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FUZZY LOGIC IN THE ASSESSMENT OF HAZARDS TO SHIP POWER PLANT OPERATOR

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Abstract

Complex technical objects such as ship power plants are the source of many hazards to their operators. Identification and elimination of these hazards on the finished objects is a very labor-intensive task and involves significant financial outlays. It would therefore be advisable to carry out these activities much earlier - at the design stage. However, this entails certain difficulties. Depending on the design phase, the designer has a limited amount of information from which the operator's safety can be assessed. Additionally, this information is associated with considerable uncertainty. These difficulties can be overcome by using subjective estimates of persons having practical knowledge in the field of our interest - experts. Such knowledge can be formulated most easily in linguistic categories, i.e. fuzzy logic language.

This paper presents the construction basis for a ship power plant operator risk assessment system at the design stage.

This system was based on a fuzzy inference mechanism. Use of this system will enable the identification of hazards for ship power plant operators and will indicate the necessary corrective actions.

Keywords: *safety, design process, ship power plant, hazard, fuzzy inference*

1. Introduction

Design of complex technical objects is a very complicated task, involving a series of steps. In the early stages of the project a general outline of the object is created Patterns of individual installations are formed. Thus we can say that the resource about the proposed facility is very limited as the project situation is progressively changing. The designer's knowledge expands with the project's progress. During the design process the available information is associated with a high degree of inaccuracy and uncertainty. Therefore, the most accurate analysis of the risks associated with the functioning of this facility should be undertaken at the existing facility during its operation. This approach, however, involves time-consuming and costly modifications in case of any irregularities. The solution may be to analyze operator hazards during the design process of a technical facility. However, as already mentioned, this is subject to certain limitations. By supporting the knowledge of experienced operators of similar technical objects it is possible to analyze operator risk in the early stages of design. This knowledge is not always available in an easy-to-use form. In most cases it is the work experience of experts in the field. Acquiring and recording this knowledge to allow its continued use is not an easy task. In the view of the author, the most convenient solution for collecting a considerable amount of knowledge and its use is to build a computer system. The aim would be to obtain information on the proposed facility during its design and conduct a risk analysis of its operator. A suitable record of the knowledge acquired from experts can be implemented using fuzzy logic. It allows you to reflect the fuzziness of concepts expressed by people in everyday language. Fuzzy logic allows you to perform inference in a manner very similar to human reasoning. Thus, the use of fuzzy logic makes it easier to map the path of experts' inferences.

The specific complex technical object is a ship power plant. It contains a large number of different kinds of machines and devices connected to systems providing propulsion and performing many other important functions. Such an accumulation of potentially hazardous structural units (the term adopted from [6, 7]) in a limited space of engine room poses a real hazard to its operators. Therefore it is advisable to carry out risk analysis within the engine room.

2. A risk analysis during the design process

Design of engine room can be done in the following phases:

- possible conceptual design,
- offer project,
- preliminary design (contract),
- technical-classification design,
- design workshop (working)
- passing documentation (operating).

This paper [6] assumes that the potential impact on the operator's safety during the design process occurs during the initial phase of the project and the technical classification phase. The early stage of the project allows only for a general assessment of hazards. It can be used to pre-determine the hazardous areas [6, 7]. These areas are selected on the basis of operating in a given operating condition of the vessel's structural units in terms of hazards posed to the operator. In areas of potential danger remedies are proposed to lower the level of risk for the operator. At the technical classification design stage, during hazard analysis, the same areas are taken into account again. In this phase, many important details become clearer, such as the construction and placement of structural units. It is therefore necessary to reassess the subsequent identification of hazardous agents. After their assessment, it is possible to identify risks and propose risk mitigation measures.

3. Fuzzy risk assessment

In both stages of the project, the operator's risk assessment is made based on fuzzy logic. Inference in the initial phase of the project is based on information about the types of risks generated by the various structural units. Also factored in is the possibility of operator contact with the manifestation of the hazard. For the purposes of risk assessment, the operator has taken six types of hazards (Fig.1). Each hazard is assigned a corresponding gamut of manifestations.

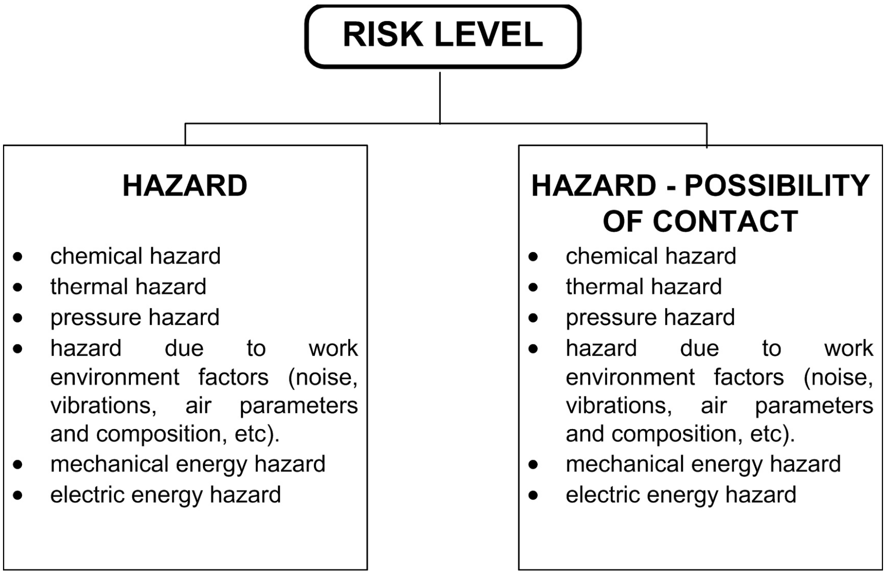

Fig. 1. Risk assessment scheme

In order to determine the level of risk posed by the various manifestations of hazards a survey was built. Based on the results obtained from the responses of experienced ship power operators fuzzy sets have been prepared. Sample collections are shown in Fig.2.

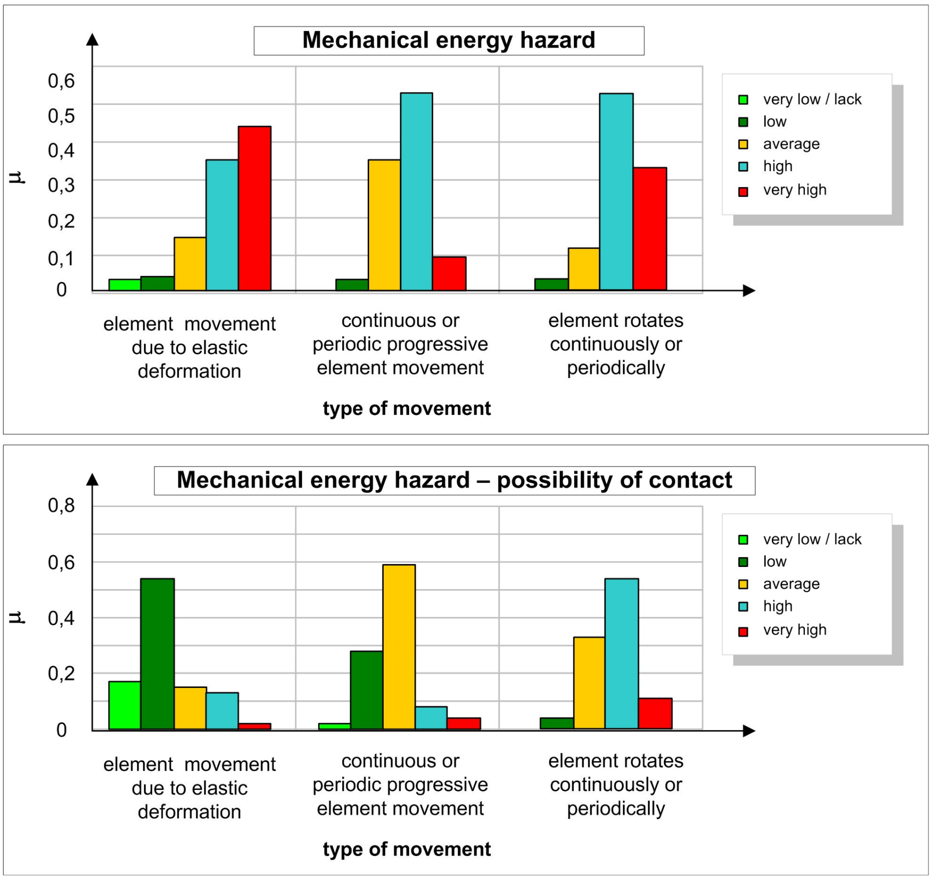

Fig. 2. Fuzzy sets: mechanical energy hazard and mechanical energy hazard – possibility of contact

The resulting fuzzy sets defining the operator's level of risk are reflected using the five linguistic terms:

– very low/lack,

– low,
– average,
– high
– very high.

These sets assume the shape of a triangle (Fig. 3).

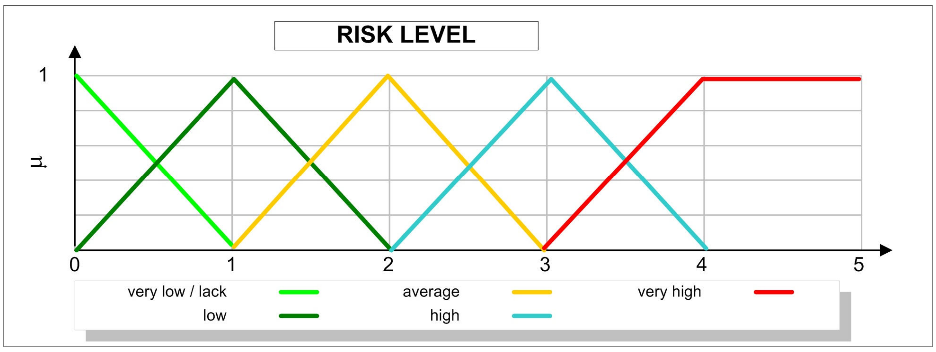

Fig. 3. Fuzzy sets representing level of risk

The result of inference is an acute value between 0-5. Referring this value to the collections from Fig.3, we can assess the level of risk by using linguistic terms. Getting the resulting value of the risk level for the given type of hazard is performed using fuzzy inference mechanism based on the Mamdani model [4, 5, 8].

The overall level of risk resulting from the impact of all types of hazards generated by the considered structural units is obtained after aggregation, using the same model of inference.

Using this method of risk assessment allows the operator to pre-identify areas in which his actions may pose a potential risk to operators. Analysis and risk assessment of operator at the preliminary stage of the project is elaborated in [1].

The next phase of the project includes outlines of individual pipelines installations at a ship power plant, structural solutions for foundations and the mounting of the main machinery and equipment, construction of the shaft together with the necessary strength calculations, vibrations, etc., the plan for dismantling machinery and equipment in the power plant, plans of workshops and storerooms.

At this stage the available knowledge enables a more detailed definition of the risk level of the operator. It can be assumed that it will be a function of factors derived from [8]:

– operation of machinery and equipment,
– accessibility to the site of operational activities,
– position of the operator performing specific operational activity,
– type of operational activities.

Risks associated with the work of machines and equipment are dependent on their function. In this case again the following types of hazards are considered:

– chemical hazard,
– thermal hazard,
– pressure hazard,
– hazard due to work environment factors (noise, vibrations, air parameters and composition, etc),
– mechanical energy hazard,
– electric energy hazard.

We shall take into consideration only those structural units which at the initial stage of the project obtained a significant risk level (**RL**). It is necessary to check whether the remedial measures (**RM**) provided for those units sufficiently reduce the risk to the operator. Depending on the manner in which a unit will be operated, the operator will be exposed to various hazards. The type of activity undertaken by the operator has a significant impact on the type of hazard generated by the structural unit. For each hazard, it is necessary therefore to examine the effects of actions that will be carried out by the operator.

The operator carrying out the operation of the structural unit is mainly exposed to the hazards associated directly with this unit ($\mathbf{H_u}$). However, in view of the specificities of the engine room, in some cases it is necessary to take into account the risks in the surroundings of an operator ($\mathbf{H_s}$). When the immediate environment of the operator contains units that are a potential hazard, their impact should also be taken into consideration.

It is assumed that the accessibility to the place of operational activities in question (**APA)** together with the location of the structural unit at the correct height (**LSU)** significantly affect the course of the work performed by the operator and the position adopted by him when performing maintenance. These values will define the (**ON**) operational nuisance. Forced unusual positions of the operator's body and access restrictions when operating the structural unit increase the possibility of injury to the operator.

With regard to the impact of operations on the operator's risk, one should consider such factors as:

- the degree of activity differentiation (**AD**) - number of different elementary operations performed at the specified structural unit,
- the maximum range of performed movements (**RPM)** – the way activities are performed, for example by hand, arm, with or without the use of tools, etc.,
- the variability of adopted position (**VP**) - information that specifies the dynamics of the movements made by the operator .

The combination of these factors in risk assessment system operator is presented in Fig.4.

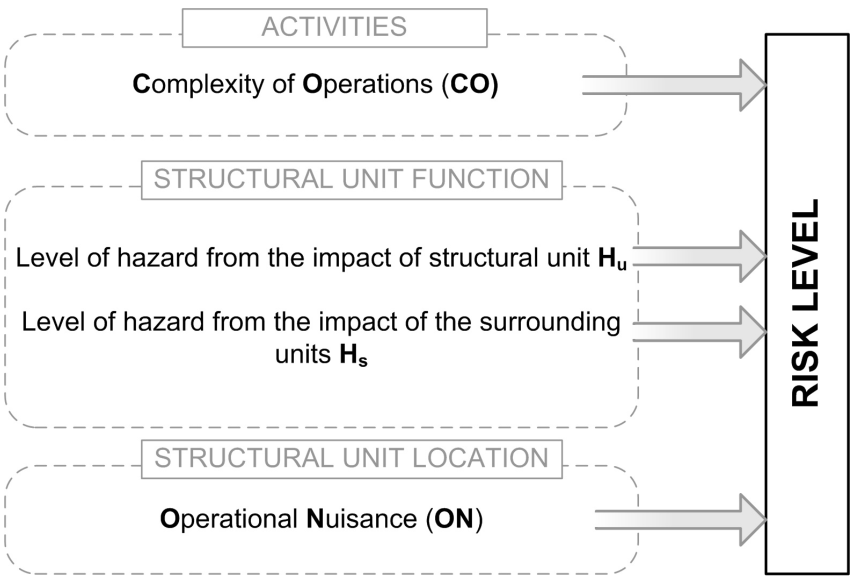

Fig. 4. An overview of the operator's risk assessment system

Building a fuzzy risk assessment system operator requires the creation of fuzzy representation of individual factors and their relationships by the relevant rules. Initially, for purposes of representing individual linguistic variables, fuzzy sets have been adopted in triangle and trapezoid shapes. Examples of fuzzy sets describing the factors that constitute operational nuisance (**ON**) are shown in Figures 5, 6 and 7. Under the numerical values on the abscissa, different scenarios of difficulties in accessing the structural unit are included. For example, the value of 10 was assigned to accessing the unit using only fingers requiring the operator to bend/lean against it at the same time.

Fuzzy rules are created in the form of **IF-THEN** expressions. If there are multiple premises, the **AND** operator is used. Created fuzzy rules have the following form:

IF *the accessibility to the place of operational activities APA is difficult* **AND** *the location of a structural unit LSU is below the knee* **THEN** *operational nuisance ON is substantial.*

IF *activities differentiation AD is large* **AND** *the range of performed movements RPM is wide* **AND** *the variability of adopted position VP is high* **THEN** *the complexity of operations CO is high.*

IF *the complexity of operations CO is high* **AND** *the hazard level H_u is high* **AND** *the operational nuisance ON is substantial* ***THEN*** *risk level RL is high.*

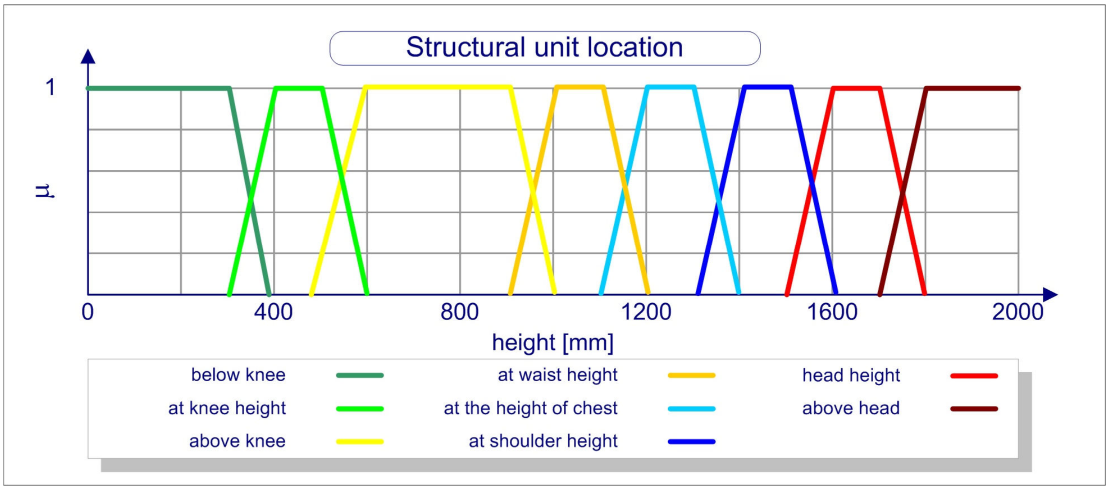

Fig. 5. Fuzzy sets describing the location of the structural unit

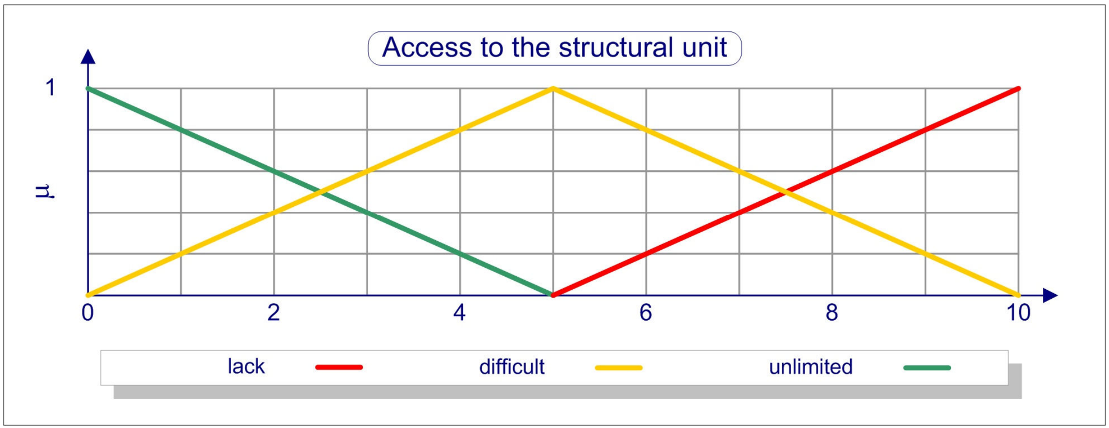

Fig. 6. Fuzzy sets describing the access to the structural unit

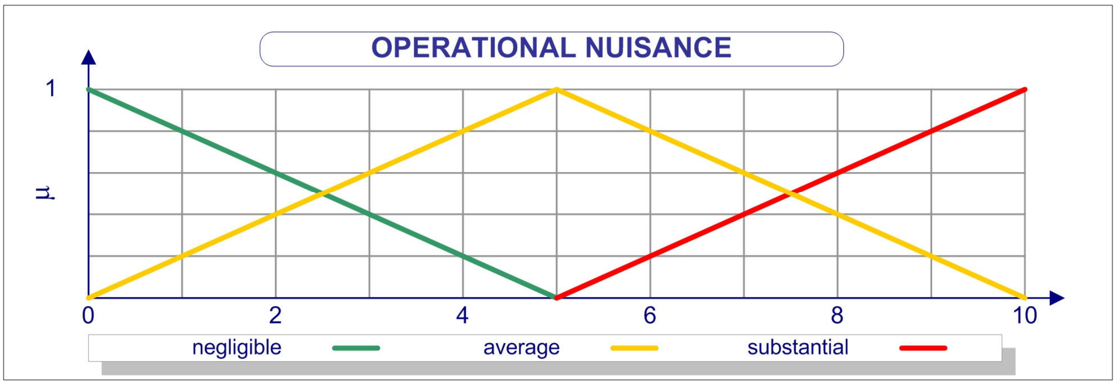

Fig. 7. Fuzzy sets describing the operational nuisance

Depending on the information required, the system will collect information through properly prepared windows that require making a specific choice or, for example, situational diagrams to be complemented by appropriate values (Fig.8).

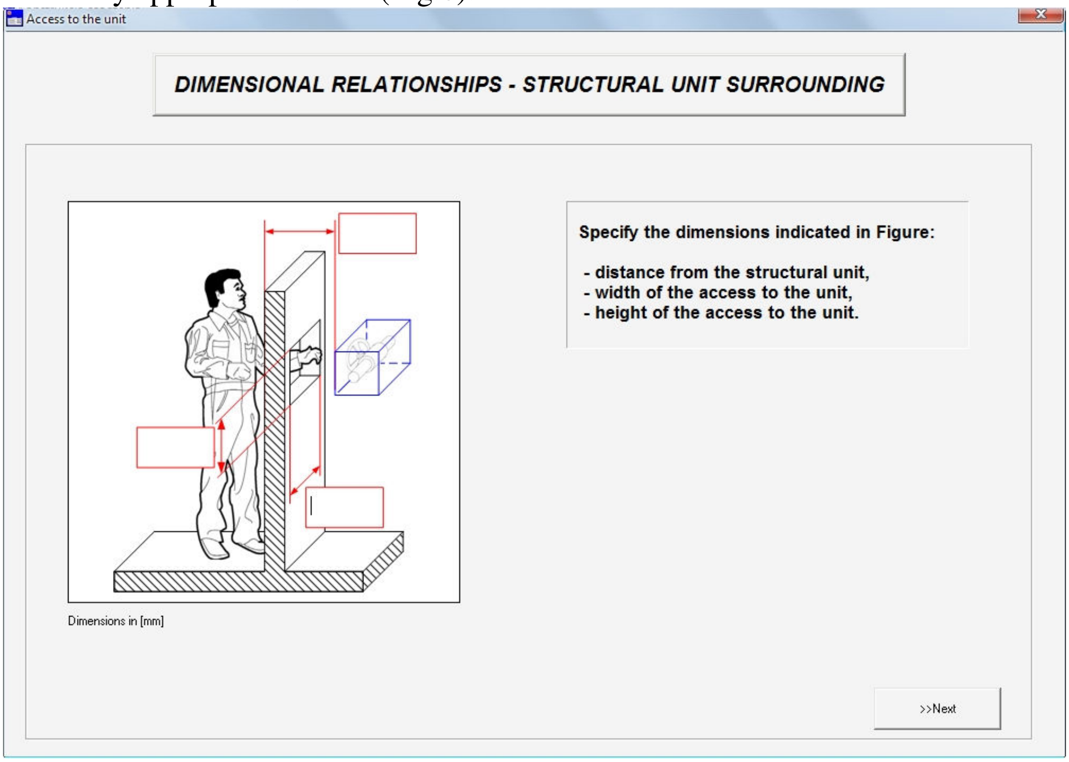

Fig. 8. Sample screen of operator's risk assessment system

The obtained information is converted into corresponding fuzzy sets based on the knowledge accumulated in the base system.

The result of the operator risk assessment process during the implementation of specific operational activities is a value in the interval <0, 10>. This value makes it possible to qualify the level of this risk as low, medium or high. Depending on the result, it will be possible to take appropriate action to improve the safety of any operator. Data collected by the system will enable identification of factors that significantly endanger the operator.

4. Conclusions

The solution based on fuzzy logic offers significant potential in safety modeling in the ship power plant. It is particularly useful in the early stages of the design where information about the safety of the operator is negligible or associated with considerable uncertainty.

The risk assessment carried out at the stage of preliminary design of the engine room, in view of the limited amount of available information, provides an initial opportunity to identify areas of risk. It is very important that specific preventive measures can be provided at this early stage of the project. However, as the project develops, new factors appear that are not included in this assessment and that could significantly threaten the operator. Then it becomes necessary to further evaluate hazardous areas, taking into account precisely these factors. In addition, it is necessary to verify measures already introduced.

Application of fuzzy inference allows interoperability of assessment systems for the various phases of the project. Moreover, inference performed by this method is very similar to human reasoning which makes it easier to process the relevant knowledge into a language understood by the computer.

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