PARAMETERIZATION OF THE DISLOCATION PLASTICITY MODEL FOR COLD-ROLLED AND ANNEALED COPPER M1T BASED ON DYNAMIC INDENTATION, 3D MODELING AND MACHINE LEARNING

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To develop engineering applications, it is necessary to rely on theoretical models of material behavior under dynamic and quasi-static loads. Modern progress in the development of plasticity models, given the growth of computing power, allows us to consider the studied material in a wide range of deformation rates and experimental schemes (Taylor test, flat plate impact, tensile testing machines, etc.). Parameterization of theoretical models for a specific metal or alloy will allow better compliance with engineering practice. A combined experimental and theoretical approach is presented for determining the model parameters and studying the dynamic plasticity of metals using modern machine learning methods. The presented approach allows for the identification of model parameters for the studied metal in a short time.

Today, there are a large number of experimental methods for studying the behavior of metals under dynamic loading. Among them, one can note experiments on flat impact of plates, split rods, etc. However, varying wide ranges of deformation rates for such experiments is impossible. The paper proposes to conduct an experiment on the impact of a solid ball with an obstacle, in which a wide implementation of deformation rates up to 10^6 s^{-1} is possible, which is comparable with experiments on flat impact of plates. A gas gun is used to throw strikers. The striker is a ball, 4 and 10 mm in diameter, made of tungsten carbide, the target is a copper plate of the M1 brand, 5 mm thick.

In the numerical part, the dislocation plasticity model taking into account the dislocation kinetics, supplemented by a submodel of grain size change and pore growth, is implemented in a three-dimensional case using the smoothed particle hydrodynamics (SPH) numerical scheme [1]. This model was previously tested for the problem of the shock wave structure during plate collision [2]. The model was parameterized for the case of copper cylindrical strikers [3]. To significantly accelerate the parameterization process, it is proposed to use modern machine learning methods. The model operation is emulated using an ANN (artificial neural network). The ANN is trained using a database that contains the calculation results of the dislocation plasticity model. The model is parameterized using the Bayesian statistical method. In this paper, an expanded approach to model parameterization, compared to [3], is proposed, which allows increasing the number of identifiable model parameters, as well as a more detailed comparison of the geometric profiles of the samples. To identify the pattern of grain size change and pore growth, microstructural analysis was performed using optical microscopy methods for cold-rolled and annealed plates.

The work was supported by the Russian Science Foundation (project no. 24-71-00080, rscf.ru/project/24-71-00080).

References

1. **Rodionov, E. S.** Taylor impact tests with copper cylinders: Experiments, microstructural analysis and 3D SPH modeling with dislocation plasticity and MD-informed artificial neural network as equation of state [Text] / E. S. Rodionov, V. G. Lupanov, N. A. Gracheva, et al. // Metals. – 2022. – Vol. 12. – P. 264. https://doi.org/10.3390/met12020264.
2. **Mayer, A. E.** Modeling of plasticity and fracture of metals at shock loading [Text] / A. E. Mayer, K. V. Khishchenko, P. R. Levashov, P. N. Mayer // J. Appl. Phys. – 2013. – Vol. 113, No. 19. – P. 93508. http://dx.doi.org/10.1063/1.4805713.
3. **Rodionov, E. S.** Modified Taylor impact tests with profiled copper cylinders: experiment and optimization of dislocation plasticity model [Text] / E. S. Rodionov, V. V. Pogorelko, V. G. Lupanov, et al. // Materials. – 2023. – Vol. 16. – P. 5602. https://doi.org/10.3390/ma16165602.