JOURNAL OF MARITIME RESEARCH

Vol XVII. No. III (2020) pp 37–46

ISSN: 1697-4040, www.jmr.unican.es

Fatigue due to on board work conditions in merchant vessels

Ángel M. Costa[1], Rebeca Bouzón[1], José A. Orosa[1], Rosa de la Campa[1,*]

ARTICLE INFO

Article history:
Received 9 November 2020;
in revised form 10 November 2020;
accepted 3 December 2020.

Keywords:
Fatigue, Ship, Accident, Human Factor, Work Conditions.

ABSTRACT

Several publications point to the human error like the fundamental cause of the practical whole of the accidents. Inside these accidents, the fatigue has been identified like a recurrent cause, already was as first cause or like an important factor that produces the human error. Investigations carried out during the course of these years have shown that the chronic fatigue problems, the problems related to the stress and other problems of the health are associated with the conditions of work on board. On board, the fatigue related to the work depends directly on the characteristics on the work environment that the worker is exposed and, specifically, to the type of demands imposed by the task.
With the aim to define in an objective way the levels of fatigue associated with the tasks and related aspects of the engineering department crew on board merchant vessels, a survey on workers of this department was conducted. The results showed a high level of complexity in the work performed due to the tremendous physical and mental needs required to perform the typical tasks on board these vessels.

1. Introduction.

Several publications [Donaldson, 1994],[kIRWAN, 1987] have implicated human errors as the fundamental cause of numerous maritime accidents. This type of error is one of the more critical taxpayers' factors being 80 percent of them [Akyuz et al., 2016]. In this sense, the European Platform of Information on Maritime Accidents (EMCIP) [EMSA, 2015] investigated the incidents and accidents that occurred on board European vessels during 2011–2014 and found that 67% of these incidents occurred due to human errors.

Among these errors, fatigue was identified as a recurrent cause, usually the first cause or an important factor that leads to the production of other human errors [Reyner, 1998], [Louro et al., 2012], [Smith & Allen, 2013], [U?urlu et al., 2015]. Further investigations during the course of years [Jensen et al., 2006], [Wadsworth et al., 2008] has revealed that chronic fatigue issues or problems related to stress and other health conditions are associate with the work environment on board maritime vessels [Akamangwa, 2016].

Fatigue can be defined as a decrease in the capacity of answering or action of a person, due to the resting of our organs [Arquer, 1997]. Fatigue can manifest in distinct forms, although it can be differentiated into three major groups:

- **Physiological symptoms**: these symptoms are characterized by the presence of changes associated with a decrease in the capacity to make certain efforts.
- **Conductual symptoms**: these symptoms are associated with the deterioration of the level of performance or through the apparition of physical expressions, such as a yawn. It is necessary to undertake studies on the tendency to assume a greater level of risk when the degree of fatigue increases [Brown et al., 1970].
- **Subjective symptoms**: these symptoms refer to the perception by the workers of their feelings of discomfort or pain (physical fatigue), difficulty in keeping the eyes open or remaining awake (fatigue related with dizziness), or difficulty in concentration, to take decisions, and to think rapidly (mental fatigue) [Wiker et al., 1989].

At the same time, fatigue can be induced by diverse factors such as long periods of physical or mental activity, insuf-

[1]Department of Nautical Sciences and Marine Engineering, School of Nautical Science and Marine Engineering, A Coruña.
[*]Corresponding author: Rosa de la Campa. Phone: +34981167000; Fax: +34981116710. Email: rosa.mary.campa@udc.es.

ficient rest, environmental conditions (level of noise, illumination, temperature, etc.)[Wickens et al., 2004] and the organisational conditions under which the work is performed (structure organization, style of supervision, labour climate, etc.). The level of stress generated by the characteristics of the task, by the environmental conditions and the characteristics of the organization in which it develops the activity [Bowers et al., 1996], often interferes in the way a worker processes information, although the interference is always accompanied by degradation of the level of performance [Driskell et al., 2014].

Regarding fatigue in relation to work, it depends directly on the characteristics of the work environment that the worker is exposed to and, specifically, to the type of demands imposed by the task on the worker. The most important factors of the task that are related to the possible apparition of fatigue could be the following [Gutiérrez et al., 2005]:

- **Physical load**: the relation existing between the physical load and the apparition of fatigue when the worker is in a situation of continuous muscular work until reaching the point of exhaustion.

- **Mental load**: when the workers are subjected to situations of overloaded mental tasks, fatigue may occur, which in turn affects the performance of the worker negatively.

- **Physical environment**: factors such as the level of noise, vibrations, illumination, and temperature can act as a risk factor for the worker's health.

- **Moment of the day and the level of deprivation of dream**: the circadian rhythms affect the level of performance as well as the degree of drowsiness that a person suffers from. The performance associated with work could be the product of a series of actors that interact among themselves (the demands of different tasks, the specific shift system and the individual differences). The main causes of somnolence are the age, general health, quantitative requirements, job satisfaction, fatigue during the night shifts—which had a greater general level of fatigue among workers than during the day shift[Leung et al., 2006] —and the quality of the dream[Cotrim et al., 2017].

- **Psychosocial conditions of the work**: the psychosocial conditions of the task, such as the worker's level of commitment, roles, interpersonal and team relations, career progression in the enterprise, the supervisory style, and even the loss of interest in work are related to the occurrence of fatigue.

In consequence, based on previous statements, the present paper aims to determine the real working conditions in merchant ships in accordance with the type of vessel, the engine room automation level and the type of navigation, between other parameters.

2. Materials and Methods.

To analyse the work environment in a vessel and to examine the possible causes that produce fatigue among personnel on board, it is important to understand the concept of the International Maritime Organization (IMO). The IMO is a skilled organisation of the United Nations that is responsible for the security and protection of navigation and to warn regarding sea pollution from vessels. The IMO constitutes the Assembly, which is a body of work that is evaluated by committees and subcommittees, with the Committee of Maritime Security (MSC) being the oldest and, in case of fatigue, the most influential personnel.

On 4 November 1993, the IMO adopted the Resolution A.772(18) "Fatigue Factors in Manning and Safety", which defined fatigue as a decrease in the human performance [IMO, 1993], decrease in the reflections as well as a decrease in the capacity to conduct rational trials. The IMO used this factor to tackle the question of fatigue and the hours of rest.

On the other hand, during the sixty-eighth period of MSC sessions, the International Confederation of Free Trade Unions (ICFTU) presented the results of a survey regarding the hours of work, which was prepared by the members of the National Union of the United Kingdom (*National Union of Marine, Aviation and Shipping Transport Officers*) (NUMAST), some of which are given below:

1. The ship's crew on board have a greater volume of work, which increases the workload on an individual, thereby resulting in fatigue.
2. The coastal navigation presents greater fatigue that the oceanic ones, because the realization of scales in port is more frequent.
3. The organisation of the work and the structuring of the resources govern by forms elaborated does too many years.
4. The countries with less-developed maritime tradition presented with more problems related to fatigue.
5. The crew members considered that the major reason for the fatigue on board was insufficient crew.

After this survey, the ICFTU presented a MSC study on fatigue, conducted by the International Federation of Workers of the Transport (ITF) in front of the sixty-ninth period of sessions. This study was based on the answers of 2,500 marines belonging to 60 nationalities who loaned services on board from 63 ships of distinct pavilion [Phillips, 2015]. The major reasons indicated by this study were the intensity of work hours and the insufficient rest time in the maritime sector.

Fatigue is not only relevant to the immediate and negative consequences of the action of a fatigued crew, but also with respect to the health and the quality of life of the worker [IMO, 2011].

Regarding the international regulation on the necessary personnel on board of a fuselage, the Resolution A.1047(27) [IMO, 2011] states "Principles of Minimum Safe Manning", which revokes to the resolutions A.890(21) "Principles of Safe Manning", and to A.955(23), "Amendments to the Principles of Safe Manning", which establishes the guidelines for the application

of the relative principles to the minimum endowment of security which guarantee that a fuselage has a sufficient and efficient endowment to guarantee the crews' security and protection.

The minimum endowment of security of a fuselage was established taking into account all pertinent factors, including the following:

- The size and type of the ship;
- The number, power and type of main and auxiliaries engines units;
- The level of automation of the fuselage;
- The construction and equipment of the vessel;
- The maintenance methods employed;
- The load to transport;
- The frequency of the scales in the ports, the length and nature of the trips made; ? The zone(s) of navigation, routes of the vessel and operations undertaken; and
- The measure of activities performed during training on board.

Regarding the number of hours of work and rest of personnel on board in ships, there exist two agreements: the International agreement on the norms of the degree and the guards of the people of sea [IMO, 1978], amended in 2010, and the Maritime Labour Convention [ILO, 2006].

The STCW is the international norm that regulates the minimum numbers of hours of rest; these rules are applicable to the officials and sailors that form a part of the guards of navigation, the guards of machines or guards whose functions are committed or designated to security, prevention and protection. The minimum numbers of hours of rest to the sailors and officials to whom these committees are assigned are 10 hours during a period of 24 hours and 77 hours during a period of 7 days. Thus, at most, in two periods, one person is likely to have a minimum 6 hours of rest. The interval between two consecutive periods is thus, at most, 14 hours. When a worker has to be traceable at all times (as is the case in the spaces of machines without permanent endowment), he or she enjoys a compensatory rest period if they worked during the rest period.

At the same time, the MLC [ILO, 2006] treats man-hours and rest hours for people at sea. One of the differences with the STCW roots in that, it establishes only the hours of rest, whereas the MLC[26] establishes that the maximum man-hours cannot exceed 14 hours during a period of 24 hours or 72 hours during a period of 7 days; there is no exception that allows a period of rest of 70 hours during a period of 7 days to (maximum) 2 weeks. The MLC [ILO, 2006] recognizes that the man-hours of workers at sea equal that of other workers, which is 8 hours, with a weekly rest day; the days of rest correspond to the official holidays. This not being an obstacle allowed the members to form a collective agreement to establish normal man-hours that are no less favourable that that proposed by the Agreement.

Subsequent to the survey presented by the ICFTU during the sixty-eighth period of sessions of the Committee of Maritime Security, this same Committee, in their seventy-first period of sessions, tackled the question of fatigue and assessed directions required to consider the IMO performances [IMO, 2001] and elaborated, in their seventy-fourth period of sessions, guidelines for modules of each part involved in the safety aspects of the ship.

The aim of these guidelines was to gather information regarding adaption to a practical format involving all aspects involved in the security of the ship.

The guidelines were composed of destined modules, each for one part of interest, as detailed below:

- Module 1: Fatigue.
- Module 2: Fatigue and the Ratings.
- Module 3: Fatigue and the Ship's Officers.
- Module 4: Fatigue and the Masters.
- Module 5: Fatigue and the Training Institutions and Management Personnel in charge of Training.
- Module 6: Shipboard Fatigue and the Owners / Operators / Managers.
- Module 7: Shipboard Fatigue and the Naval Architects.
- Module 8: Fatigue and the Maritime Pilot.
- Module 9: Fatigue and Tugboat Personnel.
- Appendix: Fatigue related documentation.

During the proposal of amendments to the Guidelines on fatigue that appear in the annex of the circular MSC/circ.1014[IMO, 2015], it was established that a tool be used to evaluate fatigue, such as a program based on the operational needs in vessels and fatigue studies that allow anticipation of their possible effects.

The said tool would be required to mainly identify the programs of work shifts that can cause fatigue with the aim to improve their conditions. There are unforeseen situations that may modify the shifts, such as illnesses of the crew, technical problems and meteorological conditions. We have to analyse the programs of shifts that in practical situations contribute to the determination of possible fatigue effects.

Åhsberg et al. [Åhsberg et al., 1997] developed an instrument for perceiving fatigue in a work evaluation, designated on the likes of the Swedish Occupational Fatigue Inventory (SOFI), which integrates five dimensions of fatigue, namely, fault of energy, physical tiredness, physical discomfort, fault of motivation and somnolence, as defined below:

- **Fault of energy**: this dimension refers to the general feelings of decrease in the strength.
- **Physical tiredness**: it collects the general feelings of the body resulting from dynamic work and signs of metabolic exhaustion.

- **Physical discomfort**: a dimension that describes corporal feelings resulting from a load of static work.
- **Fault of motivation**: it refers to the feeling of neither being engaged with the work nor being excited about it.
- **Somnolence**: it collects the feelings of somnolence.

The validation was performed through a series of experimental studies and descriptive characters, with a careful observation of the command of some dimensions on others in as a function of the work type evaluated. Originally, the SOFI [Åhsberg et al., 1997] was composed of 25 expressions, five for each dimension, with the scale of assessment of 11 points.

In their first experimental study, Åhsberg and Gamberale [Åhsberg & Gambrale, 1998] analysed fatigue generated by two types of physical work. Their second experimental study [Åhsberg & Gambrale, 2000] identified the dimensions of fatigue preferably associated with a certain form of mental work. In order to analyse the effect of shift system on fatigue perceived by SOFI, workers were engaged in rotating shifts [Åhsberg et al., 2000]. Finally, the SOFI was administered to people that developed this activity in five professions with totally different work load [Åhsberg, 2000].

The instrument was later revised [Åhsberg, 2000], and the number of expressions in each dimension was reduced to four, such that the questionnaire finally consisted of 20 elements, and the answer scale was changed to 1–7 points.

In Spain, an investigation was conducted to check the reliability and validity of SOFI in the Spanish population [González-Gutiérrez et al., 2005]. The results obtained showed that the Spanish adaptation of the SOFI was a valid and reliable instrument to evaluate fatigue related to work from a multidimensional perspective in the Spanish population.

The resultant adaptation to the Spanish language includes 15 expressions related to physiological answers (cognitive, motor and emotional aspects), through which the five basic dimensions of fatigue (fault of energy, fault of motivation, somnolence, physical unrest and physical effort) can be measured. The reliability of the instrument was satisfactory, and the examination of the convergence gave important results. This adaptation constituted an extremely notable product, taking into account the previous errors in suitable tools to measure the fatigue level related to work in the context of the Spanish language.

Next, a modification [Sebastian et al., 2008] of the SOFI Spanish version was developed, called as SOFI Spanish Modified version (SOFI-SM) which allowed evaluation of a new dimension called as emotional fatigue or irritability. The irritability in this version refers to a dimension that describes the feelings of irritation, nervousness, anger or irascibility.

The original version of the SOFI requires that the participant describe in 11- points scale, with "0" indicating minor extension and "10" indicating major extension. However, in this survey, the scale was reduced and the questions were classifieds on the scale of Likert [Likert, 1932]; this scale builds according to a series of items that indicate a positive or negative attitude, with each item possessing five possible answers ranging from value 1 to 5, where "1" indicates a strong disagreement and "5" indicates total agreement.

It is interesting to point out that it is necessary to develop these subjective methods of evaluation of labour fatigue for maritime ships considering the dearth of literature on the same [De Alwis et al., 2016].

Based on these comments, and in a similar way than the previous studies of MSC study of fatigue, a survey about fatigue on board merchant ships was done. Like in these previous studies, this survey was organised in 25 questions. Eight of the questions are related with descriptive aspects like the type of vessel and other seventeen questions were related to the fatigue level like, for instance, the engine room automation level, the type of navigation, working hours, and sleeping hours. As an up to date of the previous methodology, an original point of view was incorporated into our methodology. In this sense, it was employed the social media, "Facebook" using the page on Marine Engineering. This new procedure lets us to improve the time and agility needed to analyse this kind of database of responses obtained. What is more, it is interesting to highlight that, as it is well known, Facebook is a social networking that, once developed and administrated by the authors, more than 4900 marine engineers in different merchant vessels were connected and let us to respond the survey in a reduced time period of five days.

3. Results and discussion.

As it was explained before, a survey of the engineering department crew on board merchant vessels was conducted to understand their levels of fatigue in association with their respective tasks and related aspects. In particular, this poll was conducted through the social media, "Facebook" using the page on Marine Engineering. As a result, the survey was filled in 108 merchant ships reaching what it can be considered as a representative participation level, as we can see in Figure 1. In this sense, it is interesting to highlight that the mean, the median and the mode of the numerical punctuation obtained from each question showed similar values for each variable analysed, which can be identified with a normal distribution centred in the average value. What is the same, a no compensation between extreme values will not offer us, in this case, a non-representative average scale value.

If we now start the analysis of the obtained results, it was obtained in Figure 2 that the rank or positions of the respondents who answered the poll. At the same time, with regard to the age of the respondents who participated in the survey, 70% are in the range between 25-45 years.

The most usual turns within the population polled have been other different that the proposed in the poll, followed for the unattended machine type. This conclusion is reflected in Figure 3.

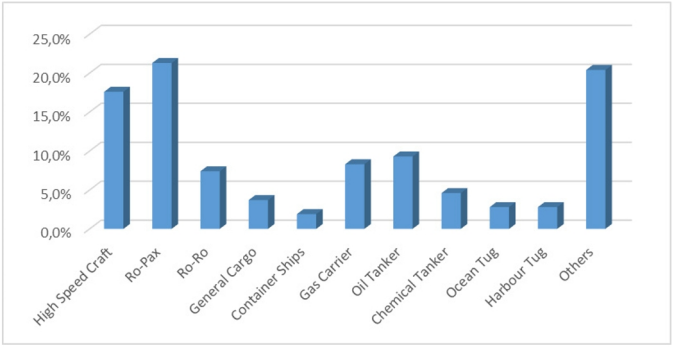
The fast technological development and the reduction in the number of crew members in the vessels' engineering department have contributed to the greater workload on the crew [Oldenburg et al., 2010], in addition to seeing altered the tasks to make[Lundh & Rydstedt, 2016] .

As seen in Figure 4, the level of automation of the machines on which the crew worked were either half or more than half. On a scale of 1 to 5, 31.5% of the crew answered 3 and 30.6% answered 4 with reference to the machine automation level. On the scale of 1 to 5, the value 5 indicates total accordance; therefore, 30.6% value indicates sufficient agreement.

Figure 5 shows the type of navigation. A detailed analysis of the responses revealed that 56.5% of the personnel sailed on vessels that make trips near the coast and hence "coastal navigation", while 42.6% sailed in vessels that moved away from the coast and hence "oceanic navigation".

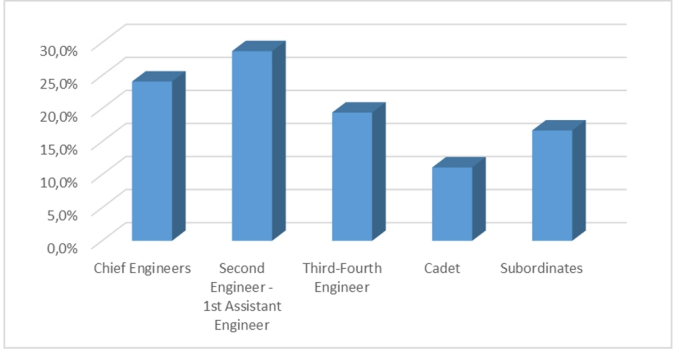
The relation to the demand corresponding to a particular job post was also noticed with reference to the physical load, mental load, motivation, job requirements, and insufficient staff.

Figure 1: Percentage of different vessel types responded by the crew members.



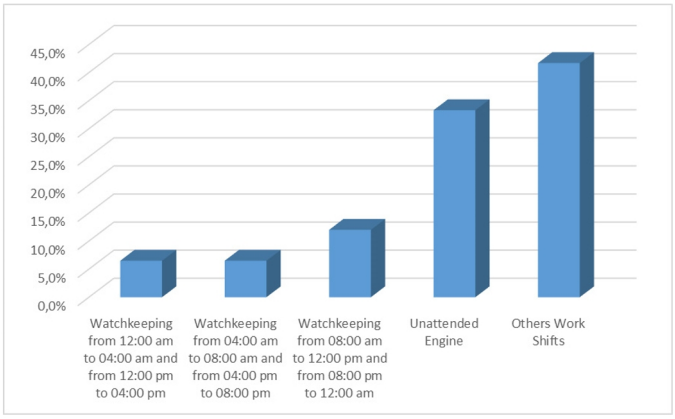
Source: Authors.

Figure 2: The percentage wise segregation of officials on board the vessel.



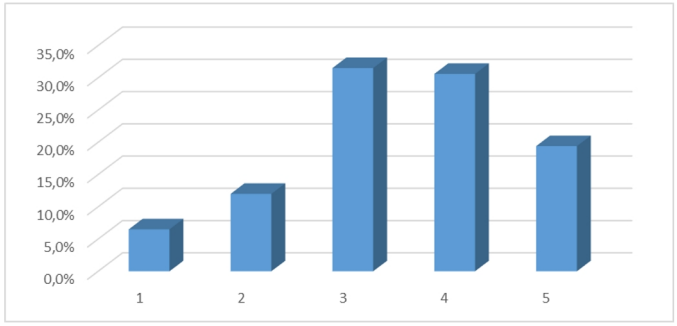
Source: Authors.

Figure 3: The percentage-wise segregation of work shifts of the crew members.



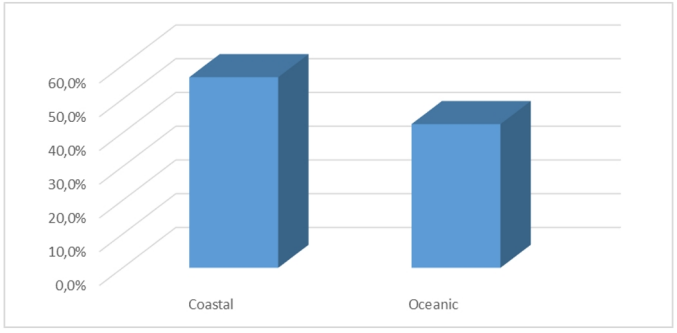
Source: Authors.

Figure 4: The engine room automation level at the maritime vessels.



Source: Authors.

Figure 5: The type of navigation made by the respondents.



Source: Authors.

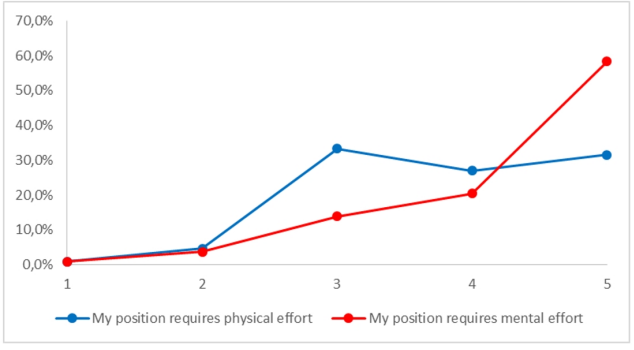
Figure 6 shows that the greatest percentage of answers for the first question, "My position requires physical effort" is 3 (corresponding to 33.3% of respondents). This observation indicates that his work position requires a medium level of physical effort, whereas the answer given in terms of percentages (31.5%) indicate that the respondent considered that his position required a high level of effort.

Figure 7 shows the corresponding percentages of responses to the questions: “I feel fatigued when I initiate my work day” and “I feel fatigued at the end of my work day”. The most common answer in the first case, with 36.1% of the results, corresponded to a medium level of fatigue (3/5); 10.2% of the respondents felt extremely fatigued at the start of the work every day. Comparing this data with the highest percentage registered in the second question, where 48.1% of the respondents ensured feeling extremely fatigued at the end of every day indicates recovery during the rest hours.

In Figure 8, the answers given to the questions, “I have enough time to perform my tasks” and “I can rest in the middle of my work” the majority of the respondents are enough agree with this affirmation, at the same time that they put of self-evident that it is possible to make these works.

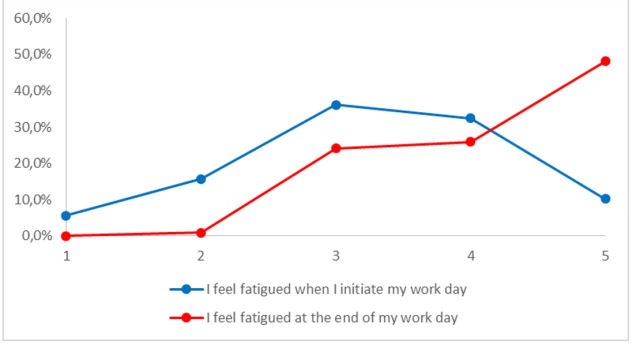
This figure also evidences the high collaboration among the members of the engineering department. According to the answers given by the respondents of the ICFTU, although the number of crew members were insufficient, there was a strong commitment to help each other among them.

Figure 6: ”My position requires physical effort” and ”My position requires mental effort”.



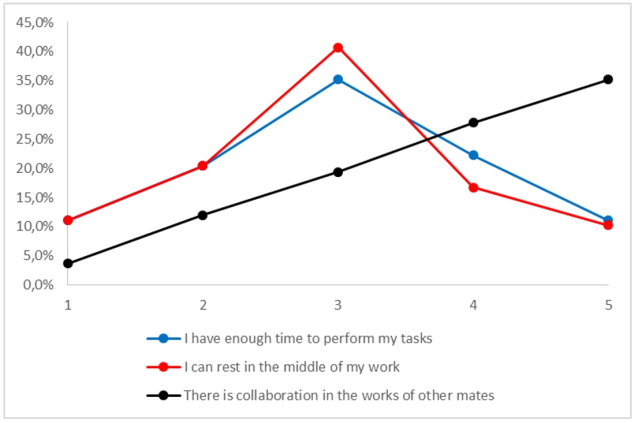
Source: Authors.

Figure 7: ”I feel fatigued when I initiate my work day” and ”I feel fatigued at the end of my work day”.



Source: Authors.

Figure 8: ”I have enough time to perform my tasks”, ”I can rest in the middle of my work” and ”There is collaboration in the works of other mates”.

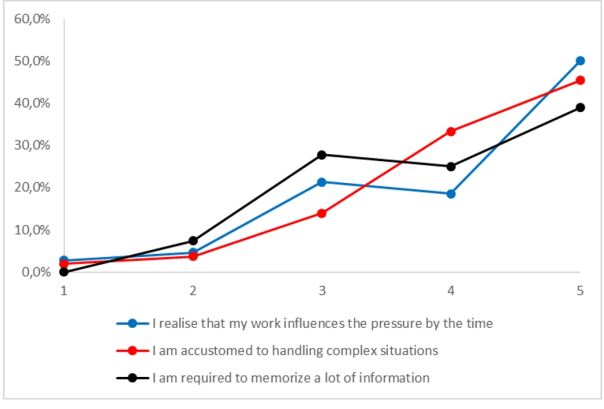


Source: Authors.

Figure 9 shows the workers’ perception of their work as highly complex due to the need for retaining a lot of information and the pressure felt due to the time limitation, which produces a lot of stress and fatigue by the end of a work day. Previously, they agreed on having sufficient time to perform work, but our results showed that performing the task within the tight deadlines produced extreme pressure.

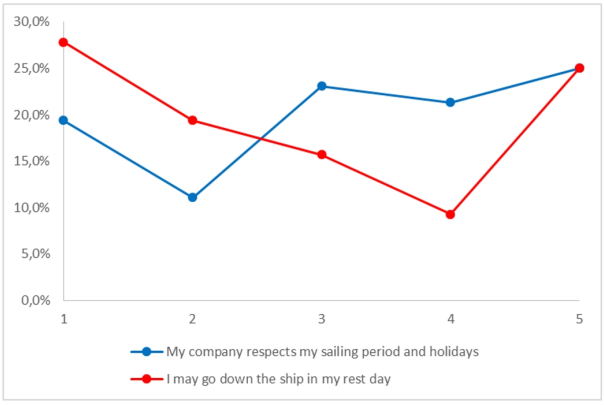
Figure 10 shows that 69.4% of the respondents considered that their companies respected their period of sailing/holiday. Because of the diversity in the responses, and depending on the type of navigation (oceanic or coastal) and the time of stay in port, can present greater ease to go down the ship during the rest days.

Figure 9: “I realise that my work influences the pressure by the time”, “I am accustomed to handling complex situations” and “I am required to memorize a lot of information”.



Source: Authors.

Figure 10: “My company respects my sailing periods and holidays”; “I may go down the ship in my rest day”.



Source: Authors.

Table 1 shows the mid-results of the answers obtained from the respondents. The term UMS refers to an unattended machine (Unattended Machinery Space). In this type of guards, the engineer crew team work in spaces of engines (room and control) during the schedule from 08:00 AM to 12:00 PM and 01:00 PM to 05:00 PM. During this period, only one engineer remains in charge of the alarms until 08:00 AM on the following day and goes down to make a round at the end of the afternoon.

Appreciable differences indicate that oceanic navigation personnel felt more fatigued that the coastal ones, although in both the cases, fatigue existed.

In oceanic navigation, the machine was more automated, which is justified because the vessels are more modern. According to the Society of Small and Average Dockyards of Reconversion (PYMAR), the report of activities of the sector of naval construction of 2014 [PYMAR, 2014] suggests that the improvement in the world-wide contracting of vessel constructions could only be appreciated in two groups: passage vessels and gas tankers. However, this increase has little weight on the contracting of gross tonnage. The greater percentage of ships delivered during this period correspond to 31.2% of general load vessels, followed by container vessels with 20.5% and tank ships with 14.5% loads; in any one of these cases, the major type of navigation were long distance.

We can thus note that oceanic navigation crew is more motivated than the coastal ones, although coastal navigation crew can go ashore in their rest day and are provided more respect for their sailing periods and holidays. Considering all these points, it can be said that greater motivation is related directly with vessels being more modern. A detailed analysis obtained results by rank on board and the type of navigation (Figure 13).

Comparing by ranks and the type of navigation, the Chief Engineers' polled differed in several answers, for instance, the oceanic navigation chief engineers were in total accordance with the affirmation “I am accustomed to handling complex situations”, which corresponded to the value of 5 on scale versus that of value 4 for the coastal navigation ones. This greater habit to treat complex situations among the oceanic navigation chief

Figure 11: Average results of the survey.

Code	Question	Answer
Q01	Time in the rank (years)	2-5
Q02	Age (years)	35-45
Q03	Turns	UMS
Q04	My position requires physical effort	4
Q05	I have enough time to perform my tasks	3
Q06	I realise that my work influences the pressure by the time	5
Q07	I can rest in the middle of my work	3
Q08	I am accustomed to handling complex situations	4
Q09	There is collaboration in the works of other mates	4
Q10	My position requires mental effort	5
Q11	I am required to memorize a lot of information	4
Q12	My company respects my sailing period and holidays	3
Q13	The machine is automated	4
Q14	I feel fatigued at the end of my work day	4
Q15	I feel fatigued when I initiate my work day	3
Q16	I may go down the ship in my rest day	3
Q17	I feel motivated in my work	4

Source: Authors.

engineers justify the condition, as they are required to put in greater effort than the coastal navigation ones. A similar trend was observed for the requirement to memorize a lot of information. On the other hand, the oceanic navigation engineers do not consider their engine room automated, unlike the coastal navigation, and they do not have sufficient time to perform their works.

In both the cases, the chief engineers begin their work after the same level of rest, but end up with different level of fatigue, with it being higher in the coastal chiefs, because of the greater number of manoeuvres they have to undertake.

Figure 12 shows a comparison of the average results obtained, depending on the type of navigation, in accordance with the results of the ICFTU, which indicate greater fatigue exist in the coastal navigation than in the oceanic navigation. On the other hand, oceanic chiefs feel more motivated that the coastal ones, which influences the apparition of fatigue in them.

In the case of the Second Engineer – 1st Assistant Engineer, they matched in a greater number of answers that the Chief Engineers. The engineers in the coastal navigation believe that they work under more pressure than an oceanic navigation engineer, because the time to make reparations is limited. On the contrary, Chief Engineers in the coastal navigation rated question “I am accustomed to handling complex situations” with a 5, while the oceanic navigation engineers rated with a 4; this difference can be because the former are more accustomed to working quick and are always ready to start a new trip. In both the cases, the crew begin their day with equal amount of rest. However, the oceanic navigation engineer feel more fatigued at the end of a day than coastal navigation ones. The motivation level in the Second Engineers in oceanic navigation is greater than that in coastal navigation.

Analysing the case of the Third and Fourth Engineers, the coastal ones felt that their work required more physical effort, as compared to that perceive by the oceanic ones. The ThirdFourth

Figure 12: Average results by the type of navigation.

Code	Question	Coastal	Ocean
Q01	Time in the rank (years)	2-5	2-5
Q02	Age (years)	35-45	35-45
Q03	Turns	Others	UMS
Q04	My position requires physical effort	4	4
Q05	I have enough time to perform my work	3	3
Q06	I realise that my work influences the pressure by the time	5	5
Q07	I can rest in the middle of my work	3	3
Q08	I am accustomed to handling complex situations	4	4
Q09	There is collaboration in the works of other mates	4	4
Q10	My position requires mental effort	5	5
Q11	I am required to memorize a lot of information	4	4
Q12	My company respects my sailing period and holidays	4	3
Q13	The machine is automated	3	4
Q14	I feel fatigued at the end of my work day	4	5
Q15	I feel fatigued when I initiate my work day	3	3
Q16	I may possibly go down the ship in my rest day	4	2
Q17	I feel motivated in my work	3	4

Source: Authors.

Engineers in the coastal navigation system were totally in accordance (5 grade) with the affirmation "I feel that my work influences the pressure on my by the time", whereas those in the oceanic navigation system agree (4 grade). In addition, the coastal engineers answered with neutral punctuation (3) to the affirmation "I get sufficient time to perform my work", whereas the oceanic ones showed total agreement with the affirmation. On the other hand, the answers given by the coastal engineers mark with a high punctuation the fact that their work requires mental effort and demands memorisation of a lot of information, whereas in the answers given by the oceanic ones, the punctuation was somewhat lower, although the latter ones are accustomed to handling complex situations, the answer is one point more that the given for the coastal ones. Regarding the level of fatigue at the end of the day, the coastal ones felt more fatigued that the oceanic ones as well as reported worse rest conditions. Finally, as reported in previous cases, the level of motivation in oceanic navigation engineers was more than that in the coastal navigation ones.

Finally, a rough analyses of the case of the Subordinates showed that the responses of the Third and Fourth Engineers differed a lot. The costal ones perceived their work as requiring greater physical effort as compared to that perceived by oceanic ones. The coastal Subordinates answered with a neutral (3 grade) to the affirmation "I have sufficient time to perform my work", whereas oceanic ones agreed with the affirmation, which indicates that the level of pressure by the time was more in oceanic Subordinates than in coastal ones, what can be due to the fact that, although usually there is time to perform tasks, often the need is to resolve an issue as fast as possible. Focusing on fatigue, the coastal Subordinates start their work being more tired and finish it the same way as compared with the oceanic ones. In both the cases, the motivation for the work is the same, with neutral answer (3 grade).

Figure 13: Mid-results by the type of navigation and position on board.

Code	Coastal Chiefs	Ocean Chiefs	Coastal 2nd Of.	Ocean 2nd Of.	Coastal 3rd/4th Of.	Ocean 3rd/4th Of.	Coastal Subord.	Ocean Subord.
Q01 (years)	2-5	+ 10	2-5	2-5	1-2	2-5	5-10	5-10
Q02 (years)	35-45	35-45	35-45	35-45	25-35	25-35	35-45	35-45
Q03	Others	Others	Others	UMS	4:00-8:00 & 16:00-20:00	UMS	Others	Others
Q04	3	4	4	4	5	4	5	4
Q05	3	2	3	3	3	4	3	4
Q06	5	5	5	3	5	4	3	5
Q07	3	3	3	3	3	3	3	3
Q08	4	5	5	4	4	5	4	5
Q09	5	4	4	4	4	4	4	5
Q10	5	5	5	5	5	4	5	4
Q11	4	5	4	4	5	4	4	5
Q12	5	3	3	4	4	3	2	3
Q13	4	3	4	4	3	4	3	3
Q14	5	4	4	5	5	4	4	4
Q15	3	3	3	3	2	3	4	3
Q16	5	1	3	2	2	2	4	3
Q17	4	5	3	4	3	4	3	3

Source: Authors.

Conclusions.

As per the guidelines of IMO [27], stress, like fatigue, is associated with places on board a vessel. Our survey results reflected the high level of complexity in the works performed in the engineering department.

On the other hand, the level of effort necessary to perform the task is also higher, because the typical tasks on board a vessel requires tremendous physical and mental intervention.

Notably, the time allotted to realize a task is restricted, which produces tremendous pressure to complete a task within a fixed schedule. Cumulatively, our observations suggest that the workers showed high levels of fatigue (Table 1), which seemed to be associated with the stress produced from the work conditions. Considering the strict requirements and the high complexity of the tasks on maritime vessels, it seems best to manage the tasks through active and well-managed collaboration among the resources on the vessels, allowing time for rest for everyone and thereby distributing the work load and the related stress uniformly in order to combat fatigue.

References.

Donaldson. *Safer ships, cleaner seas: Report of Lord Donaldson's enquiry into the prevention of pollution from merchant shipping*. London: HMSO Publications; 1994. Available from: <http://hdl.handle.net/20.500.11822/2044>.

Kirwan, B. Human reliability analysis of an offshore emergency blowdown system. *Applied Ergonomics*. Elsevier, 1987, 18(1), 23-33. ISSN 0003-6870. Available from: <https://doi.org-/10.1016/0003-6870(87)90067-6>.

Akyuz, E.; Celik, M.; Cebi, S. A phase of comprehensive research to determine marinespecific EPC values in human error assessment and reduction technique. *Safety Science.* Elsevier, 2016; 87, 63-75. ISSN 0925-7535. Available from:<https:-//doi.org/10.1016/j.ssci.2016.03.013>.

European Maritime Safety Agency. *Annual Overview of Marine Casualties and Incidents 2015.* Lisboa:EMSA, 2015. [Date of access: July 2020]. Available from: <http://www.emsa.-europa.eu/implementation-tasks/accidentinvestigation/download-/3833/2551/23.html>.

Reyner, L.A. Fatigue ferry crews: a pilot study. In L. Hartley (Ed.) *Managing fatigue in transportation.* Kindlington, U.K.: Elsevier Science, 1998. 339-354.

Louro, J.; Vazquez, P.; De La Campa, R.M. Accident risk factors in conventional and high speed ferry ships in Spain. *Journal of Maritime Research*. Santander: SEECMAR, 2012; 9(1), 3-8. ISSN 1697-4840. [Date of access: July 2020]. Available from: <https://www.jmr.unican.es/index.php/jmr/article/-view/161/157>. Smith, A.P.; Allen, P.H. Fatigue in the maritime and road haulage industries. In: *Contemporary Ergonomics and Human Factors 2013: Proceedings of the international conference on Ergonomics & Human Factors 2013: Cambridge, UK, 15-18 April 2013.* London:

Taylor & Francis, 2018. 183-188. ISBN 9781138000421. Available from: <https://doi.org/10.1201/b13826>.

Uğurlu, Ö.; Köse, E., Yildirim, U. et al. Marine accident analysis for collision and grounding in oil tanker using FTA method. *Maritime Policy and Management* 2015, 42(2), 163185. ISSN:1464-5254. Availble from: <https://doi.org/10.1080/0308-8839.2013.856524>.

Jensen, O.C.; Sørensen, J.F.L., Thomas, M. et al. Working conditions in international seafaring. *Occupational Medicine*. Oxford: Oxford University Press, 2006, 56(6), 393-397. ISSN 1471-8405. [Date of access: July 2020]. Available from: <https-://doi.org/10.1093/occmed/kql038>.

Wadsworth, E.J.K.; Allen, P.H., Mcnamara, R.L. et al. Fatigue and health in a seafaring population. *Occupational Medicine.* Oxford: Oxford University Press, 2008; 58(3), 198-204. ISSN 1471-8405. [Date of access: July 2020]. Available from: <https-://doi.org/10.1093/occmed/kqn008>.

Akamangwa, N. Working for the environment and against safety: How compliance affects health and safety on board ships. *Safety Science*. Elsevier, 2016; 87: 131-143. ISSN 0925-7535. Available from: <https://doi.org/10.1016/j.ssci.2016.03.027>.

Arquer, M. Isabel de. *NTP 445: carga mental de trabajo: fatiga*. [Madrid]: INSHT, 1997. [Date of access: July 2020]. Available from: <insst.es/documents/94886/326962/ntp_445.-pdf/a0a57c8d-2ae3-445b-b525-b57d0ad54592>.

Brown, I.D.; Tickner, A.H.; Simmonds, D.C.V. Effect of prolonged driving on overtaking criteria. *Ergonomics.* London: Taylor & Francis, 1970; 13(2), 239-242. Available from: <https://doi.org/10.1080/00140137008931137>.

Wiker, S.F., Chaffin, D.B. and Langolf, G.D. Shoulder posture and localized muscle fatigue and discomfort. Ergonomics 1989; 32(2): 211-237. ISSN 1366-5847. Available from: <https-://doi.org/10.1080/00140137008931137>.

Wickens, C.D.; Lee, J.D.; Liu, Y. et al. *An introduction to human factors engineering*. 2^{nd}. ed. Upper Saddle River: Pearson Prentice Hall, 2004. ISBN 0-13-183736-2.

Bowers, C.; Weaver, J. ; Morgan, B.Jr. Moderating the performance effects of stress- In: James Driskell and Eduardo Salas, eds., *Stress and human performance.* Hillsdale, N.J.: Lawrence Erlbaum Associates, 1996, 163-192. ISBN 78-11389-83045.

Driskell, T.; Driskell, J. E.; Salas, E. . *Stress, performance, and decision making in organizations.* In: S. Highhouse, R. S. Dalal, & E. Salas (Eds.). *Judgment and decision making at work.* Routledge: Taylor & Francis Group, 2014. 251-276. SIOP organizational frontiers series. ISBN 978-0415886864.

Gutiérrez, J.L.G.; Jiménez, B.M.; Hernández, E.G. Mental workload and fatigue in special nursing services. *Revista Latinoamericana de Psicologia.* 2005; 37(3), 477-492. ISSN 01200534.

Leung, A.W.S.; Chan, C.C.H., Ng, J.J.M. et al. Factors contributing to officers' fatigue in high-speed maritime craft operations. *Applied Ergonomics.* Elsevier, 2006; 37(5), 565-576. Available from: <https://doi.org/10.1016/j.apergo.2005.11.003>. ISSN 0003-6870.

Cotrim, T.; Carvalhais, J.; Neto, C. Determinants of sleepiness at work among railway control workers. *Applied Ergonomics.* Elsevier, 2017, 58, 293-300. Available from: <https://doi.org/10.-1016/j.apergo.2016.07.006>.

International Maritime Organization. *Fatigue factors in manning and safety: Adopted on 18th session in November 1993: Resolution A.772(18)*. London: IMO, 1993. [Date of access: July 2020]. Available from: <http://www.imo.org/en/Knowledge-Centre/IndexofIMOResolutions/Assembly/Documents/A. 772-(18).pdf>.

International Transport Workers' Federation. *Lucha contra la fatiga, la seguridad de los buques requiere de una dotación realista.* 2006

Phillips, R.O. A review of definitions of fatigue - And a step towards a whole definition. *Transportation Research Part F: Traffic Psychology and Behaviour.* Elsevier, 2015, 2948-56. ISSN 1369-8478. Available from: <https://doi.org/10.1016/j.trf-.2015.01.003>.

International Maritime Organization. *Principles of minimum safe manning: Resolution A.1047 (27): Adopted on 30 November 2011*. London: IMO, 2011. [Date of access: July 2020]. Available from: <http://www.imo.org/en/OurWork/HumanElement/VisionPrinciplesGoals/Documents/1047(2_A207)-.pdf>.

International Maritime Organization. International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW): Adoption: 7 July 1978; Entry into force: 28 April 1984; Major revisions in 1995 and 2010. In: *IMO* [online]. [Date of access: July 2020]. Available from: <http://www.imo.org/en/About/Conventions/ListOfConventions-/Pages/InternationalConvention-on-Standards-of-Training,-Certification-and-Watchkeeping-for-Seafarers(STCW).aspx>.

International Labour Organization. *Maritime Labour Convention 2006*. ILO, 2006. [Date of access: July 2020]. Available from: <https://www.ilo.org/wcmsp5/groups/public/–ed_ -norm/—normes/documents/normativeinstrument/wcms_09025-0.pdf>.

International Maritime Organization. *Guidance on fatigue mitigation and management: MSC/Circ.1014*. London: IMO, 2001. [Date of access: 2020]. Available from: <http://www.imo-

.org/en/OurWork/HumanElement/VisionPrinciplesGoals/Documents/1014.p df>.

International Maritime Organization. Sub-Committee on Human Element, Training and Watchkeeping. *Revision of the Guidelines on fatigue in the annex to MSC/Circ.1014: 3rd session. Agenda item 8. HTW 3/8.* London: IMO, 2015. [Date of access: July 2020]. Available from: <https://www.intercargo.org-/wp-content/uploads/2015/09/htw-3-8-revision-of-theguidelines-on-fatigue-in-the-annex-to-msccirc1014-australia.pdf>.

Åhsberg, E.; Gamberale, F.; Kjellberg, A. Perceived quality of fatigue during different occupational tasks development of a questionnaire. *International Journal of Industrial Ergonomics.* Elsevier, 1997; 20(2), 121-135. ISSN 0169-8141. Available from: <https://doi.org/10.1016/S0169-8141(96)00044-3>.

Åhsberg, E.; Gamberale, F. Perceived fatigue during physical work: an experimental evaluation of a fatigue inventory. *International Journal of Industrial Ergonomics* 1998; 21(2), 117-131. ISSN 0169-8141. Available from: <https://doi.org/10.1016-/S0169-8141(96)000716>.

Åhsberg, E.; Gamberale, F.; Gustafsson, K. Perceived fatigue after mental work: An experimental evaluation of a fatigue inventory. *Ergonomics. Routledge:* Taylor & Francis Group, 2000; 43(2), 252-268. ISSN:1366-5847. Available from: <DOI 10.1080/001401300184594>.

Åhsberg, E.; Kecklund, G.; Åkerstedt, T. et al. Shiftwork and different dimensions of fatigue. *International Journal of Industrial Ergonomics.* Elsevier, 2000, 26(4), 457-465. ISSN 0169-8141. Available from: <https://doi.org/10.1016/S0169-8141(00)00007-X>.

Åhsberg, E. Dimensions of fatigue in different working populations. *Scandinavian Journal of Psychology.* Wiley, 2000, 41(3), 231-241. ISSN 1467-9450. Available from: <https://doi-.org/10.1111/1467-9450.00192>.

González Gutiérrez, J.L.; Jiménez, B.M.; Hernández, E.G. et al. Spanish version of the Swedish Occupational Fatigue Inventory (SOFI): Factorial replication, reliability and validity. *International Journal of Industrial Ergonomics.* Elsevier, 2005; 35(8): 737-746. ISSN 01698141. Available from: <https://doi-.org/10.1016/j.ergon.2005.02.007>.

Sebastian, C.; Idoate, G.V.; Llano, L., et al. SOFI-SM: cuestionario para el análisis de la fatiga laboral, física y psíquica. *Revista digital de seguridad y salud en el trabajo.* Universidad de Huelva, 2008; 2, 1-22. ISSN 1988-7817. [Date of access: July 2020]. Available from: <http://rabida.uhu.es/dspace/handle-/10272/3420>.

Likert, R. A technique for the measurement of attitude. *Archives of Psychology.* 1932, 22(140) 5-55. Available from: <https://psycnet.apa.org/record/1933-01885-001>.

De Alwis, M.P.: Lo Martire, R.,;Äng, B.O. et al. Development and validation of a webbased questionnaire for surveying the health and working conditions of high-performance marine craft populations. *BMJ Open.* London: BMJ Publishing Group, 2016, 6(6). ISSN: 20446055. Available from: <doi:10.1136/bmjopen-2016-011681>.

Oldenburg, M.; Baur, X.; Schlaich, C. Occupational risks and challenges of seafaring. *Journal of Occupational Health.* Wiley, 2010; 52(5), 249-256. ISSN 1348-9585. Available from: <doi 10.1539/joh.k10004i>.

Lundh, M.; Rydstedt, L.W. A static organization in a dynamic context - A qualitative study of changes in working conditions for Swedish engine officers. *Applied Ergonomics.* Elsevier, 2016, 55, 1-7. ISSN 0003-6870. Available from: <https://-doi.org/10.1016/j.apergo.2016.01.006>.

PYMAR. *Informe de actividad del sector de construcción naval: 2014.* Madrid: PYMAR, 2014. [Date of access: July 2020]. Available from: <http://www.pymar.com/sites/default/files/pymar_informe_anual_2014.pdf>.