Brodogradnja/Shipbuilding/Open access CrossMark Volume 68 Number 2, 2017

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http://dx.doi.org/10.21278/brod68205

ISSN 0007-215X
eISSN 1845-5859

ASSESSMENT OF THE INFLUENCE OF RADIATION AND DEFORMATION ON THE ELASTOMER DETERIORATION BY USING FUZZY LOGIC

UDC 629.5.081
Original scientific paper

Summary

Elastomers belong to the group of polymer materials and they have an important role as technical material in the shipbuilding industry. The radiation crosslinking of elastomers shows significant advantages over chemical crosslinking. It can improve mechanical strength, resistance to chemicals and insulation properties of elastomers. An undesirable side reaction, which can occur during radiation, is the degradation process. This results in cracks breaking, chemical disintegration and reduction of mechanical properties of elastomers. In this paper fuzzy logic is used to estimate the influence of radiation and deformation on the behavior of elastomer samples. A Gaussian model is created according to both the experts' experience and the measuring data. The results of the model are calculated by using the Normalized Roth Mean Square Error (NRMSE) and the Roth Mean Square Error (RMSE). The so developed model gives new conceptions, which offer a possibility to improve the application of elastomer materials.

Key words: Elastomers; Fuzzy logic; Gaussian model; NRMSE; RMSE;

1. Introduction

According to their mechanical properties, polymer materials fall into three groups: plastomers, duromers and elastomers. This classification shows in the size of the modulus of elasticity, as can be seen in Table 1.

Rubber is an elastomer, the characteristics of which classified it as one of the most important materials in different application areas, as shown in Table 2. Elastomers are used in the production of shock absorbers, foundation, valves, various seals, conveyor belts and other products that require resistance to mechanical strain, weathering, ozone and temperature change or required operating conditions. Many products, based on natural rubber, are used in maritime industry for the protection of offshore structures and the outer hull. They are also used for the protection of the internal tanks from the corrosion of seawater, because they fill cracks and damaged tanks surfaces [2].

The polymer applications in shipbuilding, offshore technology and the submarine can be traced through the MZOS project "Application of polymers in shipbuilding" [3].

Table 1 Important Mechanical Properties of Polymer Materials and Fibers [1]

POLYMER MATERIALS	MODULUS OF ELASTICITY (E) *MPa*	ELONGATION %	EXAMPLE
Elastomers	1- 10	10^3	Natural rubber
			SBR
			Polyisobutene
			Polystyrene
Plastomers	10^2- 10^3	$1\text{-}210^2$	Polyvinyl chloride
			Poly(methyl methacrylate)
Fibers	10^4- 10^5	$1\text{-}310^1$	Silk
			Cotton
			Polyamid 66
			Poly(ethylene-terephthalate)
			Carbon fibers

Table 2 Elastomers - Properties and Applications [4]

ELASTOMERS	BASIC PROPERTIES	APPLICATIONS
CR	Exceptional resistance to elevated temperatures, ozone, oil and atmosphere, excellent flame resistance, poor electrical properties of NR	Static and dynamic seals, linings of steel
NBR	Excellent resistance to oil, relatively poor electrical properties, poor properties at low temperatures	Hoses for petrol, chemicals and oil
NR	Excellent physical properties, good abrasion resistance, good electrical properties, sensitivity to the action of ozone and atmosphere	Seals, tires, inner tubes
SBR	Good physical properties, good electrical properties, excellent abrasion resistance	Seals, tires

Elastomers belong to the group of polymer materials and play an important role as technical material in the shipbuilding industry [5]. In comparison to other technical materials, elastomers offer a lot of beneficial characteristics. The use of elastomers is significant in shipbuilding industries due to their excellent flexibility, damping and energy absorption characteristics, non-toxic properties, variable stiffness and ability to seal against seawater, moisture, heat, and pressure [6].

It is well known that elastomers are used for the production of sealants, thermal and acoustic components, lubricating shaft bearings, parts for damping of vibration, etc. In recent years, the sandwich plate system (SPS) material has attracted attention [7].

The SPS material comprises two metallic face plates and a solid elastomer core. It is reported that this material, as a heavy engineering material, is superior to conventional steel and reinforced concrete.

It is especially important to emphasize that this elastomer composite is of significant benefit to new build and repair applications for the shipbuilding industry.

Conventional chemical methods or the exposure to ionizing radiation from radioactive sources are used in order to improve the properties of the polymer structure of elastomers [8]. The properties of elastomers are improved by cross linking. Cross linking is a process where long molecules of polymers are linked together. The vulcanization is the earliest chemical method comprising adding of sulfur under heat to natural rubber, which creates links within latex molecules. Vulcanization of rubber produces superior mechanical properties and less sticky material than non-vulcanized rubber [9]. Although radiation crosslinking is not as widely used as chemical crosslinking, it offers several significant advantages over chemical crosslinking such as: improved mechanical strength, resistance to chemicals and insulation properties, control of the degree of crosslinking with the radiation dose, etc. [10].

However, the process of degradation is an undesirable side reaction which may occur during radiation. These undesirable changes are usually cracks and chemical disintegration of elastomers. The process of disintegration is basically a chemical or physical reaction where one or more covalent bonds break thus resulting in macromolecular configuration changes [11].

Elasticity and durability are very important characteristics in current material technologies. For example, hardening and elasticity loss of elastomer sealant caused the disaster of the spaceship Space Shuttle Challenger in 1986, only 73 seconds after launching. Due to hardened elastomer, hot gases leaked from the rocket, which set fire on the gas tank and caused the explosion of Challenger and the death of all the seven crew members [12].

Therefore, predicting material characteristics by means of mathematical models is becoming more important in numerous science and technology fields. One of the desirable characteristics of mathematical models is that it allows us to examine the effects of various properties of material, including data which are not measured, on the material behavior [13].

A mathematical model offers a relationship between available input data and particular output data. It is sometimes possible to describe this relation with appropriate laws of physics and the adequate model enables a generalization of the acquired information. It is important to note that the use of a mathematical model can result in significantly lower laboratory analysis costs.

The fuzzy logic is a type of mathematical modeling which offers powerful tools for the creation of an approximate model and for its analysis [14, 15, 16]. Certain algorithm of a FIS (Fuzzy Inference System) mechanism enables the evaluation of a characteristic stored within the model itself. In this way, we speed up the calculations within the system as well as the process of achieving a solution.

Different estimations are acquired as output sets - estimation of the amount of damage per surface unit of a particular elastomer sample, for example. The data are treated by functions developed within the mechanisms of inference in the context of FIS. A Mamdani algorithm of fuzzy logic is chosen to analyze data and Gaussian models were made for a creation of response functions for the influence of primary and secondary radiation dose to the length, width and number of damages.

2. Fuzzy Logic

In the classical sets theory, the basic characteristic of a set means that it is precisely defined for each element of a wider set (universe of discourse) whether it belongs to the set or not. If X is a universe of discourse and A is an arbitrary subset of the universe of discourse, in the classical sets theory membership, or non-membership, of an arbitrary element x of the universal set X to set A is defined by a characteristic function $\chi: X \rightarrow \{0, 1\}$ defined as:

$$\chi(x) = \begin{cases} 1, x \in A, \\ 0, x \notin A \end{cases} \quad (1)$$

The concept, which was introduced by Lotfi Zadeh in 1965 [17], is based on redefining the characteristic function where a co-domain of characteristic functions, which is a two-member set {0, 1}, is substituted by a whole interval [0, 1]:

$$\mu: X \rightarrow [0, 1] \quad (2)$$

If an element $x \in X$ certainly belongs to the set *A* then $\mu(X) = 1$, but if it certainly does not belong to the set *A*, then $\mu(X) = 0$. If value $\mu(X)$ is a number belonging to the interval $[0, 1]$ and is different from 0 and 1, that number is interpreted as degree of membership of the element to the set *A*. If this number is closer to the value 1, the possibility of membership to the set *A* is stronger. If this number is closer to 0, the possibility of membership to set *A* is smaller. Function $\mu(X)$ is defined as a membership function and the set *A* is defined as a fuzzy set, often denoted as a pair $(A, \mu(X))$.

The classical bivalent mathematical logic is based on the classical sets theory. A statement is true, the value of the characteristic function is 1, or a statement is not true, the true value of the characteristic function is 0. The logic based on the fuzzy set is polyvalent. That means that each statement is associated to the degree of its authenticity - the value of membership function.

Fuzzy logic is suitable to reality more than classical logic. It is therefore used in numerous fields of human activities. Nowadays, it is applied to various domains: such as social researches (psychological and sociological researches) and technology. It is incorporated even in household appliances.

Fuzzy inference system (FIS) can be described in four phases [18]:

1. Fuzzification
2. Inference
3. Aggregation
4. Defuzzification

In the first phase (fuzzification), the input variables are fuzzificated. In the fuzzification phase, numeric values are translated to linguistic [18]. Based on total available data, a number of fuzzy sets are defined for each input variable. Their membership functions are defined as well, Figure 1.

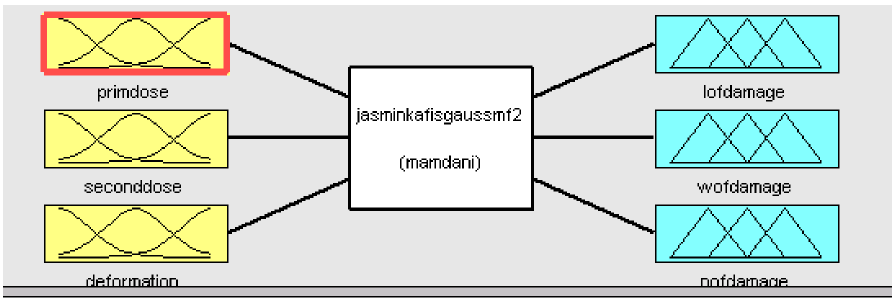

Figure 1: Structure of the Fuzzy Inference System

In the second phase (inference), the output variables are fuzzified in an analogue way, as has been done for input variables in the first phase. In this phase, fuzzy rules are defined. Their number and shape depend on the quality of available information. This phase is crucial for this method. In the application of these rules, crisp values of input variables are associated with as many membership function values of each output variable as is the number of the rules chosen.

In the third phase (aggregation), the values of membership functions for each output variable, obtained in the previous phase, are united. Therefore, each output variable is assigned as a fuzzy set.

In the fourth phase (defuzzification), linguistic values are transferred back to numeric ones [19]. The fuzzy value for each output variable is calculated.

3. Fuzzy Inference System

Research in the field of applying fuzzy logic in navigation and shipping can be traced through the MZOS project entitled "Neural Networks and Fuzzy Logic in Turbine Regulation and Ship Rudder Systems" [20, 21].

The characteristics of elastomer which have been evaluated in this work with fuzzy logic are: length, width and amount of damage per square unit of a particular sample. Fuzzy Inference System is defined for each of these characteristics. Input set for evaluation is based on the data for primary and secondary radiation dose and for deformations applied to elastomer samples. Output set includes length, width and amount of damages.

In this paper, primary and secondary radiation dose and two fuzzy sets (little, big) have been defined for input variables. For each output variable, three fuzzy sets have been defined (little, medium, big). In addition to the number of fuzzy sets, it is necessary to define their shape by means of membership functions. For each fuzzy set, the value which best reflects the linguistic meaning of the set has been defined.

4. Material and Methodology of Research

Centrifuged latex containing 60 % of dry rubber has been used as a test material. It is made by The Rubber Research Institute of India [22]. The chemical composition and characteristics of a typical centrifuged latex containing 60 % of dry rubber are shown in Table 3.

The radiation has been carried out in the Laboratory for Radiation Chemistry and Dosimetry of the Institute "Ruđer Bošković" in Zagreb [23]. Latex samples with different length and width have been submitted to gamma radiation (γ) in the 60Co panoramic irradiator. Latex samples have been exposed to various primary radiation doses and after that uniaxially stretched latex samples have been radiated by secondary radiation doses. Varied primary and secondary radiation doses and extensional strains are shown in Table 4.

Table 3 Chemical Composition and Characteristics of Centrifuged Latex Containing 60 % of Dry Rubber

Characteristic	Requirement
Dry rubber content, percent by mass, Min	60.0
Non-rubber solids, percent by mass, Max	2.0
Coagulum content, percent by mass, Max	0.05
Sludge content, percent by mass, Max	0.10
Alkalinity, as ammonia, percent by mass of latex	0.6 Min
KOH number, Max	1.0
Mechanical stability, Min	475
Volatile fatty acid number, Max	0.15
Copper content, ppm of total solids, Max	8
Manganese content, ppm of total solids, Max	8

Table 4 Varied Radiation Doses of Radiation and Extensional Strain

Primary dose of radiation kGy	Deformation $\varepsilon = \frac{l - l_0}{l_0}$	Secondary dose of radiation kGy
100	1.0	0
or	1.5	100
200	2.0	or
	2.7	200

Table 5 shows the samples tags. If the first number in brackets is 1, it denotes values for the primary radiation dose of 100 kGy. If the number is 2, it denotes values of 200 kGy.

The second number in brackets denotes deformation of samples. The third number in brackets shows the amount of the secondary dose of radiation. If the third number in brackets is 0, it denotes that this sample has not been exposed to radiation. If the third number in brackets is 1, it denotes the secondary dose of radiation of 100 kGy or if the number is 2, it stands for the radiation dose of 200 kGy.

Elastomer samples subdued to varied radiation doses under varied deformations have been recorded by transmission light microscope under various magnifications. The testing has been performed with a transmission light microscope BIM 312 T and Scanning Electron Microscope **QUANTA 250 FEI** in The Center for Researches of Metals in Pula [24].

Table5 Samples Tags

Sample number	Sample tag
1	[1 – 0 – 1]
2	[1 – 0 – 2]
3	[1 – 1.5 – 1]
4	[1 – 2.7 – 1]
5	[1 – 2 – 1]
6	[2 – 0 – 0]
7	[2 – 0 – 1]
8	[2 – 0 – 2]
9	[2 – 2.7 – 1]
10	[2 – 2.7 – 2]

5. Results

Typical microstructures of a centrifuged latex containing 60 % of dry rubber are shown in Figure 2.1 and Figure 2.2.

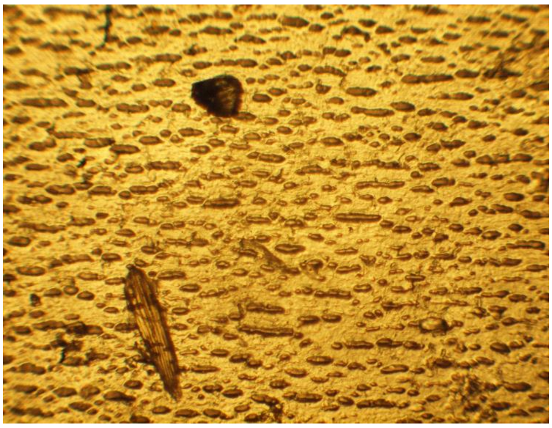

Figure 2.1. Light Optical Microscope (LOM) Micrograph of Latex Sample 4

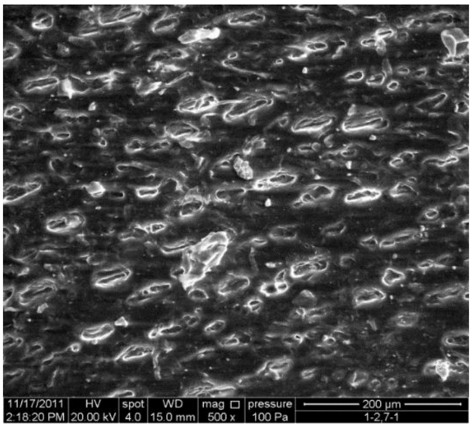

Figure 2.2. Transmission Electron Microscopy (TEM) Micrograph of Latex Sample 4

Table 6 shows the results of measured dimensions, damage lengths, widths of elastomer samples and amount of damage on the specified sample dimension with the amount of damage per surface unit. These values have been used for defining the input and output sets of fuzzy logic.

The number of damage per a surface unit has been calculated by the number of damages on the specified sample dimension (*N*) per surface area of samples (*A*) or by using this formula:

$$n = \frac{N}{A} \qquad (3)$$

For example, for the first sample the number of damages per surface unit could be calculated:

$$n = \frac{8}{7.91 \cdot 6.84} = 0.148 \qquad (4)$$

In the same way, as is shown above for sample 1, values have been calculated for all the samples in Table 6.

Table 6 Measured Data for Defining Input - Output Sets of Fuzzy Logic

Sample tag	Length x width of samples x10^{-1} *mm*	Number of damages per specified surface N	Damage length x10^{-1} *mm* $\bar{d}_1$	Damage width x10^{-1} *mm* $\bar{d}_2$	Number of damages per surface unit n
1 [1 – 0 – 1]	7.91 x 6.84	8	$\bar{d}_1$= 0.6375	$\bar{d}_2$= 0.50625	0.1480
2 [1 – 0 – 2]	7.96 x 6.89	12	$\bar{d}_1$= 0.4425	$\bar{d}_2$= 0.44083	0.2190
3 [1 – 1.5 – 1]	12.00 x 11.17	15	$\bar{d}_1$= 0.7693	$\bar{d}_2$= 2.66530	0.1110
4 [1 – 2.7 – 1]	5.17 x 4.39	7	$\bar{d}_1$= 0.2443	$\bar{d}_2$= 0.78290	0.3080
5 [1 – 2 – 1]	18.93 x 13.14	10	$\bar{d}_1$= 1.1800	$\bar{d}_2$= 3.12100	0.0414
6 [2 – 0 – 0]	15.29 x 7.46	8	$\bar{d}_1$= 0.6725	$\bar{d}_2$= 0.43380	0.0701
7 [2 – 0 – 1]	11.50 x 8.13	9	$\bar{d}_1$= 0.4640	$\bar{d}_2$= 0.52200	0.0960
8 [2 – 0 – 2]	16.29 x 9.45	8	$\bar{d}_1$= 0.5063	$\bar{d}_2$= 0.58230	0.0520
9 [2 – 2.7 – 1]	10.87 x 8.42	9	$\bar{d}_1$= 0.2940	$\bar{d}_2$= 0.97800	0.0980
10 [2 – 2.7 – 2]	14.17 x 11.62	9	$\bar{d}_1$= 0.5100	$\bar{d}_2$= 0.53200	0.0540
11 [2 – 2 – 2]	13.17 x 9.47	8	$\bar{d}_1$= 0.3325	$\bar{d}_2$= 2.17800	0.0640

6. Gaussian Model

Analyzing the data from Table 6, it can be concluded that the number of damages grows simultaneously with the growth of the radiation dose applied to the non-deformed samples 1 and 2. But samples which have been subdued to deformation manifest a different behavior (samples 3, 4 and 5) by applying the same radiation dose. Both the primary and the secondary radiation doses cause different influence on the number of damages and their sizes in the deformed samples. Based on these conclusions, the membership functions and the rules of fuzzy mechanisms have been established in order to evaluate the values of output parameters in the following way:

a) For the length damage, evaluation of three-value areas has been defined.

The first area has been allocated with the linguistic meaning "little", the second one with "middle" and the third one with "big".

$d_{1little}$ = [0.2443; 0.4425]

$d_{1middle}$ = [0.464; 0.510]

d_{1big} = [0.6375; 1.180]

For each of the three areas a Gaussian function has been defined.

$$f(x, \sigma, c) = e^{\frac{(x-c)^2}{2\sigma^2}} \quad (5)$$

x - value of variable from output parameter area

σ - standard deviation

c - arithmetic mean

e – Euler's number ≈ 2.718281828

b) For the width damage, estimation of three-value areas has been defined.

The first area has been allocated with the linguistic meaning "little", the second one with "middle" and the third one with "big".

d_{2litle} = [0.4408; 0.532]

$d_{2middle}$ = [0.5823; 0.978]

d_{2big} = [2.178; 3.121]

c) For the estimation of the number of damages, three-value areas have been defined.

The first area has been allocated with the linguistic meaning "little", the second one with "middle" and the third one with "big".

n_{little} = [0.0414; 0.064]

n_{middle} = [0.096; 0.111]

n_{big} = [0.148; 0.30]

Parameters $\boldsymbol{\sigma}$ and $\boldsymbol{c}$ have been defined for each of the three areas separately by using interpolation and taking the measuring data into account.

The Mamdani model has been used to evaluate width, length and number of damages per unit of sample surface due to low number of input and output data.

The Mamdani model is one of the main algorithms of the fuzzy theory [16]. The Mamdani model is used for the evaluation of characteristics when the number of input sets of available data is "relatively low".

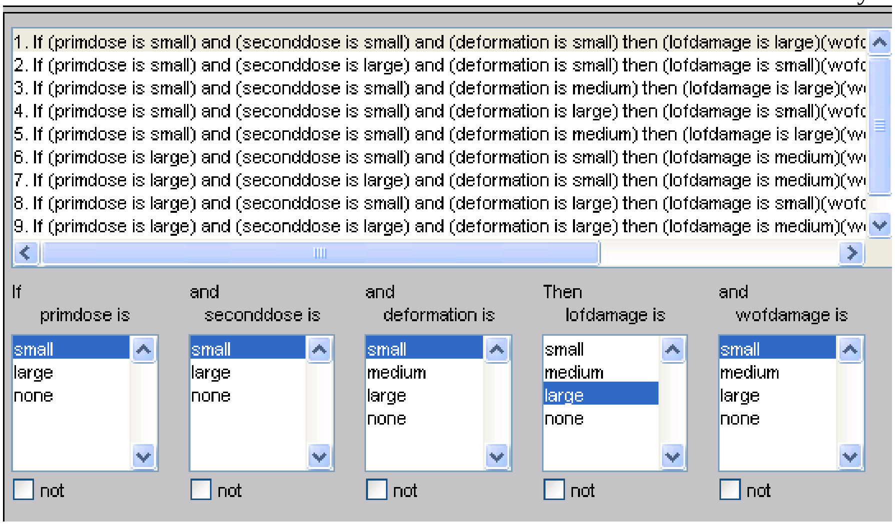

Figure 3 FIS Rules, Gaussian Model

From the analysis of length damages, as per data shown in Table 6, it can be concluded that there are many numbers closer to the lowest numbers (like: 0.2443; 0.294; 0.3325; 0.4425 .etc.). This means that there are more often smaller length values than larger ones, out of which fuzzy boundaries have been derived. Thus, a domain has established for each membership function. Shapes of membership functions for output variables for length damages are presented in Figure 4. Membership functions for other input variables have been defined in a similar manner.

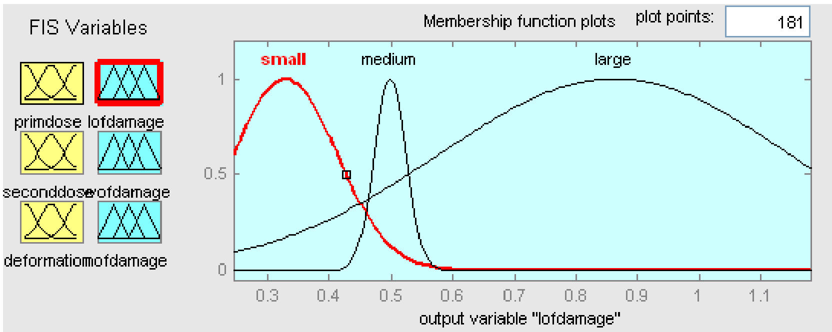

Figure 4 Shape of Membership Function for Length Damages Output Variable

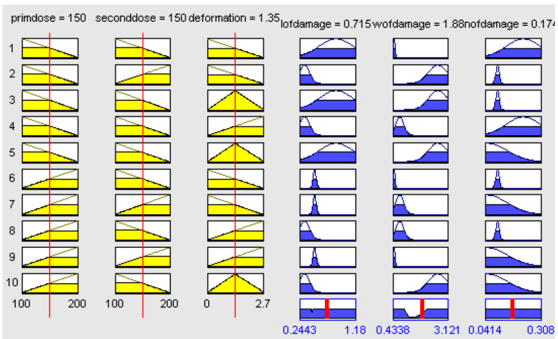

Figure 5 Deduction Diagram According to the Gauss Model

7. Analysis and Evaluation of the Model Efficiency

A verification of the Gaussian model has been carried out in the program package Matlab in the following way: matrices of the examined lengths, widths and number of damages have been marked with $\mathbf{X_1}$, $\mathbf{X_2}$ and $\mathbf{X_3}$, while matrices of the values obtained from the model have been marked with $\mathbf{Y_1}$, $\mathbf{Y_2}$ and $\mathbf{Y_3}$.

Values $\mathbf{Y_1}$, $\mathbf{Y_2}$ and $\mathbf{Y_3}$ have been obtained from the model within the fuzzy deduction mechanism, so that the tested values $\mathbf{X_1}$, $\mathbf{X_2}$, $\mathbf{X_3}$ have been manually entered into the Rule Viewer and values $\mathbf{Y_1}$, $\mathbf{Y_2}$ and $\mathbf{Y_3}$ are read. The tested values and values obtained from the Gaussian model are shown in Table 7.

Once the matrices of both the tested values and the values obtained from the model have entered in the program, the Normalized Roth Mean Square Error – NRMSE has been calculated for each of the output parameters. Roth Mean Square Error - RMSE and Mean Square Error – MSE have been calculated as well using the following formulas [14]:

$$NRMSE = \frac{\sqrt{\frac{\sum_{i=1}^{N}(x_i - y_i)^2}{N}}}{\sigma} \quad (6)$$

$$NRMSE = \frac{RMSE}{\sigma} \quad (7)$$

$$RMSE = \sqrt{MSE} \quad (8)$$

$$MSE = \frac{\sum_{i=1}^{N}(x_i - y_i)^2}{N} \quad (9)$$

Table 7 Tested Values and Values Obtained from Gaussian Model

Sample	X_1	Y_1	X_2	Y_2	X_3	Y_3
1	0.6375	0.645	0.5063	1.01	0.148	0.176
2	0.4425	0.860	0.5063	1.01	0.148	0.176
3	0.7693	0.695	2.6653	1.89	0.111	0.167
4	0.2443	0.722	0.7829	1.86	0.308	0.182
5	1.18	0.715	3.1210	1.80	0.041	0.180
6	0.464	0.859	0.5220	1.01	0.096	0.080
7	0.5063	0.860	0.5823	1.01	0.052	0,080
8	0.294	0.859	0.9780	1.05	0.098	0.084
9	0.510	0.844	0.5320	1.52	0.054	0.085
10	0.3325	0.860	2.1780	1.59	0.064	0.081

For each of the output parameters, the Normalized Roth Mean Square Error, Roth Mean Square Error and Mean Square Error have been calculated.

X1 = [0.6375 0.4425 0.7693 0.2443 1.18 0.464 0.5063 0.294 0.3325 0.51];

X2 = [0.50625 0.44083 2.6653 0.7829 3.121 0.522 0.5823 0.978 2.178 0.532];

X3 = [0.148 0.219 0.111 0.308 0.0414 0.096 0.052 0.098 0.064 0.054];

Y1 = [0.645 0.86 0.695 0.722 0.715 0.859 0.86 0.859 0.844 0.86];

Y2 = [1.01 1.01 1.89 1.86 1.8 1.01 1.01 1.05 1.52 1.59];

Y3 = [0.176 0.176 0.167 0.182 0.18 0.08 0.08 0.084 0.0849 0.08];

```
MSE = sum(power(X1-Y1,2))/10;
RMSE =sqrt(MSE);
std(X1);
GAUSSmodellength = RMSE/std(X1)
MSE = sum(power(X2-Y2,2))/10;
RMSE = sqrt(MSE);
std(X2);
GAUSSmodelwidth=RMSE/std(X2)
MSE=sum(power(X3-Y3,2))/10;
RMSE=sqrt(MSE);
std(X3);
GAUSSmodeldamagenumber
```

GAUSSmodellength = 1.4592

GAUSSmodelwidth = 0.7638

GAUSSmodeldamagenumber = 0.7713

The influence of various radiation doses on the samples behavior have been reported in 3D analysis of response functions. Figures 6 to 8 show the dependence of output variables on varied radiation doses. The dependence of examined factors on the doses which have not been experimentally used can be seen in these Figures, thus showing the importance of the fuzzy method in applied researches.

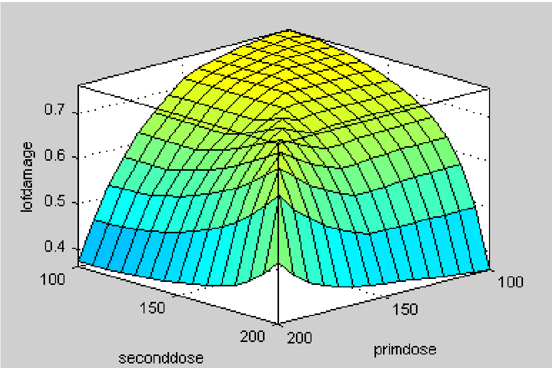

Figure 6 3D Response Functions: Influence of Primary and Secondary Dose on Length Damage

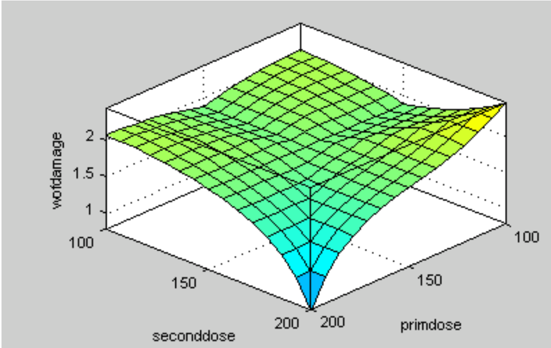

Figure 7 3D Response Functions: Influence of Primary and Secondary Dose on Width Damage

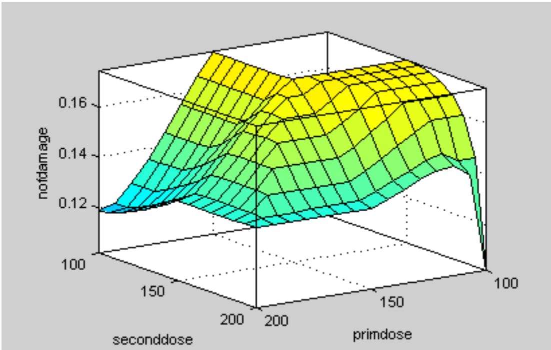

Figure 8 3D Response Functions: Influence of Primary and Secondary Dose on Number Damage

Through the 3D response functions analysis, it is possible to notice the influence of applied deformation on particular elastomer samples (Figures 9 to 12), and the deformation influence that has not been experimentally applied.

The results have shown that primary and secondary doses do not have the same effect on elastomer behavior. That is shown in Figures 9 to 12 of the 3D response functions.

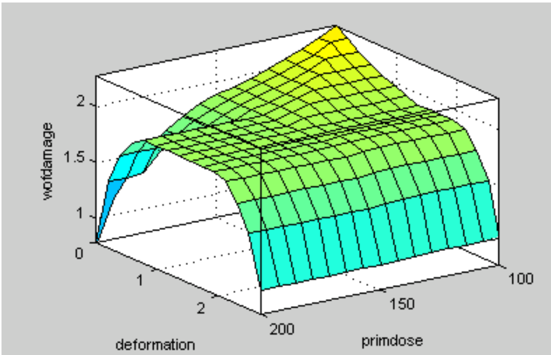

Figure 9 3D Response Functions: Influence of Primary Dose and Deformation on Width Damage

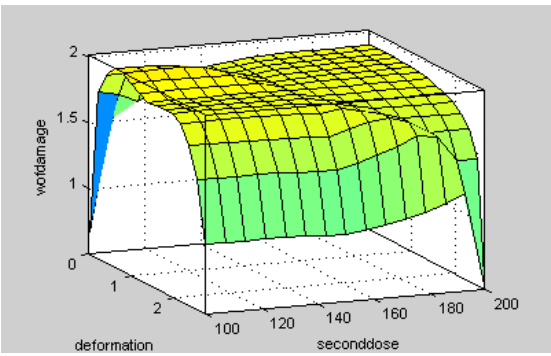

Figure 10 3D Response Functions: Influence of Secondary Dose and Deformation on Width Damage

05As shown in Figures 11 and 12 (3D response functions show the influence of primary and secondary dose and of the deformation of length damage), it is evident that the growth of the secondary dose results in a major effect.

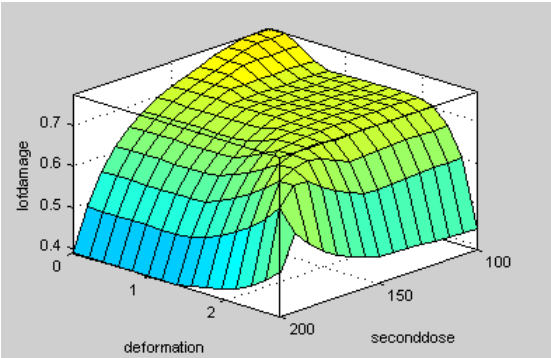

Figure 11 3D Response Functions: Influence of Secondary Dose and Deformation on Length Damage

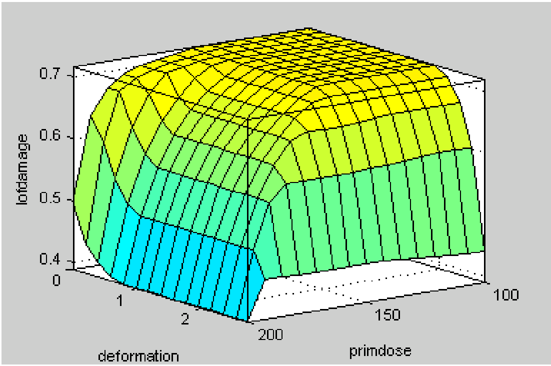

Figure 12 3D Response Functions: Influence of Primary Dose and Deformation on Length Damage

8. Conclusion

Research works and results of the MZOS project: "The application of Neural Networks and Fuzzy Logic in the Turbine Regulation and Ship Rudder Systems", pointing out to the properties of the test material, experimental and simulation methods, have contributed, together with the research results, to the elaboration of new technological solutions applicable in the shipbuilding industry.

In this work, fuzzy logic has been applied to evaluate values of length, width and the amount of damage on elastomer samples with reference to the radiation dose that the samples have been subdued to.

The data obtained through optical microscopy and by using the Fuzzy Inference System, enabled the formation of models and definition of functions which help us to evaluate the characteristics stored within a model. The Gaussian model has been created as well.

The influence of deformation on the samples treated with equal overall dose has also been estimated, as well as the influence on samples where the overall radiation dose has been increased for the same deformation.

The overall radiation dose of 200 kGy has been applied to samples 1, 3, 4 and 5, while samples 6, 8, and 9 have been treated with an overall dose of 300 kGy. Values of length, width and number of damages have been tested with regard to the values obtained from the Gaussian model.

Observing the values for samples 1,3,5, and 4 it leads to the conclusion that length damage increases along with the growth of deformation, except for the deformation $\varepsilon = 2.7$.

According to the Gaussian model for these samples it can be agreed that length increases with deformation growth, while values for width damage and the number of damages vary irregularly. Diversity in behavior of samples can be noticed at the dose of 150 kGy, which has not been applied to samples.

The system enables users to solve and explain various problems by using fuzzy rules on the characteristics observed, without any experimental analysis. With the change of parameters, the model thus developed enables prediction of different properties of the elastomeric materials.

For further research, it is important that numerical algorithms, by using certain radiation doses and strains, enable the development of a model for the selection of elastomeric materials.

Acknowledgements

The present work was supported by the Ministry of Science, Education and Sports of the Republic of Croatia (Research Project Quantitative Methods in the Function of the Optimal Maritime System Management 112-1121722-3308 and by Research Project Information-communication technologies in smart maritime systems 112-1121722-3314). The author wishes to thank Professor Julije Skenderović for the cooperation in the development of this research, for interesting discussions, after which parts of this work have been written.

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Submitted: 02.05.2016.
Accepted: 05.02.2017.

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