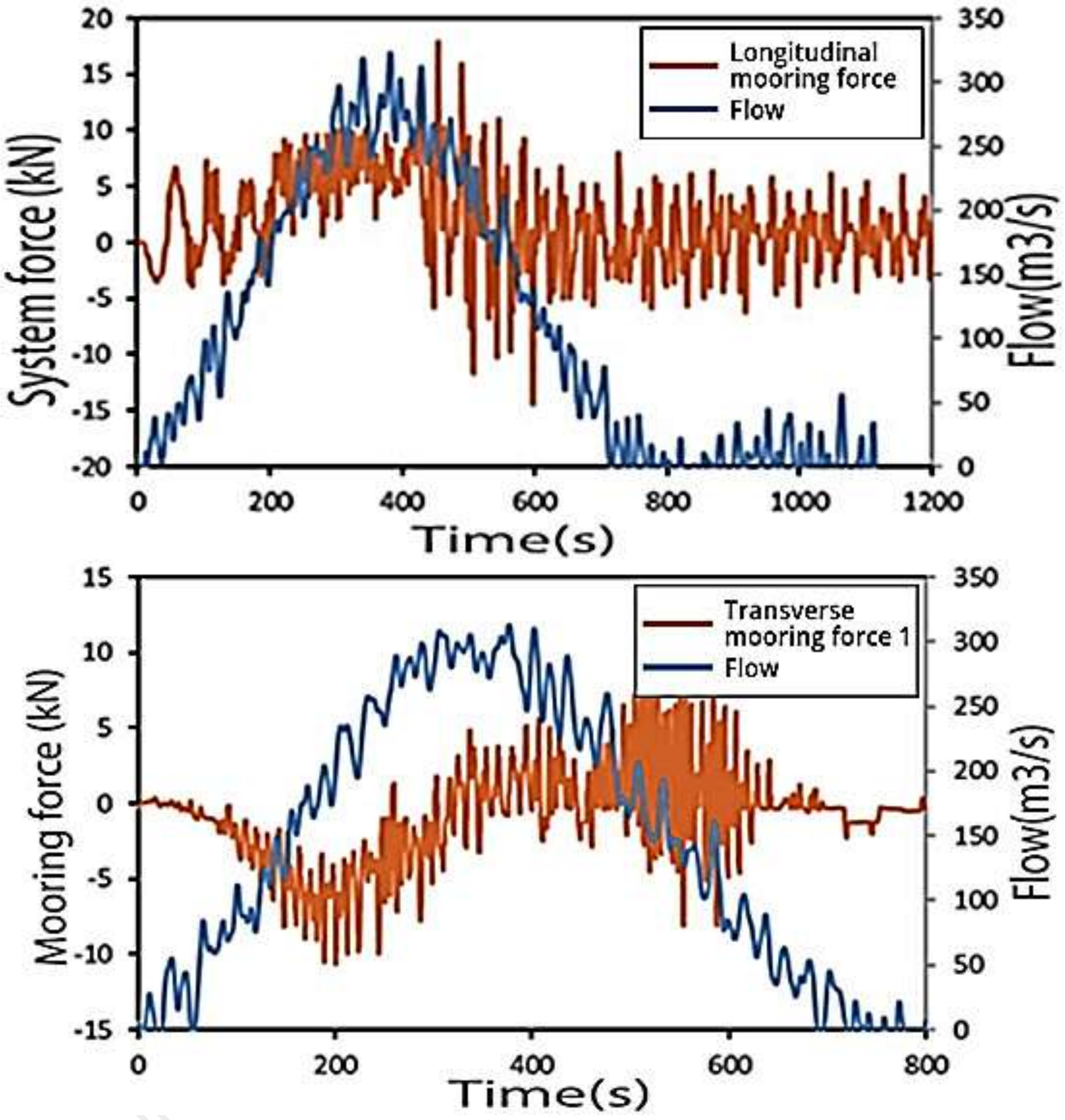
Figure4.11 Mooring force process line of a 1500t single ship berthed at the upper part of the lock chamber(Water level combination: 134m~112m, valves open on both sides, water filling tv=6)



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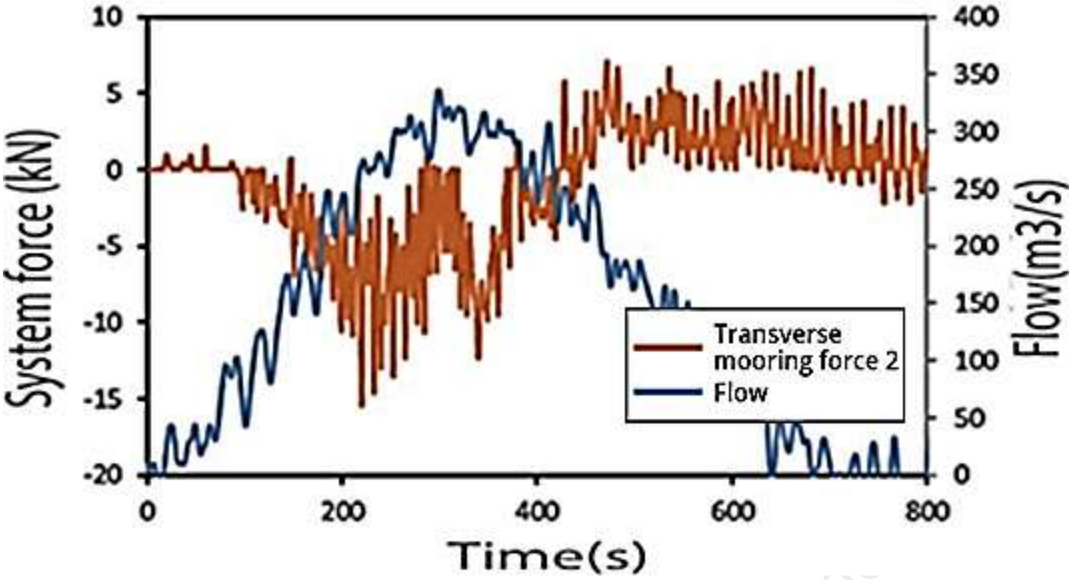
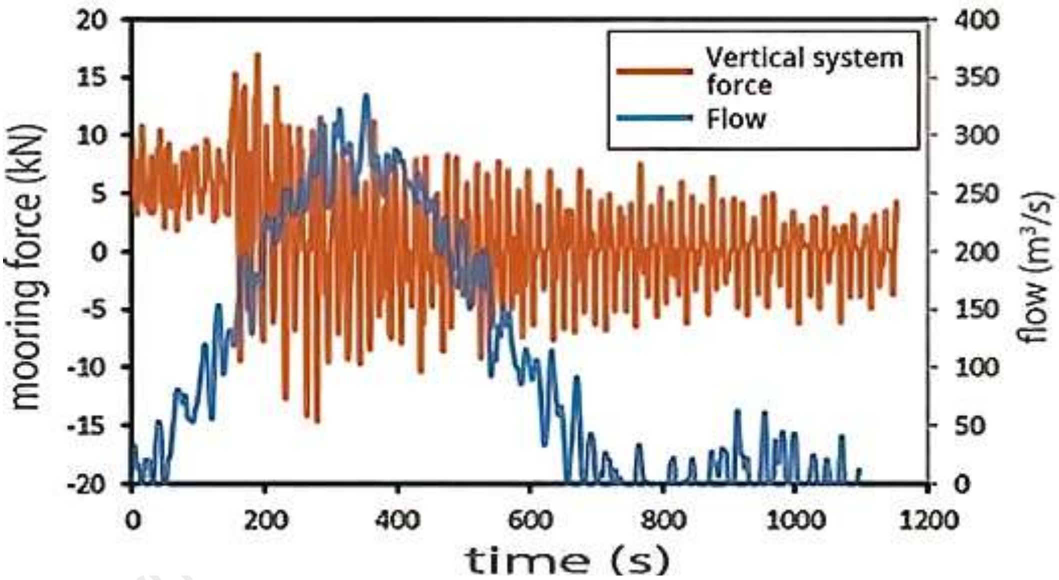


Figure 4.12 mooring force process line of a 1500t single ship moored at the upper part of the lock chamber



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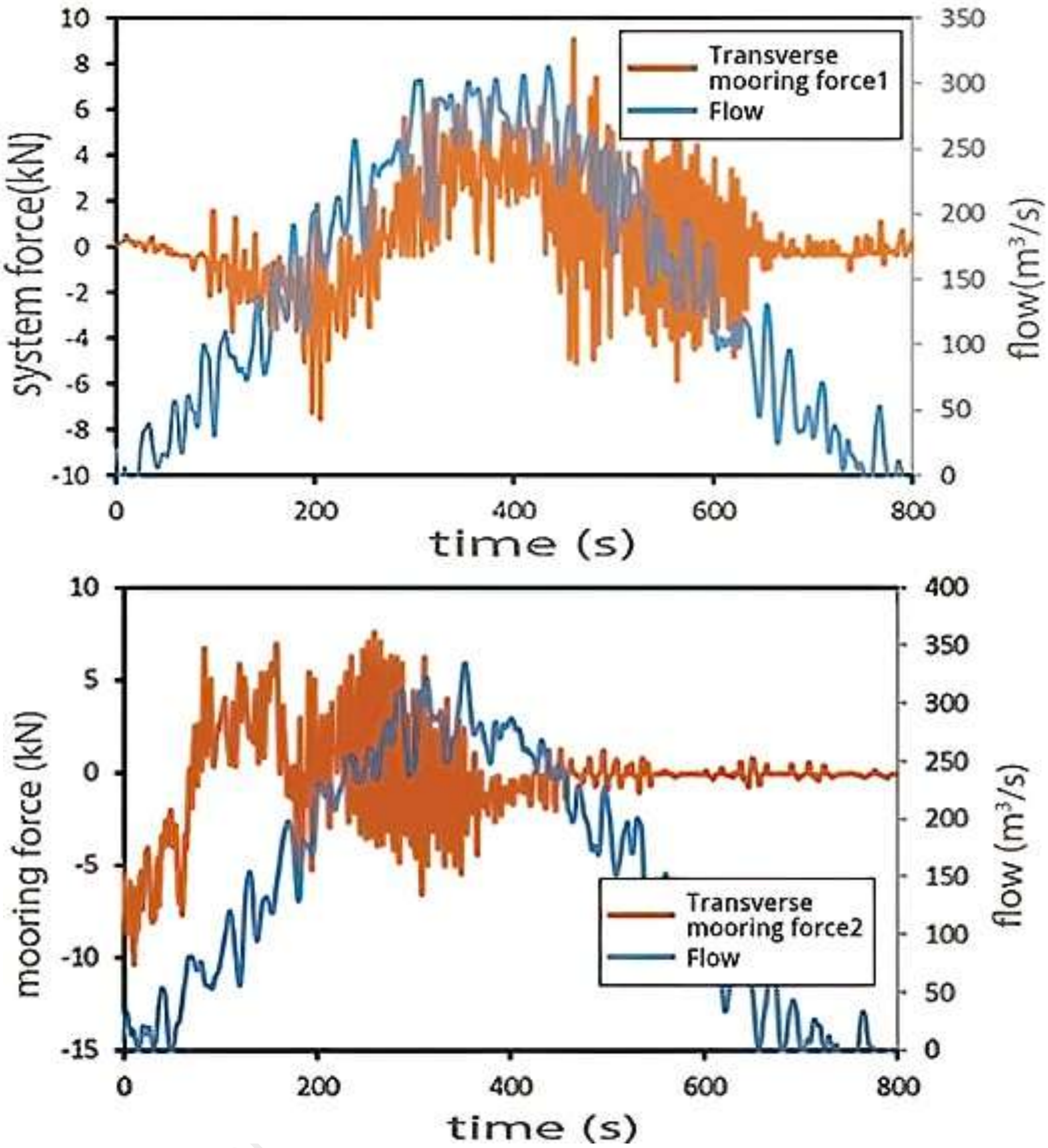

Figure4.13 mooring force process line of a 1500t single ship berthed at the upper part of the lock chamber (Water level combination: 134m~112m, valves open on both sides, water filling tv=8min)

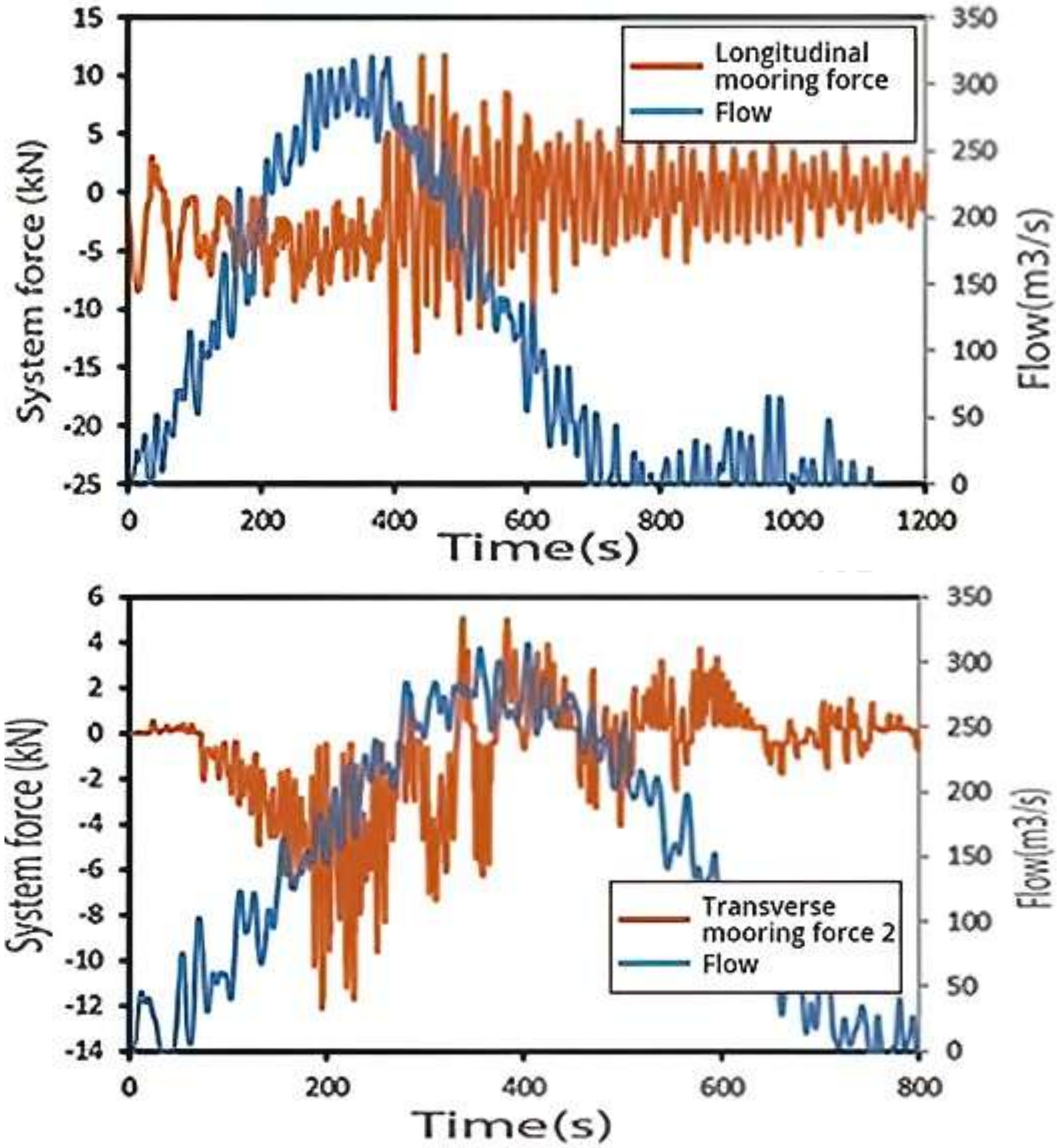

Figure 4.14 Mooring force process line of a 1500t single ship moored in the middle of the lock chamber (Water level combination: 134m~112m, valves open on both sides, water filling tv=6min

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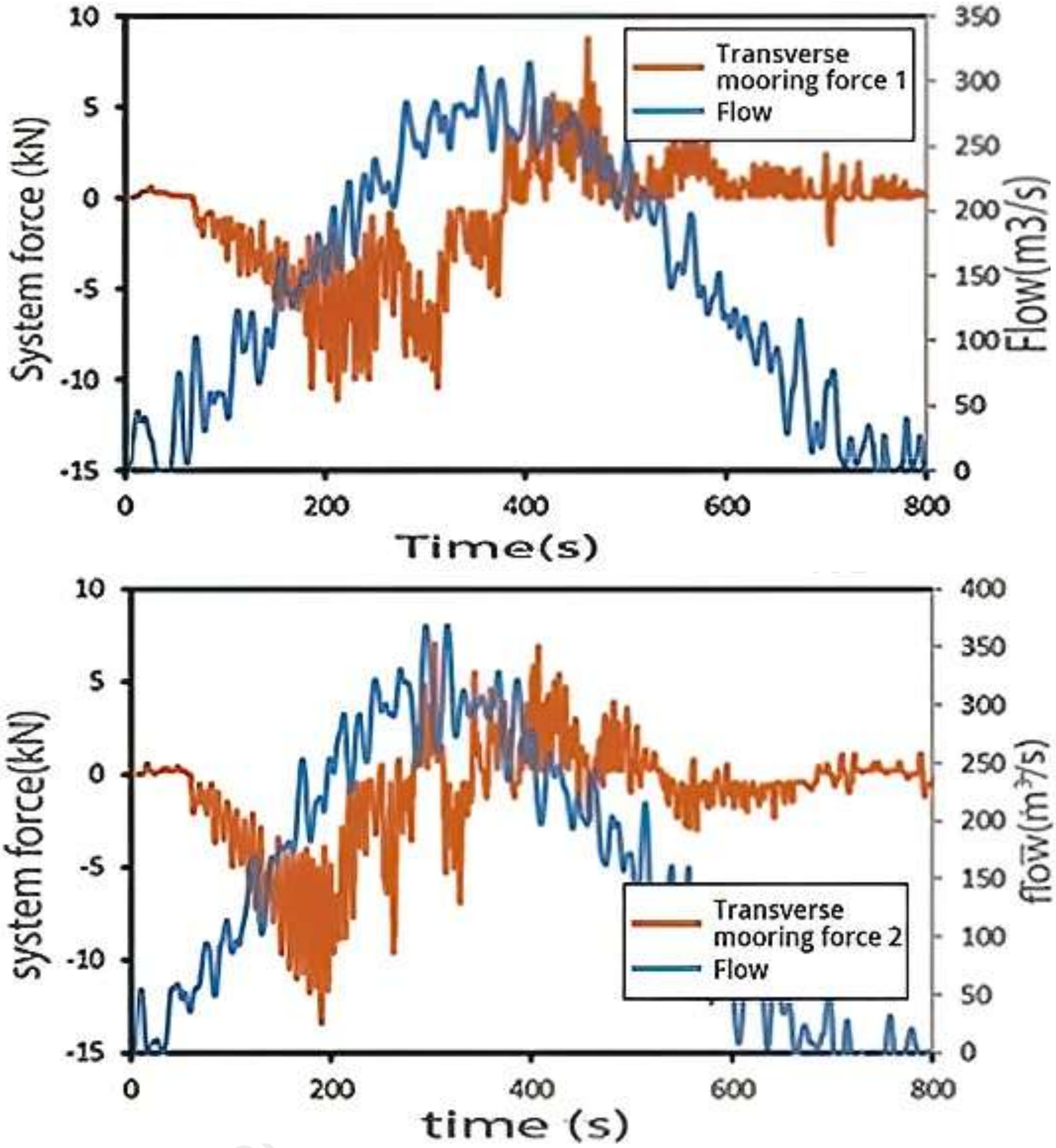

Figure 4.16 mooring force process line of a 1500t single ship berthed in the middle of the lock chamber(Water level combination: 134m~112m, valves open on both sides, water filling tv=8min)

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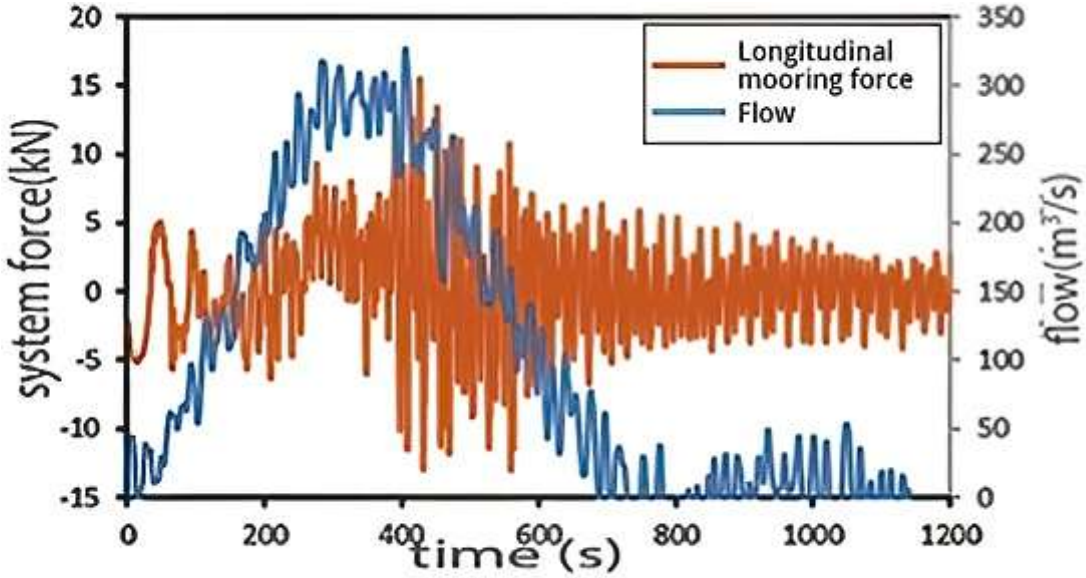

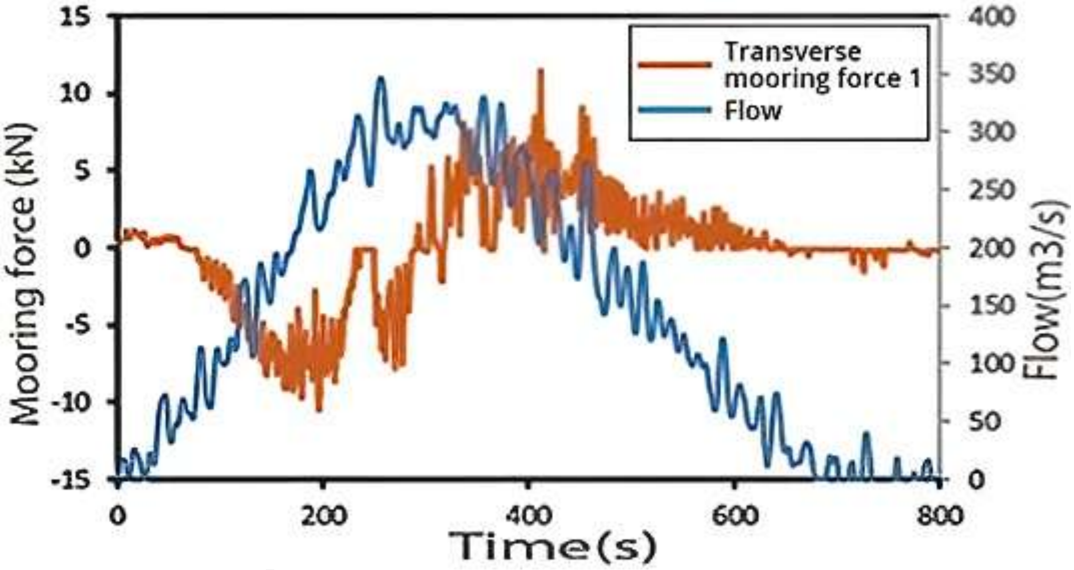

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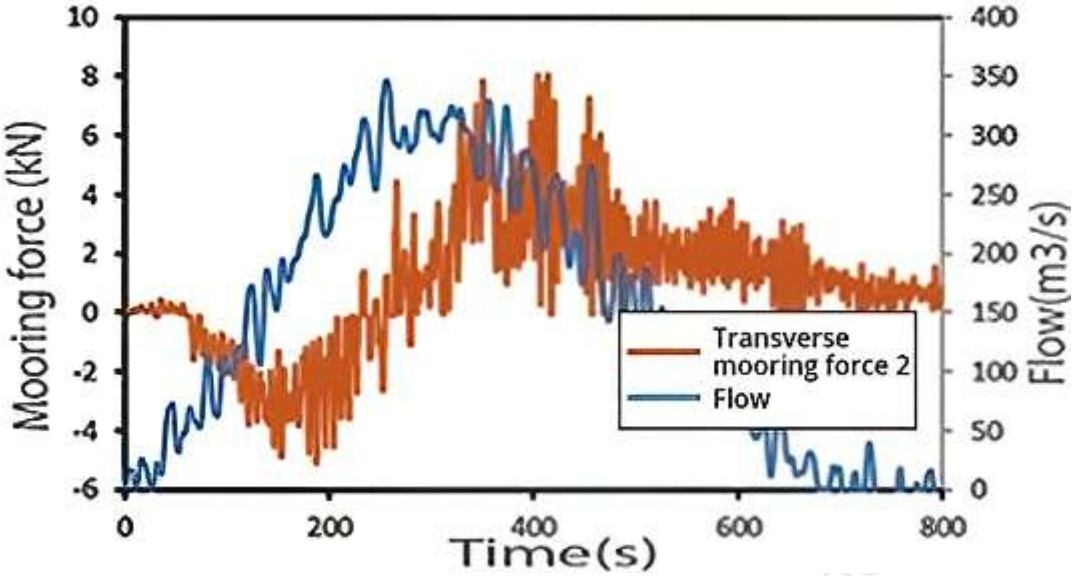
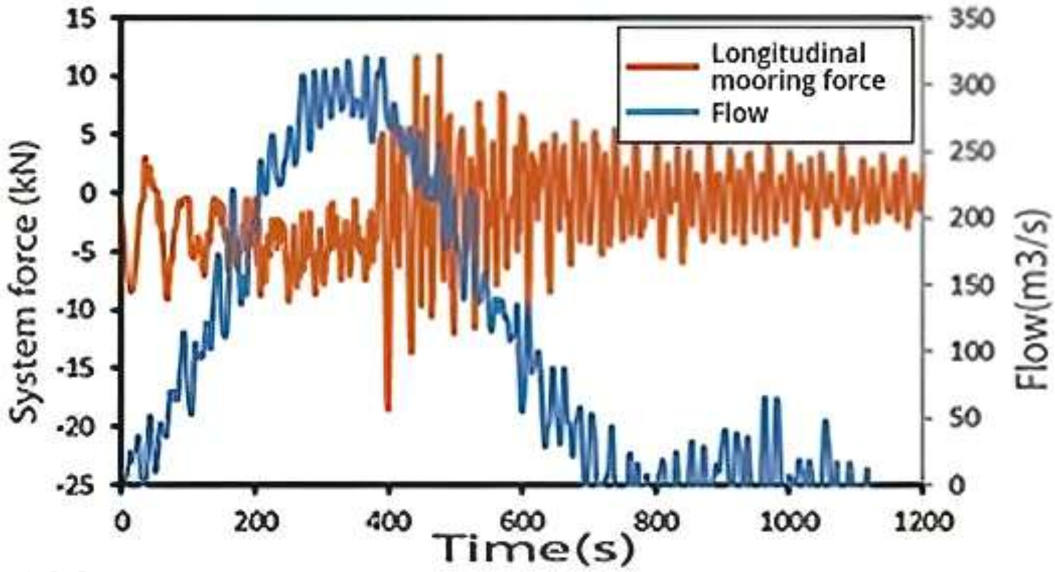


Figure 4.17 Mooring force process line of a 1500t single ship berthed at the lower part of the lock chamber(Water level combination: 134m~112m, valves open on both sides, water filling tv=6min)



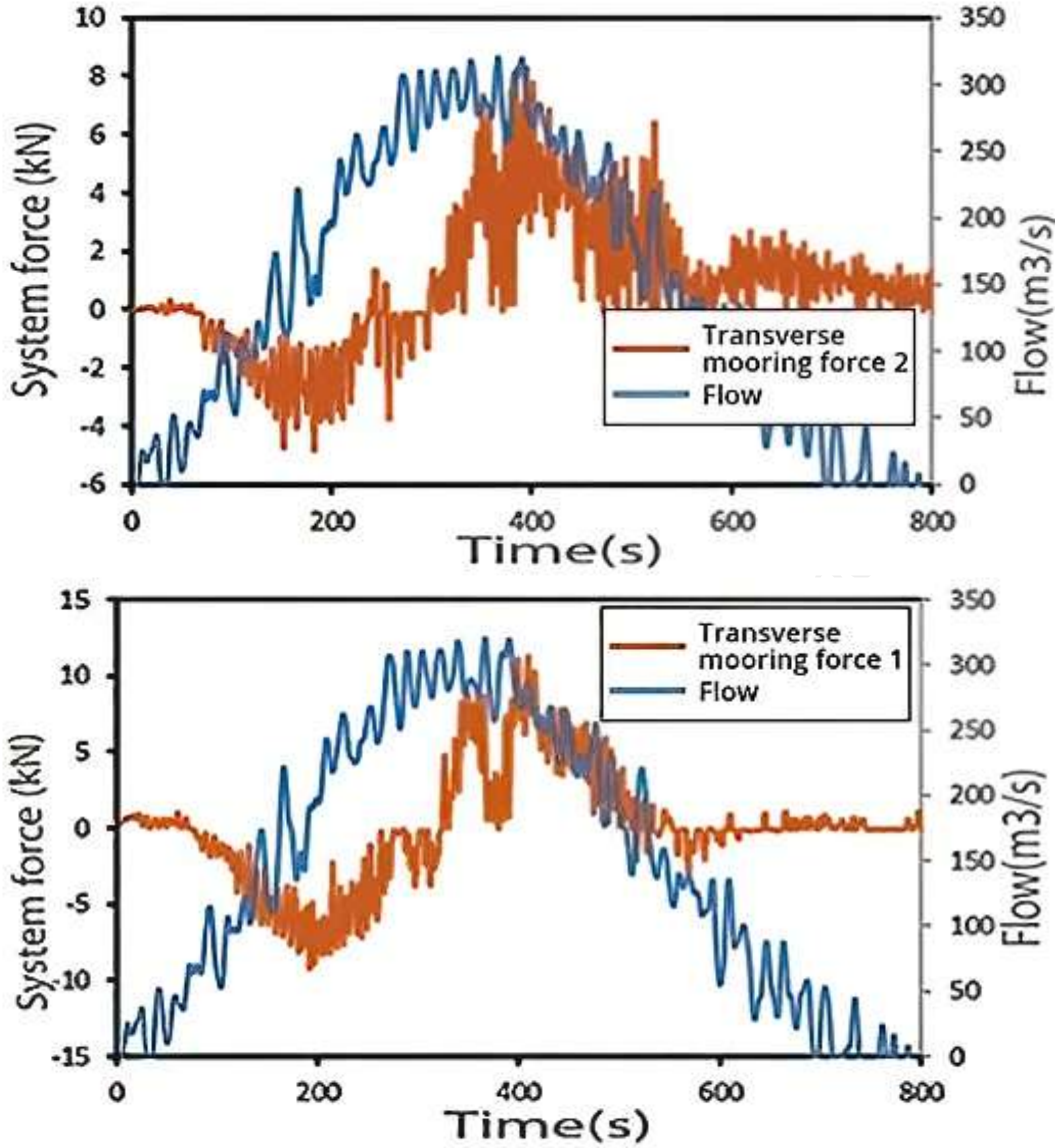


Figure 4.18 Mooring force process line of a 1500t single ship moored at the lower part of the lock chamber(Water level combination: 134m~112m, valves open on both sides, water filling tv=7min)

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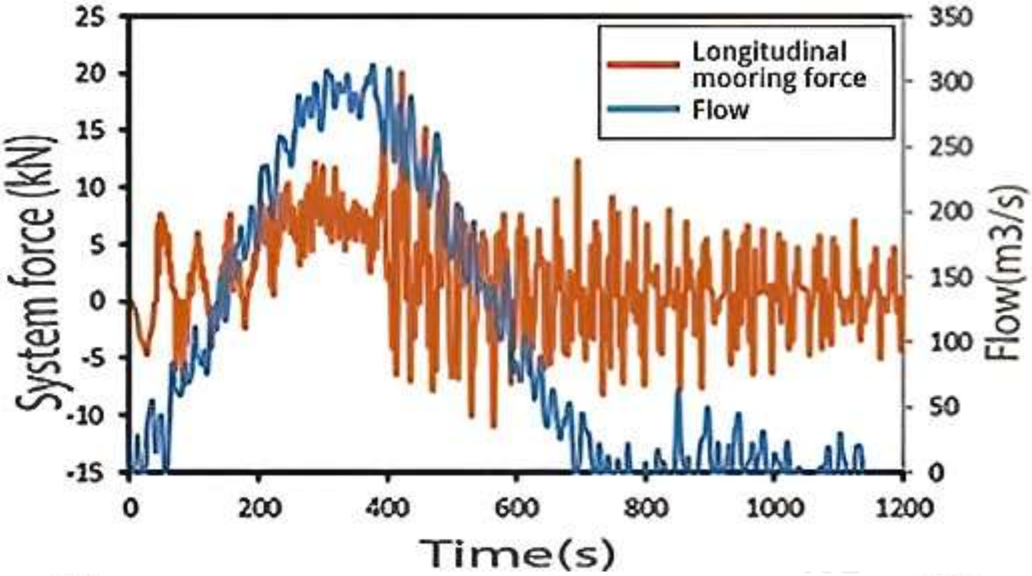

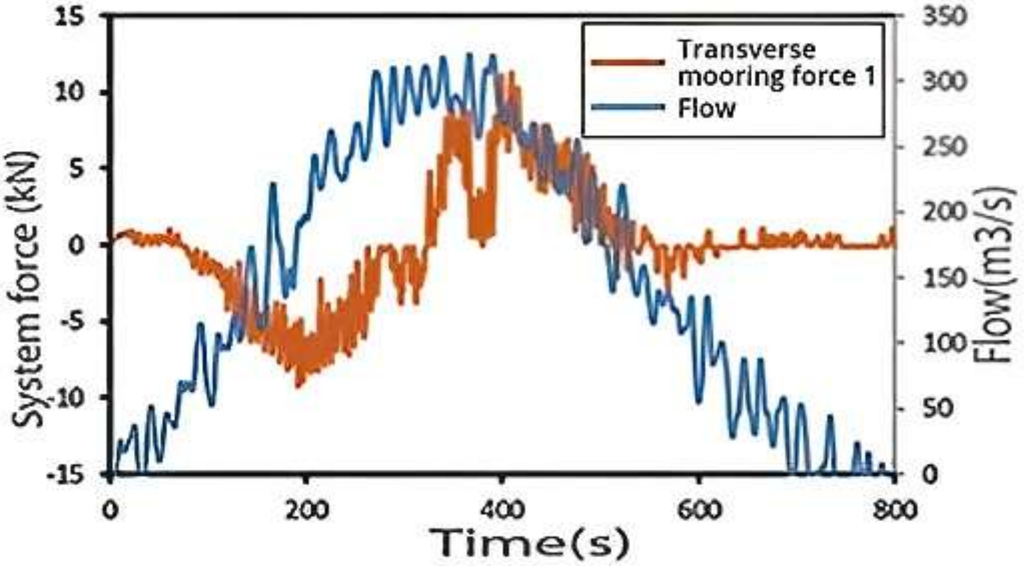

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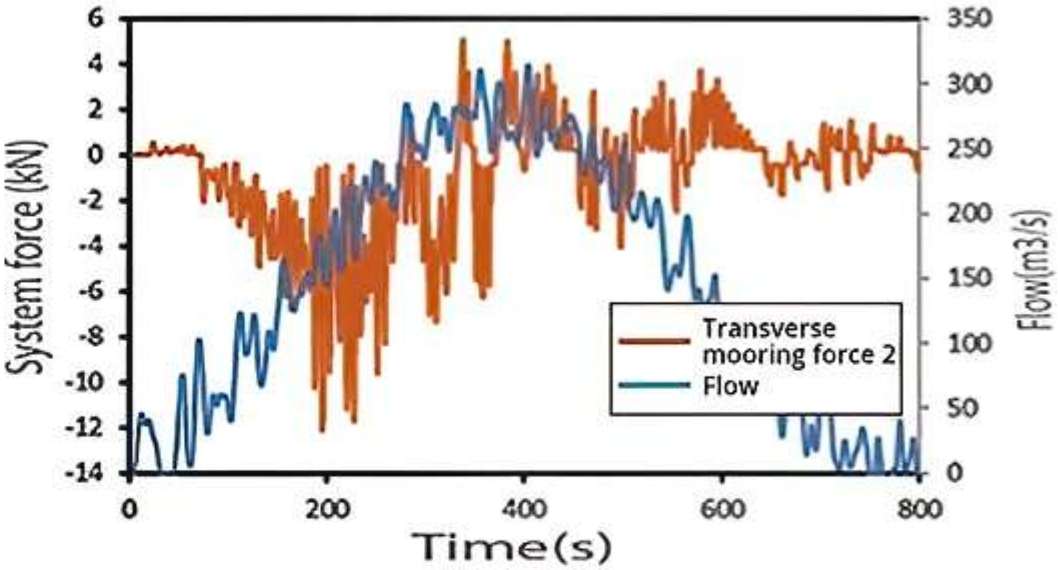

Figure 4.19 Mooring force process line of a 1500t single ship berthed at the lower part of the lock chamber(Water level combination: 134m~112m, valves open on both sides, water filling tv=8min

4.6.2 2×1000t fleet

Under the maximum design water head condition, Table 11 shows the maximum value of the ship's mooring force in the lock chamber under different valve opening speeds on both sides of the 2×1000t fleet, and Figures show the change process line of the ship's mooring force.

Table 11 Maximum mooring force value of 2×1000t (bilateral operation, H=22m)

Note: Facing downstream, a positive value of the longitudinal mooring force indicates that the direction of the mooring force is upstream, and a positive value of the transverse mooring force indicates that the direction of the mooring force is to the left.

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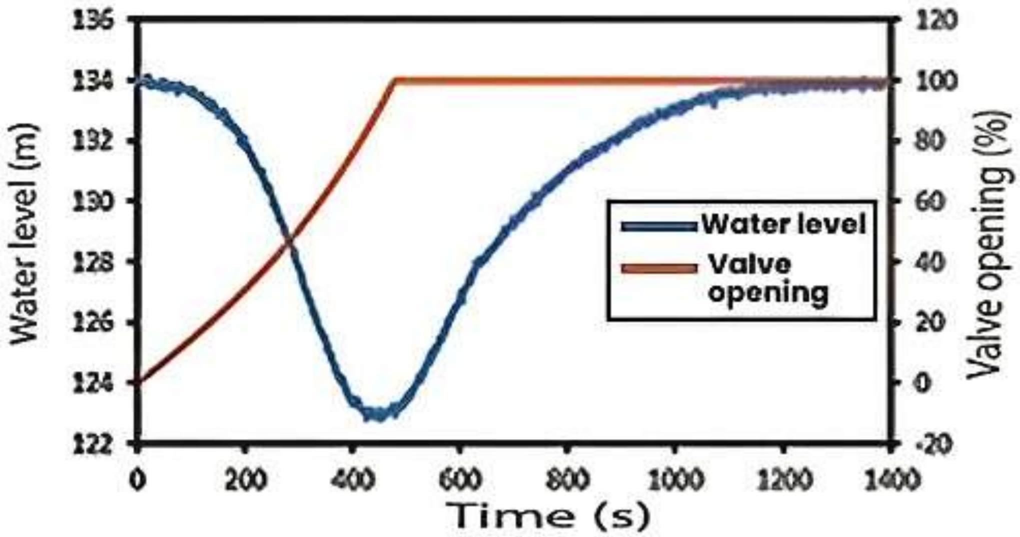
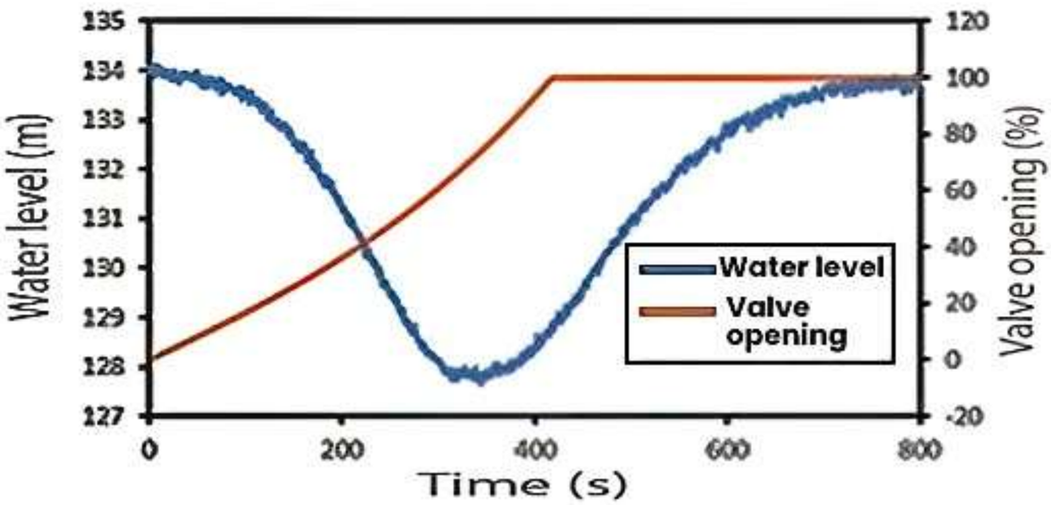
Table 11: Bilateral water filling and emptying of the upper part of the lock

Stop location	Valve operation mode	Valve opening time	Longitudinal (kN)	Horizontal 1 (kN)	Horizontal 2 (kN)
The upper part of the lock chamber	Bilateral water filling	6	14.57	5.14	7.10
			-8.96	-12.73	-15.42
		7	20.05	9.75	8.52
			-10.97	-10.64	-14.73
		8	17.90	9.50	9.95
			-14.43	-10.60	-13.43
	Bilateral water emptying	6	5.67	1.86	1.69
			-7.67	-0.92	-1.18
		7	5.25	1.77	1.21
			-6.65	-1.61	-1.46
		8	5.87	1.84	1.64
			-6.31	-1.83	-1.90

It can be seen from the chart that when the bilateral valves are running, and the water-filled valve opening time tv=6min~8min when the bilateral valves are opened, the maximum longitudinal mooring force of the designed 2×1000t fleet is 20.05k


Water level (m)
Valve opening (%)
Time (s)
Water level
Valve opening


Water level (m)
Valve opening (%)
Time (s)
Water level
Valve opening

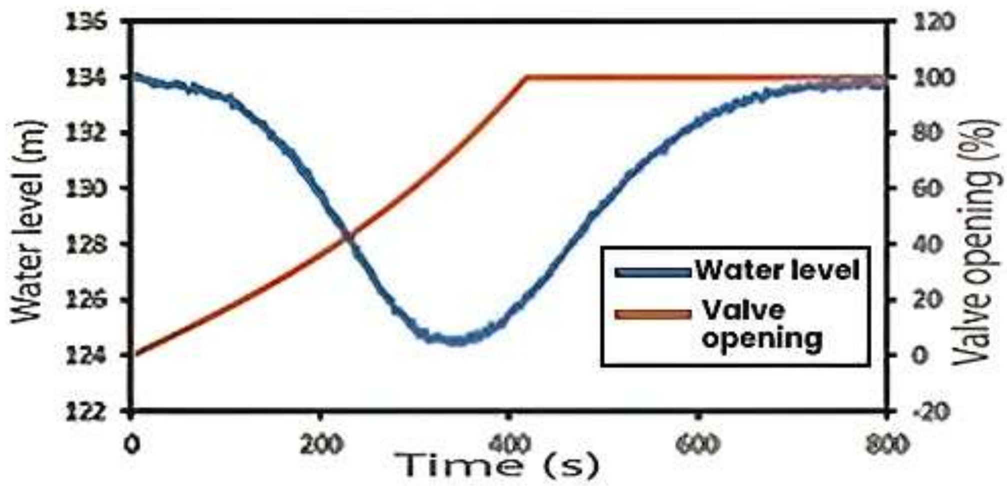

Water level (m)
Valve opening (%)
Time (s)
Water level
Valve opening

Figure 4.31 Pressure process line of bilateral water-filled measuring points for tv =8min

4.10 Inlet, Outlet, and Pilot Channel Flow Conditions

4.10.1Flow conditions at the water inlet and upstream approach channel

The water inlet at the upper gate head is arranged with vertical multi-branch holes on the gate wall. The top elevation of the corridor water inlet is 120.7m, and the water inlet area is 2~4×4.0m×4.0m (number of holes on each side×width×height) =128.0 m2. During the model test, a vertical axis vortex appeared at the highest navigation water level when the door was opened for 7 minutes (no bubbles were formed), and a vertical axis vortex appeared when the lowest navigation water level was combined, as shown below.

Figure4.32 Flow pattern at the water inlet (Maximum water head working condition, water filling for 7minutes), Flow pattern at the water inlet (Lowest water level combined working condition, water filling for 7 minutes)

4.10.2 Optimization plan

To improve the flow pattern of the water inlet, the water inlet elevation is reduced by 3m, and the water inlet area is adjusted to 2~5×4.2m×4.0m (number of orifices on each (side×width×height) =168.0m2, see Figure 4.32. The water flow conditions at the water inlet and the upstream approach channel are based on the combined working conditions of the maximum design water head condition and the minimum navigation water level. The hydraulic characteristic values of the water inlet and the upstream approach channel are listed in Table 16 during the water-filling process of the Mashi ship lock. Typical working conditions of the water inlet and the upstream approach channel the channel flow pattern is shown in Figure 4.34~Figure 4.37. It can be seen from the chart:

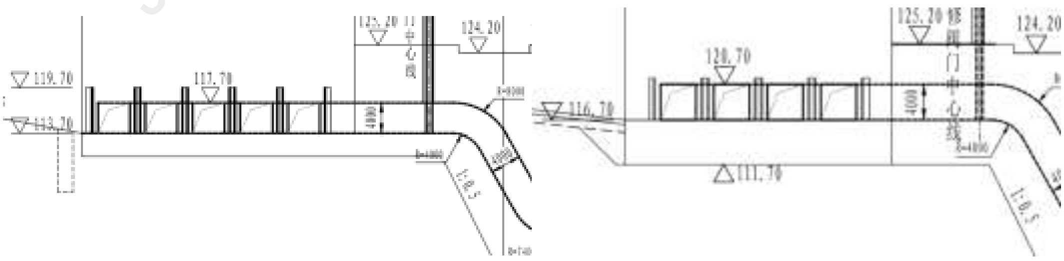


Figure 4.33 Optimized layout of water inlet

(a) Before optimization (b) After optimization

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a) Maximum design water head condition: the water filling valve is opened bilaterally for 5 to 8 minutes, the maximum water filling flow is 330.02m3/s, the maximum average flow speed of the water inlet is 1.96m/s, and at this time, the upstream water inlet is submerged to a depth of 16.3m, so the flow conditions at the inlet are better, and the water surface is very stable when filled with water; the maximum average longitudinal flow velocity in the upstream approach channel is 0.54m/s, which meets the specification requirements.

b) Minimum navigation water level combined working condition, the submerged water depth of the upstream water inlet is 12.3m, the water filling valve is opened bilaterally for 5 to 8 minutes, the maximum water filling flow is 283.51m3/s, the maximum average flow rate of the water inlet is 1.69m/s, The water flow conditions at the nozzle are good, but when the water-filled valve is opened bilaterally for 7 minutes, a short-duration liquid surface depression vortex appears, and there is no aeration. When the water-filled valve is opened bilaterally for 7 minutes, the maximum cross-sectional average flow velocity of the upstream pilot channel is 0.78m/s. Meet specification requirements.

Table 16: Water filling process of Mashi ship lock, hydraulic characteristic values of water inlet and upstream approach channel.

water level combination	Valve opening time (min)	Water head (m)	The cross-sectional area of the upstream approach channel (m^2)	Maximum flow rate (m/s)	Maximum cross-sectional flow velocity of water inlet (m/s)	Maximum cross-sectional flow velocity of approach channel (m/s)
	5	twenty-two	616.70	330.02	1.96	0.54

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Maximum design head (134~112)	6	twenty-two	616.70	313.18	1.86	0.51
	7	twenty-two	616.70	291.86	1.74	0.47
	8	twenty-two	616.70	281.88	1.68	0.46
Minimum navigation water level combination (130~112)	5	18	325.90	283.51	1.69	0.87
	6	18	325.90	271.32	1.62	0.83
	7	18	325.90	254.36	1.51	0.78
	8	18	325.90	240.13	1.43	0.74

Figure 4.34 Inlet flow pattern after optimization

Figure 4.35 Inlet flow pattern after optimization (Lowest water level combined working condition, water filling for 7 minutes)

Figure 4.36 Optimized water inlet flow pattern (Lowest water level combined working condition, water filling for 8 minutes)

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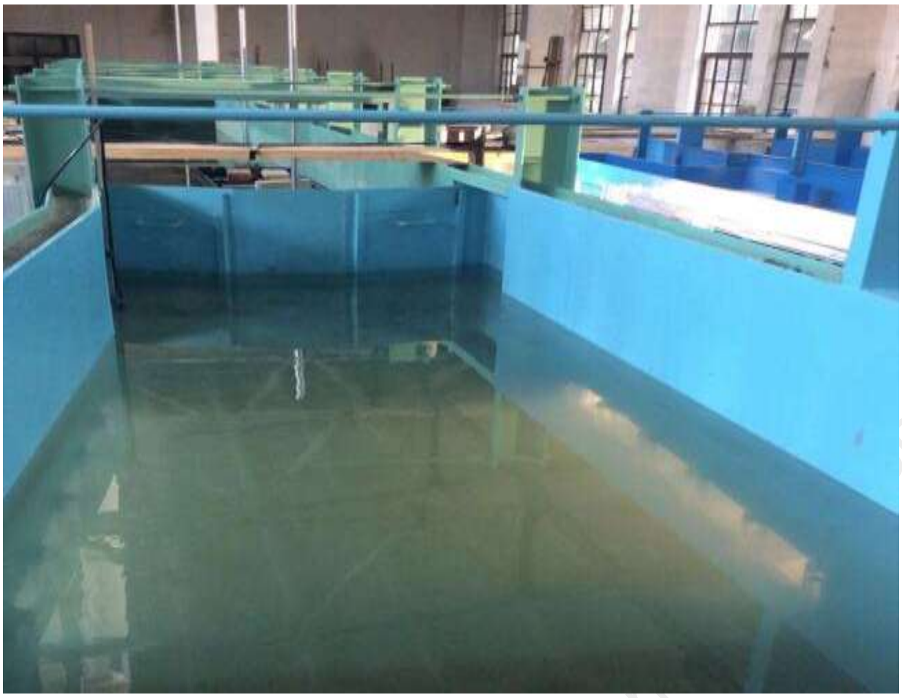

Figure 4.37 Inlet flow pattern after optimization (Lowest water level combined working condition, water filling for 9 minutes)

4.11 Flow conditions at the outlet and downstream approach channel

The water outlets downstream of the Mashi ship lock all use top-outlet grille-type energy dissipation chambers. The size of the grille holes is 2 to 14 × 3.7m × 0.9m (14 × length × width). The total area of the water outlets is 93.24m2; the energy dissipation chamber set up three flow sills to adjust the outflow distribution of the water outlet holes. During the test, the size and arrangement of the sill were adjusted to smoothen the outlet flow further when the unilateral valve was operating. After the adjustment, the downstream outlet flow was even, the water surface was relatively stable, and no adverse hydraulic phenomena, such as vortexes, were observed. The flow pattern of the water outlet and downstream approach channel under typical working conditions is shown in Figure 4.38. During the water release process of the Mashi ship lock, the downstream bottom elevation is 107.2m. Under the minimum navigation water depth and maximum design water head conditions, the downstream water level is 112.0m, and the water passing section is 272.64m^2. The downstream approach channel is the largest when the water release valve opens at 7 minutes. The average flow velocity of the section is 0.99m/s, which meets the specification requirements. The hydraulic characteristic values of the downstream approach channel are listed in Table 17.

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Taking into account factors such as the hydraulic characteristics of the lock chamber filling and releasing water, the ship berthing conditions in the lock chamber, the water delivery time requirements, the water flow conditions in the approach channel, etc., it is recommended that the Mashi ship lock's filling and releasing valves be opened at a bilateral constant speed of tv=7min in the initial stage of operation.

Table 17: the water release process of the Mashi ship lock and the hydraulic characteristic values of the downstream approach channel

water level combination	Valve opening time (min)	Water head (m)	The cross-sectional area of the downstream approach channel (m^2)	Maximum flow rate (m/s)	Maximum cross-sectional flow velocity of approach channel (m/s)
Maximum design head (134~112)	5	twenty-two	272.64	294.93	1.08
	6	twenty-two	272.64	283.64	1.04
	7	twenty-two	272.64	270.96	0.99
	8	twenty-two	272.64	260.65	0.96
Minimum navigation water level combination (130~112)	5	18	272.64	255.03	0.94
	6	18	272.64	243.93	0.89
	7	18	272.64	231.54	0.85
	8	18	272.64	225.39	0.83

Figure 4.38 Water flow pattern at the water outlet and downstream approach channel under typical operating conditions after optimization (Maximum design water head working condition, water level combination: 134.0m~112.0m, valve tv=7min bilateral opening

Conclusion

Mashi locks according to the navigation 2 × 1000-ton top push fleet, 1500-ton single ship design, the effective scale of the lock chamber for the 190m × 23.5m × 4.8m (length × width × threshold minimum depth), the maximum design head of 22.0m, the design of the water transfer time requirements for 10 ~ 12min. Mashi locks hydraulic indicators are higher, the status of the shipping is important, and the water conveyor system's performance directly affects the locks' performance that can operate safely and efficiently, so it is necessary to perform a hydraulic model test of the water transfer system. The water transfer system's performance directly impacts the safe and efficient operation of the lock, so it is necessary to carry out hydraulic modelling tests of the water transfer system. The main research results are as follows:

(1) The analysis of 1:25 overall physical model test results of the Ma Shi lock shows that the overall arrangement of the water transfer system is reasonable for the energy dissipation and decentralization of the side branch holes and open ditches of the long corridor channel at the bottom of the lock adopted in Ma Shi lock.

(2) The recommended operation mode of charging and discharging valves is tv =7min continuous opening on both sides, and the water transfer time under various water level conditions can meet the design requirements.

(3) Recommended water transfer valve operation mode, the maximum design head conditions, the gate chamber charging, draining the maximum flow rate of 291.86 m3/s and 270.96 m3/s, respectively, the corresponding valve section of the corridor maximum average flow rate of 9.86m/s and 8.11m/s, respectively; the lowest navigable water level combination, the gate chamber charging, draining the maximum flow rate of 254.36 m3/s and 231.54 m3/s, respectively. 231.54 m3/s, the maximum flow velocity of the valve section corridor is 8.59m/s and 7.82m/s, respectively; the above hydraulic characteristic values meet the specification requirements.

(4) In the open ditch, after adding a dissipative can (can height 0.8cm, distance from the branch hole 1.2m), under different operating conditions of the lock, the water flow in the lock chamber is relatively smooth. There is no drift of the ship in filling up the water. Recommended water valve operation mode, the maximum design head condition, 1500t design single ship in the lock chamber berthing, the maximum longitudinal bollard force

16.96 kN, the maximum transverse bollard force 11.20 kN, to meet the specification requirements.

(5) after the valve gate, the sudden expansion of the body after slowing down the slope, the maximum design head condition, non-constant flow filling valve bilateral continuous opening (tv = 7min) measured the lowest instantaneous pressure of 1.25 m water column, the lowest instantaneous pressure at the turn of the rising Ken -0.26; water discharge valve bilateral continuous opening (tv = 7min) measured the lowest instantaneous pressure of 0.86m water column. Bilateral water filling can meet the specification corridor pressure requirements.

(6) After optimization of the water transfer system inlet (the inlet elevation is lowered by 3m, and the inlet area is adjusted to 2~5×4.2m×4.0m (the number of orifices on each side×width×height) =168.0m2), the surface of the water near the inlet on the head of the Mashi lock is very smooth in the process of water filling. Under the recommended door-opening method, no adverse hydraulic phenomenon is seen in the maximum head condition. In the lowest navigable water level combination, the liquid surface depression vortex may appear when the gate is opened for 7min but not mixed with gas, and the vortex disappeared when the gate was opened for 8min; during the water discharge process, the flow at the lower gate head inlet was uniform, and the surface of the water was relatively smooth. Therefore, it is recommended to open the gate at the maximum head condition tv =7min and the lowest navigable water level combination tv=8min.

(7) In the recommended operation mode of the water transfer valve, the upstream channel's maximum longitudinal average flow velocity is within 0.8m/s, and the downstream channel's maximum longitudinal average flow velocity is within 1.0m/s, which meets the requirements.

5.2 Outlook

As we diagram the course through the complexities of the ship lock plan, the excursion closes with a reflection on the previous, an evaluation of the present, and a dream for what's in store. This in-depth investigation delves into ship lock systems' multifaceted dynamics, contemporary advancements, and historical foundations. The

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conclusion serves as a signpost for new knowledge gained, problems solved, and initiatives in the field of inland waterway infrastructure to come.

In exploring the complicated waters of the ship lock plan, our process fills in as an extension between the verifiable establishments, the contemporary developments, and the future desires of the inland waterway framework. As we close this thorough investigation, we wind up at a crossroads where reflections on the past, evaluations of the present, and dreams for the future meet, directing comprehension we might interpret transport lock frameworks.

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