ANNUAL OF NAVIGATION 24/2017

DE GRUYTER OPEN

DOI: 10.1515/aon-2017-0009

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CAUSES OF SHIPS GROUNDINGS IN TERMS OF INTEGRATED NAVIGATION MODEL

ABSTRACT

The paper presents an influence of the navigational model change on the structural and qualitative changes of the ships groundings in international shipping. Data was analyzed based on reports of 75 seagoing vessels in international shipping in the 2000–2014. This study is an attempt to assess the causes of ships groundings in the new integrated navigation model.

Keywords:
ships grounding, losses of vessels.

INTRODUCTION

Tendencies to increase the sizes of built ships have forced the maritime authorities to detailed shallow bathymetric surveys, due to the increased draught of vessels entering the ports. Regardless of it, there is still a need for a reasonable margin of safety while navigating in shallow waters, including the ability to calculate the necessary under-keel clearance.

Ships grounding may lead to the propulsion system damage, the loss of hull integrity or to the partial or total loss of the cargo. At the same time the effects of the accident can be extremely dangerous to the environment, particularly to the sea habitat. The effects of that kind of a failure are generally very serious, including the possibility of a vessel loss.

In conclusion, the ships grounding is one of the most serious threats to the safety of navigation and the marine environment. Knowing the emergency procedures can significantly reduce the impact of an accident, both technically and environmentally [Jurdziński, 2005].

PRELIMINARY ANALYSIS

A period of classical navigation definitely came to the end in this century. An integrated navigation model changed the nature of the global fleet's failure possibilities. A safety of sea-going ships should be one of the most important areas in the world's shipping. In the process of exploitation, ships are subjected to maritime accidents such as grounding or collisions. Total ships losses are also the results of that kind of accidents. Recent studies show the downward trend; these changes are also noticeable in the failure structure.

Changes in failure structure in the period of 1990–2013 are as follows [Bužaňcić-Primorac, Parunov, 2016]:

– construction failure	30,0*)
– collisions	16,0
– contacts with obstructions	23,0
– groundings	18,0
– fire	1,0
– explosion	12,0
*) numbers rounded	100,0

Type of vessels with the highest number of failures:

– general cargo vessels	(46–58);
– fishing vessels	(19–24);
– bulk carriers	(10–7);
– passenger vessels	(7–6).

The number of total ships losses is getting smaller. Figure 1 shows the graph presenting the losses of large vessels from 2005 to 2014 [Bužaňcić-Primorac, Parunov, 2016].

Changes in the failure structure of sea-going ships in international shipping are the results of a change in the modern maritime navigation model.

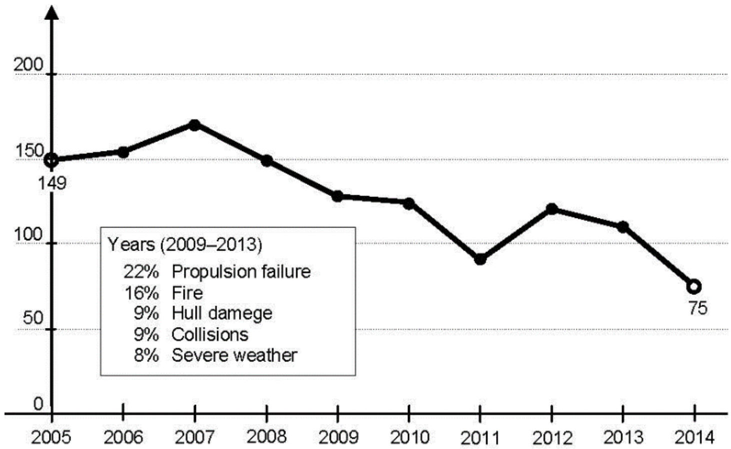

Fig. 1. Total losses of large vessels from 2009 to 2013 [Bužaňcić-Primorac, Parunov, 2016]

Elements of the integrated navigation model include the following processes:
- reliable and continuous land-to-ship and ship-to-ship communication;
- reliable methods for continuous positioning;
- reliable anti-collision systems on ships;
- methods of navigation systems integration;
- introduction of electronic maps (ECDIS) to the navigation process;
- introduction of integrated bridge systems (IBS);
- unification of navigation devices;
- introduction of automation and optimization of navigation processes considering particular criteria;
- use of vessel traffic services in confined and busy waters (VTS);
- improve navigation safety by SOLAS Convention development;
- automated navigation data recording (VDR);
- maritime environment protection (MARPOL).

On this basis the modern definition of maritime navigation can be established [Jurdziński, 2014].

MODERN INTEGRATED NAVIGATION MODEL

Maritime navigation is the process of acquiring and processing navigational information which result in the following sub processes:

- shipping routes planning;
- vessel motion control;
- vessel positioning;
- tracking and processing of collision hazards information in internal and external environmental conditions;
- modifications of the route and the motion vector depending on the interfering factors [Jurdziński, 2014].

All decisions on the bridge must be based on a sufficient amount of reliable information depending on the sailing phase and external disturbances affecting the movement of the ship. Maritime navigation is a continuous process, all the time, from departure port to the arrival location.

The contemporary model of integrated navigation has changed the decision making processes on the bridge while navigating the ship. Figure 2. shows a simplified modern integrated navigation model.

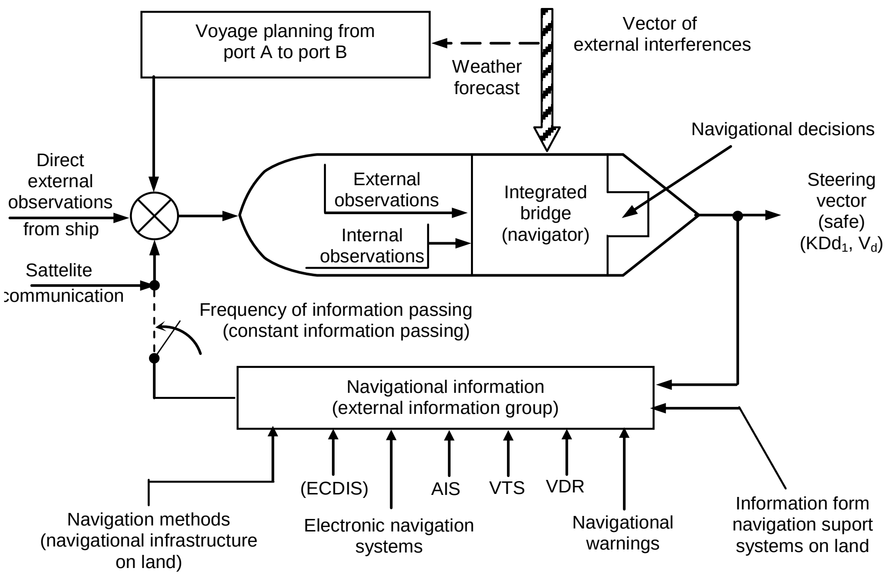

Fig. 2. Simplified modern integrated navigation model

Basic activities of a navigator in the process of vessel control

- navigation planning;
- ship position control;

– speed and course control;
– collision avoidance/risk assessment (ARPA);
– propulsion control;
– phone/radiophone communication within the ship;
– internal communications;
– external radio communication: ship-to-land, ship-to-ship;
– responding to the alarm signals from own vessel systems and foreign ships;
– observation of weather condition;
– control of the lights and day signs shown by the ship itself, activation of sound signals as required;
– documentation of events related to navigation and operation of the ship.

Integrated navigation system use

The use of integrated navigation system on the ship introduces a number of improvements of the navigation process such as:
– improving the efficiency of work on the bridge;
– reduction of bridge crew;
– increasing the volume of information flow between the navigator and the environment;
– facilitating the bridge equipment operation;
– faster data acquisition and processing;
– reduction of fatigue of the bridge crew;
– increasing the efficiency of bridge space utilization;
– improved functionality and aesthetics of the bridge design;
– overall enhanced navigation safety for ships.

SHIPS GROUNDINGS

Technological changes in the operation of ships did not cause the total elimination of ships failures. Statistics show constantly the occurrence of ships systems damage. Changes to the navigation model only show structural changes in ship failures. Overall number of total ships loss is decreasing as global tonnage rises. Collisions and groundings still exist with quantitative variations. Main causes of accidents on sea-going ships are [Rothblum, ther's no year]:

- crew's fatigue;
- insufficient communication;
- lack of technical knowledge;
- unfamiliarity with the ship equipment;
- lack of sufficient equipment for ship automation;
- making decisions without sufficient information;
- poor maintenance of technical systems on board;
- the impact of environmental disturbances;
- not enough amount of practical training of the crew.

Definition of grounding

Ships grounding is a type of occurrence at sea when the ship touches the seabed. Typically, a large pressure of the hull on the seabed causes damage to the ship's structure. This can lead to complete loss of the ship and to marine pollution. There are two types of grounding according to the circumstances of the accident:

1. Grounding of a power driven vessel underway.
2. Grounding of a drifting vessel.

Another classification refers to the hardness of the sediments on the seafloor:

1. Soft shoal — this is a failure of the ship entering the soft mud or sand covering the seabed.
2. Hard shovel — it occurs when the ship enters a rocky sea floor.

Grounding means entering the shoal in the water area away from land, while stranding is always associated with a hull contact with a shoreline.

The definition of 2013 says: 'The assessment of a model of ships groundings scheme can be based on historical data, opinions of publishers and forecasting'.

Historical data should be used with caution due to changes in the navigation model, hence the current forecasts may vary considerably because of the safety standards changes in the new navigation model.

Failure prognosis are different for different types of ships [Styliadis, Koliousis, ther's no year]. Assuming an average ship is utilized for 25 years, there is a statistical probability that every ship can enter the shoal 2 times throughout its lifetime [Styliadis, Koliousis, ther's no year].

The number of accidents decreases in time, which does not mean that this applies to groundings. The main factors of ships groundings are as follows [13]:

- regional hydrographic factors - disruptions information;
- meteorological factors, weather forecasts, fog, currents, wind, rain;

- geographic factors, sailing parameters, width, depth, etc.;
- vessel motion parameters, depth, etc.;
- state of the crew training, motivation to work;
- obeying collision regulations;
- ship's technical condition (system defects, technical deficiencies);
- commercial pressure applied by ship owners to crew;
- crew's fatigue
- inadequate navigational infrastructure.

There are two cases where a ship enters the shoal [Bužaňcić-Primorac, Parunov, 2016]:

1. The grounding of ship in motion (powered grounding).
2. The grounding of drifting vessel (drift grounding).

The ship's entry into the shoal in motion occurs when the bottom of the ship in motion collides with the seabed as a result of navigational error or lack of vigilance of the crew. The types of errors in navigating vessel can be summarized as follows:

1. Sail in the direction of shoal without changing the course.
2. Sail along the shoals, where the ship is lifted by wind, current or wave to the shallows.
3. Determine the wrong position from where the wrong course is going through the shallow.
4. Wrong erroneous course through inaccurate depth area.
5. Descend from the fairway, while crossing a narrow area.

The second case of grounding occurs when a vessel restricted in her ability to maneuver due to loss of steering or main engine problems, drifts freely under the influence of current, wind and wave and enters the shallow. Figure 3 shows the examples of different types of ships groundings.

Hull damage types caused by groundings are divided into five categories [Rothblum, ther's no year]:

- extensive deformation of the plates;
- perforation of plates;
- plates bending;
- plates crushing;
- plates tearing by a sharp rocky bottom.

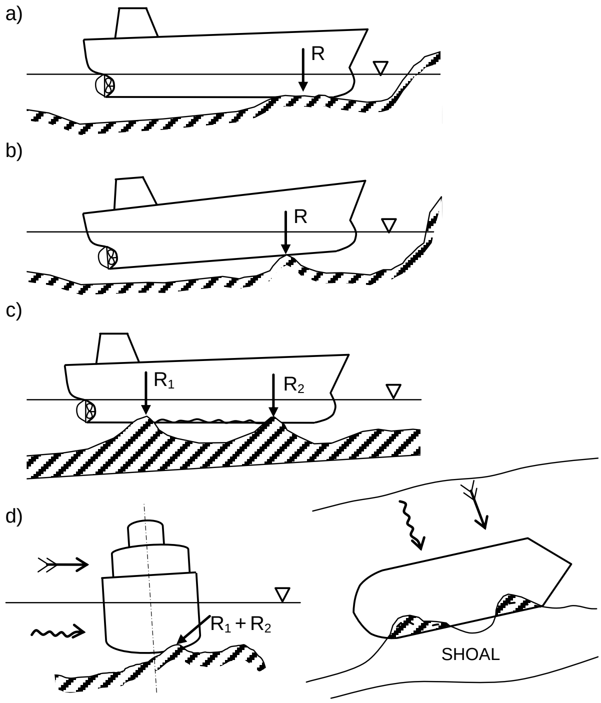

Fig. 3. Types of vessel position on shoal and hull damages: a) a part of a hull sits on a flat seabed; b) hull get stuck on the pointy shoal (rocky), causing a vessel inclination to the rear direction: c) getting stuck on two hard rocky shoals: d) deformation of side part of a hull plates on the hard rocky shoal causing ships roll

Impact of international regulations on methods changes

In the 1970s, on the IMO Forum a very intensive effort to improve safety of human life at sea has been initiated. The SOLAS Convention was appended by Chapter XII and 40 regulations were added to Chapter V. Significant changes in the SOLAS Convention took place between 2001 and 2002. As a result of these changes, a captain is required to carefully plan the navigation from port A to port B. This resulted in a new navigational model where a master affects safety of the ship from a wharf of a port of departure to a wharf of a port of destination, with crew members having no influence on decisions made by a master in the selection and execution of a ship's route. The use of an integrated navigation system on a bridge, accurate external disturbances forecasting and assistance from inland navigation advisory centers have a significant impact on the safety of the ship.

FAILURE ANALYSIS OF GROUNDINGS FORM 2000 TO 2014

It can be considered that in the maritime navigation, the new model of integrated navigation was fully realized at the turn of the century (XX/XXI). It is expected that changes to the navigational model must particularly affect the structural change of ships' failures structure in international shipping. The author's intention is to make a preliminary analysis of the failures of vessels groundings during 2000–2014. A group of vessels grounding accidents was selected for further analysis based on the reports from the following sources [Karlsen, Kristiansen, 1980; Minicki, 2015]:

- MAIB — Marine Accident Investigation Branch;
- MCIB — Marine Casualty Investigation;
- DMA — Danish Maritime Authority;
- BSU — Federal Bureau for Maritime Casualty Investigation.

Statistical data covers the years 2000–2014. Names of the vessels are shown in Annex 1 [Styliadis, Koliousis, ther's no year]. A group of 75 ships was tested. Causes of the accidents were divided into six groups. The results are shown in Table 1.

An important source of information on vessel groundings is their geographic layout. It's about the exact sailing area. Seven faults were identified. Table 2 shows the number of shallow entrances in particular areas.

Tab. 1. Causes of the accidents

Cause of accident	Percent in the whole amount of accidents
External conditions	9.5
Technical failure	6.2
Independent navigational factors	20.9
Navigational error	28.0
Human factor	33.6
Other vessels	1.9
Sum	100.0

Tab. 2. Number of groundings related to the sailing area

Sailing area	Number of accidents	%
Shores and shoals	19	25.3
Coastal waters	14	18.7
Straits	12	16.0

Sailing area	Number of accidents	%
Rivers and canals	11	14.7
Ports	8	10.7
Anchorages	8	10.7
Open sea	3	4.0
Sum	75	100.0

An interesting element of the groundings analysis is an identification by a ship type. The total number of analyzed vessels was divided into six types:

- general cargo;
- tankers;
- container vessels;
- ro-ro vessels;
- bulk carriers;
- other ships.

Table 3. presents the percent distribution of these categories.

Tab. 3. Grounding according to the vessel type

Type of the vessel	Number	%
General cargo	24	32.00
Tankers	14	18.67
Container vessels	13	17.33
Ro-ro	12	16.00
Bulk carriers	5	6.67
Other ships	7	9.33
Sum	75	100.0

The surprising result is the number of general cargo vessels. The remaining three categories are similar in terms of number of groundings. The frequency of grounding occurrence in various categories of ships is shown below with three main causes of grounding:

1. General cargo ships

1.1. Invalid watch organization 18.92%

1.2. Ignoring procedures 12.16%

1.3. Sleeping on watch 12.16%

2. Tankers
2.1. Errors in navigation 20.93%
2.2. Misuse of navigational aids 16.28%
2.3. Poor internal communication 11.63%
3. Container vessels
3.1. Inadequate coverage of watches 17.14%
3.2. Misuse of navigational aids 14.29%
3.3. Errors in navigation or maneuvering 11.43%
4. Ro-ro
4.1. Errors in navigation or maneuvering 16,67%
4.2. Strong external disturbances (wind) 16.67%
4.3. Ignoring procedures 13.33%
5. Bulk carriers
5.1. Errors in navigation 30.50%
5.2. Misuse of navigational aids 20.00%
5.3. Insufficient under keel clearance 10.30%
5.4. Limited visibility 10.00%
6. Other ships
6.1. Errors in navigation or situation evaluation 26.32%
6.2. Lack of expertise and inexperienced crew 15.74%
6.3. Inadequate watch coverage 15.79%

From the analysis of the grounding causes, it can be straightforwardly assumed that the main cause of this kind of a failure is a human error. In the summary of the causes of all grounding events, the following items may be listed in quantitative order:

1. Errors in navigation, maneuvering or situation evaluation.
2. Inadequate watch cover (time and hours).
3. Misuse of navigational aids.
4. Wrong organization of navigational watches.
5. Insufficient knowledge and experience of the crew (bridge staff).
6. Sleeping on watches.
7. Poor internal communication.
8. Bad weather conditions (strong external disturbances — wind).
9. No navigational equipment on the bridge, poor organization of the bridge.
10. Alcohol.

11. Technical malfunctions on the ship.
12. Bathymetric issues (wrong depth on charts).
13. Errors in nautical publications.
14. Failure of anchoring equipment.
15. Limited visibility.
16. Factors that change under keel clearance.
17. Bad interpretation of navigational marks.
18. Ignoring procedures.
19. Other vessels traffic.

CONCLUSIONS

1. Analysis of 75 randomly selected ships with have experienced grounding, represents a representative amount of information to identify the causes of accidents on sea-going ships in international shipping.
2. The results of the analysis show that navigational errors are the main source of ships groundings.
3. Despite the use of integrated navigation model on ships, the number of failures on the shoal has only decreased slightly.
4. The analysis of accidents reasons shows that the level of crew training on vessels in international shipping is rather poor.
5. The largest group of grounding causes can be attributed to the human factor, as it played a decisive role in 78% of cases. The main causes of accidents dependent on the human factor are as follows:
   - poor handling of marine systems;
   - improper organization of navigational watches;
   - poor internal communication;
   - lack of maritime knowledge and experience of bridge crew;
   - errors in navigation and maneuvering;
   - bad interpretation of navigation marks;
   - misuse of aids to navigation;
   - falling asleep;
   - alcohol consumption;
   - navigation error of other vessel;
   - other factors.

APPENDIX 1

List of ships groundings analysed in the paper [Manicki, 2015]

No.	Ship's name	Date of accident	Source
1	**Arslan II**	14.01.2014	MCIB
2	**Navigator Scorpio**	03.01.2014	MAIB
3	**Stena Alegra**	28.10.2013	MAIB
4	**Ovit**	18.09.2013	MAIB
5	**Fri Ocean**	14.06.2013	MAIB
6	**Danio**	16.03.2013	MAIB
7	**Douwent**	26.02.2013	MAIB
8	**Beaumont**	12.12.2012	MAIB
9	**Amber**	15.11.2012	MAIB
10	**Huelin Dispatch**	21.09.2012	MCIB
11	**Coastal Isle**	02.07.2012	MAIB
12	**Carrier**	03.04.2012	MAIB
13	**Norcape**	26.11.2011	MAIB
14	**CSL Thames**	09.08.2011	MAIB
15	**Karin Schepers**	03.08.2011	MAIB
16	**Pantanal**	31.03.2011	MCIB
17	**Clonlee**	16.03.2011	MAIB
18	**K-Wave**	15.02.2011	MAIB
19	**Arklow Raider**	16.11.2010	MCIB
20	**Maersk Kendal**	16.09.2009	MAIB
21	**TS Royalist**	05.04.2009	MAIB
22	**Maria Soltin**	29.03.2009	DMA
23	**Karin Schepers**	22.03.2009	DMA
24	**Mirabelle**	16.12.2008	DMA
25	**Antari**	29.06.2008	MAIB

26	**Moondance**	29.06.2008	MAIB
27	**CMV Norfolk Express**	30.05.2008	BSU
28	**MCL Trader**	17.05.2008	DMA
29	**Kemira Gas**	14.05.2008	DMA
30	**CFL Performer**	12.05.2008	MAIB
31	**Pacific Challenger**	09.04.2008	BSU
32	**Astral**	10.03.2008	MAIB
33	**Wani Will**	24.02.2008	DMA
34	**Sea Mithril**	18.02.2008	MAIB
35	**Riverdance**	31.01.2008	MAIB
36	**Pride of Canterbury**	31.01.2008	MAIB
37	**LT Cortesia**	02.01.2008	BSU
38	**Ladoga-3**	15.11.2007	BSU
39	**Quest**	27.06.2007	DMA
40	**Minerva Concert**	14.05.2007	DMA
41	**Volgo-Balt 209**	22.03.2007	BSU
42	**Golden Sky**	15.01.2007	DMA
43	**Aqua-boy**	11.11.2006	MAIB
44	**Harvest Caroline**	31.10.2006	MAIB
45	**Thunder**	10.08.2006	MAIB
46	**Plato**	04.08.2006	DMA
47	**Felucca**	03.06.2006	MCIB
48	**Kathrin**	12.02.2006	MAIB
49	**Berit**	05.01.2006	MAIB
50	**CP Valour**	09.12.2005	MAIB
51	**Dieppe**	05.12.2005	MAIB
52	**CMS Doria**	20.10.2005	BSU
53	**Lerrix**	10.10.2005	MAIB

54	**Bro Traveller**	17.09.2005	MCIB
55	**Anglian Sovereign**	03.09.2005	MAIB
56	**Halifax**	19.08.2005	BSU
57	**Sardinia Vera**	11.01.2005	MAIB
58	**British Enterprise**	11.12.2004	MAIB
59	**Stolt Tern**	01.12.2004	MAIB
60	**Balmoral**	18.10.2004	MAIB
61	**Jackie Moon**	01.09.2004	MAIB
62	**Waverley**	20.06.2004	MAIB
63	**Attilio Ievoli**	03.06.2004	MAIB
64	**HC Katia**	03.12.2003	MAIB
65	**Jambo**	29.06.2003	MAIB
66	**Sea Hamex**	28.01.2003	MCIB
67	**Sea Mariner**	08.09.2002	DMA
68	**Whithaven**	09.03.2002	MCIB
69	**Sardinia Vera**	01.02.2002	MAIB
70	**Willy**	01.01.2002	MAIB
71	**Princess Vanya**	01.12.2001	MCIB
72	**Lysfoss**	07.05.2001	MAIB
73	**Finnreel**	14.03.2001	MAIB
74	**P&O Nedlloyd Megellan**	20.02.2001	MAIB
75	**Asian Parade**	02.02.2000	MCIB

MAIB — Marine Accident Investigation Branch
MCIB — Marine Casualty Investigation Board
DMA — Danish Maritime Authority
BSU — Federal Bureau for Maritime Casualty Investigation

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Received April 2017
Reviewed August 2017
Published 29.09.2017

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STRESZCZENIE

W artykule przedstawiono wpływ zmiany modelu nawigacyjnego na zmiany strukturalne i jakościowe powstawania awarii wejścia statków na mielizny w żegludze międzynarodowej. Opracowano dane na podstawie raportów wejść na mieliznę 75 statków morskich w żegludze międzynarodowej w latach 2000–2014. Niniejsza praca stanowi próbę oceny przyczyn powstawania awarii wejścia statku na mieliznę w nowym modelu zintegrowanej nawigacji morskiej.