IDENTIFICATION METHOD FOR MARKS ON FRACTURE SURFACES AND CASE STUDY (FAILURE OF PROPELLER BLADE OF EXHAUST GAS VENTILATOR)

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ABSTRACT

There is possible to find some marks on the fracture surfaces. That marks are following the crack tip positions during the crack propagation. We can assume that these marks are connected with changes in characteristics of loading or in chemical regimes.

We can measure positions of marks on the crack surface. We can try to estimate kinetics of crack propagation as dependence on load and position of crack. Mainly in the case, in which we can assume fatigue crack propagation, we can propose a model of kinetics. But it is very difficult or even impossible to determine exactly the real load.

If we know data about the character of failed part operation, if we can design a kinetic model of crack propagation and if we have determined positions of marks on the fracture surface, we can compare that data. This comparison can be done by computer program by help of calculation of overlap integrals. The data about operation and positions of marks on crack surface can be presented as sum Gauss curves. Computed overlap integral will depend on the coefficient in kinetic model. The maximum values of the integral will be points in which coefficients in kinetic model mean the most probable values. We can assume by this way a real crack propagation rates and lifetime.

The presented method was applied on the case of fatigue fracture of exhaust gas propeller blade on the classic coal power plant. The application of this method contributed to the explanation of real crack propagation rate and lifetime.

INTRODUCTION

There is possible to find some traces on crack surfaces. These traces map positions of crack front by this way, as the crack propagates. We can assume that these marks on a crack surface are connected with some changes in the character of loading, chemical condition if a chemical corrosive solution is in the contact with the affected part. There is possible introduce following changes as a probable reason for creating marks on fracture surface: shut down and start up procedures, changes in the forces, in the ratio R, in the frequency, temperature and chemical conditions. We can measure the positions of marks on the fracture surface after breakdown and in the majority of cases we can try to create a model of kinetics for the crack propagation. The kinetics depends on the values of forces and on the position of crack front. Usually there is very difficult or even impossible to obtain precise values of forces (loading) due to mixture of modes, unknown real frequency, etc.

METHOD

If we know data about the use of damaged part, if we can create a model of kinetics for crack propagation and if we know the positions of marks on the fracture surface, we can compare these data sets. This comparison can be done on a computer by the computing of overlap integrals by the way that we are finding the biggest probability that the data sets are in agreement.

Data about the usage can be represented by a sum of Gauss functions, where each function introduces one change in parameters of usage.

$$S(t)= \Sigma G_i(t, t_i, wt_i) \qquad (1)$$

G_i	Gauss function
t	time
t_i	position of line on the t axis
wt_i	width of line

The positions of marks on the fracture surface can be represented again by a sum of Gauss functions

$$M(a) = \Sigma K_j(a, a_j, wa_j) \qquad (2)$$

K_i	Gauss function
a	crack length
a_i	position of line on the a axis
wt_i	width of line

The width of Gauss line can represent a deviation in the measuring of the mark position on the fracture surface. The comparison of gained data will be done by overlap integral. This type of solution includes the possibility that every change in the character of usage has not initiate a trace on the fracture surface as well as every trace on the fracture surface was not created by change, which is one part of the evaluated set of changes.

We will install parameter into kinetics model, which enable us to test various load or frequency. The crack propagation rate can be expressed as a function:

$$da/dt= g_1(K,R,f) = f * g_2(K,R) \qquad (3)$$

da/dt	crack propagation rate
g_1	function of K, R, f
K	stress intensity factor
R	R ratio ($R= F_{min}/ F_{max}$)
f	frequency
g_2	function of K, R

If we do not know the real frequency, we can express the variability in this parameter by coefficient p by this way:

$$da/dt=p* f * K^n * g_3(R) \qquad (4)$$

p	parametr
n	constant
g_3	function of R

In the case when we do not know exactly load parameters, we can express the variability by a parameter p in the relations for stress intensity factor /1,2/.

We can change function S into function S_a by the computed crack extension rate after relation 3 or 4. Function S_a is function of crack length as well as function M.

$$S_a(a, p) = \sum G_i(a, a_i(p), wa_i(p)) \qquad (5)$$

Now we can compare functions M and S_a by the overlap integral:

$$I_o(p) = \int S_a(a, p)\ M(a)\ da \qquad (6)$$

$I_o(p)$ overlap integral

This integral is function of parametr p. Function $I_o(p)$ we get by changing of parameter p in a interval which follows from time of equipment operation. The function $I_o(p)$ expresses the non-standard measure of probability of agreement between operation data set and the data set of measured trace positions on the fracture surface. Maxima of this function show possible values of parametr p which results into real crack propagation rate. It is possible to estimate real full time of crack propagation after knowledge of crack propagation rate along the whole investigated crack length.

The estimate of real crack propagation rate and the lifetime can help for good set of inspection intervals, possibly to changes in design.

APPLICATION OF METHOD

The method was used for the fatigue fracture of exhaust gas propeller blade on a coal power plant unit. The propeller of ventilator is driving the exhaust gas after desulphurisation. The propeller was made from stainless steel and there were no traces from corrosion on the fracture surface. The fracture was caused by fatigue initiated from weld joint or from heat affected zone. The propeller was operated in two regimes, it means in two power levels, despite this difficulty the method results in better understanding of crack propagation through the wall of propeller blade.

Parameter p included into stress intensity factor was used to vary the set of operation data. A program written in Turbo Pascal on PC was used to compute the overlap integrals.

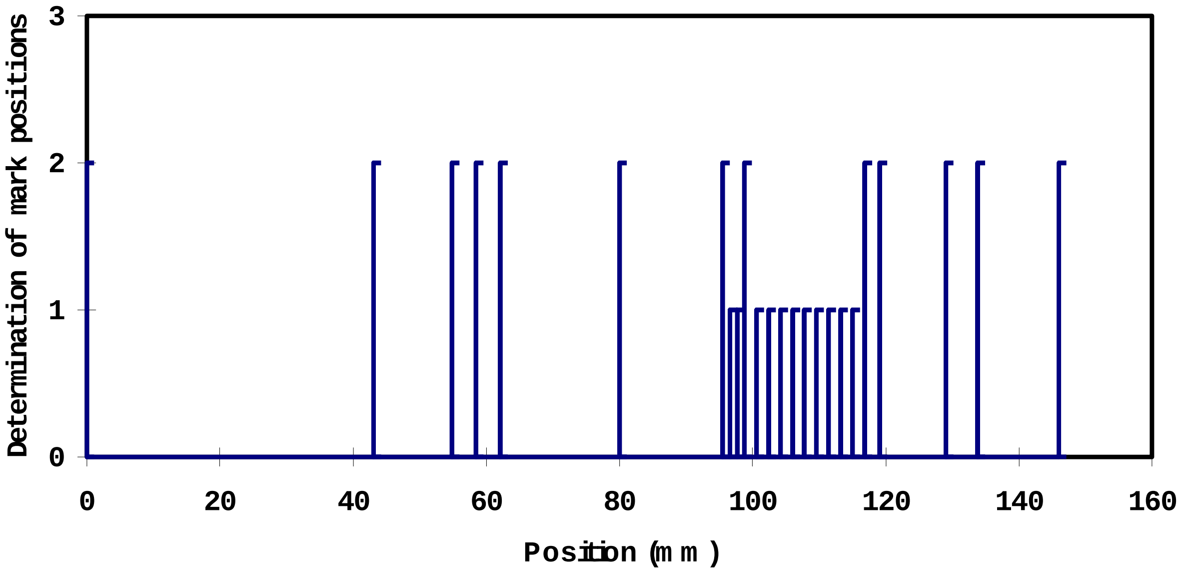

Figure 1: Traces on the crack surface

The initial data are presented in Fig.1 and Fig.2. The Fig.1 shows the data about positions of traces on the fracture surface. The zero point is the final position of the crack front just before the breakdown. The Fig.2 shows the structure of operation, every vertical line means one shut down of unit. The zero point is the time of final break.

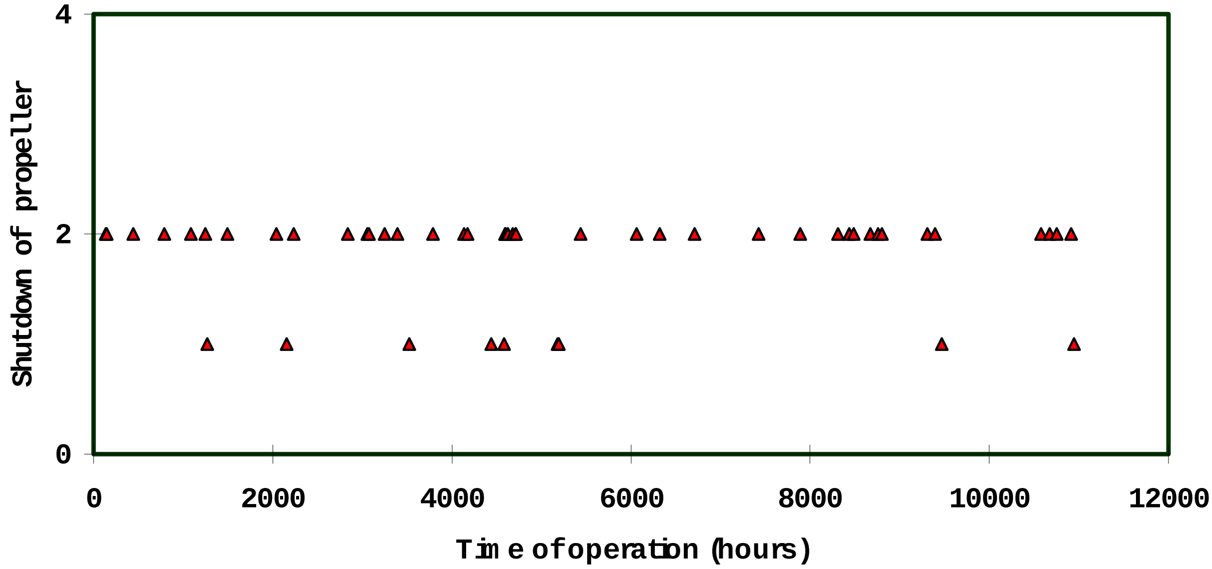

Figure 2: Operation of the ventilator

Next two figures show the results of overlap computing. The first one, Fig.3 is showing dependence of overlap integral $I_o(p)$ on parameter p for three different numbers of lines, which represent the shutdown data. There is clear that the local maximum which we should take into account is the maximum for p= 58. The second one, Fig.4 is showing again the same dependence, but now for three different positions of final crack stage. It is convenient to try to vary this position slightly because this position could be affected by several factors, for example by an overloading followed after abrupt brake or quick acceleration. Again it is visible that the main maximum is for p=58.

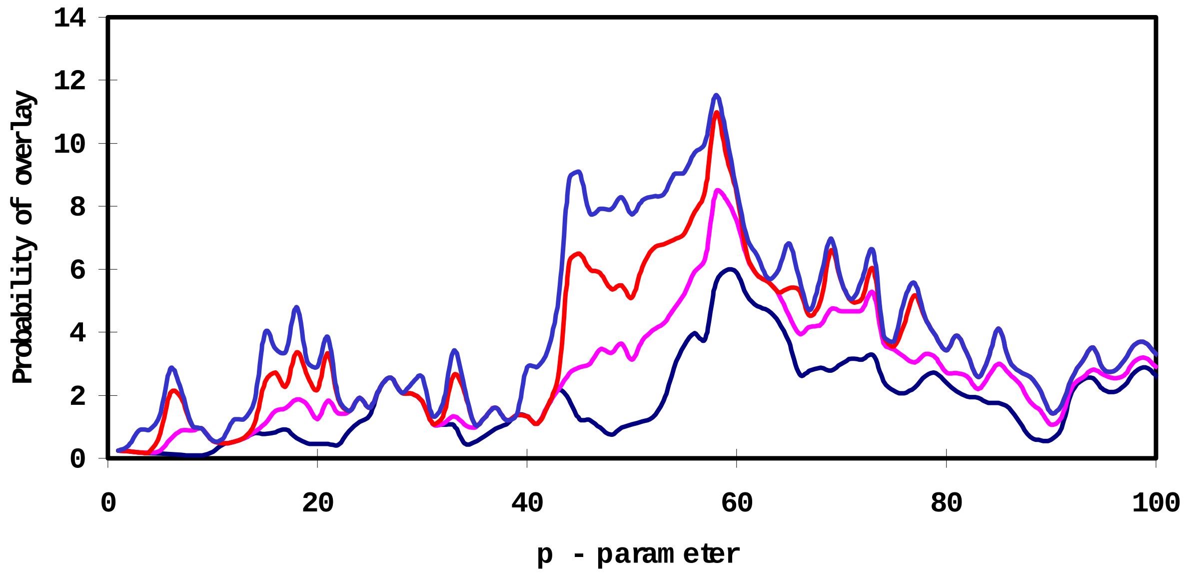

Figure 3: Dependencies of overlap integral on p – parameter for various number of lines

The last figure, Fig.5, shows the dependence of crack propagation rate and crack area on the elapsed time for parameter p which was determined after Fig.3 and 4.

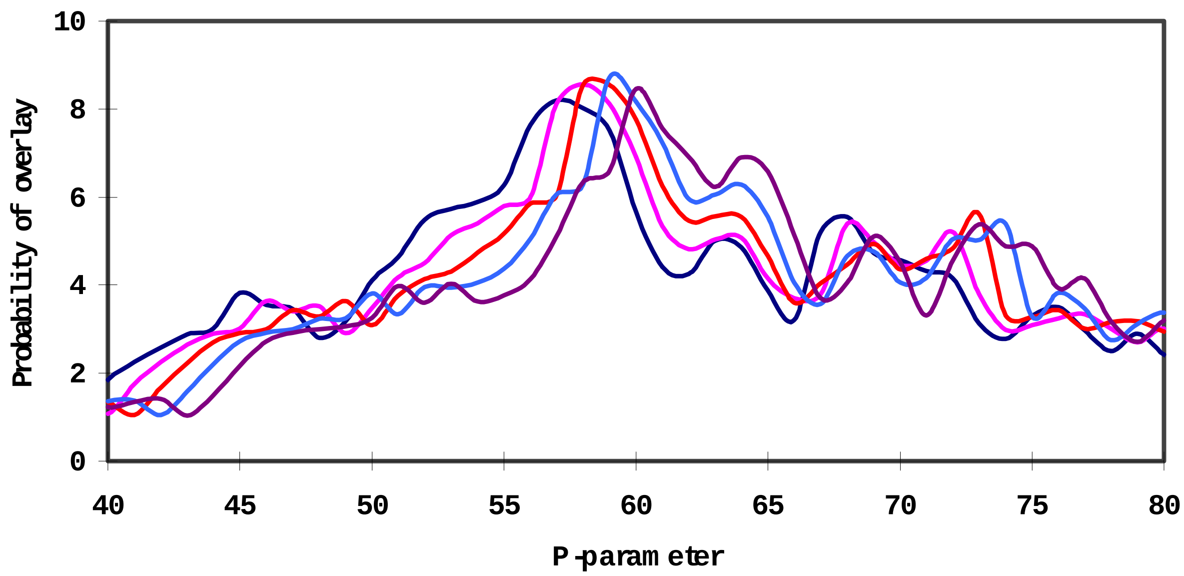

Figure 4: Dependencies of overlap integral for various positions of final crack stage

The crack propagation was relatively slow and the crack extents more then 7500 hours, it means more then one year, through the investigated area of fracture surface (about 160 mm long) before final breakdown. It is possible to estimate that the crack was not initiated on the exhaust end of blade but somewhere in the last third of blade wall.

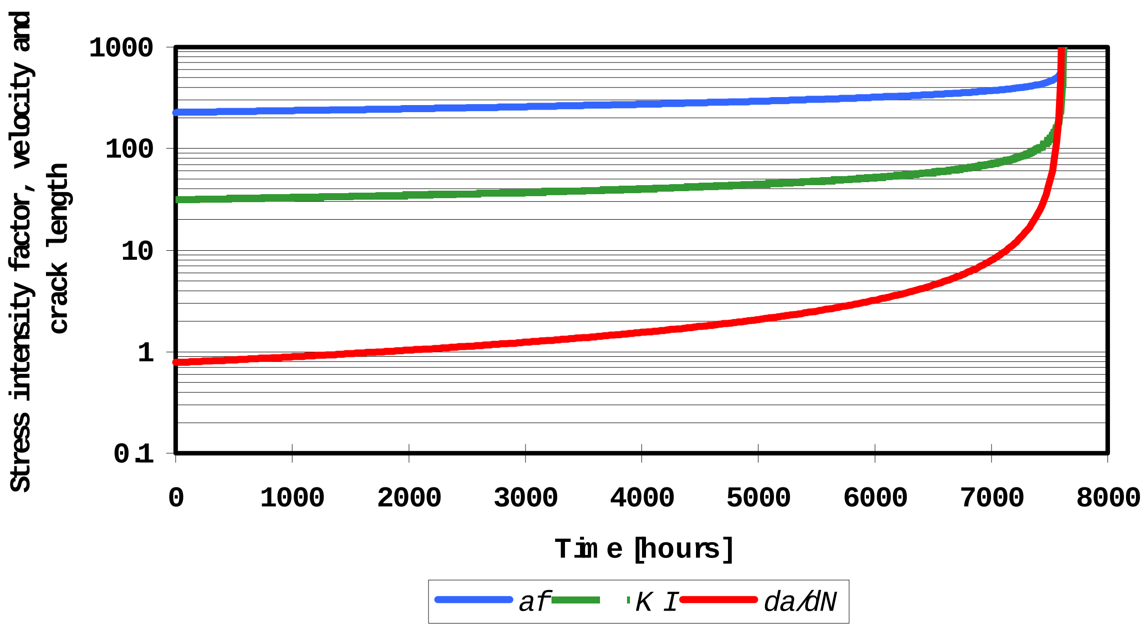

Figure 5: Crack propagation – kinetics for the propeller blade

CONCLUSION

Presented method has many possible difficulties, mainly the lack of data and too many changes in the regime of loading or in operation at all. The method is successful if the function $I_o(p)$ has significant local maxima from which is possible to compute the most probably real crack propagation rate. Data collected for this purpose can have such a character, that the function $I_o(p)$ will have no significant maxima and therefore it will be impossible to use it for determination of a real crack propagation rate.

On the other hand if we have both data sets, operation data and positions of marks on the fracture surface, this method can result in determination of the most probable real crack propagation rate and the lifetime.

The method was successful for the investigated case and results enable us to determine the most probable real crack propagation rate and the lifetime.

REFERENCES

1. Hellan K.:Fracture Mechanics, Elsevier Applied Science Publishers,1980,
2. Murakami Y.: Fracture Mechanics Test Specimens, Pergamon Press,1987