CONSTITUTIVE BEHAVIOUR OF DP500 STEEL EXPOSED TO PRIOR CYCLIC LOADINGS

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1. Introduction

Recent studies in the area of hybrid analysis linking two phenomena, i.e. viscoplasticity and fatigue, clearly show that an initial cycling may influence the stress-strain curves of a material significantly [1, 2]. As a consequence, mechanical behaviour of structures designed using data for the as-received material may be different from that of the structures working under typical application conditions. Therefore, it is required to develop a reliable constitutive model capable to take into account an influence of the fatigue loading history on the stress-strain characteristics.

2. Research methodology

Paddle-shaped flat specimens cut out of a sheet made of DP500 steel in the as-received state were subjected for testing. Both fatigue and standard tensile tests were performed on the MTS 858 servohydraulic testing machine working in the closed loop feedback. Force controlled cycles were executed for the frequency of 1 Hz, stress ratio R = 0, and constant stress amplitude for the given specimen. Two series of the DP500 steel specimens were tested. The first series of fatigue specimens was tested at the cyclic stress range of 500 MPa, while the second one at 520 MPa. Both series were stopped when the total strain attained the level of: 4%, 8%, 11%, and 14%. In the next step of the experimental programme the standard tensile tests were carried out on the initially deformed specimens. The mechanical characteristics enabled evaluation of an influence of the pre-fatigue, expressed in the form of damage parameter D, on the particular coefficients of the JC constitutive equation [3].

3. Experimental results

It was assumed that the stress–strain curve of material in the as-received state is expressed by a basic relationship of the JC equation [3]:

$$\sigma(\varepsilon) = \left(A_0 + B_0 \varepsilon^{n_0}\right) \tag{1}$$

Taking into account the cumulated fatigue damage coefficient D, and the cyclic stress amplitude σ, the value of coefficients of the JC equation for the material after the prior fatigue load can be expressed as follows [4]:

$$A(\alpha_A, \beta_A, D, \chi_A, \sigma_0, \sigma, \delta_A) = A_0 + f(\alpha_A, \beta_A, D) + g(\chi_A, \sigma_0, \sigma) + h(\delta_A, D) \tag{2}$$

$$B(\alpha_B, \beta_B, D, \chi_B, \sigma_0, \sigma, \delta_B) = B_0 + f(\alpha_B, \beta_B, D) + g(\chi_B, \sigma_0, \sigma) + h(\delta_B, D) \tag{3}$$

$$n(\alpha_n, \beta_n, D, \chi_n, \sigma_0, \sigma, \delta_n) = n_0 + f(\alpha_n, \beta_n, D) + g(\chi_n, \sigma_0, \sigma) + h(\delta_n, D) \tag{4}$$

where α, β, χ - coefficients of the equation describing cyclic hardening of the material in the initial phase of cyclic loadings, δ - coefficient of the fatigue damage development rate, D - cumulated fatigue damage coefficient, σ_0 - reference value of the cyclic stress maximum, σ - cyclic stress maximum. Subsequently, the tensile characteristics of the DP 500 steel were used to calibrate constitutive model described by Eqn. (1-4). Comparison between the experimental results and predictions obtained using relationship proposed is shown in Fig. 1.

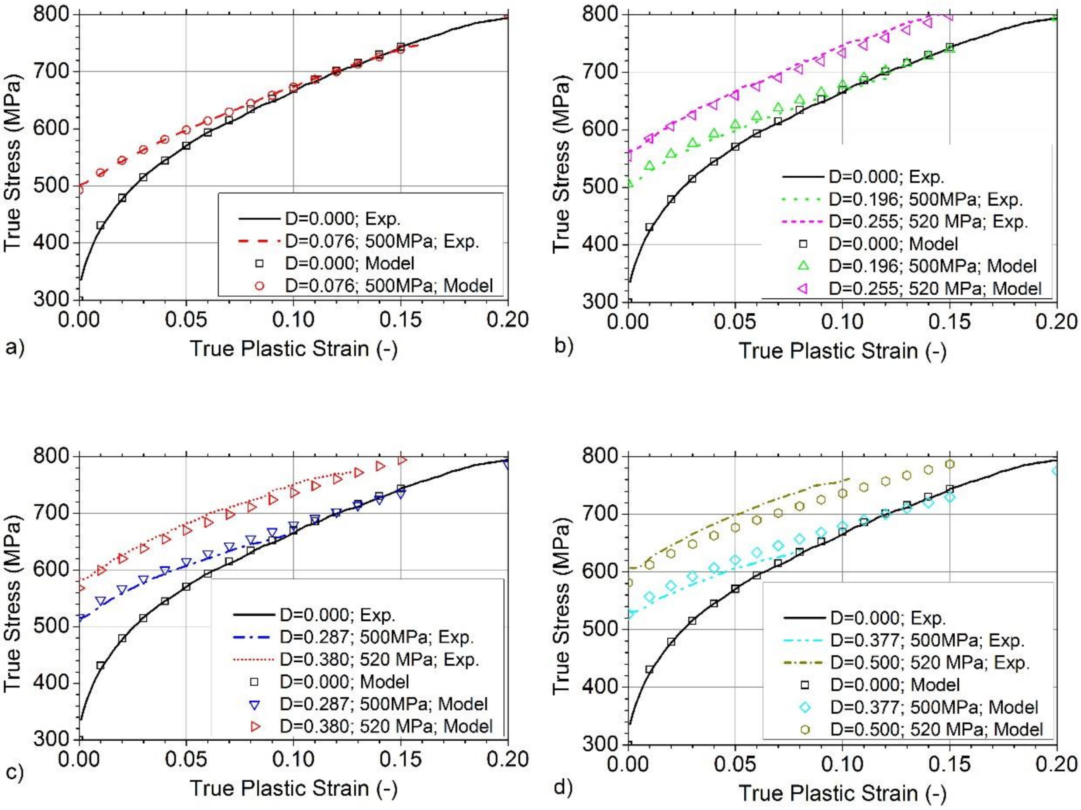

Figure 1. Plastic strain development for the DP500 steel tested in the as-received state and after different history of the fatigue, determined experimentally and numerically using the proposed model for the fatigue predeformation equal to: a) 4%; b) 8%; c) 11%; d) 14%.

4. Conclusions

The research carried out enables to conclude that:

- DP500 steel under the conditions of tensile fatigue loading exhibits a tendency to hardening in the initial cycles. Further exposure of the material to cyclic loading causes its softening. The reason of such behaviour can be attributed either to the change of dislocation structure or development of fatigue micro-damage [1].
- Variation of stress–strain characteristic of the steel due to initial fatigue loading can be expressed using the JC constitutive equation that takes into account the cyclic stress amplitude and fatigue damage parameter D, components based on the measurements of selected inelastic strain. The proposed model enables assessments of an influence of the initial cyclic hardening and fatigue damage development on the tensile curves [4].

5. References

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