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Formation of chemical elements under superdeep penetration of lead microparticles in ferrous target

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Abstract. The results of experimental research of physical and chemical transformations in a ferrous target, caused by intensive deformation mobility of its structural elements for times of shock-wave treatment (~10^{-3} sec), at simultaneous development of process of superdeep penetration of lead microparticles are represented.

Introduction

Superdeep penetration is registered in case if a microparticle penetrates into a metal barrier on depth more than ten own sizes and then formed channel (crater) is collapsed (closed) after a microparticle. The physical and chemical features of superdeep penetration results consist in formation in a target of the channel zones or new structural elements, which including new formed phases and areas of the microstructural transformation in a target material. The activity of the chemical reaction passing between the target's elements and penetrable particles is conditioned mainly by two reasons. 1 – deformation mobility of the target material components arising due to the high concentration of the dislocation, vacancies and other defects of the crystal structure; 2 – formation in channel zone of dense high-temperature plasma, arising in the process of the superdeep penetration [1]. Basically, these two reasons are "distension" of chemical bonds in target and influence of the charged particles of plasma on bonds breaking in the target structure. Long (to 0,4 ms) and stable existence of plasma is caused by that the time of receipt of new charged particles - dissociation products in a channel zone does not exceed a time necessary for their relaxation.

Renewal of plasma structure during movement of a microparticle is realized due to entry in a zone of the charged particles while the microstructure of a target will be in a condition of deformation mobility (thermodynamic instability) [1]. Depth, on which microparticles penetrate, depends from many factors, including equilibrium condition between the incoming charged particles and the particles leaving this zone. The superdeep penetration is accompanied by intensive electromagnetic radiation (energy value 200-250 MeV), and X-ray radiation (energy value 80-200 MeV), which testified the movement of the concentrated powerful electrical charges [3-5].

Chemical reactions are essentially intensified; phase changes actively proceed during high-energy mechanical action in materials [5-7]. Synthesis of new elements at use of actual technological processes, except for interest for fundamental science, has great practical value.

The purpose of the given work is experimental investigation of elements formation in metallic iron during the SDP process.

Materials, technique, experiments

The throwing microparticles have been made from lead. The sizes of particles were 10^{-5} – $5\cdot10^{-4}$ m. The targets made of steel (admixtures C ≤ 0.25, P = 0.07, S = 0.06; the remainder Fe), had the shape of the cylinder at which diameter and height were equal accordingly 40 and 200 mm. Average speed for clot of particles at impact about a surface of a target was ~1000 m/s. Explosive with the detonation speed 3650 m/s as a power source was used. The dynamic alloying of a target material by lead microparticles implemented in conformity with the scheme – fig. 1 and a technique of realization of the experiments [8].

The microstructure and chemical compound of materials were researched before and after treatment by means of an optical microscope "Polivar" and a microscope "Com-Scan" with an analyzing micro-X-ray adapter. The contents and quantity of chemical elements researched by means of electronic micro-X-ray spectral analyzer "Nanolab-7 ".

The scheme of superdeep penetration of microparticle in a metal target is shown on fig. 2. Behind a moving particle at impact of plasma flows (point 3) two opposite directed jets are formed. Masses and velocities of these jets depend on an angel of a meeting of flows. Increase of density of own energy of flow occurs (point 3) due to formation of group of local points (plasma focuses), having ultrahigh density of substance. These points are the most probable sources of formation of new elements. The synthesized isotopes of new elements are confirmation of nuclear interactions. Such changes of an element composition are registered at microprobe analysis of a material in the central part of "channel" zones (tab.1).

Some photos of microstructure of steel target with the residues of the penetrated microparticles on various depths are shown on a fig. 3. The chemical composition of microparticles and new formed phases in a channel zone is analyzed simultaneously.

Various isotopes of chemical elements (abundances of elements in initial materials) are registered depending on chemical composition of pair materials interacting in SDP mode – penetrating microparticle and a target. The most contain of manganese (up to 45 mass %) is observed at use of pair Pb + Fe and Fe + Fe. Manganese (up to 30 mass %) also has been found out in alloys of iron at action high-temperature (up to 1 keV) plasma jets in explosive generators of closed type [2,4]. Concentration of sulfur related to manganese in a zone of interaction is always less and is proportional to its contents.

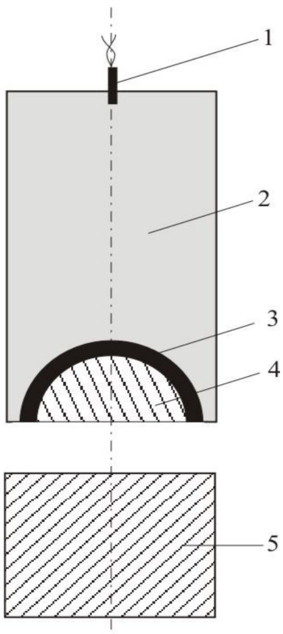

Fig. 1. The scheme of the explosive accelerator for a throwing of microparticles: 1 – detonator; 2 – charge of explosive; 3 – metallic shell of a cumulative cavity; 4 – microparticles; 5 – target

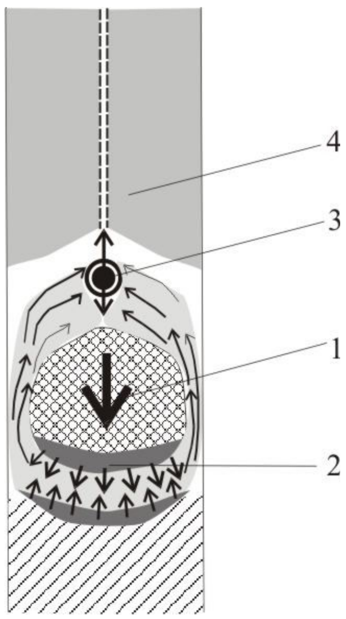

Fig. 2. Model of penetration of a particle in a target [1]: 1 – microparticle; 2 – plasma; 3 – area of impact of plasma flows (plasma focus); 4 – channel structure

Table 1. The contents of chemical elements in the channel zone of a ferrous target after a dynamic alloying by Pb microparticles

№ sample	Chemical elements, %							
	Ti	Cr	Fe	Al	Mn	S	Cu	Pb
1.1 (fig. 3,a)			28,61	13,99	39,17		0,55	
1.2 (fig. 3,b)	0,31	0,18	43,83	0,00	30,39	25,01	0,28	
1.3 (fig. 3,c)			41,64	0,22	45,74		0,12	
1.4 (fig. 3,d)				0,03	40,00		0,54	

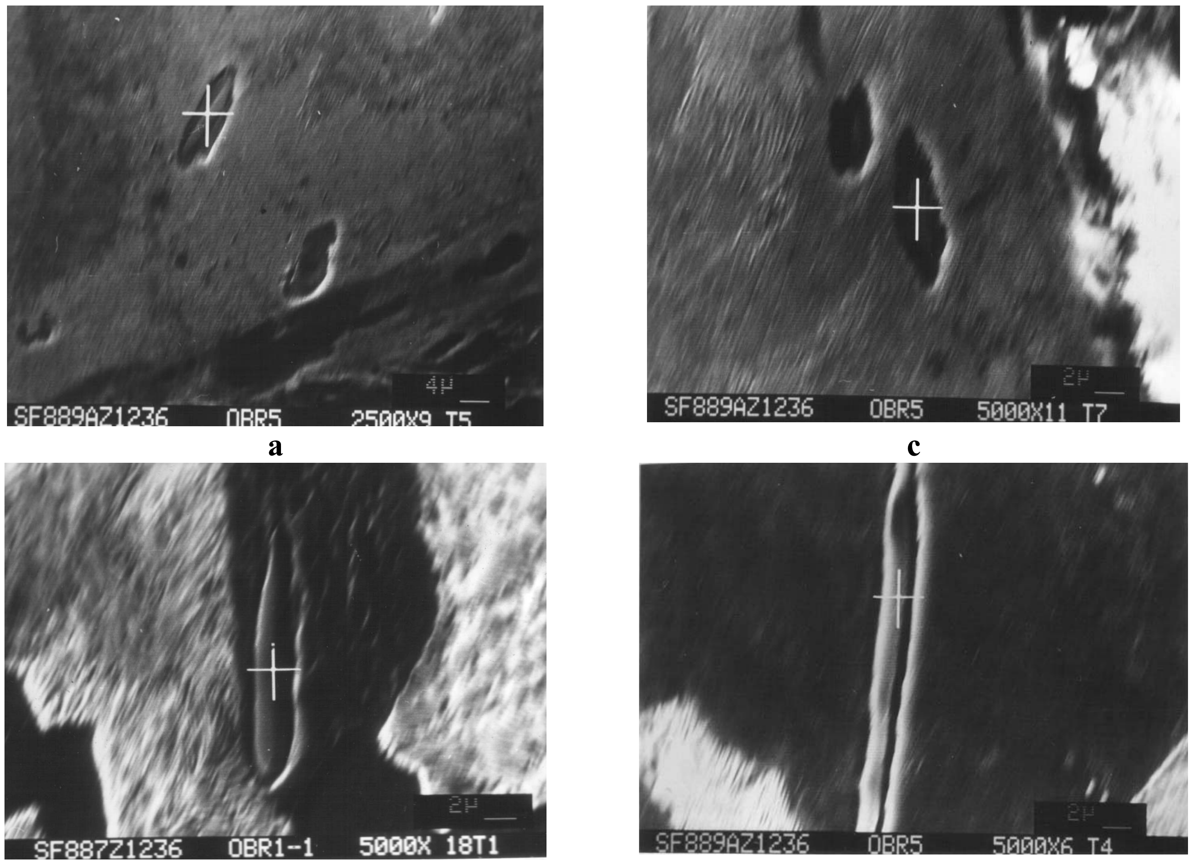

Fig. 3. Structures of steel targets with channels and the residues of the penetrated particles after treatment by lead microparticles in the SDP mode: **a** – a sample 1.1, ×2500; **b** – a sample 1.2, ×2500; **c** – a sample 1.3, ×5000; **d** – a sample 1.4, ×5000.

The brief analysis of experimental results

The structural element - the channel zone, generated as a result of microparticle penetration, is defined after etching and to be above a metallographic specimen plane. New structural elements (NSE) pierce all volume of a steel matrix by all its height. Concentration Mn near to a surface in NSE less than 13 mass %, and it decreases in 13.7 times from the center of NSE to walls of the channel. Obviously, that the entered substance is braked on depth in local zones of channels. Thus entered substance and arising in these zones Mn are precisely localized in a channel zone with a diameter 2-12 microns and length in tens millimeters.

Lead (Pb) serves as a marker at use of working substance on the basis of lead (fig. 3). Presence in a channel zone of this marker serves the unambiguous proof of that change of a chemical compound in this zone is result SDP. Therefore, only in point **b** (tab. 1) the increased concentration of manganese has no proofs of high-energy interaction. A typical feature of this anomaly is high concentration of sulfur – 18-25 mass %. If to make an assumption, that in these zones alloy Fe-Mn-S is received then this material has the increased resistance to wear and friability related to Fe. Alloy Fe-Mn-Pb having high resistance to wear and strength in other points can be formed. Such alloy is an effective strengthening material for structural elements. High maintenance Mn in zones of channels with confidence allows to predict increase of resistance to wear of the processed iron. Thus we do not consider additional technological capabilities for control of structure and properties of the composite material created at SDP.

Conclusion

1. Characteristic changes for superdeep penetration of phase composition of structural changes in local zones of a ferrous target are revealed, comparison of their chemical compound with an initial material is spent.

2. In a volume of a ferrous target at superdeep penetration there are new structural elements which consist of entered substance of microparticles, a matrix material and products of their interaction, and new chemical elements, which were absent in the initials materials. The composition of new formed phases cannot be described by known diagrams of condition and represents metastable compound of a variable composition.

3. Use as a marker Pb, absent in a target material, allows to identify new elements of structure, which formed as a result of physical and chemical interactions between of entered substance and a matrix material.

3. It is established, that manganese has the most concentration (up to 45 mass %) in channel zone. It is supposed, that isotopes of Mn formed from iron. Transmutation of an iron and formed new chemical elements are proof of realization of nuclear reactions at the SDP.

4. Alloying of a microstructure of a ferrous target by Mn at the SDP determines the essential increase of the resistance to wear due to the formation of the composite material.

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