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Electric welding: historical origin, evolution and Ukraine's contribution

There are five active road bridges in Kyiv today that connect the banks of the country's largest river, the Dnipro. The construction of one of them started in 1940 and lasted until 1953.

At the time of its construction, it was the largest all-welded bridge in Europe. For the first time in the history of engineering construction, all its welds were made by means of automatic welding. This engineering wonder was designed under the direct guidance of the outstanding scientist Evgeny Paton, whose name was given to the bridge that is now used by the residents of Ukraine's capital city.

What is Paton's role in the global evolution of electric welding, and what is metal welding?

Since time immemorial, mankind has tried to join together fragments of metal articles and metal ingots of natural origin. This made it possible to increase their size, create complex shapes and rectify casting defects. But because of many technological limitations, the process was flawed. This was overcome using physical strength and one of the few metal working processes known at the time: forging (cold and high-temperature hammering). Foundry welding was also used: the parts to be joined were immersed in molten metal. After that, the craftsmen waited for the structure to solidify. Such connections were neither strong nor reliable.

But with steel increasingly finding its way into different areas of life and the economy, scientists and technologists faced more and more theoretical and practical questions about metal processing and joining.

And the result was a new method of joining metal products! What is metal welding? In this process, parts are joined together by inter-atomic bonds through heating and plastic deformation.

When did electric metal welding appear?

At the turn of the 18th and 19th centuries, the electric arc was discovered, and studies of its practical application started. In 1802, the Russian physicist and electrical technician Vasily Petrov was the first to put forward the idea that the high temperatures produced by an electric arc could be used to melt metals. After that, scientists around the world, including such well-known names as Michael Faraday of Great Britain, conducted various electric arc experiments, which for decades were limited to theoretical studies. The transition to practical application took place at the end of the 19th century. It was also during this period of history that steel and iron production was brought to industrial scale. The need for a simple and reliable way of joining metal parts was growing increasingly.

In 1881 in Paris, the scientist Nikolay Benardos demonstrated a method of welding using a carbon electrode. It was the ElektroGefest machine, and it won a gold medal at the Paris international exhibition. Notably, while Benardos had Greek ancestry, he was born in a village in the present-day Mykolaiv region of Ukraine and studied at the University of Kyiv. In 1888, the Russian scientist Nikolay Slavyanov created and patented welding equipment that used consumable metal electrodes having similar characteristics to those of the metals to be welded. It was this technology that became the basis for the worldwide spread of electric arc welding.

Using the first welding equipment, it was possible to eliminate defects in cast parts that occurred during the casting process, as well as to repair worn equipment parts. At the turn of the century, electric welding continued to be improved. For example, methods of using electric arcs initiated by three-phase and alternating currents were proposed. And the process did not stop there.

In 1906, the Swedish inventor Oscar Kjellberg improved Slavyanov's invention. He patented a welding electrode that was coated with flux. This is a special material that protects welds from oxidation and accumulation of detrimental impurities. His invention has remained almost unchanged to the present time.

Kyiv as the global centre of welding technology

In 1904, the young scientist Evgeny Paton, who was born in France and graduated from Dresden University of Technology, was asked to establish a department of bridge construction at Kyiv Polytechnic Institute. In those years, bridge building was inseparably linked to steelmaking and other related processes. That is why Paton took a great interest in electric welding in the 1930s. Over the years, the department he chaired developed into the Academy of Sciences Electric Welding Institute. Evgeny Paton headed the Institute from its founding in 1934 until his death in 1953.

The Kyiv Electric Welding Institute has become a global centre for the study of welding. The discoveries and inventions made here have found practical applications in many areas of industry and the economy.

For example, during World War II, the institute made a significant contribution to the defence capability of the USSR by proposing the technology for welding special steels for tank turrets, which had previously been riveted or cast in one piece.

But Evgeny Paton's main invention was the development of the ideas of Benardos and Kjellberg. His approach to high-speed automatic submerged arc welding became known as the Paton method. For this purpose, mechanised self-propelled machines – welding tractors – were created. They move directly over the surface of the workpieces to be welded and drive the electric arc along the weld, feed flux and provide other auxiliary processes without human involvement. The most active period of development of automatic welding was in 1959-65. Today, it is used in many industries: for metal plate welding, as well as welding pipes, machinery bodies, household goods and more.

Electric current

An essential part of electric welding is the source of current. At first, very bulky welding generators were used. As the process spread, there was a need for more compact equipment. A notable reduction in size occurred in the early 1940s, when shipyards and tank factories increasingly employed welding rather than riveting parts.

They used transformer units or transformers connected to electric mains. After World War II, they became available for civilian sectors of the economy and even for domestic use.

Today, inverter welding machines are the most popular type. They are based on a complex system of welding current conversion using microcircuits and transistors. This device looks more like a computer. It makes it possible to combine several types of welding in one compact device: from manual arc welding to plasma arc cutting.

Modern welders are highly skilled professionals who require advanced training. The training courses provide both a diploma and the appropriate professional certification. Professional qualification allows a welder to work in such complicated fields as ship repair and shipbuilding, boiler and petrochemical equipment manufacture, heavy machine tool building, as well as the automotive and aerospace industries.

Present status and future of welding

Today, there are more than 150 various welding methods. One of the main classifications of this metal joining process is based on the type of heat energy used, known as the thermal class. It classifies the types of welding depending on heat energy used. The key types of welding under this criterion are:

- arc welding
- gas welding
- electron-beam welding
- plasma welding
- electric slag welding
- laser welding

In electric arc welding, the source of the arc is alternating, direct or pulsating current, which is passed between two electrodes (one of them being the workpiece welded). The applications of electric welding and the metals to be welded are dependent on the type of current used.

The heat generated by the arc melts the edges of the workpiece and the electrode, producing a weld pool. This is a small volume of liquid metal that forms a welded joint when it solidifies.

The most popular types of electric arc welding are:

- manual arc welding
- automatic submerged arc welding
- semi-automatic gas shielded arc welding

Metal arc welding can easily be automated and ensures high productivity.

In the second half of the 20th century, electric welding processes became very highly automated. Special robots have been developed that operate without human involvement. Today, it is almost impossible to imagine any segment of the machine building industry without them.

In 1969, electric welding was brought to the space industry. This happened during experiments on the Soyuz 6 spacecraft. Welding work was carried out using an electron beam with a low-pressure compressed arc and a consumable electrode. In 1984, the URI welding machine developed at the Paton Electric Welding Institute was used to perform electron beam welding outside a spacecraft, in open space.

These experiments confirmed the efficiency of electric welding in the vacuum and weightlessness of space. These experiments could someday help to make it possible to colonise other planets. And Elon Musk, the American who is already planning expeditions to Mars, will admire not only Sergey Korolyov and the Yuzhmash rockets, but also the welding machines created in Kyiv by the followers of the Paton dynasty.