Conference Paper

# Ultrasonic Vibroacoustic Processes, Excited By Heating By Impulse Currents of Metals

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## Abstract

When passing impulse currents through a conductor, powerful vibro-acoustic oscillations are generated in it. The parameters of these oscillations are easy to control. Changing the duty cycle of pulses allows for such equipment as welding with the allocation of a large amount of heat, and regimes of controlled cooling and ultrasonic quality control of the welded joint.

**Keywords:** welding, vibration, pulse current, diagnostics, ultrasound

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## 1. INTRODUCTION

The impact of ultrasound on the region of the welded metal samples can significantly improve the weld quality. The additional influence of ultrasound allows to increase the uniformity and decrease the graininess in the weld area [1, 2]. Under the action of ultrasound residual stress in the region of the welded connection is reduced 2.5-3 times [3 - 6]. The effect of pulse current also can improve the quality of welded joints [7]. Since the passing pulse current through the metal samples is accompanied by the generation of powerful ultrasonic vibrations, the parameters of which can be controlled within a wide range [8], it is possible to combine guided modes of welding, cooling and subsequent diagnostic nondestructive testing of the weld without the involvement of specialized hardware on each of these stages. Occurs when transmission of the pulse current fluctuation of metal can be used as a source of cyclic loadings and the means of diagnosing the state of the conductive structural elements [9, 10]. For configuration of operating modes in addition to specifying the amplitude of the pulsed current is sufficient to control the frequency and duty cycle of the generated current pulses. Features of mechanical vibrations substantially depend on the parameters of the current.

## 2. MATERIALS AND METHODS

The work investigated the possibility of excitation of high frequency vibroacoustic vibrations in the samples by passing them pulsed current of high density. The change in the duty cycle allows to obtain a controlled vibration in terms of significant heating of the sample by a pulsed current, and almost without such heating. This allows you to select the welding modes, controlled cooling, and vibro-acoustic nondestructive testing of welded connections using a common set of hardware resources. As materials of metal samples can be used electrodes made of silver, gold, copper, titanium, stainless steel, aluminum, and various alloys. Control of operation is provided by the vibration control multi-component accelerometer is installed on the electrode or on the clip in which the fixed electrode.

To reduce the impact of electrical interference and noise in the measurement of vibration as the characteristic amount used for its evaluation in view of the magnitude of the acceleration. To control the amount of current during the pulses can be applied non-contact sensors of magnetic induction. Evaluation of vibration and magnetic fields can be used to maintain the control system of the optimum modes of welding, cooling and diagnostics of quality of welded joints.

## 3. THE STUDY OF THE ACTION OF THE PULSE CURRENT

In [8] presents a methodology for assessing the vibratory response of the pulse current. In this method, to eliminate the influence of heating the samples under the action of the current was investigated the effects of single pulses. Heating of the samples from these single pulses was negligible. The results obtained here show that the generation of mechanical vibrations in the conductor associated with the passage of the front and rear fronts of the pulses. Repeated action of pulse high density can cause significant heating of the conductor. The heating effect of the high current density used in electric welding. The symmetrical nature of vibro-acoustic response of front and rear edge of the pulse current allows by changing the duty cycle to provide a similar vibration impact for a large average current, which results in strong heating necessary to perform welding, as well as the mode of controlled cooling with the impact of short pulses, as shown in Fig. 1. The action of the single current pulse generating mechanical vibrations allows to implement a non-destructive diagnostic testing of welded joints. In the mode of welding current pulses with an amplitude of $I_W$ separated by relatively short intervals of no current $\Delta t_1$.

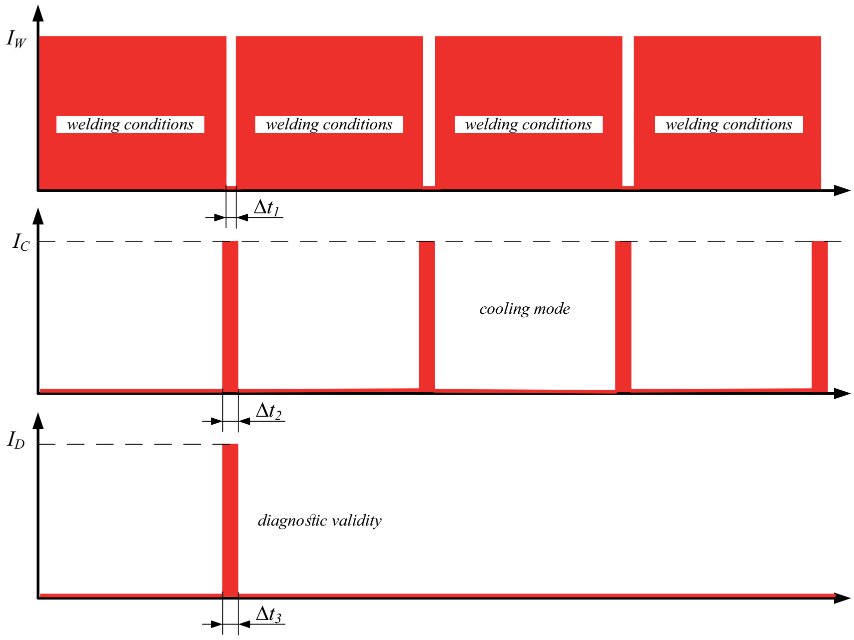


**Figure** 1: Controls the amplitude of current pulses, their duration and frequency allows a wide range to change the welding conditions, cooling and diagnostics with the provision of the maximum amplitude of mechanical vibrations.

In cooling mode adjustable current pulses $I_C$ have a relatively small duration $\Delta t_2$. Similar characteristics have a single current pulses with an amplitude $I_D$ and duration $\Delta t_3$ used for non-destructive quality control of welded designs.

Generated during the passage of the leading and trailing edges of current pulse of vibro-acoustic processes in the sample can overlap each other if they are close in time. Such processes can be considered as two independent damped oscillation described by the ratios:

$$A1(t) = \begin{cases} 0 & \text{if } t < t_S \\ AM \sin\left(\frac{t-t_S}{T}\right) \cdot \exp\left(-\frac{t-t_S}{\tau}\right) & \text{if } t \geq t_S \end{cases} \quad (1)$$

and

$$A2(t) = \begin{cases} 0 & \text{if } t < t_E \\ AM \sin\left(\frac{t-t_E}{T}\right) \cdot \exp\left(-\frac{t-t_E}{\tau}\right) & \text{if } t \geq t_E \end{cases} \quad (2)$$

for

$$T = \frac{1}{\omega_C} \quad \tau \approx 1,2 \cdot T_P \quad (3)$$

where $T_P = t_E - t_S$ - is the pulse duration, $\omega$ – the natural frequency of the structure; $t_S$ and $t_E$ - the start and end time of the current pulse.

Vibroacoustic process is described by their superposition:

$$A(t) = A1(t) - A2(t) \quad (4)$$

The time constant of decay $\tau$ may vary within considerable limits depending on the properties of the metal sample. Given value corresponds to the real samples of copper which in Fig. 2 shows the dependence of the vibration response time at different durations of the current pulse.

Addition of oscillations ensures the existence of a region where the amplitude can both increase significantly and decrease depending on the ratio of their phases. In Fig. 2 shows the area where maximum Amax and the minimum Amin values of recorded accelerations. Operation with such durations allows to obtain the maximum magnitude high frequency mechanical impact on the area of the welded connection.

The choice of the duration of the current pulse or the interval between the end and the beginning of the neighboring pulses provides a significant increase in the amplitude of the vibro-acoustic response with a substantially different heat. This effect is related to the symmetric character of the vibration response to the passage of a front and rear fronts of the pulses of current through the weld area.

Process parameters:

- The amplitude of the current *Imax*;
- The frequency of impulses *F = 1/T* (*T*-period);
- The pulse duration *Tw*;
- Duty cycle *W = (Tw/T)*.100%;
- The magnitude of the acceleration *Apik-to-pik = Amax-Amin*;
- The rate of attenuation of vibro-acoustic oscillations or the damping rate.

Control vibroacoustic response can be performed using conventional small accelerometer mounted on the electrode with which the welding is performed, as shown in Fig. 3.

When short duration current pulses can be performed by cooling the weld area in terms of vibro-acoustic effects for the improvement of the quality of the metal in the region of the welded connection and reducing residual stresses.

Addition of oscillations arising from the action of the leading and trailing edges of the current pulse, illustrated in Fig. 4, which shows dependence of the transverse (blue) and axial (red) acceleration against time. The corresponding spectral representation for the vibro-acoustic response is shown in Fig. 5.

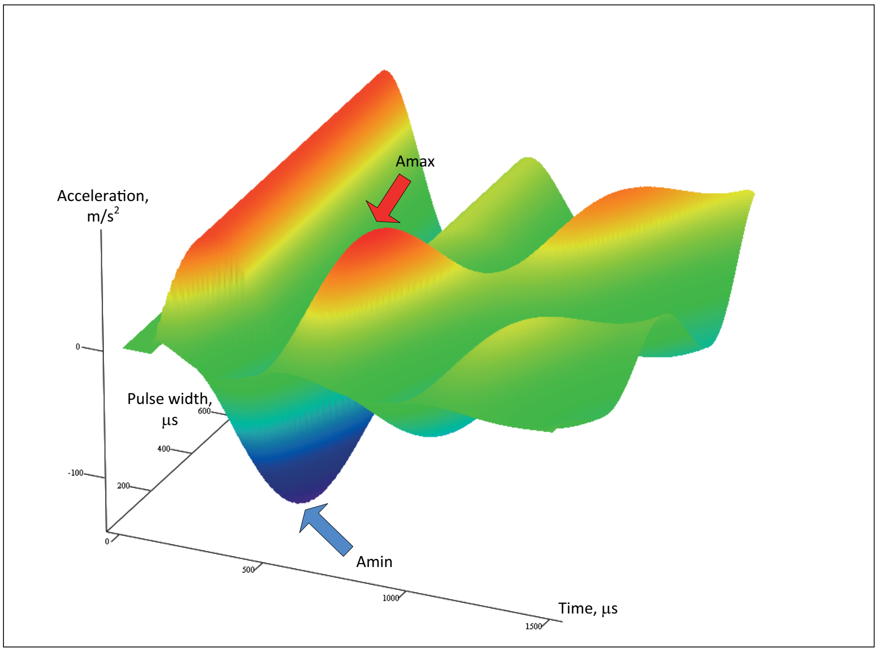


**Figure** 2: The dependence of the magnitude of vibration on the duration of the current pulse, as a result of the addition of oscillatory processes generated at the front and rear fronts of the pulse.

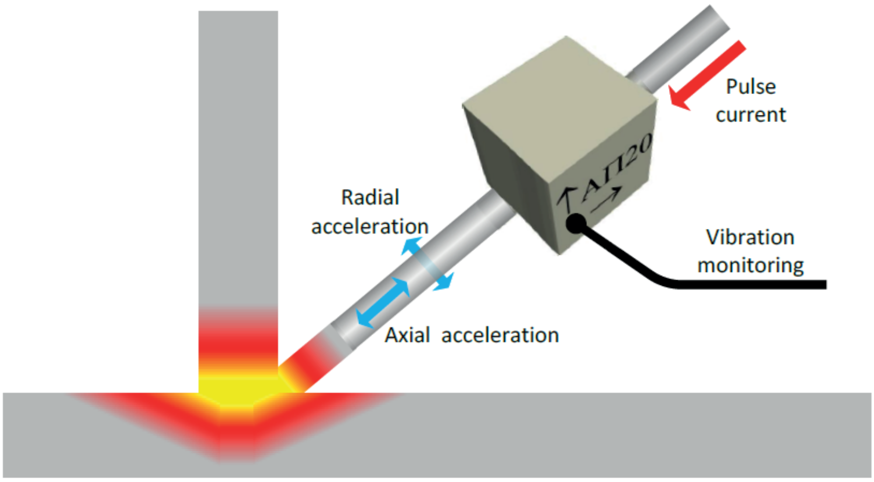


**Figure** 3: The vibration excitation electrode pulsed current welding mode.

## 4. CONCLUSION

The process of improving the quality of welded joints when exposed to ultrasound [13] can be combined with processes managed by cooling and diagnostics. This can be accomplished using a pulse mode of welding current. Excited by the mechanical oscillations can be controlled within wide limits [14]. Control vibroacoustic process using the accelerometer, mounted on the electrode allows to optimize the welding conditions, cooling, and also to diagnose the quality of the seam.

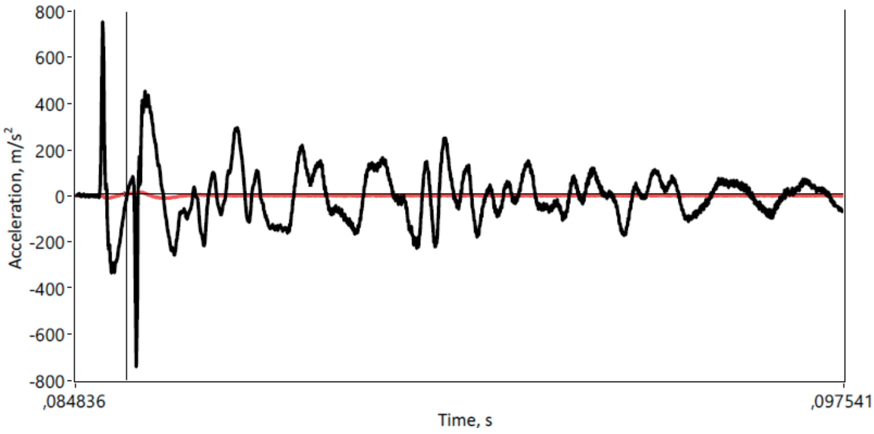


**Figure** 4: The vibration signals. A sample of copper 30x3x0,5 mm, rectangular cross-section.

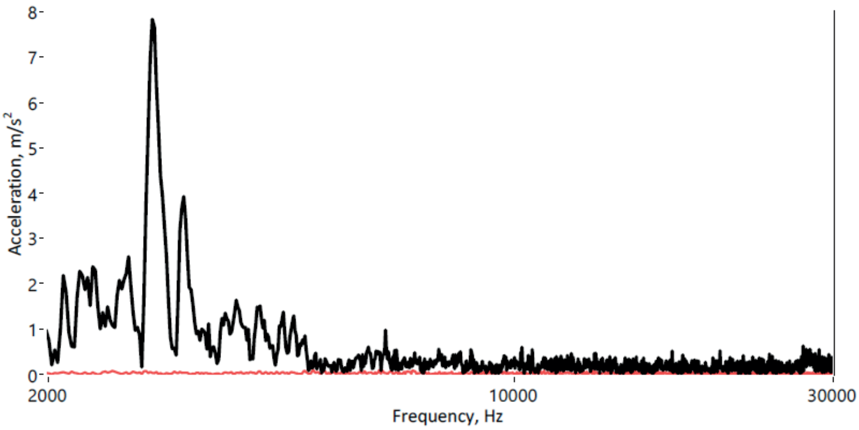


**Figure** 5: The spectra of signals of the acceleration vibration. A sample of copper 30x3x0,5 mm, rectangular cross-section.

The response of the sample to allow the current pulse can be divided into two areas. First by passing the current pulse is the excitation deformation and the redistribution of the current under the action of changes in the magnetic field generated by this current. In the second time domain in the sample are observed own damped oscillations. Such fluctuations can be used to perform non-destructive testing.

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