22nd IAHR International Symposium on Ice
Singapore, August 11 to 15, 2014

Floating Ice Induced Ship Casualties

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It is very important to analyze sea-ice-induced ship casualties because transport activity at high latitudes is growing. A significant search is underway for an Arctic alternative to the southern (Suez) route from Europe to Asia. However, despite global warming and forecasts of an ice-free Arctic, ice conditions are still rather difficult. The Vilkitsky Strait was closed by ice for almost the entire navigation season 2013. Several accidents occurred, including the rupture of a tanker by an ice floe, nipping and overwintering last year.

The frequency of ship casualties in the Polar regions is much smaller than in the world ocean. But due to a low self-purification capacity of Arctic and Antarctic nature and harsh weather conditions, we should try to avoid any type of failure and minimize the risks involved. An analysis of ship accidents caused by sea ice in the Russian Arctic over the previous century (Marchenko, 2012) shows that a majority of casualties were related to floating ice. In significant number of cases, the accidents could be avoided if captains took into consideration sea ice properties, distinguished between “strong ice” (multiyear ice, icebergs) and “soft” first year ice.

In this article, several cases on serious casualties with floating ice are presented. These cases include incidents with holing of the icebreaker *Admiral Lazarev* (1965, East Siberian Sea), the cruise ship *Maxim Gorkiy* (1989, Greenland Sea) and the tanker *Nordvik* (2013, Kara Sea); sinking of the adventure vessel *Explorer* (2007, South Ocean) and freighter *Nina Sagaydak* (1983, Chukchi Sea), nipping and drift of several vessels in Okhotsk Sea (2010-2011, 2013-14,) and *Akademik Shokalskiy* (2013-14, South Ocean).
The analysis of accidents should be done to avoid accidents in future.

Proceedings of the 22nd IAHR International Symposium on Ice

ISBN: 978-981-09-0750-1
doi:10.3850/978-981-09-0750-1_1194

1. Floating ice and possible ship accident scenarios

Floating ice is any form of ice that floats in water, including grounded ice and drifting land ice (McGraw-Hill, 2003). Sea ice can be met not only in Polar region seas. In winter time, sea ice can create problem for navigation as far from poles as in Caspian Sea, Azov Sea. Even on 39-40^{o} North, in Bohai Sea (China), risk of ice is very high and loss to the economy is huge (Zhang Zhaohui et al. 2005). Icebergs from Antarctic can reach Australian coast. So the sea area with floating ice is quite large.

From engineering and navigation points of view, the main features of floating ice are physic-mechanical properties, concentration and drift (speed and direction). Pieces of floating ice can have different sizes, origins and properties. These differences have been presented numerically in overviews of the physical and mechanical properties of sea-ice (Timco & Weeks, 2010; Weeks, 2010). Freshwater ice is stronger than sea ice. Compared to first-year ice, multiyear ice loses brine and is subjected to compression over time, thus approaching freshwater ice properties. Rotten ice, as it is commonly referred to, is more easily overcame by ships, than multiyear ice. In-situ and laboratory tests have quantitatively confirmed these empirically known facts. Distinguishing between different types of ice remains an outstanding question.
Dangerous ice formations are multiyear ice fields, ice floes and ridged ice, floeberg, zone of compressed ice, icebergs, bergy bits, growlers, ice islands and their fragments (Mironov and Tunik 2012).
The ice phenomena dangerous for shipping are icing, too early formation of ice cover, ice sticking to ship hull, intensive ice drift ("ice river"), strong ice compression, inflow of unusually severe ice formations, narrowing of navigable channel, sharp change in ice drift direction.
The most possible scenarios of casualties caused by floating ice are

1) Concentration of ice is rather small (less than 15-20 %), only some ice-floes float in the water. Ship, keeping considerable speed, can collide with hard ice floe and be holed. The holed ship can be saved be skillful actions of the crew or sink. The question of rescue of the crew and passengers arises in this case.
2) Ship can be trapped by drifting ice, unable to move or move in undesirable direction. To get free the ship, the expensive help of icebreakers can be used, or ship can get free herself, if ice conditions will change. Sometimes waiting of better ice condition turns to overwintering.
3) Ship can be involved in drift with considerable speed (up to 1-2 nautical miles per hour - ice jet) with compression and damaged. Even icebreakers can be powerless against such drift.

We can distinguish the following four types of the outcomes from accidents induced by floating ice (Marchenko, 2012): forced drift, forced capturing (and possible overwintering further), shipwreck and serious damage to the hull in which the crew could still save the ship. It should be noted that the allocation of these four groups is very conventional. For example, a forced drift or forced overwintering can be fatal. Sometimes, overwinterings were accompanied by drift. The most eloquent example of the difficulties of classification is the drift of the caravan with the icebreaker *Lenin* in the Laptev Sea. It began in October 1937 as overwintering. However, in mid-November, the ice field in the overwintering location was broken by the south-west gale hack, and the vessels were brought into the open sea, where they drifted until the summer of 1938. One

vessel, the timber carrier *Rabochy,* was crushed by ice and compression hummocking and sank on January 23, 1938. The other ships were damaged. This event involved all four types of accidents.
Let's look through the cases characterizing the possible scenarios of floating ice action on the ships, using the recent events as examples.

2. "Ice floe hit" cases

The typical situation here is follow - concentration of ice was rather small (less than 15-20 %), only some ice floes among ice. Fog often reduced visibility. Ship, keeping considerable speed, collided with hard ice floe and was holed.

Canadian Institute for Ocean Technology has prepared the database concentrated on iceberg collisions with ships in the North Atlantic off Newfoundland and Labrador. It does include a few incidents further north, around Greenland, and also in the fiords of Alaska (Hill 2006). There are over 560 incidents in the database. The database focuses on incidents of ships striking icebergs which being ice of glacial origin also includes the smaller categories of growlers and bergy bits. Sometimes it is unclear whether a "piece of ice" is a small iceberg or sea ice floe.

One of the last incidents in the database is collision of Shrimp Trawler BCM *Atlantic* with probably a bergy bit. It happened 18 Mar 2000. Operating in ice in heavy snow, she was holed and sank, 53°09.4'N 52°11'W, approximately 240 km to the east of Goose Bay, Labrador. Crew took to boats and had been rescued by FAME 3 hours later (Hill 2010).

Admiral Lasarev. 1965 East-Siberian Sea, near Aion Island
On 17-18 August 1965, the icebreaker *Admiral Lasarev* was seriously damaged by ice to the west of Aion Island (Abonosimov 2002) (Marchenko 2012).
Two huge ice-floes appeared suddenly out of the fog at the night on 17 August 1965, they were impossible to see until it was too late to turn. The icebreaker endured (faced out) the first hit, but was thrown back to the other side. There the other ice floe was waiting for her and cut the bottom of the ice-breaker like a great saw. The master decided to turn the vessel to shallow water and after several hours she sank at 70 °03`48``N, 168 ° 52`30``E. The water depth was 12 m and there were only 20 centimeters to spare before the icebreaker was covered with water.
The freighter *Amguema*, towboat *Donets*, and icebreakers *№ 5* and *Leningrad* soon came to help and the struggle for the survival of the icebreaker began. Three of four stokeholds were waterlogged. In the fourth stokehold, sailors worked waist deep in the water. Three divers from the icebreaker *Leningrad* welded the 6-m hole in the dark cold water. On the next day, powerful pumps removed the water from the icebreaker and the icebreaker *Leningrad* towed the *Admiral Lasarev* to Pevek.

Maxim Gorkiy.1989. Greenland Sea, near Svalbard/Spitsbergen
On around midnight of 19 June 1989 luxery cruise ship *Maxim Gorkiy* hit an ice floe while she carried mostly German tourists from Iceland to Spitsbergen fjord and begun to sink rapidly (Hovden 2012). All passengers and one third of the crew left the sinking ship. The Norwegian coast guard vessel *Senja* arrived on the scene some three hours later, when the *Maxim Gorkiy* was already partially submerged. The passengers were evacuated from the lifeboats and ice floes by helicopters and the *Senja*, taken to Svalbard and later flown back to Germany. Meanwhile the crew of the *Senja* had managed to stop the *Maxim Gorkiy*'s sinking, by which time her bow had

already sunk down to the level of the main deck. Divers from the Senja found two large gashes, 30 inches by 8 feet (76x 244 cm) and 2 inches by 19 feet (5x 579 cm). On 21 June the *Maxim Gorkiy* was towed to Svalbard where quick repairs were made to make her watertight enough to survive a return to Germany for repairs.
The reported reason of the accident was that the Master has decided to pass the ice field with high speed, because he had the impression of being in the light ice conditions.

Explorer. 2007. South ocean near King George Island
In 2007, Toronto-based GAP Adventures' *Explorer*, which has crossed the Antarctic Ocean for four decades, has become the first ship to sink there. All 154 passengers from over 14 countries and crew were rescued after several hours.
23 November, she hit an iceberg in the Bransfield Strait close to King George Island. The object struck by the *Explorer* made a reported 25 by 10 cm gash in the hull which allowed water to enter. One passenger reported sea water in the cabin at about 03:00 UTC. A mayday call was put out by the ship at 04:24 UTC, and rescue operations were quickly coordinated by the Coast Guard Corps of the Argentine Republic, and the Chilean Navy Center for Search and Rescue.
By 07:30 UTC, passengers, guides and crew were evacuated and had taken to the *Explorer's* lifeboats. Norwegian ship MS *Nord Norge* arrived on scene at approximately 10:00 UTC and picked up people in distress. The *Explorer* was completely submerged at 19:00 UTC, approximately 20 hours after the initial impact and damage to its hull.
The *Explorer* was designed, like most ships, with compartments which could be sealed off by watertight doors; the ship would not sink if holed and one compartment flooded, but was not safe if more compartments were flooded, either by a gash spanning compartments or imperfect sealing between compartments. GAP Adventures reported that there was a crack in addition to the hole, but it is not clear if it spanned compartments.
The report cites the decision by the Master of the vessel to enter the ice field based on his knowledge and information available at the time as the primary reason why the *Explorer* suffered the casualty. "He was under the mistaken impression that he was encountering first year ice when in fact, as the Chilean Navy Report indicated, was much harder land ice.“ The Master of the *Explorer* was very experienced in Baltic waters but he was unfamiliar with the type of ice he encountered in Antarctic waters.
The report lauds the performance of the Master and crew in organizing and evacuating the passengers, and notes that lives were likely saved due to the actions of these individuals.
Cruise-ship tourism has boomed in both Polar regions since the beginning of 21st century. The question about safety of polar cruises seriously raised up after *Explorer* shipwreck.

Mt Stena Poseidon, *Mt Palva.* 2012. Northern Sea Route
Two ships, both operated by Neste Shipping, were damaged by ice in the Russian Arctic in 2012. Ice conditions were still quite harsh in early June and resulted in damage to the west-bound ship *Mt Stena Poseidon*. *Mt Palva* sailed from Murmansk on the 14 July with a Northern Sea Route passage time of 8.6 days. The ice conditions were harsh in some places, and the vessel sustained some damage. The damage to both vessels was primarily caused by contact with ice blocks. Damage could have been avoided by the vessels reducing their speeds (Haapanen 2013).

Nordvik. 2013. Kara Sea, the Matisen Strait

In September 2013, the tanker *Nordvik* was holed by an ice floe and suffered an ingress of water in the Kara Sea (CHNL 2013). The *Nordvik* was supposed to deliver fuel from Ob' Bay to the port of Khatanga. The case is interesting because the new regulation acted in Russian Arctic since 2013. All vessels need to have the permission issued by Northern Sea Route Administration (NSRA) to navigate in the waters controlled by administration.

The tanker *Nordvik* had been given permission by the NSRA to sail in the Kara and Laptev seas under light ice conditions and only under escort by an icebreaker. The Federal Agency for Sea and River Transport stated that the tanker acted in violation of the permit by entering waters with medium ice conditions without an icebreaker escort. Experienced captains submitted that it was quite possible that the ice conditions had changed rapidly and that the tanker had unintentionally ended up in an area with heavy ice conditions. The Commission has not yet decided the case proceedings. Nevertheless, on the 4 September, the tanker *Nordvik* was struck and holed by ice while sailing in the Matisen Strait to the north of the Taimyr Peninsula. The tanker quickly began taking in water through one of the ballast tanks.

The ship's owner, Khatanga Commercial Port, was negotiating with the nuclear icebreaker operator Rosatomflot to have the tanker escorted to the port of Khatanga. However, all four icebreakers were occupied escorting a Russian military group of 10 different vessels of the Northern Fleet that were led by the heavy missile cruiser *Petr Veliky*. On the 10th of September, the hole (which measured 100 cm x 10 cm) was plugged with a cement box to stem the water ingress. Fortunately, there were no any oil leakage.

On the 11 September, a total of 1800 liters of diesel oil was reloaded from the *Nordvik* into the tanker *Boris Vilkitsky*. The next day, the *Nordvik* and the *Boris Vilkitsky* were accompanied by two nuclear-powered icebreakers (the *Taymyr* and the *Vaygach)* out of the Matisen Strait. On the 14th of September, the tankers reached open water, departed the NSR waters three days later and sailed to the Anabar River. The case was settled but raised the question of ecological safety in the Arctic. The popular headline at the time was "Four icebreakers for missile cruiser – none for damaged tanker" (Pettersen 2013).

The accident showed that ice conditions in the Arctic remain harsh and unpredictable. The course of events revealed that vessels or ship owners do not always follow the NSRA rules and orders. Seafarers, located in remote places of the Arctic can not expect that rescue and evacuation measures will be provided immediately..

3. Nipping/ trapping by ice cases

The situation when ship was not able to cross surrounding her ice and needed to wait for better ice conditions, often till next navigation season/ summer happened quite often at the beginning of 20th century. The captures by ice with further overwintering occurred quite often during the initial period of Northern Sea Route mastering. There were 8 overwinterings over 20 navigation seasons between 1914-1934, or 40% of years (Marchenko 2012).

To be seriously trapped by ice is rather rare nowadays thanks to the help of powerful icebreakers and reliable ice condition forecast. Nevertheless, we can cite here 3 events, happened during last 4 years. Generaly now it is possible to extricate any vessel using modern equipment and technique. The question is time and money. Sometimes it is more profitable to wait better ice condition or even leave vessel for overwintering.

15 fishing trawlers 2010-2011. Okhotsk Sea, Sakhalin Gulf

In December 2010, 15 fishing trawlers (700 persons) had been captured by sea ice while fishing on the south of Okhotsk Sea. 5 ships needed icebreaking assistance to extricate. As Far East Shipping Company reported, the rescue operation took the whole month (30 December 2010 – 31 January 2011) and cost more 5 ml USD, 3 icebreakers were involved. Fortunately, none of vessels had been damaged, nobody injured (Borisov 2011),(Sloggett 2011).

The extricating of last vessels was most dramatic. The first vessel *Mys Elizavety* had been escorted 23,6 miles, the second – *Professor Kizevetter* – 62 miles. After escaping these two vessels, ice field enlarged significantly. So icebreakers had to make channel in the ice 140 miles long to escape refrigerator *Bereg Nadezhdy* and 150 miles for factory ship *Sodruzhestvo*. During the rescue operation icebreakers were working at full capacity, there was no emergency. Towing ropes were broken several times caused by severe ice conditions.

Akademik Shokalskiy. 2013-2014, South Ocean.

The latest sea ice accident happened near Antarctic in December 2013. MV *Akademik Shokalskiy* is ice-strengthened ship, built in Finland in 1982, originally used as research vessel, but last years used for adventure cruise by Aurora Expeditions. Two Guardian journalists were on the board that's why the story has been widely described in Media from corresponding point of view. The cost of rescuing the passengers of the Akademik Shokalskiy, has been estimated at up to A$2.4m (£1.3m) (Jha 2014).

On 8 December 2013 *Akademik Shokalskiy* with 48 passengers (Australasian Antarctic Expedition) and 20 crew members aboard left New Zealand port Bluff for Antarctica to repeat the voyage of Australian explorer Douglas Mawson in 1911 -1913.

On 24 December 2013, *Akademik Shokalskiy* became trapped in heavy ice a few miles from the coast of Antarctica. *Akademik Shokalskiy* asked about assistance and the icebreakers *Xue Long* and *Aurora Australis,* and a French research vessel *L'Astrolabe* tried to approach and extricate *Akademik Shokalskiy,* but failed. The icebreaker *Xue Long* has herself become trapped in the ice, roughly 70NM from *Akademik Shokalskiy*. It has been decided to evacuate passengers and part of the crew with help of helicopters. But due to bad weather all celebrated New Year on the board and were evacuated on 2 January 2014.

Five days after the rescue, the *Akademik Shokalskiy* managed to escape the pack ice thanks to a change in the weather, and arrived back in New Zealand.

Diomid. 2013-2014. Okhotks Sea, Sakhalin Gulf

At the end of December 2013, cargo vessel *Diomid* was on a route from Magadan to Vladivostok, loaded with empty containers. 27 December, *Diomid* entered into Sakhalin Gulf to shelter from a storm raging in Okhotsk Sea and was captured by ice. 29 December, vessel tried to get free, but failed and reported being trapped in ice (RIA-NOVOSTI 2014).

29 December - 12 January, vessel was in the same position, reportedly waiting for icebreaker to get her free. Temperature was -10, -18°C, wind 10-12 m/s NW-W Ice 10/10; thickness - 0,5 m

16 January, 12 of total 15 crew members were evacuated by helicopter and sent to Khabarovsk, vessel was settled for overwintering. The rest of the crew – two mechanics and a guard – will remain on board until the springtime to protect the ship from pillaging.

4. Ice jet cases

Ice jet is the most dangerous sea ice phenomena. This is the drift with considerable speed (up to 1-2 nautical miles per hour) in the boundary stream flow in strongly over layered sea, creating the effect of “a pure slide” in the layer of density shift and storm surge effect near boundary of compact ice and fast ice (Benzeman, Komendantov, and Shmatkov 2004), (Mironov and Tunik 2012).

There have been many confirmed cases of ice jets in the Arctic. The ice in ice jets is brash ice that is crushed and sometimes compressed. Ice jets occur in straits, bays or open sea areas near the border of fast ice or sedentary pack ice. For example, north and west of Dikson Island at the edge of the ice, at the outlet of the Yenisey Gulf, in the Karskie Vorota Strait, Yugorsky Shar Strait. The severity of the phenomenon depends not only on the flow velocity of the stream but on the degree of cohesion and compaction of the ice. The flow of water and thin ice is not difficult for almost any ship. However, even nuclear-powered ships cannot overcome relatively slow streams containing brash ice with concentrations of 9/10 to 10/10. The examples are drift faced by the nuclear-powered ships *Sibir* and *Arktika* and the icebreaker *Kiev* in the Yugorsky Shar Strait in March to April 1980 and the drift of the icebreaker *Kapitan Sorokin* in the Yenisey Gulf in November 1977 (Benzeman, Komendantov, and Shmatkov 2004).

The last dramatic navigation of 1983 year was widely described in Russian literature (Smirnov et al. 1993). Some of the descriptions were translated to English (Barr and Wilson 1985). At the end of navigation in 1983, the ice conditions in the eastern Arctic were unusually severe. Powerful pack ice with thicknesses of up to 3 to 4 m moved from the Central Arctic between Aion Island and the coast of northern Chukotka, across the De Long Strait. Almost constant north-western and northerly winds pinned the huge Ayon Ice Massif to the shore. There were no cracks or crevasses or other ice-free places for hundreds of nautical miles from the shore. The thickness of the ice consolidated into a monolith reached 10 m thick in the coastal zone.

These harsh conditions and frequent ‘ice jets’ caused the loss of the motor ship *Nina Sagaydak* and serious damage to more than 30 ships (October 1983). One of them, the *Kolya Myagotin,* was saved only thanks to the able and courageous actions of the crew and the assistance of other ships. Fifty-seven ships were ice bound during the ice compression.

Conclusion

The above cases show the real danger of floating ice for shipping. Even at the present level of technology, this danger remains. Should be carefully investigated and documented the incident, to improve the safety of navigation. This is especially important with the intensification of industrial and transport activities in the Arctic.

Acknowledgments

The author would like to thank the SAMCoT project (funded by the Research Council of Norway), the SMIDA project (funded by the Norwegian Centre for International Cooperation in Education) and her colleagues for supporting this study.

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