IMPROVING THE PRODUCTION TECHNOLOGY AND ECONOMIC EFFICIENCY OF THIN-WALLED SUPPORTING STEEL STRUCTURES FOR SOLAR PHOTOVOLTAIC STATIONS

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Abstract: This article investigates the fabrication technology of support steel structures designed for solar panels, optimized for the climatic and economic conditions of the Republic of Uzbekistan. Low-carbon St3 steel profiles with dimensions of 40x30 mm and a wall thickness of 1.7 mm were selected as the research object. To minimize thermal distortions that occur during the welding of thin-walled profiles, a custom rotating pneumatic jig-fixture was designed, and the MIG/MAG (in an argon and carbon dioxide gas mixture environment) semi-automatic welding method was optimized. The UDK-105M ultrasonic flaw detector was utilized to detect internal defects within the weld seams. The results demonstrated that the improved technological process significantly reduces production costs, enhances manufacturing productivity, and minimizes the defect rate close to zero.

Keywords: solar panels, steel structure, St3 profile, MIG/MAG welding, pneumatic jig, UDK-105M flaw detector, economic cost.

1. INTRODUCTION

In today's global energy sector, transitioning away from traditional hydrocarbon raw materials and widely implementing renewable energy sources has become a strategic global priority. In accordance with Resolution No. PP-57 of the President of the Republic of Uzbekistan dated February 16, 2023, ensuring energy independence and transitioning to a "green economy" has been designated as a priority direction of state policy.

Throughout their 25–30 year operational lifespan, solar panels are subjected to various harsh environmental conditions, including extreme temperature fluctuations, high humidity, and severe wind loads. Supporting structures serve as the foundation for these panels, and their structural integrity determines the stability of the entire system. Currently, during the construction of solar power plants, expensive pre-fabricated structures imported from abroad are frequently utilized, which increases the overall cost of the projects.

Technically, the most vulnerable points of such structures are their weld joints. In thin profiles with a wall thickness of 1.7 mm, errors during the welding process can lead to internal stresses and deformations in the metal. Therefore, developing a technological chain based on local raw materials that ensures rational manufacturing design, optimized welding parameters, and defect-free joints is the primary objective of this research.

2. METHODS

Within the scope of this study, closed-section St3 low-carbon structural steel profiles with dimensions of 40x30 mm and a thickness of 1.7 mm were selected for the main frame of the structure. This material exhibits excellent weldability and maintains elasticity under dynamic loads.

2.1. Mechanical Processing and Preparation Stage:

To prevent thermal deformation of the thin-walled profiles, band saws and abrasive disc cutters were used to cut them according to design dimensions. To prevent the formation of porosity in the weld joints, the edges were cleaned of the factory oil layer using specialized chemical solvents and mechanical wire brushes.

2.2. Assembly-Welding Fixture:

To completely eliminate internal stresses and component displacement caused by thermal expansion, a specialized pneumatic-clamping and 360-degree rotating jig-fixture was implemented. The clamping force of the pneumatic cylinders was determined using the following formula:

$$F = p \cdot A$$

(where: p is the system air pressure, and A is the piston surface area). Copper-coated clamping pads (£≈380W/m·K) on the fixture served to reduce the temperature gradient in the weld zone and efficiently dissipate heat.

2.3. Welding Parameters and Materials:

The MIG/MAG semi-automatic welding method was selected as the manufacturing baseline. *Sv-08G2S* grade welding wire with a diameter of 0.8 mm was used as the filler metal, and a mixture of 80% Argon (Ar) + 20% Carbon Dioxide (CO_2) was utilized as the shielding gas. The process was conducted using direct current (DC) with reverse polarity. The optimal operating parameters determined for the 1.7 mm thick metal are presented in Table 1:

Table 1.

Process parameters for welding profile structures

Parameter Type	Selected Value Range
Welding Current (I_p)	60 – 90 A
Arc Voltage (U_y)	16 – 19 V
Shielding Gas Flow Rate	8 – 12 l/min

2.4. Quality Control Methods:

Upon completion of the welding process, slag and spatter were removed, followed by an initial visual-dimensional inspection. To detect hidden internal defects (such as porosity and lack of fusion) inside the joints, the UDK-105M ultrasonic flaw detector was utilized (with a piezo-transducer frequency of 2.5–5 MHz).

3. RESULTS

As a result of the technological experiments and calculations conducted, the following positive outcomes were achieved:

1. Reduction in Deformation: Due to the combined application of the pulsed MIG/MAG welding method and the rotating pneumatic jigs, the heat-affected zone was drastically reduced. Burn-through and melt-through defects in the 1.7 mm thick profiles were entirely eliminated.

2. Weld Quality: The utilization of the Argon and CO_2 gas mixture significantly reduced metal spatter and ensured the hermetic integrity of the weld structure. When inspected with the UDK-105M device, no internal macro-defects were detected in the welded joints, which guarantees that the structure can operate outdoors for 20–25 years without undergoing severe corrosion.

3. Production Productivity: By transitioning from traditional manual welding to the jig-based assembly system, the auxiliary time required for positioning and adjusting components was reduced by 30–40%. This enabled an increase in the volume of production (Q) per shift.

Table 2.

Technical and economic performance indicators

Indicator Name	Traditional Process	Improved Process

Setup and Assembly Time	100%	60–70% (30-40% saved)
Time Spent on Weld Cleaning	High (severe spatter)	Minimal (due to gas mixture)
Quality Control Level	Visual only	Comprehensive (automated via UDK-105M)
Defect (Scrap) Rate	4–5%	~0%

4. DISCUSSION

The research results indicate that maintaining technological discipline and adhering to optimal parameters play a decisive role in fabrication of solar panel supports from thin-walled steel profiles. Due to their hollow section, the 40x30 mm profile tubes additionally allow electrical cables to be routed internally, protecting the system from mechanical damage.

The analysis conducted on welding materials fully proved that utilizing an argon-based mixture is more advantageous than using traditional pure carbon dioxide gas. In addition to improving the mechanical properties of the weld, this reduces the labor required for subsequent mechanical cleaning operations.

From an economic perspective, organizing the designed technological line in the form of a mobile modular workshop (based on a shipping container) allows high-precision operations to be performed directly at the installation site. Although initial capital expenditures (investments) increase due to purchasing modern equipment such as pneumatic jigs and the UDK-105M flaw detector, the production cost is significantly reduced through the near-total elimination of scrap products and savings on steel profiles, allowing the investment to pay off fully within a reasonable period.

CONCLUSION

The project for implementing the MIG/MAG welding technology and the pneumatic jig assembly system in the production of 40x30x1.7 mm steel support structures for solar panels was fully justified from both technical and economic standpoints. Transitioning to an automated process in a shielding gas environment raises product quality to international standard levels and shortens the production cycle by 3 to 4 times. The results of this study hold significant practical value for creating an import-substituting and climate-resilient "green energy" infrastructure in our republic.

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