PROBLEMS OF SEAGOING NAVIGATION IN BOSPHORUS STRAIT

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ABSTRACT. – Problems of seagoing navigation in Bosphorus Strait. Navigation in the Black Sea basin has been known since ancient times and the old navigators used to pass from one sea to another through the main straits. In this case the Bosphorus Strait was the main passage between the Mediterranean basin and the Black Sea. Passage of vessels through the strait is hampered by several physical and geographical factors: morphology emersion and submersion, the hydrological and climatic parameters. In this respect the Turkish government had to raise the lights, to establish anchoring and mooring areas, to protect the coast, etc.. Due to the facts that the depth of the strait is extremely small, only 35 m in the northern part, at the entrance from the Black Sea, deep draft vessels have to travel at low speeds and use the high performance sonar. The fog, common in transitional seasons, often hampere navigation and very many accidents happen because of this inconvenience. Most accidents due to weather conditions (fog, wind) are specific to small vessels, which are not equipped with modern navigation equipment. The existence of surface currents, with the dominant north-south direction, from the Black Sea to the Mediterranean, affect navigation only around heads and islands where causes circular currents. In this case are affected only pleasure boats or those who have small engines. Bosphorus Strait is one of the most important waterways of the planetary Ocean .

Keywords: strait, navigation, risk, morphology , hydro-climatical factors.

1.INTRODUCTION

Although the Black Sea is considered an inland sea, navigation is extremely busy as Romania, Bulgaria, Ukraine and Georgia, four of the 6 riverain countries, have no other opening to the planetary Ocean. In this context Bosphorus Strait acquires a special importance and the Turkish authorities seek reasons for maintaining it at a maximum operational level.

In terms of geography, physical and human, the strait has been extremely well studied, but, in terms of interdisciplinary connections between the natural environment and how it affects navigation, investigations were undertaken only vague.

This study tries to highlight some links between the natural condition and the intensive navigation or, especially, the shortcomings created by the existence of risk factors on the movement of the seagoing ships.

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The biggest difficulty in finalizing of this work is the fact that the most required data for carrying out this study focused not only on a single beneficiary, but to many companies that are sometimes skeptical to provide information. For this reason it was used only the material obtained via mapping and interpretation of raw data from meteorology and hydrology.

For navigation in the Black Sea and the adiacent straits were printed publications with general and particular character by the *United Kingdom Hydrographic Office*, London, 2003 and *Service Hydrographique et Oceanographique de la Marine*, Paris, 1994. In this direction can be used the reference works developed by: *Penck, 1919, Bratescu, 1942, Algan et al., 2001, Yilmaz, 2006, Oktay et al., 2002, Major, 2002, Major et al., 2002, Gökaşan et al., 2005, Ylamy, 2006, Eris et al., 2007, Gökaşan et al., 2009,* etc.

2. REGIONAL SETTING

Bosphorus Strait, known as the Strait of Istanbul, has a length of about 32 kilometers and a width of 1.5 kilometers. It lies between the Istanbul peninsula (Europe) and Kocaeli Peninsula (Asia Minor). The Black Sea entrance is 4.7 kilometers wide and the exit to the Sea of Marmara is only 2.5 kilometers. The narrowest sector of the Strait does not exceed 600 m (Fig. 1).

Fig. 1. ***Bosphorus Strait – Satellite images***
(after NASA, in 2004)

The maximum depth reaches 120 m at the entrance from the Black Sea, and the lowest is recorded near the south entrance from the Sea of Marmara, which reach 36 m in the strait are two thresholds, one in the south, near Beşiktaş, to 33 m depth and another in the north by 61 m.

The strait's route is very sinuous and narrow. Hydrographic factors, in addition to the morphological ones, are extremely variable and misleading, making navigation very difficult due to busy traffic conditions, both across and along the strait. With all these difficulties for navigation, Strait has maintained his most important function of the single waterway linking the Black Sea and Mediterranean.

The boundaries of the navigation zone governing maritime traffic in the Bosporus Strait are: - the north area is bounded by a line joining points 41º16 'lat. N, 28º55' long. E; 41º21 'lat. N, 29º16' long. E; 41º21'lat. N, 28°55' long. E; 41º14' lat. N, 29º16' long. E; - the southwest area is bounded by the line joining the head and Yelkenkaya Burnu point is located 2 nautical miles away from the alignment south of town Buyuk Cekmece Baba-Burnu.

3. METHODS, TECHNIQUES, MATERIALS

Such an intensive study requires a labor team, from which to obtain and analyze information from different sources and areas.

The most important information was taken from the cartographic material used in navigation, but also those developed by geologists, geomorphologists, hydrologists, meteorologists, etc.

The details of the maneuvers to be made to in the existence of special events for navigation were taken from textbooks, literature, and also from personal experience of the vessel ordered for 25 years.

At the same time were consulted also materials from media covering the accidents occurred in the area of the Bosphorus and Dardanelles straits, or the Black Sea and even the Mediterranean.

Hydrological and meteorological stations in Istanbul have provided the most important data on currents, waves, fog, strong winds, etc.

4. RESULTS

The latest studies on palaeogeographic evolution of the Bosphorus Strait (*Gökosan et al, 1997*), supported by other specialists (*Gorur et al., 2001, Aksu et al., 2002, Hiskott et al., 2002, Hiscott and Aksu, 2002 , Mudie et al., 2002, Oktay et al., 2002*, etc.) have demonstrated the formation of this connection through 4 stages:

- baseline, a river, longer spill in the Sea of Marmara and beyond the turn of water, a river north, much shorter, spill into the Black Sea;
- second stage, which forms a small tectonic basin, located between Buyuk - Dere and Beykoz, changing the structure of river network;

- third stage, when there are intense tectonic processes that outlines the general structure of the strait south of the divide that persists to the Black Sea;
- fourth stage, where most faults are reactivated, and north to the Black Sea, the waters turn collapses, forming the last section of the strait.

The first three stages were conducted in the Pleistocene and the last, after the peak of the last glaciation (Würm).

Petrographical composition of the Bosphorus Strait indicates the existence of rocks belonging Paleozoicului (sandstone, clay shale, crystalline limestone, conglomerates, arkoze, quartzites), Cretaceous and Miocene (mainly limestone and conglomerates). Are pierced by an eruptive represented Diabaz and borders of the upper Eocene period.

Tectonic model of the Bosphorus Strait region indicates the presence of two faults north and south of the strait, and several faults oriented northeast - southwest, which delimit blocks in rotational motion in the direction of movement of those clock (*Oktay et al., 2002*). Seismic sections revealed 14 faults present in the current structure of the Strait between the fault 13 and 14 are the latest, dated as having 7 400 to 7 200 years. They have determined the collapse of the old balance of water starting at 250 m altitude, heading date, located at -70 m (*Gökasan et al., 2002*). Transverse seismic profiles, reveals the role of faults in the formation of the Straits.

Early communication between the Marmara Sea and Black Sea through the Bosphorus Strait, was given the Quaternary (*Penck, 1919*), Andrew - Levantine (*Bratescu, 1942*) or the end of Pleistocene - Holocene (*Gökaşan et al., 1997, Ryan et al., 1997, Major et al., 2002, Aksu et al., 2002, Hiscott and Aksu, 2002, Hiscott et al., 2002, Gökaşan et al., 2009*, etc.).

The link between the Mediterranean Sea and Black Sea has been conducted on the principle of catastrophic discharge (*Ryan and Pittman, 1999*). Based on the analysis of samples collected in the northern Black Sea during the Russian expedition – American in June 1993, the authors argue the following sequence of events:

- 17 000 years ago the Black Sea was a freshwater lake, whose level is at about -140 m above the present level;
- The 14 000 years ago, the Black Sea rose to -15 m from the present, while the Marmara Sea is at -60 m from the present. There was a violent flow of water Black Sea through the Bosphorus Strait, Marmara Sea to the formation of this sea cone Self submersion;
- 9 000 years ago the Black Sea dropped to -120 m from the current level and the Marmara Sea level rise from -60 m to -30 m from the present. Threshold of a dam north of the Bosphorus is effective for maintaining the Black Sea in isolation;
- In 7 200 years ago Marmara Sea level rise from -15 m and the Black Sea dropped to -156 m from the current zero. Threshold of northern Bosphorus collapses forming a huge waterfall that Mediterranean waters are leaking at a rate of 50 to 100 km^3/day (*Görur et al., 2001*). Thus the Black Sea level rose from -156 m to -10 m in a year. The authors associated this increase catastrophic water Black Sea Flood myth Bible.

On entering the Bosphorus Strait, Marmara Sea presents a delta submersion which reduces its depths. Therefore ships, especially those with deep-draft, need to follow that fairway passing this area. In this case the Asian shore of the Marmara Sea has reduced depths, and the European higher.

Climatic factors with positive and negative influences that affect navigation in the Bosporus Strait are the winds and fog.

Winds have general direction NNE-SSV and channels along the corridor by encouraging the passage of the N-S direction and preventing it, on the opposite direction, for the large vessels. When the winds beat lateral vessels are required to position itself as route and fuel consumption, and attention increase. Low tonnage vessels failed to strong side winds.

In the past, the most important impediment in coastal navigation in the Bosporus Strait was represented by fog. Following the facilities with radar equipment, but also the appropriate signs, this phenomenon is now much diminished. Fog may be dangerous now only for fishing vessels or those with not suitable equipment. Mist-frequency is higher in the transitional seasons (spring, summer) but also in winter, or in the morning. There is a certain connection between phenomena on the occurrence of fog and shipping accidents in the strait, but not very obvious.

Black Sea has a positive hydrological balance: surplus that flows into the Sea of Marmara, through Bosphorus, the only communication with the planetary Ocean. In turn the Black Sea recieve water from Mediterranean origin with a deep current of high salinity. Surplus of fresh water (river intake + precipitation - evaporation), first, and the waters of Mediterranean origin, second, results in the Black Sea hydrological structure specific, with strong stratification of salinity and density, with a minimum temperature in the layer located between 50 - 100 m, by reducing oxygen with increasing depth, until its total disappearance of the 200 m, the presence of hydrogen sulfide starting from about 150 m, etc.

Average volume of water coming out annually from the Black Sea is about 260 km^3, and that of water which penetrate deep current is about 123 km^3.

In the Bosphorus Strait are two major currents, both of whom are permanent, in the same direction: the surface current from the Black Sea to the Marmara Sea; the deep current, from the Sea of Marmara to the Black Sea.

The main cause of the occurance of the currents in Bosphorus Strait is the existence of constant water leak from the Black Sea to the Mediterranean. Leakage is caused because the Black Sea area is situated at a higher level than the Sea of Marmara. The average is 0.4 m. The volume of water carried by the current surface is 2.5 times the volume transported by the counter current (*Algan et al., 2001*).

Average speed of maximum current in the Bosporus Strait, under normal conditions, is from 4 to 5 knots at Cape Beylerbeyi (41º03' lat. N, 29º03' long. E) to Kadikioy, increasing to 7 knots under special conditions from head Rumeli Hisar and Anadolu Hisar city. In this area is known as „devil's current".

Average speed, in normal circumstances can be judged from 2 to 2.5 knots in the Bosporus Strait and between 1 to 1.5 knots in the Dardanelles. Surface

current in northern strait, extending to a depth of 40 to 49 m and in the south only by 10 to 20 m.

Morphographic and morphometric characteristics, climatic conditions and sea currents, are natural factors that can positively or negatively affect navigation through the Bosphorus Strait (*Romanescu, 2008*).

5. DISCUSSIONS

Most accidents occurred in the Bosporus Strait was caused by negligence or phenomena related to hydro-climatic conditions unfavorable.

It should be noted that in normal conditions in the Bosporus Strait means that there is a wind direction NNE-SSV, which have a force of 2 to 3 on the Beaufort scale (in the strait), and atmospheric pressure are the 2 to 3 mb in May higher than in Izmir.

In winter occur winds with direction SE–NW and SW–NE, when depressions passing over or around the region. These winds, especially those from SW–NE, causes the increase of water level and, in the same time, weaken or expand current product. Sometimes, if the wind is very strongly opposed to current, current width begins to decrease or even be replaced by another current sometimes weak, led by wind in a northerly direction. If the mainstream is so reversed, wake vortex side reappear, turning the road opposite the normal direction, with countercurrents going south on the coast near each bay.

Current with direction N–S reaches a speed of 0.5 to 1 Kn to Garipce and Poyarz Burun, occupying the full width of the strait. Between Fil Burun and Dikilikaya, current focus will be in the vicinity of European coast and slowly increase speed to 1 Kn. Further current moves to head Kavak Burun, reaching speeds of 1.5–2 Kn. From Akartabya by Selvi Burun current focus is on the east coast and the speed is 1 to 1.5 Kn. Current doesn't enter in the bay of Buyukdere Limani and bound to Kirec Burun and Zmur Banky. Between Selvi Burun and Tarabya Koyu current fills the strait and has a speed of 1 to 1.5 Kn. Next leave the east coast and reached shore in the right of locality Yenikoy. South of Istinye Koyu, till Kandilli, fill again the whole strait. From this point to the southern entrance the current follow the east coast of the strait and reaches speeds of 3 to 4 Kn. In special circumstances current can reach speeds of 7 Kn, particularly between hussars Rumeli and eastern coast. The high speed may occur also in conditions of storm wind with direction N–S, when southern winds ceased activity.

This high-speed marine currents and the existence of a sinuous route through the narrow corridor make a barrier to normal navigation. For this reason it requires increased vigilance on the part of seafarers and large and deep-draft vessels are required to have on board a Turkish pilor, good knowledge of these places

For small tonnage ships and for most pleasure boats are very dangerous circular currents. Their existence is due to the multitude of heads, bays and parts with varying depths.

In the northern strait, the entry into Halic (Golden Horn), north of Arnavutkoy (41º04' lat. N, $29^0$03' long. E), formed strong circular currents known popular Whirls.

A second circular system of currents is in the Gulf Bebek Koyu. Countercurrent along the coast of north-east of the Galata – Defterdar Burnu, is stronger in the afternoon and evening decrease in force. Normal current speed is over 0.5 Kn. In the presence of winds of the south-west the vortex of Defterdar Burnu may disappear completely. In this situation the mainstream may occupy entire width of the Straits.

In the southern Strait, wake vortex is more near the west coast and less near the east.

North of town Uskudar is showing a narrow strip of counter, running due north along the coast. When there winds of the south-west, this counter is expanding, reaching even to the middle of the strait.

Between Kandilli and Anadolu Hisar is located a little whirlpool, with weak influence on navigation and Kanlika north, the west coast, another whirlpool is formed like. Further, to the north, is a complex system of vortex flow. This whirlpool is crossing the middle bay Buyukdere, following their route north-east along the coast, through the right head Mezar Burnu. Normal speed countercurrent is 0.5 Kn.

If mainstream is stronger, where the width is reduced and, a whirlpool is formed near Kirec Burnu, which extends its position to Mesar Burnu. In this case, another whirlpool is formed in the north-east of acetic last point, which extends up to Tellitabya Burnu. Usually this whirlpool is formed from strong NE winds.

On the east coast, from Cape Selvi Burnu to the north entrance of the Strait, there is a circular system of currents, rather wide, stretching from coastal cable 4. Counter form of the vortex flow along the coast, from Incir Limani to Beykoz Limani, with a speed of 0.5 Kn.

When the water level in the strait is high because of strong winds from the south (with force 7/8 - storm), and the wind suddenly changes direction, the Black Sea water is directed through the strait with an increased force to Koybaşi. At the same time formed a very strong whirlpool in Incir Limani and Beykoz Limani. In such conditions, in these bays the counter current is extended further than the middle of the Straits. Edge mainstream reach Selvi Burnu.

In the north of Umureri Limani is a large whirlpool, where the mainstream will go on the main route and passing the north of the bay Kavak Burnu. The mainstream;s whirlpool, directed to Kavak Burnu, is separated by a circular system which occupies the entire area of bay Kecilik Koyu. A countercurrent is heading north along the coast of the bay Kecilik Koyu, at a rate of speed of ¼ Kn. The cape Fil Burnu is separating the whirlpool from the bay Kecilik Koyu by the small whirlpool that occupies the southern area of Poyraz Burnu. In the west, in Buyuk Limani, it is a whirlpool and a wide countercurrent, which is heading north, between Garipce Burnu and Rumeli Hisar.

Hydrographic ensurance, for optimal navigation in the Bosphorus Strait, consists in:

- construction and installation of navigational lights and signals required for orientation;
- editing of navigational charts and of charts catalogs (necessary for choosing of the charts used on a special navigation area or for a particular trip);
- permanent and operational organization of navigational information through "Notices to mariners" and "hydro-meteorological Bulletins" who inform the masters about the changes of navigation conditions;
- preparation of detailed descriptions on shipping (Pilot Books), which contains information on navigation conditions;
- editing of the documents which contain nautical information such as: characteristics of navigational aids ("List of Lights", "List of Radiosignals"); tide characteristics ("Tide Tables"); shipping routes (the safe and economic); nautical stars coordinations; nautical almanacs.

Hydrometeorological information is achieved by:

- gale warnings;
- synoptic-codes (SYNOP, SHIP, MAFOR etc.);
- weather bulletins (especially radio, in VHF, in English language).

Gale warnings are received through Inmarsat systems, NAVTEX, facsimile, etc. All ships in the area receiving weather bulletins continuously. Gale warnings are received continuously; this causes audio-visual alarms on the main navigational bridge. Notices of gale warnings received by NAVTEX and Inmarsat are official juridical documents, same as the logbooks being evidences for damage caused to vessels.

For safety of navigation in the Bosporus Strait, ship's officers are obliged to make appropriate hydro-meteorological observations. This observations can be made when the ship is underway (to avoid bad weather areas, prevent difficult situations when the ship is in a storm area, choosing the right way against wind and wave, early manoeuvre for reducing hazards in which can be the ship at a time), on the road (early prepare of quickly departure manoeuvre to leave the anchorage area; quickly going to open sea; and choosing the right way of the ship against wind and wave depending of loading situation the), at the quay (multiply the shore lines in advance; stop or restrict the loading operation) etc.

Due to the great importance that Bosphorus Strait has now for navigation was urgently required to legal regulation of the transit condition. First legal regulatory regime for the passage of vessels through Turkish Straits was signed at Montreaux in 1936 (Switzerland).

6. CONCLUSIONS

Although navigation in the Mediterranean basin, and implicit in the Black Sea, is datin from old historical periods, rules for use of the straits have been issued much later, in 1936.

Bosphorus Strait is the only link that connected the Black Sea with the planetary Ocean and because of that several countries (Ukraine, Romania, Bulgaria and

Georgia) can use only this route. Hence its strategic importance, economic, geopolitical is extremely important for the riverain countries.

Due to the fact that Bosporus Strait has small depths, a sinuous, steep shores, strong surface currents and whirlpools in the bays, the navigation is hindered and sometimes dangerous.

From this reason the strait's technical navigational equipment is very modern and effective.

Infrastructure with all facilities is not preventing all dangerous situations; catastrophic accidents still occur and often navigation is interrupted due to hydro-meteorological risk conditions.

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