

# Method for Estimating the Risk with Residual Service Life of Rolling Stock

Waa'il Mahmood Lafta Al-waely

**Abstract** – In this paper we use fuzzy set method to solve one of the important problems in mechanical engineering (risk when extend the service life). The residual service life for rolling stock can change depending on it's using conditions. The Paper offer's a new method depending on fuzzy set method by using the material mechanical and chemical corrosion mathematical model to determine the residual service for rolling stock with the value of risk of it's usage in future.

## I. INTRODUCTION

It's very important when we want to extend the service life for any rolling stock determine the risk of it's using. The concept of service life means the time period since the beginning of the use of the tool or machine till the time period when it becomes unsafe or non-economic to use. The concept of service life is of great importance for mobile equipment used to transport large quantity of people, such as: Planes and trains and special used equipment (which we are trying to reduce the probability of failure to its possible minimums) such as: military mobile equipment. The service life for the equipment relies on the intensity and quality of the equipment's employment, and consequently the service life of certain equipment changes significantly depending "on these factors. Since the term or concept (density and quality of employment) is not specific or Fuzzy, so we can see that the service life function Fuzzy (non specific) Overall, the service life remaining for certain equipment (TR) can be determined by the equation number (1).

$$T_R = T_D - T_S \quad (1)$$

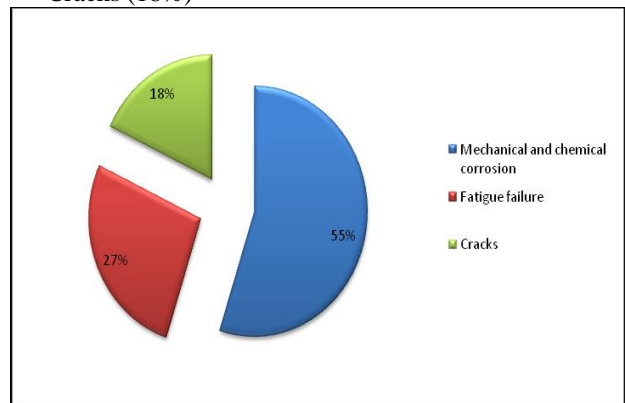
Where  $T_D$  - means the service life of the specified equipment as designed (by manufacturer)

$T_S$  - means the service life experienced by the equipment from the date of its inception to the present time (the time of testing).

Reality forced us in many cases to deal with the equipment under non-integrated information on the history of use where equipment come for maintenance without a history log (which are often missing or non-integrated) and there is no precise idea of the system and its future work and after maintenance the remaining service life of the equipment should be determined.

The identification of the remaining service life of the equipment currently relies on a study of the equipment without taking into account the Fuzzy factors (nonspecific) that affect the work of the equipment Therefore, in this paper we present a new theory to determine the remaining service life of the equipment by studying the Fuzzy factors (nonspecific) That affect service life remaining of the equipment, and this theory relies on the (Fuzzy Set theory). Perhaps the most important factors that affect the service life of the equipment are (Fig. No.1):

- Mechanical and chemical corrosion (55%)
- Fatigue failure (27%)
- Cracks (18%)



**Fig.(1) the most important factors that affect the service life of the equipment**

Through the diagram above we note that the mechanical and chemical erosion plays a greater role in determining the remaining service life of the equipment.

## II. FUZZY SET METHOD:

The emergence of a Fuzzy theory is a revolution in the development of classical algebra and a upgrade to a higher level so that it is now possible to take the information and data that was not specified in the mathematical modeling process, Posing the possibility of absorbing information and more data in a mathematical model to a problem. The theory is based on the idea of removing the Fuzzy boundaries on the logic of reparation classical groups, Which says that the group contains a specified number of elements each element that does not belong to this group cannot be attributed by any link, Which often contradicts with nature and human behavior. In the past stripping everything around us mathematically was necessary to be able to carry out mathematical simulation of the phenomena we wish to process and control,

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But it seems that with the accumulation of science, information and discoveries, it became necessary to expand the mathematical abstraction and the tendency to try to simulate the phenomena as it is in nature and away from abstraction for the sake of ease and simplification, And here came the idea of Fuzzy groups in the expression of groups as a way out of the trouble of limited simulation of phenomena. Instead of to express that an element belonging to a group with an answer yes or no, now the question is if the item belongs to a group, what is the degree of its membership, and this degree of membership is the spectrum between the value's zero and one, in other words there's a factor that can describe these value's which is called the "Membership Factor". Now we can say the logic of yes or no - true or false - white or black is a special case of spaces in the gray gradient black or white, which lies between the two, from here came the name "Fuzzy". Fuzziness theory Allows us to expand the Mathematical simulation of the phenomena, when we know the mechanisms of a project in a specific and classic way, we will come out with only one proverb that gives an idea about the number of these mechanisms, but when we try to know the group of mechanisms and mechanical technicians ready to work, we will fall in the trouble of judging the belonging to this group or not, it is well known that readiness of an equipment is an issue related to the large amount of criteria which its impact differs due to climate conditions and surrounding situations, so How can we formulate this group within the logic of Yes - No, this example shows us that it is imperative to take into account the Fuzzy groups and its presentation. The primary objective of the Fuzzy theory, not the removal of Fuzzy ambiguity but also to recognize its existence and its impact on the mathematical model.

At the very beginning there was confusion between the concept of possibilities and Fuzzy groups, because of the similarity between the distribution factors and membership factors, that's why it is necessary to put the difference in mind. While through statistics we are trying to predict the future, through the search for values that are more frequent, by simulating the Fuzzy groups we disclosure the elements of the mathematical model, which has no digital reflection and define it as a Fuzzy set. We Say about the group to be Fuzzy (Fuzzy) A in X and is expressed as follows:

$$A = \{ (x, \mu_A(x)) \mid x \in X \} \quad (2)$$

Where  $\mu_A(x)$  is the degree of belonging to the element x to the Fuzzy group A which its value's are between [0,1].

It is mathematically common to find for each group a membership factor of its own, where as the form and nature of the membership factor has a major impact on defining a group, Here begins the subjective element to intervene in the matter, and to alleviate it must take into account possible standards available that influence the formation of membership factor.

We may generally distinguish two types of factors, linear and nonlinear, in the case of non-linear the concave or curvature has a role in the expression of optimism or pessimism in the evaluation process that we have, through the mathematical model.

### III. MECHANICAL AND CHEMICAL CORROSION AS A FUZZY FUNCTION (NON SPECIFIC)

Usually we always rely in our account of the mechanical and chemical corrosion at the expense of the corrosion rate

(equation (3)) which in turn depends on the thickness of the metal as a key factor.

$$a = \frac{S_1 - S_2}{k_1 k_2 (t_2 - t_1)} \quad (3)$$

Where  $S_1$  - represents the thickness of the metal at the exit of the equipment from the factory (or after the last maintenance), mm.  $S_2$  - represents the thickness of the metal when the test is taken (currently), mm.

$k_1$  - factor represents the amount of slope in corrosion scheme rate and time on the horizon.

$k_2$  - factor represents the type of relation between corrosion speed and time (Linear or nonlinear).

$t_1$  - Represents the service life at the beginning of use, years.

$t_2$  - represents the service life when selected, in years.

By observing equation (3) we find that it contains factors that could be adopted as Fuzzy factors (non specific) as follows:

- The first thickness of the metal ( $S_1$ ): the first thickness of the metal depends on the thickness of iron slices, according to standard specifications there is the permittivity of productivity in thickness (+0.3, -0.75) for the slices of metal, so this factor can be considered ambiguous factor.
- Thickness ( $S_2$ ) measured at time  $t_2$ : that this thickness depends on the accuracy of measurement and depends on the accuracy of measuring devices and the experience of the examiner. According to the standard specifications there is measurement permittivity (+1, -1) and thus this factor can be considered as Fuzzy.
- Factors  $k_1, k_2$  have different values as follows:  $k_1 = (0.5 - 1.5), k_2 = (0.75 - 1.25)$ . Thus, these two factors can be considered as Fuzzy factors.

### IV. APPLYING THE THEORY

From a Number of mobile equipment we selected equipment called "Hopper Ballast Wagon for transport and lying ballast", where this equipment is used to fresh gravel when making or maintaining new or old railway lines. This equipment operates in harsh working conditions: weather conditions such as humidity and high temperatures, rain and other extreme load conditions, On the other hand the nature of its work is distributing gravel on all parts of the railway or road, this kind of work gives some parts of the equipment very high stresses and pressure which leads to a reduction of service work and raises the specter of failure, and to apply our theory we selected the most important part of the equipment which is the part of loading and unloading gravel (Hopper). Figure (2) represents the general appearance of the equipment.



Fig .2. Represents the overall appearance of the equipment.

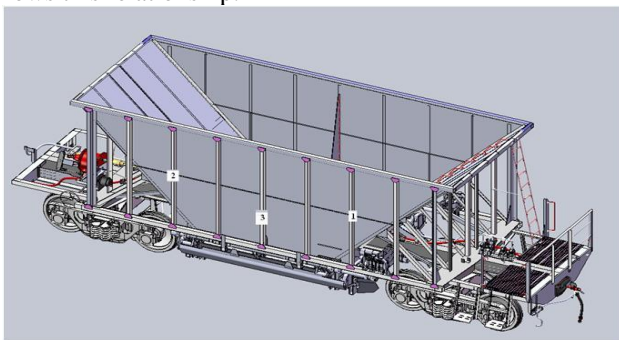


The offer method consists of four stages:

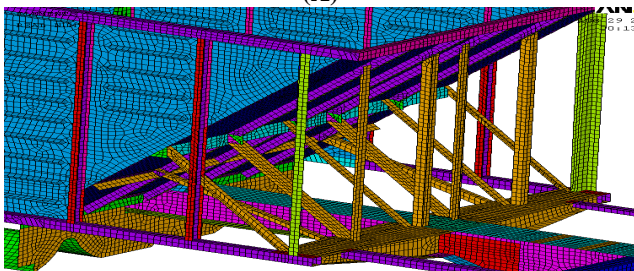
Stage 1: Through studying the style of the machines work and noticing the density of its use during the different stages of work and studying all documents available (by design and operation) and making the required tests, we appointed the factors ,and it's membership functions, which affect in the strength of the machine and its service life.

Stage 2: Using computer software like (Solid Works) and (Ansys), we built a model shown in Figure (3), where we entered all the factors that affect the machine during work, Also at this stage we find the input belonging function through the identification of Fuzzy factors that affect the service life of the machine and its relationship with the inputs data.

Stage 3: depending on the program (Ansys), we calculated stresses on the equipment's hopper, to find the relationship between the thickness of the metal and the stress on the equipment's hopper was calculated stresses at different thicknesses of the metal in three points of the hopper, Fig. (4) shows this relationship.



(A)



(B)

Fig.3. (A) The model under study (as Solid works model) (B) The model, divided by Finite Elements Method (by using program Ansys)

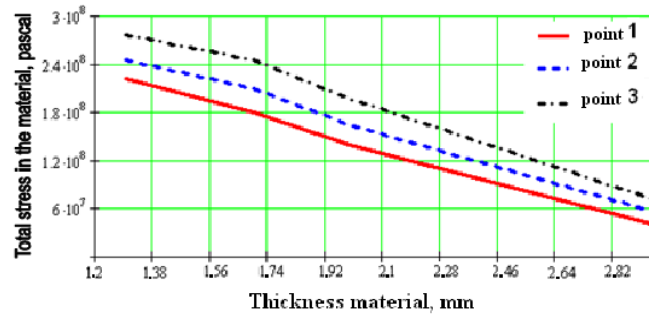


Fig. 4. The relationship between the thickness of the metal and the total stress.

Depending on equation no. (3), we configured the following mathematical model:

$$S(t_3) \geq [S]$$

$$a = \frac{S_\phi(t_1) - S_\phi(t_2)}{(t_2 - t_1)K_1K_2} \quad (4)$$

$$S(t_3) = S_\phi(t_2) - a(t_3 - t_2)$$

Where:

$[S]$  - Represents the least thickness of the metal that is allowed.

$S_\phi(t_1)$  - Represents the thickness of the metal when the equipment first left the maker factory, as a Fuzzy function, mm.

$S_\phi(t_2)$  - Represents the thickness of metal when tested as Fuzzy function, mm.

$S(t_3)$  - Represents the thickness of the metal after the service life  $t_3$  (future), mm.

Stage 4: Depending on the mathematical model above and the MATLAB program, we can get the thickness of the metal at the service life  $t_3$  and through the Fig.4, we can find the membership function of total stress depend onto the machine's service life as in fig.5.

Table.1. The membership function for the input information.(stage 3).

	Parameters	Source of information		Membership Function
		Model value	Deviations	
1	The thickness of the metal when the equipment first left the manufactory factory, mm.	Figure 5576.06.01.000 in machine catalog	SI standard	$\mu_{x_1} = \begin{cases} 1 - \frac{3.0 - x}{0.7}; & (3.0 - 0.7) \leq x \leq 3.0 \\ 1 - \frac{x - 3.0}{0.3}; & 3.0 \leq x \leq (3.0 + 0.3) \\ Else & 0 \end{cases}$
2	The thickness of metal when tested a, mm.	From the checking of the rolling stock physical properties	From the catalog of the thickness measurement device "BOLAT-M"	$\mu_{x_2} = \begin{cases} 1 - \frac{9.8 - x}{0.1}; & (9.8 - 0.1) \leq x \leq 9.8 \\ 1 - \frac{x - 9.8}{0.1}; & 9.8 \leq x \leq (9.8 + 0.1) \\ Else & 0 \end{cases}$
3	Factor represents the amount of slope in corrosion scheme rate.	According to the experimentally information in the references	According to the experimentally information in the references [7].	$\mu_{x_3} = \begin{cases} 1 - \frac{1.0 - x}{0.5}; & (1.0 - 0.5) \leq x \leq 1.0 \\ 1 - \frac{x - 1.0}{0.5}; & 1.0 \leq x \leq (1.0 + 0.5) \\ Else & 0 \end{cases}$
4	Factor represents the type of relation between corrosion speed and time (Linear or nonlinear)	According to the experimentally information in the references	According to the experimentally information in the references [7].	$\mu_{x_4} = \begin{cases} 1 - \frac{1.0 - x}{0.25}; & (1.0 - 0.25) \leq x \leq 1.0 \\ 1 - \frac{x - 1.0}{0.25}; & 1.0 \leq x \leq (1.0 + 0.25) \\ Else & 0 \end{cases}$



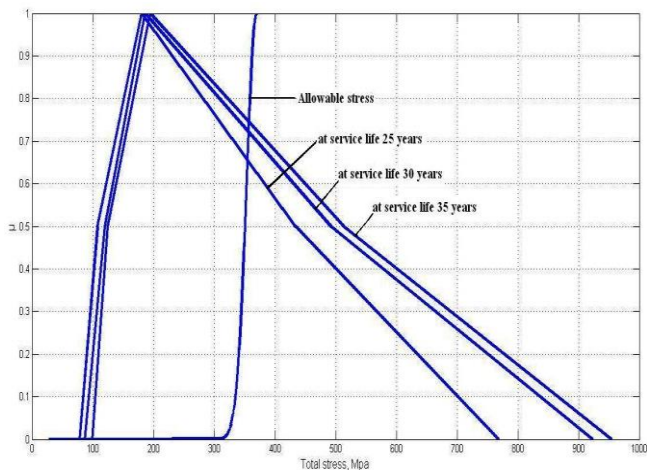


Fig.5. Membership functions of total stress depend onto the service life.

I. RESULTS:

Then from compare this values with the maximum allowable stress on the metal and use the law:

$$Risk = 1 - \mu \tag{5}$$

We can determine the remaining service life of the machine with the amount of usage risk in the future, as in Fig.6. For the focus of study example, the service life for the machine is 20 years, but through the application of this theory (where the maximum allowable stress of the metal is 190 MN \ m<sup>2</sup>) we found out that the machine can work for an additional 5 years more with using risk 31% . By using this curve we can find the residual service life for machine, under study, with the amount of risk when using it. From curve below, very clear the machine can works for 2 years with reliability 100%.

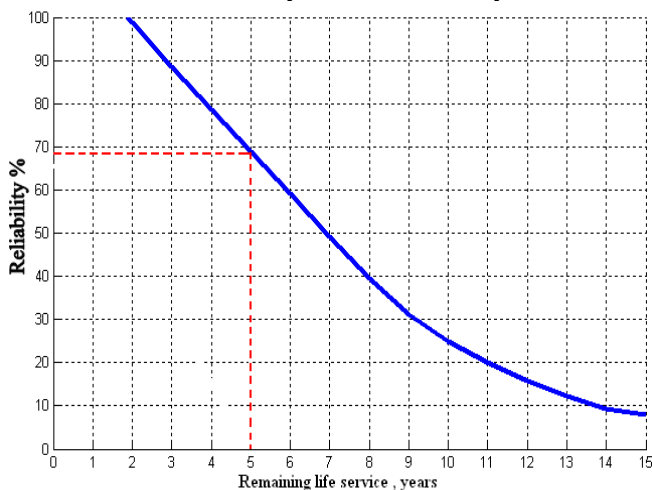


Fig.6. The reliability of remaining service life for the studied machine

II. DISCUSSION AND CONCLUSIONS:

By using the offered method, we can find the residual service life for machine, under study, with the amount of risk when using it or we can determine the amount of risk, at first, depends on the intensive of machine work (if we can determine the kind and intensive of machine usage in future)

and then from it we can find the residual service life for machine with this amount of risk.

We can use this method to make the (working plan) for several machines and distribute the jobs depend upon the reliability of service life of rolling stock (for the rolling stocks that work after finished their design service life).

In this paper, we studied the effect of one factor (mechanical and chemical corrosion) to calculate the residual service life for rolling stock (with study four uncertainly factories) and neglected the effect of others factors (fatigue failure and cracks). For future studies, we recommend to development new method to calculate the risk with residual service life by study the effect of all these factors (mechanical and chemical corrosion, fatigue failure and cracks) depends into Fussy set method. Really when we studied effect of one factor (mechanical and chemical corrosion of the metal), we found four uncertainly factors But when we study the effect of all these three factors (mechanical and chemical corrosion, fatigue failure and cracks) we may be find more than 35 factors.

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