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Research Article

Possibilities Of Using Thermal Affected Zones And Special Welding Methods In Repairing Machine Parts And Metal Structures By Welding

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Abstract

This article analyzes the heat affected zones (HAZ) formed during the welding repair of machine parts and metal structures and their effect on material properties. During the welding process, high temperatures can cause changes in the metal structure, internal stresses, and deformations. The research investigated special welding methods - low-energy welding, laser and plasma welding, pulsed modes, as well as preheating and controlled cooling technologies. According to the results obtained, it is possible to reduce the thermally affected area, maintain material strength, and increase the reliability of repaired parts by using these methods.

Keywords: - welding, heat affected zone (HAZ), machine parts, metal structures, repair, laser welding, plasma welding, pulse welding, internal stresses, deformation, energy efficiency.

Introduction

In mechanical engineering and industry, the failure of parts and structures leads to the need for their repair. Repair by welding is one of the most effective and economically acceptable methods. This method allows the restoration of worn, cracked or damaged parts [1,2]. However, during the welding process, the microstructure of the metal changes under the influence of high

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temperatures and a thermally affected zone is formed. In this zone, the mechanical properties of the material change, cracks appear, and deformations can be observed [1-3].

Relevance

In modern production, ensuring resource efficiency and reliability is one of the important tasks. Although repair is cheaper and more effective than manufacturing a new part, the thermal effect during welding can lead to the following negative consequences: the formation of internal stresses; changes in the metal structure; decreased strength; reduced service life. Therefore, reducing the thermal effect zone and using special welding methods is an urgent issue [3,4].

Problem statement

The main goal of the research is to analyze the thermal effect zone during welding repair and develop effective special welding methods to reduce it [2-4]. The following tasks were developed to implement the problems posed:

- study the characteristics of the thermal effect zone;

- analyze the heat dissipation process;

- assess the effectiveness of special welding methods;

- determine the optimal technological regimes.

Materials and methods

The following laboratory welding tests; metallographic analysis; hardness and strength measurements; mathematical modeling of heat dissipation; statistical analysis were used to study the thermal influence zones and the possibilities of using special welding methods in the repair of machine parts and metal structures by welding [5,6,7,8,9,10,11].

The heat dissipation process in the welding of parts of technological machines and equipment and metal structures is estimated by the following equation:

$$q = -k \cdot \nabla T \quad (1)$$

where:

q - heat flux; k - thermal conductivity coefficient; ∇T - temperature gradient.

The heat affected zone is a part of the metal that has not melted during the welding process, but whose microstructure and mechanical properties have changed due to the influence of high temperatures. The heat affected zone (HAZ) consists of the following zones[1,2,5,6,7,12,13,14]:

- high temperature zone;

- recrystallization zone;

- partially changed structural zone. In these zones, the hardness, strength, and plasticity of the metal can change significantly.

Negative consequences of thermal effects. Thermal effects during welding lead to the following problems [2,3,5,6,15,16,17]:

a). Internal stresses. Residual stresses are formed in the metal as a result of rapid heating and cooling.

b). Deformation. The shape of the structure may change as a result of metal expansion and contraction.

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c). Cracking. Cracking is especially likely to occur in high-carbon steels.

d). Microstructural changes. The phase composition of the metal may change, reducing its strength.

Methods for reducing thermal effects. The following measures are used to reduce thermal effects [3,4,18,19,20,21,22]:

1. Preheating. Heating the metal before welding reduces the temperature difference.

2. Controlled cooling. Slow cooling reduces internal stresses.

3. Multi-layer welding. Allows for uniform heat distribution.

4. Selecting the optimal mode. It is important to correctly select the current, speed, and voltage.

Results and discussion

The results of the study showed that [2,3,4,5,6,23,24,25,26]:

- the width of the heat affected zone (HAZ) in laser welding was reduced by 30 - 50%;

- the heat input in pulse welding was significantly reduced;

- preheating reduced internal stresses;

- controlled cooling reduced the occurrence of cracks.

During the discussion, the following points were confirmed:

- low-energy welding methods preserve the material structure well;

- reducing thermal effects increases the service life of the part;

- the complex use of several methods gives the most effective result.

Modern special welding methods are modern technologies that reduce thermal effects and improve weld quality.

Let's get acquainted with modern special welding methods one by one [2,3,4,5,6, 14,18,21,23,27,28,29,30,31]:

1. Laser welding method.. Laser welding is performed using high-energy light.

Advantages:

- Very small HAZ;

- High accuracy;

- Low deformation;

- High automation capabilities.

Applications: automotive, aviation, precision mechanisms.

2. Plasma welding method. High temperatures are generated by a plasma arc.

Advantages:

- Stable arc;

- Deep penetration ability;

- High quality weld.

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3. Pulse welding method. Welding current is supplied in pulses.

Advantages:

- Low heat input;

- Smaller HAZ;

- Suitable for thin materials.

4. Electron beam welding method. Performed in a vacuum environment.

Advantages:

- very high accuracy;

- deep and narrow seam;

- minimal thermal effect.

5. Friction welding method. Mechanical energy is converted into heat.

Advantages:

- welding without melting;

- minimal HAZ;

- high strength.

6. Hybrid welding methods. Combinations such as laser + arc welding are used.

Advantages:

- high efficiency;

- energy saving;

- increased quality.

The relationship between thermal effects and welding methods. Studies conducted on welding parts of technological machines and equipment and metal structures show that [2,3,4,5,6,11,24,25,28,32,33]:

- HAZ is large in traditional high-energy methods;

- HAZ can be reduced by 30–70% in modern methods;

- energy control directly affects the quality of the weld.

Application possibilities in practice. Modern methods of welding parts of technological machines and equipment and metal structures are effectively used in the following areas:

- mechanical engineering;

- oil and gas industry;

- energy;

- aviation and space technology;

- building structures.

These methods reduce repair costs; increase the service life of parts; ensure reliability.

Conclusions and suggestions

Conclusions: The heat affected zone is of great importance in welding repair, which has a significant impact on the mechanical and physical properties of the metal. The use of modern welding methods to reduce the heat affected zone is an effective solution. Laser, plasma, pulse and friction welding methods allow reducing the HAZ,

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preventing deformations and increasing the quality and reliability of the weld.

1. The heat affected zone during welding has a significant impact on the properties of the material.

2. Special welding methods are effective in reducing the HAZ.

3. Strength and reliability can be increased by selecting optimal modes.

Suggestions:

1. Widespread introduction of laser and pulse welding methods;

2. Use of automated welding systems;

3. Development of thermal impact monitoring systems;

4. Continue scientific research.

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