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A MODEL-BASED APPROACH TO THE OPTIMIZATION OF DYNAMIC SURFACE PLASTIC DEFORMATION

Mykola KURYLENKO

Higher Education Student, H7 Agricultural Engineering
Mykolaiv National Agrarian University
Mykolaiv, Ukraine

Abstract. *The paper presents a model-based approach to optimizing technological processes of dynamic surface plastic deformation. Mathematical modeling, technological parameters, and material properties are integrated to determine rational processing conditions. Deformation intensity is used as the main optimization criterion, while required surface-layer characteristics serve as constraints. The approach enables systematic selection of effective processing regimes and provides a basis for improving surface strengthening of engineering materials.*

Keywords: *surface plastic deformation, dynamic deformation, mathematical modeling, process optimization, deformation intensity, surface strengthening, technological parameters.*

The performance and durability of machine components are strongly influenced by the condition of their surface layers. In modern manufacturing, particular attention is therefore given to finishing technologies capable of modifying surface properties and increasing the resistance of components to operational degradation. Surface plastic deformation (SPD) is among the technological approaches that can effectively improve the functional characteristics of engineering surfaces without altering the overall geometry of a component.

The application of SPD results in plastic deformation of the surface layer and the formation of a strengthened zone with modified structural and mechanical characteristics. The resulting surface condition can significantly affect the resistance of components to wear, cyclic loading, and other operational factors. However, the effectiveness of the treatment is highly dependent on the selected processing conditions.

A major problem in the development of SPD technological processes is the determination of a combination of parameters that provides the required characteristics of the strengthened layer while making efficient use of the material's available strengthening capacity. Conventional parameter selection is frequently based on experimental data and technological experience. Although this approach can provide acceptable results, it does not allow the entire range of possible processing conditions to be systematically evaluated or the most appropriate solution to be identified. To address this problem, an optimization-based approach to the design of technological processes involving dynamic SPD methods has been developed. The approach integrates mathematical models of the deformation process with a systematic analysis of alternative processing conditions. Its principal objective is to determine processing parameters that ensure the most effective realization of the material's strengthening potential under specified technological constraints.

The optimization procedure treats the intensity of deformation as the principal criterion for evaluating alternative technological solutions. The selected processing conditions correspond to a deformation intensity approaching the equilibrium level while simultaneously satisfying the prescribed requirements for the treated surface. This makes it possible to consider the interdependence between deformation parameters and the resulting characteristics of the strengthened layer rather than optimizing individual technological parameters separately.

The calculation procedure incorporates a set of initial technological and material parameters. These include the required thickness of the strengthened layer, the specified deformation level, the initial and required surface roughness, the mechanical characteristics of the workpiece material, the permissible range of indenter radii, and an array of possible processing regimes. Depending on the particular technological objective, one of the specified characteristics – strengthened-layer depth, deformation level, or surface roughness – is introduced as a limiting condition.

A systematic search through the set of admissible processing variants is then performed. Solutions that do not meet the specified technical requirements are

excluded, while the remaining alternatives are evaluated using the adopted optimization criterion. This procedure reduces the selection of processing parameters to a controlled search within the feasible design space and provides a rational basis for determining the required SPD regime.

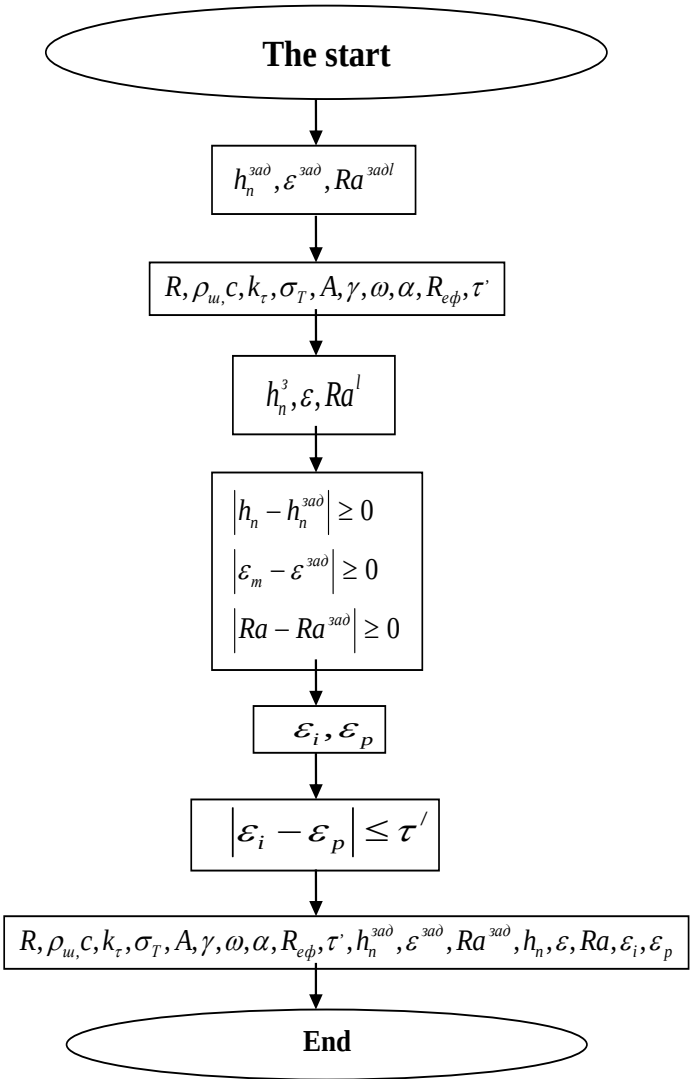


Fig. 1. Flowchart of the algorithm for optimizing dynamic surface plastic deformation.

The developed approach combines mathematical modeling, technological constraints, and optimization criteria within a unified procedure for SPD process design (Fig. 1). Its application makes it possible to move from predominantly empirical selection of processing conditions toward a more systematic determination of rational technological parameters. As a result, the approach provides a basis for achieving the required surface-layer characteristics and for increasing the efficiency with which the strengthening potential of engineering materials is utilized.

An optimization algorithm has been developed to determine rational processing parameters for dynamic surface plastic deformation, ensuring maximum utilization of the material's strengthening potential. Surface-layer quality parameters of the treated components are introduced as constraints in the optimization procedure.

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Анотація. *У роботі представлено модельний підхід до оптимізації технологічних процесів динамічного поверхневого пластичного деформування. Математичне моделювання, технологічні параметри та властивості матеріалу інтегровано для визначення раціональних умов обробки. Інтенсивність деформування використовується як основний критерій оптимізації, тоді як необхідні характеристики поверхневого шару визначаються як обмеження. Запропонований підхід дає змогу систематично здійснювати вибір ефективних режимів обробки та створює основу для підвищення міцності поверхневого шару конструкційних матеріалів.*

Ключові слова: *поверхневе пластичне деформування, динамічне деформування, математичне моделювання, оптимізація технологічного процесу, інтенсивність деформування, зміцнення поверхні, технологічні параметри.*

Scientific Supervisor:
Olena Baranova
Assistant
Mykolaiv National Agrarian University