Economic evaluation for use of advanced welding equipment

To cite this article: P Y Petrov et al 2017 IOP Conf. Ser.: Earth Environ. Sci. 87 092021

View the article online for updates and enhancements.
Economic evaluation for use of advanced welding equipment

P Y Petrov¹, I V Alekseev², E A Kolesnik³

¹ Federal State Government-Funded Educational Institution of Higher Education «Moscow State University of Railway Engineering After Emperor Nicholas II (Moscow State University of Railway Engineering)», Yaroslavl branch, 13 Suzdal Highway, Yaroslavl, 150030, Russia
² «Transmashholding» CJSC, 26 Butyrsky Val St., Moscow, 127055, Russia
³ Federal State Government-Funded Educational Institution of Higher Education «Tyumen Industrial University», 38 Volodarskogo St., Tyumen, 625000, Russia

E-mail: py_petrov@mail.ru

Abstract. Stable and sustainable predicted development of industrial enterprises within global competition is ensured by regular improvement of technologies and introduction of innovative technological equipment. In terms of comparative analysis of the various power supplies application in the welding production, the equality of relative resource efficiency of various equipment and specific economic effect has been calculated. The research showed that the costs per 1 meter are the smallest for semiautomatic welding in a protective gas environment using inverter power supplies, contributing to the economic benefit during its application.

1. Introduction

Mechanical engineering is, first of all, the technologies. Scientific-technological progress and innovations are the key factors in the development and growth of the machine building complex, and hence the entire economy as a whole [1]. The experience of Western European technology companies is evident here, especially, when 7-10 years later they introduce improved equipment, acquire licenses, finance expensive researches in the field of innovative technologies, etc.

But the strategic attractiveness of the enterprise is determined not only by modern production capacities and financial potential, but also by the ability to quickly implement advanced management systems and production technologies. Advanced technologies should be understood as technologies that correspond to the technological mode according to the methods of influence on the processing object in production and/or service provision [2]. The implementation of such technologies becomes possible with the availability of capital equipment per unit of labor for enterprise, which corresponds to the latest innovations in academic and applied science by its indicators.

Therefore, the introduction of new energy- and material-saving technologies for welding, surfacing and cutting, new welding materials, equipment, in-process control systems and effective calculation methods that ensure the improvement of the operational properties of welded structures is one of the most important factors of scientific and technological progress.

At the same time, the introduction of innovative equipment should be evaluated not only from the position of gaining an economic effect, but also as an element of the implementation of the innovation strategy, which is considered as a functional element of the corporate strategy [3].
2. Main idea
In spite of the strategic viability of innovative technologies introduction, their practical implementation within the framework of a specific production will become possible if technical, organizational and economic benefits are achieved. The technical effect is determined by the actual economy of resources when comparing two or more technological processes with respect to the manufacture of the same (one-type) product. Such resources are labor, material and technical, energy, information and financial resources. Whereas, the technological process is the organized process of manufacturing products or providing services of a certain quality, consisting of separate technological operations performed with the use of material and technical means and other resources in accordance with a certain technology strategy [4].

The organizational effect is to create a more efficient management system for the industry or enterprise through the use of technological equipment, which is a more universal object of management, the use of which allows building simplified logistics chains at the enterprise and between enterprises [5]. Firstly, it will be based on improving the production cycle and the efficiency of resource management, which will lead to an increase in production without additional costs. Secondly, it will promote the overall management of the company and the optimization of all business processes occurring in it. Thus, it allows creating conditions to improve the performance efficiency.

The economic effect of new technology introduction and its application will be positive in case when advanced technology costs ($C_{at}$) will be significantly less than the existing technology costs ($C_{et}$):

$$C_{at} \ll C_{et}, \ C_{at} = C_d + C_{nfa} + C_{et} - RC_{dfa}$$

where: $C_d$ – disassembly costs; $C_{nfa}$ – costs of newly fixed assets; $C_{et}$ – employee training costs; $RC_{dfa}$ – residual cost of deducted fixed assets.

As a rule, new technological equipment consumes fewer resources, thus, in particular, it is more energy efficient. If the cost of the basic ($C_{be}$) and advanced ($C_{ae}$) equipment ($C_{be} < C_{ae}$), as well as the cost of the resources used for the basic ($C_{rbe}$) and advanced ($C_{rae}$) equipment for a certain period ($C_{rbe} > C_{rae}$) are known, then it is not difficult to determine the number of periods (T) to achieve the equality of relative resource efficiency:

$$T = \frac{(C_{ae} - C_{be})}{(C_{rae} - C_{rbe})}.$$  (2)

With the change in the technological mode, technologies and equipment of traditional types of manufacturing are also changed, including technologies for manufacturing parts, assemblies and machines using methods of welding production. The general trend of the transition from forge to arc welding and further to modern welding technologies is characterized by a relative decrease in the volume of material for the formation of a welded seam, a reduction in energy costs per volume unit to form a welded joint, and an increase in the efficiency of power plants.

Until recently, during a direct or comparable assessment of the overall economic importance of national welding production, the specialists basically operated with the total cost of the welding technology produced in the country or the volume of the internal welding market. Such approach did not take into account the real economic contribution by manufactured welding engineering to the formation of the added value at all stages of manufacturing welded products, structures and constructions. Since welding and related technologies are basic, non-alternative technologies in industrial production and construction; a significant increase in the real contribution of these technologies to the economy of the state should be expected [6]. This is confirmed by recent studies conducted in the US and Germany on the initiative of AWS and DVS.

It is known that Vasily Petrov discovered the era of electricity application for welding metals, using the world's most powerful electric battery in his experiments. In «News of Galvano-Volt Experiments"
of 1803, Vasily Petrov explains how he received an electric light and a white flame between two pieces of wood charcoal (the battery was a Voltaic pile of 4,200 pairs). The introduction of new methods and types of welding in the production required the development of appropriate power supplies. The next stage in their development was the use of a power system, including a DC generator and a parallel electric (voltaic) battery. Such system was proposed by Nikolai Benardos within 80 years after the discovery of the possibility of electric arc application for welding metals.

There was a whole industry in the Soviet Union aimed at the development and production of power supplies for all types of industrial welding. Today in Russia, just several plants remained with a small line of power supplies. Very difficult situation underwent factories, the significant output of which is autonomous welding units. They are Welding equipment plant «Iskra» LLC, «Uraltermosvar» CJSC, «AMP-Komplekt» LLC.

This stimulates the owners of enterprises, at which welding technologies are used, where they are not so much cheaper but more efficient in producing the power supply units both in Russia and abroad.

Permanent growth is maintained by the market sectors of power supplies for fusion welding, automatic control and tracking systems, diagnostics and non-destructive quality control of welded joints. It is worth noting the similarity of opinions both of European engineering equipment manufacturers and consumers of this equipment; in general, it corresponds to the thematic areas of scientific researches and technological developments, which are presented in national scientific centers, welding institutes and university laboratories.

Operation of the power system «power source - welding arc – bath» flows steadily if the supply delivers enough energy for the welding process and covering the losses in the system. In addition to well-known power supplies (rectifiers, dc collector generators) modern welding equipment supplies of a new type having corrective feedbacks on the energy parameters (current, voltage), designed to create conditions for stable arc burning and maintaining the established regime [7].

The first power supply for arc welding was the most powerful battery at that time. Today, power supplies of various types and modifications are used. A new stage in the modern development of power supplies for welding became the massive introduction of inverter sources.

Typical indicators of the welding inverter were its universality, i.e. application for various welding methods: MMA, TIG, MIG, MAG. The introduction of inverter welding equipment for semi-automatic and automatic welding, produced by the enterprises of Sweden, Germany, Austria, England, the USA, Ukraine and Russia, is growing at a particularly rapid rate. The use of a welding wire with a diameter of 1.2 mm and a gas mixture as protective gas is mainly characteristic for welding and assembly production. Inverter supplies are also used for automatic welding under a flux layer [8].

The performance of modern inverter power supplies made it possible to expand the range of its functional characteristics and implement any law changing the instantaneous parameters of the mode. Measurement and registration of supply functional characteristics parameters guarantees verification of its compliance with the required ones and ensures high quality of performing manual arc welding processes, both with a consumable electrode and in the shielding gas environment [9], [10].

This makes inverter power supplies as a potential object of flexible control for current parameters at the output. The welding inverter control system can be built on a various element base. When using a single-chip microcontroller, the best combination of the simplicity of the control circuit and the complexity of the algorithms is achieved.

Comparing inverters and traditional welding supplies, it is usually noted that the cost of welding rectifiers is lower than the cost of inverters, but the latter consume almost twice less electricity when used in the same welding conditions (24 and 12.5 kW, respectively), while the cost of electricity for 1 year work with one- / two-shift operation will be: for a welding rectifier - 42,850 / 85,700 rubles, and for an inverter - 22,312 / 44,624 rubles. According to the formula (2), it is easy to calculate that the equality of relative resource efficiency is achieved after 1.71 / 0.85 years with one- or two-shift equipment operation, respectively. That is, for a period of up to 1.71 / 0.85 years, the lower total costs will be with the use of traditional equipment, and higher – with advanced.
To evaluate the economic efficiency of inverter supply application, we conducted experiments for the main types of arc welding methods at the production base of «Elloy» LLC (Nizhny Novgorod) using inverter welding equipment with a “Weld Telecom” device.

For manual arc welding with coated electrodes (hereinafter - MA) the following materials and equipment were used: SSSI 13/55 Ø5 mm electrodes, VDU-506 supply. Welding modes: I = 250A, U = 23V.

For semi-automatic copper-coated welding in CO2 (hereinafter - SA CO2) the following equipment and materials were used: welding wire SV08G2S Ø1.2 mm, VDU-506 supply with PDG-508. Welding modes: I = 250A, U = 23V.

For semi-automatic welding of copper-coated wire in a gas mixture medium (hereinafter - SA FOGON) following equipment and materials were used: welding wire SV08G2S Ø1.2 mm, VDU-506 with PDG-508. Welding modes: I=250A, U=23V.

For semi-automatic welding of copper-coated wire in a gas mixture with an inverter power supply (hereinafter - SA FOGON + inverter), the following materials and equipment were used: wire SV08G2S Ø1.2 mm, Sinermig-401. Welding modes: I = 250A, U = 23V.

It is known that for assessing the cost of implementing technology, business projects and enterprises as a whole uses such approaches as cost, revenue and market. Taking into account the specifics of the welding industry in comparison of the use of different welding equipment in the production of the same type welded joints and structures, it is sufficient to use a cost approach with an estimate of unit costs per 1 running meter of the weld. The cost of materials and energy was determined by the following known dependencies:

Costs for electrodes (wire) \( (C_e) \):

\[
C_e = \alpha I t_w K_f/1000 \times C_m, \quad (3)
\]

where: \( \alpha \) – metal deposit factor, g – ampere per hour; \( I \) – welding current, A; \( t_w \) – welding time 1 m of weld seam per hour; \( K_f \) – reduction of magnification factor of electrode and wire consumption through burning, splatter; \( C_m \) – cost of 1kg of electrodes (wire), rub.

Values of \( K_f \) are equal to 1.43 for MA, 1.10 for SA, \( C_m = 30.5 \) rub for MA, 53 rub for SA.

Costs for gas \( (C_{gas}) \):

\[
C_{gas} = q_{gas}/1000 \times t_w \times 60 \times C_{gas}, \quad (4)
\]

where: \( q_{gas} \) – protective gas consumption for SA welding, l/min; \( C_{gas} \) – cost of protective gas, rub.

Let us take \( q_{gas} \) according to reference data, and \( C_{gas} = 32 \) rub/m³ for SA in CO₂, 97 rub/m³ for SA FOGON.

Electricity costs \( (C_{el}) \):

\[
C_{el} = \alpha I t_w/1000 \times q_{ewm} \times C_{el}, \quad (5)
\]

where: \( q_{ewm} \) – electricity consumption per 1kg of welded metal, kW h/kg; \( C_{el} \) – Electricity cost, rub. Electricity cost comprised 1.89 rub/kW per hour.

Labor costs \( (C_L) \):

\[
C_L = (t_w + t_{des}) \times C_{sh}, \quad (6)
\]

where: \( t_{des} \) – desemeing time of 1m welded seam per hour; \( C_{sh} \) – cost of standard hour. \( C_{sh} \) cost was 80-60 rub./hour.
The results of cost calculation for various versions are provided in table 1.

**Table 1. Comparative calculation of the cost of 1 m seam by different types of welding**

| Cost groups                      | MA | SA in CO₂ | SA in a mixture | SA in a mixture and inverter |
|---------------------------------|----|-----------|-----------------|-----------------------------|
| Costs for electrodes, rub.      | 9.27 | 8.16       | 6.55            | 6.43                        |
| Costs for gas, rub.             | 0.00 | 0.50       | 1.06            | 0.79                        |
| Costs for electricity, rub.     | 1.51 | 0.56       | 0.35            | 0.26                        |
| Labor costs, rub.               | 10.80 | 4.55       | 2.66            | 1.86                        |
| Total cost per 1 meter of seam, |     |            |                 |                             |
| rub.                            | 21.57 | 13.77      | 10.62           | 9.34                        |

The economic effect is achieved through:

1. Energy saving. The inverter welding equipment of MS series is characterized by high efficiency (85%), high cos φ (up to 0.97), low power consumption in the idle mode.
2. Economizing the electrode material, reducing the cost of cleaning the welded joints. The function «arc force» is provided for welding machines of «MS» series. The functional principal is based on an additional short-term increase in current, at the moment of overlapping of drops of molten metal in the arc gap. The current pulse helps the drop to detach from the electrode rod, thereby making the process of transferring the droplets through the arc gap controllable and uniform. At the optimum value of forcing, the seam turns out to be dense with even scales, and splatter is practically absent.
3. Economy of the wage fund. Some models (MC-500MR, MS-400T, MS-400TR, MC-315 AC / DC, MC-500 AC / DC) have a built-in memory channels. This allows you to store the optimal welding modes for each technological operation in the machine memory. As a result, there is no loss of working time for the reconfiguration of equipment, and also the requirements for the qualification of welders are reduced.
4. Reducing the cost of transportation, installation and storage of equipment. Welding equipment series «MS» has excellent mass-dimensional characteristics. There is no need for loading and unloading equipment. The compactness of the equipment makes it possible to unload the storage facilities.
5. Reducing losses from equipment downtime. Welding equipment of the «MS» series was designed using the latest achievements of scientific and technical progress:
   - IGBT transistors «Toshiba» with 50% power margin and operating temperature range from -40ºС to +150 ºС;
   - three protection circuit against network overload, from over-current and from over-voltage;
   - DSP-processors Delphino Texas Instruments, instantly reacting to the slightest interference;
   - three-layer varnish coating of printed circuit boards, protection against overheating, from incorrect phase connection;
   - the equipment is adapted to work with Russian electrical networks.
   Thus, the use of inverter power supplies as advanced welding technological equipment in welding production is technologically and expediently justified from the economic point of view.

3. Conclusion

In terms of changing technological structures, rapid renewal of technologies and production equipment, an economic evaluation of the advanced equipment introduction appeared to be relevant. The definition of the equality of relative resource efficiency for the prospective equipment and the one being used is proposed.

Arc welding methods remain important technologies for manufacturing parts, machines and structures and require the development and introduction of new equipment. Welding inverters are considered as advanced supply units. It is shown that the equality of the relative resource efficiency
for traditional rectifiers and inverters is 1.71 / 0.85 years with single- / two-shift equipment operation, respectively. Investigations carried out for various welding options and application of various power supplies showed that the lowest costs per 1 m of welded seam are observed in semi-automatic welding in protective gases using a welding inverter. At the same time, the costs were calculated for all groups of resources used in welding. The sources of economic benefit are shown when using welding inverters.

References

[1] Kolesnik E A, Pavlova L L 2017 Import substitution: the functioning and development of the labour market in the region (Tyumen: Tyumen industrial University Tyumen) p 167
[2] Granin Y D 2014 Globalization and national forms of global strategies Herald of the Russian Academy of Science 84(2) 135-141
[3] Dmitrievskii A N, Mastepanov A M and Bushuev V V 2014 Resource-innovative strategy of Russia’s economic development (Moscow: Herald of the Russian Academy of Science) 84(5) 329-334
[4] Petrov P Y 2017 Definition of terms «technology» and «technological process» in the standards (Moscow: Tekhnologiya mashinostroeniya) 2 58-61
[5] Stepanova N V and Razumakov A A 2013 The 8 international forum on strategic technologies (IFOST 2013) 1 240-242
[6] 2004 Equipment and supplies Advanced Materials & Processes 162(8) 103-116
[7] Kuskov V N, Kolenchin N F, Shadrina P N and Safronov A V, Fund ISSL, 11 Protoplasma 2012 vol 3 p 625
[8] Knyaz'kov A F, Knyaz'kov S A and Dementsev K I 2009 An Inverter Power Source for Welding with Modulated Current Welding International 23(12) 957-962
[9] Fysikopoulos A, Pastras G, Stavridis J, Stavropoulos P and Chryssolouris G 2016 On the Performance Evaluation of Remote Laser Welding Process: An Automotive Case Study Procedia CIRP 41 969-974
[10] Benyounis K Y and Olabi A G 2008 Optimization of different welding processes using statistical and numerical approaches A reference guide Advances in Engineering Software 39 483-496