STRUCTURE AND MECHANICAL PROPERTIES OF HEAT-RESISTANT STEEL MANUFACTURED BY GAS METAL ARC WELDING TECHNOLOGY *

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Additive manufacturing (AM) has made it possible to develop new approaches to the design of parts, their production, and the combination of different materials within a single component [1, 2]. In comparison to the conventional manufacturing of metal products using casting and forging, additive manufacturing is quite new and is actively developing for the involvement in the production process.

The AM based on the Gas Metal Arc Welding (GMAW) technology has limitations. The cyclic thermal effect of new layers on previous ones is affected the structure and mechanical properties of the product. The heat input plays an important role in the formation of the structure and mechanical properties of components printed by GMAW. The way to control the heat input for GMAW is printing modes such as Cold Metal Transfer (Fronius) and coldArc (EWM) [3]. The principle of these technologies is to weld with a short electrical arc as well as changing cycles of short circuit and arc burning.

It is important to predict the distribution of heat in the product and adjust the printing modes to control the process of structure and phase formation. A detailed analysis of structure evolution during printing is necessary to design manufacturing strategy to achieve required mechanical properties and optimal structure.

The aim of the present work is to study the structure, mechanical properties, and deformation behavior of specimens cut from the wall printed by the multi-layer arc deposition method under various heat input modes (standard and coldArc) using pearlitic steel wire.

OK Autrod 13.14 wire was deposited layer-by-layer on heat-resistant steel substrate made of 12Cr1MoV (Fig. 1, a). As a result of the high rate of heat transfer to the substrate at the lower part of the walls, a lath martensite structure was formed both in the first layers of the walls and in the heat-affected zone in the substrate. The central part of the walls consists of a mixture of acicular ferrite and allotriomorphic ferrite. The upper part of the wall (0–10 mm from the top) is characterized by a coarse-grained structure, with distinguishable boundaries of the former austenite grains up to 290 ± 40 μm in size, inside which acicular ferrite was formed.

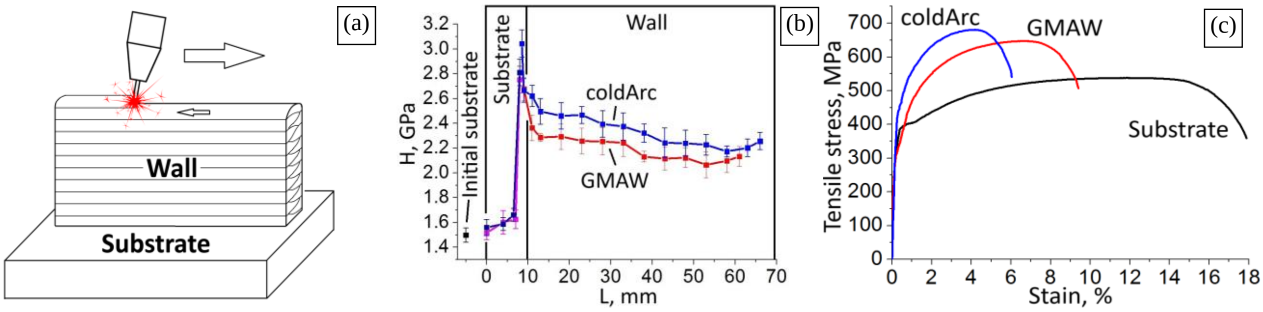

Fig. 1. Printing scheme of the wall (a), microhardness of substrate and wall (b), stress–strain diagrams of specimens (vertical) (c).

The material of the walls, compared to the substrate, has higher strength characteristics by 40–45%, and plasticity is reduced by 50–70% (Fig. 1, b, c). The increase in strength is associated with a higher cooling rate and the formation of a fine structure of acicular ferrite. The main difference between the 3D printing modes is the reduced heat input in the coldArc mode, which results in less heat accumulation and faster cooling of the wall. Thus, a more dispersed structure was formed. The cooling rate and the level of heat input are the main factors affecting the structure formation (martensitic, bainitic or ferritic structures).

REFERENCES

[1] D. Ding, Z.Pan, D.Cuiuri, H.Li, "Wire-Feed Additive Manufacturing of Metal Components: Technologies, Developments and Future Interests," The International Journal of Advanced Manufacturing Technology, vol. 81, pp. 465–481, 2015, doi:10.1007/s00170-015-7077-3.

[2] D. Jafari, T. H. J. Vaneker, I. Gibson, "Wire and Arc Additive Manufacturing: Opportunities and Challenges to Control the Quality and Accuracy of Manufactured Parts," Materials & Design, vol. 202, pp. 109471, 2021, doi:10.1016/j.matdes.2021.109471.

[3] C. R. Cunningham, J. M. Flynn, A. Shokrani, V. Dhokia, S. T. Newman, "Invited Review Article: Strategies and Processes for High Quality Wire Arc Additive Manufacturing," Additive Manufacturing, vol. 22, pp. 672–686, 2018, doi:10.1016/j.addma.2018.06.020.

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