Investigation of the Influence of Dynamic Parameters on the Formation, Structure and Properties of Bimetallic Compounds during Explosion Welding with Simultaneous Stamping

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Abstract. This article reports on the study of the influence of dynamic parameters on the formation, structure and properties of bimetallic compounds during explosion welding with simultaneous stamping. The results of the study of the impact of the collision speed and contact speed on the strength, wave parameters and the amount of molten metal obtained by the explosion of a bimetallic compound of the iron + steel 3 alloy are presented. It is shown that the formation of a bimetal during explosion welding is significantly influenced by impact velocity, with an increase in which there is an increase in the values of the maximum deflection and radial deformation.

1. Introduction
One of the ways to improve the efficiency of explosion welding is to develop new promising energy-saving technologies that allow not only to expand the range of manufacturing flat bimetallic blanks, but also to obtain finished bimetallic products of complex configuration, such as cylindrical or spherical shape [1-5]. In explosion welding as a result of a powerful charge, the negative energy of motion and deformation of the welded bimetal can be used rationally for the simultaneous stamping of a bimetallic billet. This will eliminate the use of expensive press equipment and increase the efficiency of explosion welding [6-10]. In the process of explosion welding, the main dynamic parameters responsible for the formation of a durable bimetallic welded joint are the velocity of the impact \( V_i \) and the velocity of the collision point \( V_c \) [11-16]. Therefore, to obtain high-quality bimetallic compounds with a given profile, it is important to study the combined effect of dynamic parameters on the quality of welding and the formation of bimetals.

The aim of this work was to study the effect of velocity of the impact and velocity of the collision point on the formation, structure and properties of the bimetallic compounds at explosion welding with simultaneous stamping.

2. Materials and methods
During the research, the main material used was a pair of armco-iron + St3 5 + 10 mm thick, which has good weldability and does not cause difficulties in the manufacture of samples for mechanical testing and metallography. Explosion welding with simultaneous stamping was carried out according to a scheme with a parallel arrangement of plates mounted on a metal matrix with a cylindrical profile (Figure 1).
The detonation rate of the explosive was controlled by an electrocontact method [17] with time recording using electronic counting frequency meters. After explosion welding with simultaneous stamping, measurements were made of the cylindrical profile of the resulting bimetallic billet to determine the radial deformation $e_r$ and maximum deflection $f_{max}$. The radial deformation of the stamped bimetal was determined using the method of applying “coordinate grids” [18]. Metallographic studies and determination of the tensile strength of the layers $\sigma_{pull}$ of welded joints were carried out according to standard test procedures for bimetallic and composite materials [19-22].

![Figure 1: Explosion welding pattern with simultaneous stamping](image)

3. Results and discussion

The obtained results of research of influence of dynamic parameters showed that with increasing velocity of the impact in the range $V_i = 290 \ldots 570$ m/s at constant velocity of the collision point $V_c = const$ the tensile strength of the connection layers $\sigma_{pull}$ armco-iron + St3 first increases to strength balance and higher, and then remains constant at $V_i > 500$ m/s is reduced (Figure 2, a).

![Figure 2: Influence of the velocity of the impact $V_i$ (a) and the velocity of the collision point $V_c$ (b) on the strength $\sigma_{pull}$ of the armco-iron+St3 compound](image)

Metallographic studies of the boundary of the armco-iron + St3 compound have shown that with an increase in velocity of the impact $V_i$, there is an increase in the amount of fused metal $K_{fus}$ and wave parameters: height $2a$, length $\lambda$ (Figure 3, 4). At the same time, the presence of low joint strength at low values of $V_i$ is explained by a small amount of plastic deformation of the contact metal layers, which is not enough to form a strong welded joint (Figure 4, a). The decrease in joint strength at high impact velocities is associated with excessive plastic deformation of the metal in the heat-affected zone, which leads to the formation of microcracks and a large amount of fused metal $K_{fus}$ (Figure 4, b).
A similar tendency in the separation strength of the layers $\sigma_{\text{pull}}$ is also observed with an increase in velocity of the collision point in the range $V_c = 2240 \ldots 3750$ m/s with a constant value of velocity of the impact $V_i = \text{const}$ (Figure 2, b).

![Figure 3](image)

**Figure 3.** Effect of impact velocity $V_i$ for changing of the height $2a$ (1), $\lambda$ wavelength (2) and the amount of fused metal $K_{\text{fus}}$ (3) a compound of armco-iron + St3.

![Figure 4](image)

**Figure 4.** Microstructure of a bond region armco iron + St3 for different values of velocity of the impact: a - $V_i = 290$ m/s; b - $V_i = 570$ m/s.

Metallographic studies have shown that a sharp decrease in the separation strength of the layers $\sigma_{\text{pull}}$ of the armco-iron+St3 compound at high value of velocity of the collision point is due to a significant increase in the amount of brittle fused metal $K_{\text{fus}}$ (Figure 5, 6).

At the same time, with increasing velocity of the collision point, the wave sizes $2a$, $\lambda$ decrease and at $V_c > 3200$ m/s they are practically absent, and a continuous layer of brittle melts is observed (Figure 6, b).

The results of experiments to study the influence of dynamic parameters on the formation (stamping) of bimetallic compounds showed that an increase in the velocity of the impact $V_i$ practically does not significantly affect the value of the maximum deflection $f_{\text{max}}$ and radial deformation $\varepsilon_r$ of the bimetal. With an increase in velocity of the collision point $V_c$, on the contrary, there is a significant increase in the maximum deflection $f_{\text{max}}$ and the radial deformation $\varepsilon_r$ of the bimetal (Figure 7).
Figure 5. Effect of velocity of the collision point $V_c$ for changing of the height $2a$ (1), $\lambda$ wavelength (2) and the amount of fused metal $K_{rus}$ (3) a compound of armco-iron + St3.

Figure 6. Microstructure of a bond region armco iron + St3 for different values of velocity of the collision point: a - $V_c = 2520$ m/s; b - $V_c = 3750$ m/s.

Figure 7. Influence of velocity of the collision point $V_c$ on the maximum deflection $f_{\text{max}}$ and radial deformation $\varepsilon_r$ of armco iron + St3 bimetal.
The different influence of dynamic parameters is probably due to the redistribution of part of the charge energy in the direction of increasing the energy of the package movement spent on stamping the bimetal, which should be clarified during further research.

The obtained results of the research served as the basis for the development of new manufacturing processes using combined explosion welding with simultaneous stamping of bimetallic bronze-steel inserts of sliding bearings and pump linings of drilling equipment.

4. Conclusions

1. It is experimentally established that with an increase in velocity of the impact \( V_i \) and the velocity of the collision point \( V_c \), there is an increase in the separation strength of the layers \( \sigma_{\text{sep}} \) of the armco-iron+St3 compound and an increase in the amount of molten metal, while the wave sizes \( 2a, \lambda \) increase with an increase in \( V_i \), and with an increase in \( V_c \), on the contrary, decrease.

2. Research of influence of dynamic parameters on the formation showed that the change in velocity of the impact \( V_i \) also has a significant impact on the stamping, while increasing the velocity of the collision point \( V_c \) there is a significant increase of the maximum deflection \( f_{\text{max}} \) and the radial deformation \( \epsilon_r \) bimetal.

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