Research on key problems of Arctic navigation safety

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Abstract: Arctic shipping can bring significantly potential business profit, which has become a focal point at present. However, compared to the enormous risk, related research on the safety and security issues are not sufficient. In the essay, the natural factors, such as weather, ice are summarized, and the facility insufficiency and human factors aroused by low temperature and severe ice conditions are analyzed. Besides that, the requirement of international conventions has already proposed the basic technical demand for the ship facilities and lifeboat in Arctic area. In the end, the suggestions for safety and security, providing better equipment and facilities, enhancing crew competence, decent preparations before navigation are proposed.

1. Introduction
As the globe grows warmer, the Arctic sees a rising temperature, with the sea ice around melting away at an increasing rate. Statistics show that the ice layer in the Arctic has shrunk by 20% in these years, and the coverage of sea ice tapered off year by year. Against this backdrop, the Arctic navigation routes draw wide attention from major economies around the globe. The Arctic shipping routes refer to the passages that run through the Arctic Ocean and connect the Atlantic and the Pacific. Currently, there are two major routes — the Northeast Passage (NEP) that runs along the upper coastlines of Russia, and the Northwest Passage (NWP) that goes through the Canadian archipelago. Thanks to these two routes, vessels going between the Pacific and the Atlantic no longer need to detour to the Panama Canal and the Suez Canal, which used to be the only channels connecting these two oceans. Thus, as shortcuts, these two routes have reduced the voyage miles, cut the cost of transportation and allowed the vessels to steer clear of threats of pirates in Somali and the Indian Ocean. Navigation around the Arctic, however, are faced with safety challenges because of the harsh natural conditions along the two passages — floating ices, icebergs and freezing at a low temperature. As the Arctic shipping routes take an increasingly important position in transoceanic transportation, there will be more vessels sailing along these routes, and so will the likelihood for marine accidents. Moreover, insufficient infrastructure and shortage of manpower for emergency aids in the Arctic often lead these accidents spiralling into disasters, adding to the safety threats for vessels navigating in this area.

2. Main Problems

2.1. Natural factors
The Arctic is subject to some major weather systems, including polar fronts, Arctic fronts, Arctic cyclones, Arctic anticyclones (polar high), polar vortexes and polar low pressure. Most of these systems occur in the winter half-year (October to March), while the summer half-year is dominated Arctic cyclones, which are quite different from and much weaker than those in winter. In July and...
August, aside from one or two cyclones from the North Atlantic Ocean, most cyclones that drift to the Arctic hail from the mid-latitude regions of Siberia and Canada. In some years, there were up to six cyclones in the Chukchi Sea, and four to five in the East Siberian Sea in July. Meteorological and hydrological analyses of the Arctic passages revealed the meteorological features of the Arctic — low temperature, few strong winds, thick fogs, poor visibility and weak wind waves, as well as the environmental features like large deposits of ice, wide ice coverage, accumulation of ice blocks around pressure ridges, ice hummocks and water channels. The sea ice may block the seawater pipes of vessels. When a vessel enters a sea ice zone, the chunks of ice will cover the fence of the sea suction valve and block the water inlet. At the same time, as fine-grained ice flows with the water into the cooler pipeline inside the cabin, the cooling pipes of the auxiliary engine will be blocked; in worst scenarios, the cooling system will break down, the temperature of the cooling water will rise to an excessively high level, leading the auxiliary engine to failure and the vessel’s power system to a complete shutdown. Due to the severe weather conditions, the Arctic shipping routes are not in the position to accommodate a massive fleet of merchant ships in winter. Therefore, only seasonal shipping passages are available along the Arctic shipping routes in summer. Overcoming the problems caused by sea ice is the key to ensuring safe navigation along the routes.

2.2. Insufficient facilities

The low temperature is a major contributor to navigation safety risks across the Arctic, and other additional perils include icing on vessels and their operation systems, emergency rescue difficulties, insufficient harbor facilities and supplies, complicated hydro meteorology and poor low-temperature performance of vessels. In a vessel, an organic system, the liquids serve as the major medium for energy transfer, and icing of the liquids at a low temperature will be detrimental. Research on vessels operating at a low temperature shows that icing on ship decks affects walking, icing in the water tanks reduces stability, icing in fuel storage tanks impairs fuel feed, icing on compass decks interferes with communication and navigation, and icing of the pipeline dysfunctions the operation systems. Therefore, during the design and building stages of a vessel, efforts should be made to coordinate the various systems involved, with an all-around protective design to preclude local problems from jeopardizing the overall operation of the vessel.

At a low temperature, emergency rescue measures, port facilities and supplies in the Arctic are poor, so vessels should be designed with due consideration to the harsh voyage environment in the Arctic, build up the emergency capacity, and improve the crew’s self-saving abilities. Existing vessels in service are equipped with safety management systems in response to adverse conditions like low visibility and rough seas. For vessels into the Arctic, a region of complicated natural conditions, higher requirements are to be met. Specifically, as much of the meteorological and hydrological information of the Arctic remains unknown, and the crew members are short of experience for navigation in this area, the crew need to get more firsthand experience in navigation, thereby enriching the information of the routes and building up their sailing skills.

At extremely low temperatures, steel vessels are prone to embrittlement. To deal with this problem, we should probe into the low-temperature sustaining technology, and develop suitable materials and devices. To ensure a better life for the crew members operating at low temperatures, we can refer to the lifestyle of the indigenous peoples in the Polar Regions, so that the crew can maintain physically healthy in such cold environment.

Due to the high latitudes, the navigation and communication equipment are influenced by different degrees and work abnormally. The limitations and reasons are as illustrated as below:

| Equipment and System | Latitude of limitation | Reasons                  |
|----------------------|------------------------|--------------------------|
| VHF, HF and MF       | No limitation          | /                        |
| GMDSS                | 80°                    | Signal instability and interruption |
| VHF DSC              | No limitation          | /                        |
| AIS                      | No limitation | Shortage of regional base station |
|-------------------------|---------------|----------------------------------|
| 121.5 and 123.1 VHF to air | No limitation | /                                |
| Iridium satellite phone | No limitation | /                                |
| Gyro-compass            | 85°           | In 70°-90°, amount of error is about 2°-5° |
| Magnetic compass        | 60°           | The horizontal direction force of the earth's magnetic field is weakened |
| GNSS compass            | No limitation | /                                |
| Radar                   | No limitation | /                                |
| Searchlight             | No limitation | /                                |
| Weather fax             | No limitation | /                                |
| GPS                     | 80°           | Signal instability and interruption |

2.3. Human factors

The low-temperature environment around the Arctic constantly presents physiological and psychological challenges to the crews, while the huge whoops when the vessels collide with the icebergs pose even more psychological pressure on the crew. When a vessel has to navigate in an icing environment for a long time or the first mate aboard short of experience for navigation in icing areas, the captain will have to stay at the console for long, increasing the risk of fatigue navigation.

When navigating in the vicinity of icebergs, the crew members will have to stay on high alert, for a minor distraction may result in a marine accident. Moreover, the crew members can easily run out of energy, for they have to deal with the frequent steering commands before the vessel finally sails outside the zones choked with icebergs. Meanwhile, the crew need to assess the various hydro-meteorological information on the spot to find out a safe passage, making it far more laborious than navigation in other sea areas.

3. Provisions of international convention

In compliance with the requirements of Chapter 6, Part I-A of the Polar Code, the equipment aboard the vessels that navigate in the polar areas should be provided with proper operating fluid to fit the prospective work environment. As for life saving and communication devices, the following requirements should be met: (1) For vessels exposed to ice accretion, means shall be provided to remove or prevent ice and snow accretion from the escape routes, muster stations, embarkation areas, survival crafts, its launching appliances and access to survival crafts; (2) For vessels constructed on or after January 1, 2017, exposed escape routes shall be arranged to facilitate access of crew members in polar wears; (3) For vessels intended to operate in low temperatures, embarkation arrangements shall be assessed, with full regard to any effect of crew members in additional polar wears; (4) Vessels shall provide support to ensure safe evacuation of persons during navigation in ice-covered waters or iced waters, including survival equipment, proper ventilation for closed or semi-closed life boats and rafts, with the impact of incoming low-temperature air taken into consideration; (5) Each person aboard shall be provided with one set of sizeable life-saving cold-wather gear (the thermal insulation type) and thermal wares; (6) Suitable life-saving supplies shall be provided to meet the demand of people aboard to survive alone (life-saving equipment for individuals) and collectively (life-saving equipment for collective purposes), including life-saving facilities and devices for collective purposes to protect persons aboard from invading cold wind, life-saving gear to help maintain normal body temperature, as well as equipment to prevent frostbite on hands and feet.

4. Suggestions

4.1. Providing better equipment and facilities

Efforts should be made to research, develop and/or improve life-saving and communication equipment aboard the vessels as required by the Polar Code: (1) developing lightweight thermal wears; (2)
developing easy-to-use and efficient de-icing devices; (3) improving the bottom design of lifeboats to keep the boats upright floating on ice; (4) improving ventilation installations of closed and semi-closed lifeboats & rafts, with due consideration to the incoming low-temperature air; (5) building lifeboats with fire-proof materials or providing fire-prevention measures so that persons on board have enough time to make off to the released lifeboats in the event of a fire caused by oil spilling; and (6) developing devices to accommodate life-saving gear for collective purposes that can move and float on the ice.

4.2. Enhancing crew competence
To prepare for a voyage in the polar regions, the crew members must receive systematic training to perform polar operations and analyze hydro-meteorological information. The training materials shall include previous polar navigation reports, sea ice atlas, navigation guidelines, and training videos related to polar operations. Based on the mechanics of the vessel and the schedules of the crew, training should be provided to equip them with relevant safety knowledge, professional skills and psychological guidance.

4.3. Preparations before navigation
Before embarking on a voyage, the crew should review materials about the area of voyage, especially the hydro-meteorological information and icing conditions, to check whether this voyage will involve any icing zones around its ports of loading, whether the ports will be blocked with ice. Before entering an icing zone, the crew should take in meteorological information of the zone as much as possible from the bridge resources to monitor the development of ice conditions around the navigation zones. The main engine and steering system shall be carefully monitored to ensure they work reliably, and quickly respond to various operation commands. Navigation-aid equipment and communication devices aboard, the radar in particular, should be maintained to ensure normal operations.

Equipment for safe navigation and the necessities for the crew members should also be prepared. Here is a list of articles necessary for the crew on voyages in polar areas: 100% UVA/UVB protection sunglasses, polar clothes and footgear, medical aids, food, vitamins, fuels, storage battery, detonator, anti-freezing agent, explosive, fuses, sleeping bags, firelock, powder magazine, fishing wheel, emergency medical supplies and repair kits.

The shipping company should provide vessels that are about to navigate in the Arctic with a complete set of information on the meteorological conditions to allow the persons aboard to capture the icing conditions of the area and respond timely to severe weather events and emergencies.

5. Conclusion
In conclusion, adverse natural conditions like low temperatures, icing and snow accumulation, remoteness, and fragile environment around the Arctic waters all present great threats to the vessels heading there. Vessels sailing in the Arctic should adequately consider the distinctive risks around the Arctic waters. Besides, as per the mandatory requirements stipulated in the Polar Code, relevant equipment and gear should be prepared to ensure human, property and environmental safety during the navigation.

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