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Principles of Integrative Modelling at Studying of Plasma and Welding Processes

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ABSTRACT

The relevance of the problem subject to the research is conditioned by need for introduction of modern technologies into the educational process and insufficient adaptation of the higher school teachers to the applied information and automated procedures in education and science. The purpose of the publication consists in the analysis of automated procedures efficiency in engineering training and development of structurally functional model of information skills for students and teachers during their teaching in welding and allied technologies. The leading approach to research of this problem is the structurally functional method of the objects studying. This method based on representation of technological structure as hierarchical sequence of the interconnected devices and division of a matter into objects and means of influence that allows to allocate the processes providing functioning between means of influence. In the publication the structurally functional models of information skills formation for students and teachers in engineering and natural-science training are presented. The materials of the publication can be useful for students and teachers at studying of welding and allied technologies and development of scientifically-methodical maintenance for engineering and natural-science disciplines.

KEYWORDS
Designing, model, information, automation, plasmatron

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Introduction

Use of the information and automated technologies in the modern education where the engineering teaching becomes more significant, means not only their application in technologies of training, but also acquisition of knowledge about their role at all stages of life cycle of studied industrial processes. Any technology, as is known (Orlov, 1988), in the development passes some stages - from designing up to a production cycle. The knowledge got trained, should be

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based on the saved up experience of system application of the automated means and methods at all technological stages of designing and to consider last development, allowing to raise efficiency of all studied procedures (Lisovsky, 2006). In a wide number of the processes with the big innovative potential a fitting place occupy the electric plasma technologies (EPT), based on application of low temperature plasma generators - plasmatrons or plasma torches (Zhukov et al., 1999). Studying of such technologies, means and methods of their designing and automation is necessary for the majority of the students, specializing in welding and allied technologies, metallurgy and mechanical engineering.

For the study of plasma processes physics in the modern standard of vocational training the small amount of time is allocated. For this reason the teacher, having illustrated the basic properties of plasma, as a rule, has time to mention only concrete technologies and devices in which properties of this condition of matter (plasma and MHD generator, displays, devices of thermonuclear synthesis) are used. However, approaching to a problem of teaching in the Higher school the natural-science disciplines it is necessary to pay attention to innovative pedagogical technologies among which the idea of introduction the integrating courses into the student teaching (Gapontseva et al., 2001) is interesting. In these courses the models of continuous natural-science education of various integration levels are constructing by allocation and ranking of the general concepts. In this connection, it is necessary to pay additional attention to the description of such device as plasmatron, that will allow to enter organically it, as integrative physical model not only into the programs of similar intersubject courses, but also in existing programs of physical, professional («Modellingof technological processes and systems», «Welding technology and equipment», etc.) and general scientific disciplines (for example, «Concepts of modern natural science»). Now the considerable quantity as special (Cherednichenko, Anshackov & Kuzmin, 2011; Kaydalov 2007), and the educational literature (Kurnaev, 2008; Orlov & Dorozhkin, 2005) is published, but, nevertheless, some elements of this model remain, as a rule, beyond the framework of consideration, not allowing to integrate it widely enough into educational process.

Authors save up wide experience in the area of plasmatrons designing and application in various EPT (Anakhov & Pyckin, 2012). The special priority during the mentioned elaborations was directed to the plasmatron designing for metal cutting (Anakhov, 2014). The analysis and generalization of the data which have been saved up during research of the modern market of metal cutting plasmatrons, testifies, that domestic plasma cutting technologies are less competitive not only in comparison with foreign, but also in relation to other cutting processes (laser, mechanical, hydroabrasive) which also have the potential of introduction, especially for small thickness metals cutting. To overcome this backlog it is possible due to designing new highly effective plasmatrons with application of the automated methods at all stages of a design cycle. Students and teachers erudition in main principles of integrative models application during designing - the essential factor of a learning efficiency in the disciplines connected with electric plasma and welding processes.

Materials and Methods

During the following methods were used:

— theoretical (a structurally functional method for study of technical objects);

— diagnostic (gas-dynamic and thermo physical analysis of plasmatrons);

— empirical (nondestructive check and metallography);

— experimental (acoustic measurements);

— methods of mathematical statistics and a graphic presentation of results.

The experiment and research study were carried out on the basis of Russian State Vocational Pedagogical University, Ekaterinburg in which the scientific investigations in plasma technologies were conducted in the small investment enterprise of Open Company "TERUS" (director - S.V. Anakhov). Technological tests of plasma equipment and technologies, designed on the basis of the considered in this publication researches, also were conducted in the enterprise "Polygon", Ekaterinburg.

The experiment and research study were carried out in four phases. At the first phase were carried out numerous researches on a problem of plasma technologies safety which results were used for designing of new metal-cutting plasmatrons with the lowered level of noise emission. At the second phase the experience of this plasmatrons operation allowed to formulate main principles and methods of their designing from the point of their efficiency view. At the third phase the special attention during the new plasmatrons elaboration was directed to the use of computer-aided design on the basis of various integrative models. At the fourth phase the experience of plasmatron designing was generalized, systematized and adapted for the educational requirements.

Results

Construction of the integrative physical model «plasmatron»

Construction of the physical model begins with the direct description of technical device and definition of corresponding concepts.

Electric plasma technologies (EPT) - one of modern effective tools for materials processing by concentrated streams of energy. Creation of plasma electrotechnical installations - the priority directions of development for a lot of corresponding industrial branches. Such installations use a transformation of electric energy into the thermal in various kinds of gas electric discharge, carried out in the low temperature plasma generator – plasmatron or plasma torch. The device has been invented in the beginning of aXXth century alongside with the first discoveries in the plasma physics and technology of plasma generation. Now the wide spectrum of plasmatrons for various technological needs is issued: first of all - for metal cutting, and also for welding, sputtering, heat and plasmachemical treatment, afterburning of waste harmful gases, etc. It is obvious, that all technologies of plasmatrons application are based on the effect of high-energy influence on materials in the various phase structure arising in a temperature range of plasma arc (jet) (≈3 thousand up to 25 thousand K). In spite of the fact that there are the constructional features in different plasmatrons, providing the necessary technological parameters of process, the general principles of transformation of energy and matter are identical.

In this publication the technological scheme of plasma cutting of metals by jet plasmatron will be considered. Standard elements of such scheme are: the power supply, system of plasma gas preparation, the closed system of water cooling and plasmatron, transforming material and power streams into the energy of low temperature plasma jet for the influence on metal. In case of the other technologies use into the scheme the additional elements may be added for providing receipt into plasmatron the matter of various phase structure (powders, gas-vapor mixtures, neutralized gases, etc.), selection of treatment products, working control of devices, etc.During the exploitation of such scheme the manual or automatic control of parameters of process - current strength (I) and voltage on the arc (U), consumptions of water and gas (Q), temperatures (T) and pressure (P) of gases on an input, and sometimes and on an output of the scheme should be carried out.

Interrelation of the processes providing stable performance of corresponding technological procedure, it is convenient to consider, having resorted to a structurally functional method of training and scientific researches (Zhuravlyov & Shevchenko, 2007). Basis of this method is a representation of technological structure as hierarchical sequence of the interconnected information devices that allows to consider various technologies as equivalent in information sense and to optimize them, using principles of cybernetic management. Division of a matter into **objects of influence** (mass, energy and the information) and **means of influence** (material-power complexes) allows to allocate the processes providing movement of a matter between means of influence. Let's pay attention to separate blocks of this technological scheme of plasma cutting, having considered them about the opportunity of inclusion into the educational process.

As **objects of influence** in any low temperature plasma technology there are the electric power and the matter, entering into the plasmatron in various phase conditions (plasma gas, cooling water, powders, gas-vapor mixtures) and with different, but nonzero energy (under pressure). Objects of external influence are also the solid-state materials - in technologies of plasma cutting, welding, deposition. The description of physical properties of these objects, obviously, at once opens a wide panorama of the environment and their material-power structure.

Receiving and transfer of materials and energy occurs by technological channels from corresponding technological systems into the plasmatron. At these stages there are necessary descriptions of processes on the base of aero- and hydrodynamics laws, the theory of electric circuits of direct and alternating current (with a different degree of immersing in a theoretical material, depending on specificity of course and training contingent).

In the plasmatron processes of **treatment and interconversion of materials and energy** are carried out. The purpose of modeling for air-gas path (AGP) of plasmatron is minimization of aero- and hydrodynamic losses of plasma gas, and also maintenance of conditions for stabilization of burning arc in an interelectrode space. Kinetic energy of a gas stream at its passing through the swirl port is partially transformed to energy of the ordered rotary movement for arc stabilizing, and partially - to energy of turbulent pulsations of a stream. Excitation of the gas discharge in the interelectrode space and the subsequent transfer of electric energy to the arc provides a plasma jet generation at the output from the plasmatron nozzle (under condition of stable submission of plasma gas). At this stage it is expedient to consider conditions of power balance by the known calculation procedures of plasmatron performance index (Zhukov et al., 1999). It is useful to pay attention in this case not only on the thermal losses, but also on transition of the certain part of energy in energy of acoustic vibrations and radiating emission, causing negative effect of influence on the working personnel. The special attention should be turned on phase transformations occurring at this stage in conditions of high-temperature influence: plasma gas conversion into low temperature plasma and physical and chemical conversions of matter feeding into the plasma arc. Plasma state of matter, occurring at this stage, gives a wide opportunities for its properties consideration on an example of a plasma arc (jet) both at a qualitative level, and on examples of concrete calculations (a degree of ionization, temperatures, velocities, componential structure, etc.).

Influence on external object occurs in the majority of plasma technologies by high-energy thermal-kinetic influences on a workpiece. Besides consideration of the conditions providing appropriate effect (fusion or surface modification at the certain temperatures and speeds of plasma jet moving, temperatures and speeds of particles of evaporated or implanted materials) it is necessary to pay attention to the negative factors arising at work of plasmatron - high noise level (up to 120-130 dB), radiating emission and presence of harmful aerosols and gases (at work with doped alloys and toxic gas mixtures). By consideration of a noise problem it is useful to take into account the author's plasmatron model as resonant acoustic radiator (Anakhov & Pyckin, 2012) in which AGP of plasmatron is represented as oscillatory system, consisting of acoustic masses in wide areas and rates in narrow areas of AGP. Consideration of the questions connected with protection against the above-stated harmful factors, and also with plasmatron application in nature-conservative technologies, will be, undoubtedly, interesting to experts and students in ecology and safety field.

Stable work of technological scheme is impossible without corresponding **influence on** itsseparate **elements**, providing the control and optimization of technological and physical parameters of processes, and also serviceability of the operated equipment. Such influence should be carried out as during work (manual or automatic), and at a stage of the preliminary theoretical analysis and designing of technology. The ideas of the complex, integrative approach, considered in this publication, can help as directly development contractors, and students, learning the bases of engineering designing.

Modelling in plasma technologies designing

Consideration of the integrative modelling principles used at studying physics of plasma processes allows to pass to studying the modelling principles applied at designing of plasmatrons and plasma technologies. Among all variety of applied at designing methods we shall pay special attention on the **formalized (automated)** procedures. Wide use of such procedures, minimizing influence of the human factor on received result, - prominent feature of modern designing. The area of their application, including designing in area of plasma technologies also extends. For use of the formalized procedures at the technical device designing the knowledge of the basic laws, defining achievement of the requisite value of purpose parameter, an opportunity of modelling of corresponding objects, processes and the phenomena is necessary. In this case there is an opportunity of algorithmization of designing procedure on the basis of schemes, functional and parametrical dependences, conventional attitudes-logic, etc. for their subsequent use in human-machine system.

Formalization of control by designing process of plasma technologies and the equipment can be carried out on the models of attainments basis (Lisovsky, 2006). There are four kinds of such models.

As the first kind **I&R models** in which are generalized experience and attainments of the designer on the various technical disciplines, concerning the subject environment of designing, are considered. Such generalizations, in turn, represent a database generated from models of lower level, leaning on the concrete objects (for example, classifications of plasmatrons and their elements), procedures and the phenomena considered during designing. For algorithmization of designing procedure the procedural models of sequence of the design tasks solutions are formed. The structure of procedural model, in turn, includes models of two types: **object-oriented design modelsof attainments** and **models of decision-making**. The first are formed on the basis of I&R models in the form of special information units and intended for the solution of separate stages of a design task according to the sequence, set by algorithm. Models of decision-making allow to formalize reasonings of the designer on the purposes, criteria, methods, opportunities, reliability, adequacy of a solved task and represent, as a rule, procedure of multi criterion optimization in conditions of uncertainty (rationalization). For comparison of the various parameters expressed in various physical units it is possible to use some universal measuring systems in the form of scales (function of an accessory, a degree of conformity, a probabilistic, percentage or verbal scale) - so-called **models of scales of values**.

Models of the solutions search functionate on the basis of application of automated alternative methods. Basis of such methods is analytical or numerical search of concrete variants for various admissible combinations of parameters. Thus, as a rule, the greater number of variants allows to receive the best final solution. Really, as a rule, use methods (algorithms) of the simplified search - partial (selective) search and reduction of the search area. In the first case use the determined methods, allowing to choose parameters according to some law, and methods of accidental search. For the decision of such retrieval tasks use, as a rule, mathematical methods of the probability theory and the correlation analysis. The opportunity of the analysis of the additional information, received at calculation of the previous variants, allows to realize the techniques of area of search reduction. For illustration of applicability of such methods to plasma technologies designing one can mention the procedure for definition of the parametrical parities criterion, consisting in a choice of essentially important constructive and technological parameters with the subsequent establishment between them the functional attitudes.

One of the most radical means for modernization of designing procedures is introduction of the automated methods of the integrated information technologies on the basis of use of modern computing means and network solutions. It is necessary to carry systems of the automated designing to such technologies, the engineering analysis, technological preparation and manufacture (system CAD/CAM/CAE - Computer-Aided Drafting, Manufacturing and Engineering), and also management of the industrial information (PDM - Product Data Management). In plasma technologies, as usual, apply machine-building CAD systems, intended for development of details and mechanisms on the basis of parametrical designing their constructive elements, technologies of superficial and volumetric modelling (the COMPASS, Solid Works, CATIA, Autodesk Inventor, etc.). Integration CAD, CAM and CAE systems in new technology of computerized integrated manufacture CIM (Computer-Integrated Manufacturing) can make process of designing and manufacture in plasma technologies the uniform automated and highly effective working system.

During the automated designing it is necessary to optimize a design construction. Now there is a plenty of the software intended for these purposes. However, means of automatic definition of a construction by association of the analysis and optimization now are still insufficiently developed and applied, as a rule, only for simple objects of the lowered dimension. With reference to procedures of designing in plasma technologies it means iterative application of optimization methods at a stage of the analysis of the CAE-system working results with the subsequent geometrical or parametrical updating in CAD subsystems. Nevertheless, the important advantage of methods of the analysis and optimization of a construction is the opportunity of early revealing of designing mistakes (before creation and research of the real prototype), and, hence, essential reduction of designing costs.

The principles of integrative modelling in plasma and welding processes, formulated in this publication, promoted the elaboration of new plasmatrons for precision cutting of metals with essentially new systems of gas vortex stabilization for plasma arc. As the researches, carried out by authors, show, the efficiency of their application does not concede to the best import samples on parameters of cut quality, productivity, energy consumption and safety. Training to main principles of integrative modelling can become the essential contribution to increase of educational process efficiency in the area of welding and plasma technologies.

Discussions and Conclusion

The idea of integrative models introduction in education was offered earlier (Gapontseva et al., 2001; Kotlyarova, 2015), however it was applied, basically, to teaching disciplines of universal character - mathematics and physics. Offered to consideration in this publication the integrative physical model «plasmatron» can become the element of various integrative courses and essential illustrative addition to known elective courses by plasma physics and plasma technologies (Kurnaev, 2008; Orlov & Dorozhkin, 2005).Approaches offered in the publication supplement known principles of mathematics integration with various parts of natural-science and humanitarian knowledge (Zakirova & Shilova, 2016).

Studying of designing foundation on the basis of various integrative models and technologies of plasma cutting allows essentially to expand system principles of plasmatron designing (Lisovsky, 2006) and known methods of their application (Cherednichenko, Anshackov & Kuzmin, 2011).

Complex consideration of physical aspects of integrative model **«plasmatron»** functioning will be useful for training by physical and engineering profession of electric power, metallurgical and ecological specialties.

Illustrative elements of this model should cause interest at students-humanists studying natural sciences by discipline «Concepts of modern natural sciences».

Application of the principal guidelines of automation in procedures of plasmatron designing, considered in this publication on the basis of various models and forms of algorithmization, allow to raise essentially both quality of educational process and efficiency of plasmatrons use in various industrial technologies.

Disclosure statement

No potential conflict of interest was reported by the authors.

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References

Anakhov, S. V. & Pyckin, Yu. A. (2012). *Plasma torches: the problem of acoustic safety. Thermophysical and gas dynamic principles of design of low noise plasma torches.* Ekaterinburg: RIO UrO Russian Academy of Sciences, 224 p.

Anakhov, S. V. (2014). *Principles and methods of design in electric plasma and welding technologies*. Ekaterinburg: Publishing house of the Russian State Vocational Professional University, 144 p.

Cherednichenko, V. S., Anshackov, A. S. & Kuzmin, M. G. (2011). *Plasma electrotechnic installations.* Novosibirsk: Publishing house of Novosibirsk state technical university, 602 p.

Gapontseva, M. G., Gapontsev, V. L., Tkachenko, E. V. & Fedorov, V. A. (2001). "Natural science" as the integrating factor of continuous education. *The Education and science journal, 3,* 3-18.

Kaydalov, A. A. (2007). *Modern technologies of thermal and remote cutting of constructional materials.* Kiev: Ecotechnology, 456 p.

Kotlyarova, I. O. (2015). University teachers' readiness to apply the modern educational technologies. *The Education and science journal, 1,* 103-114.

Kurnaev, V. A. (2008). *Plasma-XXI century.* Moscow: Publishing house the Moscow engineering-physical institute, 80 p.

Lisovsky, S. M. (2006). *System integrator designing of electric plasma technologies and equipment* (Doctoral dissertation).Saratov state technical university, Saratov, 405 p.

Orlov, P. I. (1988). *Foundations of designing.* Moscow: Mashinostroeniye, 560 p.

Orlov, V. A. & Dorozhkin, S. V. (2005). *Plasma - the fourth condition of matter.* Moscow: Laboratory of knowledge, 144 p.

Zakirova, V. G. & Shilova, Z. V. (2016). Integrative Connection of Mathematics and Economics. *IEJME-Mathematics Education, 11(8),* 3021-3036.

Zhukov, M. F., Zasipkin, I. M., Timoshevsky, A. N., Mikhailov, B. I. & Desyatkov, G. A. (1999). *Electricarc generators of thermal plasma.* Novosibirsk: Nauka, 712 p.

Zhuravlyov, V. F. & Shevchenko, V. Ya. (2007) *Structurally functional method of technical objects and researches studying.* Ekaterinburg: Publishing House of the Russian State Vocational Pedagogical University, 90 p.