THE HUMAN FATIGUE IN MARITIME DOMAIN

Majid SAFAHANI

Captain, IRISI Maritime Training
Institute No 115
Ghaem magham farahani street
PO Box: 15875-6318 Tehran / Iran
Mobile +989121456846
Office +982188830337
Home +982122954336
Fax +982188307617
majidsafahani@yahoo.com, majid.safahani@gmail.com

ABSTRACT

Human fatigue is a common problem in all modes of transportation and maritime transport is no exception. According to the International Maritime Organization; fatigue can be described as a state of feeling tired, weak and sleepy which results from mental and physical pressure over a period of time. It can be augmented by exposure to harsh environment.

Two types of fatigue are recognized by experts; Acute and chronic.

The main causes of fatigue are:
· The disturbance of circadian rhythms
· Continuous wakefulness
· Cumulative sleep loss

Different risk factors such as long working hours, lack of sleep, poor quality sleep, job demands and nature of shift, port frequency, noise, motion, lighting and vibration are subsidiary to the main causes. These factors are all alive on board ships.

Some of the symptoms of human fatigue are:
· Slowed reaction time
· Increased errors
· Individual's underestimation of their performance degradation
· Impaired judgment and decision making
· Limited situational awareness

The consequences of fatigue at sea are; increased personal injuries, groundings, collisions, health decrement and adverse physiological effects. In order to manage and reduce human fatigue in maritime sector, the international regulatory bodies; such as IMO and ILO have set certain rules and regulations. Flag state and port state control officers are responsible to check the compliance of ships with mandatory requirements of the international conventions; therefore Fatigue related legislations are checked by them.

There are also a number of guidelines for fatigue management and mitigation. These are set out by IMO and some flag state administrations. Fatigue may be addressed at three levels; legislative level, operational level and controlling level. The aim of this project is to evaluate fatigue related legislations and guidelines in the shipping industry.

Since seafarers are the main sufferers and beneficiaries; therefore their point of view is very important. The result of this research indicates that:

Fatigue is a common problem across shipping industry and it is a major contributory factor in causing maritime accidents. There are fatigue related legislations; but the evaluation of their efficiency is not done properly. Shipping companies have strategies for fatigue management, but they seem to be inadequate and deficient.

Under recording of working hours is prevalent among seafarers all over the world and is done to comply with mandatory requirements of the related legislations.
Great majority of the seafarers who have taken part in this study are of the opinion that fatigue related training, would be very effective in safety and health improvement and accident prevention.

**Keywords:** Fatigue, Maritime, Convention

1. **INTRODUCTION**

The word fatigue is used to describe a range of disorders and sufferings, varying from a general state of lethargy to a specific work-induced burning sensation within one's muscles.

"Physiologically, "fatigue" describes the inability to continue functioning at the level of one's normal abilities." (Hawley et al 1997)

"Interest in fatigue, including lack of sleep, as a factor in accidents at sea has in recent years grown". (IMO, STW37/INF.5, NOV 2005)

The trend and tendency of developing conventions and guidelines by international organizations in order to manage and mitigate fatigue in maritime industry is a clear evidence of above statement. Several analyses on international accident reports indicate that fatigue has been a direct or indirect contributory factor. Due to the nature of life and work of seafarers, fatigue is present in maritime transport section; there is competitive economic pressure to increase ship utilization as well as competitive pressure to decrease size of crew. This will increase the work load of Master and crew on board ships.

The IMO and ILO; have particular interest on seafarers and watch keepers working hours; in order to control the working hours on board, IMO has set certain rules in the STCW and SOLAS conventions and the ILO in its turn has addressed this problem in ILO convention 180 now incorporated into International Maritime Labour Convention (MLC) 2006. There are also a number of codes and guidelines addressing fatigue mitigation and management such as MSC/Circ.1014, June 2001.

The aim of this paper is to evaluate fatigue related legislations and guidelines in the shipping industry from the seafarers' point of view.

2. **FATIGUE IN MARITIME DOMAIN**

This paper offers the readers:

1- General description and knowledge of fatigue, its causes and consequences in maritime domain.
2- Analyzing the frequency of fatigue in seafarers' life and work, using questionnaire and reviewing time table of a ship engaged in liner service plus evaluating port state control in this matter and finally;
3- Discussing current problems.

2.1. **Causes of Fatigue**

Fatigue is a common problem in shipping industry, IMO in MSC/Circ. 1014 June 2001 has defined fatigue as “A reduction in physical and/or mental capability as the result of physical, mental or emotional exertion which may impair nearly all physical abilities including: strength; speed; reaction time; coordination; decision making; or balance.”

2.1.1. **Work Schedules**

* Circadian Rhythms: This is the natural body's rhythm and is repeated almost every 24 hours; it is also called internal body clock. The circadian rhythm affects many functions of the body such as; body temperature, digestion, hormone levels and most importantly sleeping behaviour.

Generally the physiology of human body is designed so that to work during the days and sleep at nights. Most of the functions of human body are at their maximum activity during day time and at their minimum activity at night.
The disruption of circadian rhythm may adversely impact on the quality and quantity of sleep, task performance and create a sense of personal dislocation and imbalance. This is a common problem in the seafarers as they are mostly shift workers.

**Sleep Issues:**
Human body requires restorative sleep in order to be alert, restorative sleep has four elements:
1. Duration; an average adult requires 7 to 8 hours sleep in a 24 hour period.
2. Continuity; the sleep period must be continuous and without interruptions.
3. Quality; five stages of any sleeping cycle must be complete as each stage provides a different benefit.(see table 2.1)
4. Time of day; sleeping during the night has higher quality than during the day.(see figure 2.1) (Calhoun 1999)

During the sleeping session the human body cycles through different levels of sleep.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Duration</th>
<th>Description</th>
<th>Effects</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Transition</td>
<td>10 Minutes</td>
<td>Transition phase between waking and sleeping</td>
<td>Asleep without knowing it</td>
<td>Micro sleep and Automatic Behaviour Syndrome</td>
</tr>
<tr>
<td>2. Light sleep</td>
<td>15 Minutes</td>
<td>Light level of sleep</td>
<td>Feel briefly alert and refreshed</td>
<td>50% of all sleep is in this stage</td>
</tr>
<tr>
<td>3. Delta sleep</td>
<td>15-20 Minutes</td>
<td>A deeper sleep</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Deep sleep</td>
<td>20-70 Minutes</td>
<td>Deepest stage of sleep</td>
<td>Will feel groggy if awoken; occurs early in the night</td>
<td>Sleep Inertia</td>
</tr>
<tr>
<td>5. REM sleep</td>
<td>After 70-80 Minutes of sleep</td>
<td>Dreaming state</td>
<td></td>
<td>Rapid Eye Movement</td>
</tr>
</tbody>
</table>

Table 1: Stages of sleep, (Adapted from Calhoun, 1999)

Each stage has its own effect on human body. (See table 1)

**Irregular Schedules:**
Those mariners who work at night and sleep during daytime has a reduced alertness during their work due to the natural tendency of the body (circadian rhythm).
In this case the day time sleeping is not restorative since the body tries to stay awake during day time. The body can adjust to a change in schedule, but it takes a few days for the adjustment. If there is an abrupt change in the shift schedule it puts the body out of synchronization with body's circadian rhythm.

Figure 2: Human body core temperature cycle (Adapted from Calhoun, 1999)

2.1.2. Environmental Factors

Motion:
It must be said that it is much more difficult to work in a moving environment than a stationary environment and the energy consumed to perform a task is much higher. The ship motion could cause sleep disturbances. (Dobie, 2003)

Wilson (et al, 1993) by using a simulator found that performance and cognitive processing were substantially degraded. Motion-induced fatigue is in fact of significant importance. It may increase the incidence of mistakes which could remain unnoticed.

Vibration:
Whole-body vibration could affect personal comfort, efficiency at work and even personal safety and health. Dobie, (2003) Vibration could be transmitted to the human body in different ways. First from the surface of the body, second from a part of the body that is in contact with the ship, e.g. feet or buttocks and third from the individual part of the body. Vibration could have other indirect effects on human's performance.

Noise:
Noise has two distinct effects on human body, one is the long term impact which is the hearing loss and the other is the short-term impact which is fatigue and reduced human performance. (Calhoun 1999) The noise has been defined by scientists as unwanted and undesirable sound. The noise has physiological effect which has an impact on human performance due to fatigue.

Lighting:
Lighting is the key to maintain human biological clock, i.e. the circadian rhythm. The sun light provides this light even on cloudy days. Some crew members on board merchant ships spend the majority of their times without being exposed to natural sun light, therefore they are only confined to electric lightings; this can lead to shift of sleep patterns and fatigue. One thing is unfortunate; the electrical lighting which is normally installed on board ships is not strong enough and fatigue will rise.

2.2. Consequences of Fatigue
Field studies and laboratory tests indicate that fatigue affects performance, safety, health and physiology of humans. Almost all the risk factors which have been addressed in previous sub-sections are present in maritime environment. This project summarizes the consequences of fatigue as follow:
2.2.1. Accidents and Injuries
Number of hours worked before the casualty and number of hours worked during last 24, 48 and 72 hours before the casualty is highly important in the occurrence of the casualty. In personal injuries which are related to fatigue, in average the mariners have worked 7.7 hours prior to accident and in non-fatigue related personal injuries the mariners have worked only 3.2 hours prior to the injury. 33% of personal injuries and 16% of ship casualty accidents have fatigue as a casual or contributory factor. McCallum et al, (1996)

2.2.2. Performance
Fatigue is usually defined operationally in terms of performance decrements. There are not enough researches in the field of maritime domain but the relationship between fatigue and performance among seafarers can be considered almost the same as other transport sectors.

The human performance is affected by a number of factors, including the nature of the specific job, the job role and life stress experienced. (Sanquist et al, 1996)

The mariners experience various physical and environmental stressors, such as weather, ship vibration and noise. The impact of these factors may be very large and unfortunately unpredictable, since for example the bad weather can affect the entire crew in terms of sleep and balance.

2.2.3. Health
Fatigue is linked to ill health. It is a common factor in worker's consultations with General Practitioners, and prospective studies have shown that there is a clear relation between negative work conditions, fatigue and subsequent illness. (Leone et al, 2006)

Shift work is a normal practice on ships and sleep deprivation and disturbed sleep are the most common effect of shift work which may lead to fatigue and ill health.

The quality and quantity of sleep can be reduced. The long term effect is not well known but some papers mention gastrointestinal disorders as common sickness in shift workers. There is evidence of night shift workers complain of heart burn, abdominal pain and peptic ulcer. (Alvarez et al 2004)

2.3. Is Fatigue Common Among Seafarers?
When considering fatigue risk factors the maritime domain is a unique surrounding.

It includes all the risk factors which were mentioned before. Fatigue risk factors are not as widespread in any other transport sectors as in maritime industry. Technical advances and commercial pressures lead the industry towards more reduction of manpower on board ships and this will intensify fatigue problem in the industry.

2.3.1. Seafarers' point of view:
The author has designed a simple questionnaire to acquire some answers to the questions which were raised during the course of the research.

The questionnaire was distributed among 640 students of a Maritime Training Institute and officers employed on ships owned by a company in the Middle East. The respondents are of mixed nationalities including, Pakistanis, Ghanaians, Ukrainians, Indians and Filipinos. This company has been chosen because its crew is a good representative sample of present seafarers around the world. The company normally runs its ships with one deck officer and one engineer officer in excess of the requirement of SMD. However there are certain limitations on the data which has been gathered by this survey; The word "fatigue" has been repeated several times in the questionnaire, which could have affected respondents mind at the time of answering. The respondents usually work on ships with average crew of 22. The name of the shipping company and training institute has been omitted intentionally to avoid sensitivity. Total number responded within 45 days was 204; out of which 18 were disregarded for various reasons, mostly because the respondents had less than 20 months service at sea as an officer or they failed to complete part A of the questionnaire.

It was explained to the respondents that there is no obligation in answering the questionnaire; however it may be useful if they do so. In preparing the questionnaire utmost effort has been made not to relate any questions to the respective company. Wherever there was a relation it was up to the respondents if they want to answer or not. The questionnaire contains thirteen questions. The respondents need mention neither their names nor
their nationalities but they should indicate their age, rank, sea service, certificate of competency, department and type of shift system employed on their ship. Master and all deck officers are considered in one group and chief engineer, other engineers and electronic officers in another group. The deck officers are engaged in 3 shifts system (4 on 8 off) while at sea and 2 shifts system in port. The engineers are engaged on day work.

Here is the result of the questionnaire and respective diagrams.

01. Human fatigue is a causal factor in maritime accidents such as collisions, groundings, personal injuries...
   a) Very effective   b) effective   c) neutral   d) not effective

![Diagram 2.1:](image)

02. While on a tour of duty on board ship I become fatigued.
   a) Never   b) rarely   c) sometimes   d) often   e) very often

![Diagram 2.2:](image)

03. My company has strategies for managing and mitigating fatigue.
   a) Yes   b) no

![Diagram 2.3:](image)

*Note-1: If your answer to question 3 is "b) no" then automatically answer "c) Neutral" will be selected for question 4.*

04. These strategies are effective.
   a) Very effective   b) effective   c) neutral   d) not effective
Diagram 2.4:

05. I am aware that there are fatigue related legislations and guidelines.  
   a) Yes  
   b) no

Diagram 2.5: 
*Note-2: If your answer to question 5 is "b) no" then automatically answer "c) Neutral" will be selected for question 6.*

06. To my professional judgment these legislations and guidelines are:  
   a) Very effective  
   b) effective  
   c) neutral  
   d) not effective

Diagram 2.6:

07. Port state control verifies the compliance of the crew with the legislations  
   a) Very effective  
   b) effective  
   c) neutral  
   d) not effective

Diagram 2.7:
08. Have I ever filled working hours/rest period form?
   a) Yes  b) no

Diagram 2.8:

09. I fill up these forms just to comply with mandatory requirements
   a) Always  b) never  c) sometimes  d) often

Diagram 2.9:

10. I feel fatigued more:
    a) At sea  b) in port  d) no difference

Diagram 2.10:

11. I have had training about fatigue prevention and management.
    a) Yes  b) no

Diagram 2.11:
12. Fatigue related training would be useful in accident prevention.
   a) Very effective  b) effective  c) neutral  d) not effective

![Diagram 2.12](image)

13. Fatigue related training would be useful in health and safety issues.
   a) Very effective  b) effective  c) neutral  d) not effective

![Diagram 2.13](image)

2.3.2. Liner Service Time Sheet
Another approach to the question of prevalence of fatigue among seafarers can be through monitoring time tables of liner services.

Table 2.2 shows the timetable of a container ship calling at several ports in Europe. The vessel is part of a liner service and there are many other vessels doing the same round. The author has reproduced the information for 4 ports during a routine voyage of this vessel; focusing on Master’s timetable. Apart from Le Havre all other ports have between 2 to 3 hours river passage; and the sea passage from one port to the other includes crossing traffic separation schemes. Most of the time during the sea passage the presence of Master on the bridge is inevitable.

The white color in the table indicates the vessel is sailing at sea; however during this time the Master may need to be fully alert for carrying out his administrative tasks such as sending arrival/departure reports or attending the bridge due to heavy traffic density and make preparation for the next port of call. The yellow color represents that it is either before or after an indispensable operation e.g. Arrival, Departure, Berthing, Un-berthing and commencement or completion of cargo operations which requires the attention of the Master in particular.

The red color indicates that the Master is definitely busy carrying out some tasks.

During this time the ship has called four ports within seven days and the Master had at least four nights without sleep or completely disturbed rest, during this whole period the Master may get rest at times which is not suitable as per natural body clock (circadian rhythm). His rest time may happen either at sea or in port, during the sailing period he may be called on the bridge by the officer of watch because of heavy traffic and during the port stay, his rest may be disturbed by noise, motion and several visitors such as port state control, surveyors and auditors, suppliers, stevedores, technicians and many more.
12th March Arrival Felixstowe at 0830   Berthing 1045   Cargo Operation 1540-2305   Un-berthing 2326

13th March Departure Felixstowe at 0100   Arrival Hamburg on 13th at 1524   Berthing at 2120   Cargo Operation 2310 to next day

14th March Operation completed at 2140 in Hamburg

15th March Un-berthing at 0001   Departure at 0612   Arrival Antwerp at 1830

16th March Berthing Antwerp at 0424   Cargo Operation at 0600-1315   Un-Berthing at 1540   Departure 2318

17th March Cargo Operation at 0600-1315   Un-Berthing Antwerp at 1540   Departure 2318

18th March Arrival Le Havre Berthing 1350 Cargo Operation 1530-1825 Un Berthing 2145 Departure 2330

Table 2.2: Master's actual time table on a container ship

2.3.3. Compliance With Legislations And Guidelines
The author has derived the following data from Paris MOU web site; using the advanced search option selecting a flag randomly which was in black list but improved steadily moving to grey and finally white list in the last 4 years.

Survey condition can be summarized as follow:
- Survey period from 1st JAN 2005 to 1st OCT 2007.
- All types of ships from, different owners and multi-nationality crew visiting Paris MOU ports.
- Total No of inspections 234 from 89 ships.
- Number of inspections with nil deficiency: 106.
- Total Number of deficiencies: 844.
- Number of initial inspections: 135
- Number of more detailed inspections: 68
- Number of expanded inspections: 31
- 9 deficiencies related to crew working hours/ rest period timetable have been raised.
- Countries in which PSCOs raised these 9 deficiencies are United Kingdom, Germany and Spain.
- None of these 9 deficiencies were a ground for detention.

Another survey from Paris MOU web site, using advanced search method, choosing a very reputable European flag which has always been in the white list had the following results:
- Survey period from 1st JAN 2005 to 1st OCT 2007.
- Type of ship; container ships of 3000 GT and above.
- Total number of inspections; 614
- Inspections with deficiencies; 39
- Total number of deficiencies; 93
- All ships are engaged in liner service.
- Similar timetable as 3.4.2

No deficiency has been raised for crew fatigue, working hours and rest period during the time of survey.

3. DISCUSSION AND ANALYSES
The author would like to raise an argument that despite the existence of current international rules and regulations for safe operation of merchant ships especially those directly involved with manning, training and hours of work; it seems that fatigue is alive in maritime transportation sector.

Here is a short outcome of the questionnaire:

In responding to question 1, 97% of respondents are of the opinion that fatigue is an effective or very effective causal factor in maritime accidents and only less than 2% does not recognize fatigue as a contributory factor.

After reviewing the definition of fatigue by IMO more than 87% stated that they become fatigued while they are on a tour of duty, 7% rarely feel fatigue on board and less than 6% never become fatigued in their carrier.

In responding to question 3 more than 62% are not aware of any strategies employed by their company for management and mitigation of fatigue and only less than 38% are aware of such strategies. Only 11% of those with the knowledge of the existence of the strategies are convinced that these strategies are effective and practicable.

More than 58% of the respondents are aware of fatigue related legislations and guidelines; out of which less than 44% surmised that these legislations and guidelines are effective and practicable and about 56% believe they are ineffective. The verification of working hours/ rest period carried out by port state control officers are believed to be ineffective by more than 66% of the respondents.

More than 88% of respondents have filled in working hours/ rest period forms out of which 65% always filled in the forms to comply with mandatory requirements no matter the actual working hours and 26% most of the times filled in the forms to comply and only less than 9% filled in the actual information in the forms no matter the compliance.

When it comes to fatigue at sea and in port there is vast difference between deck officers and engineers; only 8% of deck officers feel more fatigued at sea but 77% of them feel more fatigue in port and 15% feel no difference between port and sea. However for the engineers more than 42% feel more fatigued at sea and only 20% in port and 37.5% feel no difference between sea and port.

In respect of fatigue management and mitigation training; more than 83% of the respondents never had any training but more than 72% believe training is either effective or very effective in accident prevention and more than 87% are of the opinion that training will assist better health and safety.

Because of the scope of their coverage the author strongly believes that STCW convention and ILO-180 now incorporated in to MLC 2006 should be discussed separately.
4. CONCLUSIONS
Despite the widespread evidence that fatigue occurs frequently enough to be a significant maritime issue, it remains difficult to detect reliably and counteract effectively. Given that fatigue is a safety issue in shipping industry, the next logical question is how to address it. Unfortunately there is no simple solution. It should be evident that no single approach can eliminate fatigue as an issue from maritime transportation sector.

Fatigue is a problem with diverse causes, requiring multi-aspect and comprehensive approach. Based on current research, such an approach should have at least the following components:

a) Education and training;
b) Robust legislation about hours of work, work/leave ratio;
c) Guidelines to introduce effective countermeasures and
d) Employment of appropriate design and technology.

The facts which have been discussed in previous chapters of this paper reveal that fatigue is a common problem among seafarers. It is believed by most of them that fatigue is a very important contributory factor in causing personal injuries and casualties such as collisions and groundings.

The seafarers' point of view is that the industry does not lay enough stress on it and the present legislations require revision. The author would like to point out that:

The professional opinion of all interested parties should be taken in to account for revision of the regulations.

The long term effect of fatigue on seafarers' health and physiology has been forsaken by the present rules.

The legislations should consider seafarers in different groups, e.g. deck officers, engineers, deck ratings, engine ratings and Masters; as the only common point for them is: they are confined in their work place but each group has diverse interests and different restrictions.

Although weather conditions, ship types and many other factors have been discussed in IMO resolution A 890(21), for more consistency they should be moved into the main legislations.

This paper emphasizes on the need for defining service time and leave ratio plus clear definition of rest period quality in the legislations.

This can be either due to deficient training (lack of competence) or insufficient manning of the ships.

Reconsideration of minimum safe manning certificate which imposes extra expenditure on the industry and is not welcome by some stakeholders is another choice.

Present guidelines do not satisfy the purpose they were intended for. The guidelines are more or less in line with legislations. They also need reconsideration; taking into account the requirement of each individual concerned. A guideline with a general view on all seafarers can not satisfy the need of the industry.

Each operational environment should be encouraged to develop guidelines for duty and rest scheduling that reflects the demands of that particular work setting.

Guidelines should highlight the role of the ISM code; the requirement of which is mandatory for the industry; the proper implementation of the code can well reduce fatigue among seafarers. Its effect can be outstanding, since the code should be complied with, by ship personnel as well as shore staff.

The most significant problem is falsification of working hours and rest period records. This is mainly due to lack of respect for the existing legislations and guidelines. There should be severe punitive measures by controlling bodies for both seafarers and management for so doing; therefore the procedure for verification of working hours and rest period is to be revised completely. Apart from establishment of punitive measures, training and awareness campaigns could be very useful in culture changing, as this has already been discussed and proved effective in other industries and fields.

Fatigue related training will be welcomed by the seafarers but it is definitely needed by others in the industry. Since the combination of the risk factors are present and influential on fatigue inducement in maritime domain, a decrease in any one of the risk factors will have a direct reducing effect on fatigue. The author
concludes that none of the risk factors should be left unnoticed. Indeed any improvement, even very limited, in legislations, guidelines, and company strategies and cultures may make a significant improvement in public utility. A successful approach will attempt to maximize each individual component, resulting in an effective overall success.

Despite the fact that many seafarers complain that verification of working hours and rest period is not done properly by controlling bodies, the author is of the opinion that this should be evaluated after revision of legislations and guidelines. Meanwhile more punitive measures by controlling bodies are required to overcome financial benefit which is obtained by some shipping companies in avoiding the rules.

Controlling bodies can put more force on shipping companies by requiring better implementation of ISM code.

5. REFERENCES


Asia-Pacific web site, Available at: www.tokyo-mou.org/ Accessed: 11 June 2007


Smith, A.,(2006). Adequate Crewing and Seafarers' Fatigue: The International Perspective, Centre for Occupational and Health Psychology Cardiff University, Available at: www.cardiff.ac.uk Accessed: 08 March 2007


6. BIBLIOGRAPHY:


324