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THE DEVELOPMENT OF EXPLOSIVE METALWORKING IN POLAND

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The author coordinated the research in Poland by the collaboration with civil and military scientific and research centres. In result they elaborated detonation process of spraying coats designed and constructed stands equipped with detonative devices, they also elaborated the techniques of basic coating parameter measurement and built devices for commercial and scientific services.

In the research the author's achievements within the range of explosive welding have been used. The experience of the scientific teams was very effective. It was observed that many phenomena that take place in the processes of detonative layer coating and explosive welding are the same. In order to obtain a required connection the plastic strain of the connected material surfaces has to be achieved and cumulative flows have to be formed. There are a similar range of the connecting process conditions and the mechanisms of plastic strain.

The highest connection strength is obtained when an intermediate zone is formed. The zone has to be composed of the two connected materials. The intermediate layer is formed as a result of mechanical alloying of the materials due to large plastic strain. The plastic strain leads to forming meta-stable phases that have properties of pseudo solid solution, chemical compounds, intermetallic phases and fragmentation corresponding to nanomaterials and amorphous states.

Keywords: detonation, spraying, explosive welding, plastic strain, explosive metalworking

W Polsce, pod kierunkiem Autora, przy współpracy z instytucjami naukowo-badawczymi, cywilnymi i wojskowymi, opracowano: detonacyjny sposób natryskiwania powłok, zaprojektowano i wykonano stanowiska wyposażone w urządzenie detonacyjne, techniki pomiarowe podstawowych parametrów strumieni natryskowych oraz urządzenia do prowadzenia usług komercyjnych jak i do prowadzenia prac o charakterze naukowo-badawczym.

W pracach badawczych wykorzystano dorobek Autora z zakresu zgrzewania wybuchowego metali. Doświadczenia zespołów badawczych okazały się niezwykle efektywne. Udowodniono, że w procesach nakładania powłok detonacyjnych i zgrzewania wybuchowego, występuje wiele wspólnych zjawisk. Podstawowym warunkiem uzyskiwania wymaganego połączenia jest odkształcenie plastyczne warstw wierzchnich zderzających się materiałów z formowaniem strumieni kumulacyjnych. Istnieje podobny zakres warunków łączenia i podobne mechanizmy odkształcenia plastycznego.

1. Introduction

The main feature of materials explosive processing is the use of the high pressure induced by collision velocity of bodies powered by energy of explosive materials or flammable gases detonation combustion. Value of induced pressure, its distribution in the loaded material and duration have primary importance in achieving physical changes in materials. They set the ranges of materials processing.

Behavior of materials under dynamic loads, the physical and chemical phenomena which occur during the process prove the existence of a specific field of materials science. In this range the role of diffusion processes is significantly reduced and the importance of abnormal mass transport is increased, particularly in the areas of the energy accumulation induced by collision velocity. During operation conditions with a very high pressure electron shells are rebuilt, it is possible the formation of metastable phases, a new kind of plastic deformation at a rate of more than $10^4 s^{-1}$ and others. As a result, high local pressures create conditions of possibility of obtaining new varieties of materials that are difficult or impossible to obtain by conventional methods and the use of a new technological processes of materials processing.

2. The achievements of Polish centers of a fundamental nature

A distinctive contribution of Polish centers to the development of discussed issues may include the follwing:
- the implementation of several postdoctoral works,
- conducting more than 50 doctoral dissertations,
- publishing hundreds of works in various journals,
- including journals in the JCR database,

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– delivering dozens of papers at national and international conferences.

In the Institute of Plasma Physics and Laser Microfusion were conducted studies on laser compression of the plasma. The essence of this study was explosive combination with each other and compression of D-T with followed additional laser compression. There have been elaborated methods of shock wave energy accumulation induced by detonation of explosive materials including the method of spatial stimulating of explosive charge detonation combustion and methodology for measuring the effects and behavior of materials under pressure, which extend at least terapascal and materials which enhance several times its density with respect to the starting material.

Shortly after the Second World War, Institute of Precision Mechanics (IMP) undertook the study of physical processes of formation of cumulative jets and their penetration into the substrate. In this way IMP turned to solving the current problem which was to obtain the cumulative bullets with extremely high efficiency measured by penetration depth. In subsequent years, the issue was conducted by the research unit of Polish Army. The issue of the formulation of the cumulative streams is still the subject of the research conducted in Polish research centers. The connection between the material as well as the geometry of the cumulative inserts and the non-continuous turbulent stream flow is still under detailed analysis. There are also conducted some works which give the verification to the idea which was formulated at the end of last century, concerning the process of streams formulation, their penetration into the surface and strength parameters of the material on the basis of the hydrodynamics laws.

3. Achievements in the development of technological processes

Plastic forming of materials

Plastic processing that uses combustion energy MW was developed in the Institute of Precision Mechanics in the middle of the last century. This technology was used in the railway production plants, in the chemistry industry, energy and others. A major achievement was the development of unique design water tank with inclined walls, which resulted in that the detonation wave generated air flow which was damping the explosion energy.

Explosive welding of metals

The achievements of members of the Institute of Precision Mechanics in the field of construction of cumulative bullets allowed, in a very short period of time, to master the process of explosive welding of metals. The basis of this work was the assumption that the explosive welded materials are in the solid state, including the zone of the greatest pressure. The basic condition for creating the connection is the plastic deformation of both surface layers of bonded materials. Impact velocity is selected in such a way that induced pressure is arousing plastic wave with velocity greater than the velocity of contact point.

Unfortunately, despite the positive results of the welding of austenitic stainless steel plates with carbon steel, with following rolling operation and production of containers made with this material for the plant fertilizer producer, technology has not found wide industrial application.

Regardless of the work of the IMP, explosive welding was carried out at the Institute of Welding Gdansk University of Technology. Studies carried out by this Institute found particular application in the shipbuilding industry.

Other technological processes

In the eighties of the last century the Institute of Plasma Physics and Laser Microfusion obtained positive results of implementation of machined elements made of powder materials.

The Military University of Technology developed a process for the diamond synthesis of dense varieties of the boron nitride and impact strengthening of machine elements such as the strengthening of the outer layers of beaters for crushing coal and strengthening of rail turnouts. Developed processes have not found interested users.

Institute of Heat Engineering developed the explosive technology of tubes mounting on strainer heat exchanger bottoms and effectively implemented this technology into industrial practice in Boiler Factory (FAKOP) in city of Sosnowiec.

Studies on the issues of combined technologies of explosive plating with subsequent plastic forming were led by Czestochowa University of Technology with Military University of Technology since the eighties of the last century. In 1980, at the International Conference in Budapest, Warsaw University of Technology students presented an original way of explosive welding of amorphous metallic copper alloys with steel alloy. A characteristic feature of this combination is that fact that this kind of alloys show very little deformation.

4. Detonation spray coating method

At the end of the last century on the initiative of IMP employees attempts, to develop the technological process of spraying coatings formed by detonation combustion of flammable gases, have been made. Originally designed and constructed detonation device was made and used in a spray coating process, in particular for regeneration and other coatings with specific properties.

The most important achievement of this center, dealing with discussed issues, was the development of a station with original measuring technique. Further achievement was to prove that the greatest strength of the coating-substrate connection is obtained in a case where the intermediate zone is formed consisting of surface layers of both joined materials. The intermediate zone is formed by mechanical alloying, due to the large plastic deformation of materials. In the intermediate zone can take place mechano-chemical synthesis, chemical and physical interaction of the components of the substrate and coating materials that lead to the formation of new phases: solid solution, chemical compounds or intermetallic phases, crystalline or amorphous state. ‘High energy’ plastic deformation changes the thermodynamic properties of the alloys with limited solubility, which can show unlimited solubility after such deformation.

An industrial center in the city of Opole has been active in the development and implementation of explosive coating since the early eighties of the last century. Developing new

products and further technologies took place in the early years of in cooperation with the national science. This traditions is continued by the company from the city of Opole which in year 1990, which successfully emerged from the ruins of the national company. Development and industrial application of explosive coating technology has is therefore over 30 years-old of tradition in Poland and a dimension of dozens of processes and products.

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