

THE PROBABILISTIC CALCULATING OF FATIGUE CRACK PROPAGATION USING FCPRBCALC PROGRAM

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Abstract: *The paper gives examples of the probabilistic assessment of a steel cyclic loaded structure. Fatigue progression of the cracks from the edge and from the surface is used as a basis for proposing a system of inspections. The newly developed method Direct Optimized Probabilistic Calculation (DOProC method) was used for solution. The method was applied in FCProbCalc software.*

Keywords: *DOProC method, FCProbCalc, Fatigue Crack, Inspection of Structure, Safety Margin.*

1. Introduction

Reliability of bearing structures which are subject to load cycles is affected considerably by degradation processes being, in particular, the result of fatigue of the basic material. Methods are under development now which would detect failures and defects, if any, resulting from initiation cracks. Linear fracture mechanics is among alternative methods. Mechanical engineering experts have been dealing with such issues for many years. Results have been gradually taken over and implemented into designs of the loading structures in buildings. Because input variables include uncertainties and reliability should be taken into account, probabilistic methods should be used in investigation into the propagation rate of the fatigue crack.

This paper describes the use of the original method and method which is under development now: the Direct Optimized Probabilistic Calculation ("DOProC") can be used for a probabilistic design and assessment of reliability of structures with the specified designed probability of failure, without using any simulation techniques. The DOProC method deals, as the other probabilistic methods, with tasks where at least certain input quantities are of a random nature. In many cases, this calculation method is very efficient and provides accurate estimates of resulting probabilities. Only a calculation error and an error resulting from discretizing of input and output quantities are involved there.

DOProC method has proved to be a good solution, among others, in probabilistic analysis of fatigue crack propagation in constructions subject to cyclical loads. Detailed methods with examples of the probabilistic assessment for a construction subject to fatigue load are available, a particular attention being paid to cracks from the edge and those from the surface. Similarly to other probabilistic analysis, this information is used as a basis for designing a system of inspections of the cyclic load construction, the aim being to analyze real propagation of fatigue cracks in those structural details which tend most to be damaged by fatigue. If no fatigue cracks are found, the analysis of inspection results give conditional probability during occurrence.

In order to improve quality of probabilistic calculations, a special software - FCProbCalc - was developed. Using this software, it is possible to monitor effectively and flexibly development of fatigue damage in structures, to determine times for inspections and to ensure that the construction will be fit for operation in terms of fatigue safety. The methods and application can considerably improve estimation of maintenance costs for the structures and bridges subject to cyclical loads.

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2. Probabilistic calculation of fatigue crack propagation

Three sizes are important for the characteristics of the propagation of fatigue cracks. These are the initiation size, the detectable size and the final acceptable size which occurs prior to failure caused by a fragile or ductile crack. The fatigue crack damage depends on a number of stress range cycles. This is a time factor in the course of reliability for the entire designed service life. In the course of time, the failure rate increases, while the reliability drops.

The topic is discussed in two levels that affect each other: the probabilistic solution to the propagation of the fatigue crack and uncertainties in determination of quantities used in the calculation. When investigating into the propagation, the fatigue crack that deteriorates a certain area of the structure components is described with one dimension only: a . In order to describe the propagation of the crack, the linear elastic fracture mechanics is typically used. It is based on the Paris-Erdogan law:

$$\frac{da}{dN} = C \cdot (\Delta K)^m, \quad (1)$$

where C , m are material constants, a is the crack size and N is the number of loading cycles.

3. FCProbCalc software

FCProbCalc was developed using the aforementioned techniques. By means of FCProbCalc, it is possible to carry out the probabilistic calculation of propagation of fatigue cracks in a user friendly environment. The attention is paid to propagation of fatigue cracks from the surface and edge. On the basis of these data, times for the first and next inspections are determined, the goal being to identify fatigue damage to structural details which most tend to be damaged by fatigue.

Using FCProbCalc it is possible to specify propagation of fatigue crack from the edge for a certain time interval - the resistance of the structure $R_{(a_d)}$ and $R_{(a_{ac})}$, load effect S as well as probability of elementary phenomena U , D and F which are the source information for determination of the time of the first inspection. If no fatigue damage is found during the inspection, times for next inspections have been determined on the basis of the conditioned probability.

4. Conclusions

This paper addresses application of the new probabilistic method, DOProC, for probabilistic assessment of steel structures which are subject to load cycles and which tend to suffer from fatigue cracks. The method was included into FCProbCalc which is the software which makes it possible to solve very efficiently the probabilistic task of fatigue crack propagation in a user-friendly environment.

FCProbCalc was used for the probabilistic assessment of fatigue damage to a bridge structure where cracks were propagating from both the surface and edge. Times were specified for inspections of the bridge structure, where the purpose was to monitor occurrence of certain fatigue cracks. The comparison proved that velocity of propagation of the fatigue crack from the surface is considerably slower than that from the edge.

Appendix

For a lite version of FCProbCalc and for other software products based on DOProC method please visit web pages <http://www.fast.vsb.cz/popv>.

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