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Iryna Zakharova\*

Doctor of Technical Sciences, Professor  
Pryazovskyi State Technical University  
49000, 29 Hohol Str., Dnipro, Ukraine  
<https://orcid.org/0009-0000-5403-2153>

## Welding processes in the restoration of industrial and energy facilities

**Abstract.** The research relevance is determined by the constant development and changes in the production environment and technological requirements to ensure increased safety, durability, and efficiency of industrial and energy facilities. The study aims to analyse methods and strategies for improving the efficiency of welding and joint quality control, to achieve greater stability and reliability of energy facilities. The methods used include observation, comparative and descriptive, monitoring, abstraction, and others. The study analysed various welding technologies and their impact on the quality of welded joints. Various methods of calculating welded structures concerning materials and technical requirements were considered. In addition, various methods of quality control of welded joints, including visual inspection and non-destructive testing, were investigated. The study determined that the correct choice of technology, calculations and quality control can improve the strength, reliability, safety, and economic feasibility of welded structures. The studied welding technologies and quality control methods used are more effective for use in specific conditions and there is no general solution. In addition, the proper application of these methods demonstrated that they can significantly reduce the recovery time and increase the overall productivity of the process of restoring industrial and energy facilities. Therefore, the optimal use of welding technologies and quality control methods can significantly improve the efficiency and durability of industrial and energy facilities. The practical significance of the study is to contribute to improving the safety, reliability, and efficiency of the rehabilitation of industrial and energy facilities by improving the quality control procedures for welded joints

**Keywords:** non-destructive testing; microstructure; bond strength; electrodes; quality control methods

### INTRODUCTION

The application of welding processes in the restoration of industrial and energy facilities is critical in the modern technological context. This aspect is becoming increasingly important as infrastructure wear and tear increases and the need for efficient rehabilitation. Welding is a key process in many industries, including construction, engineering, shipbuilding, and energy. Weld quality determines the safety, strength, and durability of welded structures, as well as the efficiency of industrial and energy facilities. Welded joints that do not meet quality standards can lead to serious accidents, injuries and even death. Studying welding technologies and quality control methods helps ensure the safe operation of welded structures. Welds must have sufficient homogeneity and chemical composition similarity to the

base metal to withstand operational loads. The calculation of welded structures helps to determine the required welding parameters and weld dimensions at the design stage. The right choice of welding technology and quality control methods can significantly reduce the cost of welding, as well as the maintenance and repair of the entire structure. Welding technologies are constantly being improved, and new technological solutions are emerging that are changing welding and quality control methods for the better. It is necessary to constantly increase the level of knowledge and improve skills to meet modern requirements.

The research addresses the need to adapt welding methods to modern requirements of technological development and standards, as well as to ensure the quality,

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\*Corresponding author



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safety, and efficiency of the infrastructure rehabilitation process. With the development of technology, new welding methods and materials are emerging that can be more efficient and safer. The research aims to adapt these innovations to the needs of infrastructure rehabilitation. Welding standards are constantly being reviewed and updated to ensure that production and quality are maintained. Therefore, it is important to continuously monitor and modify welding process flow charts in production to meet new requirements. Defects and damage in welded joints can lead to serious accidents and damage. The development of welding methods should aim to minimise these risks. Efficient use of materials and optimisation of work time is important for the economic viability of the infrastructure rehabilitation process.

Following V. Korzhyk *et al.* (2024), the development of new welding technologies and the improvement of quality control methods for welded joints are important to ensure the reliability and safety of industrial and energy facilities. The study does not consider the impact of environmental variables on welding quality. V. Kachynskiy & M.P. Koval (2021) emphasise the need to consider the individual characteristics of each welding process and choose the optimal approach to quality control. The paper does not focus on the need to further investigate the impact of welding defects on the service life of structures. According to A.S. Novodranov *et al.* (2023), the developed conditions and criteria for assessing the effectiveness of welding technologies and inspection methods can increase production efficiency and ensure high-quality welded joints. The study does not address the possibility of introducing new methods of non-destructive testing of welded joints.

O.F. Kryvyi & Yu.O. Morozov (2022) note that ensuring the stability and uniformity of the quality of welded joints is a key task in the implementation of any project. The researchers do not mention the need to further study the impact of vibrations on the strength and reliability of welded structures. Yu.K. Bondarenko & Yu.V. Loginova (2022) emphasises the importance of continuous monitoring and updating of welding quality control methods by modern standards and technologies. However, the study does not provide sufficient information on the possibility of using new materials in welding. V. Lebedev *et al.* (2022) raise the important issue of developing effective quality management systems aimed at continuous improvement of welding processes and quality control of welded joints. The study does not address the important issue of the influence of preliminary mechanical stresses on welding quality.

The study aims to evaluate methods and strategies aimed at improving the efficiency of welding and quality control of joints, ensuring greater safety and reliability of energy facilities.

## MATERIALS AND METHODS

Using the observation method, the welding processes were studied in detail in practice. The observation took place at the E.O. Paton Electric Welding Institute, Kyiv, during

May-July 2023. During this method of direct observation of the workflow, the various stages of welding were monitored, and any deficiencies or malfunctions identified were carefully considered. This method was used to obtain important practical information about real welding conditions that cannot always be reflected in theoretical models.

A detailed study of different types of welding was carried out using comparative and descriptive methods. The characteristics of each method, including its advantages and disadvantages, as well as the impact on the quality and reliability of welded joints, were studied. This method made it possible to make an objective assessment of different welding technologies and determine the best approach for a particular task.

Using the monitoring method, various welding parameters were checked over a long period, from September 2023 to February 2024. During the welding process, continuous monitoring was carried out, during which data on temperature, welding electrode speed and other important parameters were recorded. This contributed to the timely detection of changes in the quality of the welded joints and was used to respond promptly to any deviations from the optimal parameters.

The abstraction method was used to identify the main general principles and patterns of welding processes and their impact on the rehabilitation of industrial facilities. By separating the essentials from the details of specific situations, this method was used to focus on the key aspects of welding and to consider them in a generalised way, which contributed to the development of general principles and recommendations for industrial site restoration.

The functional method was used to determine the optimal welding quality functions and their dependence on various process parameters. This method was used to study the functional dependencies between the input welding parameters and the output quality of the joints. Synthesis methodology was used to combine various aspects of welding and joint quality control to create a comprehensive strategy. This method was used to compare different methods and approaches to optimise the use of resources and achieve maximum results. The classification method was used to help structure various aspects of the welding and joint quality control processes. By grouping the input data according to certain criteria, a structured picture of the processes was obtained, and the main trends and patterns were identified. The analogy method was used to establish parallels between already known and new situations in the field of welding and industrial facilities restoration. This method was used to transfer the knowledge and experience gained in previous cases to new conditions, which contributed to a more effective understanding and solution of problems in the restoration process.

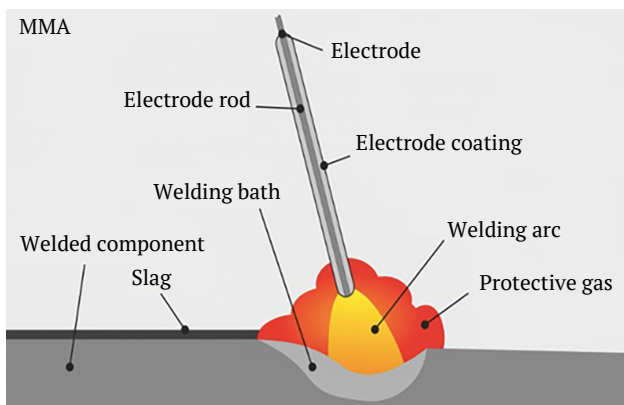
The induction method was used to thoroughly investigate the available data and examine their interrelationships to formulate general statements and conclusions. By studying the experience and observations already made in the field of welding, the main regularities and principles

governing the processes of welding and joint quality control were identified. This was used to draw conclusions about the effectiveness of certain welding methods and identify key areas for further research.

## RESULTS

Welding plays a valuable role in the restoration of industrial and energy facilities that have been worn out due to various factors. This technology opens up wide opportunities for the restoration and improvement of metal structures, allowing for effective solutions to several problematic situations. Welding is used to repair damaged components (Tanasković *et al.*, 2021). This can include repairing cracks, tears, distortions, and other types of defects in metal structures such as beams, pipes, machine bodies, and tanks. A wide range of welding processes allows for effective repair of various types of damage, ensuring their strength and durability. In addition, welding can be used to manufacture new parts to replace worn or damaged ones. This provides effective restoration of the functionality of an object and extends its service life. Welding can be used to produce exact replicas or modified versions of parts that meet the specific needs of the facility. Finally, welding can be used to connect new components to existing structures when a facility is being modernised or expanded. This process allows new elements to be integrated into existing infrastructure, ensuring their reliability and interaction with the entire system.

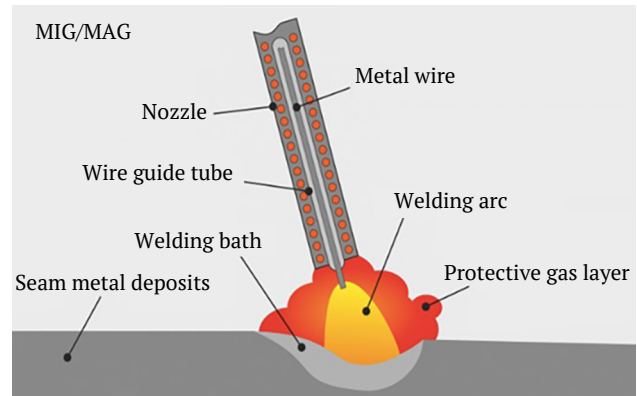
Manual metal arc welding (MMA) is the most common and versatile method used in refurbishment (Fig. 1). It allows welding different types of metals and repairing different parts and structures (Nalle *et al.*, 2024). This technique enables welding in hard-to-reach places, even in the ceiling position, which is often necessary to avoid an emergency.



**Figure 1.** MMA (manual metal arc)

**Source:** Main types of welding (2020)

Metal inert gas (MIG) and metal active gas (MAG) use an automatically fed electrode wire that delivers a higher welding quality than manual arc welding (Fig. 2). This welding method is widely used in remanufacturing applications where production and cost-effective processes with high quality are important.



**Figure 2.** Metal inert gas (MIG) and metal active gas (MAG)  
**Source:** Main types of welding (2020)

Automatic submerged arc welding uses a flux that protects the weld pool from weathering. This method is designed for thick-walled structures, special steels, and high-performance welds in industrial environments where maximum welding quality and uniformity are required. Each of these methods has its advantages and limitations, and the choice of a specific welding method in the rehabilitation process depends on the welding quality requirements, the characteristics of the object being repaired and the availability of equipment. The use of welding in the restoration of metal structures has several significant advantages that make it the only effective method.

Welding ensures a high-quality joint that is comparable to the strength of the base metal. This guarantees a long-lasting repair and high resistance to stress and environmental influences. Welding can be a more cost-effective way to repair damage, especially in cases where replacing entire components is not cost-effective or an option. The use of welding can save money while maintaining the functionality and useful life of the facility. Welding is a versatile method that can be used to repair a wide range of metal components, from the smallest parts to large structures (Chludzinski *et al.*, 2021). This versatility makes welding an important tool in the restoration of a wide variety of objects.

Thus, welding proves to be not only an effective but also a practical solution for the restoration of damaged metal structures due to its durability, cost-effectiveness, versatility, and speed of repair work. The choice of welding type for a particular project or restoration work is influenced by several important factors that determine the quality and efficiency (Ghiasvand *et al.*, 2021):

- ⦿ chemical and physical parameters of the base metal;
- ⦿ operating conditions of the structure;
- ⦿ conditions of repair operations;
- ⦿ welding position;
- ⦿ units in the repair batch;
- ⦿ availability of qualified employees;
- ⦿ repair timeframes.

Furthermore, the choice of welding type may be limited by budgetary considerations. Some methods can be costly

in terms of equipment and materials, so it is important to balance cost with capability. Welding work should be carried out by qualified specialists with relevant experience and certificates. Welding plays an important role in the rehabilitation and maintenance of industrial and energy facilities.

Welding can effectively repair and strengthen boiler and turbine vessels that have been damaged by cracks or other defects. Welds reliably seal damaged areas, ensuring the safe and efficient operation of the equipment. Welding is used to repair and strengthen damaged or old pipelines. This prevents leakage of liquids or gases and ensures reliable and safe operation of the system. Welding can be used to manufacture and install new parts on machines, machinery, and other equipment that have worn out or failed (Zhang *et al.*, 2021). This extends the service life of the equipment and ensures its efficient operation. Welding is used to connect new structures or parts to existing systems when modernising or expanding industrial and energy facilities. This ensures the stability and reliability of structures that can withstand heavy loads and keep the facility running smoothly. All of these examples demonstrate the possibilities and diversity of welding applications in the rehabilitation and maintenance of industrial and energy facilities.

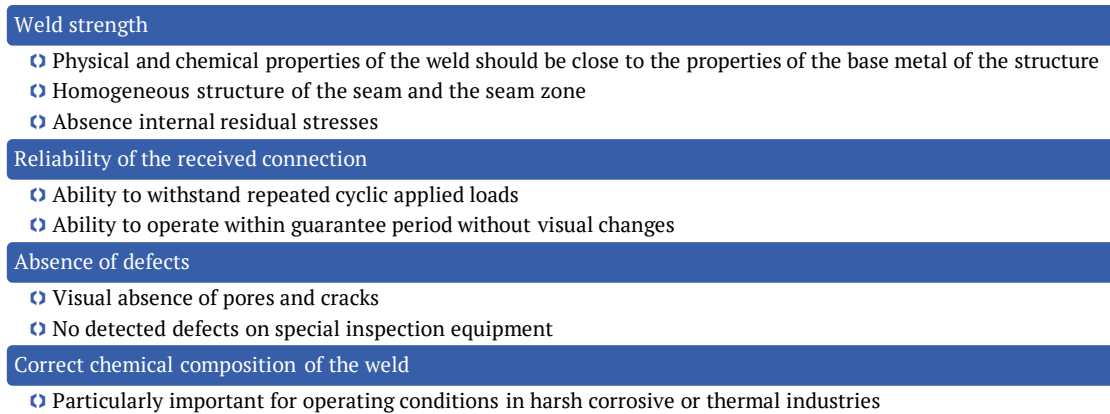
When repairing and restoring industrial and energy facilities, the choice of welding technology is one of the key aspects of project success. A variety of welding processes, including arc, gas, surfacing and electron beam welding, offer a wide range of possibilities for the restoration of various types of structures and materials (Skoblo *et al.*, 2001). The choice of a particular technology depends on several factors. The material to be welded is important in determining the most effective method. Different materials have different properties and react differently to different welding processes. For example, different methods can be used to weld steels, such as Tungsten Inert Gas (TIG) for high quality and precise welding, or Metal Inert Gas (MIG) for fast and high productivity welding (Kesse, 2021). An important aspect is the size and shape of the welded joint. For large structures or bulky components, automated methods such as submerged arc welding or laser welding can be effective, allowing for faster turnaround times without sacrificing quality. At the same time, for small or complex parts, more precise methods such as spot welding or vacuum welding can be chosen. The technical requirements for a welded joint include requirements for strength, tightness, thermal effects and other parameters. The choice of technology must meet these requirements and ensure compliance with quality and safety standards. All of these factors are considered when choosing a welding technology for the rehabilitation of industrial and energy facilities. The right choice of technology not only allows for efficient performance of the task but also ensures high quality and durability of the restored facilities, which is important for the stable operation of industrial systems (Korzhyk *et al.*, 2017).

The calculation of welded structures is an integral part of the process of rehabilitation and construction of

industrial and energy facilities. There are various welding methods used for this purpose. Today, the most common are electric welding, which can be arc or resistance welding, and gas welding. In addition, there are manual, semi-automatic and automatic welding methods. Depending on how the elements to be welded are arranged, there are different types of joints: butt, corner, lap and tack. Before starting welding, a set of calculations must be performed that consider various aspects and requirements of the structure. The calculations include the choice of materials. This is important because the material determines the strength, durability, and other characteristics of the structure. For example, corrosion-resistant materials can be used for facilities that operate in aggressive environments, and heat-resistant materials can be used for structures that are exposed to high temperatures. The next important step is to determine the dimensions of the welded joints. This includes selecting the optimal weld parameters, such as penetration depth, width, and length. The correct weld size ensures not only strength but also ease of use during the welding process (Li *et al.*, 2022). Another important aspect is the calculation of material thickness. The thickness of the material determines not only the strength but also the resistance of the structure to external influences. When restoring industrial or energy facilities, properly performed calculations ensure the required strength, reliability, and safety of the structure. They are used to avoid unforeseen situations and ensure the long-term and efficient operation of the facility throughout its entire service life.

Reliability is assessed by the ability of a product to perform its functions over a certain period of service life while maintaining its characteristics within the limits provided for its operation. The quality of welded joints depends on many factors, which can be divided into two main categories: technological and structural and operational. Technological factors include welding materials, equipment, preparation, and execution of welding operations, as well as the experience and qualifications of the operator. As for the design and operational aspects, these include the properties of the base material, product design, operating conditions, quality control methods and system, and the requirements of standards. All of these factors must be considered and controlled to effectively manage welding quality. After the welding process is complete, quality control of welded joints is an important step. This is a necessary procedure to ensure that the welded joint meets the established standards and is free from defects that could adversely affect the safety and reliability of the structure.

Product quality is defined as a set of characteristics that affect its suitability to meet the established needs following its intended use. Product quality control is aimed at ensuring that these characteristics meet the established requirements, which can be defined in standards, drawings, specifications, product passports and other regulatory and technical documentation. Quality parameters of welded joints are established based on various characteristics shown in Figure 3.

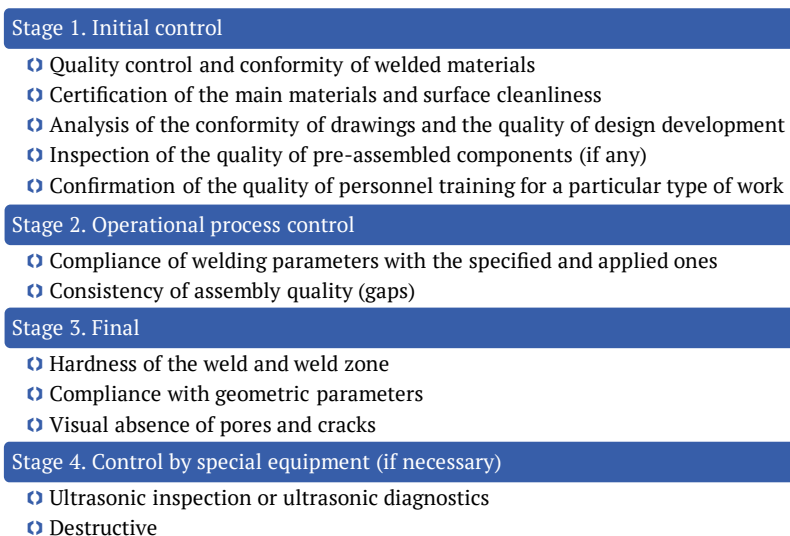


**Figure 3.** Criteria that determine the quality of weld seams

**Source:** compiled by the author

One of the inspection methods is visual inspection, during which the inspector assesses the appearance of welded joints for cracks, unsuitability, and other defects. In addition, non-destructive testing methods are also used, including ultrasonic and radiographic inspection. These methods can reveal internal defects that may not be visible by visual inspection, providing a more complete assessment of the quality of welded joints. It is also important to conduct mechanical tests, such as tensile or impact tests, which allow us to assess the strength and deformation

properties of welded joints (Ran *et al.*, 2021). Quality control of welded structures is not only a means of verifying compliance with standards, but also an important component in the process of ensuring the safety and reliability of industrial and energy facilities. Responsible implementation of this procedure is key to preventing potential industrial accidents and ensuring the long-term and safe operation of structures. As shown in Figure 4, inspection methods are divided depending on where they are applied in the production process, at a certain stage of the technological process.



**Figure 4.** The general approach to welding quality control depends on the complexity of the structure

**Source:** compiled by the author

Initial inspection includes inspection of both the basic and welding materials that make up the products and the finished welded assemblies and parts that come from other enterprises or sites. At this stage, the operating capability of the welding equipment and the qualifications of the workers are also assessed. Operational inspection includes an assessment of the welding process that is carried out after a specific operation has been performed (e.g., pre-welding preparation

inspection, weld seam assembly inspection), as well as inspection during the welding process itself. Final testing is the evaluation of the finished weld after all manufacturing processes have been completed. This stage includes an external inspection of the product, measurement of its dimensions and testing. During acceptance testing, it is checked whether the manufactured product meets the requirements set out in the regulatory and technical documentation.

Based on this inspection, a decision on the suitability of the structure for use is made. Acceptance testing is the final and most critical step in the production of welded joints. Thus, welding technologies, calculation of welded structures and quality control of welded joints are key stages in the restoration of industrial or energy facilities that ensure their strength, reliability, and safety.

## DISCUSSION

The use of welding processes in the restoration of industrial or energy facilities is a key aspect of maintenance and repair in modern industrial production. It is an effective way to repair damaged components and ensure their functionality and durability. It is important to note that welding is an extremely effective method of repairing damaged parts or components of industrial structures. It produces strong welded joints that can withstand heavy loads and operating conditions. Various welding methods, such as arc welding, gas welding, surfacing and others, enable the restoration of various types of materials and structures, making them versatile in various manufacturing industries. The use of welding in the restoration of industrial facilities can significantly reduce repair costs compared to replacing damaged parts. This is a cost-effective approach, especially in cases where replacing components requires significant time and resources.

Welding processes used in the restoration of industrial and energy facilities have a significant impact on the efficiency of production processes and resource conservation. This approach allows elements and structures that have been damaged or worn out to be preserved and restored instead of being completely replaced. This saves resources that would otherwise be spent on manufacturing new components, as well as reducing waste and negative environmental impact (Mehmeti *et al.*, 2019). Keeping facilities running smoothly is another important aspect of the use of welding in remanufacturing. Replacing damaged or worn components without delay avoids production downtime and ensures continuous operation of industrial and energy facilities (Sidliarenko, 2023). This approach to maintenance and repair helps to ensure production stability, reduce maintenance costs, and increase the overall efficiency of industrial enterprises. Thus, welding processes in the restoration of industrial or energy facilities are a necessary and effective means of ensuring the reliability and productivity of industrial equipment. This approach helps to conserve resources, reduce costs, and ensure the smooth operation of production processes.

According to A. Ahola *et al.* (2022), study of the fatigue characteristics of welded parts of an old, deteriorated steel railway bridge is an important aspect when considering its rehabilitation. Fatigue performance determines the ability of a material to withstand repetitive loads, which is critical for the safety and durability of a structure. In the context of a railway bridge, which is subjected to significant dynamic loads from trains, the fatigue analysis of the joints and welds plays a crucial role in determining the extent of damage

and the possibility of repair. These data are consistent with the theses presented in the previous section. The study of fatigue performance of welded bridge components involves the analysis of many factors, including the geometry of the welded joints, the type of materials used, the load history and the operating conditions. Understanding these characteristics helps engineers develop rehabilitation strategies and ensure the safety of the rehabilitated structure.

Referring to the definition of K. Łyczkowska & J. Adamiec (2022), the phenomena associated with the cracking of repair welds are an important aspect of welding technologies. Cracking can occur as a result of various factors, such as incorrectly selected welding parameters, the presence of internal stresses in the material, insufficient surface preparation, and metal structure features. These phenomena can lead to the formation of microcracks in the welded joint, which can significantly reduce the strength characteristics of the weld and impair its durability. It is worth noting that several criteria must be considered, and appropriate measures taken to prevent cracking of welds in repair. This may include the correct choice of welding materials, considering their composition and heat treatment, optimal adjustment of welding equipment, control of stresses in the material, as well as ensuring sufficient surface pretreatment and removal of possible defects. This approach minimises the risk of cracking and ensures a high-quality repair joint.

H. Zhou *et al.* (2021) determined that predicting and reducing out-of-plane welding deformations are key challenges in the manufacture of typical blocks such as semi-submersible lifting and dismantling platforms. These deformations can occur due to uneven thermal effects during welding, leading to distortion of geometric parameters and structural failure. Even minor deformations can have a significant impact on the subsequent assembly and operation of the platform, so their prediction and control are important stages of the production process. These results confirm the above study, as various methods and technologies are used to reduce out-of-plane welding deformations. This may include optimising the welding process by selecting optimal parameters, using special clamping, and fixing devices, as well as applying local heating and stress control methods. In addition, preliminary modelling and analysis of potential deformations using modern software tools plays an important role (Kostenko *et al.*, 2023). This integrated approach allows for effective control of the welding process and minimisation of the negative effects of deformation on the quality and reliability of the final product.

B.E. Kogo (2021) demonstrated that the analysis of thermal and residual stresses in welded joints of clad pipelines is a key aspect of the welding process. Clad pipelines, consisting of a base steel pipe and a protective coating layer, pose special technological challenges during the welding process. When heated during the welding process, the materials expand and contract, which can lead to thermal stresses in the welded joints. Residual stresses in welded joints can occur due to uneven cooling and shrinkage of the metal during the cooling process after welding. These

stresses can affect the mechanical properties of the joint and the ability of the pipeline to withstand operational loads such as pressure and temperature. In agreement with this opinion, various numerical modelling and experimental analysis methods are used to analyse thermal and residual stresses in welded joints of clad pipelines. Numerical models based on finite element methods allow for predicting the stress distribution in the joints and optimising the welding process to minimise their impact. Experimental methods, such as strain measurements and bell tensile testing, are used to verify and validate the results of numerical modelling and assess the quality of welded joints (Oliinyk & Tuts, 2023).

As noted by Y. Li *et al.* (2022), a new approach to occupational health risk assessment in welding projects includes a comprehensive approach to analysing the potential hazards faced by welders in the work environment. This approach considers not only the physical aspects of the job, such as exposure to hazardous substances and working conditions but also the psychological and social factors that can affect the overall well-being of welders. The application of a new approach to occupational health risk assessment in welding projects allows for a more accurate and comprehensive assessment of potential health hazards to welders and the development of appropriate measures to prevent and minimise them. Analysing the results and conclusions obtained, it is possible to note that such an approach may include training personnel in safe working practices, the use of special protective equipment, regular medical examinations and health monitoring, as well as regular audits of the working environment to identify and eliminate potential hazards.

J. Choi *et al.* (2023) determined that modelling predictive maintenance systems for laser welders on continuous galvanising lines based on machine learning with welder control data is an important area of research in industrial production. This system can predict possible failures or malfunctions in the equipment used for laser welding based on data collected in real-time from the welding process systems. One of the main advantages of using machine learning models in predictive maintenance systems is their ability to process large amounts of data and identify complex relationships between various welding process parameters and possible malfunctions. This allows for a quick response to potential problems and minimises equipment downtime, which in turn helps to improve production efficiency.

## CONCLUSIONS

Welding processes are a critical aspect of modern engineering practice in the rehabilitation of industrial and energy facilities. Not only does it allow for the restoration of damaged or consumable components, but it also ensures their durability and functionality. Welding is a technology that

creates stable and strong joints that can withstand significant mechanical loads and harsh environments, making them indispensable for industrial applications. This is especially important in industrial production environments where equipment and structures are subject to significant wear and tear and require reliable connections to ensure smooth operation and worker safety.

For decades, around the period 1950-2000, welding trends were directed in two aspects: increasing productivity and quality of the joint, where the amount of applied metal was given precedence, and this was the impetus for the development of submerged arc welding, electro slag welding. However, this required highly skilled workers and high equipment costs. In recent years, advances in inverter technologies, a reduction in the metal intensity of structures, and a shift from specific welder skills to semi-automation, even manual welding was observed. Further development of welding is seen in the robotisation of the process and the unification of welding materials. Various welding methods, such as arc welding, gas welding, surfacing and others, provide versatility in restoring different types of materials and structures, which allows them to be widely used in various industries. In addition, welding in the restoration of facilities can significantly reduce repair costs compared to replacing damaged parts, making it a cost-effective solution.

Welding processes used in the refurbishment of industrial and energy facilities help to conserve resources, increase the efficiency of production processes, and ensure production stability. This maintains the uninterrupted operation of facilities and ensures the reliability and performance of industrial equipment. Thus, the use of welding processes in the rehabilitation of industrial and energy facilities is an important element of modern industrial practice, ensuring efficiency, cost-effectiveness, and reliability in production processes. In addition, the use of welding processes opens up opportunities for the introduction of innovative technologies and methods in the restoration of industrial and energy facilities. This contributes to the continuous improvement of the quality and efficiency of repair work, which in turn contributes to the competitiveness of enterprises. Thus, the use of welding in the rehabilitation of industrial and energy facilities plays an important role in ensuring the sustainability and development of the industrial sector. The impact of the welding process parameters on the structure and properties of the restored materials should be further studied.

## ACKNOWLEDGEMENTS

None.

## CONFLICT OF INTEREST

None.

## REFERENCES

- [1] Ahola, A., Lipiäinen, K., Afkhami, S., Lilja, H., & Björk, T. (2022). Fatigue performance of the welded details of an old, demolished steel railway bridge. *Engineering Structures*, 256, article number 113966. doi: [10.1016/j.engstruct.2022.113966](https://doi.org/10.1016/j.engstruct.2022.113966).
- [2] Bondarenko, Yu.K., & Loginova, Yu.V. (2022). Use of statistical methods to support the required quality of welded products (Review). *Technical Diagnostics and Non-Destructive Testing*, 2, 44-53. doi: [10.37434/tdnk2022.02.06](https://doi.org/10.37434/tdnk2022.02.06).
- [3] Chludzinski, M., dos Santos, R.E., Churiaque, C., Ortega-Iguña, M., & Sánchez-Amaya, J.M. (2021). Pulsed laser welding applied to metallic materials – A material approach. *Metals*, 11(4), article number 640. doi: [10.3390/met11040640](https://doi.org/10.3390/met11040640).
- [4] Choi, J.S., Choi, S.W., & Lee, E.B. (2023). Modeling of predictive maintenance systems for laser-welders in continuous galvanizing lines based on machine learning with welder control data. *Sustainability*, 15(9), article number 7676. doi: [10.3390/su15097676](https://doi.org/10.3390/su15097676).
- [5] Ghiasvand, A., Yavari, M.M., Tomków, J., Grimaldo Guerrero, J.W., Kheradmandan, H., Dorofeev, A., Memon, S., & Derazkola, H.A. (2021). Investigation of mechanical and microstructural properties of welded specimens of AA6061-T6 alloy with friction stir welding and parallel-friction stir welding methods. *Materials*, 14(20), article number 6003. doi: [10.3390/ma14206003](https://doi.org/10.3390/ma14206003).
- [6] Kachynskiy, V.S., & Koval, M.P. (2021). [Registration of technological parameters and quality control in the process of press welding of pipes with a magneto-controlled arc](#). In *Proceedings of the 21st International Scientific and Practical Conference "Quality, Standardisation, Control: Theory and Practice"* (pp. 25-29). Kyiv: Association of Machinery Technologists of Ukraine.
- [7] Kesse, M.A. (2021). *Artificial intelligence: A modern approach to increasing productivity and improving weld quality in TIG welding*. Lahti: LUT University Press.
- [8] Kogo, B.E. (2021). *Thermal and residual stress analysis of welded joints in clad pipelines*. London: Brunel University London.
- [9] Korzhyk, V., Khaskin, V., Voitenko, O., Sydorets, V., & Dolianovskaia, O. (2017). Welding technology in additive manufacturing processes of 3D objects. *Materials Science Forum*, 906, 121-130. doi: [10.4028/www.scientific.net/MSF.906.121](https://doi.org/10.4028/www.scientific.net/MSF.906.121).
- [10] Korzhyk, V.M., Khaskin, V.Yu., Illyashenko, E.V., Peleshenko, S.I., Grynyuk, A.A., Babych, O.A., Alyoshin, A.O., & Voitenko, O.M. (2024). Hybrid laser-plasma welding: Efficiency and new possibilities (review). *The Paton Welding Journal*, 1, 13-21. doi: [10.37434/tpwj2024.01.02](https://doi.org/10.37434/tpwj2024.01.02).
- [11] Kostenko, M.V., Sheveleva, A.E., Gergel, I.Y., & Loboda, V.V. (2023). Plane deformation of a piezoelectric bimaterial with two electrically conductive and charged interface cracks. *Bulletin of Cherkasy State Technological University*, 2, 146-154. doi: [10.24025/2306-4412.2.2023.278565](https://doi.org/10.24025/2306-4412.2.2023.278565).
- [12] Kryvyi, O.F., & Morozov, Yu.O. (2022). [Mathematical modeling of the influence of structural inhomogeneities on the strength of welded joint so](#). In *Proceedings of the International Scientific and Technical Conference "Ship Electrical Engineering, Electronics and Automation"* (pp. 44-47). Odesa: Odesa Maritime Academy.
- [13] Lebedev, V., Brykov, M., & Makarenko, N. (2022). [Combination of processes and combined solutions in improving the technique and technology of arc welding and fusion](#). In *Proceedings of the International Scientific and Technical Conference "Strength and Durability of Modern Materials and Structures"* (pp. 134-136). Ternopil: V.A. Palianytsia.
- [14] Li, Y., Liu, W., Chen, Z., Jiang, L., & Ye, P. (2022). A novel approach for occupational health risk assessment and its application to the welding project. *Journal of Cleaner Production*, 378, article number 134590. doi: [10.1016/j.jclepro.2022.134590](https://doi.org/10.1016/j.jclepro.2022.134590).
- [15] Łyczkowska, K., & Adamiec, J. (2022). The phenomena and criteria determining the cracking susceptibility of repair padding welds of the Inconel 713C nickel alloy. *Materials*, 15(2), article number 634. doi: [10.3390/ma15020634](https://doi.org/10.3390/ma15020634).
- [16] Main types of welding. (2020). Retrieved from <https://plasmatec-weld.com.ua/news/osnovni-vidi-zvaryuvannya>.
- [17] Mehmeti, B., Kelmendi, J., Ilijazi-Shahiqi, D., Azizi, B., Jakovljevic, S., Haliti, F., & Anić-Milošević, S. (2019). Comparison of shear bond strength orthodontic brackets bonded to zirconia and lithium disilicate crowns. *Acta Stomatologica Croatica*, 53(1), 17-27. doi: [10.15644/asc53/1/2](https://doi.org/10.15644/asc53/1/2).
- [18] Nalle, C.Y., Aditya, M.B., Putra, F.G., Nalle, M.N., & Sumarta, R.P. (2024). [Analysis of electric current on aluminum plate welding using MMA \(Manual Metal Arc\) method](#). In *Proceeding of 1<sup>st</sup> International Conference on Artificial Intelligence, Navigation, Engineering, and Aviation Technology (ICANEAT)* (pp. 144-146). Rogojampi: Akademi Penerbang Indonesia Banyuwangi.

- [19] Novodranov, A.S., Topchev, D.D., Mangold, A.M., Shapovalov, E.V., & Kolyada, V.O. (2023). Use of welding additive technologies in manufacture of metal parts of a complex shape (Review). *Automatic Welding*, 1, 16-21. doi: [10.37434/as2023.01.03](https://doi.org/10.37434/as2023.01.03).
- [20] Oliinyk, A., & Tuts, O. (2023). Complex mathematical process of harmful substances spread during main gas pipelines accidents. *Ecological Safety and Balanced Use of Resources*, 14(1), 54-60. doi: [10.31471/2415-3184-2023-1\(27\)-54-60](https://doi.org/10.31471/2415-3184-2023-1(27)-54-60).
- [21] Ran, M.M., Sun, F.F., Li, G.Q., & Wang, Y.B. (2021). Mechanical behaviour of longitudinal lap-welded joints of high strength steel: Experimental and numerical analysis. *Thin-Walled Structures*, 159, article number 107286. doi: [10.1016/j.tws.2020.107286](https://doi.org/10.1016/j.tws.2020.107286).
- [22] Sidliarenko, A. (2023). Mathematical models of road construction, reconstruction and repair under conditions of uncertainty. *Bulletin of Cherkasy State Technological University*, 3, 113-127. doi: [10.24025/2306-4412.3.2023.287845](https://doi.org/10.24025/2306-4412.3.2023.287845).
- [23] Skoblo, T.S., Vlasovets, V.M., & Moroz, V.V. (2001). Structure and distribution of components in the working layer upon reconditioning of parts by electric-arc metallization. *Metal Science and Heat Treatment*, 43(11), 497-500. doi: [10.1023/a:1014857107509](https://doi.org/10.1023/a:1014857107509)
- [24] Tanasković, D., Petrović, S., Đorđević, B., Matavž, A., & Mijatović, T. (2021). [Algorithm for defining quality of base material for repair welding](#). *Structural Integrity and Life*, 21(3), 279-284.
- [25] Zhang, Y.M., Wang, Q.Y., & Liu, Y.K. (2021). Adaptive intelligent welding manufacturing. *Welding Research*, 100(1), 63-83. doi: [10.29391/2021.100.006](https://doi.org/10.29391/2021.100.006).
- [26] Zhou, H., Wang, J., Zhang, H., Liu, J., & Mo, Z. (2021). Prediction and mitigation of out-of-plane welding distortion of a typical block in fabrication of a semi-submersible lifting and disassembly platform. *Marine Structures*, 77, article number 102964. doi: [10.1016/j.marstruc.2021.102964](https://doi.org/10.1016/j.marstruc.2021.102964).

**Ірина В'ячеславівна Захарова**

Доктор технічних наук, професор  
Приазовський держаний технічний університет  
49000, вул. Гоголя, 29, м. Дніпро, Україна  
<https://orcid.org/0009-0000-5403-2153>

## **Застосування процесів зварювання у відновленні промислових та енергетичних об'єктів**

**Анотація.** Дослідження є необхідним у зв'язку з постійним розвитком і змінами у виробничому середовищі та технологічних вимогах для забезпечення підвищення безпеки, міцності та ефективності промислових та енергетичних об'єктів. Мета даного дослідження – аналізувати методи та стратегії, спрямовані на підвищення ефективності зварювання та контролю якості з'єднань, з урахуванням досягнення більшої стабільності та надійності енергетичних об'єктів. Серед використаних методів слід зазначити, такі як спостереження, порівняльно-описовий, моніторинг, абстрагування та інші. У дослідженні було проведено аналіз різних зварювальних технологій та їх вплив на якість зварних з'єднань. Розглянуті різні методи розрахунку зварних конструкцій з урахуванням матеріалів та технічних вимог. Крім того, було досліджено різні методи контролю якості зварних з'єднань, зокрема візуальний огляд та неруйнівний контроль. В результаті дослідження було встановлено, що правильний вибір технології, розрахунків та контролю якості дозволяє підвищити міцність, надійність, безпеку та економічну обґрунтованість зварених конструкцій. В досліджених зварювальних технологіях та використаних методах контролю якості є більш ефективні для застосування в специфічних умовах і не існує загального рішення. Крім того, виявлено, що правильне застосування цих методів може значно скоротити час відновлення та підвищити загальну продуктивність процесу відновлення промислових та енергетичних об'єктів. Отже, оптимальне використання зварювальних технологій та методів контролю якості може значно покращити ефективність та довговічність промислових та енергетичних об'єктів. Практичне значення дослідження полягає в сприянні підвищенню безпеки, надійності та ефективності відновлення промислових та енергетичних об'єктів шляхом вдосконалення процедур контролю якості зварних з'єднань

**Ключові слова:** неруйнівний контроль; мікроструктура; міцність з'єднання; електроди; методи контролю якості