

УДК 665.9.046

Исследование микроскопических характеристик и испытание на износ стальной поверхности после ультразвуковой ударной обработки

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Поступила в редакцию 22.05.2025.

Цель работы — исследование влияния ультразвуковой ударной обработки (УУО) на эксплуатационные характеристики металлических материалов для получения информации о возможном применении таких материалов в узлах трения. В статье исследовали образцы из стали 45, которая подверглась УУО после закалки. Экспериментально установлено, что закалка стали приводит к увеличению твёрдости поверхности на 37,4 % и уменьшению шероховатости на 32,9 %. Для сравнения, после УУО твёрдость поверхности увеличивается на 47,2 %, а шероховатость уменьшается на 56,4 %. Триботехнические испытания проводили по схеме «шар—диск» как в условиях трения без смазочного материала, так и при смазке маслом. Установлено, что после УУО образцы имели минимальный поверхностный износ, относительно умеренную скорость увеличения износа в условиях трения без смазочного материала и самый низкий коэффициент трения. Так, процесс закалки и УУО позволили снизить износ поверхности на 10,8 % и 52,60 % соответственно. При смазке маслом УУО снижение износа составило 18,26 %. Кроме того, в работе рассматриваются микроскопические механизмы износа и наблюдаемые характеристики износа образцов стали 1045 при различных условиях смазки, в частности, как смазочные масла могут отрицательно влиять на триботехнические характеристики стальных поверхностей, обработанных ультразвуком.

Ключевые слова: ультразвуковое воздействие, закалочная обработка, микроструктура, твердость поверхности, степень износа, смазка.

DOI: 10.32864/0202-4977-2025-46-4-400-410

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Для цитирования:

Фулань Лю, Яньцин Тан, Иньминь Цзянь, Тянь Фанг.
Исследование микроскопических характеристик и испытание на износ стальной поверхности после ультразвуковой ударной обработки.
Трение и износ.
2025. — Т. 46, № 4. — С. 400—410.
DOI: 10.32864/0202-4977-2025-46-4-400-410

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For citation:

Fulan Liu, Yanqing Tan, Yinming Jiang, and Tian Fang.
[Study on Microscopic Characteristics and Wear Testing of Steel Surface after Ultrasonic Impact Treatment].
Trenie i Iznos.
2025, vol. 46, no. 4, pp. 400—410 (in Russian).
DOI: 10.32864/0202-4977-2025-46-4-400-410

Study on Microscopic Characteristics and Wear Testing of Steel Surface after Ultrasonic Impact Treatment

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Received 22.05.2025.

Abstract

Ultrasonic impact treatment is a surface strengthening technique that utilizes ultrasonic vibrations to enhance the topography, stress, hardness, and other surface characteristics of materials, thereby improving their resistance to wear, corrosion, and similar performance attributes. This paper focuses on the application of ultrasonic impact treatment on 1045 steel, which underwent this process subsequent to quenching. Experimental analysis of the surface hardness and roughness of untreated, quenched, and ultrasonic impact-treated 1045 steel specimens demonstrates that the quenching process results in a 37.4 % increase in surface hardness and a 32.9 % reduction in surface roughness. In comparison, the ultrasonic impact treatment leads to a more substantial improvement, with a 47.2 % increase in surface hardness and a 56.4 % decrease in surface roughness. To evaluate the friction and wear characteristics of the different specimens, a series of ball—disk tests were conducted under both dry friction and oil lubrication conditions. The results indicate that the surface subjected to ultrasonic impact treatment exhibited the lowest coefficient of friction, minimal surface wear, and a relatively moderate surface wear development rate under dry friction conditions. Specifically, the quenching process reduced the surface wear rate by 10.8 %, while the ultrasonic impact treatment led to a substantial reduction of 52.60 %. Under oil lubrication conditions, ultrasonic impact treatment decreased the surface wear rate by 18.26 %. Additionally, this research delves into the microscopic wear mechanisms and observed wear behaviors of the 1045 steel specimens under different lubrication conditions. It particularly examines how lubricating oils may adversely affect the tribological performance of ultrasonically treated steel surfaces. By providing a comparative analysis of the specimens subjected to ultrasonic impact treatment and those processed through traditional quenching, this paper aims to enhance the understanding of the effects of ultrasonic impact treatment on the performance of metal materials and to offer a reference framework for optimizing the tribological applications of such materials.

Keywords: ultrasonic impact, quenching treatment, microstructure, surface hardness, wear rate, oil lubrication.

DOI: 10.32864/0202-4977-2025-46-4-400-410

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