JOURNAL OF MARITIME RESEARCH

Vol. IX. No. 2 (2012), pp. 67 - 72

ISSN: 1697-4840 www.jmr.unican.es

The Seasickness Phenomenom

J.M. Riola* and R. Pérez[1]

ARTICLE INFO

Article history:
Received 06 March 2012;
in revised form 02 April 2012;
accepted 01 June 2012

Keywords:
Sea sickness, safety on board, marine engineer, ship movements.

ABSTRACT

Motion sickness is one of the main reasons why transport by sea becomes a bad memory for a number of people, mainly due to its main symptom, nausea. The aim of this technical paper is to characterize from a mathematical and psychological point of view a condition that has affected many of us in a personal manner. Regarding the mathematical characterization, an existing model will be reviewed and described. In the psychological aspects, a statistical study of two hundred and thirteen people was performed in order to provide a comprehensive view of the different psychological factors affecting the passengers. Motion sickness also impacts onboard safety, as it reduces the effectiveness and the operating capability of the crew when responding to hazardous situations..

1. INTRODUCTION

Antonio de Guevara (Guevara, 1559) lived between the XV and the XVI century, and although he can be cited as a bishop or historian, as well as official chronicler at the court of Charles I, he documented to the naval world some accounts of his travels with the Emperor, to England in 1522 and Tunisia in 1535. In his mind to explain life on board the galleys, Fray Antonio devoted to the topic of seasickness and recorded several descriptive paragraphs *"on entering the force of the sea, made so much violence in our stomachs and heads, parents and children, old and young men of colour were left paralysed, and began to release the soul from their mouths together with everything that they had ate that day and previously"*. And with his huge spirit the healer recommended *"so that you do not feel dizzy or ill at sea, put a paper of saffron on the heart and you may stay upright in the boiling of a storm"*.

This paper will not dare to discuss the remedies of Fray Antonio, just to bring some light to the phenomenon and resolutely join his complaint:*"It is incredible that in the Renaissance, science cannot remedy such a wretched state!"*.

For general sickness using the term motion sickness and for the more specific meaning of motion seasickness, it uses the term sickness. But the most important part to know is why there is this dreaded affliction. The role and sense of roll is well known to keep the body position and coordinate the movements. The vestibular apparatus or organ of roll is located inside the bony labyrinth in the temporal bone and has a three-dimensional structure. Actually the function of this effect is evident only when needed. Within the cavity of the bone is the membranous labyrinth, composed of epithelial sheets.

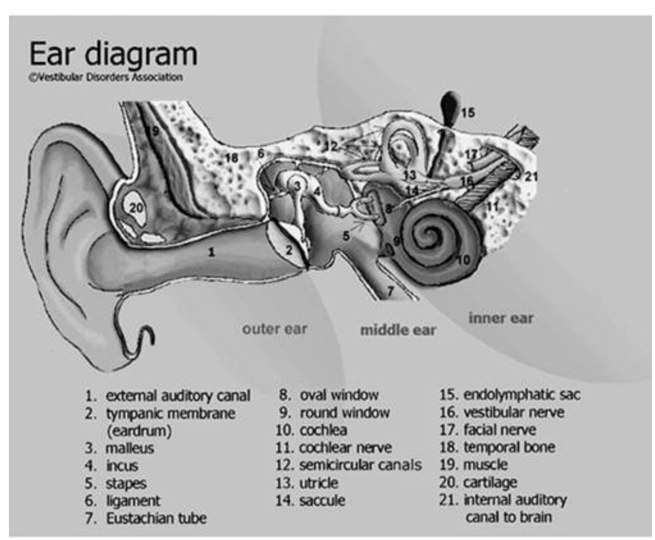

Fig. 1. Ear diagram. SOURCE: http://www.vestibular.org

* Corresponding author. Phd Naval Architect, Escuela Tecnica Superior De Ingenieros Navales Upm, Arco De La Victoria 4, 28040 Madrid, Spain. Email: josemaria.riola @upm.es, Tel. +34 625370225.

1 Phd Naval Architect, Etsin Upm, Arco de la Victoria 4, 28040 Madrid, Spain. Email: rodriperfer@hotmail.com, Tel. +34 636394699.

Journal of Maritime Research, Vol. IX. No. 2 (2012), pp. 67-72

This labyrinth is filled with endolymph and the exterior contains perilymph. The labyrinth has two structures: the three semicircular canals and two otolith organs, known as bags and saccule utricle, which are the cause of the phenomenon being studied. The utricle and saccule have an area, the macula, which is covered in hair cells. Both maculae are covered with a viscous tissue, which contain calcium carbonate crystals, the otoliths. In vertical position, the macula of the utricle is in a horizontal plane and the saccule in a vertical plane. The utricle and saccule stereocilia are embedded in the gelatinous otolithic membrane.

When one moves their head to say no, the brain receives information from both sides simultaneously through the vestibular nerve, consisting of an increase in pulse rate from one side and a reduction in the opposite direction. The semicircular canals are sensitive to movements of the head tilt and influence to angular or rotational acceleration of the head with respect to any of the three axes. Sensory transduction in the utricle and saccule, the force that causes the ciliums, is the inertia that causes displacement of the otolithic membrane shear with respect to the layer of ciliated cells, an effect that is amplified because the otoliths are denser than the membrane itself. The utricle and saccule can respond to any static tilt or acceleration of the head, arising from its own motion or gravity, so that the semicircular canals, which incidentally are circular, are more sensitive to the speed and the utricle-saccule sensitive to accelerations. The dizziness is usually caused by the fluid that stimulates the hair cells of the semicircular canals having an inertial strength when the body has stopped moving. However, the final causes of this mishap on boats are the otoliths of the utricle and saccule, being the most sensitive to vertical acceleration. As to the peculiarity of the reaction of vomiting, is due to a reflection of the autonomic nervous system, which has abundant sensors along the digestive system and needs to be free of everything superfluous, such as food, to remedy the problem of roll and allows to the body to send all the blood that the central nervous system may need to solve it.

2. Seasickness phenomenom

Seasickness is commonly defined as the unpleasant subjective sensation of unsteadiness, discomfort and nausea usually associated with a personal impression of complete physical disability. The symptoms start with malaise, soon followed by nausea and vomiting, dizziness, cold sweats, heartburn, weak pulse and a depressive mental state. The movement of ships

at sea are the cause of seasickness and can be mitigated. In fact, one of the constant concerns of naval engineers because such movements are the cause of many ship failures.

A ship at sea is excited by the waves and move around in response to its six degrees of freedom, so the vessel will swing and turn on each of the three spatial axes. These movements depend on various circumstances, first, the state of the sea in that area, which is determined by the waves and the period between them. Manoeuvring itself also influences the speed and direction on the sea and the ship's characteristics, forms, mass and inertia. Of the six possible moves are roll, heave and pitch being the greatest influence on the seasickness, but research in this area concludes that without any doubt, that it is the vertical accelerations, both in frequency and amplitude that are the main causes. If the frequencies of the oscillating vertical accelerations are close to the natural frequencies of the ship, the resonance conditions will increase the amplitude of oscillations. By decreasing the capability of the crew there is a reduction of the operation of the systems and the general safety of the ship.

To compound this phenomenon, no two people have the same response to the same movement, or even that the responses are the same for one person at one time or another. The existence of ongoing movements can represent a slight decrease from faculties to a state of total loss of working capacity. On one hand to take into account the maximum allowable movements to perform certain operations with a minimum of security, made in one area for a limited period of time and, secondly, the amount of supported movements for an extended period. In the first case, a method of using a lateral force estimator can be used. This is to assume that the crew has to perform a job at one point holding up without falling. The limit of allowable movements will be one in which the combination of forces: weight, inertia forces due to vertical and transverse accelerations and wind power, a result that does not leave the base of support. For example, for a crew working on a wind-protected deck with slip-resistant shoes, looking in the fore-aft direction and assuming that the three most important movements are those of roll, heave and pitch, the movement limit can be estimated from the expression:

$$z + (\Phi \cdot x) + \Theta \cdot (4 \cdot z + y) \leq \left(\frac{g}{\omega^2} \right) \quad (1)$$

But of course, this level of movement, necessary to bring down a person is unthinkable in a passenger ship. In this case there is the wider significance onset of seasickness with a loss of comfort that it entails. In the initial publications about sickness on ships, the level of the roll movements have been used most frequently as an indicator, not because there is a direct relationship between their size and appearance, but because they were the most important and most studied some decades ago.

As stated in the work (Griffin, 1984), there have been many papers on the relationship between the movement of vessels and the occurrence of motion sickness in passengers. In the same way that in those physiologically, it is concluded that the root cause of an outbreak of this disease is the vertical acceleration a passenger gets for some time. It will analyze the model for calculating the probability of sickness of a passenger on a boat on the regular incident wave train. Defining a Cartesian coordinate system referring to the ship, with origin located in the centre of gravity, and based on oscillatory movements of small magnitude, it follows that the vertical acceleration, instant, at one point the ship, with coordinates *(x , y, z)* is given by the expression:

$$a = z'' + (\Phi'' \cdot y) + (\theta'' \cdot x) \quad (2)$$

The instantaneous vertical acceleration is the only function of the horizontal position of the person and the value of the movements of heaving, rolling and pitching. These three movements are not independent. Most are produced by the waves, and in the case of regular waves of period T_W, the three would have a sinusoidal waveform of the same period. What is possible is that there is a lag between them. Given that passengers are generally distributed in all four quadrants of the vessel, it follows that an error is not significant when taken as an average value of motion in a period of several minutes or more:

$$M^2 = Z^2 + (\Phi^2 \cdot y^2) + (\Theta^2 \cdot x^2) \quad (3)$$

Having defined the acceleration that the passenger is under must be related to their effect on motion sickness. The experts in the field use the concept of dose dizzying movement, or that causes seasickness, *Motion Sickness Dose Value (MSDV)*, which is the product of the *RMS* acceleration by the square root of time considered. The probability that a passenger suffered seasickness, or the percentage of those who suffer within a collective, is a first approximation, proportional to this parameter. In order to facilitate statistical analysis, different authors consider that there is seasickness when the passenger begins to experience vomiting, allowing field measurements to be made sufficiently reliable. This should be taken into account in interpreting the final results of tests carried out with this model. In order to normalize the relationship between dose *MSDV*, or the level of acceleration, and the state of illness of a group of passengers, various standards have been established among which *ISO* and British Standards.

To speak of incidence data and quantify the effectiveness degradation defines two operational criteria, the *Incidence of Sickness (Motion Sickness Incidence-MSI)* and *Task Interruption (Motion Induced Interruptions-MII)*. There are other possible criteria such as *Vomiting Incidence BS6841/87* basis of *British Standard*, *ISO 2631* for use in high-speed vessels, the Subjective Illness Rating or Motion for small vehicles. The incidence approach to seasickness *MSI* is based on the results of tests over three hundred volunteers, conducted by (O'Hanlon and McCauley, 1974), which is the basis of *MIL-STD-1472C*. *MSI* define as the percentage of subjects who vomit after two hours of motion and relate it to the vertical accelerations suffered by the ratio:

$$MSI = 100 \cdot \left[0.5 \pm erf \left(\frac{\pm \log_{10} \frac{a_z}{g} \mp \left(0.819 + 2.32 (\log_{10} w_e)^2 \right)}{0.4} \right) \right] \quad (4)$$

Where *erf* is the error function, a_z is the vertical acceleration mean and w_e is the dominant frequency of encounter with the waves. The task abort criterion is based on *MII* knowing how many times per unit time due to movements large enough for a slip or loss of roll, the operator is obliged to interrupt the work task, changing his position or holding. *STANAG* recommended a thirty-five percent of *MSI* in two hours, or twenty percent in four, a break of one minute and vertical acceleration with a mean square value of simple amplitude *0.2 g* and operating limits. With the acceleration values obtained were calculated operational criteria *MSI* and *MII* on the premises most critical of the ship. The main deficiency is that *MSI* index does not include staff habituation over time. Although dependent on weather patterns of each case, it seems that as a rule, there undergoes a maximum three to five hours of exposure, progressively reduced and cancelled virtually for all of the crew, there are always exceptions, between two and five days.

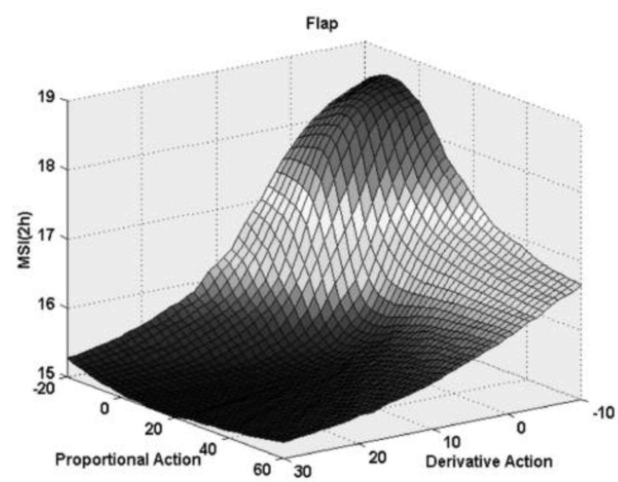

Fig. 2: MSI data[4].

The purpose of the criterion is to obtain the *MSI* values for each state of the sea, course and speed. *MSI* has a maximum in a frequency range close to *0.17 Hz*, but with the speed of the ship and her encounter with the waves, the area of maximum discomfort and move graphs can be obtained *MSI* course and speed manoeuvre to exit the area by reducing the movement and improving comfort on board. The tasks that require a minimum of manual dexterity have difficulty on the basis of accelerations *1.75 m/s²*. To design appropriate forms as possible to decrease the problem of this study, it will be needed to know the excitation source, in this case the waves, the response of the vessel to the excitement and impact of such movements on the welfare of people (Pérez & Riola, 2010).

3. Study of factors afflicting passengers

A wonderful sea voyage could be cancelled and even become a series of curses for humans afflicted with an intrinsic propensity: the seasickness. The data package for the implementation of this article have been collected on the ferry that covers the route between the island of Pangkor and Lumut (Malaysia), the ferry that connects the island of Niteroi in Rio de Janeiro (Brazil), a Norwegian cruise ship, a British merchant ship and a ferry from the Spanish Mediterranean, during the years 2007 and 2010 (Giron et al, 2003).

Something very common in the survey, was the fact that male respondents, felt that the seasickness is a sign of weakness in a man that is unacceptable and should be for this reason, by which, most of them minimized the effects that they were airborne, coming to boast of their capability with the condition. Seventy-four percent of respondents were male, and the remaining twenty-six percent were female. It seems that women more than men felt dizzy, but the ones most affected by motion sickness, according to the sample, are children, since, from their limited perspective; note that it moves them around violently.

The elderly also often experience this difficulty. It is possible that women, more than men are prone to becoming dizzy while travelling, but there is no substantial research that proves it. It is true that during certain periods such as menstruation or hormonal pregnancy, lower sensory capacities of women, may make them dizzy more easily, but according with this study, in general, the women are not more prone to this inconvenience. Of fifty-five women surveyed, thirty-four were seasick.

Some experts think that the seasickness is caused by a conflict between incoming somatosensory information to the brain for rolling. Because this entity occurs widely in women it could be related to sex hormones such as estrogens and progesterone. It could be a genetic link, related to the two copies of chromosome X, combined perhaps with another susceptibility factor. It seems unlikely to be a psychological disorder that affects more women than men, although it is always difficult to exclude, the man-woman relationship and clinical aspects are hard to believe that this entity is only psychological in origin. Fourteen women with babies on board were surveyed, only three were seasick.

Emotional factors, such as fear, anxiety, acting together with the movement to cause seasickness, and a mother caring for her young child lacks these agents most likely to affect them. Most of the mothers surveyed who were responsible for a child, failed to notice the symptoms of seasickness, possibly because maternity stimulates blood flow and reactive circulation, clears the mind and while the mother/father is in charge of a child, the sight and hearing will send the feelings of lightheadedness. There may be reciprocity in how disparate researchers understand infant behaviour, infant-mother relationship, describing this relationship offers functional feeling for subsequent relationships that the child will develop in his/her life.

Scientists believe that the most important factor in the development of dependence *mother-son*, physical contact is positive and that these specific activities cause neurochemical responses in the brain that lead to normal organization of brain systems responsible for attachment. The special bond that forms between mother-infant or primary care giver-infant has several key elements:

- It is an enduring emotional relationship with a specific person.
- This relationship produces security, peace, comfort, pleasure and enjoyment.
- The loss or threatened loss of the person evokes intense anxiety.

The effect of habituation or acclimatization is very important, and makes the incidence of occurrence different for the crew than that of the passengers. It is possible that during a long voyage on a cruise, passengers get used to the movements of the ship. Seasickness is likely to further affect the passengers on board ship rather than sailors who are accustomed to the movements of vessels. Passengers who are on board for transportation needs are affected by this nuisance to a lesser extent than the passengers on board cruise ships. But the transportation needs of these passengers' mean they significantly suffer more illness than the crew members. This can be because they may not have prepared well for life on board, or it may mean more simply that people, who are often used to sailing or travelling on passenger vessels of a short duration, may not be as uncomfortable because they have already completed the journey. The data obtained in surveys can be seen in *Figure 3.*

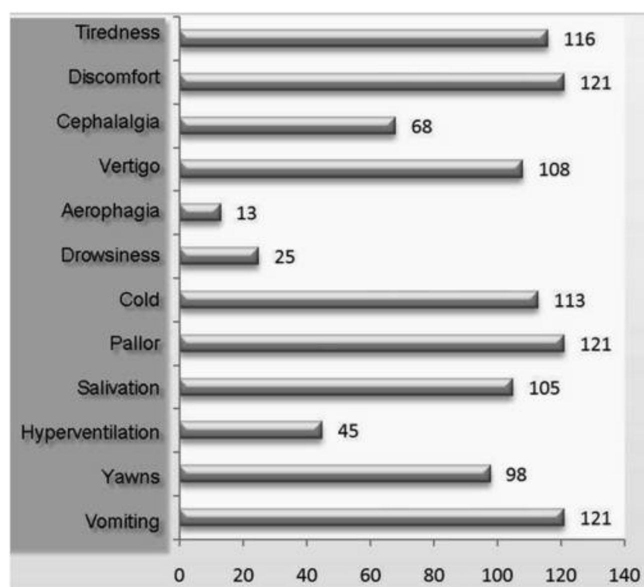

Fig. 3: Seasickness symptoms in the passengers

Research on motion sickness is often restricted to consider cruise ships, as this is the case where these are the greater proportion of annoyance, besides being the most substantial in loss of profit, which means a passenger cannot leave the cabin, and are unable to enjoy and spend money on their travel. Cyclic nausea and vomiting are characteristic of respondents (Arieli et al, 1999). This can be preceded by yawns, hyperventilation, salivation, pallor, cold sweating and abundant drowsiness. Aerophagia may occur, dizziness, headache, malaise and fatigue. When nauseous the patient is weak and unable to concentrate. With prolonged exposure to motion, the patient can adapt and recover their well-being. However, symptoms may reappear if the person increases the movement or motion resumes after a short stop. Motion sickness can cause vomiting, prolonged hypotension, dehydration, starvation and depression. Motion sickness can be a serious complication in patients with other diseases. Being tired and tense increases the vulnerability to sickness. It is possible that feelings of discomfort have a relationship with personal and psychological aspects.

Some people experience motion sickness more than others in the same situation. The dual concept of man in body and mind, where the individual is viewed as a psychosomatic unity, defines emotions that trigger bodily changes, mechanisms described from a physiological standpoint. Currently, the relationship between psyche and soma can be taken from unequal prospects. The first, which compete more to neurology, refers to diseases that act directly or indirectly through toxic states on the brain. The second is the reaction to the loss of health, namely, the psychological consequence of medical illness and go more in the field of psychiatry. The third would be one where the disease is a total or partial result of perception, and assume that the perspective from the current psychosomatic medicine. The age of people is very important and decisive in making a study on motion sickness. Sea Sickness kinetic rarely affects young children, but after two years of age there is a substantially increased sensitivity to it.

From the age of twelve sensitivity decreases again, although some adults continue to suffer this problem long into life. Adults are more susceptible to the kinetic experiment. At a younger age there is a greater likelihood of seasickness, as is well known by parents. But it is true that children should leave them on their own, because they instinctively pick the most suitable positions. However, newborns and children up to two years or so do not suffer from this problem. From that age the sensitivity increases and children are often more dizzy than adults. In adults the problem is reduced and in older people increases again. The vision of other people with seasickness, psychological contagion, is a point well studied so it seems of vital importance. Although it is a factor dependent on the person being interviewed, it is possible to say that humans are social beings and as such there is always a mental factor that can tip the scales one way or another. Ninety-one percent of people predisposed for suffering the seasickness ended with the symptoms.

With a person predisposed to motion sickness is to refer to those who are continually thinking that they will get dizzy, adopting a passive attitude. When the people are navigating, they must not be passive. Once on board the person has to do everything possible to be continuously active and not stop doing things. Entertainment and continuous activity largely prevent discomfort. If the body is in good condition it is better able to adapt to the movement. The person should try to sleep well the night before the trip so that the body is not tired. The position and somehow the activity of the individual is a fundamental parameter of seasickness. Based on the standing position, and taking into account the survey, if the person stays lying in prone position, the seasickness is less and, according to the crew member's opinion, more if they bend their head down.

The percentage of those polled who were seasick on the basis of their position during the voyage was ninety-six percent for those who were standing and only four percent for those who were lying down. It seems that the best is the supine (face up) position, or lie down with the head well supported. Reading should be avoided. To reduce susceptibility, keep the vision at an angle of forty-five degrees above the horizon. As respondents commented, they find it useful to avoid looking at the sea or other moving objects. When travelling, if the person feels dizzy, he can separate the light from outside and look at some specific point inside the vessel. This technique allows the mind to focus and avoid eye coordination seasickness. It is important that a cabin is well ventilated and to go out onto the deck to breathe fresh air. If a person is in a cruise ship, he needs to avoid moving around the ship. The survey shows that the interviewees (passengers, not crew members) who moved frequently during a trip felt their situation worsened. It is best to stay seated and quiet. Among the respondents the fact that was highlighted was that they were harmed by sudden movements.

Sometimes, movements that are very sharp, rising up or bowing, made them feel a little dizzy. It is best to make slower movements to avoid them. As a conclusion it is possible to say that it is better to concentrate on a particular point inside the boat, and if possible avoid looking at somebody suffering from seasickness. The percentage of affected people refers to environmental conditions such as temperature, smell or visual field, was forty-six percent. Poor environmental conditions, temperature, smell and field of view, affect the number of victims that occur on a ship.

This paper argues that the cause of dizziness is due primarily to over-stimulation of the vestibular apparatus by motion. But as individual susceptibility is variable, visual stimuli and poor ventilation, smoke, carbon monoxide and steam may be triggers. Regarding the temperature one must say that it is not appropriate to take too much heat. The sensation of heat increases the chances of feeling seasickness and syncope. According to respondents, getting into close spaces, such as cabins, felt they increased the inconvenience. If entering into compartments was required for any work, they stayed the shortest time possible because they really went ill. It is necessary get some air when a person feels bad.

This is one of the most interesting sections of the sample and illustrates very well how one can establish a connection between the ship's tonnage and the percentage of sickness experienced on board. It is difficult to ensure that, due to displacement, in an oil tanker of a hundred thousand tons, people get dizzy to a lesser extent, than in a passenger vessel of three thousand tons, as influenced by other parameters. For example while that a merchant ship the crew are professional, on a ferry most of them are passengers. Still one can ensure that a decisive factor is the shift by the design of the ship, its most full, long length and low speed, in addition to its block coefficient close to unity.

Displacement is a decisive factor, since for a sea causing a 65% of seasickness in a vessel of 300 tons, to fall to 20% in a 30.000 tons ship. On ships there are higher accelerations bow to aft. Predominately in large vessels of heave, and pitching movements while in smaller vessels the pitch, and the roll movements are the most important factors to be considered.

4. Conclusions

This paper presents an overview of the most important concepts of motion sickness, and tips to reduce its effects. Of the influential elements in this document, there are several, with food and beverages consumed, the temperature, the smells, the physiological state. But the crucial factor is the oscillatory vertical acceleration that appears on the ship. In conclusion it is necessary to mention that there are basic design criteria to avoid the possibility of motion sickness, such as inhabited compartments placed as close as possible to the centre of gravity and aligning the seating bay looking toward the bow. It is necessary to provide people with spaces or areas with the maximum possible light and ventilation, limiting strong smells, heat, noise and vibration. It is important to design components to decrease the movement, both fixed bilge keels, propellers...

The optimization of the sea keeping of a ship (i.e. decreasing the seasickness) and improvement of the comfort aboard a ship, passes through of the knowledge of a good weather statistical description of operation zone, doing previous testing with scale models in a Model Basin with generation of waves (wave generator) and the application of a operative criteria. To achieve this one must take into account several factors, starting with the design of forms and its interior. Although it cannot be generalized, because it will depend on the type of ship, for fast passenger ferries is recommended exploring high/low-cain spoon bow, with V-bottom chined hulls, which will produce smaller amplitude movements, high flotation coefficient, less draught, largest beam and metacentric height, which provides the convenient natural period.

References / Bibliography

Arieli, R.; Shupak, A.; Shachal, B.; Shenedrey, A.; Ertracht, O. & Rashkovan, G. (1999): Effect of the anti-motion-sickness medication cinnarizine on central nervous system oxygen toxicity. *Undersea & Hyperbaric Medicine*, 26(2), 105-9

Guevara, A. (1539): *Arte del Marear y de los inventores de ella: con muchos avisos para los que navegan en ellas*. Consultado el 11 de marzo de 2013 en www.filosofia.org/cla/gue/gueam673.htm.

Girón, J.M.; Esteban, S.; de la Cruz, J.M.; de Andrés, B. & Riola, J.M. (2003): Fast ships's longitudinal attenuation with T-foil and flaps. *RTO AVT Symposium on Novel Vehicle Concepts and Emerging Vehicle Technologies.* Bruselas: RTO press.

Griffin, M.J. (1984): Physical characteristics of stimuli provoking motion sickness. *AGARD Conference on Motion Sickness*. Bruselas: Advisory Group on Aerospace Research and Development press.

O´Hanlon, J.F. & McCauley, M.E. (1974): Motion sickness incidence as a function of frequency and acceleration of vertical sinusoidal motion. *Aerospace Medicine*, 45, 366-369.

Pérez, R. & Riola, J.M. (2010): Estudio del fenómeno del mareo, desde los factores psicológicos hasta el emplazamiento en el buque. *Revista ANALES de mecánica y electricidad*. March-April, 2-9.