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WELDING PRODUCTION IN THE ECONOMY OF UKRAINE

G.I. LASHCHENKO
STC «E.O. Paton Electric Welding Institute of the NAS of Ukraine»
11 Kazymyr Malevich Str., 03150, Kyiv, Ukraine. E-mail: office@stc-paton.com

The growth in volumes of production and consumption of structural materials continues to be an important component in the development of modern economy. For stabilization and growth of the Ukrainian economy, it is necessary to dramatically increase the consumption of rolled metal with an emphasis on industrial construction, implementation of large-scale infrastructure projects, heavy, power and transport engineering. Moreover, the processes of welding, cutting, surfacing and coating are the most preferred and widespread means for creating a wide range of competitive products. In the near term, it remains vitally important for Ukraine to maintain different power, processing, mining, agricultural, defence equipment and infrastructure facilities in order to extend their service life through the use of innovative welding and metal treatment technologies. 9 Ref., 2 Figures.

Keywords: *welding production, national economy, metal consumption, industry of Ukraine, machine building and innovative technologies, small business*

Role of welding in the development of the national economy. The highly-developed material production is the basis of modern civilization. A large role here is played by structural materials. At first, the 20th century was called the «cast iron age», since the melting of cast iron in the world exceeded the production of steel, and in 1913 it amounted to 78.5 mln t (steel — 72.4 mln t). By the end of the 20th century, steel production reached 800 mln t, and the production of cast iron — about 500 mln t (approximately 63 %), which allowed calling it the «steel age». In the second half of the 20th century, such knowledge-intensive technologies of steel production as vacuum arc remelting, electron beam melting, plasma remelting, electroslag and induction melting were developed and introduced into the industry. The development of these processes was stimulated not only by the need in manufacturing civilian industry products, but to an even greater extent by the requirements of the military-industrial complex, which needed a high-quality metal to solve its problems.

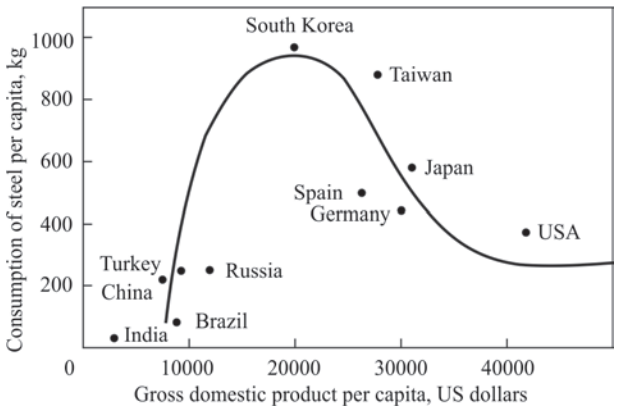

Figure 1. Curve of intensity of steel application

Analysts from the International Iron and Steel Institute (IISI) came to the firm conclusion about a direct correlation between the growth in steel consumption and the general economic level of countries with high growth rates of gross domestic product (GDP). By the end of the 20th century and in the subsequent years in such countries as the USA, Germany, and Japan, the annual consumption of rolled steel was maintained at the level of 420–590 kg/person. In Ukraine, in 2007 the own consumption of rolled steel amounted to approximately 25 % of the industrial, i.e. 8.7 mln t, and the specific consumption of rolled products reached approximately 190 kg/person. In Russia, this indicator was at the level of 250 kg/person. For many countries, an increase in domestic steel consumption is an essential condition for building a highly-developed economy (Figure 1) [1]. Therefore, the dynamic development of the Ukrainian economy is impossible without a significant increase in metal consumption. At the same time, in connection with the intensification of the deindustrialization process in the Ukrainian economy, in 2013 the specific consumption of rolled steel decreased to about 140 kg/person.

Although steel holds a leading position in the world market (93 % by weight of the total production of structural materials), its positions are pressed by aluminum, plastics and polymers; composites and ceramics are being introduced into production. Alloys based on nonferrous metals (Al, Cu, Ni, Mg, Ti) and plastics amount to about 7 % of the group of structural materials. In the group of nonferrous metals and plastics, dominating positions are occupied by aluminum (38 %) and plastics (23 %) [2].

Starting from the second half of the 20th century, the demand for steel was satisfied not only due to the growth of the physical volume, but to a significant ex-

tent due to its quality. The increase in strength and other service characteristics of steel contributed to the stabilization of its consumption (by weight). A certain effect on steel consumption was also caused by the expansion in the use of aluminum and plastics.

Over the past 20 years, more than 1000 new grades of steels for different purposes have appeared on the world market, the range of rolled steel has expanded significantly, including with different coatings. Unfortunately, amid the situation in the world, achievements of Ukrainian metallurgists look very modest.

In advanced countries with the developed economy, the main consumers of steel are industrial and civil engineering, shipbuilding, heavy and power engineering, automotive, transport engineering and pipeline transport. For most of these countries, automotive and shipbuilding industries are the locomotives of the modern economy.

The industrial use of aluminum is caused by its low density (2.7 g/cm^3), which is approximately three times less than that of steel, increased cold resistance, corrosion resistance in oxidizing environments and in air.

Aluminum and its alloys are characterized by a low melting point (the melting point of pure aluminum is 660 °C), high thermal and electrical conductivity, increased linear expansion coefficient as compared to steel, and a lower elasticity modulus.

Aluminum alloys are widely used in many branches of machine building, as well as in civil and industrial construction [3]. Moreover, in aircraft vehicles, the share of structural materials from aluminum alloys occupies up to 80 % of their weight. In the last decade, a special attention has been paid to the use of aluminum alloys in automobile, carriage and shipbuilding. A significant part of aluminum products in the form of ultra thin rolled metal and foil goes to the production of containers and packaging.

In 2003, the average consumption of aluminum and its alloys per capita was the following: in Ukraine — 2.0 kg, in Russia — 2.5 kg, in Western Europe — 19.8 kg, in Germany — 27.1 kg, in Japan — 27.9 kg and in the USA — 29.2 kg [3]. The growth in the consumption of aluminum alloys in different countries is usually associated with the release of new products. It should be noted that as to the values of ratio of strength and yield to density, high-strength aluminum alloys are significantly superior to cast iron, low-carbon and low-alloy steels, pure titanium and are only inferior to high-alloy steels of higher strength and titanium alloys.

It is considered, that a factor restraining the volume of aluminum production is its cost, determined by a high energy consumption of metallurgical production of aluminum.

According to [3] in 2003, a domestic demand for aluminum products in Ukraine amounted to about 360 thou t per year. The main consumers were construction industry (275–280 thou t) and aerospace industry (52 thou t). The rest was the manufacture of cable products and packaging foil.

In the world practice, titanium alloys of different strength groups have also gained an industrial application [2]. The group of low-strength alloys includes alloys with a tensile strength of up to 750–800 MPa; medium-strength alloys have a strength of 1100–1200 MPa without a heat treatment; high-strength titanium alloys after strengthening heat treatment (hardening and subsequent aging) can have a strength of more than 1400 MPa.

The main advantages of titanium and its alloys include:

- high corrosion resistance in many natural, biological and technological environments, where the use of traditional steels and alloys is impossible or requires additional methods of protection;
- higher or equivalent specific strength and fatigue life in comparison with corrosion-resistant steels and alloys;
- ecological cleanness and a good biological compatibility with living tissues, which allows the successful use of titanium and its alloys for the manufacture of endoprostheses.

Due to its unique properties, titanium finds its application as a structural material for the construction of submarines, aircrafts, rockets and space vehicles, automobiles, small coastal vessels as well as in the production of consumer goods. Titanium alloys are used for the manufacture of heat exchange equipment of NPP, hydrofoils, propellers, stressed elements of the bottom part of offshore platforms, drill pipes, etc.

Among the new rapidly growing applications of titanium, it is worth noting the construction of liquefied gas plants and regasification terminals (up to 250 tons of rolled titanium per a unit). In general, the manufacture of titanium products in the form of rolled ingots, slabs, forgings is considered a very promising area of production, taking into account the global increase in demand for these products [4].

It should be noted that in Ukraine 16 deposits of titanium ores of different degree of credibility were explored and 14 are in operation (see B. Sobolev. Stockholm Syndrome of Ukrainian Titanium. ZN.UA — 2018. — No. 17). According to the data of the US Geological Survey, in Ukraine 1 % of the world's reserves of ilmenite and 5 % of rutile are concentrated, and this is the main raw material for the production of titanium. According to different sources, the indicator of the share of Ukraine in the explored reserves of titanium ores is 20 %.

Ukraine has all the elements of the titanium production chain by Kroll process from extraction of ores (ilmenite, rutile) to rolling of finished metal and producing strength, nonmagnetic pipes and other products. In addition, in Zaporozhye a specialized Institute of Titanium operates. Also, Zaporozhye Titanium-Magnesium Plant (ZTMK), production of pigments at the «Sumykhimprom» and at the «Crimea Titan» as well as electron beam melting of finished titanium slabs and billets at three Kiev enterprises should be mentioned. Among the latter, the Antares plant should be distinguished with a capacity of 5 thou t of titanium slabs per year, which is about 7 % of the world production of these products. Four electron beam furnaces finished in 2000–2016 together with ZTMK are able to melt over a half of the titanium sponge into a high-quality commercial metal. The Scientific and Production Center «Titan» at the E.O. Paton Electric Welding Institute can melt 3 thou t of titanium billets per year and roll them into pipes to strengthen oil wells. The Transcarpathian Metallurgical Plant (town of Vyshkovo, Transcarpathian region) produces up to 3600 tons of titanium powders per year. Recently, all three enterprises are held hostage by a one monopolist, which is ZTMK, and mostly stand idle.

The global consumption of rolled titanium is approximately 135 thou t per year.

The Russian corporation «VSMPO-Avisma» annually produces about 30 thou t of finished rolled titanium and its alloys, including about 10–12 thou t for its own consumption (the main consumers are military-industrial complex and aerospace industry). The dependence of Boeing Company on Russian supplies of rolled titanium amounts to 45 %, that of EADS is about 60 %, Bombardier, Embrayer, Pratt & Whitney, Rolls-Royce — to almost 100 %.

Ukraine so far supplies mainly titanium ore concentrate to the world markets. Thus, according to the data of the State Customs Committee and the State Statistics Service, 295 thou t were shipped in 2015, 463 thou t in 2016, and 583 thou t in 2017, of which about 35 % of the mentioned concentrate were shipped directly from the Russian Federation. At the same time, during 2003–2017 the average selling price of ilmenite concentrate amounted to not more than 20 US dollars per ton. At the same time, from a one ton of concentrate about 200 kg of metallic titanium can be produced, the price of which in the mentioned period ranged from 5 to 40 US dollars per kilogram. If Ukraine had the corresponding production capacities of rolled titanium, then it would not lose from 625 to 5000 % of profitability. The processing of rolled metal into the end products such as medical prostheses, sports equipment or spectacle frames would provide an added value from 600 to 1200 %.

According to the estimates of experts, to create the own production of rolled titanium in Ukraine with a capacity equal to Russian, about 2.5 bln US dollars are required. There are companies and people throughout the world interested in that, but to attract them, the purposeful work of the government and other state structures is needed.

In material production, different technologies for shaping of metal products (stamping, bending, casting, forging, welding, etc.) are used. At the same time, many years of world experience testifies to the many advantages of using welding technologies [5].

However, it should be noted that welding is only a definite technological method for producing permanent joints and therefore, it cannot be an independent production by itself, or end in any production process. It should be considered as a means to achieve another goal — producing welded structures or directly products. The manufacture of welded structures represents a complex production process, consisting of a whole range of interrelated operations that differ in their nature, duration and purpose. Here, different technologies are used. At the stage of preparing rolled metal, straightening and cleaning dominate. In the process of manufacturing parts for welded structures, different technologies of cutting, bending and stamping are used. The assembly and welding operations are performed based on the application of different welding techniques and methods and postweld treatment is carried out using the technological processes that reduce stress-strain state and improve the structural and physicomechanical characteristics of welded joints.

The abovementioned package of works is generally considered as welding production, which is necessarily organized taking into account the characteristics and nature of a product manufactured by the relevant branch (machine building, automobile, shipbuilding, aerospace, etc.).

Recently, the term «welding production» is interpreted more widely [6]. The composition of welding production includes research centers, leading research and development works on new welding technologies, equipment and materials; industrial enterprises producing welded structures, main and auxiliary welding equipment, welding consumables, means for industrial and environmental protection; a network of organizations providing communication between the developers and consumers of welding equipment; system for training engineering and working personnel, consisting of educational establishments of the I–IV accreditation levels and vocational schools.

Welding production in its development covered a path from performing a separate welding operation, which has an auxiliary character (rewelding of defects

of casting and forging parts, repair of worn parts, etc.), to performing complex operations at the modern workplaces, sections, workshops, plants-welding centers, formed by technological, subject or mixed principles.

More than a half of the gross national product of industrialized countries is created by welding and related technologies. In this case, up to 2/3 of the global consumption of rolled steel goes to the production of welded structures and erections, and the thickness of welded parts ranges from micrometers to meters, the mass of welded structures — from fractions of a gram to hundreds and thousands of tons [1].

Welding and related technologies make it possible to create original designs of modern cars, aircrafts, ships, locomotives and wagons, apparatuses and installations for chemical industry and power engineering, provide a high reliability of pipeline transport, many types of building constructions, electronic means and devices, including those operating in extreme conditions, rocket and space engineering, etc.

The widespread use of welded structures (WS) is predetermined by the possibility of:

- combining the advantages of a composite structure in production with the advantages of monolithic structures in operation;
- expanding the selection of more rational design solutions when creating high-quality and reliable structures;
- using dissimilar materials in structures that are most suitable for the operating conditions of different elements, which makes it possible to fully use the properties of materials, reduce the weight and metal consumption of structures;
- reducing production costs by improving the technology of parts manufacturing.

Depending on the purpose of welded structures and the requirements specified to them, certain structural materials are used.

Welding production played a key role in the formation of an industrial society, which is especially vividly illustrated on the example of the USSR [7].

At this stage, the main driving factor of development was the opportunities provided by welding technologies in creating new types of products and increasing the scale of their production.

Postindustrial society originated from the industrial society and was formed on its basis. Therefore, the tasks solved by welding production in the postindustrial period are partially preserved. This refers to the creation of new types of products and the increase in their output volumes. However, the task of the first priority is providing a high quality of products with new consumer characteristics, including the quality of welding products themselves, i.e., welded structures.

On the one hand, welding production, being one of the elements of a postindustrial society, participates in its formation by providing its products, and on the other hand it uses the achievements of a postindustrial society for its development. At the same time, the increase in the knowledge-intensive technologies in welding production contributes to the improvement of quality of products, their efficiency and competitiveness. According to the American and German Welding Societies, the processes of welding, cutting and coating in the future also will be the most preferable and widespread methods to create a wide range of competitive materials and products.

Welding production, most of which is concentrated in the structure of machine building enterprises, fully experienced negative processes in the country's economy that have taken place in recent years. At the same time, in Ukraine there are several potential directions for increasing metal consumption.

At the facilities of basic industries in Ukraine (ferrous and nonferrous metallurgy, machine building, power, coal mining, oil and gas industries, etc.) 36 mln t of load-carrying metal structures are in service [8]. The diagram of the fund of metal structures being in service is shown in Figure 2. The majority of metal structures are the structures of buildings and erections (about 60 %), metal sheet erections (mainly steel tanks), electrical grid facilities (masts, power transmission towers), as well as bridges. The basis of the metal fund being in service consists of metal structures put into operation in 1950–1983, i.e. they served 33–66 years.

According to the carried out studies [8], the physical wear of metal structures at the time of their failure amounts to 35–40 %. Regarding industrial buildings, this means that the average service life is 40–50 years. According to the estimates of experts, by 2001, 7–8 % of the existing metal fund was already at the

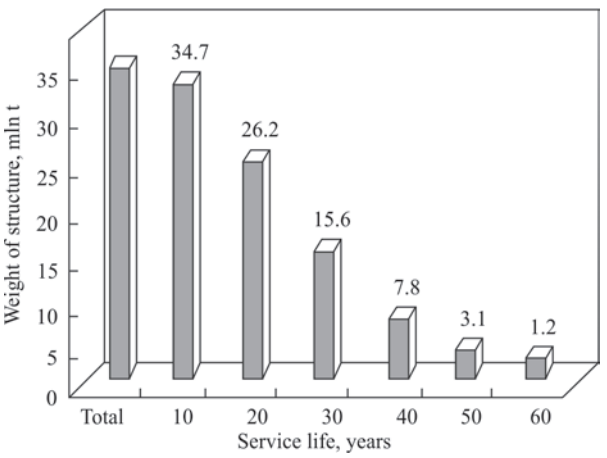

Figure 2. Diagram of fund of metal structures being in service in Ukraine

ending stage of its service life. In the last years the situation has worsened. The lack of financies for the replacement of structures forces owners to extend the life of structures, the physical wear of which reaches 35–40 %, which often leads to accidents and the material damage is tens of times higher than the cost of their restoration and replacement.

Today it can be stated that more than 25 % (3 mln t) of the existing metal fund of building structures needs urgent replacement [9]. Technically, this task does not cause great difficulties, since Ukraine has the production facilities capable of producing up to 450 thou t of metal structures for different purposes annually. But for this purpose, a state program of works with related financial resources should be developed.

According to the data of «Ukravtodor», about 10 mln t of rolled metal produced by domestic metallurgical plants will be needed only for the reconstruction of principal roads.

Significant volumes of rolled steel (at least 2 mln t during 5 years) are required to restore the rolling stock of railways. Such railway car building works of Ukraine as PJSC «Kryukovsky Railway Car Building Works», PJSC «Azovvagonmash» and PJSC «Dneprovagonmash» still have some opportunities for the annual production of 15–20 thou of new cars.

A huge metal fund has been accumulated in the gas transportation system (GTS) of Ukraine, the total length of which is 37.6 thou km; including the length of main gas pipelines — 22.2 thou km. As a part of the GTS, 81 compressor stations are operating with 765 gas pumping units with a total capacity of 5.6 mln kW.

The aging of the main funds of GTS not only reduces the reliability of its operation, but is also fraught with sudden destructions, accidents and it endangers the life and health of the working personnel and people living in the areas where the gas pipelines are laid. At the same time, gas-pumping units of GTS are obsolete, energy-consuming, which leads to excessive gas consumption for own needs, which in 2006 amounted to 4.6 bln m^3.

Over the years of independence of Ukraine, thanks to the efforts of scientists and specialists of the E.O. Paton Electric Welding Institute and other organizations, the diagnostic methods and repair technologies were developed that help to extend the life of pipelines and other critical technical systems and facilities. However, the problem of degradation of the linear part of pipelines cannot be solved only by the use of repair technologies. Replacement of pipes on long sections of the GTS with new pipes of modern steel is inevitable. Fundamental proposals were also prepared for the modernization of gas compressor stations of GTS using the scientific and production potential of the domestic enterprises «Zorya-Mashproekt» (Nikolaev), OJSC «M.V. Frunze Sumy Machine Building Scientific Production Association», JSC Motor-Sich (Zaporozhye), possessing advanced technologies of electron beam welding, brazing, thermal spraying, etc.

In the meantime, the fate of the Ukrainian GTS is in a «suspended» state. Although NAK has not been purchasing Russian gas for Ukrainian consumers since the autumn of 2015, the obligations of transporting the gas of «Gazprom» through our transportation systems are fulfilled properly. Thus, «Ukrtransgaz» supplied the following volumes of Russian gas to consumers: in 2017 — 93.5, in 2016 — 82.2, in 2015 — 67.1, in 2014 — 62.2 bln m^3. In 2019, the contract between «Naftogaz» of Ukraine and «Gazprom» on the transit of natural gas to the EU is ending. Russia continues to push an idea of constructing an alternative «Nord Stream-2».

For Ukraine, the important issue is even not the amount of profit from transit (more than 2 bln dollars/year), but the guaranteed volumes of gas that allow loading pipelines and preserving the GTS. It is possible to solve this problem by cooperation with a European partner — operator of the gas transportation system, who in the future together with «Naftogaz» of Ukraine will conduct negotiations with «Gazprom» on the supply of gas to the EU.

In December 2017, the Government of Ukraine officially began the procedure of selecting an international partner for the joint management of the Ukrainian GTS. By the autumn of 2018, Germany and other European countries agreed to the construction of the «Nord Stream-2» gas pipeline. Most likely it will be built in any case. Therefore, the issue of transportation of gas to Europe via Ukrainian pipelines has become even more acute. Many decisions on this issue depend on the positions of the USA, EU and Russia and on our government as well, although to a lesser extent. Certain prospects for increasing metal consumption in Ukraine are associated with an increase in the use of renewable energy (wind, solar, biogas and biofuel), which should form the basis of our energy strategy. The question is, first of all, about the creation of wind power plants and pumped storage units, and in the long term — the construction of a Pan-Eurasian energy system.

Other directions can also be mentioned. For example, according to the American entrepreneur Elon Musk, out of 11 branches of the superhigh-speed ground transport Hyperloop 5, branches can go through the territory of Ukraine, three of which are drawn through Kyiv: the first will connect China, Europe and Canada, the second — Asia, the Middle East, Europe and North Africa, and the third — Spain and China. By means of such a transport, it will be possible to get from Dnipo and Kryvyi Rih to India, and from Kharkiv, Donetsk or Odessa to America. This is not fiction, however not a day of tomorrow as well.

For the next 5–7 years it remains vitally important for Ukraine to maintain different energy processing, mining, agricultural, defense equipment and infrastructure facilities in order to extend their service life. These works can only be performed basing on welding and related technologies.

Therefore, repair technologies based on welding, surfacing, spraying and thermal cutting will continue to be in demand both in the short and medium term. The domestic welding production has a corresponding potential for repair works. Here the initiative of small business can also be involved. This is convinced by numerous examples of active participation of small businesses in the modernization and repair of military equipment. However, such work should be systematic and appropriately organized with the involvement of specialists from the «big» business, having a sufficient level of knowledge and experience. Especially innovative technologies are needed.

If we talk about welding production in Ukraine in terms of equipment and materials, the existing production capacities of Ukrainian manufacturers allow satisfying domestic needs for a group of goods of electric welding equipment and welding materials, as well as deliver products to foreign markets [6].

The further sustainable development of markets for welding equipment and materials is possible with the active transfer of high welding technologies and other innovations. Welding production suffers from a disease typical for the whole Ukrainian industry: elimination of sectoral science and most of the experimental production units, which are the necessary links for implementation of research and development results in industrial volumes.

In the former times, the potential of sectoral science was determined not only by the presence of sectoral research institutes, but also by the functioning of key and medium-sized enterprises which had their own design bureaus and well-equipped factory laboratories. For example, many years ago the Kakhovka plant of electric welding equipment created a branch of the experimental design bureau, which provided a significant acceleration in the introduction of new welding equipment into production and today this enterprise is a modern engineering centre. Unfortunately, today in Ukrainian mechanical engineering not many such examples still exist.

But, according to the opinion of the author of this article, not everything is so hopeless. These functions should be taken over by a small business. Such a process is already underway in Ukraine. Here are some examples.

For instance, the research and production company «VISP» (Kyiv) has been present for almost 15 years on the Ukrainian market and has established itself as a reliable developer and supplier of welding equipment (installations, machines, rotators, manipulators), equipment for plasma and arc spraying, different means of automation and other products. «VISP» closely cooperates with the PWI of the NASU in the field of technology for arc welding of stationary pipe joints, surfacing of copper, including the friction stir method. The joint works are also carried out with the Institute of Metal Physics and other institutes of the NAS of Ukraine.

«Navko-Tech» LLC (Kyiv) performs technological works, designs and manufactures specialized equipment for automatic welding of rectilinear and circumferential welds, installations for surfacing of cylindrical, conical and plane surfaces and welding complexes based on industrial robots Fanuc.

«Steel Work» LLC (Kryvyi Rih) specializes in protecting industrial equipment from destructive factors at enterprises of the mining, metallurgical, cement, coal and other industries using innovative welding technologies.

The companies mentioned above and many other companies make a tangible practical contribution to the development of domestic welding production. The further fate of the Ukrainian welding production largely depends on changes in the structure of the domestic economy, production strategy of the country and some other factors.

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