The use of artificial intelligence to control the processes of welding and direct arc growth under the influence of disturbing factors

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Abstract. We develop a method to improve the quality of welded joints and process performance in arc welding and direct arc growing under the influence of disturbing factors based on the use of artificial intelligence.

Keywords: Welding process, direct arc cultivation, adaptive system, control algorithm, artificial intelligence, disturbing factors, quality of welded joints

Introduction

In the modern world, the increasing production rate and desire to ensure the quality of the goods produced lead to the need of developing new scientific and engineering solutions in the field of applied technologies and welding equipment.

The development of new production methods for critical structures is currently an important issue for all branches of engineering. Progressive additive technologies and modern digital production create natural conditions for the transition to a qualitatively new level of technical equipment. The widespread introduction of additive technologies is prevented mostly by the high cost of equipment, the need to develop new materials, low reproducibility of results, and the lack of a standard terminology. Overcoming these obstacles and ensuring the economic feasibility of manufacturing single products of any shape are the motivation for using artificial intelligence for direct arc growing products [1].

In recent years, the volume of welding and assembly work at open assembly sites has been increasing. The need to use advanced methods of mechanized and automatic welding in shielding gas is obvious, but the effect of disturbing factors, including climatic factors, makes them difficult to apply. The complexity of the welding process under the influence of disturbing factors complicates its adjustment by the welder [2].

With additive direct arc growth, there are problems of obtaining uniform surfacing and determining the process modes that grow with the increase in the geometric complexity of the product being manufactured. This leads to the emergence of a new direction in the field of automatic welding processes – adaptive and intelligent methods for building control systems [3].

Currently, adaptive and intelligent control systems are becoming more common in the automation of production in the field of light and heavy industry. Intellectualization and automation of control systems is necessary for solving problems under the influence of constantly changing disturbing factors, allows to improve the quality of manufactured products and increase labor productivity [4].
Artificial intelligence can be defined as the property of an automatic device or a network of neuron-like elements to respond to information arriving at its input devices in much the same way as a person reacts in such informational conditions [5].

Adaptive control systems with elements of artificial intelligence are based on optimization algorithms, search, classification and clustering. Expert systems and fuzzy decision support systems can be used as the intellectual component in such systems. They allow the control system to make a decision on the change of the regulator parameters, depending on the influence of disturbing factors and control error.

The study of approaches to the intelligent control of welding processes is a comprehensive scientific and engineering challenge that combines the latest advances in the field of technologies and equipment for welding production, as well as the theory of automatic control. The successful solution of this problem, and in particular, in relation to the processes of arc welding in shielding gases, as well as arc production of products, requires the development of science-based approaches to the construction of intelligent welding systems with adaptive control.

In this regard, the aim of this work was to improve the quality of welded joints and process performance by developing and implementing intelligent control algorithms and applying artificial intelligence to the processes of arc welding and direct arc growing under conditions of disturbing factors.

The main task was to establish such control actions that would compensate the disturbances of the process and ensure the formation of a welded joint in accordance with the existing requirements.

With regard to the process of arc welding in shielding gases, the main conditions for obtaining high quality welded joints that comply with regulatory documents are reliable protection of the welding zone. If we address the welding process as an object of control, we consider that the object’s control goal is the effectiveness of gas protection, which depends on a large number of parameters. These parameters are set by the welder, and with random process disturbances can quickly and accurately react to their change. The flow of protective gas is considered as the main control on the effectiveness of gas protection [2].

Establishing the relationship between process disturbances and control actions, as well as the development of control algorithms, is the main aspect in solving the problem of intelligent control of automatic welding equipment.

The difficulty of this task is associated with the fact that welding is a non-linear, time-varying process that covers many practical areas. Therefore, to obtain a clear mathematical relationship between the input and output parameters of the system is quite problematic. In such situations, various approaches are used to solve the problem for building intelligent control systems, Fig. one.

Analysis of the existing literature has shown that there are several ways to build such systems [5, 6].

1. Implementation and integration of tracking devices, which allow to determine the current state of the control object and measure a number of characteristics of perturbing factors.

2. Development of control algorithms. At this stage, the influence of disturbing factors on the control object is evaluated, control actions are calculated, which allows to change the state of the control object and compensate the effect of disturbing factors in order to obtain the desired control result.

3. Implementation of control devices. Testing the performance of the developed control algorithms by modeling the control system to verify that the requirements of static and dynamic characteristics are met.
The implementation of the welding process control algorithm was performed using the example of gas-shielded arc welding under wind exposure using artificial intelligence technologies. The parameters of the welding mode (welding speed, wire feed speed, electrode tilt angle, voltage, electrode overhang, shielding gas consumption) were used as input parameters of the model, and process and welded joint characteristics were used as output parameters.

At the same time, the technological adaptation algorithm is implemented by calculating the coefficients that correct the welding mode selected on the basis of the technological maps.

Establishing the relationship between process disturbances and control actions was achieved through a combination of experimental methods and means of modeling and simulating welding processes [2, 7].

As a result of numerous physical experiments, the dependencies (calculated and experimental) between the flow of protective gas, the speed and frequency of wind amplification, and welding modes were established, providing effective gas protection. A criterion for the effectiveness of gas protection was also established [8].

The data of the physical experiment were confirmed using mathematical modeling in the ANSYS software environment and identified the most significant technological factors for which it is possible to conduct welding under the influence of wind, Fig. 2.

We simulated the flow of shielding gas and investigated the effect of the nozzle shape and tip shape on the effectiveness of gas protection in various welding methods, protective media, as well as wind speeds, welding speed, torch angle. The effect of technological and structural factors on the effectiveness of protection was investigated: the type of joint, the size of the gap, the design parameters of edge cutting [2].
Using the obtained ratios, we formed a knowledge base for a fuzzy decision-making system, which adjusted the flow rate of protective gas depending on disturbing factors.

Measurements of characteristic disturbances of the process are carried out by using high-speed sensors. The dependences formed the base of the algorithm for intelligent control of the welding process, on the basis of which we created an automatic device with an adaptive control system, Fig. 3.

**Figure 2** Establishing the relationship between process perturbations and control actions using mathematical modeling

**Figure 3** Automatic device with an adaptive control system: 1 - LEDs; 2 - position sensor start button; 3 - burner position sensor; 4 - microcontroller of the torch position sensor; 5 - electronic protective gas flow meter; 6 - current sensor based on the Hall effect; 7 - main microcontroller; 8 - information display; 9 - sensor measuring wind speed and direction
If it is impossible to adjust the welding parameters (e.g., when an emergency mode occurs; the welding current or wind speed is exceeded), the controller generates a command to turn off the power source and stop the welding process.

The automated device can adjust the parameters of the welding process in real time, control them and save data via the Internet, which allows the work supervisor to monitor any number of welding posts at any distance.

*The use of artificial intelligence for direct arc cultivation under the influence of disturbing factors*

Direct arc cultivation of products of complex shape is a non-trivial task requiring the attraction of knowledge from several areas of science and technology. The underlying principle of technology is simple: it is the same arc surfacing, characterized by high process performance and performed in three dimensions. The main problems in direct arc growth are: stabilization of arc burning and metal transfer, controlling the thickness of the deposited walls, obtaining the desired microstructure, and calculating the technological and electrical parameters of the welding process. One of the ways to solve metallurgical problems and stabilize the process of arc growing can be the use of Smart-Arc arc burning control technology [9, 10]. Issues related to the control of the thickness of the cladding and the determination of process parameters cause a number of difficulties, which are primarily related to nonlinearity and the lack of accurate mathematical models of the process. In these situations, artificial intelligence technologies can be widely used, as evidenced by the volume of publications [11, 12].

As a solution to the problem of controlling the thickness of the controlled deposition and determining the parameters of the growing process, an adaptive intelligent control system was developed, Fig. 4.

*Figure 4*  
Fig. 4. The general scheme of the process control system of arc welding using artificial intelligence technology

It is based on artificial intelligence technologies and methods for constructing adaptive regulators. The input information to the control system is transmitted from sensors that measure current disturbances...
and the state of the growing process. The process is controlled by regulating the flow of the gas mixture, welding current and voltage, wire feed speed and welding speed.

The developed adaptive intellectual control system consists of several parts that allow it to correctly respond to disturbances and control the process of direct arc growth:

- The feature extraction system makes a preliminary filtering of the received information and identifies anomalous system behavior;
- The intelligent decision support system chooses the most correct response depending on which signs are most likely at a given point in time. By reaction we meant a change in the feed rate, welding speed, welding current, welding voltage, or gas mixture flow rate;
- The system for determining the parameters of the regulator calculates the change in the coefficients of one of the regulators depending on the response of the intelligent decision-making system;
- The digital controller will determine the exact value of the control depending on its coefficients.

The described approach to the construction of an adaptive intelligent system allows you to fully control the process of direct arc growth due to the presence of a closed-loop control system with feedback. This system can be trained to control any welding process by changing the knowledge base of the decision module and modifying the feature extraction module.

**Results**

1. Developed a device for controlling the parameters of arc welding in shielding gases based on artificial intelligence, which allows automatic correction of welding conditions under conditions of disturbing factors.
2. They proposed an approach to creating a process control system for direct arc cultivation using artificial intelligence.

**Summary**

Thus, one of the ways to control the modes of arc welding and arc growing under the influence of disturbing factors, as well as obtaining high-quality joints and improving the performance of the process, is the transition to automated welding with intelligent control.

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