SOI: 1.1/TAS DOI: 10.15863/TAS
International Scientific Journal
Theoretical & Applied Science

p-ISSN: 2308-4944 (print) **e-ISSN:** 2409-0085 (online)

Year: 2023 **Issue:** 09 **Volume:** 125

Published: 18.09.2023 **http://T-Science.org**

Issue **Article**

Murtoza Shavkidinovich Toirov
Navoi State Mining and Technologies University
associate professor of the Department of «Mechanical Engineering», Ph.D.
(99) 943 41 71
murtoza.toirov@mail.ru

Ulugbek Yunusovich Ochilov
Navoi State Mining and Technologies University
assistant of the Department of «Mechanical Engineering»
(91) 990 79 95
ulugekochilovuzbekistan@mail.ru

FEATURES OF ENGINEERING METHODS OF RESEARCH RESULTS ON BUTT WELDING ON METAL PIPELINES

***Abstract**: This article discusses the use of flash butt welding (FBW) for increased labor productivity in pipeline construction. However, despite its promise, FBW technologies and equipment have limitations in creating defect-free welded joints. The Ishikawa diagram is used to systematize and analyze factors that cause defects, which are then ranked on a Pareto diagram. The main causes of defects are found to be associated with human factors, such as the qualifications of workers, as well as imperfections in machinery and equipment, material deviations, and technology and measurement limitations. A correlation matrix is used to analyze the causes of decrease in quality and determine that improving methods and means of FBW processes, along with FBW technologies, is the solution. However, a complete computer model of FBW processes has not yet been created due to difficulties in describing energy release and other energy phenomena. A physical and mathematical model is necessary to take into account energy processes in the welding zone.*

***Key words**: defects in welded joints, Ishikawa diagram, Pareto diagram, human factor, qualification of performers, process monitoring systems, setting modes, assembly and installation problems.*

***Language**: English*

***Citation**: Toirov, M. Sh., & Ochilov, U. Yu. (2023). Features of engineering methods of research results on butt welding on metal pipelines. *ISJ Theoretical & Applied Science, 09 (125)*, 267-273.

***Soi**: http://s-o-i.org/1.1/TAS-09-125-30 ***Doi**: crossref https://dx.doi.org/10.15863/TAS.2023.09.125.30

***Scopus ASCC**: 2200.*

Introduction

For a significant increase in labor productivity in the construction of pipelines, it is very promising to use flash butt welding of FBW [1]. Unfortunately, modern FBW technologies and the equipment used do not allow to fully create defect-free welded joints [2, 3]. Analysis of the causes of defects is difficult to implement due to their diversity [4]. One of the effective tools for systematization and analysis of significant factors that cause any consequence is the Ishikawa diagram [5].

Traditionally, all possible causes on the Ishikawa diagram [8] are categorized according to the principles: (human) - due to the human factor; (machines, equipment) - associated with equipment; (materials) - related to materials; (methods, technology) - related to the technology of work, with the organization of processes; (measurement, control) - related to methods of measurement and quality control. Subsequently, these reasons were ranked on the Pareto diagram [6]. On fig. 1 shows the Ishikawa diagram indicating the main cause-and-effect relationships for ensuring the quality of welded joints during the implementation of the FBW process.

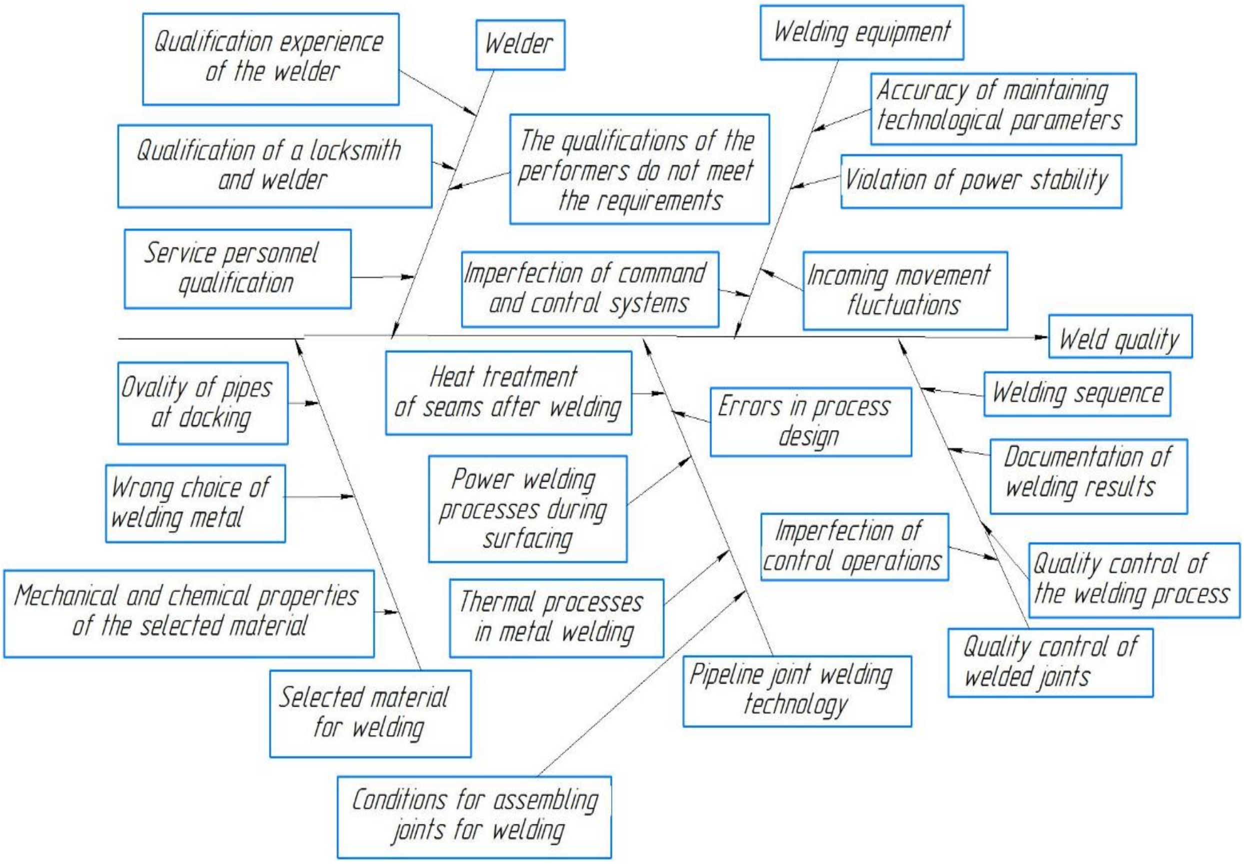

Fig. 1. Ishikawa diagram of the implementation of the FBW process, indicating the cause-and-effect relationships.

It has been established that the common cause of defects in the implementation of FBW processes associated with the human factor (human) is the qualification of the performers that does not correspond to the complexity of the process. The Pareto diagram showed that the absence of process monitoring systems and the possibility of adjusting modes, assembly and installation problems of the welding machine at the joint, as well as machine failures and vague wording in the RE also contribute to the occurrence of defects.The main reasons for the occurrence of defects due to imperfections (machines, equipment) are the instability of the welding mode parameters, the energy parameters of the process, the supply current, as well as the design flaws of the equipment. The Pareto diagram showed that the main among them are the instability of the technological parameters of the welding mode and the instability of the upsetting mechanisms. Among the reasons for the decline in product quality associated with (materials) are deviations in the ovality of pipes and their initial mechanical properties, the presence of internal and surface defects and contamination of the pipe cavity. The Pareto diagram showed the primary influence on the occurrence of defects of the ovality of pipes and their initial mechanical properties, the presence of internal defects.

There are still a number of problems grouped into the category (methods, technology), including the lack of the possibility of intervening in the welding process, difficulties in flashing and upsetting, the need for maintenance to improve the mechanical properties of the welds and the HAZ. The Pareto diagram shows that the main ones are the impossibility of prompt intervention in the welding process. In many respects determine the quality of FBW. The Pareto diagram shows that the main disadvantages associated with methods for measuring and controlling the quality of welded joints are: the inability to predict the quality of welds directly in the welding process and the lack of a system for monitoring deviations in the assembly of joints. For further in-depth analysis, a correlation matrix was built between the causes of a decrease in the quality of welded joints and the conditions for performing welding work, which made it possible to determine that the integral way to solve most of these problems is to improve the methods and means of all stages of the FBW process with simultaneous improvement of FBW technologies based on high-quality and quantitative analysis of phenomena occurring during welding. It is known that the necessary properties of welded joints are ensured by setting the optimal parameters of the welding mode using computer analysis methods [7]. However, a sufficiently complete computer model of the processes occurring in the contact zone has not yet been created. This is due to the problems of describing the heat release in the contact zones, the formation of a permanent connection in the liquid-solid phase, and structural transformations in the weld and HAZ.

Since heat release is a system-forming factor, exclusive attention is paid to it [8]. Powerful heat release in the joint is due to the flow of current through numerous bridges of liquid metal in the joint, which randomly appear and explode, which leads to the removal of a significant amount of metal in the form of spatter. Therefore, the main problem of computer simulation of the FBW process is to take into account the basic energy phenomena in the physical and mathematical description. The main technological factors are the reflow rate V , allowances for reflow $\delta$and upsetting Δ, at the installation reach L (distance from the machine clamps to the joint), as well as the open-circuit voltage U , fig. 2.

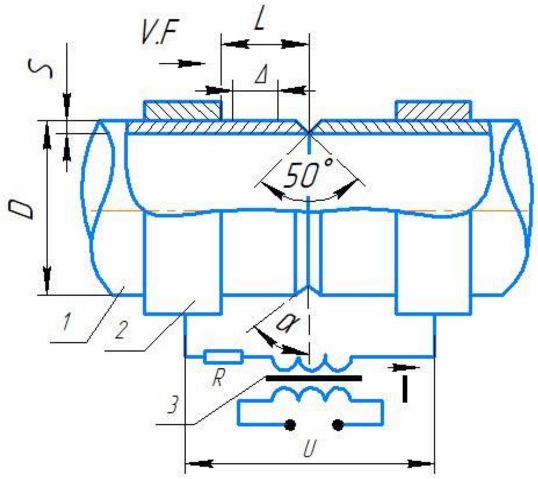

Fig. 2. Scheme of the flash welding process.
1 - Weldable structure, 2 - clamps, 3 - welding transformer.

In this regard, the physical and mathematical model should take into account the energy processes occurring in the zone immediately adjacent to the joint, fig. 3.

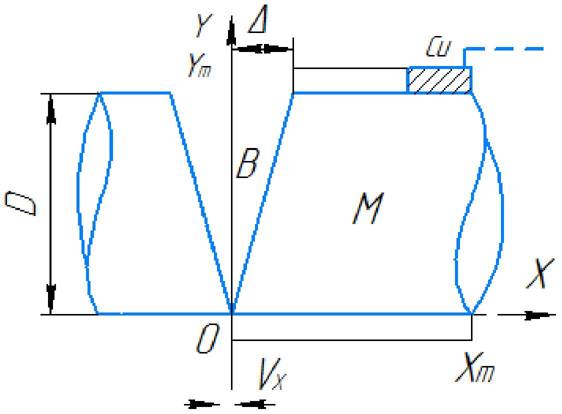

Fig. 3. Reflow process zone: M - steel of the pipe wall, Cu - copper retainer (current lead), B - air.

Since the welded joint is symmetrical, the processes in the end part of one of the pipes are characteristic of the second. Taking into account the fact that all axial sections of the pipe are the same, the process was considered only in one of these sections in the Cartesian coordinate system x,y . The center of coordinates was placed in the corner of the contact zone of the pipes. During melting, this center is immobile, and the metal moves at the melting speed along the $v_x x$ coordinate . Since the shape of the joint changes during reflow, the free space into which the metal moves is included in the modeling space. The zone occupied by metal is designated *M*, free - *B*. The main physical dependencies necessary for the development of a mathematical model of the FBW process, including the temperature distribution in the simulation zone by solving the heat equation, the boundary conditions for the heat exchange of the simulation zone with the surrounding space, as well as the distribution of heat generation in the metal from the flow of electric current through it and heat generation from arcs - of the spark process in the joint at the break of the jumpers are presented in [9].

It is known [10] that FBW processes can be divided into 5 stages, which are implemented in the following sequence: initial short circuit in the joint, preliminary heating of the edges during the arc- spark process, obtaining a steady temperature distribution in the joint, forcing flashing before upsetting and upsetting of the joint with subsequent cooling. Since at stage 1 the process is in the resistance welding mode under conditions of continuous edge approach, the main parameters of this process are the short-circuit current of the joint, the $v_x$edge approach speed and the edge preparation angle α. On fig. Figure 4 shows the dependence of the heating time of the contact metal on the angle of cutting edges at different values of the speed of their convergence, the initial *short circuit* in the joint. The obtained results of modeling the initial stage of the process show that at angles of cutting over 15 ^{0} the flashing is stably excited at real speeds of the initial stage of flashing 0.1…0.3 mm/s. Therefore, the cutting angle α = 15° can be considered optimal.

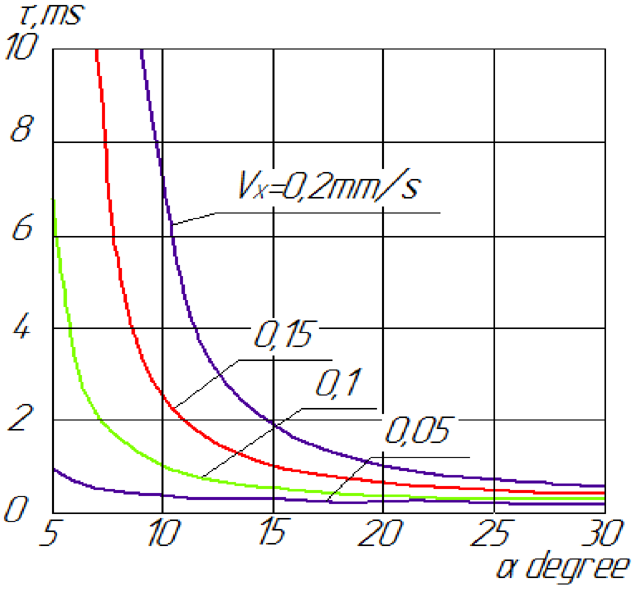

Fig. 4. Dependence of the τ heating time of the butt metal to the melting temperature on the angle of α cutting edges at different speedsv_x their convergence.

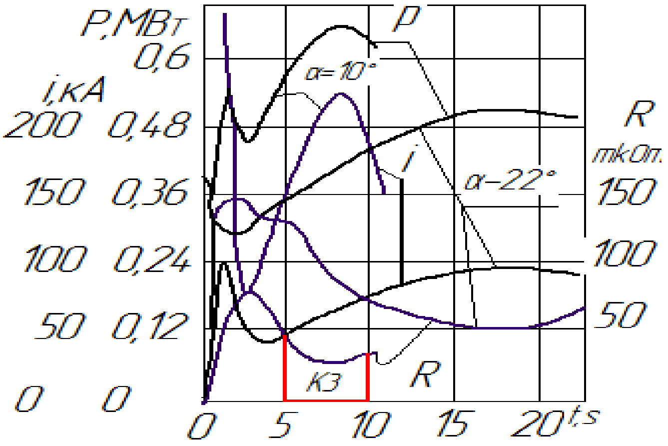

Fig. 5. Influence of the bevel angle on the power, current and electrical resistance of the joint in the initial phase of the process at a melting speed of 0,14 mm/s.

Short circuit - area of short circuit of the joint.

Preliminary heating of the edges during the arc-spark process at stage 2 is accompanied by removal of edge metal Since the beginning of this stage occurs at cold metal, then it is characterized by an increased intensity of heat extraction in the arc zone spark process. Therefore, it is the shape of the groove that determines the rate of increase in the area of the melted metal as the edges approach each other. On fig. 5 shows the change in heat dissipation power and joint resistance in the initial phase of the process at different values of the angle of cutting edges. The power consumed for melting is determined by the amount of heat carried away by the drops metal and heat flow into the metal of the joint.

At the beginning of reflow, the power of the thermal flow into metal which has a low temperature. As the metal warms up, this power decreases, and the total power of the process and the welding current decrease accordingly. The power carried away by the drops increases as the growth of the reflow area faster than the decrease in the heat flux in edges. Therefore, after the initial decrease in current, its increase begins. Maximum current and power is reached when the fusion has removed the grooves and covered the entire cross section.

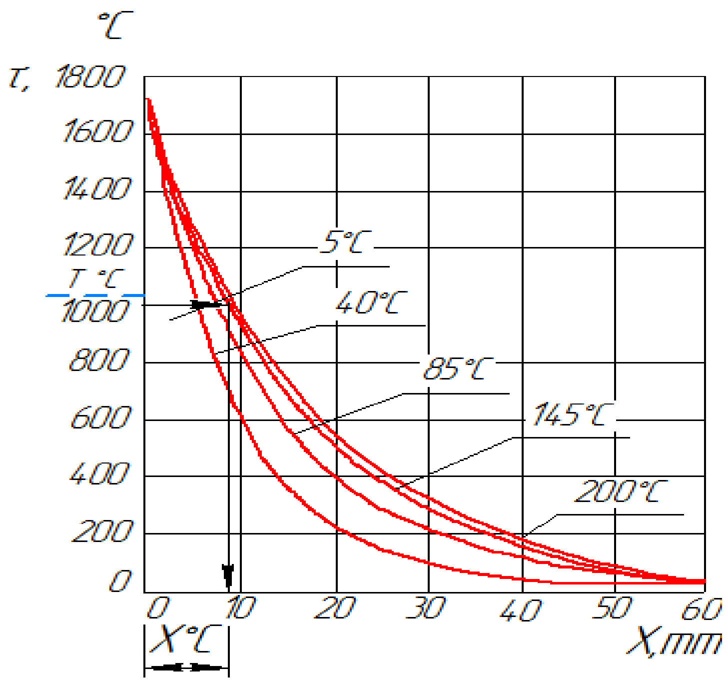

Fig. 6. Temperature distribution over the depth of the metal at different times of melting and determination of the allowance for upsetting X_{oc} by the temperature Toc of metal deformation during joint upsetting.

Stage 3 is characterized by a steady temperature distribution in the joint. Since at this stage the melting covers the entire cross section of the joint, the power of the heat flux into the metal gradually decreases, and the temperature distribution stabilizes. In this case, the optimal combination of the edge approach rate and the energy parameters of the process should ensure a uniform temperature distribution without chaotic arc breaks and short circuits. If at this stage the heat input is excessively high, and the edge convergence rate is too low, then there is a high probability of occurrence of local tearing of the metal, which increases the risk of defects in the formation of the seam. On fig. 6 shows the change in the temperature distribution over the depth of the metal during melting. The resulting temperature distribution makes it possible to determine the optimal value of the melting allowance.

This allowance is determined by the optimum temperature for completing the deformation of the metal during upsetting. When welding steels, this temperature is 1000 ... 1200 ° C. It is also desirable that the precipitation temperature be below the phase transition temperature (760 ^{0}C), which excludes the formation of hardening structures. According to the value of the deformation temperature during upsetting Toc and the resulting temperature distribution, it is possible to determine the allowance for reflow Xos, fig. 6. According to the tensile strength σs at the selected temperature Tos , fig. 7, and the cross-sectional area of the joint - upsetting force.

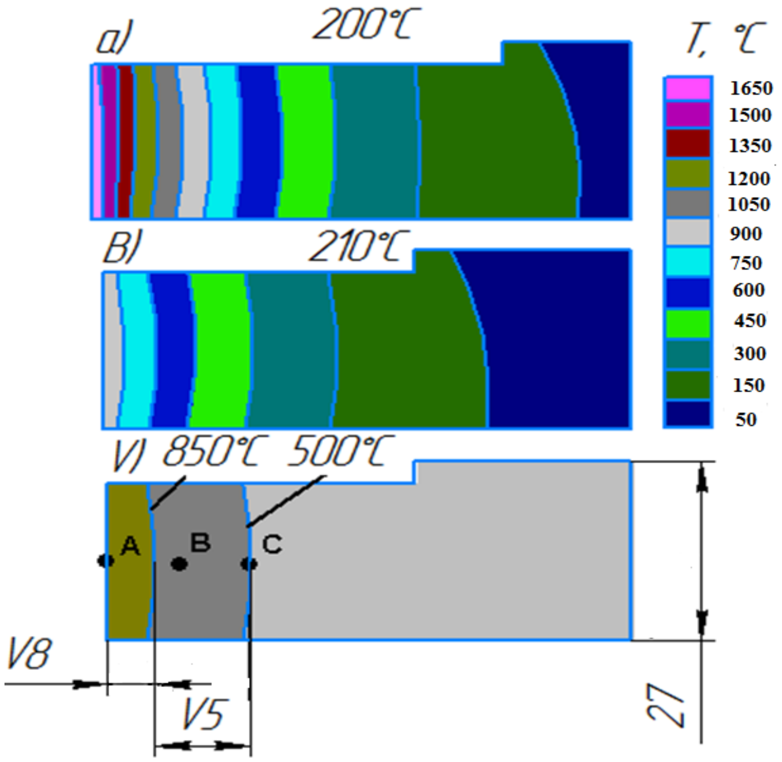

Fig. 7. Temperature distribution in the wall of a steel pipe at the moment end of melting (a), at the moment of end of upsetting (b) and location of zones of complete (X8, T>850oC) and partial (X5, 850oC >T >500oC) structural transformation (c).

To ensure the fusion of the joint at stage 4, flashing is forced before upsetting. To do this, the speed is increased to the maximum allowable value of the power of the machine. On fig. Figure 8 shows the influence of the value Vx4 of the flashing speed at the stage of its forcing on the power P of heat release in the joint, on the welding current I and on the resistance of the joint R. at a speed of 0.4 mm/s, the resistance of the joint drops below 50 μΩ, the internal resistance of the machine. Therefore, it is more rational to stepwise increase the reflow rate: at the first stage - Vx3 to the limit value at which the stability of the process is maintained, and at the second stage, the value of Vx4 to the maximum for the power source with varying the reflow interval.

Based on the results obtained, which are in good agreement with the data of [11], a cyclogram with Vx4 = 1.2 mm/s was adopted. At stage 5, joint settlement and cooling occur. Sludge plays an important role in weld quality as it forces molten metal and contaminants out of the joint. The duration of upsetting is determined by the capabilities of the upsetting mechanism of the welding machine and should be as short as possible, since after short circuit the temperature of the metal decreases rapidly (Fig. 8). The performed analysis made it possible to determine how the main physical and technological conditions for the flow of FBW affect the possibility of obtaining defect-free welded joints of joints in large-diameter main pipelines, including the bevel angle of the joint edges, allowance for flashing, forcing flashing and upsetting. The presented research methods can also be used to solve other problems of welding production, for example, the creation of intelligent control systems.

References:

1. Zhuravlev, S.I., & Konovalov, N.A. (2013). *Features of the construction of main pipelines using flash butt welding.* Sat. Materials of the International Scientific and Practical Conference "Problems and Methods for Ensuring the Reliability and Safety of Oil, Oil Products and Gas Transportation Systems". (pp.206-207). Ufa: State Unitary Enterprise "IPTE".

2. Zhuravlev, S.I. (2013). Ways to solve the problems of introducing flash butt welding on main pipelines of large diameters (review). *Izvestia of higher educational institutions. Engineering*. 2013. No. 8, pp. 64 - 71.
3. Konovalov, N.A., & Tretyakov, E.S. (2013). *Using methods of expert assessments in improving equipment and technologies for flash butt welding of pipelines.* Sat. Proceedings of the VI All-Russian Conference of Young Scientists and Specialists "The Future of Mechanical Engineering in Russia". (pp.108-109). Moscow: MSTU im. N.E. Bauman.
4. Zhuravlev, S.I., Konovalov, N.A., & Poloskov, S.I. (2013). *Technological features of flash butt welding of pipelines of large diameters*. Sat. scientific papers of the VII International scientific and technical conference "Modern problems of mechanical engineering". (pp.180-185). Tomsk: Publishing House of the Tomsk Polytechnic University.
5. Ishikawa, K. (2007). *La gestion de la qualité , outils et applications pratiques. Traduit par Jean-Marie Douchy*. (p.242). Paris: L'Usine Nouvelle.
6. (2001). Reed WJ The Pareto, zipf and other power laws. *Economics Letters* 2001. Vol. 74, Issue 1, pp. 15-19.
7. Ichiama, Y., & Satio, T. (2004). Factors affecting flash weldability in high strength steel - a study on toughness improvement of flash welded joints in high strength steel. *Welding International*. 2004 Vol. 18. No. 6, pp. 436 - 443.
8. Erofeev, V. A. (2002). *Prediction of the quality of electron beam and laser welding based on computer simulation:* Monograph. (p.140). Tula: TulGU.
9. Zhuravlev, S.I., Erofeev, V.A., & Poloskov, S.I. (2013). Physico-mathematical model of flashing in the process of flash butt welding. *Welding and Diagnostics*. 2013. No. 4, pp. 26 - 30.
10. Mardonov, B.T., & Toirov, M.Sh. (2023). Reliable evaluation of strength effects of welding defects for steel pipes and tube systems. *Science and technology magazine “Development of science and technology”. “Fergana polytechnic institute”.* Number №1. 2023, pp. 20 - 25.
11. Kuchuk -Yatsenko, S.I. (1992). *Flash butt welding.* (p.236). Kiev: Naukova Dumka.
12. Kuchuk -Yatsenko, S.I., Shvets, Yu.V., Zagadarchuk, V.F., et al. (2012). Flash butt welding of thick-walled pipes made of high-strength steels of strength class K56 / *Automatic welding*. 2012. No. 5, pp. 5 - 11.