







# Experimental Tests of Discrete Strengthened Elements of Machine-Building Structures

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**Abstract.** Computer simulation and bench tests of components and full-scale structures of internal combustion engine are performed in order to evaluate discrete and continual strengthening technology. The contact pressure distributions, friction coefficients, wear, roughness and hardness of the contacting surfaces of the tested machine parts were determined. The numerical characteristics that determine the effectiveness of such combined strengthening method are established. Conceptual fundamentals of discrete continual strengthening have been developed. Positive effects in the “load – contact – friction – wear” chain were found due to the proposed strengthening method. The positive effect of the coordination of micro and macroscale processes and states of loaded parts, which are strengthened by the discrete and continuous method, is also established. It is confirmed that the entire set of tribo-mechanical characteristics is improved with such strengthening, in contrast to traditional methods, an application of which results in improvement in some characteristics at the cost of the others.

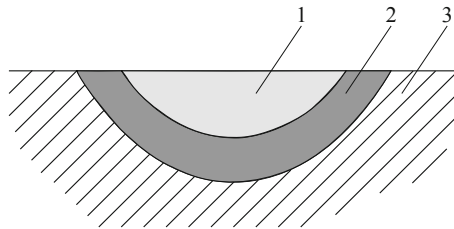
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## 1 Introduction

The method of combined strengthening of contacting parts of engineering structures is proposed in [1]. It is the combining two types of strengthening methods. The first one is the discrete strengthening. In accordance with it, a plurality of strengthening zones islands is applied to the surface layers in contacting under load. The material of these discrete strengthening zones (DSZ) has higher physical and mechanical characteristics. The material is introduced by transfer from electrode to the part during pulsed electric spark doping [1]. At the same time (Fig. 1), due to the high intensity and short duration, the formed composition has a high degree of integration. This is achieved by mixing the material of the electrode and the base material of the strengthened part in the flame of an electric arc and subsequent rapid cooling. Formed caverns are filled with melted material. Subsequent grinding creates the nominal surface of the part with the “DSZ archipelago”. Under load, this surface is differentially deformed. As a result, the

main power flows are transmitted through the islands of the “DSZ archipelago”. Due to the high physical and mechanical characteristics of DSZ material, this leads to a decrease in friction and wear.

The reciprocal contact part is proposed to be processed by means of continuous strengthening based on micro arc oxidation. A distinctive feature of this method of strengthening is the buildup of the surface layer of metal oxides (for example, aluminum) of various phases. Concurrently, the formed ceramic layer has a natural strength relationship with the main material, since the formation of the surface layer occurs from this material under the action of an electric field in a special bath [1]. As a result, the part core remains with the same characteristics, and the surface layer acquires increased strength and wear resistance.



**Fig. 1.** The discrete strengthening zone indented into the main material of the strengthened part: 1 - “white” layer; 2 - interlayer; 3 - base metal.

Thus, the proposed technologies have high characteristics in terms of strength, friction, and wear. At the same time, combination of these two technologies has distinct synergetic effect. That is each of the two techniques used by themselves gives less advantage than their simultaneous application on reciprocal surfaces. To identify the processes and conditions that lead to this effect, more research is needed. Some of them are presented in this paper.

The aim of the work is to determine the influence of the discrete and continuous strengthening technology on operational loads, contact interaction, and friction and wear in the interface of the contacting parts of machine-building structures.

## 2 Literature Review

Surface hardening is an overall broad research topic that attracts huge interest and substantial effort [2–14]. In particular, it includes electro-spark coatings [3, 5] as a very promising and cost-efficient technology. This coating can be used as they are or may as well be further processed by different other techniques such as thermal and plasma oxidation methods [3]. The structure and the resulting mechanical properties of the modified surfaces depend greatly on the electrodes materials, energy conditions and other parameters [2–7, 11, 12]. Recent works [13, 14] provide good example of technology performance as it shows that the reduced wear and improved surface hardness for twist drills can lead to the average tool life enhancement of a factor of 5 or more.