Analytical Research of the Container Ships Cargo Area Fires in the Period From 2010 to 2020

Analitičko istraživanje požara u teretnom prostoru kontejnerskih brodova u razdoblju od 2010. do 2020.

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Abstract

Container transport by sea has almost doubled in the last decade. Accordingly, container ships' size has increased significantly, and the latest container ships carry up to 24000 Twenty-foot Equivalent Units (TEU). In the near future, the appearance of container ships with a capacity of 25000 TEUs can be expected on the market, because the design is already available. It is known that 10-12% of transported containers contain International Maritime Dangerous Goods (IMDG) cargo. The above stated reasons directly impact the frequency of container ship fires in cargo spaces. According to the Insurance Companies, fires occur on average every two months, and this is a growing problem of container transport by sea. In this paper, 23 fires in the cargo area, either in cargo holds or on deck, were analysed. The analysis results determined the most common causes of fires and have shown that the current fire protection systems on container ships are ineffective. It is unacceptable that firefighting systems' inefficiency results in the loss of human lives, abandonment of vessels, environmental pollution, and extensive property losses related to cargo and ship structure. Due to all the above, it is necessary to continuously work on new regulatory and technical solutions to improve the fire safety of cargo areas on container ships.

KEY WORDS

Container ship fires
IMDG cargo
fire extinguishing systems

Sažetak

Kontejnerski prijevoz morem gotovo se udvostručio u posljednjem desetljeću. U skladu s tim, veličina kontejnerskih brodova značajno se povećala, a najnoviji kontejnerski brodovi nose do 24 000 jedinica ekvivalenta dvadeset stopa (TEU). U bliskoj budućnosti na tržištu se može očekivati pojava kontejnerskih brodova kapaciteta 25 000 TEU, jer je dizajn već dostupan. Poznato je da 10 – 12 % transportiranih kontejnera sadrži opasni teret (IMDG). Spomenuti razlozi izravno utječu na učestalost požara na kontejnerskim brodovima u teretnim prostorima. Prema podacima osiguravajućih društava, požari se u prosjeku javljaju svaka dva mjeseca, a to je sve veći problem kontejnerskog prijevoza morem. U ovom radu analizirana su 23 požara u teretnom prostoru, bilo u skladišnim prostorima ili na palubi. Rezultati analize utvrdili su najčešće uzroke požara i pokazali da su postojeći sustavi zaštite od požara na kontejnerskim brodovima neučinkoviti. Neprihvatljivo je da neučinkovitost protupožarnih sustava rezultira gubitkom ljudskih života, napuštanjem plovila, onečišćenjem okoliša i velikim imovinskim gubitcima vezanima uz teret i strukturu broda. Zbog svega navedenog, potrebno je kontinuirano raditi na novim regulatornim i tehničkim rješenjima za poboljšanje protupožarne sigurnosti teretnih prostora na kontejnerskim brodovima.

KLJUČNE RIJEČI

požari na kontejnerskim brodovima
IMDG teret
sustavi za gašenje požara

1. INTRODUCTION / *Uvod*

Container ships' size and design have remarkably changed over the last decade. It is standard for large container ships to carry 22 – 24 rows and 8 – 11 container tiers on deck. In addition to bringing benefits, an increase in size and container carrying capacity brings certain issues along. One of the more significant problems is related to fires and explosions in the cargo area. Increased ship size and capacity result in concentrating more boxes on a smaller number of ships. A higher number of containers on one ship increases fire risk. Fires and explosions incur massive losses, which, in the worst-case scenario, can reach up to one to two billion USD on mega container ships [1].

As part of multimodal transport, containerization has played an essential role in seaborne trade over the last five decades. The standard-sized 20 and 40-foot containers are mostly carried by purpose-built container ships. The first purpose-built container ship, named American Lancer, with a 1210 TEUs capacity, was delivered in 1968 in the USA. The world's largest container vessel HMM Algeciras, having 23964 TEUs capacity, was delivered on 23. April 2020 at the DSME shipyard in South Korea. Another 11 sister vessels were delivered during 2020. In the last 52 years, container ships' capacity has increased by almost 2000% [2]. Container ships' capacity in the last decade has increased from 15000 TEUs to 24000 TEUs. In 2018, newly built container vessels represented 23.5% of the world's total deadweight tonnage (dwt) delivered [3]. Most of the tonnage was attributed to the Neopanamax and Ultra Large Container Ships (ULCS), whose capacity grew by 33% in 2018 [4]. ULCS achieved the lowest fuel consumption per TEU per mile and reduced Greenhouse Gases (GHG) emission per TEU per mile.

The total container ships fleet in January 2019 accounted for 5152 ships with an aggregate capacity of 266 million metric tons, which represented 13.4% of the entire world fleet. The capacity since 2018 has increased by 4.9% [5]. In 2018, 1875 billion tons of goods were carried by containers, which accounted for 17% of the total seaborne trade [3]. In 2019, global container throughput reached 802 million TEUs and had increased by 2.3% compared to 2018 [5], while comparing to the 2010 figures of 531.4 million TEUs [6], the aggregate increase in the last ten years is above 50%. A large share of container trade is carried across the major East-West trading routes: Asia – Europe, the Trans-Pacific, and the Trans–Atlantic. These three routes account for more than 40% of the global containerized trade. The largest container vessels are utilized on these routes. Asia has a major role in container handling traffic and in 2018 accounted for 64% of the world's total, Europe 15%, North America 8%, Latin America and Caribbean 7%, Africa 4%, and Oceania 2% [5]. As can be seen, nearly two-thirds of the global container handlings were in Asian ports. China, Taiwan, and Hong Kong accounted for one half of the total regional traffic. In 2019, 7 out of the 10 world top container ports were located in China [7] with the container throughput over 106 million TEUs. Out of China in top 10 there were Singapore, Busan and Dubai.

This paper aims to identify the main causes of fires and explosions in the cargo spaces of container ships, to evaluate the effectiveness of a fixed fire extinguishing system, the ability of overall firefighting measures and the loss of life caused by fires and explosions. To achieve this, 23 fire accidents between 2010 and 2020 were thoroughly investigated and analysed, although during this period there were many more.

The paper is structured in 4 sections. Section 2 presents literature review related to cargo fire problems on container vessels. The reviewed literature can be divided into three categories: articles published in scientific journals, accident investigation reports issued by the various flag state administrations, and various initiatives undertaken by the shipping industry stakeholders. In section 3, reports on the major fire cases that occurred in the last decade are analysed. Section 4 describes activities initiated by the container-shipping companies, the International Union of Marine Insurance (IUMI), the International Maritime Organization (IMO), and the Classification Societies as a response to the frequent container fires. The final section contains research results and certain technical solutions which can be considered for installation on newly built container ships to enhance fire safety and reduce risk of fire. The results of the analytical research provide insight into the most common locations of fire outbreaks. The most common causes of fires have been revealed, and the assessment of the effectiveness of fire extinguishing systems in cargo space, and overall firefighting activities on container ships has been made.

2. LITERATURE REVIEW / *Pregled literature*

Previous papers published in various journals have concentrated on the analysis of accidents related to the transport of containers on deck, the impact of IMDG cargo on fires, the share of cargo fires in total container ship fires, loss of human lives caused by container ship fires, etc.

Langerbecker at al. [8] in 2008 made a risk model for the operation of container vessels. The risk model was made based on the reported accident categories on fully cellular container ship in the period 1993 – 2004. In this period there were 1582 reported accidents onboard container vessels with 80 dead and 28 missing crew members. The accidents were broken down to the different accident categories. Fire and explosion were recognized as one of the top-ranked hazard categories. This category is with the largest loss of human life and it resulted in 42 fatalities.

In 2010 Moctar at al. [9] concluded that fire and explosions on container vessels contribute to one third of all recorded fatalities onboard container vessels and that the fire accidents are second-largest cost contributor of all encountered accidents. The fires onboard container vessels are difficult to handle due to inadequate fire detection and firefighting capabilities, especially on deck. They conducted a series of full-scale tests with two loaded Twenty-foot containers. Their research aimed to estimate cargo fire risk for the container ships by measuring gas temperature in the container, temperature of the container steel structure, and gas concentration inside the box under various conditions regarding the temperature and ventilation.

Ellis [10] in her study in 2011 was focused to the factors leading to the accidental release of containerized dangerous goods carried onboard container ship. Records of dangerous goods cargo accidental release in an 11-year period (1998 – 2008) in UK and USA were analysed to recognize and categorize main contributing factors. According to this study it was estimated that the incidents relating to packaged dangerous goods account to 15% of all fatalities. Self-ignition and mis-declared packaged dangerous goods are main contributing factors for the fatal accidents.

Chen at al. [11] in 2013 reviewed fire and explosion safety related regulations, investigated main contributing factors to the explosions and fires on container ships based on the statistical date published by the Marine Incident Investigation Branch (MAIB). For the assessment of fires and explosion in container line supply chain they used the Intelligent Decision System tool.

Gafero and Sunaryo [12] in 2018 made container ship accident analysis due to container stacked on deck. One of the factors that are recognized in this paper as a trigger for fire accidents is connected to the placement of containers with IMDG cargo and the container packaging incompatibility with the IMDG code.

Callesen at al. [13] at the Technical University Lyngby, Denmark recognized a problem with container ship fires. In 2019 they did extensive research where the focus was put on analysis of four types of IMDG cargoes (calcium hypochlorite, compressed charcoal briquette, rechargeable batteries, and divinylbenzene) that initiated most fires in the period between 1996 – 2017. The authors studied 39 fire accidents in the given period and they conclude that calcium hypochlorite and charcoal briquette caused almost 50% of all fires.

The fire investigation reports analysed in this paper were issued by the casualty investigation departments of the various vessel's flag state maritime authorities. Most of these reports are available on the relevant authorities' websites, while some reports were obtained through the author's direct contact with the flag state administrations.

IUMI in September 2017 released "Position Paper on firefighting on container vessels" [14]. This paper emphasized that large fires on container ships are among the most serious hazards for the world shipping industry, given the loss of human lives, economic losses, and the threat of environmental pollution. The main reasons of increased number and severity of fires are the growing sizes of container ships and ineffective fire detection and firefighting systems presently installed onboard the vessels.

Allianz Insurance, in its "Safety and Shipping review 2018" [15] emphasized several issues related to the rapid growth of ULCS. Major fires are identified as one of the most significant safety challenges. Firefighting capabilities on board these vessels have not kept pace with the increasing vessel size. Cargo is not being properly declared despite of IMO requirements that shippers declare container contents; there are still many cases where the shippers avoid following these requirements. 12% of global container trade contains dangerous cargo. In 2015 incorrectly declared cargo increased by 65%. The salvage of ULCS, due to their size, it is a problem to find a suitable port that can accommodate them and provide safe refuge following a fire.

On the International Salvage Union Associate Members' Day in London on 23. April 2019, the challenges that salvor and crew face responding to cargo fires on large container ships were discussed [16]. One recent check in the USA on the container content showed that 20% of the containers were found with mis-declared cargo. Limited space between boxes makes access to the seat of the fire very difficult for the efficient firefighting operation. Once the fire breaks out, the crew is exposed to smoke, noxious gasses, and explosions. There is also a risk of losing control and a need to abandon the ship.

As per literature review, fires on container ships have been attracting great attention of the global maritime industry. This comes as no surprise considering the possible loss of life, substantial property loss, and possible environmental pollution which are all consequences of fires on container ships. It is estimated that significant container ship fires occur every two months. In 2019, there were six such cases [17]. Many fires that have occurred on container ships have not been registered because of their size. They have not attracted publicity in the maritime world nor the press and, due to lack of data, were not analysed further.

3. ANALYSIS OF MAJOR FIRE INCIDENTS / *Analiza velikih požarnih incidenata*

This chapter presents an analysis of major fire accidents in the period between 2010 and 2020. The purpose of this tabular analysis is to determine what the most common causes of fire are. Table 1 represents a chronological order of fire cases in the given period. The fire locations, the extent of the damage and the fire causes are also presented in the table. Data on the number of injured and dead persons, the extent of the external assistance in extinguishing the fire and whether the ship was abandoned after the fire broke out due to its escalation are shown in Figure 4 for all analysed cases.

As can be seen in Figure 1, 10 fires broke out on the deck, while 13 in cargo holds. Five of the fires that started in cargo holds spread to the deck, while eight were contained in cargo holds and extinguished.

Table 1 Overview of fires in cargo spaces on container ships in the period 2010 - 2020

Tablica 1. Pregled požara u teretnim prostorima na kontejnerskim brodovima u razdoblju 2010. – 2020.

Case	Name TEU capacity Year of built	Date of accident Duration	Location	Extent of damage	Cause
1	Charlotte Maersk 9612 2001	07.07.2010 12 d	Deck (above hold No.6)	160 containers and deformation of No. 6 hatch covers	Self-ignition of methyl ethyl peroxide (MEKP)
2	MSC Flaminia 6750 2001	14.07.2012 57 d	Cargo hold No.4, spread to other CHs and deck	Major structural damage, 1500 burnt containers	Overheating and self-ignition of divinyl benzene (DVB)
3	ZIM Rio Grande 4253 2008	20.07.2012 3 hrs	Deck midship, loading bay 34	One container	Decomposition of thiourea dioxide
4	Amsterdam Bridge 4380 2009	09.09.2012 3 d	Deck (above hold No.6)	Serious structural damage and 33 containers damaged	Fire of diacetone alcohol
5	Eugen Maersk 1550 2008	18.06.2013 5 d	Aft deck, aft most loading bay	Minor structural damage and several burnt containers	Cotton fire due to the friction heat after collapse of container stack
6	Hansa Brandenburg 1740 2001	15.07.2013 4 d	Hold No.5	Total loss, ship scrapped	Explosion of undeclared IMDG cargo – calcium chlorate
7	Maersk Kampala 6802 2001	28.08.2013 7 d	Deck (foremost loading bay)	Minor structural damage, 6 burnt containers	Fire started in the container stack bottom and spread to others
8	Maersk Londrina 8700 2012	25.04.2015 2 d	Fire/explosion in hold No.7	Several burnt containers	Explosion/fire of IMDG cargo – calcium chlorate
9	Hanjin Green Earth 13100 2013	01.05.2015 14 d	Explosion/fire in hold No.9, spread on deck	Major structural damage, several hundred containers burnt and damaged	Mis-declared calcium chlorite
10	Caroline Maersk 9578 2000	26.08.2015 4 d	Hold No.9	3 containers, minor structural damage	Mis-declared cargo of charcoal tablets
11	UASC Barzan 18691 2015	07.09.2015 7 d	Explosion/fire in hold No.2	9 containers burnt and serious structural damage in CH No.2	Undeclared IMDG cargo, very likely calcium chlorite

12	MSC Katarina 12400 2012	20.11.2015 12 hrs	Hold No.2	One container burnt, several other damaged	Self-ignition of charcoal
13	Ludwigshafen express 13177 2013	21.02.2016 13 hrs	Deck (above hold No.9)	One burnt container, 2 damaged	Self-ignition of charcoal
14	CMA CGM Rossini 5770 2004	15.06.2016 5 d	Hold No.5	2 burnt and 38 damaged containers	Explosion/fire of lithium-ion batteries
15	CCNI Arauco 9000 2015	01.09.2016 26 hrs	Hold No.8	130 burnt and damaged containers, major structural damage	Explosion/fire of undeclared IMDG cargo – paint thinner
16	APL Austria 6350 2007	12.02.2017 5 d	Hold No.4, spread to deck	Several hundred burnt and damaged containers, major structural damage	Explosion/fire of mis-declared calcium chlorite
17	MSC Daniela 13800 2008	04.04.2017 10 d	Deck aft, loading bay 58	Several hundred burnt and damaged containers, major structural damage	IMDG cargo fire – polystyrene (PS)
18	Maersk Honam 15282 2017	06.03.2018 17 d	Hold No.3	2000 burnt and damaged containers, major structural damage, third of the ship's structure replaced	Sodium dichloroisocyanurate dehydrate (SDID)/form of calcium chlorite
19	Yantian Express 7236 2002	03.01.2019 19 d	Deck (above hold No.2, spread to CH No.2/deck No.1	Several hundred burnt and damaged containers, major structural damage	Self-ignition of mis-declared coconut charcoal
20	APL Vancouver 9326 2013	31.01.2019 14 d	Hold No.7, spread to deck	582 burnt and damaged containers, major structural damage	Lithium-ion batteries not declared (undeclared) as IMDG cargo
21	ER Kobe 5700 2001	13.02.2019 4 hrs	Deck	15 burnt and damaged containers	Fire of charcoal
22	KMTC Hong Kong 1585 1998	24.05.2019 3 d	Deck (in port)	35 burnt and damaged containers	Explosion/fire of mis-declared calcium chlorite
23	COSCO Pacific 10062 2008	05.01.2020 6 hrs	Hold	2 burnt containers	Lithium-ion batteries not declared (undeclared) as IMDG cargo

Source: Authors based on [18-42]

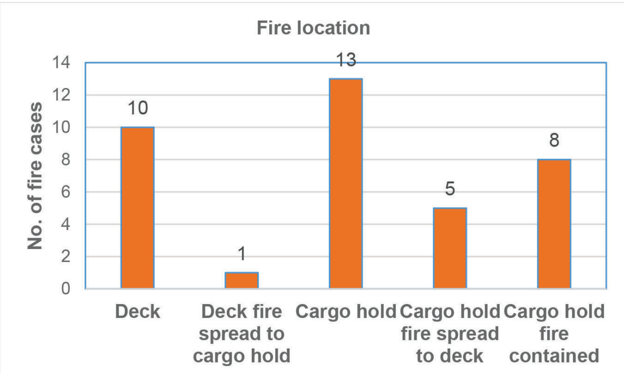

Figure 1 Fire locations in analysed cases
Slika 1. Lokacije požara u analiziranim slučajevima

Figure 2 represents the causes of 23 analysed fires. It can be noted that the two most common causes of fires are various forms of calcium chlorite and charcoal. However, the consequences of fires caused by calcium chloride are much more severe due to this chemical's nature. Calcium hypochlorite $Ca(ClO)_2$ [43] or calcium chlorite $Ca(ClO_2)_2$ [44] and its forms represent one of the most dangerous IMDG cargoes and were responsible for many container ship fires in the past. That is why the Cargo Incident Notification System (CINS) issued "Guidelines for the Carriage of Calcium Hypochlorite in Containers" in January 2018 [45]. The document describes this cargo's characteristics, the IMDG classes, the potential risks associated with its transport, the selection of containers, storage, packaging, and inspection before loading the ship. This figure shows that 22 out of 23 fires were caused by IMDG cargo. Only one fire (highlighted blue) was caused by the non-IMDG cargo, i.e. the self-ignition of the cotton in the container as a result of the heat released due to the friction caused by the collapse of the container stack stow. Ten fires out of 22 were caused by the IMGD cargo which was either not declared as IMDG or was mis-declared. Given that the total number of fires analysed is 23, this means that 43% of fires were caused by undeclared or mis-declared IMDG cargo.

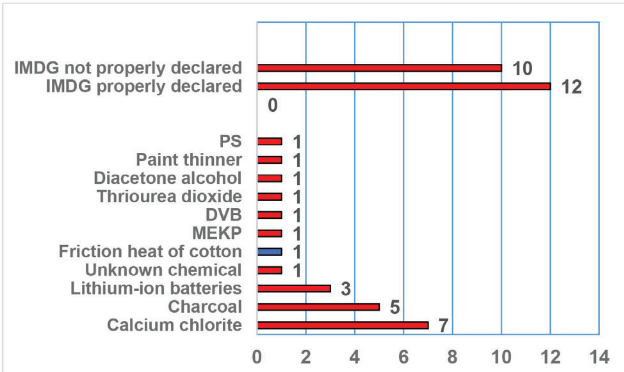

Figure 2 Causes of fire in analysed cases
Slika 2. Uzroci požara u analiziranim slučajevima

The evaluation of the fixed CO_2 fire extinguishing system and efficiency of the entire firefighting operations is based on the data obtained from the investigation reports related to the fire cases analysed in this paper. Cargo holds' fixed CO_2 fire extinguishing system efficiency is presented in Figure 3. As already mentioned, 13 fires broke out in cargo holds. In one case, the fire was extinguished very quickly, and there was no need to release a fixed CO_2 firefighting system. In 12 cases, the crew decided to release a CO_2 firefighting system. In only one case the CO_2 system proved to be effective, and the fire was extinguished, while in the other 11 cases it was partially or entirely inefficient. There are several main reasons for the inefficiency of the CO_2 system:

- limited efficiency for extinguishing deep-seated fires inside containers, especially for those types of cargo (e.g., lithium-ion batteries, cotton in bales) that smolder for a long time after the flame is extinguished and which re-ignite when the oxygen re-enters the scene of the fire;
- CO_2 extinguishes fire by reducing oxygen content as it is heavier than air, but it has a limited cooling effect. This poses a risk of fire re-ignition once oxygen is re-introduced to the cargo hold;
- if the container on fire is located on higher tiers close to the hatch covers, CO_2 won't have a fire extinguishing effect due to the constant inflow of fresh air;
- some IMDG cargoes are known as oxidizing materials (e.g., calcium hypochlorite), which release oxygen as a result of their instability and decomposition at elevated temperatures;
- limited gas tightness of the cargo holds due to the design and construction of the hatch covers. Namely, the covers of large container ships are of lift-away type, consisting of several panels for each cargo hold opening, arranged transversely, and separated by a longitudinal gap of less than 50 mm. The panels rest on bearing pads placed on top of the hatch coamings and do not have rubber packing which makes the cargo hold weather tight. The designed air gap between hatch covers and hatch coamings is 10 - 20 mm;
- if the fire spreads rapidly, there is a significant risk that some of the ventilation flaps and covers won't be accessible due to the smoke on deck;
- technical malfunctions of the CO_2 system due to poor maintenance, poor and improper installation of the system, and pipe leakage during system activation.

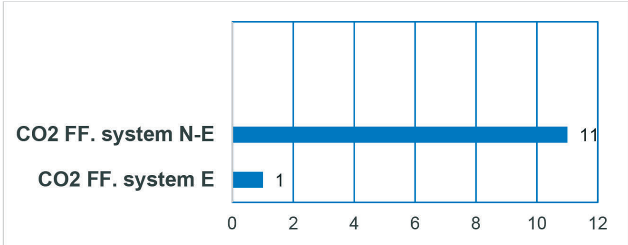

Figure 3 CO_2 firefighting system efficiency (N-E – Not Effective, E – Effective) as elaborated from the investigation reports.
Slika 3. Učinkovitost CO_2 sustava za gašenje požara (N-E – nije učinkovito, E – učinkovito), obrađeno iz istražnog izvješća

Figure 4 shows the overall efficiency of the fire extinguishing operation. The following four elements were analysed: the extent of damage, whether the ship was abandoned after the fire broke out due to the sudden escalation of fire and danger to human lives, whether the fire was extinguished by the crew or by external assistance (firefighting personnel, tugs, salvage teams, helicopters, etc.), and whether there were any deaths or injuries during firefighting operations.

The extent of damage to the ship and cargo is classified into three categories: minor, severe, and major. The number of damaged containers and the severity of structural damage to the ship was taken as the criteria for determining the degree of total damage caused by the fire. Damages up to 10 containers and damages to the ship's structure that can be repaired within one week are classified as minor. Damages from 10 to 100 containers and damages to the ship's structure requiring repair from one week to one month are classified as serious, while all damages requiring repair for a period longer than one month and if the number of damaged containers exceeds 100 are classified as major.

The ship was abandoned due to the sudden escalation of fire and danger to human lives in cases 1, 2, 4, 6, 17, 18 and 19.

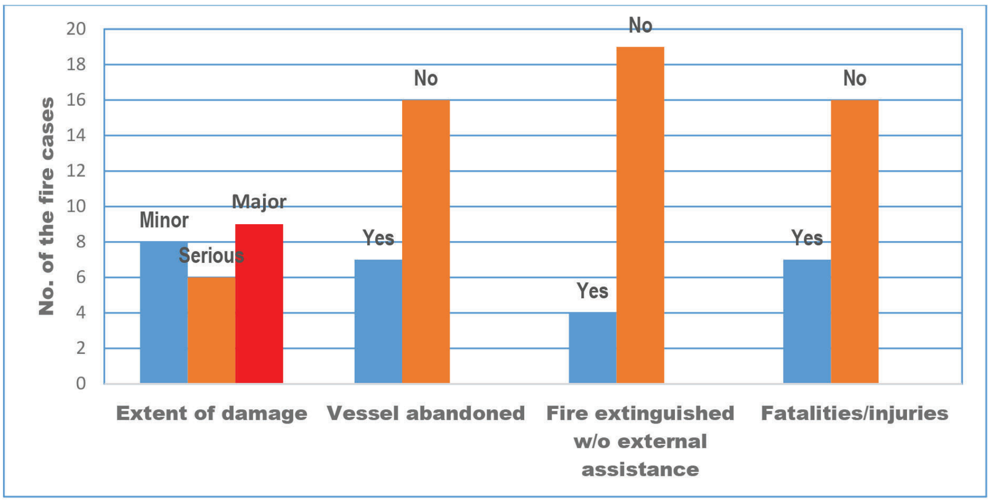

Figure 4 Firefighting operations efficiency as elaborated from the investigation reports
Slika 4. Učinkovitost vatrogasnih operacija obrađenih iz istražnih izvješća

The fire was extinguished by the crew without external assistance only in cases 3, 13, 21 and 23. In the cases where the fire was extinguished with external assistance, various resources were used, such as firefighting tugs, firefighters, firefighting planes, rescue vessels and helicopters, coastguard vessels, towing tugs, and salvage teams. The resources used in these cases range from one firefighting tug and firefighting team (case 5) to several firefighting tugs with firefighting teams, helicopters, two salvage companies and towing tugs (case 18).

Cases 1, 2, 15, 16, 18, 20 and 22 resulted in either dead or injured personnel. In case 2 there were 3 dead and 2 seriously injured crew members. Case 18, fire on MV Maersk Honam was one of the most devastating fires on container vessels up to date as it resulted in the loss of 5 crew members' lives and 22 crew members treated in the hospital. In case 22 more than 200 people were treated in the hospital due to respiratory problems. Injuries in cases 1, 15, 16 and 20 were limited to 1 to 3 persons who suffered burns and respiratory problems.

From the obtained results, it can be concluded that fires in the cargo area on container ships represent a significant problem that impacts container ship fire safety. Therefore, classification societies, insurance companies, responsible authorities, and the largest container companies have taken specific actions to reduce the risk of fire outbreaks and reduce their consequences on container vessels. Some of these actions are presented in the following chapter.

4. INFLUENCE OF THE CONTAINER FIRES FREQUENCY ON INTERESTED PARTIES OF CONTAINER TRANSPORT BY SEA / *Utjecaj učestalosti požara kontejnera na zainteresirane strane uključene u pomorski kontejnerski transport*

The frequency of container fires in the last decade and their consequences related to injuries or loss of life, serious damage or loss of assets, and environmental concerns have attracted significant attention among the interested parties of container transport by sea. Consequently, the largest container-shipping lines, insurance companies, IMO, and classification societies have taken certain actions to reduce the risk of fire and enhance firefighting efficiency in the event of an outbreak.

Due to many fires on container ships between 2000 and 2010, the five largest container-shipping lines established a CINS initiative [46] in September 2011. The purpose of this initiative is to collect information on operational cargo-related incidents, analyse all collected information and data on cargo and container related incidents, establish an area of concern and propose actions to improve safety in the container transport chain, and address areas of concern to relevant authorities. Based on the purposes above, relevant authorities can make amendments to the IMDG code and advise on training issues related to packing and securing cargo in containers. Today, the 17 largest container-shipping lines are members of the CINS initiative.

On 22.05.2014, IMO brought amendments to the International Convention for the Safety of Life at Sea (SOLAS) 1974 resolution MSC.365 (93) Regulation 10 – Firefighting. A new paragraph 7.3 was added [47]. This paragraph applies to ships constructed on or after 01.01.2016, which were designed to carry containers on or above the weather deck. In addition to the standard equipment and arrangements:

- ships shall carry at least one water mist lance which shall consist of a tube with a piercing nozzle capable of penetrating a container wall and producing water mist inside a confined space when connected to the fire main;
- ships designed to carry five or more container tiers on or above the weather deck shall have mobile water monitors. Ships with breadth less than 30 m at least two monitors and ships with the breadth of 30 m and above at least four mobile water monitors;
- the mobile water monitors, hoses, fittings, and required fixing hardware shall be kept ready for use in the area outside of cargo space not likely to be cut off in the event of a fire in the cargo space;
- a sufficient number of fire hydrants shall be provided such that all provided monitors can be operated simultaneously for creating an effective water barrier forward and aft of each container bay.

On 17.10.2019, Norwegian insurer GARD organized a two-day conference with a container ship fire topic [48]. Representatives from leading container carriers, ship owners, flag states, fire experts, IMO, IUMI, CINS, Baltic and International Maritime Council (BIMCO), International Association of Classification Societies (IACS), and the World Shipping Council attended the conference. The following issues were discussed: root causes of container ship fires, cargo supply chain, fire detection, firefighting, innovation in firefighting equipment, proposals on how to reduce risk of container ship fires, and how to improve firefighting efficiency.

Classification Society American Bureau of Shipping (ABS) in May 2017 developed and offered to the ship owners new optional class notation "Firefighting on Deck Container" (FOC) for further enhancement of the firefighting capabilities for deck cargo on board container ships [49]. Firefighting equipment installed on ships with FOC class notation and firefighting capability is beyond SOLAS's standard equipment.

In 2019 Classification Society Det Norske Veritas Germanische Lloyd (DNV GL) further developed an optional class notation for firefighting on deck container ships and offered five slightly different class notations: FCS (C) - Extended level beyond SOLAS, FCS (HAZID) - Hazard identification, FCS (FD) - Enhanced fire detection, FCS (FF) - Enhanced firefighting, FCS (HF) - Firefighting by hold flooding, to the ship owners [50]. First ULCS MSC Gulsun with a class notation FCS HAZID was delivered on 09 July 2019. Features of this class notation are fixed fire monitors, which have a range of over 100 m. Their purpose is to slow and stop the spread of fire by cooling effect. In addition, a system of thermal cameras has been installed, whose goal is to alert the crew of the potential fire in the event of any irregularity.

In January 2021, Classification Society Bureau Veritas (BV) published the new guidelines developed based on a thorough analysis of container ships' cargo fire incidents. These guidelines include improved firefighting capabilities on deck with water monitors and water spray systems subdivided into sections, increased protection of accommodation blocks and life-saving equipment, improved firefighting and fire containment in the cargo hold, and fire detection appliances in the cargo hold and deck. The guidelines are amended to BV Rules for the Classification of Steel Ships NR 467 [51].

5. CONCLUSION / *Zaključak*

Due to the container ships' growing size and number, cargo fires' frequency and consequences represent a major challenge for all participants in container sea transport. Despite technical improvements of firefighting systems, consequences of fire accidents are still significant, and it is necessary to work on further improvements of both fire detection and firefighting systems. From the analysis' results, the following can be concluded: 43% of fires were caused by undeclared or mis-declared IMDG cargo; current fire protection systems both in the cargo hold and on deck are ineffective, as only 17% of fires were extinguished without external assistance; in 30% of cases the ship was abandoned, and there were injuries or fatalities among crew members; the fires also caused significant property damage and environmental pollution. Although the CINS initiative and random container inspections contribute to the reduction of mis-declared or undeclared IMDG cargo, this problem will never be completely solved mainly due to the large difference in the cost of transporting containers with normal dry cargo and IMDG cargo. It is well-known 10 - 12% of containers transported by sea contain hazardous cargo. This means that the largest container ships can carry as many as 2800 TEUs with dangerous goods that increase the possibility of having a single container on board which may cause the fire or the explosion, especially if the cargo is inadequately stowed or packed inside the container. Once a fire starts, one can assume that the severity of the fire damage and firefighting efforts are enormous due to difficult access, distances, and the number of rows and tiers of containers. In addition to the property damage, container ship fires pose a high risk of personnel injury or death and environmental pollution. Container ships have relatively small accommodation blocks and narrow passages on deck which are frequently obstructed by the container lashing equipment and reefer container electrical cables. This has a negative effect on the firefighting efficiency in case of fire. Another cumber is that the fire inside the box develops very quickly and, once discovered by the crew, it might already be too late to fight it effectively. Due to all of the above, it is necessary to find technical solutions to further improve both the fire detection system and firefighting in the event of a fire outbreak in cargo hold or on deck. Installation of optical, thermal, and flame detectors and their connection to the central fire detection system, fixed-mount thermal cameras for remote monitoring, and video surveillance are possible solutions for earlier fire detection. Installation of a seawater drencher system in all cargo holds with distributing nozzles in hatch coamings and hatch covers, not just in those designed to transport IMDG cargo is another option for improvement. Permanently connected flexible hoses to the fire line during sea passage and the installation of remote-controlled (from the navigation bridge) electro-pneumatic valves will allow rapid activation of the system without exposing the crew to injury risks and loss of life. The installation of the seawater system, fore and aft of all cargo holds, and the creation of water curtains will help prevent the spread of fire on deck. Newer container ships are equipped with portable water monitors that can be used to extinguish fires on the higher container tiers. However, given the number of crews on container ships, monitors' weight, and the time required for their deployment, it is evident that their effectiveness is limited. Therefore, it is recommended that fixed monitors be installed on all container lashing bridges. With the ability to be remotely activated and controlled from the navigation bridge, monitors would further contribute to deck fire protection effectiveness. Future research on this topic should focus on the possibility of using other fire extinguishing agents, such as high expansion liquid foams, and gaseous fire suppression agents in the cargo holds. As it was shown, CO_2 as a firefighting agent proved to be quite ineffective. Further, it belongs to the group of greenhouse gases. This is especially significant considering the IMO strategy to reduce respective emissions in shipping by the year 2050 to 50% of emissions as recorded in 2008. From a technical perspective, it will be possible to build a 30000 TEU container ship in this decade. It will be interesting and useful to analyse the respective consequences on container transport and the infrastructure of container terminals as a whole.

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