

CHARACTERISTICS REGARDING THE DURABILITY ASSESSMENT AT IMPACT FATIGUE TESTS (The First Part)

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Abstract: Within this paper in the first part there are presented some general considerations upon the assessment mode of durability at variable loads. There are analyzed those three design philosophies, respectively: the safe- life, infinite life; safe- life, finite life and damage tolerant. In this context there are then exposed the impact fatigue characteristics as well as the durability assessment parameters at such tests.

Keyword: safe life, finite life, damage tolerant, impact fatigue,

1. GENERAL CONSIDERATIONS UPON THE ASSESSMENT OF THE MATERIALS DURABILITY AT FATIGUE TESTS

The assessment methods of the materials durability at variable loads have been improved according to the extension of the design philosophies upon the fatigue phenomenon [1]. In the main we discuss about three general design philosophies upon the fatigue, (Table1).

Table 1.

Design philosophy	Durability basic parameter	Durability curve coordinates
Safe-life, infinite-life	Stress , σ	σ -N
Safe-life, finite-life	Strain, ε	ε -N
	Hysteresis energy, ΔW	ΔW -N
Damage tolerance	Stress intensity range, ΔK	da/dN - ΔK

Where: N- is the number of cycles; da/dN is the speed of crack propagation.

Each of these philosophies has a proper methodology of obtained data representation by the fatigue tests. The first design philosophy known also under the name of unlimited durability was introduced by August Wöhler together with the first tests appearance in 1850 performed in Germany at the railway wagon axles.

The durability assessment model depending on the stress is restrictive in the sense that it is applied to a continuous environment and the fracture is defined by the specimen total separation.

This model is used in the case of the components from ferrous alloys and steel, which are alike with the experimental tests, so when some similitude conditions are respected.

Between 1940 and 1950 a series of special conditions imposed to the equipments and installations has conducted to an increase of the loadings having as result the appearance of some time variable plastic deformations. In this situation there appeared as necessary a quantitative description of the local deformations produced by the variable loads, fact that conducted to a representation of the data in the coordinates ε -N or ΔW -N.

The design philosophy safe-life, finite-life is based on the time evolution analysis of the local plastic deformations, respectively of the hysteresis energy till the fracture initiation.

The working parameters of this method are more difficult to be assessed but this method can be applied for any shape of part made of any material.

The two previously presented design philosophies are generally applied to some circumstances when the periodical inspections are not possible.

The presence of some material discontinuities of some cracks type in the strength elements and structures are unavoidable. These may appear in the material process of elaboration, mechanical processing in service or under repair.

The taking into account of the cracks presence and the time evolution under the action of the variable loads is based on the design philosophy of damage tolerance, which has developed beginning with 1960.

The durability assessment parameters in this case are: the crack propagation speed da/dN and the variation of the stress intensity factor ΔK .

2. IMPACT FATIGUE CHARACTERISTICS

Generally the fatigue tests are divided in two groups: tests with sinusoidal variation of load and fatigue tests under the several sorts of varying load condition [2].

The tests from the second group can be: fatigue tests with non-sinusoidal load, composite load, program load, random load and impact load.

In the usual meaning all those above mentioned except the load impact may be considered non impact fatigue tests.

Impact fatigue, (I.F), appears at a series of strength elements and structures where the impact loads are working loads or generally at any joints mounted by tightening and where as a consequence of wearing there appear plays in the joint assembly.

The first researches upon the impact fatigue were presented in a report published in 1849. In this report there are analyzed some results upon the cast iron behavior at oscillating loads and repeated shocks. [3].

Though the researches upon non impact fatigue have begun together with those referred to the impact fatigue, the last ones have not received in the course of the years the appropriate extension [4].

If the works which approach the non impact fatigue have presented an exponential increase, those referring to the impact fatigue do not exceed annually the number of (5-7) works.

Generally the tests at impact fatigue have at their basis the repeated collision between a hammer and a specimen, resulting thus a discontinuous load spectrum with pauses in comparison with the usual load spectra which present a continuous variation.

Depending on the research directions towards were oriented the impact fatigue tests are classified in two groups [5]:

- I.F tests with indirect impact (I.I.F);
- I.F tests with direct impact (D.I.F);

The tests from the first group, which are the object of this research, have as purpose the volume degradation analysis of the specimen under test as a consequence of the cumulated effect of the shock waves (Fig.1a)

The second group tests have as purpose the local degradation assessment of the contact surfaces depending directly on the wearing phenomenon. (Fig.1.b)

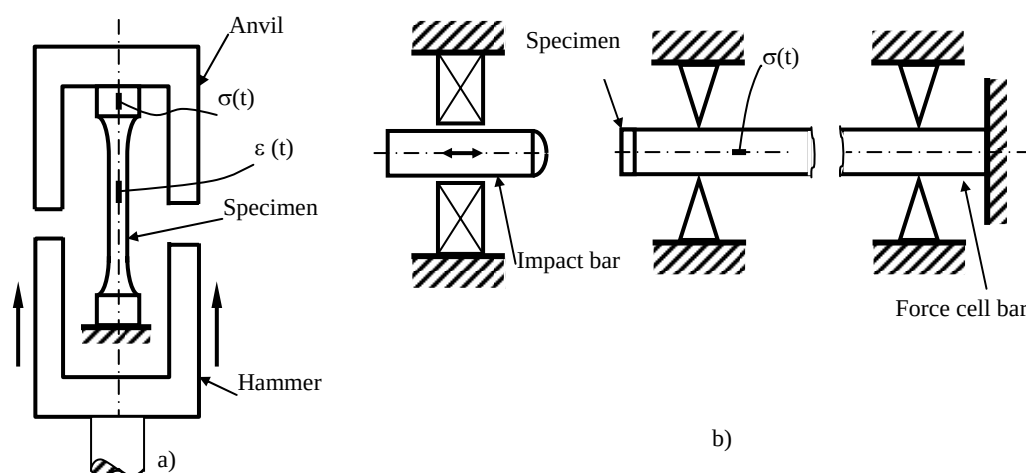


Fig.1. Types of tests at I.F.

In many situations, although the impact is directly applied on the specimen, the local aspects of the dynamic contact are negligible. The difficulties connected by the stress-strain state at the impact application, specially in the presence of the stress concentrators or cracks, are one of the causes for which these tests have not extended in the current practice. To these there is added too the fact that the materials properties depend on the deformation speed. But the researches performed till now have proved that the impact fatigue tests are more complete than the non impact fatigue ones. [2]. If in the field of the impacts with small energies these reproduce in great extent the results of the non impact fatigue tests, in the field of the impacts with high energies they emphasize the influence of the deformation speed upon the materials durability. A very actual problem connected by these tests refers firstly to the durability estimation. The high number of parameters used for this purpose makes difficult both a comparison of the materials as well as the emphasizing of the particular effects of the I.F.

3. PARAMETERS USED FOR DURABILITY ASSESSMENT AT IMPACT FATIGUE

As we have showed previously, the complexity of the phenomena which accompany the impact of two bodies has determined that till now there is not a unitary method of durability assessment at impact fatigue (I.F).

In Table 2 there are presented depending on the test type at I.F, the basic parameters of durability as well as the coordinates by which the fatigue curves are represented.

Table 2

Test type at impact fatigue (I.F)	Basic durability parameter	Fatigue curve coordinates
	Falling height of a standard of mass, H	H- N
	Impact energy, U	U – N U- W_t/W_d U- W_t/W_{st}
	Specific impact energy, U/A, U/V	U/A- N

I.I.F (indirect impact fatigue)		U/V- N
	Corrected energy of an impact, U_0	U_0 - N
	Impact stress, σ	σ - N
	Impact strain, ε	ε - N
	Hysteresis energy, ΔW	ΔW - N
	Stress intensity range ΔK	da/dN - ΔK
	Dynamic stress intensity range, ΔK_d	da/dN - ΔK_d
D.I.F (direct impact fatigue)	Contact stress, σ	σ - N
	Imprint depth, h	h- N
	Imprint diameter, d	d- N
	Imprint volume, V	V- N

where:

W_t – is the total energy cumulated up to the fracture at I.F

W_d – is the fracture energy at a single impact

W_{st} – is the fracture energy at static loading

A – is the area of the specimen section

V – is the specimen volume

The high number of parameters by which the durability is assessed at the I. I. F tests is due to the different loading conditions, generally determined by the used installations. The first researches were focused upon the impact bending. The complexity of the theoretical and experimental analysis of the stress states, the non-homogeneity of the stress distribution, etc. has made that in the most cases was used a series of parameters depending on the impact energy, U. In other cases the corrected energy of an impact was used:

$$U_0 = \eta U \quad (1)$$

where: $0 < \eta < 1$ is a coefficient of using the impact energy which depends on the specimen and bearings rigidity. In order to take into account the specimen dimensions, some authors have introduced the so called impact specific energy, defined by the ratio U/A or U/V . Obviously that one of the issues which has concerned and continues to concern those interested in this problem, consists of establishing in what extent the durability at I.F differs or not from that obtained at N.I.F. In order to make such comparisons there is necessary that in both situations the durability is expressed by the same parameters. In this sense, a series of theoretical and experimental researches were performed, which permitted to obtain some correlations directly depending on the installations used. The approach of the damage tolerant method at I.F has been done in present only on the stress intensity factor basis calculated in quasi-static conditions. In proportion of the progress obtained by Dynamic Fracture Mechanics, it follows to be introduced also the dynamic factor of stress intensity K_d , which will certainly emphasize many particular aspects of I.F,[6]. The tests at D.I.F had as purpose the study of the dynamic contact and of the local degradation of a plane surface at repeated impacts with a spherical or cylindrical body,[7].

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