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INDICES FOR ASSESSING POTENTIAL ENVIRONMENTAL HAZARD FROM FUTURE SHIP SCRAPPING PROCESS, DETERMINABLE IN SHIP DESIGN STAGE

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ABSTRACT

This paper shortly presents the issue of utilization of ships after their withdrawal from service. Information on number of floating units liquidated in previous years was presented. Hazards to the environment , health and life of workers employed in the Far East ship scrapping yards operating on the beaches, were indicated. Then, the most important rules which have to make the ship recycling process safe were referred to. This author proposed to supplement the rules by environmental hazard indices which would be determined already in ship design stage. According to the concept the indices should take into account amount of dangerous substances used for building the ship as well as degree of their harmfulness (weighing factors). Two approaches to the issue of determining the weighing factors were proposed: deterministic and fuzzy.

Keywords: ship utilization, safety, environmental protection, safety indices, weighing factors

INTRODUCTION

The issue of liquidation of ships is presently a subject of interest of international community, especially in EU countries. According to the NGO Ship-breaking Platform coalition, over 70% ships end their life on the South Asia beaches: in India, Bangladesh and Pakistan [11]. The scrapping is carried out there with the use of cheap labour, often by hands of under-age workers. As a result of bad working conditions lethal accidents happen. In 2016 in Bangladesh only about 20 persons were killed in such accidents [13]. Moreover such practice produces great danger to the environment because the disassembling is performed on the beach tide areas. Dangerous materials and substances contaminate shores and coastal waters. Moreover, they are spread over farther regions due to action of sea currents, consumed by living organisms, including fish caught for consumption.

In 2016 as much as 862 ships were liquidated worldwide, including 305 in India, 222 – Bangladesh, 141 – Pakistan, 92 – Turkey, 74 – China, 22 – EU and 6 in other regions of the world. It is essential that as much as 668 ships out of their total number were broken on the beaches. Their total tonnage amounts to 27,4 m. GT, including 23,8 m. GT tonnage of ships scrapped on the beaches. According to the data published by the NGO [12], on the list of disreputable champions which liquidated their ships on the beaches in 2016 the following EU countries can be found: Germany (with 98 ships scrapped on the beaches, out of 100 altogether), Greece (with 104 ships scrapped on the beaches, out of 113 altogether).

LEGAL REGULATIONS

To assure safe and environmentally friendly process of ship-breaking there were prepared a number of legal regulations which are presented almost in detail in [3] and [14]. The following can be found among them:

- Basel Convention on 22 March 1989, dealing with trans-border movement and liquidation of dangerous waste ;
- International Convention on Safe and Environmentally Friendly Recycling of Ships, 2009;
- Series of ISO 30 000 standards – an integrated guide for ship recycling issues dealing with safety, health and environmental protection;
- IMO Resolutions (MEPC 62, MEPC 63, MEPC 64, MEPC 68) – guidelines containing detail solutions in the area of ship recycling and operation of ship repair yards;
- Directive of EU Parliament and Council No.1257/2013 of 20 November 2013 on the recycling of ships.

The Directive came into force on 30 December 2013. It introduces obligation to keep a register of ship recycling enterprises which fulfil requirements of Hong Kong Convention. The current register can be found in the appendix to the Executive Decision of EU Commission 2016/2323 [15]. It contains 18 ship-recycling enterprises, including one located in Poland (Almex firm of Szczecin).

ENVIRONMENTAL HAZARD INDICES

In order to assure a high level of environmental safety for ship during its scrapping process it is necessary to make appropriate decisions already in design stage. To this end, it should be strived to use as low amount of dangerous materials for building the ship as possible. The materials both hazardous and neutral for the environment should be fit for recycling and using again. Hence they would not fill waste stockpiles (scrap-yards). Therefore it's worth to strive after reaching a high susceptibility to recycling of a ship during its design stage. The next issue is to decide as early as in ship design stage in what way ship disassembling process would be carried out in future. It should be so designed as to obtain a scrapping process characterized by low energy and time consumption, as well as low emission of noxious substances during such operations as paint removal, plate cutting etc.

It is required to provide new designed ships with a list of dangerous materials. It should be worked out already in ship design and building stage. According to the PRS publication on ship recycling [14], such list should cover all dangerous materials used for ship construction and outfit, operational waste as well as reserves. The list [14] specifies forbidden materials as well as those of limited allowable content, such as asbestos, polychlorinated biphenyls (PCB), substances reducing ozone layer (CFC), tin-organic compounds in anti-growth systems, heavy metals (e.g. lead, mercury), radioactive compounds. The list comprises also fuel and lubricating oils and oily bilge water.

Environmental hazard resulting from ship scrapping should be determined in compliance with the standard format of the list of dangerous materials given in the second appendix to the above mentioned publication [14].

Hence it is proposed to introduce indices which estimate potential environmental hazard caused by a ship during process of its scrapping. This would be a useful supplement to the rules worked out in this area.

The index which takes into account dangerous materials used for building a ship would have the following form:

$$I = \sum_{i=1}^{n} W_i \cdot M_i \tag{1}$$

where:

I – environmental hazard index,

W_i – harmfulness weighing factor of *i-th* dangerous material, (taking values in the range between 0 and 1),

M_i – mass of *i-th* dangerous material, expressed in kg.

Of course, the larger value of the index the greater environmental hazard from a ship under scrapping work.

It's worth to introduce one index more in order to take into account that a part of elements which contain dangerous materials may be recycled and used again. The other index would cover possible degree of the materials recycling. Its numerical value would be the smaller the greater amount of the materials could be useful again, i.e. not subjected to storage.

The index would have the form as follows:

$$I_R = \sum_{i=1}^{n} W_i \cdot M_i \ \cdot (1 - \frac{R_i}{100}) \tag{2}$$

where:

I_R – environmental hazard index which covers possible degree of recycling,

W_i – harmfulness weighing factor of *i-th* dangerous material (taking values in the range between 0 and 1),

M_i – mass of *i-th* dangerous material, expressed in kg.

R_i – recycling degree, i.e. recyclability of elements containing *i-th* dangerous material, (expressed by percentage number in the range between 0 and 100).

The above given values of the indices are of absolute form. They represent real mass of dangerous substances comprised in a ship. As a result, they will be advantageous for small ships but non-advantageous for large ones. In a sense it seems to be correct because under similar conditions scrapping the ships of small tonnage will be less hazardous to the environment than that of the ships of large tonnage.

In order to make it possible to compare potential environmental hazard from ships of different size the above mentioned indices should be related to ship mass. This way they will become relative ones expressed by the dimensionless ratio of mass of dangerous substances and mass of ship itself. Designer should strive to assure possibly low values of the indices. However, on the other hand he/she must take into account economic aspects and proceed in compliance with the ALARP approach (As Low As Reasonably Practicable).

The ALARP approach (principle) was described, a. o., in [6, 9]. It says that impermissible risk is to be lowered regardless of cost. Ship designer would have to deal with such situation if he/she used unpermitted materials or exceeded their allowable contents. In consequence, he/she would be forced to resign from them. ALARP area is another component of the risk. It requires from the designer to perform an analysis of possible reduction of risk and cost associated with this approach.

The risk should be reduced to as low level as rationally justified for economic reasons.

The third area deals with negligible risk when it is as much low that there is not necessary to attempt to its lowering.

In practice, an impermissible risk does not ought to occur as it is associated with violating the rules. In ship scrapping a negligible risk would rather not happen. Therefore it should be taken into account that such process will be in ALARP area, which is connected with necessity to conduct an analysis of possible reduction of the risk and cost associated with this.

WEIGHING FACTORS

The above discussed potential environmental hazard indices require to establish weighing factors. They have to represent harmfulness degree of used dangerous material.

Determination of the weighing factors will require forming the group of experts and conducting the tests of their opinions.

Following the Norwegian method for the environmental indexing of ships [4, 8], one assumed that the experts will assign values in the range from 0 to 10, where zero stands for a non-dangerous material and 10 – for an extremely dangerous material. Then, the values obtained as a result of elaboration of experts' opinions will be standardized, i.e. scaled down to the numerical interval from 0 to 1, where 1 will stand for weighing factor for an extremely dangerous material.

The below presented calculation example follows the document [10] which contains supplements to recommendations of the formal ship safety assessment method (FSA) worked out under auspices of International Maritime Organization (IMO).

In fact, one should expect several dozen dangerous materials for which it will be necessary to determine weighing factors. In the presented example only five materials are assumed to be considered and that only five experts will be at one's disposal. The below presented Tab. 1 shows hypothetical results of experts' activity which consisted in assigning rank values from the interval (0, 10) to the five selected materials.

Tab. 1. Rank values assigned by experts to dangerous materials

	Dangerous material				
	S1	S2	S3	S4	S5
Expert No.1	5	8	7	9	6
Expert No. 2	5	8	6	9	7
Expert No. 3	5	8	7	9	6
Expert No. 4	5	9	7	8	6
Expert No. 5	5	9	6	8	7
Sum of x_{ij} values	**25**	**42**	**33**	**43**	**32**

The next step in determining values of weighing factors is their standardization.

As we have five experts the maximum value of weighing factor possible to be assigned by each of them is 10, hence the maximum value of the sum of weighing factors amounts to 50. Individual standardized values of weighing factors amounts to, respectively:

W_1 = 25/50 = 0,5
W_2 = 42/50 = 0,84
W_3 = 33/50 = 0,66
W_4 = 43/50 = 0,86
W_5 = 32/50 = 0,64.

It should be expected that the experts would not be fully unanimous in their opinions. Some divergence in the opinions may be observed in the example data of Tab. 1. In such situation a conformity level of the achieved opinions should be estimated. For differences in weighing factors assigned to given dangerous materials either standard deviation from mean value or range may be used.

For material No.1 the standard deviation from the mean equal to 5 amounts to 0, the range –0, and the relative range –also 0%, because full conformity of experts' opinions was reached in this case.

For material No.2 the standard deviation from the mean equal to 8,4 amounts to 0,48, the range – 1, and the relative range – 10%. It may be said that we have to do with low discrepancy of experts' opinions, i.e. high conformity level.

An experts' conformity coefficient which simultaneously takes into account all estimates made for all considered cases is described in [7, 10]. It is called Kendall – Smith coefficient which can be determined from the following formula:

$$W_{K-S} = \frac{12 \sum_{i=1}^{i=I} \left[\sum_{j=1}^{j=J} x_{ij} - \frac{1}{2} J(I+1) \right]^2}{J^2 (I^3 - I)} \quad (3)$$

where:

W_{K-S} – conformity coefficient,
I – number of considered dangerous materials,
J – number of experts.

It is assumed that $W_{K-S} > 0{,}7$ stands for a high conformity of experts' opinions. In the considered example $W_{K-S} = 0{,}904$; it means that the conformity level of the opinions given in Tab. 1 is high.

In case when opinion conformity level obtained during analysis seems too low it should be checked whether this concerns weighing factors assigned by experts to all dangerous materials or only to some of them.

In case when the discrepancies are large it would be useful to engage additional experts or another group of them. It is advised to strive after achieving a high conformity of experts' opinions as only in such case obtained values of weighing factors can be deemed appropriate.

FUZZY WEIGHING FACTORS

If to achieve a high conformity of opinions of experts asked on numerical values appears impossible even after limitation of scale range down to values between 0 and 3, then it will be at one's disposal to try another approach, namely to apply fuzzy logic. It was developed for investigating uncertain or unclear issues [1].

This author already used it for analyzing reliability and risk of technical systems.

A reference to fuzzy logic can be found in [5].

The idea to use fuzzy numbers for finding values of weighing factors consists in putting questions to experts in another way.

Firstly, amount of numbers possible for selection should be reduced from 10 to 3.

Secondly, instead of the numbers, to use linguistic variables such as:

- extremely dangerous material,
- very dangerous material,
- dangerous material.

To ask experts to assign, by means of brainstorming or voting, particular materials to the sets defined by the above given linguistic variables.

Thirdly, it is necessary to replace the linguistic variables by fuzzy numbers with the use of the so called fuzzy values of Baldwin truth, described in [2].

Membership functions of fuzzy numbers corresponding to linguistic variables, hence also materials harmfulness weighing factors, take the following form:

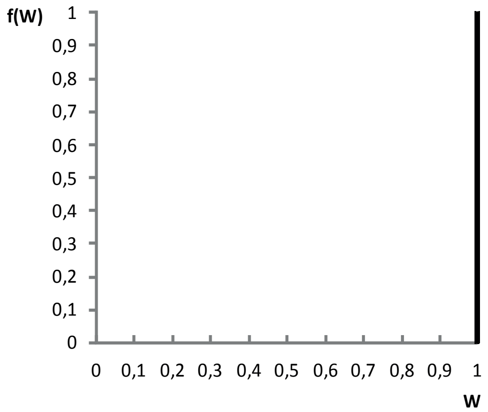

Fig.1. Membership function of fuzzy number for extremely dangerous materials

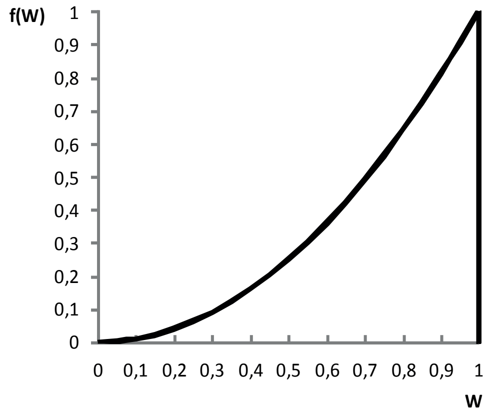

Fig. 2. Membership function of fuzzy number for very dangerous materials

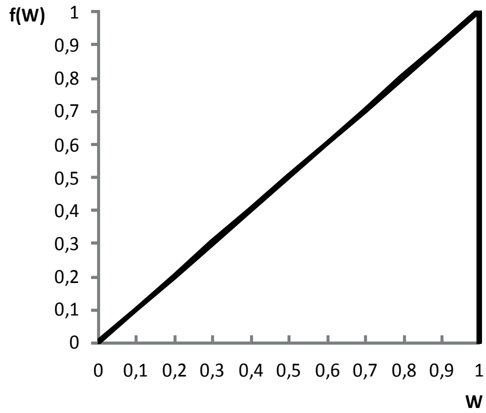

Fig.3. Membership function of fuzzy number for dangerous materials

This way we obtain weighing factors in the form of three fuzzy numbers with membership functions given in Fig. 1,2 and 3, respectively. Having them in this form we can to substitute them into the formulae (1) and (2) as it is allowed to multiply fuzzy number by real numbers. As a result, we obtain the indices in the form of fuzzy numbers. It makes it possible to achieve index values in the form of "about x "instead of the number„x", and the form of membership functions provides us with information on uncertainty level of the performed assessment.

Designers who do not intend to make use of fuzzy numbers, may use values of fuzzified weighing factors "hardened" to the form of real numbers.

By applying the calculation method of abscissa of centre of gravity:

$$W_o = \frac{\int_0^1 W \cdot f(W)dW}{\int_0^1 f(W)dW} \tag{4}$$

where:

Wo – weighing factor;

f(*W*) – membership function (Fig. 1 through 3),

W – a value on abscissa axis (Fig.1 through 3) the factors in question take the following values: 1 – for extremely dangerous materials, 0,75 – for very dangerous materials and 0,67 – for dangerous materials.

SUMMARY

The issue of scrapping the ship after its withdrawal from service should be taken into account already during ship design stage.

It should be strived after use of possibly small amount of dangerous materials, ensure as large as possible application of materials which would be suitable for recycling, as well as apply modular system to ship power plant, which would facilitate disassembling the ship.

Environmental hazard connected with ship scrapping should be estimated already in ship design stage by using the proposed indices based on the compulsory list of dangerous materials and which constitute a proposal for supplementing the rules.

BIBLIOGRAPHY

1. Januszewski E.: Logic and philosophical issues connected with fuzzy logic (in Polish). Roczniki Filozoficzne. Vol LV, No. 1, 2007.

2. Kacprzyk J.: Fuzzy sets in systems analysis (in Polish). PWN, Warszawa, 1986

3. Koziński M.: Recycling of ships in EU legislation (in Polish). Zeszyty naukowe Akademii Morskiej w Gdyni (Scientific bulletins of Gdynia Maritime University). No. 87. December, 2014.

4. Liberacki R.: A probabilistic model of environmental safety of ship power plant. Polish Maritime Research. Special Issue. Gdańsk, 2004.

5. Liberacki R.: Effect of adopted rules of inference and methods of defuzzification on the final result of the evaluation of reliability made using the fuzzy logic methods. Journal of Polish CIMAC. Gdańsk, 2011.

6. Skjong R.: Criteria for establishing risk acceptance. Proceedings of ESREL Conference. Vol.2. Maastricht. June 2003.

7. Wójcik M.: Assessment methods of conformity of experts' opinions for foresight research purposes (in Polish). Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach. (Scientific bulletins of Katowice Economic University) No. 220, 2015.

8. DNV: Environmental Differentiation of Dues and Fees for Ships. Technical Report No. 97-0212.1997.

9. IMO (MEPC 45/13). Formal Safety Assessment Including Environmental Indexing of Ships. 27 June 2000.

10. IMO (MSC – MEPC 2/Circ.5): Amendments to the guidelines for formal safety assessment (FSA) for use in the IMO rule – making process. 16.10.2006.

11. http://www.shipbreakingplatform.org/shipbrea_wp2011/wp-content/uploads/2016/04/Worldwide-overview_FINAL.pdf (30.05.2017)

12. http://www.shipbreakingplatform.org/shipbrea_wp2011/wp-content/uploads/2017/02/Stats- Graphs_2016-List_FINAL.pdf (30.05.2017)

13. http://www.shipbreakingplatform.org/ngo-platform-annual-report-2015/ (30.05.2017)

14. PRS: Recycling of ships (in Polish). Publikacja informacyjna (Informing publication) No. 33/I,. Gdańsk, 2016.

15. http://eurlex.europa.eu/legalcontent/PL/TXT/?qid=1484129918570&uri=CELEX:32016D2323 (30.05.2017)

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