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APPLICATION OF ECONOMICAL TOOLS IN RISK MANAGEMENT

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ABSTRACT

The risk of failure is now important part of many different aspects of materials and engineering applications. As part of the effective management, risk assessments are essential requirements for taking appropriate decisions for maintenance and repair. By combining both engineering and financial methods it is possible to find the appropriate time for maintenance actions. Presented decision analysis approach is demonstrated on a problem for maintenance timing of a welded tubular X-joint.

INTRODUCTION

Risk has always been an inherent part of the every day life. People accept risk because they want to achieve their goals. The evolution of the mankind increases the importance of the risk management in the industry. Risk is taken into account as an integral part of the design of structures to achieve target reliability depending on the severity of failure and on the uncertainty of the input data [1,2]. Risk is also important as a base for managerial decisions on inspection, maintenance, and investigation of the life cycle of engineering structures and equipment[1,3].

Risk assessment methods are now used widely in the electrical power plants, chemical engineering industry, general structural and machine building industry etc. This is especially critical in the case of severe working conditions for some part of the equipment. It is financially non-profitable to replace the whole equipment because only a few parts are out of order. The existing system of regular maintenance/repair does not allow achieving the best financial decisions because it is build mostly on engineering requirements. Finding an intersection point between financial and engineering requirements is way to success.

The aim of this paper is to present the strategies to prevent the risk and to analyse the possibilities to use the risk management procedures to predict the consequences of failure, to propose an approach for maintenance timing based on financial costs analysis.

LINK AND DEPENDENCE BETWEEN ENGINEERING AND FINANCE

Risk management is an interdisciplinary subject that covers different topics but the link between the engineering and finance is not always obvious. Although the effects of undesirable event usually translate into financial result the key point of understanding the link between engineering and finance is not easy seen. The main reason of this miss - understanding is the difference between tools and definitions used by engineers and managers. Both engineers and managers seek own solution of a problem and can not find a simple intersection between their aims [4].

The limitations of the organisational resources make difficult for engineers to obtain the necessary resources to maintain the expensive equipment. The engineers can not convincingly proof their requirements to the decision-makers that are usually managers and want to see the profit. The problem arise because the engineers normally do not express themselves in financial terms but in engineering analysis results as fatigue life, crack growth, etc. In addition engineers have to compete against other staff of the company for resources to support maintenance of the equipment. The competition for organisational resources usually is based on quantitative method for financial and decisions analysis.

The limitation on the maintenance resources is born from increasing the maintenance costs. The higher requirements on the maintenance costs come from equipment that is in the ageing part of its life cycle. A lot of components working in severe conditions are in or rapidly approaching the high age of their life cycle. Such kind of component has a shorter life cycle comparing to other elements of the equipment.

Typical life cycle curve is shown in Figure 1. It shows the classic shape of the Weibull life curve [2,5]. In the left side the failure rate decreases, that is known as infant mortality. There are initial defects from design and manufacturing. The central section of the curve is a period of life with approximately constant failure rate. The right part is the ageing period of the structure and it has an exponentially increasing failure rate due to some specific material failure mechanisms like fatigue, crack growth, wear and creep. This curve is used to describe almost all engineering components.

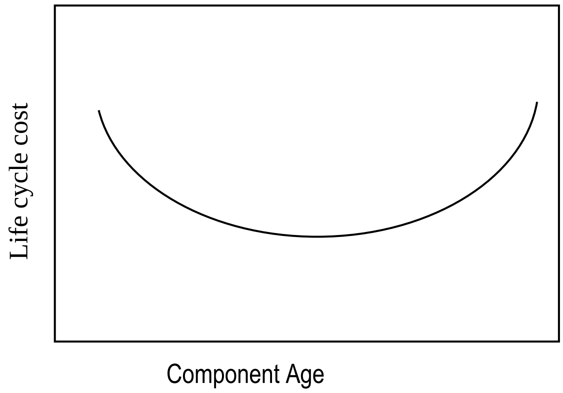

Figure 1. Life cycle curve

The management of the industrial companies has been surprised by the large increase in maintenance costs for components of industrial facilities approaching to the ageing part of their life cycles. An opinion exists that during the constant failure rate period if prudent maintenance was performed the rate of failures would not increase rapidly.

The limitation of the organisational resources is caused by lowering of price of products produced by old equipment. The dynamic of nowadays market have resulted in using a low price strategy in order to meet competition.

Managerial decisions are very difficult because of one side there is a limitation on the maintenance resources due to the low prices of the product and on the other side there is the increased need to do maintenance due to ageing [6]. At the period of ageing part of the life cycle of the equipment it is impossible to postpone the maintenance work.

In this situation a big help is using decision analysis supported with financial analyses and quantitative techniques. This approach has been developed and gives good results in the field of investment decisions where large amounts of resources are involved. It is very appropriate approach as well in maintenance decision making, in the direction to manage uncertainty by trying to find the optimal time to maintain equipment during the ageing part of its life cycle.

In the case of investment decision the aim of the approach is to prove the positive effect of invested resources but in case of maintenance decisions the aim is to determine the period during which the equipment can work reliable without maintenance, that is without additional investment [4].

The advantage of decision analysis approach is better seen for the situation when the decision is not obvious and requires quantitative methods based on both financial and engineers knowledge. The possibility to use the same well known investment decision approach for maintenance decision is reasonable since the maintenance is competing for the general organisational resources and decisions can be compared.

APPLICATION OF DECISION ANALYSIS APPROACH

The first step in the decision analysis is to determine the criterion to be optimised. The wide used criterion providing good results in financial projects is the Net Present Value (NPV). This criterion determines the futures value of recent invested resources and allows comparing different decisions. The Net Present Value can be given as,

$$NPV = \sum_{t=1}^{T} \left(\frac{B_t - C_t}{(1 + r/100)^t} \right) \quad 1)$$

where t is time in years, and sum is for a period of T years, B_t and C_t are the annual benefits and costs respectively, r is the discount rate in %.

Any project is profitable when the calculated NPV is positive and the optimal decision is with the largest NPV.

In the engineering projects as criterion for estimation frequently time to failure, or probability of failure are used. Even they are engineering criteria they result in financial consequences. It becomes possible to connect the probability of occurrence to consequence of occurrence, that is term well accepted by business oriented managers. A more accepted term for engineers to describe failure is risk. In the literature risk is determined as a product of probability of occurrence (failure) POF, and consequence of occurrence (failure) of undesirable event, CF, given in cash terms,

$$R = POF * CF \quad (2)$$

The financiers call the above mentioned parameter the expected value of the consequence. The decision-makers are interested not to know whether a component will fail, but what result will produce this failure to the company. The similarity in definitions allows to build a link between engineering terms and financial terms. The relationship defined by risk and expected value of consequence of failure is a key in the formulation of the decision model for quantitative maintenance decision making.

In maintenance decision situation it is necessary to determine a maintenance action year to optimise NPV amongst several alternatives. The alternatives correspond to performing maintenance action at the end of first, second, third etc year. Here NPV is considered as criterion that estimate the profit of non-investing, and it is used to determine the year of maintenance. In equation (1) T becomes the number of year when the maintenance/repair is performed. For the purposes of maintenance decision the main benefit B in equation (1) is seen as prevented losses and can be expressed as a reduction of the risk due to maintenance,

$$B = \Delta POF * CF \quad (3)$$

For the years before the maintenance, the benefit B can be considered equal to the risk, equation (2).

Welded tubular X-joint maintenance decision problem

Welded tubular joints are widely used in structural industry, for example in offshore structures. Their mechanical durability is very important, as a mechanical failure may have very significant consequences. Here a X-type welded joint from a large stricture [7,8] will be investigated in order to establish appropriate maintenance and repair programme that have to cover engineering and financial requirements. In the analysis two questions have to be considered. From financial point of view it is necessary to find time, till which the company have benefit and profit from the structure without maintenance. From engineering point of view the repair must not be delayed because the probability of failure and risk will increase too much.

To obtain the variation of the probability of failure with time (number of loading cycles) an approach based on Weibull reliability analysis [2] and probabilistic fracture mechanics [7] was applied. The use of Weibull analysis technique is chosen, due to its capability to give reliable results with limited amount of data. For this, data from laboratory tests was used [8]. In Table 1 crack depths for four different location of the measured crack profile are shown. The number of cycles represents the number after initial crack measurement. Here 15000 cycles correspond to 1 year in service. The above data was implemented in a probabilistic fracture mechanics model that incorporates a damage propagation mechanism [7]. The results of this simulation are probabilities to failure versus time, Fig. 2.

Table1.

Number of cycles	Wall thickness at different locations (mm)			
	I	II	III	IV
145000	17.5	22	25	22.5
180000	4.7	12.5	15.8	15.5
200000	2.6	6.8	8.2	9.2
220000	0.2	2.5	5	5.8
240000	0.01	1.2	2.5	2.5

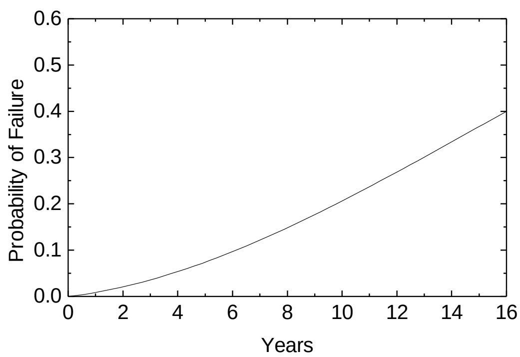

Figure 2. Variation of probability of failure with time for X-type welded joint.

The procedure for NPV estimation has to determine the appropriate time for maintenance/repair, that corresponds to a non-negative NPV. This analysis was performed using an MS Excel workbook that allows an easy NPV estimation. For the purpose of this example the following initial data was used: Consequence of failure of the tubular X-joint is 20000, the cost of maintenance and repair is 5000.

The results for variation of NPV with time are presented in Figure 3. For the first nine years the NPV is positive and later it becomes negative indicating for positive financial results have been achieved in first nine years. Therefore, best financial output will occur if maintenance work is performed during ninth year.

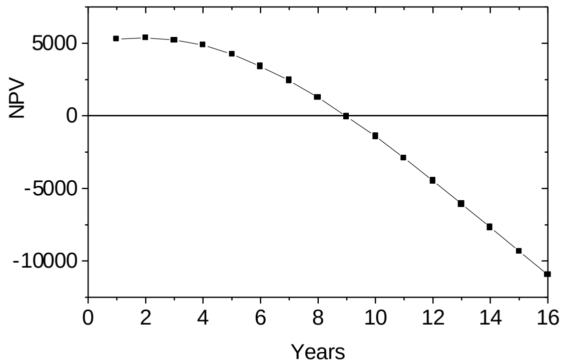

Figure 3. Variation of Net Present Value with time

It have to be noted that it is necessary to take care about some multiplication effects, due to the fact that a single accident can cause secondary effect – a new accident (e.g. plastic collapse). The probability of such cascading effect is increasing in modern industries and structures. For this purpose it is necessary to establish all relations between all possible risk events, to estimate the probability of occurrences and to evaluate the multiple consequences.

CONCLUSIONS

An approach for using NPV in maintenance decisions was presented. It allows to build a relation between engineering and financial experts, based on a mutual understandable definition of risk.

It is shown on an example that it is possible to find out the appropriate time for maintenance and repair considering both engineering and financial aspects of the problem.

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