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Safety analysis of ice navigation in Huanghua waters

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SAFETY ANALYSIS OF ICE NAVIGATION IN HUANGHUA WATERS

By

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DECLARATION

I certify that all the material in this research paper that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this research paper reflect my own personal views, and are not necessarily endorsed by the University.

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Dalian Maritime University

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ABSTRACT

Title of Dissertation: SAFETY ANALYSIS OF ICE NAVIGATION IN HUANGHUA WATERS

Degree: **M.Sc.**

Recent years, due to the important role of Huanghua Port in China's coal transportation in Winter, the navigation accidents or emergency situation which occurred on the ships navigating in ice environment of Huanghua Port draw more and more attention. Ice has great impact on both the navigation safety and port operations, especially on the ship manoeuvrability which may lead the ship into a dangerous situation. So, it is essential to identify and understand the impact of ice on the ship, and minimize the influence of wind and current complied with ice on ships to enhance the navigation safety in Huanghua port.

This paper mainly starts from introducing the navigation conditions and meteorological factors in Huanghua port and through several urgent situations happened in the beginning of this year, followed by the introduction of the calculation of the influence of ice resistance, wind pressure and flow pressure on ship's navigation, and then the method used to evaluate whether ship enable to avoid ice jam when encounters with ice it is provided, at last, security recommendations are given at the end to the ship navigating in the ice areas of Huanghua Port in Winter.

KEY WORDS: Huanghua Port, Ice Navigation, Navigation Conditions, Wind, Current, Ice-jam, Recommendations for Navigating in Ice.

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LIST OF ABBREVIATIONS

VTS	Vessel Traffic Services
AIS	Automatic Identification System
CCTV	Closed Circuit Television
MSA	Maritime Safety Administration
M/V	Motor Vessel

CHAPTER ONE

INTRODUCTION

1.1 Overview

In recent years, the frequent cold air influences the North of China, especially in the winter of 2009; the main ports in this area have suffered severe ice disaster. For Huanghua waters, it has suffered the most serious sea ice disaster in the past 30 years as a result of the influencing factors such as the continuous low temperature, flat wide shallow natural conditions, the ice under the influence of the northeast wind and ocean current. And in the circumstance of ice disaster, the 24 nautical miles artificial waterway of Huanghua coal port was covered by level ice with the thickness more than 15-30 centimeters, and the thickest ice has reached more than 1 meter, furthermore, the majority thickness of the ice in the harbor was 50 centimeters. With the thickest ice more than 1m, all of this leaded great difficulties to the berthing and the inward and outward ship, and it also had serious impact on the coal transportation and the dredging in the waterway and harbor. In general, let take the coal port as an example, the regular berthing period for a ship is 20 minutes, but under the influence of the ice blockage, the berthing period has generally increased 1 times, even the worst, some of the ships spent more than 8 hours to make fast ashore. Under these backgrounds, some of the ships were forced to break down the berth schedule and went back to the anchorage. On the aspect of port construction, the operation was carried out in the lighter ice during the heavy ice period, but the work efficiency has decreased significantly. (Li, 2011, p.50)

The sea ice jeopardizes the navigation safety of ship in winter near Huanghua port will last for a long time. From the ship navigation safety level, while navigating in ice, the ship officer must be paid attention to, and has the comprehensive understanding to the damage of sea ice on the ship, so as to take adequate prevention and contingency measures.

In order to realize the good manipulation and safe navigation of ship which navigating in the ice environment of Huanghua waters in winter and reduce the occurrence of ships' accidents, it is very important to make the correct judgment to the danger classes for the ice conditions and ice environment in Huanghua harbor. This paper mainly through the analysis of 5 ship accidents from 2009 to 2013 years, and through the quantitative analysis of ice, wind, flow effect on ship to put forward some suggestions or recommendations to the ship navigating in ice of Huanghua waters in winter to ensure the navigation safety of ships.

1.2 Research Situation for Ships Navigating in Ice of China Domestic and Foreign Countries

At present, the China domestic research is according to the provisions and experiences of marine ice navigation, and the achievements can be roughly summed up as the recommendations of ice navigation:

(1) Ship officers should analyze the ice data and the ice reports can be received carefully, and make sure timely dodge to icebergs and ice while encounters, the best way is choose a powerful route in ice environment; (Li, 2003, pp.4-5)

(2) Check whether the ship has the ice strengthening and make sure the ice classification of the ship before sailing;

(3) Take all effective method of positioning to ensure the accuracy of positioning as the basis of ice calculation and positioning when navigating in ice environment, and adequate attention should be paid to the influence of ice on the ship's speed and maneuverability, make a early action to avoid collision in head-on or crossing situations, special attention should be paid while navigating in narrow channels; (Sun, 1995, pp.89-93)

(4) When ships are navigating in ice, hull, propellers and rudder may be easily damaged, the ship must drive carefully and try to avoid reversing. The empty or light load ship should try to increase the draft to ensure the propeller and rudder are fully immersed in water; (Xu, 2002, pp.4-7)

(5) When navigating in ice, the crew should alert for the jam of the sea bottom valve or the condenser of main, auxiliary engine which can be caused by ice to avoid accident;

(6) Enhance lookout when navigating, timely action should be taken to avoid collision when encounters floe ice; if the collision is unable to avoid, the ship officer should reduce speed in order to ease the impact forces of dashing against the ice, and then change the route through the rubber ice or the ice crevasse and try to avoid approaching the rafted ice or very closed drift ice;

(7) if it is impossible to avoid the ship contact with ice, and the officer should take

the bow to contact with periglacial at right angles to prevent the bow oblique slip off into the ice which would cause the damage to the hull or the stern collide with periglacial and damage the propeller and rudder of the ship; (Song, 2005, p.48)

(8) Try to prevent the ice to freeze the ship over or the ship nipped in the rice, otherwise serious damage to the hull by ice pressure may be occur;

(9) If it is difficult to navigate when the ship is encountering a serious ice disaster. Under this circumstance, the ship master should contact the port authorities and apply an escort under the icebreakers or tugs with doubt. While escorting under icebreaker, the ship should maintain certain distance with icebreaker and pay close attention to changes in the speed of the icebreaker and keep in touch frequently;

(10) Do not try anchor in the ice areas as far as possible, if it is needful in faith, the ship should choose the weakest ice for anchor, and the cable length should no longer than two times of water depth is appropriate, or if the chain is too long, it is easily lead to broken when the ice moves. We should keep the main engine in stand-by and officers on duty to weigh anchor when necessary. (Song, 2005, p.48)

Foreign research has focused on the usage of the icebreaker navigating on the Arctic or Antarctic near the Polar Regions, and currently and generally, the ship navigating in the Polar Regions follow the “Guidelines for the ship navigating in Polar Regions”. And we also can consult a lot of thesis on the internet, and some of the countries who usually suffer the impact of the ice disaster had promulgated the guideline for the ship sailing in her territory, for example, Canadian Coast Guard promulgated the revised version of “Ice Navigation in Canadian Waters” in 2012; and Jussi Martio in

Helsinki University of Technology carried out "Numerical Simulation of Vessel's Maneuvering Performance in Uniform Ice" in 2007 and International Towing Tank Conference (ITTC) promulgated "Recommended Procedures and Guidelines on Testing and Extrapolation Methods Ice Testing Resistance Test in Level Ice" in 2002, and American Bureau of Shipping (ABS) provides the "Guide for Ice Loads Monitoring Systems" which provides requirements for the installation of, and the information to be provided by, ice loads monitoring systems fitted on ice-classed ABS vessels in 2011. Besides, some theses focus on the performance of the merchant vessels in ice in different waters also gets a huge process to improve the navigation safety. What should be highlighted is about the research on the designing and construction of icebreaker, the Russian Class is just as the leader in the field of the ice navigation technology.

1.3 Objectives and Main Contents of the Dissertation

In order to give the ship officers a comprehensive understanding on the ice navigation in Huanghua waters and let them pay enough attentions during navigation, and the following objectives have been established in this dissertation:

1. To provide a comprehensive navigation condition from the aspects of maritime meteorology and waterway;
2. To draw enough attentions of ship officers by describing dangerous cases which happened usually during heavy ice, and some of dangerous cases and ships' details is listed;
3. To supply the probable calculation formulas of ice resistance, and commend Edwards formula to ship officers for daily work;
4. To supply the calculation method to ships to judge whether the ship can be jammed or can be avoid jammed by its own operation;

5. To provide recommendations to ships and Cangzhou Maritime Safety Administration during the ice period.

This dissertation is organized in the following way: Chapter Two represents the navigation environment and meteorological conditions of Huanghua port. Chapter Three demonstrates five dangerous cases from the cases happened in the past years, and gives the impacts of ice from different aspects. Chapter Four is the core of this dissertation, it contains the stress analysis of ship navigating in ice and introduces different ice resistance calculation formula and the calculation method of wind pressure and current pressure, and then how to evaluate the ship can be avoid ice-jam is presented. Chapter Five presents the recommendations and Chapter Six is the conclusion and prospect.

CHAPTER TWO

INTRODUCTION OF THE NAVIGATION ENVIRONMENT AND METEOROLOGICAL CONDITIONS OF HUANGHUA PORT

2.1 Overview of Geographical Location of Huanghua Port

Huanghua port is located in the cross connecting area of Shandong Province and Hebei Province, and perched on the western of BoHai Bay, it owns the waters from the north of Dakou River with the geographic coordinates of latitude 38°19′N， longitude 117°52′E. It is a major port of Hebei Province coastal region and also one of the important coal loading port for generating electricity of Southern of China.

2.2 Introduction of Natural Environment of Huanghua Port

2.2.1 Maritime Meteorology

The analysis is based on the actual measurement of weather data from Lijiabao Maritime Meteorologic Observing Station during the period from 1979 to 1984.

(1) Air Temperature

Average air Temperature: 12.2 ℃;

Average highest air temperature: 17.3 ℃;

Average lowest air Temperature: 7.8 ℃;

Extreme highest air temperature in the period: 37.7 ℃; (June 7, 1981)

Extreme lowest air temperature in the period: －19.5 ℃; (December 30, 1983)

According to the statistical data, the number of days of daily average temperature below －5 ℃ is 71 days and below －10 ℃ is 23.8 days. (Maritime college of Jimei University, 2013, p.13)

(2) Wind

Huanghua New Village Meteorological Observing Station is located in three-thousand-ton dock near Dakou River Estuary with its geographical coordinates of latitude 38°16 ′N, longitude 117 °51 ′E. Wind observations using EL electrical recorder with the 9 meters height of wind speed sensor carry out continuous observation of 24 hours.

Table 1: Statistics of wind frequency in Huanghua Port of 2002

Wind force / Wind direction	1 to 3		4 to 5		More than 6		Sum	
	Time	Frequency	Time	Frequency	Time	Frequency	Time	Frequency
N	364	4.2	154	1.8	12	0.1	530	6.1
NNE	201	2.3	139	1.6	16	0.2	356	4.1
NE	389	4.4	221	2.5	61	0.7	671	7.7
ENE	238	2.7	269	3.1	103	1.2	610	7.0
E	429	4.9	390	4.5	104	1.2	923	10.5
ESE	255	2.9	181	2.1	7	0.1	443	5.1
SE	416	4.7	150	1.7	1	0.0	567	6.5
SSE	315	3.6	181	2.1	8	0.1	504	5.8
S	541	6.2	223	2.5	3	0.0	767	8.8
SSW	332	3.8	168	1.9	17	0.2	517	5.9
SW	525	6.0	304	3.5	32	0.4	861	9.8
WSW	263	3.0	87	1.0	1	0.0	351	4.0
W	331	3.8	109	1.2	5	0.1	445	5.1

WNW	148	1.7	111	1.3	22	0.3	281	3.2
NW	292	3.3	188	2.1	19	0.2	499	5.7
NNW	242	2.8	128	1.5	15	0.2	385	4.4
C							50	0.6
Sum	5281	60.3	3003	34.3	426	4.9	8760	100

Source: Safety demonstration report of affect on safety navigation.(2013). Maritime College of Jimei University.

Xiamen: Author.

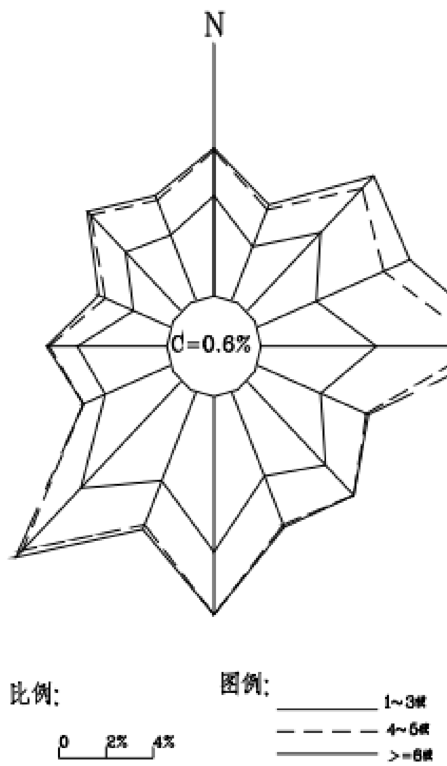


Figure 1: Wind rose of Huanghua port (2002)

Source: Safety demonstration report of affect on safety navigation.(2013). Maritime College of Jimei University.

Xiamen: Author

According to the analysis of the wind statistical data (Table 1 and Figure 1) from Huanghua New Village Meteorological Observing Station of 2002, we can get that the constant wind direction in this area is east and the second constant wind direction is southwest with the frequency of occurrence of 10.5% and 9.8%; the strong wind direction is East and ENE and the frequency of wind force more than Beaufort Number 6 was all 1.2%.

2.2.2 Hydrographic Measurement

(1) Tide and tidal change

Huanghua Tide Station is located in the general cargo dock in the coal port,

i. Datum plane and conversion figure

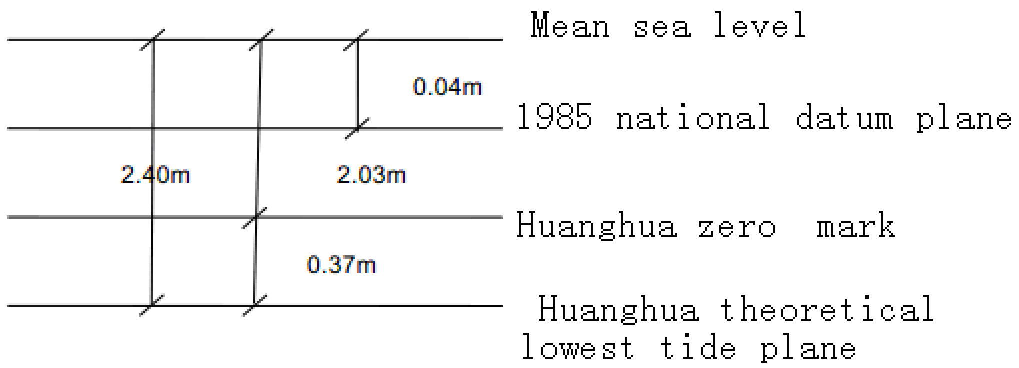


Figure 2: Figure of relationship among each datum

Source: Safety demonstration report of affect on safety navigation.(2013). Maritime College of Jimei University.

Xiamen: Author

ii. Tide types and the characteristic data of tide

According to the statistic data during the period from May, 2002 to April, 2003 from Huanghua tide testing station, after calculation, the harmonic constant of Huanghua waters is 0.64. The details of tide during this period are listed below:

Higher high water: 4.66m (April 17,2003);

Lower low water: －0.30m (January 28,2003);

Mean high water level: 3.48 m;

Mean low water level: 1.44 m;

Largest tidal range: 3.87 m(December 6,2002);

Smallest tidal range: 0.44 m(April 12, 2003);

Mean tidal range: 2.04 m

(Maritime college of Jimei University, 2013, p.18)

iii. Height of ship tiding over into the harbor

Table 2: Table of the all year water levels for tidal navigation

Water level / Frequenc / Time delay	50%	60%	70%	80%	85%	90%	95%
Tiding over for 1 hour	3.52	3.41	3.30	3.16	3.07	2.96	2.77
Tiding over for 2 hour	3.41	3.30	3.19	3.05	2.97	2.87	2.70
Tiding over for 3 hour	3.25	3.14	3.03	2.90	2.82	2.72	2.56
Tiding over for 4 hour	2.97	2.88	2.77	2.64	2.56	2.47	2.31

Source: Safety demonstration report of affect on safety navigation.(2013). Maritime College of Jimei University.

Xiamen: Author

Table 3: Table of the winter water levels for tidal navigation

Water / Frequency / Level / Time delay	50%	60%	70%	80%	85%	90%	95%
Tiding over for 1 hour	3.20	3.11	3.00	2.89	2.80	2.67	2.48
Tiding over for 2 hour	3.11	3.03	2.91	2.80	2.72	2.60	2.43
Tiding over for 3 hour	2.96	2.87	2.76	2.65	2.57	2.47	2.28
Tiding over for 4 hour	2.68	2.59	2.51	2.39	2.33	2.22	2.04

Source: Safety demonstration report of affect on safety navigation.(2013). Maritime college of Jimei University.

Xiamen: Author

(2) Sea Wave

Huanghua waters does not have a long-term wave observation data. The analysis result based on the statistical data of Platform No.7 during the period from 1972 to 1984 which has a distance about 25 Km northwest from Huanghua Port is that this district is dominated by waves, supplied by the swell.

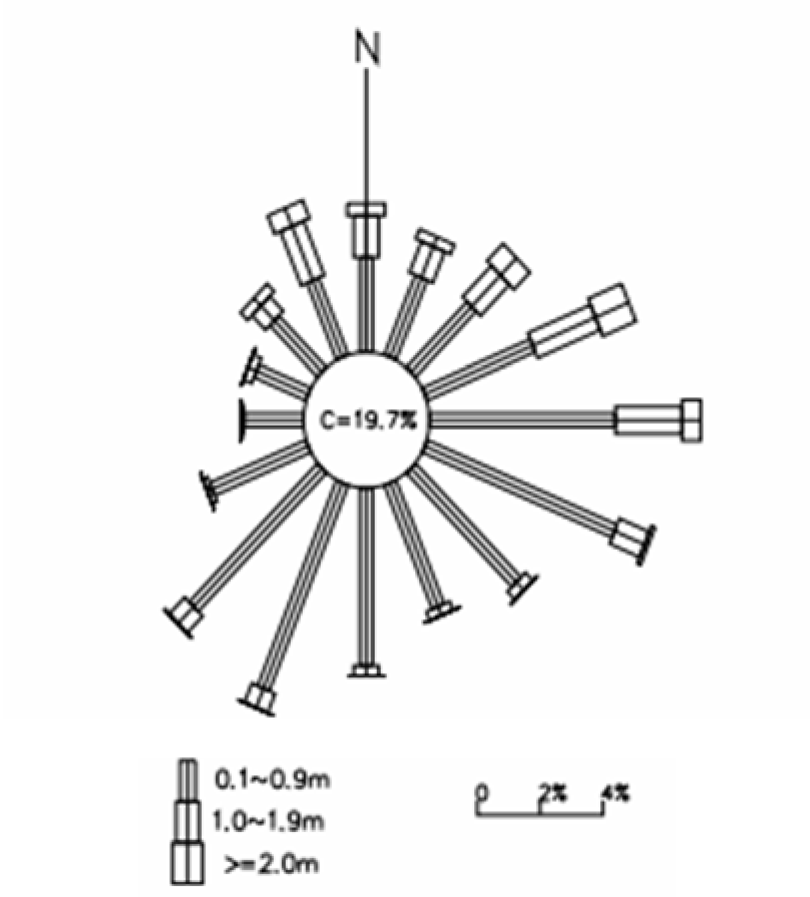


Figure 3: Tide rose of Huanghua port

Source: Safety demonstration report of affect on safety navigation.(2013). Maritime College of Jimei University.

Xiamen: Author

Height / Direction	0.1m to 0.9m		1.0m to 1.9m		2.0m to 2.9m		Higher than 3.0		sum	
	times	Frequency(%)	times	Frequency(%)	times	Frequency(%)	times	Frequency(%)	times	Frequency(%)
N	380	2.8	167	1.2	47	0.3	2	0.0	596	4.4

NNE	345	2.5	135	1.0	39	0.3	3	0.0	522	3.8
NE	371	2.7	177	1.3	84	0.6	14	0.1	646	4.7
ENE	507	3.7	294	2.2	143	1.1	14	0.1	958	7.1
E	807	5.9	288	2.1	68	0.5	13	0.1	1176	8.6
ESE	892	6.6	140	1.0	17	0.1			1049	7.7
SE	646	4.7	45	0.3	3	0.0			694	5.1
SSE	538	4.0	38	0.3					576	4.2
S	713	5.2	41	0.3					754	5.5
SSW	893	6.6	83	0.6	3	0.0			979	7.2
SW	787	5.8	94	0.7	5	0.0			886	6.5
WSW	451	3.3	23	0.2					474	3.5
W	258	1.9	11	0.1					269	2.0
WNW	244	1.8	38	0.3	2	0.0			284	2.1
NW	291	2.1	83	0.6	39	0.3	5	0.0	418	3.1
NNW	333	2.4	236	1.7	70	0.5	9	0.1	648	4.8
C	2676	19.7							2676	19.7
Sum	11132	81.7	1893	13.9	520	3.7	60	0.4	13605	100

Table 4: Statistics analysis for tide height frequency from 1972 to1984.

Source: Safety demonstration report of affect on safety navigation. (2013). Maritime College of Jimei University.

Xiamen: Author

From Figure 3 and Table 4, we can see that the usual wave direction is east, the wave direction ESE takes the second place, and the respective frequency was 8.6% and 7.7%. The strong wave direction is ESE and the second place is NE.

(3) Ice conditions

Huanghua port is located in the North China Plain which is often affected by cold wave and thus resulted in the sea ice. The ice is formed in the early December, and thaw out in the late February, and the ice period is terminated in early March. This waters owns a total of 91 days ice age and the prevailing ice age is 58 days. The maximum width of coastal ice along the 0 meter isobath distribution is estimated about 7 km in 1984, and in 1985 was 4 km; the maximum distance from the edge of floe ice away from the shore in 1984 was 46 km, and in 1985 was 43 km; the maximum ice thickness in 1984 was 35cm, and in 1985 was 30cm; the maximum height of shore ice heap in 1984 was 4.2m, and in 1985 was 3.6m. The maximum thickness of floe ice is usually 0.2m in this waters and drifting velocity is 0.3 ~ 0.4m/s, the two main directions of the ice drifting is mainly concentrated on the West (WNW, W, WSW) and East (ENE, NE).

Since 2010, the waterways and the harbor of Huanghua port did not generate large scale ice, only some ice patch appeared and the ice concentration was significantly reduced compared to the Winter of 2009 which only owned the average thickness about 10 centimeters. Ice conditions near the periphery of Huanghua port was relatively complex and the thickness of floating ice reached 30 cm, but through a series of works such as icebreaking and escorting, ice did not have a substantial impact on the port operation. (Maritime College of Jimei University, 2013, p.25)

(4) Stream

i. The tidal stream of Huanghua port belongs to semidiurnal type, the oval rate of the stations outside -1 meter isobath is generally 0.2 to 0.5, they are all positive, the current velocity vectors of each station is rotated counterclockwise.

ii. In the duration of tide rise, the average current velocity is between 0.29 m/s and 0.42 m/s and the current direction is from 240 degrees to 300 degrees; and in the duration of fall, the average current velocity is between 0.25 m/s and 0.37 m/s and the current direction is from 046 degrees to 097 degrees. Furthermore, the largest current velocity in the duration of rise is between 0.50 m/s and 0.79 m/s with the current direction from 233 degrees to 282 degrees, the largest current velocity of fall is between 0.31 m/s and 0.53 m/s with the direction from 044 degrees to 092 degrees, and the velocity in the duration of rise is larger than the velocity in the duration of fall. From the analysis of the general plane distribution trend, the outboard current velocity is larger than the inboard current velocity. And the average duration of rise is 5 hours and 40 minutes and the fall is 6 hours and 30 minutes. (Maritime college of Jimei University, 2013, p.21)

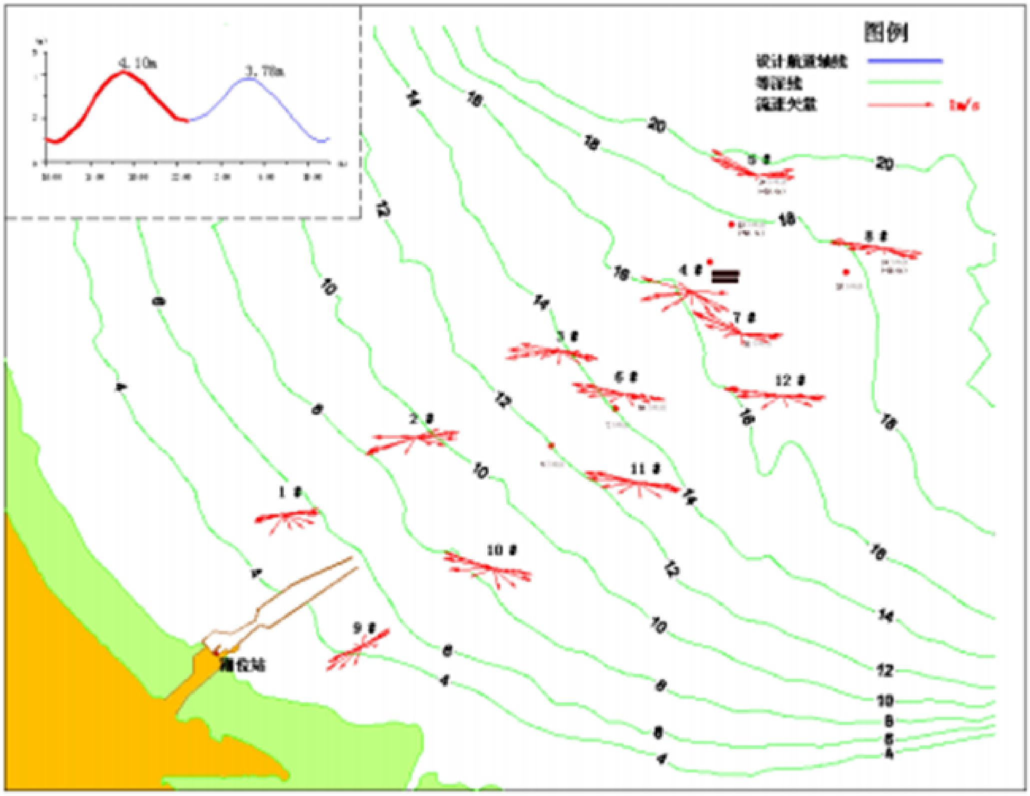


Figure 4: Tide sectors figure from 29th to 30th of August, 2007

Source: Safety demonstration report of affect on safety navigation.(2013). Maritime College of Jimei University. Xiamen: Author

Figure 4 shows the tide sectors from 29th to 30th of August, 2007.

iii. The residual tidal current in this waters is quite small, according to the statistical data from the observing stations its velocity is between 0.01 m/s and 0.09 m/s, the average residual tidal current velocity is 0.04 m/s, the direction is from north to south ashore, and the direction outward the -10 m isobath in the open-sea is from south to north.

2.2.3 Artificial Navigable Waterways

Currently, the Huanghua port 100,000 tons waterway has been completed which can satisfy the requirements for the tide sail of full load 100000 tons bulk carrier.

Table 5: Status table of Huanghua port 100000 tons waterway

Waterway's name	Axes direction	Distance (km)	Breadth(m)	Standard height of the bottom	Remark
100000 tons waterway of comprehensive dock area	059°.5-239°.5	44	210	-14.5	

Source: Safety demonstration report of affect on safety navigation. (2013). Maritime College of Jimei University. Xiamen: Author

From Table 5, we can see the overall length of the waterway is 44 kilometers, the valid breadth is 210 meters, and the designed depth is -14.5 meters, and the axes direction of the waterway is 059°.5-239°.5.

海 冰 预 报 示 意 图

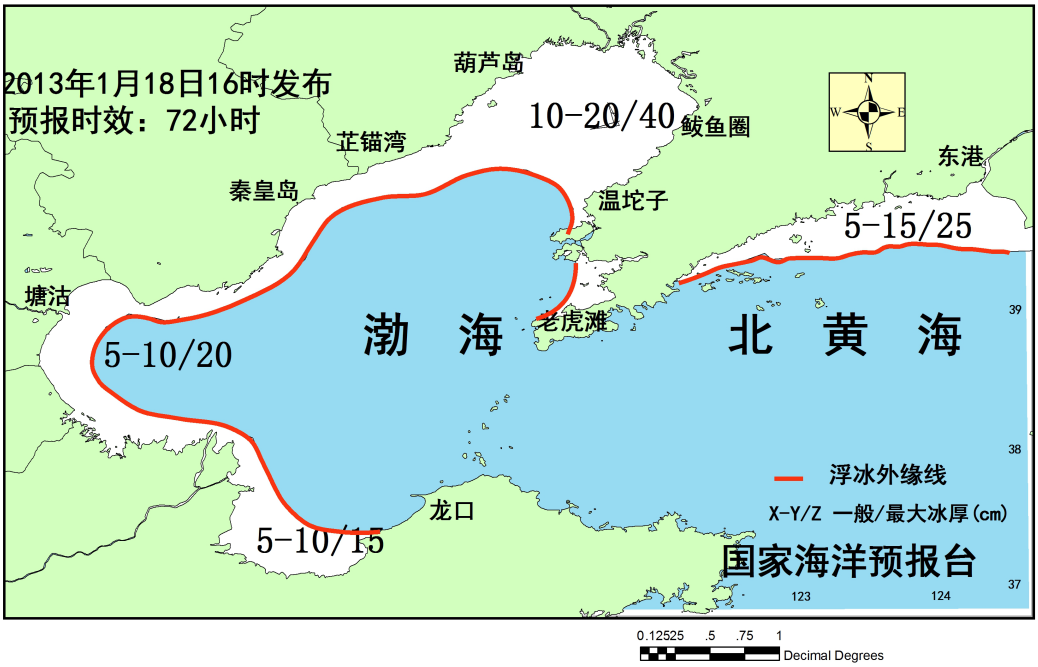


Figure 5: Schematic sea ice forecast (January 18th, 2013)

Source: Ice situation briefing (2013. Unpublished lecture handout, Cangzhou MSA, China.

Figure 5 is one of the schematic sea ice forecasts of Bo Sea from National Marine Forecast Station, and Cangshou MSA will transmit this to the relevant departments. Ships navigating in this area can consult this from the Web Site of Cangzhou MSA. Take the figures in the bottom of this picture for example, 5-10/15, 5 stands for the average ice thickness, that is, 5 centimeters, and 10/15 means the largest ice thickness can reach 10 to 15 centimeters. The red line shows the outer region of floe ice.

CHAPTER THREE

THE IMPACTS AND ANALYSIS ON SHIP SAFETY OF NAVIGATION CONDITIONS OF HUANGHUA WATERS IN WINTER

The waterway of Huanghua Port is the longest artificial waterway of China coastal ports and the full loaded ship shall import or export during the duration of rise, furthermore, the traffic density in this area is large coupled with the shallow depth and cold winds and other inclement weather often affect this area in winter. The main current in this waters is reciprocating current. Moreover, ice movement is caused by wind and streams, floating ice movement is mainly affected by the wind, As the wind direction changes, the movement of the ice will change. If there is a strong stream effect, ice may also remove against the direction of the wind. The movement direction of floating ice near Huanghua port is affected by the combined action of wind and stream. Meanwhile, the combined action of ice, wind and stream is a severe challenge to the navigation safety of the ships navigating in Huanghua waters in winter.

3.1 The Incidents that Happened in Recent Years

(1) On January 22nd, 2009, M/V “Da xxx” past the entrance of the breakwater of Huanghua port at 0058, speed reduced rapidly; 0103, M/V “Da xxx” was extruded by the ice, at that time the speed was only 1 knot and the steerage disappeared, after it took immediate emergency action to control the ship position, there was no effect and the ship was extruded by ice and drifted at a constant speed of 1.3 knot towards the direction of 291°which was exactly the same as the speed and direction of the

majority floating ice. After nearly two hours' assistance of three tugs, the ship was out of danger at 0356. During the period of assistance, the closest distance from board to the Zonghe Port breakwater was less than 300 m.

(2) On January 29th, 2009, speed of M/V "Peng xx" reduced to 2.4 knot when navigating between the buoys number 30 and number 28 in the coal port of Huanghua, at the same time, the ship was extruded out of the waterway towards the direction of East, escort tugs came to assist the ship near buoy number 28, and M/V "Peng xx" kept at full speed ahead with the pushing from the stern with tugs. At 0840, M/V "Peng xx" restored navigating at the original course.

(3) On February 3rd, 2009, M/V "Hua xx" was navigating near buoy number 32 in Huanghua coal port, and at 1349, the ship speed reduced to 3.5 knots, and the ship was extruded by large floating ice towards the South side of waterway, there was no effect with "Hard-port" and increase of the speed. 1355, the speed reduced to 0, after asking for help, and the ship then navigated with the assistance of three tugs, 1633, after the ship passed through the entrance of the waterway where there was less effect of floating ice, the ship got security clearance.(Hebei MSA, 2010)

(4) On January 2rd, 2013, M/V "An Sheng 16" was navigating near buoy number 235 on her way of arriving port, 2054, the ship was impact with the integrated force of northwest wind and ice floes which leaded the ship can not maintain the original course and yaw to the south of the waterway, the ship took immediate measurement of dropping anchor and navigating against the wind to hold the ship's position. Then, M/V "An Sheng 16" returned waterway and berthed with the icebreaking assistance of tugs.(Cangzhou MSA, 2013)

(5) On January 12th, 2013, 2250, M/V "Da Hongshan" was on her way of leaving port, when navigating near the buoy number 22 in the Huanghua coal port, influenced by the ice floes which caused the speed reduced heavily and could not move ahead any longer. With the assistance of two tugs, the M/V "Da Hongshan" gets out of the waterway for the other ships. 2340, M/V "Da Hongshan" sailed back to the waterway and made a normal clearance. (Cangzhou MSA, 2013)

3.2 Cause Analysis

3.2.1 Contrast of the Time, Location, Sea Conditions and Hydrological Factors among above Dangerous Cases

Table 6: Contrast between various factors of dangerous cases.

Ship Name	Time	Location	Sea Conditions	Hydrological Factors
Da xxx	Jan 22,2009, 0100	Buoy 30#--28#	Cloudy，wind 5-6(NW)，wave height 1.5m，visibility 8nm，temperature-8℃	2342/21-33 0000-35 0100-67 0200-131 0300-208 0400-279 0500-331 0600-349
Peng xx	Jan,29,2009, 0820	Buoy 30#--28#	Clear to overcast, wind 6(NW), wave height 1.8-2.4 m, visibility 8 nm,	0526-172 0600-175 0700-197 0800-235

			temperature-8℃	0900-275 1000-303 1055-312
Hua xx	Feb,03,2009, 1350	Buoy 32#--30#	Clear to overcast, wind 4-5(SW), wave height 1 m, visibility 8 nm, temperature-8℃	1103-156 1200-168 1300-205 1400-255 1500-298 1608-317
An Sheng 16	Jan,02,2013, 2054	Buoy 235#	Sunny,wind 4-5 (NW), temperature -9℃	2000-290 2100-244 2200-188 2300-137
Da Hongshan	Jan,12,2013 2250	Buoy 22#	Snow, Wind 3(NW), temperature -5℃	2200-35 2300-45 0000-48 0100-108

Source: Ice situation briefing(2013). Unpublished lecture handout, Cangzhou MSA, China.

3.2.2 Ship information

Table 7: Contrast of ship detail of dangerous cases

Ship's name	Length（m）	width(m)	Moulded depth(m)	Main engine output (Kw)	DWT	Construction date
Da xx	144.58	21.00	10.80	3824	14233	20070128
Peng x	184.10	31.00	15.60	7134	39924	19850621
Hua xx	176.00	27.00	15.23	5078	33800	19850228

AnSheng 16	98.00			1765	5000	20040919
Da Hongshan	135.10			2206	11450	20091120

Source: Ice situation briefing(2013). Unpublished lecture handout, Cangzhou MSA, China.

Through the analysis of relevant information showed in Tables 6 and 7, we can find some common things listed below:

1. The positions of these dangerous cases are concentrated in the waterway of the Huanghua port near the entrance of the waterway and it is the place for the ice accumulation easily.
2. The tide provided the conditions for the ice accumulation.
3. These ships are old-age ships or poor thrust power. （Li, 2011, pp.50-51)

3.3 Theorical Impact of Ship Ice Navigation in Winter

3.3.1 Ship Positioning

The damage of navigational aids will impact the navigation safety, especially the sea ice impacts the buoy heavily. At the beginning of glaciation, the ice will freeze the buoys together, combined with the movement of the drift ice, most buoys will drift under the action of the drift ice and lead to a situation of the buoy extruded by the ice which may be caused the breakdown of the chain of the buoy, or the buoy will be pressed beneath the ice and it will lose the function as a navigational aid which even can mislead the ship into running aground. Besides, the buoy which is pressed under the ice may eject suddenly when ship sailing nearby, this case will cause the collision between the ship and the buoy which can easily cause damage to ship's rudder and wheel. (Niu, 2002, pp.22-23)

3.3.2 Ship Speed

The resistance of ship navigating in ice floes is far higher than the resistance of ship navigating in water, so the speed of the ship will be greatly reduced when navigating in ice floes. If a ship navigates against wind and current in a large area of floating ice, it will suffer the enormous ice pressure and resistance which will cause the ship can not to move forward. For some special years of Huanghua port, some key navigation areas such as waterway, anchorage and harbor are affected by the abominable ice situation and the impact on the speed of ship will be further aggravated.

3.3.3 Course Stability

Ship navigating in large areas of ice, by pushing pressure and the collision of ship's side and thereby the ice will be broken or open, so as to move forwards. (Zhang, 1998, p.14) Course stability of a ship will be better due to the interaction of the ice on both sides of the ship, but it will lead to a phenomenon that it is difficult for the ship to alter its course. In detail and in other words, there will be no answer in small rudder angle, and it is difficult for a ship to return back and keep steady in large rudder angle, especially in the turning point of the channel or waterway, the turning operation will easily cause the grounding of the ship.(Li, 2012) Under various effect of natural environment, the ice will be broken up or the ice will be frozen together and form a compressed accumulation of sludge which will make the ship turn to the thin ice direction and just like the dangerous case of M/V "An Sheng 16" showed above. These impacts will be more obvious for small-shaped ships and shallow draft ships, once the ship appears in a similar situation, the ship will be deviated from the channel or waterway and grounding without adequate attention.

3.3.4 Safety of Anchored Ship

Ice has serious impacts on the ships in anchorage, such as dredging anchor and anchor chain broken. Due to the frozen ice, some anchorage will be unavailable.

3.3.5 Berthing Safety

When the ship maneuvers in harbor, the ice in harbor basin breaks up, and these ices will accumulate between the ship and the dock gradually making it difficult for the ship to successfully berth and also destroy the ship auxiliary facilities such as fender and jetty pier. When a ship encounters such a situation, the ship should ask the tug's assistance to tow out of the berth and re-berth after the ice between the ship and the dock is cleared up. (Pascoal,R. &Huang, S. 2006, pp.1644-1668)

3.3.6 Navigational Environment of the Waterway

Ice will cause the inward and outward ship to navigate at a low speed in the waterway. Some parts of the channel will be seaworthy after icebreaking, and some of the branch waterway will suspend because the heavy ice is frozen. In this case, it is difficult for low-speed ships to navigate without the assistance of ice-breakers or tugs, and it is dangerous for ships of weak construction.

3.3.7 Influence on the Avoiding Collision and Turning of the Ship in Ice Channel

When the ship navigates in ice situation, due to the influence of the ice resistance acting on the ship, on one hand, the stroke will be less than normal, and the speed will reduce quickly so that the ship can stop in a short period; on the other hand, the ice has a greater impact on the performance of the ship's turning, and the radius of turning cycle will increase obviously. Under these circumstances, the ship will almost be motionless even with a full angle rudder companied with the action of wheel, it is inconvenient for the ship to steer and turn.

So, in the navigational practice, especially navigating in ice situation, the ship officers should be fully aware of the effect of ice on the ship's manoeuvrability, and take relevant measures as soon as possible.

CHAPTER FOUR

SAFETY RESEARCH ON SHIPS NAVIGATING IN ICE SITUATION OF HUANGHUA PORT IN WINTER

When a ship is navigating in ice, under the influence of various factors, especially under the promise of the existed differences between ships and the meteorological factors, the ship's stress analysis is complicated. So, in the chapter, the author only introduces the estimation method of impact of the ice, wind and current acting on the ship, and then gives the safety recommendations to the ship inward or outward Huanghua port in winter, and the method for how to evaluate whether the ship can avoid ice-jam safely when navigating in ice.

4.1 Stress Analysis of Ship Navigating in Ice

4.1.1 Stress Diagram of Ship Navigating in Ice

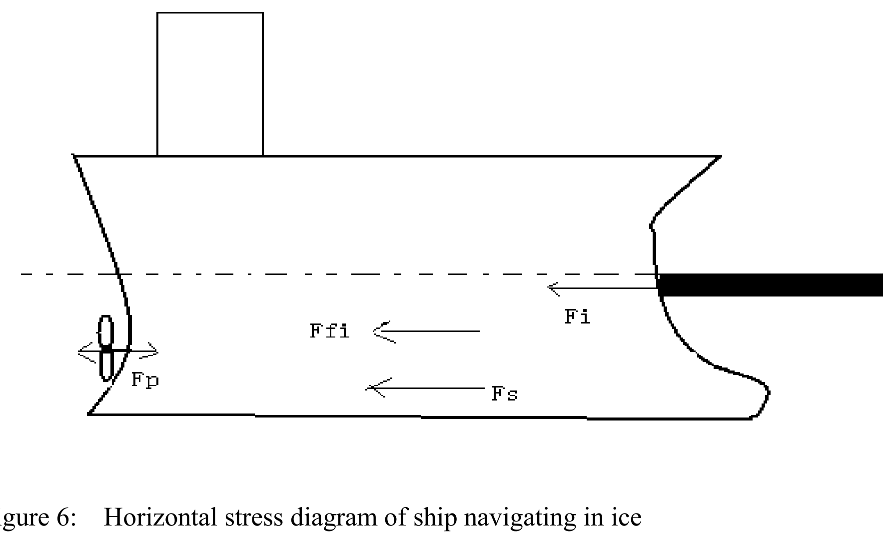


Figure 6: Horizontal stress diagram of ship navigating in ice

Source: Compiled by the author

Figure 6 shows the different stresses acted on the ship when navigating in ice, the meaning for each abbreviation has a detailed explanation in Formula 1.

4.1.2 The Expressions for the Stress Acted on Ship when Navigating in Ice

According to the Figure 6, the horizontal stress along longitudinal direction (F) when the ship navigating in ice can be expressed like this:

$$F = F_s + F_i + F_{fi} - F_p \qquad \text{(Formula 1)}$$

In Formula 1,

Fs — The sum of the water flow friction resistance, wave resistance, eddy current resistance and aerodynamic resistance and the additional resistance under the influence of wind and current;

F_i — Horizontal resistance of ice acting on ship;

F_{fi} — Friction between the ship hull and ice, snow;

F_p — Thrust of propeller

The horizontal force along longitudinal direction when ships reverse in ice can be represented like this:

$$F = F_s + F_{fi} - F_p' \qquad \text{(Formula 2)}$$

F_p' stands for the pull force when ships reverse. (Li, 2011, p.21)

4.1.3 Estimated Formula of Ice Resistance

I. **The Ranicki Formula**

$$F = T \bullet \frac{\cos\alpha \ \cos\beta - f_k \ \sin\alpha}{\sin a \ \cos\beta + f_k \ \cos\alpha} \qquad \text{(Formula 3)((Xiao.\& He, 2001, pp.7-9)}$$

In Formula 3,

T — Propulsive force of ship

α — Ship's heading

β — Boardside direction of ship's bow

f_k — Coefficient of Kinetic friction between hull and ice, here f_k=0.15

F — Downward force acting on the ice

$h = C\ F^{0.5}\ B^{-0.25}$ (Formula 4) (Xiao.& He, 2001, pp.7-9)

In Formula 4,

h —Ice thickness

C—coefficient, C=0.18

B— ship's breadth

II. **Lavice and Edward Formula**

In 1970, Lavice and Edward derived the icebreaking resistance formula (formula 3) of icebreaker according to the experimental results of ship models and real ships.

$R_{im} = c_0\ \sigma\ h^2 + c_1\ \rho_i\ g\ B\ h^3 + c_2\ \rho_i\ B\ h\ v^2$ (Formula 5)(Xiao& He, 2001, pp.7-9)

In Formula 5, the explanations of the symbolic are listed below:

R_{im}—Icebreaking resistance

h — Ice thickness

σ — Ice bending strength

ρ_i — Ice density

g — Acceleration of gravity

v — Ship's speed

B — Ship's breadth

C_0, C1, C_2 — Coefficient determined by experiments

Two different sets of coefficients are obtained by regression analysis based on the experimental data of ship models and real ships, and Formula 5 can be expressed like this:

$$R_{im} = 3.03\sigma\ h^2 + 73.04\rho_i\ B\ h^3 + 59.0\rho_i\ B\ h\ v^2 \qquad \text{(Formula 6)}$$

$$R_{im} = 1.46\sigma\ h^2 + 88.4\rho_i\ B\ h^3 + 59.05\rho_i\ B\ h\ v^2 \qquad \text{(Formula 7)}$$

(Xiao.& He,2001,pp.7-9)

III. Lewis Formula

$$R_i = \rho_w\ g\ B\ h^2\ (51.4 + 76.3F_n) \qquad \text{(Formula 8)}$$

And $Fn = v / \sqrt{gh}$ (Formula 9) (Xiao & He, 2001, pp.7-9)

In Formula 8 & 9,

R_i — Resistance of icebreaking

ρ_w — Water density

g — Acceleration of gravity

h — Ice thickness

B — Ship's breadth

F_n — Coefficient of ice thickness

IV. Edwards Formula

$$R_i = \rho_w\ g\ B\ h^2 \left\{ 64.6 + 2.37\ F_n \left[\frac{L}{h} / \sqrt{\frac{B}{h}} \right] \right\} \qquad \text{(Formula 10)}$$

And $Fn = v / \sqrt{gh}$ (Formula 11) (Xiao & He, 2001, pp.7-9)

In the formula 10 & 11,

R_i — Resistance of icebreaking

ρ_w — Water density

g — Acceleration of gravity

h — Ice thickness

B — Ship's breadth

Fn — Coefficient of ice thickness

L — Length of ship

According to the Edwards formula and improved Lewis formula, we can get the icebreaking resistance is associated with of the product of the square of the ice thickness h and the ship breadth B. In other words, $R_i \propto B\ h^2$. And according to the estimated result by Xiao Bo in his thesis which proves the Edwards formula owns the closest calculation result to the real ship, so Edwards formula is used in this dissertation for quantitative comparison. (Xiao & He, 2001, pp.7-9)

Here we quote a multi-purpose workboat to evaluate its effective thrust and ice resistance for quantitative evaluation. Details of multi-purpose workboat quoted by this dissertation are as follows:

1. Length between perpendiculars: 62 m;
2. Molded breadth: 13.6 m;
3. Draft: 3.7 m;
4. Version of Main engine and set number: MAK9M20×2;
5. Rated output power of Main engine: 1700 KW;
6. Rated speed of rotation: 1000 round/minute;
7. Shaft transmission efficiency: 0.97;
8. Diameter of propeller: 2.17 m;

According to the relevant data and calculation, the effective thrust of this ship is:

Table 8: The effective thrust of ship in different speed

Speed	1	2	3	4	5	6

（kn）						
Effective thrust（KN）	425.9	406.3	386.1	368.4	351.3	332.3

Source: Xiao, B.& He, Y.P.(2001). Icebreaker ice-breaking ability estimation method . Jiangsu ship 2001,18(3). Zhenjiang: Author.

Table 9: Calculation data of ice resistance by Edwards formula

Ice thickness（mm）		400	420	440	460	480	500	520	540
Speed（kn）	1	185.38	202.03	219.38	237.43	256.19	275.65	295.81	319.01
	2	230.19	249.08	268.67	288.96	309.96	331.66	354.06	381.82
	3	275.00	296.12	317.96	340.49	363.73	387.67	412.32	444.64
	4	319.80	343.17	367.25	392.02	417.50	443.68	470.57	507.46
	5	364.61	390.22	416.54	443.55	471.27	499.69	528.82	570.28

Source:Xiao, B.& He, Y.P.(2001). Icebreaker ice-breaking ability estimation method . Jiangsu ship 2001,18(3). Zhenjiang: Author.

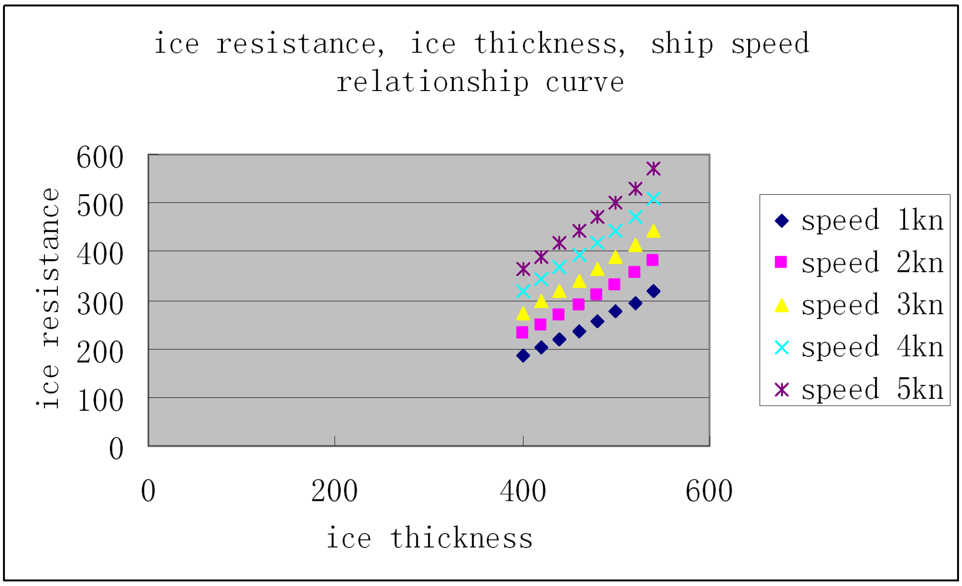


Figure 7: The curve of the relationship between ice thickness, speed and ice resistance (by the calculation of Edwards formula).

Source: compiled by the author.

Figure 7 represents the different ice resistance for the established multi-purpose workboat with the details showed above with the different speed from 1 knot to 5 knots when navigating in different ice thickness from 400 mm to 540 mm.

And combined with additional calculation, we can get the findings below:

1. When ship's speed is constant, the ice resistance of ship will increase with the increase of the ice thickness, for the ice thickness increases 10 mm, the proportion of ice resistance increases 6.1% to 8.6% correspondingly.

2. When the ice thickness is fixed, the ice resistance of ship will increase with the increase of the speed, for the speed increase 1 knot, the proportion of the resistance increases 12.6% to 24.1% correspondingly.

4.1.4 Thrust and Pull of Ship Propeller

The thrust of ship (F_p) can be expressed like this:

$$F_p = (1-t)\ \rho \bullet D_p^4 \bullet n^2 \bullet K^T \qquad \text{(Formula 12)}$$

In this formula, ρ is the water density, D_p stands for diameter of ship propeller, n is the resolution of propeller, and t stands for propeller thrust deduction coefficient, KT is the abbreviation of propeller thrust coefficient.

Considering the complex application of Formula 12 for mariners, and the ship is operating at a low speed when navigating in ice, the thrust can be approximately calculated by the corresponding bollard thrust of outputs sent by the main engine. Generally, for ordinary propeller, each 100 Kw produces 1.35~1.55 KN; for catheter variable pitch propeller produces 1.70~2.00 KN per 100 Kw. Due to the design of the propeller, the pull is about 45 percent to 60 percent of the thrust. Furthermore, in order to protect the main engine, when a ship is navigating in ice or icebreaking, it often uses 95% of the main engine rated power, but it use the full rated power when reverse.(Li, 2011, p.22)

4.2 Analysis and Calculation Method of Ships under the Influence of Wind Pressure Stress

4.2.1 Wind Force and Wind Pressure

Wind force is the level used to indicate the impact of the wind acting on the ground or sea. Currently, the international industry uses Beaufort scale which owns 13 grades from Beaufort No. 0 to No. 12 to indicate the wind force.

Wind pressure refers to the vertical pressure on the unit area and it can be expressed approximately like this： $q=\frac{1}{2}\rho_a V_a^2$.   (Formula 13)

In Formula 13, q stands for the wind pressure, ρ_a stands for the air density, and here we adopt 1.226 kg/m^3, v_a stands for relative wind speed. China ship standardization technical committee has promulgated the guideline for the calculation of wind pressure early in 1980, and the accurate calculation method can consult the guideline "CB/Z 301-80".

4.2.2 Wind Pressure and Wind Pressure Moment

The sum of the wind pressure acting on the areas above the ship's waterline is called the wind pressure force, and wind pressure force changes the ship's dynamics state and thus changes the motion state of the ship. (China Maritime Service Center, 2008, p.49)

Calculation method of wind pressure is proposed as early as 1930 by Hughes, and the expression is $F_a = q\, C_a\, (A_T \cos^2\theta + A_L \sin^2\theta)$ (Formula 14) (Yang, 1985, pp.71-72)

In Formula 14,

F_a —Wind pressure

q — Intensity of wind pressure

C_a —coefficient of wind pressure

A_T — Frontage projected area above the ship's waterline

A_L — Side projected area above the ship's waterline

θ — Relative wind bearing

From the above expression, we can see that the size of the wind pressure acting on ship is influenced by the wind speed, windage area, relative wind bearing，coefficient of the wind pressure or ship’s type and so on. The quicker the wind speed, the bigger the wind pressure is. Under the conditions of fixed wind speed, the larger of the windage area, the greater of the wind pressure is. For example, the windage area of a full-load ship is larger than a ship in ballast, or the windage area of a container ship is larger than an oil tanker or a bulk carrier, and thus the former one has the greater wind pressure than the latter one.

Wind pressure can be decomposed into the longitudinal component X_a and transverse Y_a in the ship’s maneuvering motion equations, and the expressions are like these:

$X_a = F_a \cdot \cos\alpha = q \cdot A_T \cdot C_{aX}$ (Formula 15)

$Y_a = F_a \ \sin\alpha = q \ A_L \ C_{aY}$ (Formula 16)

$F_a = \sqrt{X_a^{\ 2} + Y_a^{\ 2}}$ (Formula 17)

In Formula 15, 16 and 17,

X_a — Longitudinal component of the wind pressure

Y_a — Transverse component of the wind pressure

C_{ax} — Coefficient of longitudinal wind pressure

C_{aY} — Coefficient of transverse wind pressure

α — Leeway angle

Formula 15,16 and 17 are the another expression of wind pressure which owns the significant mechanical meaning of which composed two aspects, on one hand, the longitudinal component of wind pressure is essentially the change of the ship’s resistance caused by the wind, also known as wind resistance, and it changes the longitudinal motion state of the ship; on the other hand, the transverse component changes the transverse stress state of ship, and thus the transverse motion state of ship has changed. (Meng, 1999, p.36)

Factors affecting the size of the leeway are many and complex and they are mainly related to the following factors, such as draft, ship's shape under water, ship's windage area and ship type. When a ship navigates at a certain speed in still water and suffers the effects of wind, after the wind pressure acts on the ship for a certain time, the ship motion state over the ground will change, thus, the ship speed will change, which has not only changed the longitudinal velocity, but also changed the transverse velocity. Apparently, under the effect of the longitudinal component of the wind pressure, the ship speed may be changed. Under the circumstance of the constant main engine output, wind acts on the forward of the ship abeam will lead to the increase of the resistance and the reduction of the speed; wind acts on the aft of the ship abeam will lead to the decrease of the resistance and increase of the speed; and there is no effect on ship resistance when the wind acts on ship abeam.

4.3 Current

The current of Huanghua waters belongs to the regular semidiurnal tide, current of the inner waters of the Entrance still belongs to weak current, with the inward part of the port, current velocity decreases gradually. The current speed is between 0.5 m/s and 0.6 m/s when the tide rises and falls rapidly near the Entrance waters and decreases to about 0.3 m/s near the reclaimed land the speed in the harbor being reduced to below 0.1 m/s.

A ship keeps a movement at a certain speed in a uniform flow and the ship movement speed in the fixed coordinate system is the resultant vector of the current vector and velocity vector.

When a ship is navigating under the effect of the current, the ship not only sails along the true course at a certain speed, but also drifts to the downstream under the action of the current, at this time, the drift direction is the same as the current direction, and the drift velocity is equal to the current velocity. (China Maritime Service Center, 2008, p.50)

4.3.1 Drift Angle and its Influence Factors

Drift angle refers to the deviation between the current track and the true course, and is the deviation between the movement direction of the ship in the current and the line of aft and stern. Drift angle is an important indicator of the influence of the current acting on the movement of the ship. We divide the ship speed into two components along the longitudinal and transverse direction, and

$V_x = V + V_c \cos(\varphi_c - \varphi)$ (Formula 18)

$V_y = V_c \sin(\varphi_c - \varphi)$ (Formula 19)

$\theta_c = \varphi_c - \varphi$ (Formula 20)

In Formula 18, 19 and 20,

Vx— Longitudinal component of the ship'speed

Vy — Transverse component of the ship's speed

V — Ship speed

Vc — Current speed

θc — The deviation between ship heading and current direction θ — drift angle

θ_c is the deviation between the current direction and the ship heading, or named relative current bearing, and drift angle can be expressed as

$$\varphi = \arctan(\frac{v_c \sin\theta_c}{v + v_c \cos\theta_c}) \qquad \text{(Formula 21)}$$

Formula 21 expresses the relationship among ship speed (v), drift angle (φ), and current speed (v_c) and the deviation between ship heading and current direction,(θ_c).

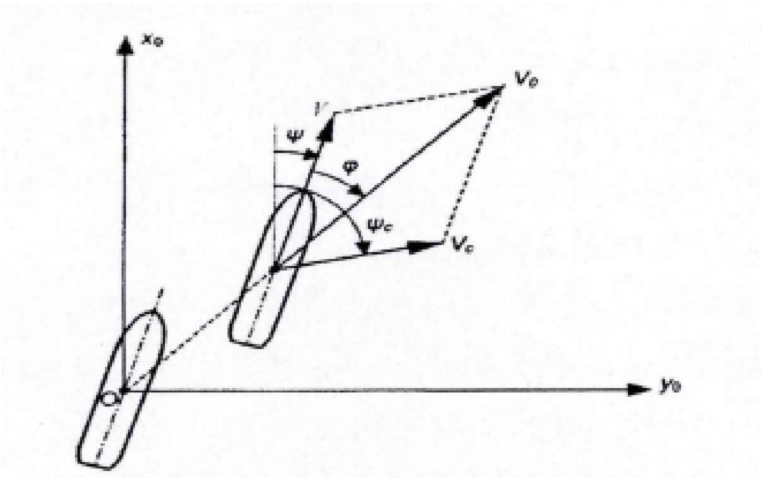


Figure 8: The influence of the ship movement under stream

Source: Meng, X.W. Ship Manoeuvrability: The effect of a Current.1999.Dalian Maritime University Press. Dalian:Author.

It is visible from Formula 21 andFigure 8, the drift angle is affected by ship speed, current speed and relative current bearing and so on. Under the circumstance of the fixed current speed, when the relative current bearing is 0°, namely against current and fair current, and in this situation the current only affects the ship speed, when against the current, $V_0 = V - V_c$, and when fair current, $V_0 = V + V_c$.

When the current direction is vertical to the direction of ship movement, namely cross-current, in this case, the influence of current depends on the speed, the higher the ship speed, the smaller the drift angle，and the smaller the drift speed; in contrast, the larger the drift angle is. When the ship speed is zero, and the drift angle is 90°, ships will drift at the current speed transversely.

When the current direction is in the section between 0° and 90° or 90° and 180°, the influence of current depends on the current speed and ship speed. In general, the higher of the ship speed, the smaller of the drift angle is； other wise，the higher the current speed, the greater of the drift angle is.

Current effect is one of the causes of ship grounding and collision accidents due to large drift which is caused by encountering a rush current while ships navigate at a relevant low speed. Furthermore, it is caused by the close distance between the ship and the navigational obstacles or other anchoring ships when navigating at a low speed. In open waters, we can reduce the current impact on ships by increasing the speed or changing course, but the ship encounters a rush cross current in a limited breadth channel, thus the only solution to lower the drift angle is to increase the ship speed. (Zhang, 2008)

Just like the incidents described in Chapter Two, there is a relevant rush current near the entrance of Huanghua port plus the decline of the speed caused by the ice in winter. Consequently, many ships dropped into such dangerous situation.

4.3.2 Calculation Method of the Current Pressure Force of Ship Suffered

The current pressure acting on the ship is mainly generated from the friction between the ship hull and water flow, the relationship between them can be expressed like this:(Yang, 1985, pp.71-72)

$R_w = K\ S\ V^{1.83}$,   (Formula 23)

and S is the size of water surface

And it can be calculated by the below expression

$$S = \nabla^{2/3}(3.432 + 0.305\frac{L_w}{B} + 0.443\frac{B}{d} + 0.643C_b)$$ (Formula 24)

In Formula 24,

∇ —volume of displacement

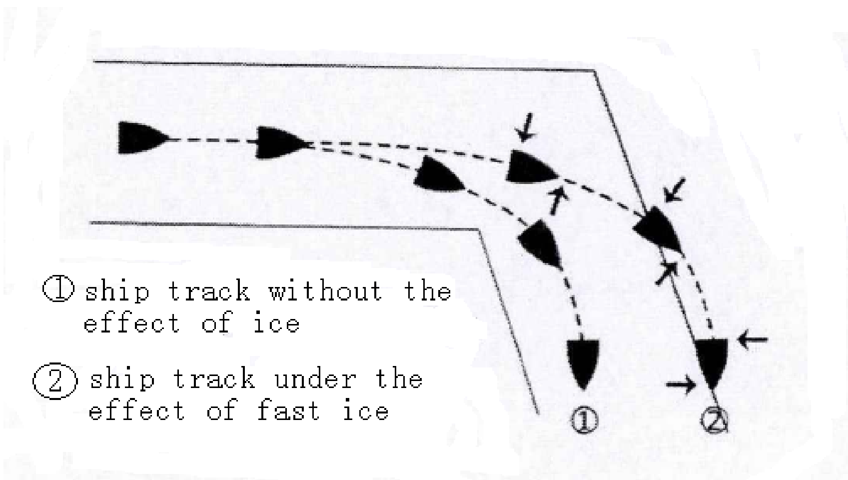
L_w —length of waterline

B —ship breadth

d —draft

C_b —block coefficient

4.3.3 The Change of Ship Track under the Effect of Floe Ice



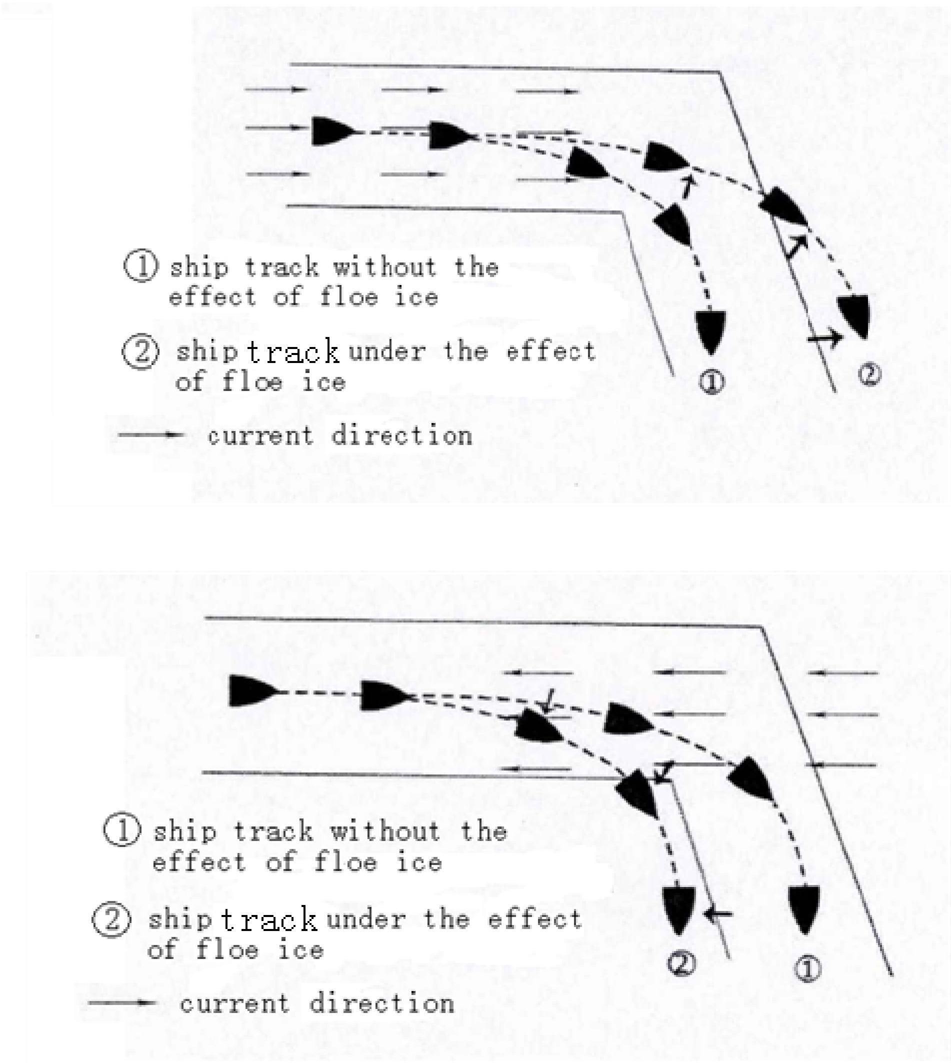


Figure 9: Ship track under and without the effect of floe ice

Source: Li,C.Y.(2012).Navigation safety analysis on Bo Sea ice region in winter. Unpublished master's thesis, Dalian Maritime University, Dalian, China.

Figure 9 represents that different current direction in floe ice condition will lead to different ship track in three different situations which can help the ship officers to determine the turning occasion for safe navigation. So, when the ship is navigating in the artificial waterway of Huanghua port, under the circumstance of the ice floes being frozen together and forming a large ice sheet, the impact of sum of the transverse sectors of the ice, wind and current will be more obvious than the impact of the tidal stream. If there is a large ice sheet at the turning point in the waterway, it is better for the ship to ask the escort by tugs to drive ice off in advance or the ship will be in the danger of stranding out of the waterway.

4.4 Methods to Measure Whether the Ship can Avoid being Jammed by Ice

4.4.1 Estimates of the Level Ice Resistance

According to the theorem of kinetic energy, we can get the equation below:

$$\int_0^s F \bullet d_s = \frac{1}{2} m v_0^2$$

(Formula 25)(Li, 2011, p.23)

In this formula, s stands for the distance of ship icebreaking, *m* is the abbreviation the Mass of ship, and V_0 is the Initial velocity when ship breaking the ice.

Assuming ships break the ice with strike at a low speed with the main engine stop before the ship stops, at this time, the thrust of propeller F_p=0, and the total resistance of ship navigating in fresh water is far less than horizontal resistance of ice acting on ship (F_i) and friction between the ship and ice, snow (F_{fi}), the main resistance acting on ship is the ice resistance and ice friction force which is the same as the ice resistance showed above in the Edwards Formula, so, Formula 25 can be expressed like this:

$$F_i \approx \frac{1}{2} m v_0^2 / S$$

(Formula 26)

4.4.2 Measures for Evaluation

In order to avoid excessive impact force with ice and damage the hull, the ship usually navigates at a certain speed, generally less than 9 knots, and breaks the ice by the propulsion of main engine.

Formula 25 can be also expressed like this:

$$\int_0^s (F_s + F_i + F_{fi} - F_p)ds = \frac{1}{2}mv_0^2 \qquad \text{(Formula 27)}$$

And in this formula, *Fs* is far more less than F_i and F_{fi}, and F_i and be calculated by Edwards Formula, F_p can be calculated by bollard thrust, F_{fi} increase as the increase of the depth of icebreaking, when ship reverses, the *Fp*' should overcome the friction between the ship hull and ice, it can be expressed like this $F_{fi}<F_p$, and take the relationship equation in to Formula 25, we can get the inequation below:

$$\int_0^s (F_i + F_p^{'} - F_p)ds > \frac{1}{2}mv_0^2, \qquad \text{(Formula 28)}$$

And thus if only $S > \dfrac{mv_0^2}{2(F_i + F_p^{'} - F_p)}$, (Formula 29)

And here is the time when the icebreaking distance by strike is larger than the right-style of the inequation, the ship can be safely reverse out of the ice and avoid being jammed by it. (Li, 2011, p.23)

CHAPTER FIVE

RECOMMENDATIONS FOR SHIPS NAVIGATING IN HUANGHUA ICE IN WINTER

Due to the special geographical position and port layout of Huanghua port, combined with the impact of ice, wind and current in winter, a ship navigating in Huanghua waters in winter should do the appropriate preparation in advance and keep careful driving, otherwise, the dangerous case may occur: Firstly, ships especially for aged ships may suffer the damage on the local structure; secondly, with occurrence of the large areas ice, ice aggregation and the increase of the ice thickness and thus the speed of ship will decrease or become zero for the increase of the ship resistance which is caused by the various external factors, furthermore, the wheel and rudder may be hurt due to improper operation; thirdly, ice is not easy to reflect the radar echo, and it also has the influence on the navigational aids, all of these will impact the safety of navigation; fourthly, ice makes the change of ship stability, and it will lead to the low work efficiency of the ship's appliances and equipments in bad weather, especially for the mooring appliances on the deck will be affected.

This chapter will give the recommendations from the following aspects.

5.1 Preparation before Entering into Huanghua Port

The more preparation work before ice navigation, the safer of the ship navigating in ice is. The crew should do the following preparatory works:

1. Collecting as much as the development trend and ice altas with the help of

shore-based support, meanwhile, pay attention to receive the ice bulletin, ice prediction can be collected through the VTS center, the ship nearby, and the meteorological ice warning;

2. Adjust the ship draft reasonably. Draft adjustment is particularly important for the safety of ship propeller and rudder when navigating in ice. For the empty load ship, propeller should be immersed in water by ballast adjustment to prevent the propeller damage by ice; for full load ship, the ship should be adjusted to the condition of trim by the stern on the promise of that there is not restricted on the draft. Besides, if the ship don't have the ice class certificate, the draft should be adjusted to 1 meter above the light load waterline or 0.5 meter below the full load waterline because here is generally the strengthen region;
3. Voyage planning. After receiving the notice of entering into port, the master should be familiar with the route of entering Huanghua port, including the limited conditions of the narrow channel, weather conditions, positioning device and hydrological conditions and keep in contact with VTS Center;
4. Ship should also be in good antifreeze condition before entering into ice, and make sure the watertight appliances are in good conditions, and do the deck antifreeze works in advance because precipitation and shipping seas on deck will cause the deck icing, furthermore, the pipes of sea water cooling system should be checked.

5. Light and partly loaded ships should be ballasted as deeply as possible, but excessive trim by stern is not recommended, as it cuts down manouverability and increases the possibility of ice damage to a more vulnerable lower area of the exposed bow.

Minister of Fisheries and Oceans Canada (Ice Navigation in Canadian Waters, 2012, p.94)

6. Experience has shown that non-ice-strengthen ships with an open water speed of about 12 knots can become hopelessly beset in heavy concentrations of relatively light ice conditions; whereas ice strengthened ships with adequate power should be able to make process through first year ice of 6/10 to 7/10 concentrations.

Minister of Fisheries and Oceans Canada (Ice Navigation in Canadian Waters, 2012, p.97)

5.2 Anchoring Operation

The ship anchored in the anchorage of Huanghua port should pay attention to the following points:

1. The anchorage should choose the place that has small volume of ice so that the main engine and windlass can operate at any time;
2. Do not payout too long chain. Generally, the chain length is should be no more than two times of water depth. Various situations should be taken into consideration to make sure the anchor can be raised quickly in the circumstance of dredging,
3. To prevent the ship from being frozen together with ice time to time, the best way is to keep a certain frequency ship-moving or adjustment of ship's ballast water so that the ship hull can move in ice;
4. To enhance watchkeeping and fixing frequently, the duty officer should keep a sharp lookout on VHF and pay attention to the dynamics of ship around in anchorage.

5.3 Mooring Operation

The current condition of Huanghua port has been introduced in Chapter Two.

When the ship do mooring operation in harbor, there may exist the phenomenon of the ice sandwiched between hull and dock which makes the ship can not be alongside the wharf. So, the ship should pay attention to the following operations:

1. Before berthing, the ship should contact the port authority to arrange tugs to break the ice on the berth to prevent its influence on berthing;
2. When berthing, the horizontal distance between ship and dock should be as small as possible, the ship should arrange the head line ashore first, and extrude the ice between the ship and dock with rudder and then berths;
3. If there is not enough room at the bottom of the berth and there has a lot of ice between the ship and the dock, the ship should gather the ice to a certain amount and then use tugs to break ice combined with the strong stream blowing the ice out. This operation can be repeated until the berthing can be carried out smoothly;
4. If there has enough room at the bottom of the berth, the ship can let the ship head towards the top of the berth, and drop anchor with the distance of 50 meters away from the dock, slack away the anchor chain to control the ship bow and then make fast of the head line and stem abeam line to extrude the ice by the blowing stream and combined with tugs to hold the ship stern. This operation can also be repeated several times until the ice is blowing out and all the lines are made fast ashore.

5.4 Security Work related to the Cangzhou Maritime Safety Administration

At present, Cangzhou MSA has adopted a series of measures to ensure the safety navigation in ice, for example, Cangzhou VTS promulgates ice situation briefing every week which is available for relevant departments and ships, it contains current situation and analysis of ice, ice forecast, ice impacts on navigation, operations and navigational aids, and some of the current situations on anti-ice, some knowledge of sea ice. Furthermore, the MSA should also enhance the following aspects:

1. Strengthen the inspection of key waters to detect the change of the ice condition timely. For the ice which can affect the safety navigation should be reported to relevant authorities timely, and the MSA should inform the relevant department to break the ice;(Wu, 2010, pp.62-63)
2. Keep a frequent inspection of navigational aids, inform the navigational aids department to repair the failures to ensure that they can work promptly when the ice condition is severe, for some special failures, if it can not restore them to its state, the MSA should take proper measures to ensure the navigation safety;
3. To supervise and urge the vessels to enhance watch-keeping and receive the ice bulletin, ice warning and the change of navigational facilities to make the ship does good ice prevention;
4. Strictly limit the small vessels and the old vessels transporting dangerous cargoes to enter the severe ice covered ports freely. The MSA should hold the principle of centralized formations for the ship entering and outing the port to ensure the safe and smooth order of port;
5. Make full use of VTS, AIS and CCTV and other advanced technologies to provide service for the ships entering into the severe ice covered waters;
6. Carry out emergency drills to increase the response capabilities of anti-frozen at sea and rescue and salvage comprehensively.

CHAPTER SIX

CONCLUSION AND PROSPECT

6.1 Conclusion

This paper mainly introduces the navigation conditions of Huanghua waters and some of the dangerous cases to raise the attention on the ice navigation in this waters. The core part of this dissertation is to introduce the force analyses of the ship navigating in ice combined with the calculation methods of ice resistance, wind pressure and current pressure, and give the reference for the ship to judge whether it can avoid ice-jam by itself, and at last recommendations is given for safe navigation in ice and for Cangzhou MSA. The main points of this dissertation are summarized as follows:

1. From the formula of ice resistance, we get the relationship among the ice resistance, ice thickness and ship speed, that is, the ice resistance is proportional to the product of ship speed and the square of ice thickness;
2. In the promise of the hull allows, this dissertation gives the calculation method to judge whether the ship can avoid ice-jam without the aid of outside help;
3. The ship needs to strengthen the good seamanship of ice navigation, if there is any doubt on the safety of ice navigation after approximate calculation, the master should not hesitate to seek escort.

6.2 Prospect

Currently, the research of China on ship navigating in ice stays at the safety recommendation measures. It is more helpful for a program to be designed according to the stress analysis and calculation of ship in ice combined with the actual outer factors such as ice, wind and current which the ship's officers can input the relevant data and then the direct overall stress analysis of ship's situation can be drawn out.

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