Maritime Technology and Society
Vol. 2(1): 22-27, February 2023
https://doi.org/10.62012/mp.v2i1.25486

Risk Analysis of Hot Working in Confined Space Using Confined Space Risk Analysis (CRSA) and Bowtie Analysis Method on LPG Tanker Repair Process

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Received 01 January 2023; Received in revised form 10 January 2023; Accepted February 2023

A b s t r a c t

Confined space is a room that is large enough and has a configuration in such a way that workers can enter and do work in it. In the ship repair process, it is not uncommon to do it in a confined space area. This study begins with identifying the characteristics of limited space on ships by grouping them into seven risk categories of enclosed space. Then carry out risk identification by explaining the components of risk, including types of hazards, dangerous work, dangerous events, and the consequences that can occur. After that, an initial risk assessment was carried out for hot working in confined spaces on ship repairs presented in matrix form. After that, risk control is carried out, and the final risk reassessment for hot working in confined space on ship repair is carried out by continuing the previously made matrix. In the final stage, an analysis is carried out using the bowtie method to analyze these risks' causes, impacts, and controls.

Keywords: Hot Working; Confined Space Risk Analysis; Bowtie Analysis

1. Introduction

In ship repair activities, one of the things that cannot be separated is confined space. It is said so because some parts of the ship are determined space areas. A confined space is a room that is large enough and has a configuration in such a way that workers can enter and do work in it. The room has limited access in and out and is not designed for a continuous or continuous workplace[1]. On ships, confined space areas include cargo spaces, chain lockers, fuel tanks, ballast water tanks, sewage tanks, and other parts of the vessels that meet the requirements are said to be confined spaces[2]. There is a lot of work with high potential in confined spaces on ships, including tank cleaning, hot work, painting, spraying abrasives, electrical work, and others [3].

One of the activities in ship repair that has been mentioned is hot working. Hot working is a forming process by heating the workpiece above the recrystallization temperature. Then an external force changes the desired shape [4]. This study's hot working activities in ship repair were plate cutting, grinding, and welding. In the ship repair process, hot working activities are one of the types of activities that are usually carried out and not infrequently in a confined space, as can be seen in Figure 1. Work carried out in a confined space can cause accidents ranging from mild to fatal, so risk management is needed to avoid or reduce the incidence of accidents that can occur, then the need for risk management. Risk management is an approach to understanding, identifying, and evaluating existing risks [5].

E-ISSN: 2828-6669; P-ISSN: 2828-7010

Fig.1. work in confined space areas [1].

This study will use the Confined Space Risk Analysis method. This method can identify risks comprehensively by analyzing all the work risk factors in confined spaces, categorizing interventions and rescue conditions based on specific criteria¸ evaluating external rescue needs, and determining if the residual risk is acceptable [6]. The research uses the Bowtie Analysis method for causes, consequences, and barriers.

2. Materials and Methods

2.1 Identification of the Problem

Identification of problems is made by looking for ideas of the current problems. The problem raised is that the risk analysis carried out by the shipyard company on ship repair work for hot working work in confined spaces is not detailed.

2.2 Literature Study

In the implementation of research, literature studies are carried out by looking for library data that support research in journals, books, final projects, and others. Observations and interviews were also carried out, and questionnaires were given to expert judgment at the place where the research took place where the specialist decision understood and understood the author's research object technically and in detail.

2.3 Data Collection

The data collected results from the author's observations and the consequences of interviews with expert judgment in the form of a questionnaire. Expert judgment is a specialist opinion in decision-making in a specific area, organization, or company [7]. The expert decision chosen is a safety officer/K3 employee with at least five years of experience and expertise in risk analysis, especially in confined spaces. The assessment expert will be asked to complete a questionnaire. In addition, the description of data related to space repair work is limited to ships in the company.

2.4 Data Analysis with Confined Space Risk Analysis.

The first is to identify the characteristics of the ship's manhole as a confined space area by paying attention to the five primary causes of a hazard: machine, material, environment, method, and human resources. Of these five fundamental causes, hazards can be grouped into seven risk categories: atmospheric, chemical, biological, falling, mechanical, physical, and ergonomic [8]. Then carry out risk identification by explaining the risk components, including types of hazards, hazardous work, hazardous events, and the consequences that can occur. After that, an initial risk assessment for confined space hot work on ship repair was carried out and presented in matrix form. After that, an initial risk assessment for confined space hot work on ship repair was carried out and presented in matrix form. In making the matrix, the writer carried out several stages: direct observation, interviews, and brainstorming with expert judgment so that the data obtained was more valid. Then, risk control and final risk reassessment for hot work in confined spaces on ship repairs are carried out by continuing the previously made matrix. In risk assessment using the appropriate guidelines in AS/NZS4360:2004. The last step is the analysis and evaluation of the results of the final risk assessment of the repair work in the confined space on ships, which is carried out by grouping and giving priority scales to the existing potential hazards based on the final risk value (risk ranking) [9,10,11]**.**

2.5 Bowtie Analysis

After getting the extreme risk variable from the

E-ISSN: 2828-6669; P-ISSN: 2828-7010

level of risk assessment in hot working ship repairs in confined spaces, an analysis was carried out using the bowtie method. Bow Tie Analysis is a method presented as a diagram like a bow tie in which there are causes, effects, barrier prevention, and recovery barriers from a failure (peak event). Bow Tie Analysis effectively covers the main elements of the risk management process: assistance, prevention, mitigation, and assessment[12].

2.6 Conclusion

From this research, it will be obtained any potential hazards that have a high value and can be identified as the fundamental causes that must be prevented and the consequences that must be overcome. By concluding later, it will be helpful for readers or further researches

3. Identification of the characteristics and potential hazards of the confined space

Identification of the elements of the limited space area on a ship is carried out by assessing it using a closed-ended question or a question with a choice of answers that have been developed. This is done so that the answers obtained are more focused because the available answer choices describe work conditions in a confined space. The answers to the questionnaire will be categorized as a potential hazard in a confined space which is grouped into seven risk categories.

Table 1. Potential hazard of hot working in confined space in ship manholes

Risk Categories		Potential Hazard
Atmospheric	1	There is residual toxic gas in the manhole (CO)
	2	Lack of air ventilation and limited oxygen
	3	There is smoke/fume from the hot working process
Chemical	4	There is residual toxic gas in the manhole (CO)
	5	Lack of air ventilation and limited oxygen
Ergonomic	6	There is smoke/fume from the hot working process
	7	There are residual materials that are toxic and dangerous
	8	There are welding electrodes, pyrolysis products from the hot working process
Falling	9	Being in a condition with limited movement
	10	Poor lighting conditions
	11	Room conditions with high temperature
Physical	12	Fall from height (access up and down manhole)
Risk Categories		Potential Hazard
	13	There is an electric current, and the walls of the tank are made of metal which is a good conductor which can cause electrocution
	14	Poor lighting conditions in the manhole
Mechanical	15	Relating to equipment with energy
	16	risks (example: gas cylinders, machines)
	17	Sharp, structured, hot working equipment

4. Discussion

4.1 Hazard Identification and Risk Assessment with Confined Space Risk Analysis

Further hazard identification is carried out at each stage of the hot working work in the ship's manhole according to the hazard category of the confined space. Then, the likelihood and severity of each hazard variable will be known for the risk assessment carried out by expert judgment. To calculate the likelihood and severity index, use the equation below:

$$I = \frac{\sum_{i=1}^{N} ai \times xi}{5 \times N} x\ 100\% \quad (1)$$

Where ai = Assessment constant (1 to 5)
x_i = Respondent's probability
N = Total number of respondents

Based on hazard identification and risk assessment results at all stages of hot work in the

E-ISSN: 2828-6669; P-ISSN: 2828-7010

ship's manhole, a total of 50 potential hazards with 76 risk levels was obtained. The potential hazards that can arise from the stages of hot working on the ship's manhole are classified into seven types of risk (according to Confined Space Risk Analysis), listed in the following table.

Table 2. Potential Hazards in the Stages of Hot Working in Confined Space

No	Stages of Work	Potential Hazard							
		A	C	B	E	F	P	M	∑
1	Manhole opening	1			1				2
2	Enter and Exit Manholes				1	1			2
3	Preparation of Hot Working Equipment				2	2	1	1	6
4	Plate Cutting	2	1		2	2	4	3	14
5	Grinding	2			2	2	3	4	13
6	Fittings and Welding	2	1		2	2	3	3	13
		Total Potential Hazard							50

The next step is risk control and final risk reassessment conducted by expert judgment. Risk assessment before control can be seen in table 3 below, while after being given control and the results are assessed can be seen in table 4 below.

Table 3. Risk Assessment Before Control

No	Risk Category	Frequency of Each Risk Level				Total Risk Level
		E	H	M	L	
1.	Atmospheric	10	8			18
2.	Chemical	2				2
3.	Biological					
4.	Ergonomic			10		10
5.	Falling	3	8	1		12
6.	Physical	9	5			14
7.	Mechanical	8	10	2		20
	Total Risk Level	32	31	13		76

Table 4. Risk Assessment After Control

No.	Risk Category	Frequency of Each Risk Level				Total Risk Level
		E	H	M	L	
1.	Atmospheric		7	10	1	18
2.	Chemical			2		2
3.	Biological					
4.	Ergonomic				10	10
5.	Falling		2	5	5	12
6.	Physical		1	6	7	14
7.	Mechanical		5	10	5	20
	Total Risk Level		15	33	28	76

From these two tables, a radar chart of the risk category can be obtained before and after the control measures show a decrease, as shown in Figure 1. A value of 0 indicates no risk has occurred, and 1 indicates a low or low risk. A value of 2 indicates a moderate risk or medium risk, a value of 3 indicates a high risk or high risk, a value of 4 indicates a very high risk or extreme risk. Then based on the hazard identification and risk assessment carried out as in Table 4.3, the three risks in hot working work on the manhole with the highest risk level value are listed in Table 4.7 as follows.

E-ISSN: 2828-6669; P-ISSN: 2828-7010

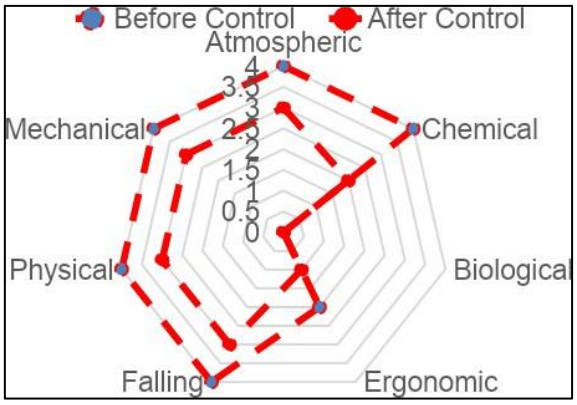

Fig.2. Level of risk category before and after control on a hot working process in ship manhole

Tabel. 5 Higest Risk

Risk Number	Risk Category	Description	Consequence	Risk Assessment 2 L.S
6.1	Atmospheric	At the stage of fitting and welding work, there is an accumulation of pyrolysis products and chemical residues contained in the manhole	Workers can experience a lack of oxygen, dizziness, nausea, fainting, and even the worst possibility is causing a fatality	= 3 x 4 = 12 (High Risk)
6.2	Atmospheric	At the stage of fitting and welding work, there is a welding flame used in the welding process	There is a potential for fire or explosion if the procedure fails or fire reacts with the remaining fuel	= 3 x 3 = 9 (High Risk)
4.8	Falling	At the stage of the plate-cutting work, the results of the plate-cutting may fall	Potentially causing injuries, broken bones, and even fatality	= 3 x 3 = 9 (High Risk)

4.2 Bowtie Analysis

After obtaining the extreme risk variable from the risk level assessment in the hot working ship repair process in the confined space, an analysis is then carried out using the bowtie method to analyze the causes, impacts, and controls of these risks. There were three variables with an "extreme" risk level, namely variable 6.1. Namely accumulation of toxic gas inhalation by workers can be seen in Figure 2. Then variable 6.2, namely fire that might occur due to procedure failure, can be seen in Figure 3, and finally, variable 4.8, namely plate fall, can be seen in Figure 4.

5. Conclusions

From the research that has been carried out, the identification results from hazard analysis and risk assessment in hot working in confined spaces using the Confined Space Risk Analysis method in the LPG tanker repair process show 50 potential hazards with 76 risk levels. Before the control, there were 32 extreme-risk levels, 31 high-risk levels, and 13 medium-risk levels. Then after the control was given control, there were 15 high-risk levels, 33 medium-risk levels, and 28 low-risk levels. From these results, three potential hazards with the highest level of risk are the presence of smoke and toxic gases in welding work, the potential for fire or explosion in welding work, and the potential for falling plates in plate cutting work. For the results of the bowtie analysis on the hot working ship repair process in the confined space, namely, there are 3 Top Events. Namely, workers are exposed to accumulated smoke and toxic gases that exceed the NAB when welding and fires/explosions arising from procedure failures during hot working work. Plate fall during plate-cutting work.

References

E-ISSN: 2828-6669; P-ISSN: 2828-7010

[1] Occupational Safety and Health Administration (OSHA) 3138-01R: *Permit-Required Confined Spaces*. US Department of Labor, 2004.

[2] International Maritime Organization (IMO) A. 1050: Recommendations for Entering Enclosed Spaces Aboard Ship. London, UK, 2011.

[3] International Labour Organization (ILO). Safety and Health in Shipbuilding and Ship Repair. Geneva, Switzerland, 2019

[4] Occupational Safety and Health Administration (OSHA): Hot Work (Including Welding, Cutting, and Heating). US Department of Labor, 2017.

[5]Pritchard, Carl L., and PMI-RMP PMP. Risk management: concepts and guidance. Auerbach Publications, 2014.

[6]Burlet-Vienney, Damien., dkk. The Need for a Comprehensive Approach to Managing Confined Space Entry: Summary of the Literature and Recommendations for Next Steps. Journal of Occupational and Environmental Hygiene, Vol. 11, No. 8, pp.485- 498, Institut de recherche Robert-Sauvé en santé et en sécurité du travail, Kanada, 2014.

[7] Benini, Aldo., dkk. The Use of Expert Judgement in Humanitarian Analysis - Theory, Methods and Apllications. ACAPS. Geneva,Switzerland, 2017.

[8]Chinniah, Yuvin., dkk. Development of a Confined Space Risk Analysis and Work Categorization Tool. Studies and Research Projects, R-955. Institut de recherche Robert-Sauvé en santé et en sécurité du travail, Kanada, 2017.

[9]Burlet-Vienney, Damien, et al. "Design and application of a 5 step risk assessment tool for confined space entries." Safety science 80 (2015): 144-155.

[10] Burlet-Vienney, Damien, et al. "Risk analysis for confined space entries: Critical analysis of four tools applied to three risk scenarios." Journal of occupational and environmental hygiene 13.6 (2016): D99-D108.

[11] Botti, Lucia., dkk. A Methodology for the Identification of Confined Spaces in Industry : A Survey. Journal of Occupational and Environmental Hygiene, Vol. 14, No. 4, pp. 271-284. Taylor & Francis, UK, 2018.

[12] Saud, Yaneira E., dkk. Bow-Tie Diagrams in Downstream Hazard Identification and Risk Assessment. Process Safety Progress, Vol. 33, No.1, pp. 26-35, American Institute of Chemical Engineers (AIChE), NewYork,2013

E-ISSN: 2828-6669; P-ISSN: 2828-7010