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ELASTIC-PLASTIC BEHAVIOR OF CARRIED ELEMENT IN THE CASE OF ALTERNATE VARIABLE LOAD

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The distribution deals with the possibility the application of the Ramberg–Osgood equation at the creation the elastic plastic calculation model of the beam. The cantilever beam made from rolled profile is loaded from alternate and variable loading of force situated on the end of beam. Tension of section beam is in the elastic-plastic region of effect. It is necessary to determinate the greatness and number of plastic reversion with probability of fracture from point of view light cycle fatigue.

1. Introduction

The utilization of the plasticity in the construction practice knocks at problems the lack of the suitable calculation models, eventually their the great complexity. Very frequently is applied the access from above when determines the limit plastic carrying power, at which are not known values the deflection, relative deformations and actual stresses. The methodic of determination of the carrying power by the access from below by the transition from elastic to plastic and by the development plastic region knocks at the great complexity of the calculation model, for example the application of FEM at single construction elements. These are problems which are connected with single, monotony load. The problematic of elastic-plastic acting at the alternate, variable load knocks at suitable calculation model of determination of the deflection, of elastic-plastic deformations their evaluation through classifying methods up to the determination of the spectrum of the ranges of elastic-plastic relative deformations which are by input characteristics at the judgement on the low-cyclic fatigue.

As early as in the thirties some authors pointed out that for the case when loads acting upon a given structure vary over a wider range some caution in applying the methods of plastic limit. They showed that in the case of variable repeated loads not only can low-cycle fatigue cause structural failure below the collapse load calculated from a mechanism of instantaneous collapse but also an accumulation of plastic deformations may occur, resulting in excessive deflections of the structure.

2. Determination of elastic-plastic response

The cantilever beam is made from rolled section IPE 300. Material of beam is from steel S235 with stress strain diagram considered by Ramberg-Osgood function. Length of cantilever beam is L = 3000 mm. Extreme values of alternate and variable loading are describes by loading spectrum for characteristic block (see table I and table II).

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For given geometrical characteristic of beam, plasticity qualities of material, expressed by stress strain diagram and values of load in introduced loading block, we determinate extreme values of stress and relative strain in the investigated place in the restraint of cantilever beam.

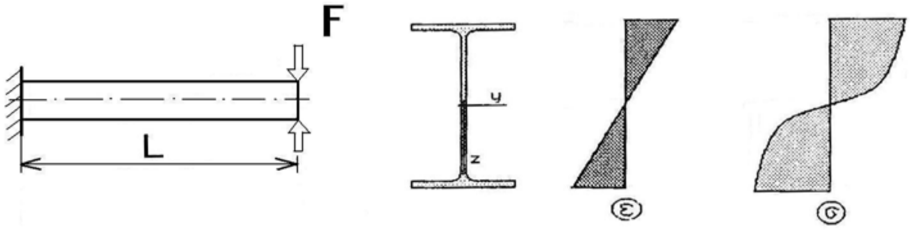

Fig. 1 Cantilever beam with strain and non linear stress during

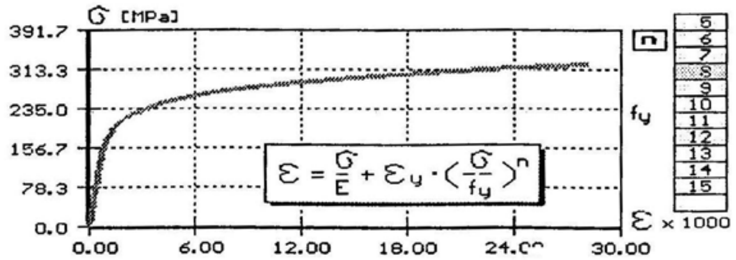

Fig. 2 Stress strain diagram described by Ramberg-Osgood function

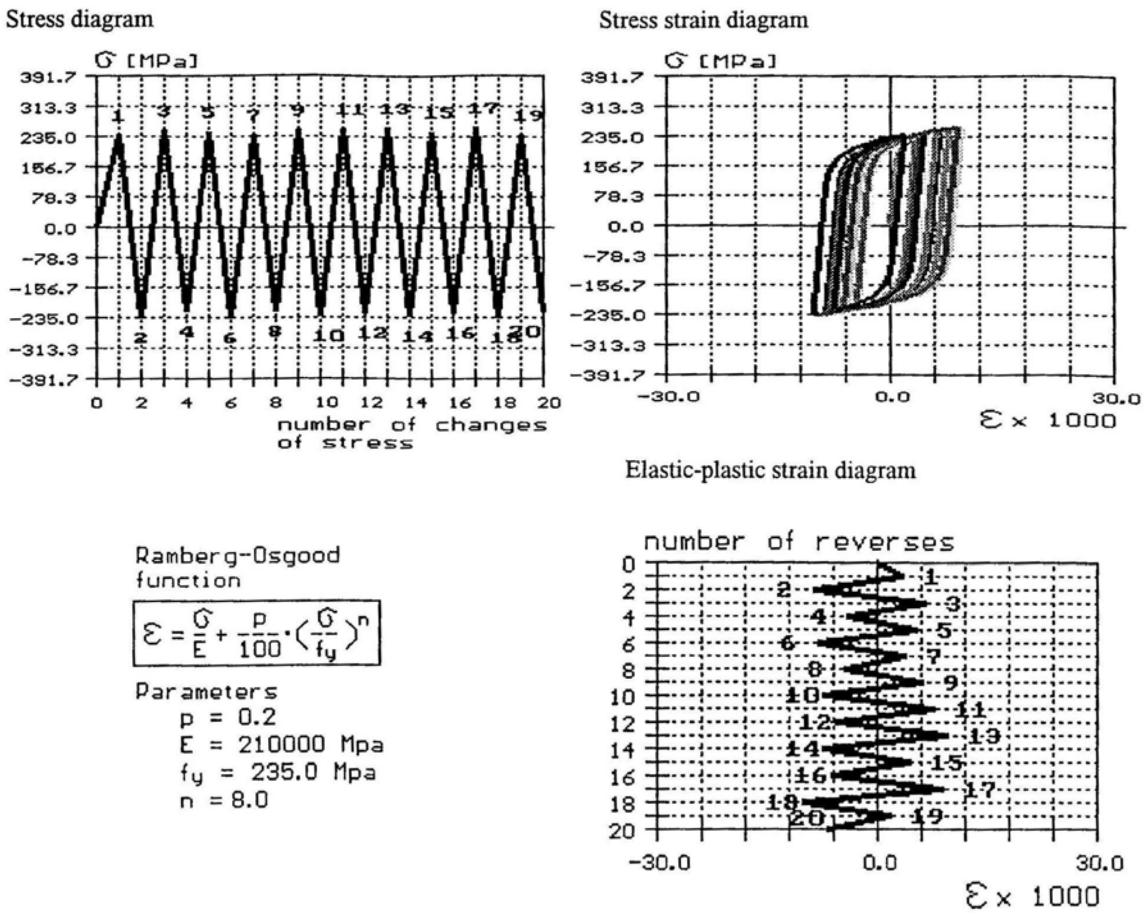

Fig. 3 Diagrams of stresses, stress-strain and elastic-plastic deformation

With regard to nom linear dependence stress and strain in the alternate tension with meditation Bauschingr′s effect will created hysteresis loops in each cycle of loading. After each of half cycle can arise plastic strain in material of beam what is characterized of wide hysteresis loop in the stress strain diagram. Elastic-plastic response is given by value of plastic reversion what express of plastic strain and number of cycles in the time of proposed live of structures.

For time diagram of loading, with alternate and stochastic variable character using some simplifying in the transformation model we obtain time stress diagram and stress strain diagram and specially time diagram of elastic-plastic deformation. Using Range Count classifying method we obtain elastic-plastic strain spectrum (see fig. 5).

Table I. – The characteristics of loading and elastic-plastic response

Num.	**F [kN]**	**M = F x L [kN.m]**	**σ [Mpa]**	**ε /1000**
1	44.560	133.680	240	3.5097
2	-43.631	-130.895	-235	-8.6500
3	46.416	139.250	250	6.6773
4	-40.846	-122.540	-220	-4.1604
5	45.488	136.465	245	5.5068
6	-43.631	-130.895	-235	-8.1434
7	44.560	133.680	240	4.0164
8	-40.846	-122.540	-220	-4.6164
9	46.416	139.250	250	6.2213
10	-42.703	-128.110	-230	-7.4289
11	47.345	142.035	255	7.8985
12	-41.775	-125.325	-225	-5.7517
13	48.273	144.820	260	9.5756
14	-42.703	-128.110	-230	-7.6356
15	45.488	136.465	245	4.5242
16	-41.775	-125.325	-225	-6.3136
17	48.273	144.820	260	9.0138
18	-43.631	-130.895	-235	-10.3099
19	44.560	133.680	240	1.8499
20	-40.846	-122.540	-220	-6.7829

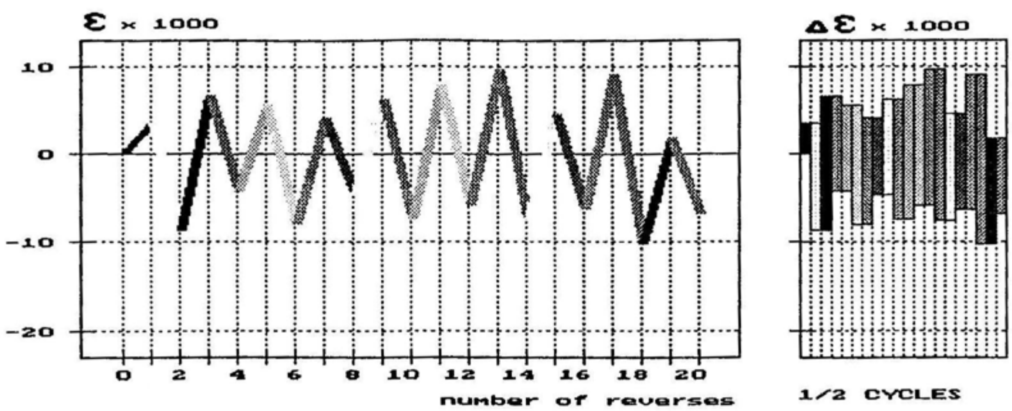

Fig. 4 Diagram of elastic-plastic strain and 1/2 cycle′s spectrum

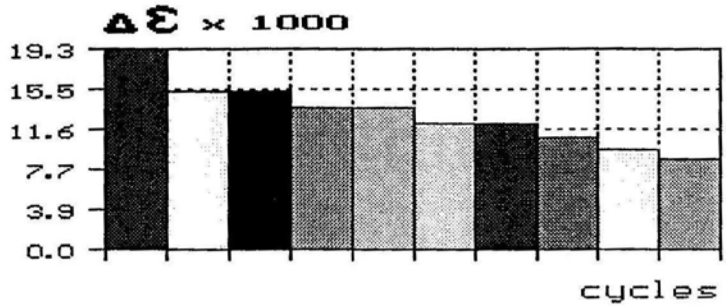

Fig. 5 Elastic-plastic strain spectrum $\Delta\varepsilon_t$

3. Determination of elastic-plastic resistance

For determination of fatigue damage is used Manson curve. The explicit formula of number cycles to failure is

$$N_f = N_T.\left(R^{\frac{z}{b}} + R^{\frac{z}{c}}\right)^{\frac{1}{z}}, \tag{1}$$

where N_T ism transit number of cycles, what can be expressed by formula

$$N_T = \frac{1}{2}.\left(\frac{E.\varepsilon_f}{\sigma_f}\right)^{\frac{1}{b-c}}, \tag{2}$$

where σ_f is coefficient of fatigue strength,
ε_f - coefficient of fatigue ductility,
b - exponent of fatigue strength,
c - exponent of fatigue ductility.

Variable value R is defined as

$$R = \frac{\Delta\varepsilon_t}{\Delta\varepsilon_T}, \tag{3}$$

where $\Delta\varepsilon_t$ is range of total deformation in spectra,
$\Delta\varepsilon_T$ - range of total deformation in the transit number of cycles N_T.

$$\Delta\varepsilon_T = 2.(\varepsilon_f)^{\frac{b}{b-c}}.\left(\frac{\sigma_f}{E}\right)^{\frac{c}{c-b}}, \tag{4}$$

the characteristics of life curve
- deterministic exponents b = - 0,105, c = - 0,656,
- deterministic value of Young′s module E = 2.10^5 MPa,
- coefficients of fatigue strength in logarithmic normal distribution are given of values m[σ_f] = 902,15 MPa and s[σ_f] = 91,465 MPa,
- coefficients of fatigue ductility in logarithmic normal distribution are given of values m[ε_f] = 1,23977 and s[ε_f] = 0,1227.

Value of exponent we determinate from equation

$$z = P.(\ln R)^2 + Q.(\ln R) + S, \tag{5}$$

with components

$$P = -0,001277.\left(\frac{c}{b}\right)^2 + 0,03893.\left(\frac{c}{b}\right) - 0,0927\,, \tag{6}$$

$$Q = -0,004176.\left(\frac{c}{b}\right)^2 - 0,135.\left(\frac{c}{b}\right) + 0,2309\,, \tag{7}$$

$$S = \ln\left[-0,889.c.\left(\frac{c}{b}\right)^{-0,36}\right]. \tag{8}$$

Boundary values of transit numbers of cycles

$$N_{T,\min} = \frac{1}{2}\left\{\frac{E.\left(m\left[\varepsilon_f\right] - 3.s\left[\varepsilon_f\right]\right)}{\left(m\left[\sigma_f\right] + 3.s\left[\sigma_f\right]\right)}\right\}^{\frac{1}{b-c}}, \tag{9}$$

$$N_{T,\max} = \frac{1}{2}\left\{\frac{E.\left(m\left[\varepsilon_f\right] + 3.s\left[\varepsilon_f\right]\right)}{\left(m\left[\sigma_f\right] - 3.s\left[\sigma_f\right]\right)}\right\}^{\frac{1}{b-c}}, \tag{10}$$

Boundary values of transit number cycles to failure are

$$N_{f,\min} = N_{T,\min}.\left(R^{\frac{z}{b}} + R^{\frac{z}{c}}\right)^{\frac{1}{z}}, \tag{11}$$

$$N_{f,\max} = N_{T,\max}.\left(R^{\frac{z}{b}} + R^{\frac{z}{c}}\right)^{\frac{1}{z}}. \tag{12}$$

An introduced characteristic creates input information necessary for generation of histograms. these histograms will have logarithmic normal distribution.

Table II. - The characteristics of response spectrum

Num. of cycle	$\Delta\varepsilon_t$ /1000	$R=\Delta\varepsilon_t/\Delta\varepsilon_T$	z	$N_{f,min}$	$N_{f,max}$
1	19.3237	6.246135	0.185554	376	3573
2	15.3274	4.954383	0.190064	590	5612
3	15.3274	4.954383	0.190064	590	5612
4	13.6502	4.412250	0.193150	745	7076
5	13.6502	4.412250	0.193150	745	7076
6	12.1598	3.930497	0.196808	943	8958
7	12.1598	3.930497	0.196808	943	8958
8	10.8377	3.503146	0.201056	1198	11387
9	9.6672	3.124796	0.205907	1530	14538
10	8.6327	2.790408	0.211374	1963	18652

4. Evaluation of reliability

The safety function is defined as

$$SF = D_L - D\,, \tag{13}$$

where D_L is resistance of structures (in this case D_L =1 as scalar quantity),
D - loading effect, expressed by histograms.

Loading effect histogram can be expressed by Palmgren-Miner hypothesis

$$D = n_b . \sum_{j=1}^{k} \frac{1}{N_{f,j}} , \qquad (14)$$

where n_b are number repeated blocks to the failure of structures,

k - number of levels in investigated block (in this case k = 10),

$N_{f,j}$ - histograms of number cycles to failure for definite level of range of elastic-plastic deformation.

Using M-Star[TM] program was determinate probability of fractures. In analysis are used 1000000 simulations. The output from M-Star[TM] is shown in figure 7.

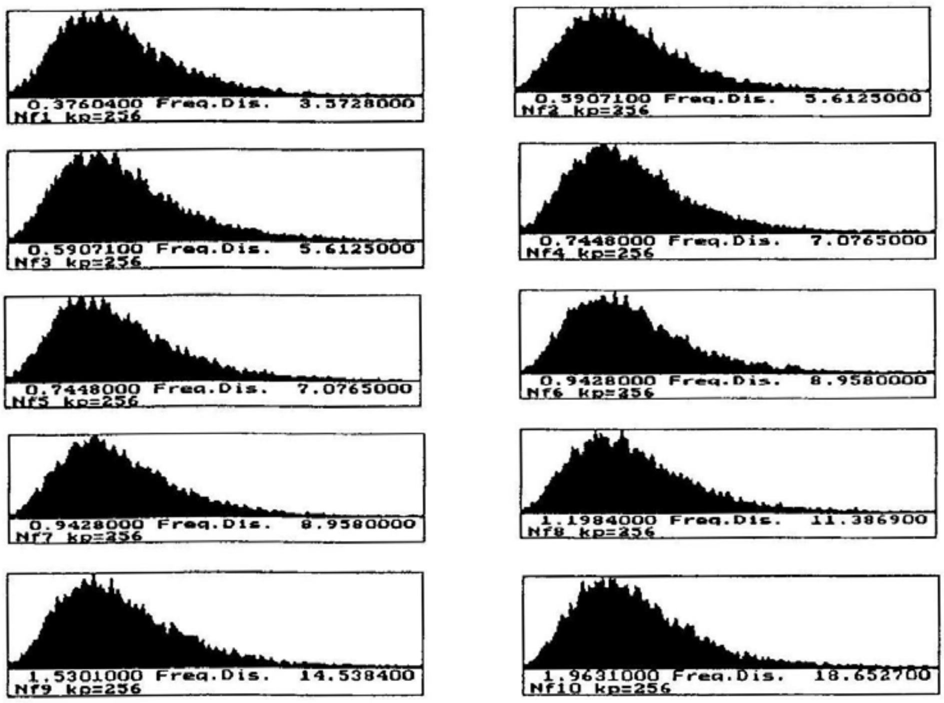

Fig. 6 Histogram of number cycles to failure, M-Star[TM] programs

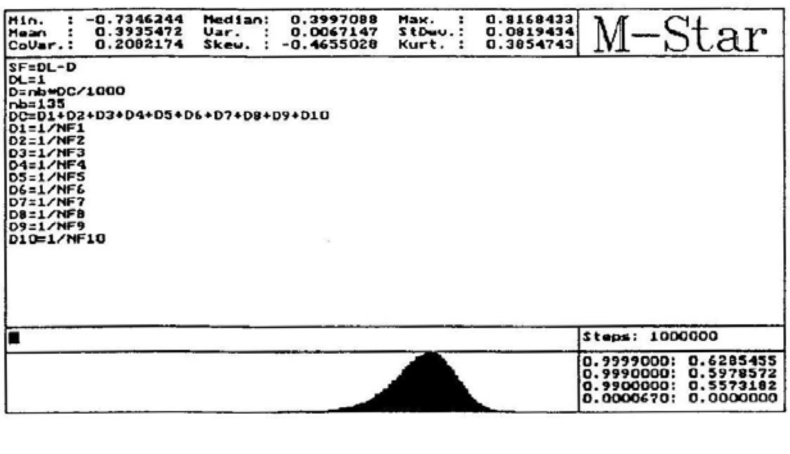

Fig. 7 Histogram of reliability function, M-Star[TM] programs output

5. Results and conclusions

Practical aplication of so methods the calculation of the reliable knocks at certain problems among which belong the information about characteristics the process of the load , the expression the adequate calculation model or the stochastic properties of the material. In the tasks which analyze the problematics the combination of the material, the reserve, the reliable etc. It is necessary to have the file of the date, which characterize the higher stated properties .

The distribution deals with the possibility the application of the Ramberg–Osgood equation at the creation the elastic plastic calculation model of the beam. It the evident that the determination the elastic plastic capacity by the access from below provides the advantages, for example the possibility the application of the criteria of admissible deformation and deflections . It is indicated the methodics the elastic plastic capacities by the application the probabilistic progress.

The resulting probabilities are shown in table at fig. 6. The probability of failure (in concrete case probability of light cycle fatigue where n_b = 135 blocks) P_f [SF $\leq$ 0] = 0,000067 < P_d =0,00007 for the level of the reliability given in the standard STN 731401.

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