APPROACHES TO SERVICE LIFE PREDICTION OF METALS IN THE NUCLEAR INDUSTRY

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ABSTRACT

A procedure to quantitatively relate target service life of nuclear components, such as pressure vessels, primary piping and containments to reliability is presented. It is shown how this is also related directly to quality control which, consequently affects maintenance procedures, inspection intervals, etc. Linear damage models as well as fracture mechanical aspects are discussed. Furthermore the effect of corrosion within the framework of the reliability concept is shown. Finally some applications and suggestions for future research are given.

I INTRODUCTION

The problem of service life prediction of components of nuclear power plants is of utmost importance for developing criteria of quality control, maintenance procedures, inspection intervals, etc. In this context it is referred to large structural components, such as containments, reactor pressure vessels, etc., mechanical components, such as pipes, valves, pumps, etc. In general terms, age-related effects may in some cases strongly adversely affect the target service life. These effects may be due to wear, corrosion and fatigue or a combination of it. An extensive survey of these age related failure occurrences is given in [1]. These
observations reveal a considerable statistical scatter. Therefore only probabilistic procedures provide a sound basis for realistically modeling of the phenomena. For this purpose reliability analysis has been proven to be a most valuable tool [2]. It is of particular advantage that all other possible failure mechanisms, such as ultimate load failure, etc., may be treated within the framework of the reliability concept. Furthermore, by utilizing this concept the significance of the various parameters involved may be determined and then, based on these results, measures with respect to quality control, etc. can be taken, i.e. designed. In reliability theory the problem of service life is generally reformulated, i.e. a finite probability by which a target service life is not met, is to be sought and defined as failure probability which is the complement of the reliability.

In nuclear engineering reliability considerations are utilized with increasing tendency for analysis (see for example [3-5]). These concepts also form the necessary basis for risk studies [6,7].

2 RELIABILITY ANALYSIS

The scope, principles and foundations of reliability theory including numerous applications are discussed in detail elsewhere (e.g. [2,8]). This encompasses modeling procedures of random variables including parameter estimation procedures, etc.. Therefore only some of the principles pertinent to the problem will be reviewed here. In this context it should be pointed out that the foundations of the theory of structural reliability have been developed by A.M. Freudenthal [9,10].

Considering that the loading of a structure and its resistance may be described by two variables only, the probability of failure, $p_f$, under a single load application may be defined as

$$p_f = \int_0^\infty F_R(x)f_S(x)dx$$  \hspace{1cm} (2.1)

where $F_R(x)$ represents the cumulative distribution function of the structural resistance and $f_S(x)$ the probability density function of the load. Type and parameters of the distributions are chosen i.e. derived, based on statistical evidence and physical reasoning respectively. If more than two variables are required to express the randomness of the load and the resistance, the limit