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Ultrasonic treatment by an intermediate striker: Tool dynamics and material improvement

M. Ganiev, I. Gafurov, I. Vagapov *

Kazan Federal University, 18 Kremlyovskaya St., Kazan, Tatarstan 420008, Russia

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ABSTRACT

A dynamic model of the ultrasonic impact tool with an intermediate striker is considered as a two-mass system with two impact joints. Direct measurements of the period of the sequence of impact pulses and duration of a single impact of striker upon the treated surface are assumed as a basis for theoretical description. Amplitude-frequency and phase-frequency characteristics of the impact oscillations of ultrasonic converter and striker are calculated with the use of methods of the theory of vibration-impact systems. An oscillatory stability of ultrasonic vibrations of striker with the rebounding from the converter tip and the surface being treated (impact mode) as well as in-phase ultrasonic vibrations without detachment of striker from the both surfaces is investigated. It is shown, that the amplitude of the impact oscillation of striker weakly depends on the pressing force in the sufficiently wide limits of variation of the pressing force value. Hardening of treated material and redistribution of residual weld stresses is investigated with the use of the metallography methods. The beneficial compressive stresses are generated (induced) inside the narrow surface layer in the result of fine crushing of crystalline grains of metal.

1. Introduction

Multi-striker ultrasonic impact tools are successfully used for vibration machining of weldments [1]. The intermediate needle-like strikers oscillate in the gap between the end face of the ultrasonic converter and the specimen being treated (Fig. 1a). This striker is employed for surface strengthening and plastic deformation of material in the local contact spot. An overview of physics and technology of ultrasonic treatment is given in papers [1,2]. An improvement of fatigue properties is achieved due to material hardening, the redistribution of residual weld stresses and creation of beneficial compressive stresses in the surface layer of the treated material.

Three physical zones of effect of the ultrasonic impact treatment on material properties and microstructure were described in [1,2]: (1) zone of plastic deformation and compressive residual stresses; (2) zone of relaxation of welding residual stresses and (3) zone of nanocrystallization [3] or "White layer" [1]. It is shown [3], that the depth of penetration of the compressive residual stresses measured by different nondestructive techniques well correlates with the depth of plastic deformation that is determined by microhardness measurements.

A comparative investigation of ultrasonic vibration-impact systems with a ball-shape and a needle-shape striker are presented in [1]. It is shown that the greater efficiency of ultrasonic impact treatment is achieved for the needle-like striker. Moreover, the needle-like strikers provide processing of rough welds in difficult-to-access places such as crossing welds. The light-weight (a few grams) strikers reduce their influence on an operation frequency and amplitude of the ultrasonic converter. This allows to keep the low-power ultrasonic converter in resonance under a large pressing force.

Two different modes of ultrasonic vibrations of the intermediate striker in the gap were described in [1]: (a) ultrasonic vibrations of striker with rebounding from the converter tip and the specimen surface, (b) in-phase continuous (without detachment) ultrasonic vibrations of an striker in synchronism with these surfaces. Along with the vibration-impact mode at the drive frequency the possibility excitation of sub-harmonic and non-periodic oscillations of a striker was noticed [2].

Our recent experiments with the advanced tool [4] show that the frequency of periodic impacts of striker upon the treated specimen is equal to ultrasonic frequency [5]. The ultrasonic impact processing is a cyclic alternation of setting-up and failure of vibration-impact oscillations of striker inside the varying gap. A dynamic model of the proposed ultrasonic tool is presented as a system of two concentrated masses with two impact joints [6].

* Corresponding author. Tel.: +7 9172845388; fax: +7 8435608942.
E-mail address: vagapovik@yandex.ru (I. Vagapov).

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