DESTRUCTION PROCESSES IN POWER PLANTS AS A PRACTICAL EXAMPLE FOR THE COURSE OF MATHEMATICAL MODELING

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I. INTRODUCTION

The study of various disciplines related to mathematical modeling often raises the question of selecting a successful subject area for building a model. In the framework of this work, a model of progressive destruction of pipelines used in power plant power units is considered. The destruction of such pipelines can lead to catastrophic consequences. Mathematical modeling is used to reduce the amount of work on "physical" diagnostics.

The model described in the paper allows students to become more familiar with the basic approaches used in statistical modeling, the use of various types of probability distributions, and the use of the Monte Carlo method for calculations.

The mathematical model of the destruction of elements of power systems, analyzed in the classroom, is considered in the form of a computer program with the with a fairly wide functionality.

In order to simplify understanding, it is divided into separate modules, each of which is considered in a separate lesson.

Module №1 “Calculation of defect size distributions parameters”;

Module №2 “Import of stress condition”;

Module № 3 “Formation of real flaws parameters distributions tables”;

Module №4 “Calculation of cyclic flaw growth”;

Module №5 “Probabilistic analysis of ductile fracture”.

a. Calculation of defect size distributions parameters

The specified module calculates the distribution parameters for the provided sample of the detected defects sizes. The calculation is performed for the following distributions: normal, lognormal, exponential, two-parameter Weibull. In addition, the module calculates the parameters of the histogram of relative frequencies. There are no restrictions on the use of this module.

The input data of the module are: a sample of N elements x1, x2, …, xN, each element describes the size of an individual detected defect in mm;

k is the number of columns (intervals) of the histogram of relative frequencies.

The output data of the module are: parameters of the distributions of the dimensions of the detected defects in mm; parameters of the histogram of relative frequencies (columns and their heights).

b. Module №2 “Import of stress condition”;

The calculation of the stress state is performed in a third-party program and is not considered in this paper.

c. Module №3 Formation of Real Fractures Parameters Distributions Tables

The specified module is designed to perform the following operations:

– formation of a table of the function g (a), approximating the density of distribution of the depths of real fractures in the interval [amin, s], depending on the options selected;

- formation of a table of the function g (ac_ratio) approximating the distribution density of the ratio of the semiaxes of the flaws in the interval [0, 1];

– calculating the value of the density of defects in a pipeline element for real flaws.

The described operations are performed based on the data for the detected flaws and depending on the options selected. Available options:

– only detected defects;

– discovered defects with the addition of undetected defects;

– detected defects with the addition of undetected defects and modeling of the repair.

The module has the following limitations of applicability:

d. Probabilistic Analysis of Ductile Fracture

The module calculates the probability of ductile fracture from through flaws, the probability of ductile fracture from surface flaws, the probability of the formation of a through flaw, the probability of a stable through flaw, using Monte Carlo method for a pipeline element at a given operating mode. The results for the element are obtained based on the calculation in the section of the pipe in the presence of one flaw.

Based on the lengths of stable through flaws, the probability of a stable through flaw in the element and the specified intervals of the nominal leak diameters, the module calculates the probability of stable leak formation for the intervals of the nominal diameters.

The module's limitations are as follows:

The random parameters are: flaw depth, ratio of flaw semiaxes.

The operating mode is set by voltage and temperature [4]. It is assumed that the regime consists of one moment in time.

The load and temperature are assumed to be uniform over the pipe wall thickness.

In direct modeling of random flaws in the entire probability space, a problem arises - the events under study have a nonzero probability only for large defects. However, the probability of the appearance of a defect with large dimensions is very small, which leads to the need for a large number of experiments with a corresponding increase in the calculation time. To get around this problem, the ability to divide the probabilistic space into non-intersecting regions called cells was implemented (implementation of a stratified sample).

II. CONCLUSIONS

For each cell, separate Monte Carlo simulation is performed, and then the results of all cells are combined. To do this, each result obtained inside a cell must be multiplied by the probability of a flaw hitting the corresponding cell.

The use of cells can significantly reduce the variance of the results, reduce the number of experiments and the calculation time.

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