FATIGUE TESTS OF CRUCIFORM SPECIMENS UNDER RANDOM LOADINGS, CONSTRUCTION OF THE STAND AND PRELIMINARY RESULTS

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The paper presents structure and operating parameters of a prototype hydraulic stand for fatigue tests of plane cruciform specimens under biaxial independent loadings. The stand includes a hydraulic supply system, system for generation of random signals, feedback control system, measuring system, system for data processing and cruciform specimen. Preliminary verification of a model worked out for fatigue life estimation of materials under multiaxial random loadings is also presented.

INTRODUCTION

Theoretical models for evaluation of fatigue life of materials under multiaxial random loadings, developed last years [1-4], should be verified in practice. In this order a special stand for tests of cruciform specimens under biaxial random stress state has been made. It is based on certain ideas applied in stands for fatigue tests of plane cruciform specimens under biaxial cyclic loadings [5,6] but the new stand is able to realize independent random loadings as well.

STRUCTURE OF THE TEST STAND

The stand for fatigue tests of cruciform specimens under plane random stress state (Fig.1.) consists of hydraulic supply system (1), loading system (2), system for random signal generation (3), control system (4), measuring system (5), system of data processing (6), specimen (7). On the stand loadings are independently forced in direc-

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tions of the specimen arms (7), according to histories of the generated random signals (3). In the feedback control system (4) a given signal is compared with the signal from the cruciform specimen (force, strain or displacement). The difference signal controls, by the servo-valve, work of servo-motors in the loading system (2). The generated loadings are independent owing to application of two independent lines of generation, control and loading. The loading system is supplied from the hydraulic supply system (1). Signals from the specimen are measured in the measuring system (5) and the obtained histories are analysed in the system for data processing Microcomputer Fatigue Damage Cumulator, (MFDC) (6). The stand is equipped with overload detectors connected with the electronic system for automatic switching off the stand when some limit values (for example minimum and maximum temperatures of oil in the tank) are exceeded. The applied servo-motors are characterized by low inertia of the piston rod, low resistance to motion (oil film) and prototype sealing rings made of teflon; leakages are carried away. Their main parameters are the following: maximum piston travel 100 mm, maximum pressure 16 MPa, maximum force 30 kN. For command signals generation (CSG) the generator of random signals is applied. Owing to such generators it is possible to generate two random signals with the required functions of probability density and power spectral density. The generators can be used for simulating service loadings on the test stand and such simulation is based on statistical analysis of loadings from real objects. The applied control system is intended to proportional control of servo-motors by servovalves. It transmits a signal from the generator to the input of servovalve in such a way that the quantity which is controlled in the specimen (force, strain or displacement) is proportional to the command signal. For data processing Microcomputer Fatigue Damage Cumulator (MFDC), described in [4], is used. MFDC calculates fatigue life from registered strain histories measured in the specimen. Software of MFDC allows also to calculate some statistical parameters of the observed histories, to register measuring data in external store of the computer and to present the data on the screen or the printer. Shape of the specimen for tests under plane stress state and long-life time was worked out on the basis of literature studies and our own investigations.

TESTS OF THE STAND

The tests were carried out in order to determine if all the systems of the stand act well. While the tests various command signals were used. Sinusoidal, rectangular, triangular and random (two versions - with feedback and in the open system) histories were applied. The obtained histories of forces, strains and displacements were compared with the command signal. For frequencies up to 35 Hz good representation of the command signal was obtained. From the analysis of the obtained statistical histories of forces, displacements and strains it appears that a type of probability distribution and forms of autocorrelation functions and power spectral density of command signals are correct.

MATHEMATICAL MODEL FOR FATIGUE LIFE ESTIMATION OF MATERIALS UNDER BIAXIAL RANDOM LOADINGS

Fatigue life calculating is divided into the following tasks [4]:

-acquisition and preliminary processing of measuring data from two- or three-directional, rectangular strain gauge rosette,

-determination of the expected fatigue fracture plane position with the method of: a) variance, b) weight fun-

ctions, or c) damage cumulation [1,2],
-determination of the equivalent stress or strain histo-
ries according to the chosen multiaxial fatigue crite-
rion [3,4]:
a) stress based for long-life time (σ_η, $\sigma_{\eta s}$, $\sigma_\eta+k\sigma_{\eta s}$) or
b) strain based for long- and short-life time ta-
king into account also plastic strains (ε_η,$\varepsilon_{\eta s}$,$\varepsilon_\eta+$ $K\varepsilon_{\eta s}$)
-schematization of the equivalent stress or strain his-
tories according to one of the following cycle counting
method: rain flow, range pair, hysteresis loop or full
cycle,
-calculating damage degree and fatigue life according to
Palmgren-Miner or Haibach hypothesis.

PRELIMINARY VERIFICATION OF THE MATHEMATICAL MODEL

Cruciform specimens of constructional steel 10HA with
increased corrosion resistance were loaded by two inde-
pendent histories having normal probability distribu-
tions, zero mean values and low-band frequency spectra
(< 40 Hz). 10HA has the following chemical constitution:
0.08% C, 0.39% Mn, 0.33% Si, 0.087% P, 0.024% S, 0.7%Cr,
0.35% Cu,0.05% Mo and σ_{TS}=442MPa,σ_Y=242MPa,σ_{af}=203MPa.

Fatigue tests of cruciform specimens were carried out
for long-life time (230 - 600 hours). It has been found
that the obtained experimental fatigue lives can be
effectively calculated with the variance method, crite-
rion of maximum normal stress in the fracture plane,
range pair method and Palmgren - Miner hypothesis. A
little worse results are obtained by rain flow method
and Haibach hypothesis.

CONCLUSIONS

From the tests of the fatigue stand of cruciform speci-
mens under biaxial tension - compression and preliminary
investigations of 10HA steel the following conclusions

can be drawn:

1. The used hydraulic and electronic systems allow to correct realization of fatigue tests of specimens under cyclic in- and out-of-phase as well as independent random loadings for frequencies up to 35 Hz.

2. Experimental fatigue life under independent random loadings can be effectively predicted with the algorithm including:

- determining the expected fatigue fracture plane with the method of equivalent stress variance,
- reduction of the complex stress state to the equivalent uniaxial one according to the criterion of maximum normal stress in the fracture plane,
- cycle counting with the range pair method,
- damage cumulation according to Palmgren-Miner hypothesis.

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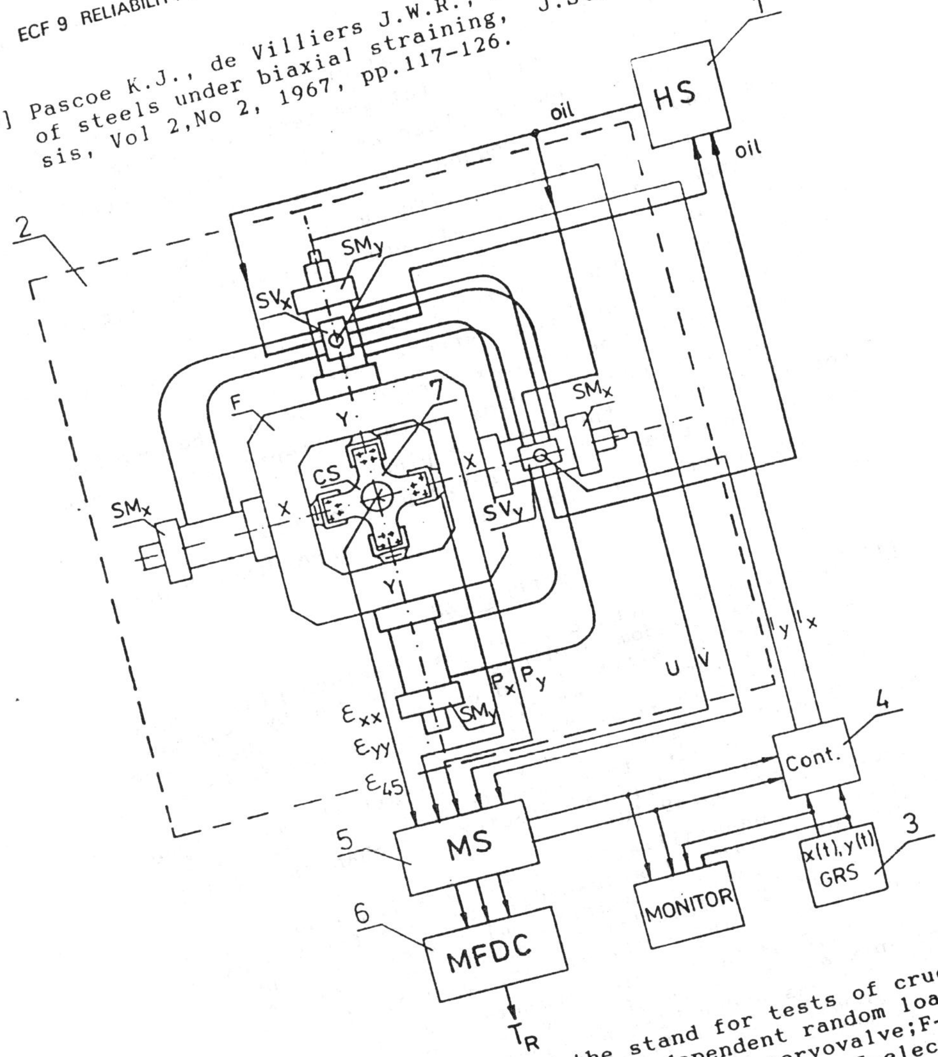

Fig.1.General scheme of the stand for tests of cruciform specimens under biaxial independent random loadings. HS-hydraulic supply;SM-servomotor;SV-servovalve;F-frame; CS-cruciform specimen; u,v-displacements; I-electrical controlling signal;P-load; ε-strain;MS-measuring system; MFDC-system for data processing;GRS-generator of random signals;Cont.-feedback control system; T_R-fatigue life.