Welding technologies in art processing of metal

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Abstract. The article presents a comparative analysis of modern welding techniques which can be applied in the artistic machining of metals. Features of designing of art objects are defined and methods for their manufacture are offered, including stages of prototyping and full-scale modeling. Factors influencing the shaping of metal art objects are revealed. Practical application of the proposed recommendations is shown in the example of manufacturing of openwork metal mannequin.

1. Introduction

Art processing of metal involves manufacturing of objects representing not only material but also artistic value. Art objects are exclusive products which reflect the different tastes and edges of personality realization in a rapidly changing world. Art object may not have practical importance, but at the same time it has artistic value, the achievement of which is provided by high technology level of artistic processing of materials [1].

The purpose of this research is to study possibilities of application of welding technology in artistic processing of metal. To achieve this objective, several tasks should be solved sequentially. It is necessary to reveal shaping features and technologies for creating metal art objects. Moreover we need to review the specifics of various types of welding and highlight their strengths and weaknesses. And also we must justify the need of prototyping and full-scale modeling.

Currently poorly studied issue about the specifics of welding technologies and their impact on the shaping of art objects, which are distinguished by high degree of esthetic expression. Urgency of work is due to the need to research the application of welding technology in the production of metal art objects.

2. Research

The development of various kinds of welding takes place in conditions when all is focused on the strength and durability of the resulting structures, while the requirements of esthetics were secondary. In the production of art objects main quality indicator is the high artistic expressiveness of the image and that requires careful selection of welding technology [2]. The main factors affecting the quality of welding in the manufacture of metal art objects are as follows: mobility of equipment, access to the weld area, the thickness of the welded parts, material weldability. All these factors affect the appearance of welds which is the main quality criteria of products.

In the art objects there are many parts in different attitude positions. Complex shapes require the free access to the weld zone, as well as mobility of welding equipment. Now let’s analyze the most common welding methods and allocate their advantages and disadvantages.
Manual arc welding with coated electrodes (MMA) is currently one of the most common methods of manufacturing, installation and repair of various welded structures. The advantages of the method are the simplicity of the process and mobility of equipment. This method allows working in different attitude positions; it is possible to weld a large range of materials and thicknesses. These advantages provided broad application of MMA in creation of artistic objects.

The disadvantages of MMA are the following: weld quality depends on the skill of the welder; difficulties in welding of thin metal (less than 2mm) [3]; surface contamination of the metal and slag splashes that causes the need of additional surfaces cleaning; shape distortion of metal that must be considered in the design [4].

The gas welding technology is easier than MMA in many ways. In addition this method has one unique feature that can be used in welding of artistic objects. It allows correcting poorly fitted parts or even adjusting the composition during the welding process. It is also possible to work with small workpieces using low-power torches. Gas welding allows welding steel, cast iron, copper, brass, lead, bronze and aluminum alloys [3].

Disadvantages of gas welding as follows: high risk of warping of metal; spray and deposits, affecting the weld appearance; heightened danger of work with gas equipment.

The feature of gas metal arc welding (MIG/MAG) is continuous automatic supply of wire to weld zone. This allows making many welds without stopping. To protect the weld pool the special gas (active, inert or mixed) is used. Using the gas mixture (Ar + CO₂) minimizes the risk of warping and burn-through thin parts. The main drawback is the high gas emission in the welding zone.

This welding technology can be recommended for the production of large-scale art objects with many of easily accessible welds.

In gas tungsten arc welding (TIG welding) weld zone is protected by an inert gas and nonconsumable electrode is used. Main advantages are: high aesthetic quality of weld; no spatter and warpage; practically any metals can be welded; welding of very thin details.

However, the performance of this method is very low and time consuming preparation of metal before welding is needed. All this makes the method expensive and unsuitable for the manufacture of large structures.

Electric resistance welding is performed by short-term heating of the parts with passing electric current and applied plastic deformation [4]. For production of art objects it is reasonable to use spot welding. With proper welding mode there are no spatter and warpage.

Also there are portable welding devices and compact handheld devices for micro welding. However this equipment not very mobile and free access to weld zone is necessary. So in many cases, this method is not applicable.

The most efficient way is to use different types of welding for specific details. For remote weld areas can be used MMA, and for easily accessible zones gas metal arc welding will be most productive.

Outcome of the analysis can be represented as table 1.

As an example of welding in the manufacture of art objects let’s examine production process of forged mannequin [5].

In figure 1 presented final sketch of mannequin "Falcon" for men's clothing store [6]. The image is based on outline of a male figure which implies a comfortable arrangement of costume, hats, scarves and umbrellas. Unlike standard mannequins, this object is an artistic interior decoration, even without garments on it [7].
Table 1. Factors providing the quality of welding.

| Welding method                      | Manual arc welding | Gas welding | MIG/MAG welding | TIG welding | Electric resistance welding |
|-------------------------------------|--------------------|-------------|-----------------|-------------|-----------------------------|
| Mobility of equipment               | high               | average     | average         | average     | high                        |
| Accessibility of the weld zone      | good               | poor        | average         | average     | poor                        |
| Minimum thickness of the welded parts, mm* | 1.5                | 0.3         | 0.5             | 0.3         | 0.1                         |
| Range of welded metals             | wide               | average     | wide            | wide        | average                     |
| Prime cost                          | low                | low         | average         | high        | average                     |
| Complexity of performance          | high               | high        | average         | average     | low                         |

* Note: The minimum thickness of the welded parts also depends on the skill of the welder.

Since sketch does not consider operational requirements, as well as structural changes that may occur during manufacturing, modeling phase is required. It includes: clarification of the artistic image (proportions, decorative elements, composition) to select the most balanced option; refinement of structural elements and their connections to each other to determine the technological features of the process of fabrication and assembly; verification of object perception from different angles to evaluate the aesthetic qualities of the object in different points of interior space.

Figure 1. Mannequin "Falcon": sketch (left) and layout (right).

The modeling process involves creating a layout that reflects the options of artistic solutions of object image, and full-scale modeling – production of a sample of the future product in full scale, that allows to reveal manufacturing features of the product.
Layout, made from simple materials, is designed to test the technical and artistic solutions. Mannequin layout is shown in Figure 1. During creation of layout main objectives are: to elaborate artistic image of future products; to work out the connection of separate parts and units of construction.

Full-scale model of the manikin considered technological features identified in step of prototyping. Volumetric part of the layout required to solve the problem of small decorative details connection.

It was decided to abandon the volumetric sample and perform planar version of object (Figure 2), which did not affect the aesthetic and artistic quality of the product. [8]

![Figure 2. Welds in the construction of the manikin](image)

As a material for a full-scale model was used steel bars as it has sufficient flexibility, strength and good weldability. For manufacture of parts was applied cold forging. For connection of details was selected manual arc welding, as satisfying the manufacturing requirements. [9]

Final steps are: cleaning, polishing and painting of mannequin.

3. Results and discussion

Based on the current research, we can recommend the manual arc welding as the most universal type of welding for connecting parts of metal art objects of any complexity. Layout allows us to offer different variations of the artistic image and clarify technological methods of manufacturing, as well as proportions, decorative elements and specifics of the composition.

Manufacturing of full-scale model allows to obtain a sample of future products and to develop manufacturing technologies, to refine manufacturing operations and to make recommendations.

While designing the art objects stages of prototyping and full-scale modeling turn out to be important and necessary because they affect the process of shaping and ensure the quality of future products.

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