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O.V. JARTOVSKY[1,*], and O.V. LARICHKIN[2]

[1] Donbass State Engineering Academy,
72 Akademichna Str., UA-34313 Kramatorsk, Donetsk Region, Ukraine

[2] JSC 'Novokramatorsky Machine Building Plant',
5 Oleksa Tykhy Str., UA-84305 Kramatorsk, Donetsk Region, Ukraine

* avpivras@gmail.com

PRESSURE WELDING THROUGH A LAYER OF HYDROCARBON MATERIAL: ELECTROMAGNETIC PHENOMENA DURING THE DIFFUSION BONDING FORMATION

The literary data dealing with the experimental studies concerning the influence of electromagnetic phenomena on the diffusion processes are reviewed and analysed. Based on the scientific facts presented in interdisciplinary experimental studies, a hypothesis is suggested. It is concerned with the influence of electromagnetic phenomena in the process of formation of a diffusion joint during pressure welding through a layer of a hydrocarbon substance. In the welded joint, at the initial moment of current transmission, energy is released during the explosion at the points of contact. When a pulsed electric current is passed through the pyrolysis products in microvolumes between the surfaces to be joined, they are also destroyed. Ionized particles are formed. Under the action of the pinch effect, they move to the centre of the welded joint. A capsule with ionized carbon particles is formed there. The 'Coulomb explosion' occurs in the capsule located in the middle of the joint. Multiple exposures of the surfaces by microexplosions in microvolumes between the surfaces to be joined and the final 'Coulomb explosion' of the capsule create the release of a large number of magnetic monopoles. This can be a determining and synergistic factor among a number of others in the formation of a welded joint. This makes it possible to explain the short time required for welding and the small deformations of the weld formation zone.

Keywords: pressure welding, hydrocarbon substances, electric explosion, electric current, diffusion.

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1. Introduction

Known methods of pressure welding can be carried out in vacuum [1] and various environments [2–4]. There is a method of pressure welding through a layer of hydrocarbon material [5, 6]. This method has high productivity and good economic performance. Physical and chemical processes accompanying the formation of the compound are little studied. Further research is required. The work [7] is devoted to the study of processes during pressure welding through a layer of hydrocarbon substance. In Ref. [7], there was proposed a hypothesis on the mechanism of activation of diffusion processes during pressure welding by pulsed current through a layer of hydrocarbon material. This hypothesis is based on interdisciplinary experimental studies. The structure of the welded joint is similar to the structure obtained by diffusion welding in vacuum. The time for the formation of a joint at the same temperature is much less than that required for this in diffusion welding in a vacuum. Interdisciplinary studies have experimentally proven the influence of electric current, electroexplosive and electromagnetic phenomena and shock waves when exposed to the surface layers of the metal. They activate diffusion processes.

The relevance of the work lies in the fact that so far there is no sufficiently complete model of the process. With the accumulation of scientific facts about the physicochemical processes accompanying the formation of a compound, the model will be improved. Of particular importance is the study of the electromagnetic effect on the surfaces to be joined during pressure welding through a layer of hydrocarbon material.

The object of the current study is the process of formation of a diffusion joint during pressure welding through hydrocarbon substances when heated by a pulsed unipolar electric current.

The subject of the study is the effect of electromagnetic phenomena in the process of formation of a diffusion joint during pressure welding through a layer of a hydrocarbon substance.

The aim of study is to develop a hypothesis about the influence of electromagnetic phenomena in the process of formation of a diffusion joint during pressure welding through a layer of a hydrocarbon substance with heating by a pulsed unipolar electric current.

Research objectives:

- analyse the literature on the influence of electromagnetic phenomena accompanying an electric explosion;
- based on the scientific facts presented in the descriptions of experimental studies, propose a hypothesis about the influence of electromagnetic phenomena in the process of formation of a diffusion joint during pressure welding through a layer of hydrocarbon substance.

Research method is a system analysis.

The initial experimental data on welding samples cannot be obtained due to the small size of the objects. Special methods and necessary devices have not been developed.

This leads to the use of the method of analogies and interdisciplinary experimental data to create a hypothesis. An analogy is considered to be a conclusion in which, from the similarity of some features of objects, a conclusion is made about the similarity of some other features of these objects. The application of this method in the scientific or industrial field involves consistent actions aimed at finding an analogue. An analogue is considered to be an object that is identical or corresponding to a given object in some parameters of the object under study. Direct, indirect and conditional analogies are known. From the similarity of some features of objects, a conclusion is made about the similarity of some other features of these objects.

With a direct analogy, the model and the original are as detailed as possible to each other.

An indirect analogy is established when the model and the original are sufficiently close relative to each other.

The conditional analogy between the original and the model is established as a result of a conditional agreement. The proof of the analogy of the object under study and the analogue and the transfer of information from the analogue to the object is established.

2. Methodology

To develop the methodology, the method of analogies was applied. The process of forming a joint by pressure welding through a layer of a hydrocarbon substance is considered. The surfaces to be welded are heated by pulsed electric current. When a pulsed unipolar electric current is passed, heating occurs at the points of contact. In the mechanical contact of surfaces, the actual area of contact is only a small part of the surface from 0.01 to 0.1% of its nominal value [8]. The value of the density of the passing electric current in the initial period of the process is in 10^3–10^4 times higher than the nominal value. When an electric current passes at the points of contact of metal surfaces, overheating and explosive evaporation of metal vapour occur. The explosion time according to Ref. [9] is about 120–300 ns. A diagram of an electrical explosion in a contact during electrical heating is shown in Fig. 1.

After the electric explosions at the points of contact of the surfaces to be welded, a shock wave is formed [10] and particles are scattered [11]. Pyrolysis products are formed. On surfaces to be welded, the action of electric current and heat produced nanotubes [12]. The microvolumes between the surfaces are filled with ionized pyrolysis products (plasma). During the formation of a compound ionized particles under

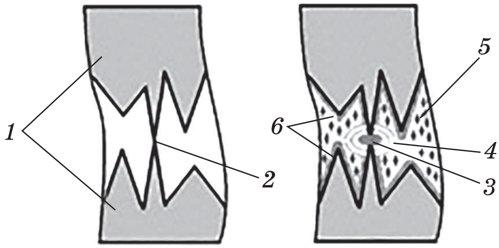


Fig. 1. Scheme of electrical explosion in a contact during the electrical heating, where *1* — connected surfaces, *2* — point of contact, *3* — electric explosion at the point of contact, *4* — shock wave, *5* — microvolume between connected surfaces, *6* — nanotubes on connected surfaces [12]

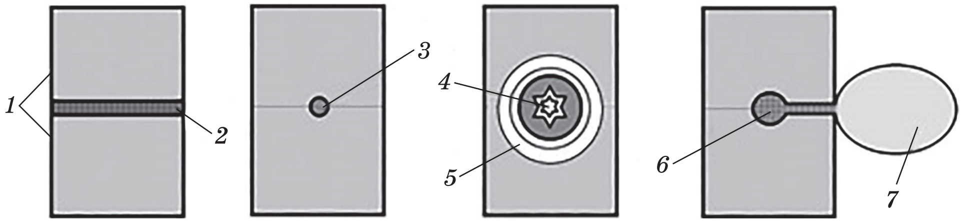


Fig. 2. Scheme of movement of ionized particles under the impact of magnetic field of pulsed electric current in the contact of welded surfaces. Here, *1* — welded blanks, *2* — ionized particles between connected surfaces, *3* — capsule with ionized particles in the middle of the joint, *4* — explosion capsule, *5* — shock wave, *6* — capsule with explosion products, *7* — explosion products (emission from the capsule) [12]

the action of a pulsed magnetic field of electric current move towards the centre. Movement pattern of ionized particles under the influence of a magnetic field of a pulsed electric current in the contact of the surfaces to be welded is shown in Fig. 2.

Based on experimental data, it can be assumed that the phenomena accompanying an electric explosion activate diffusion processes. Explosion of a capsule with pyrolysis products and ejection of products of explosion is mandatory to obtain a welded joint. On these grounds, it can be assumed that, during the explosion of the capsule, the process necessary for the formation of the compound occurs [12].

3. Results and Discussion

A number of works have shown the effect of an electric explosion on a wide range of phenomena. As shown in Ref. [13], the existence of collective processes low-energy transformation of nuclei does not contradict the known fundamental conservation laws. The possibility of thermonuclear reactions in an electric explosion has been pointed out in Ref. [14]. The paper [15] describes experiments on the study of a powerful electric explosion of titanium foil in a solution of uranyl sulphate in distilled water. Experiments indicate a distortion of the original isotope ratio of uranium and violation of the secular equilibrium of thorium. The authors of Ref. [15] do not explain the experimental results. In their opinion, elucidation of the mechanism of the observed effects requires further research. In Ref. [16], a low-energy transformation of chemical elements is based on electrophysical water ionization. The amount of solid precipitate in powder form depends on potential difference between electrodes, material, area of electrodes and ionization time. It is shown that in the process of electrophysical ionization, the formation in samples of such elements as Bk, Tb, Hf, Ho, Pu, Os, Zn, Te, Cu, Se, Pm, W etc. occurs. Particularly noticeable formation manifests itself for Bk, which is confirmed by other research methods and all these elements (Bk, Tb, Hf, Ho, Pu, Os, Zn, Te, Cu, Se, Pm, W) in samples are elements formed in the process of low-energy transmutations. The authors of Ref. [17] studied the effect of radiation, resulting from the electrical explosion of metal foils in liquids on thin foils of iron. To determine the nature of radiation, the method of conversion Mössbauer spectroscopy was used. Changes in the effective magnetic fields on the iron core are experimentally recorded that go beyond the measurement error. Value effect depends on the time elapsed after irradiation. Sign of change of effective magnetic field on iron nuclei correlates with the direction (N or S) external magnetic field applied to the sample during the process irradiation. The authors of Ref. [17] attribute the observed effect of the change the value of the effective magnetic field on the iron nuclei with the existence in the nature of 'Lochak's monopoles'. In work [18], the conditions' occurrence of an autonomous plasma formation in water during electrical discharge is studied. The resulting plasma formation excited in water a self-sustaining reaction of the synthesis of elements. Reaction was accompanied by electromagnetic radiation with a frequency of tens of megahertz and power up to tens of kilowatts. In experiments [18], tap water served as a raw material. The reaction product was the stable isotopes of the elements from helium to bismuth. The authors of [19] using the methods of mass spectrometry, scanning electron microscopy and x-ray fluorescence analysis investigated products resulting from low-energy electrical discharge between carbon electrodes in an aqueous solution of glycerol (Table 1). As established, the precipitate formed during the experiment has different from the original components of the chemical composition and microstructure (Table 2). The reaction products were studied in samples obtained from the precipitate formed in the discharge zone. The change in the elemental composition of the electrodes participating in the experiments was also controlled. To assess the change in the chemical composition of the electrodes in the process of electrical discharge from their working surfaces after experiments, the surface layers were chipped off (<1 mm). Then, they crushed to powder. To determine the amount of chemical impurities in carbon electrodes, mass-spectrometric studies are carried out. The electrodes (anode and cathode) studied before discharge. Research was also carried out after carrying out the discharge. Mass-spectrometric study was subjected also to the precipitate that formed directly in the glycerine itself during the electrical discharge.

In an aqueous solution of glycerol, the phenomenon of transformation of nuclei of initial chemical elements under the influence of electric discharge is observed.

In Ref. [19], during an electric explosion of a metal in a liquid was recorded simultaneously transformation of chemical elements and 'strange' radiation. 'Strange' radiation was detected by nuclear photographic emulsion in the form of unusual peculiar, intermittent tracks. Currently, there are no theoretical models to explain the course of observed low-energy nuclear reactions. As suggested in Ref. [20], there is some catalyst. It combines nuclei into a cluster, creates conditions for resonance and initiates the exchange of nucleons. The role of such a catalyst can be played by magnetic monopole [21]. The magnetic monopole is magnetically excited neutrino. The magnetic monopole is lepton, and can participate in weak electrical interactions. A monopole can be formed by electromagnetic phenomena in condensed environment.

Table 1. **Semi-quantitative analysis of samples (error ±10%) [19]**

Element	Source electrode, mcg/g	Electrode 'cathode', mcg/g	Electrode 'anode', mcg/g	Precipitate, mcg/g
Mg	8	160	36	415
Al	8	13	14	189
K		36	36	566
Ca		36		274
Cr				19
Mn		14		85
Fe		58	11	2547
Ni				47
Cn		36	11	2264
Zn		36		387
Ag				57
Sn				26

Table 2. **Results of elemental analysis of precipitated particles [19]**

Spectrum No.	C	O	Na	Mg	Al	Si	P	K	Ca	Mn	Fe	Cu	Zn
1	58	25.4	0.9	0.23	0.69	3.39	0.73	1.42	2	1.09	5.5		0.19
2	53	28.1	1.3	0.35	0.46	3.09	0.49	2.01	1.27	1.09	9.1		0.13
3	95	5.01							0.2				
4	62	28.2	0.8	1.59	0.08	0,31			0.95		1.03	0.45	4.5
5	63	29.7	1.6	1	0.2	0.53			2.69		1.11	0.29	
6	88	9.51		0.64		0.28			0.11		0.34		1.43

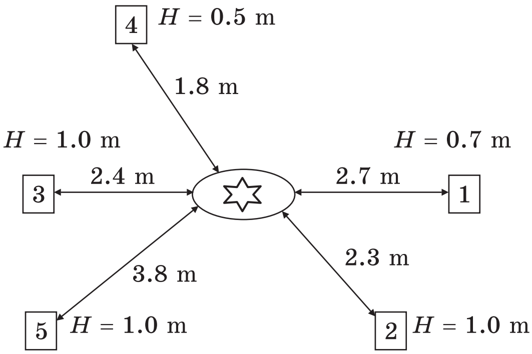


Fig. 3. Scheme of location of detectors during the explosion of conductors [22]

Paper [22] presents the results on the registration of radiation, arising from the testing of high-voltage industrial equipment. During the high-voltage tests on photographic membranes and nuclear photographic plates, traces of radiation are recorded. They are like traces obtained in research on the electrical explosion of conductors in liquids. The results of registration of radiation are presented, arising from the testing of high-voltage industrial equipment. The results of measurements of the isotopic composition of chemical elements that are part of the alloys from which the varistors are made are shown. In varistors participated in industrial tests, distortions of the isotopic composition of titanium were found. Research was carried out during industrial tests of complete switchgear. On current-carrying buses, jumpers made of wire of any metal with a diameter no more than 0.5 mm were installed. Jumpers initiated arcs. Input value of short-circuit current has a range of 1–40 kA, voltage 8–10 kV. Tests were also carried out during testing of the nonlinear surge arrester for explosion safety. There are two options for initiating an electric arc. In the first case, the columns of varistors were shunted beforehand. For this, copper wire with a diameter of not more than 0.5 mm was used. In the second case, there was preburned surge suppressor varistors' column. As radiation recorders, we used x-ray fluorographic film RF-ZMP and nuclear photographic plates with an emulsion layer thickness of 100 μm. All photographic materials after irradiation appeared in the corresponding developers. After processing, the film was placed under a microscope. The number of tracks was visually counted. Then, using a special device, the tracks were digitized and entered into computer. Before the experiment, films and nuclear plates placed in plastic bags and wrapped in two layers of black paper. For a more detailed study of the properties of detected radiation, the detectors were installed in various points of space and at different distances from the place of electrical explosion of conductors. Figure 3 shows a typical diagram location of detectors. Each test used control detectors that were delivered to the test site together with working detectors, but were not irradiated. Control detectors were processed in the same way as working ones. If any artefacts were observed on the control films, the results of these tests were disavowed. Detectors were based on fluorographic film RF-ZMP. Films in the

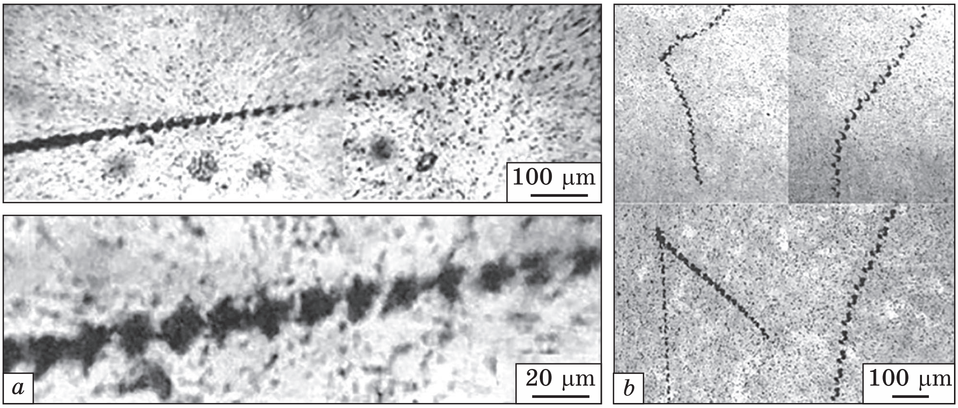


Fig. 4. Micrograph of traces registered during (*a*) the test of the surge suppressor and (*b*) electric explosion of wires [22]

amount of 3–5 were set for one act of testing at different distances from tested objects. In Figure 4, *a*, there is a micrograph of one of typical tracks recorded during tests of overvoltage limiter. Figure 4, *b* shows the tracks obtained with electrical explosion of wires. The tracks are located in surface layer of photoemulsion detectors.

Traces are noticeable differ from each other in size. Transverse dimensions 5–30 microns, length from 100 μm to several mm. As a result of experiments, it was found that, if the farther detector is located from the test site, the track width is narrower.

With the use of nuclear photographic emulsions, traces of ‘strange’ radiation during technical tests of technological electrical equipment were detected. Some of the recorded traces are qualitatively indistinguishable from traces registered with the help of nuclear photographic emulsions at experiments on electroexplosion of titanium foils in liquids.

Main matching points: traces are discontinuous, have a length of up to 1–2 mm; footprints are registered at a distance of up to 3 m from the place of the electric explosion; the thickness of the recorded traces 5–30 μm depends on the distance between the detector and the test site. The fact that isotopic distortions coincide in two different types of experiments suggests the existence of strict laws in nature that govern low-energy nuclear reactions. The results of the work correspond to the results of works [23, 24]. Authors of Ref. [25] described experiments on the study of the electric explosion of foils from highly pure materials in water. The appearance of new chemical elements has been discovered. They are detected by spectrometric measurements during the discharge process and mass spectrometric analyses of deposits. A ‘strange’ radiation was registered. ‘Strange’ radiation is accompanied by the transformation of chemical elements. A hypothesis was put forward [25]

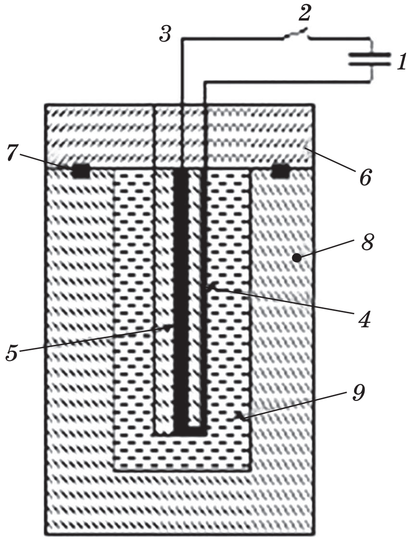


Fig. 5. Scheme of the experiment: *1* — capacitor bank, *2* — arrester, *3* — cable, *4* — foil, *5* — electrode, *6* — polyethylene cover, *7* — seal, *8* — explosive chamber, *9* — distilled water [25]

about the presence of a magnetic charge in particles of 'strange' radiation. The scheme of the experiment is shown in Fig. 5.

The capacitor bank was discharged onto a foil placed in water. The energy reserve of the capacitor bank at the charging voltage $U \approx 4.8$ kV was $W \approx 50$ kJ. Before the load, energy was transported through cables *3*, the inductance of which was $L = 0.4$ μH. Titanium foil served as a load. The foil was welded to titanium electrodes *5* using resistance welding. The electrodes were fixed on the polyethylene cover *6*. The polyethylene cover *6* was attached to the explosion chamber *8* through seals *7*. The explosion chamber *8* was also made of polyethylene. The explosion chamber was a torus. The torus contains eight holes. The holes are evenly spaced around the circumference. Distilled water was used as the working fluid. Analog oscilloscopes and high-speed analogue-to-digital converters combined with computers were used as electrical signal recorders.

To register the image of the emerging glow, three techniques were used with different temporal resolutions. The most 'fast' technique was implemented using image intensifier tubes. Six electrooptical converters in frame mode with exposure time ≈130 μs and delay time between them ≈1 ms made it possible to obtain 6 frames during one shot. The image intensifier tubes were located at a distance of 2.5 m from the setup axis. Above the setup, at a height of about 1 meter, a mirror was installed at an angle of 45° to the vertical. This made it possible to simultaneously register two glow projections. A high-speed industrial film camera of the IMAGE-300 brand was also used to register the glow. It allowed recording 300 frames per second in colour with a frame exposure time of ≈2 ms. A special quartz clock was developed to synchronize the camera. Figure 6, *b* shows that the glow occurs in the centre between the electrodes above the dielectric cover and has a spherical shape. Based on the results of more than 100 experiments, it is possible to describe the typical dynamics of a spherical glow. At the moment of current interruption, a very bright diffusion glow appears in the channel above the installation (Fig. 6, *a*), perceived as the glow of the entire

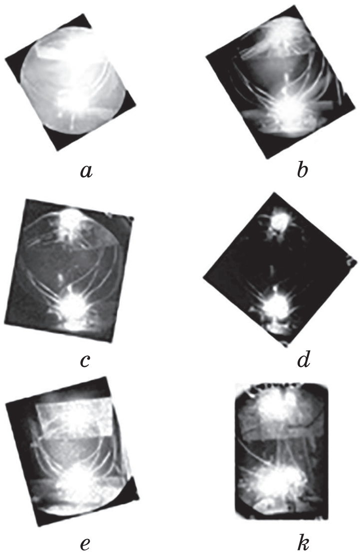


Fig. 6. Images of a spherical plasma formation obtained from screens using the electron-optical converters. The frame exposure time is 130 µs. The moment of exposure (*a*) coincides with the time of the current pulse. The delay between frames is 1 ms [25]

space. Then, the glow becomes less bright. The next frame shows a spherical glow (Fig. 6, *b*). During the next 3–4 ms, no dynamics is observed (Fig. 6, *b*, *c*, *d*). Then the luminous ball begins to crumble into many small 'balls'. In a series of experiments, it was noticed that the 'ball' first rises by 15–30 cm above the surface of the dielectric cover, and then crumbles (Fig. 6, *f*).

Based on the hypothesis [25] of the formation of magnetic monopoles, it can be assumed that the observed spherical plasma formations are magnetic clusters.

Authors of [25] assumed that the role of the ion is played by the monopole, which is in a bound state with the nucleus of the foil atom, and solvation occurs as a result of the interaction of the magnetic charge of the monopole with the magnetic moment of the oxygen atom.

Also, authors of Ref. [25] identify the main regularities experimentally observed during the transformation of chemical elements, which can be formulated as follows: the transformation predominantly occurs on an even–even isotope, which leads to a noticeable distortion of the initial isotope composition; all the nuclei of chemical elements resulting from the transformation are in the ground (not excited) state; no appreciable radioactivity was found.

To explain the transformation of elements, the authors of Ref. [24] put forward the hypothesis of magnetic-nucleon catalysis as a working hypothesis. This process presumably takes place in the plasma channel. The magnetic monopole, due to the large value of its magnetic charge, can overcome the Coulomb barrier with even a small kinetic energy and enter into a bound state with the atomic nucleus.

According to Ref. [25], magnetic-nucleon catalysis should be very similar to muon catalysis presented in the work [26]. In that work, the authors indicated that the Coulomb barrier is overcome due to the large mass of the muon. The magnetic monopole is a stable particle, which means that magnetic-nucleon catalysis should be more efficient [25]. During the experiments, it was found that the transformation and, consequently, the magnetic-nucleon catalysis occur only in the plasma channel.

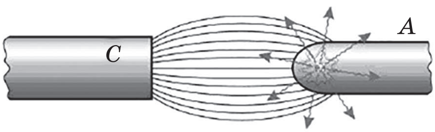


Fig. 7. Sketch of self-focusing of the electron beam on the concentrating anode surface, which excites a soliton-like density pulse in its near-surface layer, converging to the symmetry axis [27]

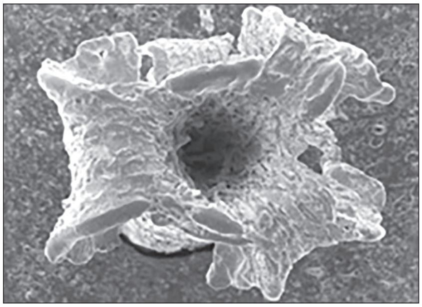


Fig. 8. Cylindrical monolithic target after the experiment, which ended with the explosion of the target from the inside and the formation of a crater passing into the axial channel [27]

In Ref. [27], the excitation of a converging wave of extreme matter-energy density in a thin near-surface layer of the anode-target was studied by creating and coherent collective acceleration of highly charged ions of the substance of the surface layer of the target in the direction of the energy focus of the target.

The sketch of the experiment had the form is presented in Fig. 7.

The experiment using this electron beam focusing scheme ended with the explosion of a cylindrical target from the inside and the formation of a crater passing into the axial channel (Fig. 8).

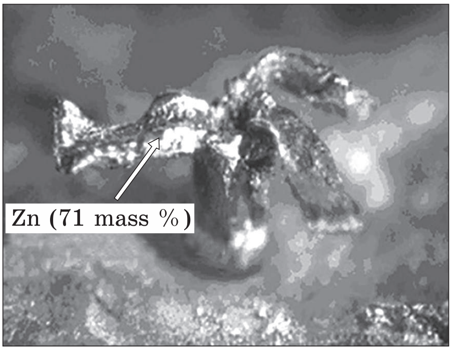
The nature of the damage indicated that the maximum energy density had been reached exactly at the focus on the axis of the cylindrical target.

On the surface of the target-concentrator there is a section of solidified silver-white 'lava'. It stood out from the exploding target. A tubular vent formed on the target.

Initially, a monolithic target rod turned into a tube. In this case, the tube under the action of forces opened into 3 'petals'. Drops of solidified metal and lava were found on the surface of the 'petals'.

X-ray microspectral analysis of the elemental composition of the observed 'lava' showed that it consists of 71% zinc (Fig. 9).

This demonstrates the formation of products of artificial nuclear fusion on a macroscopic scale. Investigations of the elemental and isotopic composition of the surface of the exploded target and the storage screen were carried out by various methods. Among the emissions from the centre of the target, all the elements of the periodic table are present in greater or lesser amounts [28–30]. Most of the chemical elements found on the storage screens and target residues were either not found in the original materials of the targets and screens, or were present in them in concentrations and amounts several orders of magnitude lower.



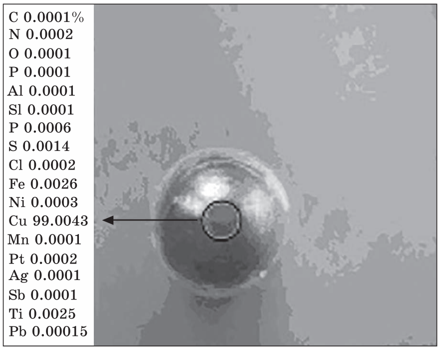


Fig. 9. Copper target after the experiment with traces of solidified silver-white 'lava' on its petals, poured out from the centre of the exploded target [27]

Fig. 10. Target before the experiment, where the target material is made of copper with 99.99 mas.% of Cu [27]

In addition, most of the formed elements have a significant discrepancy between the isotope ratio and the natural one.

An analysis of the surface layer (0.25 μm thick) of fifty similar samples containing products of laboratory nucleosynthesis by analytical chemistry methods showed the presence of lanthanides: terbium (Tb) and europium (Eu) with a mass concentration four orders of magnitude higher than the sensitivity limit of the technique, while in these elements were not detected in the initial material.

The experiments were carried out in a vacuum of 10^{-4} mm Hg. Chemically pure materials were used in them (Fig. 10).

Research method is glow discharge mass spectrometry (VG-9000, analysed mass range is up to 250 amu, mass resolution 7000–9000).

Statistical processing of data on the entire set of experiments made it possible to estimate the number of nucleons of the target material involved in the process of nuclear transformation. This value is equal to 10^{20}–10^{21} nucleons per 1 kJ of input energy.

The authors of the study studied the release of high-energy particles and dense plasma from an exploding target. The technique of etched track detectors was used for the study. The density of plasma tracks recorded at a distance of about 10 cm from the 'hot spot' reaches 10^8/cm^2 or higher.

These tracks are formed mainly by ions of the target material with energies close to the track formation threshold of 10 keV/nucleon. The lower bound for the total number of track-forming particles is 10^{11}–10^{12}. Groups of these particles with energies above 1 MeV with track density on detectors above absolute 10^8/cm^2 have been registered.

Localized track clusters have also been registered on detectors shaded from direct plasma flows in the form of either chaotic α-tracks with

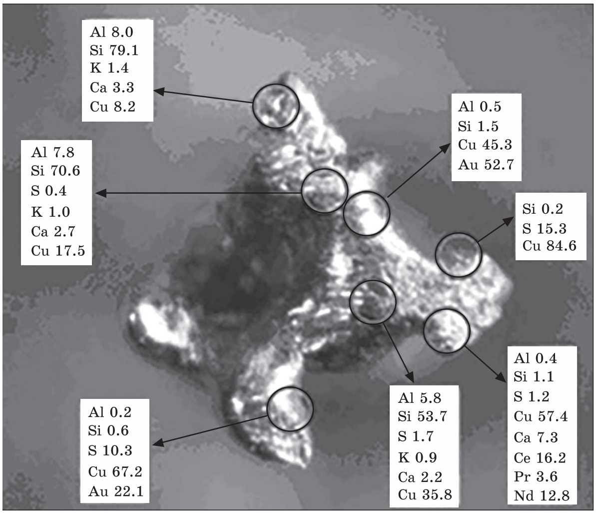


Fig. 11. Target after the experiment No. 2107 with Cu as a material of the target and storage screen. The study method was X-ray microanalysis (REMMA102, the range of determined elements is from Na to U), % [27]

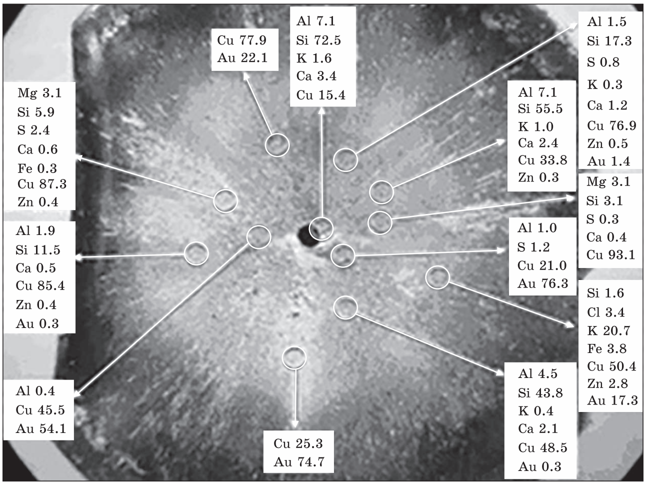


Fig. 12. Accumulative screen after experiment No. 2107 with the same (as in the previous figure) material of the target and storage screen as well as the method of investigation), % [27]

a density of up to 100/mm^2, or in the form of cantered track families. The appearance of giant track clusters with a well-defined expansion centre and with the number of tracks >100 was observed.

The appearance of both fast proton–deuteron beams and nuclear decays, registered by detectors in the form of cantered clusters, refers to anomalous nuclear-physical phenomena.

Taken together, these phenomena indicate the presence of anomalous nuclear processes associated with target collapse in experiments. All impurity types [31–37] in a volume experience a high-energy impact inexplicably other than nuclear fusion (Figs. 11 and 12) [27].

The most probable scenario of the initiation and evolution of the process, based on the concepts of the conceptual physical model underlying the developed method of shock compression of matter, and experimental data, is as follows.

In the process, it is possible to conditionally distinguish 5 phases of development.

Phase 1. As a result of the collective interaction of a shock high-current beam of relativistic electrons with the surface of a solid target, namely, the anode, a solitary wave-sheath of a highly ionized plasma of extreme density is formed in the near-surface layer of the target. Particles of highly ionized plasma, due to the action of the collective acceleration mechanism, acquire an impulse of directed motion towards the energy focus of the target. The transfer of matter and energy is carried out by the wave in an isentropic manner and is not accompanied by significant heating of the scanned volume of the target. As the wave moves, its length decreases, while the speed of movement, the steepness of the leading edge (density difference) and amplitude (density maximum) increase to values at which conditions are created at the leading edge of the shell wave for the nuclear transformation of matter.

Phase 2. The onset of nuclear transformation of the target substance in the volume of the wave leads to the formation of a mass defect [38–46]. As a consequence, the potential and kinetic energies of the shell wave increase. There is a further avalanche-like increase in the velocity of the leading-front shell wave and the density of matter in it.

This phase of the process ends when the shell wave reaches the parameters at which the evaporation of ‘energy-favourable’ classical nuclei by its trailing edge becomes impossible due to the excess of the matter density threshold in the wave, and the evaporation of ‘energy-absorbing’ heavy and superheavy nuclei begins.

Phase 3. In this phase, the increase in density and the nuclear transformation of matter in the body of the shell wave and on its trailing front continue. The energy stored by the wave is spent on the formation (‘evaporation’) of ‘energy-absorbing’; superheavy nuclei at its trailing edge.

Phase 4. This is the next phase of nuclear detonation combustion. The further movement of the shell wave to the collapse phase is accompanied by its accumulation of potential and kinetic energy due to the processing of nuclei of the original target substance into ‘energy-favourable’ superheavy nuclei. The binding energy in the volume of the wave reaches its maximum. The leading front of the wave — the inner surface of the collapsing shell is contracted to a point, the wave collapses.

Phase 5. This is the final phase of the collapse of a wave-shell, degenerating into a microscopic spherical superdense bunch of electron-nuclear plasma (megaatom). The stored energy of the wave-shell is spent to achieve the ultimate density of matter-energy in the volume of the formed megaatom and the subsequent decay (clustering) of the ‘boiled’ electron–nucleon bunch into light, medium and heavy nuclei.

4. Conclusions

An analysis of literary sources with a description of interdisciplinary experimental scientific facts was carried out. A hypothesis is proposed about the influence of electromagnetic phenomena on diffusion processes during the formation of a welded joint. The formation of a welded joint occurs under the conditions of a complex effect of a large number of various factors [7]. The electromagnetic effect on the surfaces to be welded begins from the moment the pulsed electric current begins to pass. With the passage of a pulsed electric current at the points of contact of the surfaces to be welded, its density is high. There is an overheating of the substance of the welded surfaces. It is accompanied by thermionic emission. Melt bubbles form inside the metal. With further heating, an electric explosion occurs with the formation of a plasma gap and a micropinch. During the passage of an electric current, the plasma column is deformed with the formation of constrictions. Their radius is less than the radius of the main column. The magnetic pressure in the constriction area increases. Due to the action of the pinch, electrons flow with the formation of a ‘hot spot’ and a ‘Coulomb explosion’. High temperatures and pressures lead to the pyrolysis of the hydrocarbon substance. Carbon structures are formed in the form of ionized particles. These structures move to the central part under the action of the pinch effect [12]. A capsule containing carbon structures is formed there. When a pulsed electric current is passed, a ‘Coulomb explosion’ of the substance in the capsule occurs. The presence of such an explosion with the release of a substance is mandatory for obtaining a high-quality welded joint [12]. Explosive phenomena were accompanied by the release of magnetic monopoles [22, 25], which were recorded in the form of tracks on a photographic emulsion. These tracks had different sizes at different distances from the radiation source. Magnetic monopoles, when interacting with metals, contribute to a change in their isotopic composition. The authors of studies [25] consider this to be the result of magnetic-nucleon catalysis. A concept of a physical model of the shock compression of matter, a probable scenario for the initiation and evolution of the process was proposed [27]. This model may well correspond to the processes between the joined surfaces during the formation of a welded joint. Multiple exposures of the surfaces to be joined by microexplosions and the final ‘Coulomb explosion’ of the capsule create a large amount of low-power release of magnetic monopoles. This may be a determining synergistic factor in the formation of a welded joint. This makes it possible to explain the small time required for welding and the small deformations of the weld formation zone. The proposed hypothesis has no analogues. The hypothesis represents a promising direction for developers of welding equipment and formulations of substances used for welding.

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О.В. Жартовський[1], *О.В. Ларічкін*[2]
[1] Донбаська державна машинобудівна академія,
вул. Академічна, 72, 34313 Краматорськ, Донецька обл., Україна
[2] ПрАТ «Новокраматорський машинобудівний завод»,
вул. Олекси Тихого, 5, 84305 Краматорськ, Донецька обл., Україна

ЗВАРЮВАННЯ ТИСКОМ ЧЕРЕЗ ШАР ВУГЛЕВОДНЕВОЇ РЕЧОВИНИ: ЕЛЕКТРОМАГНЕТНІ ЯВИЩА В ПРОЦЕСІ УТВОРЕННЯ ДИФУЗІЙНОГО З'ЄДНАННЯ

Оглянуто та проаналізовано літературні дані стосовно експериментальних досліджень щодо впливу електромагнетних явищ на дифузійні процеси. На основі наукових фактів, викладених у міждисциплінарних експериментальних дослідженнях, запропоновано гіпотезу, яка стосується впливу електромагнетних явищ у процесі утворення дифузійного з'єднання під час зварювання тиском через шар вуглеводневої речовини. У стику, що зварюється, в початковий момент пропускання струму відбувається виділення енергії через вибух у точках контакту. Під час пропускання імпульсного електричного струму через продукти піролізи в мікрооб'ємах між з'єднувальними поверхнями вони також руйнуються. Утворюються йонізовані частинки. Через пінч-ефект вони переміщаються до центру зварювального стику. Там утворюється капсула з йонізованими вуглецевими частинками. У капсулі, розташованій в середині стику, відбувається Кулонів вибух. Багаторазові впливи на з'єднувальні поверхні мікровибухів у мікрооб'ємах між поверхнями та завершальний Кулонів вибух капсули створюють виділення великої кількости магнетних монополів. Це може бути визначальним і синергетичним чинником серед інших під час утворення зварного з'єднання. Це уможливлює пояснення малого часу, необхідного для зварювання та малої деформації зони формування шва.

Ключові слова: зварювання тиском, вуглеводневі речовини, електричний вибух, електричний струм, дифузія.