Adam Pietras

Welding Engineering at Instytut Spawalnictwa against a Background of the Regional and All-Poland's Development since 1945 until Today

IIW International Congress and 62nd International Welding Conference: Cutting-Edge Welding Engineering - Modernity of the Future

Today's Łukasiewicz – Instytut Spawalnictwa was founded on 28 March 1945 as Państwowy Instytut Spawalniczy - National Welding Institute (since 1947 as Hutniczy Instytut Spawalniczy - Metallurgical Welding Institute). The Institute's first Director Bolesław Szupp and his Deputy Józef Pilarczyk were entrusted with a mission to create an entirely new institution in the city of Katowice. The region of Upper Silesia was the right place for the development of welding engineering as already before World War 2 this industrialised region had been known for advanced welded structures (e.g. exhibition hall in Katowice and numerous structures made for heavy industry), industrial plants and specialists in material joining technologies.

In the first years after WW2 Instytut dealt mainly with training. The post-war rebuilding of the country created demand for specialists in various industrial sectors. It was not surprising that the National Welding Institute focused on welding courses and preparing welding personnel for the reviving economy. The management personnel of Instytut prepared course books for participants in welding courses and, most importantly, organised first courses for gas and electric welders, originally held in Katowice and, since 1949, in Gliwice. In the years 1964–1975 Instytut organised specialist welding courses (MAG, MIG, TIG, under flux) at a training centre in Sławęcice near the city of Kędzierzyn. Graduates from welding courses were involved in works on Poland's large construction sites, without which it would be impossible to develop the national welding engineering sector (Elektrownia Kozienice - Kozienice Power Plant, Elektrownia Żarnowiec - Żarnowiec Power Plant, Zakłady Chemiczne - Chemical Works, etc.).

After several years of activity, in the 1950s, already in its new seat at ul. Czesława 16-18 in the city of Gliwice, the then Metallurgical Welding Institute became increasingly involved in research and scientific activity. To this end it was necessary to create new research units, i.e. Department for the Welding of Steels and Cast Irons, Department for the Welding

Building in Bł. Czesława street in Gliwice, the seat of Instytut after the transfer from Katowice

dr inż. Adam Pietras (PhD Eng.) – Director of Łukasiewicz Research Network – Instytut Spawalnictwa

of Non-Ferrous Metals, Department for Filler Metals and Welding Metallurgy, Department for Welded Structures, Department for Welding Equipment and Physical Metallurgy Laboratory. The above-named departments reflected the condition and developmental trends of the national welding engineering sector as well as addressed its needs.

The construction of new technological shops and research facilities was followed by the creation of two Instytut-related companies, i.e. Zakład Konstrukcji Sprzętu i Urządzeń Spawalniczych - Welding Equipment and Machinery Production Company and Zakład Prototypów Urządzeń Spawalniczych - Prototype Welding Machinery Production Company. In 1956, both companies were separated from Instytut and merged into a single company operating under the name of Zakład Budowy Prototypów Urządzeń Spawalniczych - Prototype Welding Machinery Production Company (ZBPUS, since 1965 as ZBUS and in the years 1977–2004 ZDIS). The ZBPUS Prototype Welding Machinery Production Company successfully built welding equipment and machinery used in Polish industrial plants.

Apart from being involved in welding personnel training, separated from Instytut in 1951, yet continuously supervised by it, Institute's workers dealt with the development of new arc welding and pressure welding technologies. In addition, the researchers developed welding consumables and technologies enabling the testing of welded structures and weldability as well as designed control systems and welding power sources, etc. The experience of the companies designing welding equipment and the expertise of research workers were utilised to build prototypes and short lots of welding machines, batches of new welding, surfacing and brazing-related consumables as well as mechanised welding stations. The post-war period saw the development of many welding machines which were next quickly applied in production lines of newly built or rebuilt industrial plants, e.g. an in-line automatic welding system composed of 12 automatic welding machines used in the welding of walls of coal wagons in Pafawag - National Wagon Production Company in Wrocław (in 1962).

The expansion of Instytut Spawalnictwa (the name used by the Institute in the years 1958–2019) lasted until the late 1960s, resulting in the creation of appropriate and convenient conditions for the development of modern welding engineering. Instytut's buildings and laboratories were repeatedly modernised and adapted for ever-changing needs of the national economy. However, in doing so, appropriate conditions for conducting welding research and providing services to welding personnel have never been compromised.

In 1968, Instytut was the principal organiser of the 21st Annual Assembly of the International Institute of Welding. Professor Józef Pilarczyk, the Director of Instytut Spawalnictwa in the years 1959–1967, was the Chairperson of the Organisational Committee; the Annual Assembly itself was held in Warsaw. At that time, Instytut Spawalnictwa was already internationally recognised as, since 1956, it had been the actual member of the organisation. The International Institute of Welding is an international research and technical organisation concerned with welding, brazing and allied processes. The IIW is the union of national welding associations

IIW Annual Assembly 1968, Warsaw, Poland

from all over the world. In 1948, upon its establishment, the IIW had 13 members. Today, the International Institute of Welding represents as many as 55 national welding organisations.

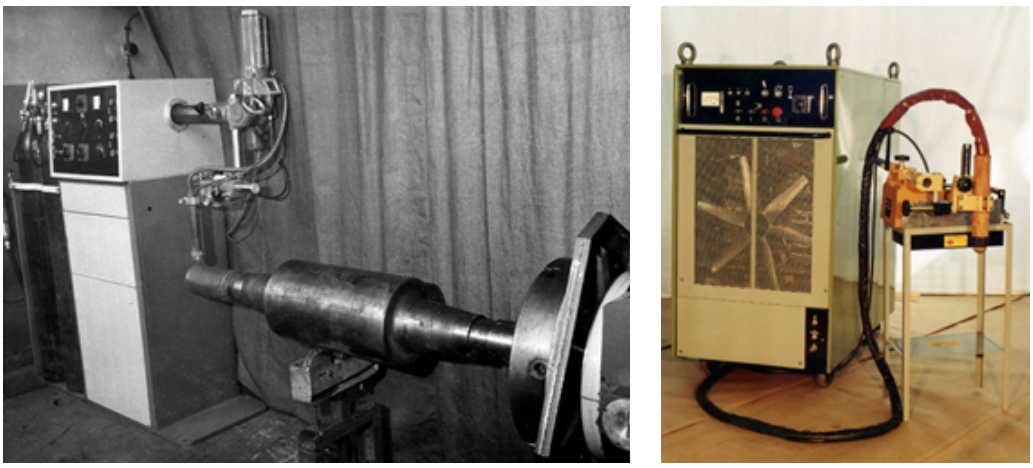
In relation to the IIW, it is necessary to mention Professor Hans E. Jaeger, one of the vice-presidents and founders of the IIW. Professor Hans E. Jaeger was the President of the IIW (1951–1954), its Treasurer and a member of the IIW Executive Board, holding the title of the IIW Vice-President and Founder until his death in 1984.

Professor Hans E. Jaeger

For Instytut Spawalnictwa, the fact of being a member of the International Institute of Welding has always been very important. The IIW membership not only enables Instytut's workers to use specialist information (available on a members-only basis) related to advanced welding techniques and contained in IIW documents but also promotes personal contacts and scientific exchange, useful in research and implementations. In the late 1990s, along with becoming a member of the European Federation for Welding, Joining and Cutting (EWF), Instytut Spawalnictwa was recognised by the EWF as an Authorised National Body and included in the harmonised system of training, examining and certifying welding personnel. Since that time (1996), qualification documents issued by Instytut are honoured in the entire "West".

A good example of modern welding techniques developed at Instytut over the years is TIG welding machines. The first TIG welding machine was built by the Institute as early as in 1959. The new welding technology was developed by the Department for Welding of Steels and Cast Irons, whereas welding equipment and fixtures were made at Zakład Budowy Prototypów Urządzeń Spawalniczych - Prototype Welding Machinery Production Company. The entire lot of TIG welding machines, developed at Instytut from the 1960s, was produced by Zakład Produkcji Urządzeń Spawalniczych - Welding Machinery Production Company in Opole (later known as OZAS Opole). The above-presented situation was standard at that time; the Institute and ZBPUS developed and made prototypes, whereas the lot production was "taken over" by a designated company. The aforesaid system enabled Instytut's workers to pride themselves in their technological achievements, yet it did not translate into their material satisfaction.

Experience of the design and operation of TIG welding machines enabled the development of plasma cutting machines. Research work and tests performed after 1962 resulted in the development of a number of machines,

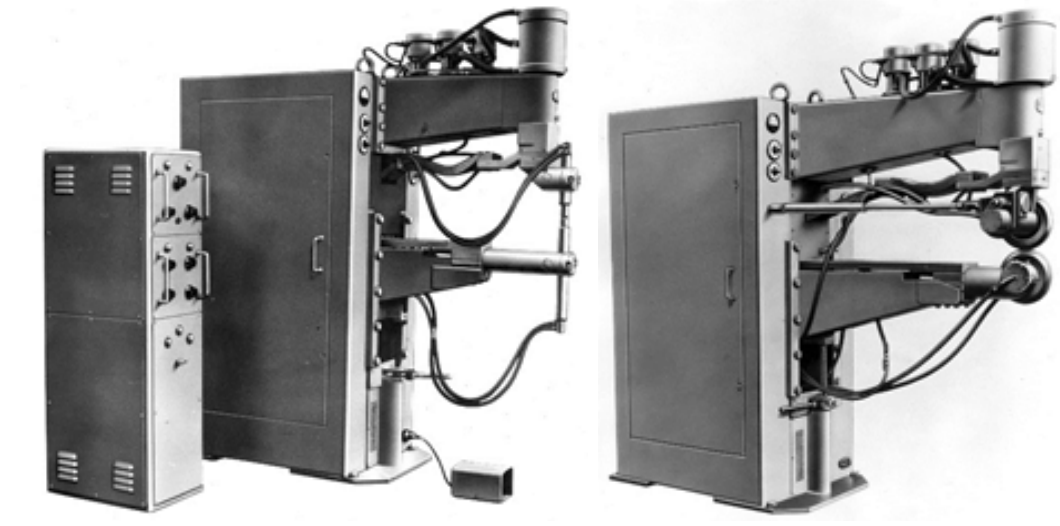


Plasma cladding (left) and plasma cutting (right) machines

hundreds of which (built at ZBUS), were applied in various industrial sectors of Polish industry. Plasma arc-related experience was used by Instytut's specialists to develop many technologies enabling the plasma cladding of machinery parts exposed to harsh conditions. The research work involved the development of technologies, surfacing powders as well as (together with ZBUS) machines and fixtures. Subsequent years (of already 21st century) saw the development of the A-TIG welding technology involving the use of activating flux, increasing, approximately by twice, penetration depth and reducing the width of the weld face. The above-presented advantages of the A-TIG technology significantly reduce welding stresses and strains of welded structures, being a serious challenge for welding engineers. The A-TIG welding method seems to be particularly useful in the mechanised and manual welding of stainless steels as well as nickel or titanium alloys.

Nearly since the very beginning of the Institute's existence, its workers have been interested in welding technologies. The 1950s saw the performance of research and the development of first short-circuit welding and spot resistance welding machines. Next, the Institute's specialists developed an entire range of spot resistance welding, seam welding and flash welding machines which found application in numerous industrial plants. When Poland's post-war automotive industry was born, car factories, on a massive scale, used Polish welding machines based on designs developed by Instytut (and ZBUS). Instytut's specialists also developed systems for controlling the operation of welding machines and for the monitoring of welding processes.

After the development of the friction welding technology, as early as in the 1950s, Instytut included this technology in its research activity. Poland's first friction welding machine, ZTa-10, was made at ZBUS in 1965. In conjunction with Instytut's technologists, the machine found application in the production of bimetallic probe tools. The above-named welding machine was subsequently modernised and, in various versions, exported. A larger friction welding machine, i.e. ZT3-22, developed in the 1970s, soon found application in the tool and automotive industries. After various modifications, the aforesaid welding machine has been used in many factories until today. Both types of welding machines were very well designed and enjoyed justified popularity in many industrial plants. Presently, Instytut is performing tests and promoting a relatively new friction welding technique, i.e. friction stir welding (FSW). Because of the fact that the FSW process involves the use of simple vertical milling machines and is useful in the welding of elements made of non-ferrous metals, its popularity in industrial processes is and will be on the rise.



First resistance welding machines built at ZBUS

One of the earliest activities undertaken by Instytut (since 1951) was the development and the making of systems enabling the control and automatic adjustment of technological welding processes and allied processes. Over the years, Instytut's specialists have designed and developed many machines including

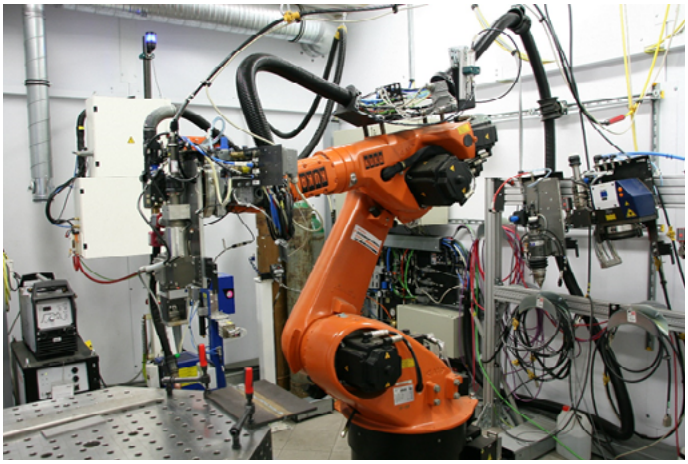
oxygen and plasma cutting machines, photoelectrically (and next numerically) controlled machines, micro-welding machines, welding machine control systems, equipment for measuring and recording technological conditions of fusion and pressure welding processes, welding process quality control devices, etc. Recent years have seen massive industrial implementation of induction heating devices having a power of up to 100 kW and an operating frequency of up to 400 kHz. These machines are primarily used in heat treatment processes in the metallurgical and electromechanical industries, for the melting of steel, in surface treatment processes as well as for the heating and joining of metals.

Important, in terms of today's national economy, and developed by Instytut since the 1960s, are technologies utilising concentrated energy, i.e. laser beam welding and electron beam welding. The first electron beam welding machine made at Przemysłowy Instytut Elektrotechniki - Industrial Electromechanical Institute was installed at Instytut Spawalnictwa in 1970. In the 1970s and 1980s, the experience gained through work with the aforesaid machine enabled Instytut to develop three new welding machines, the elements of which were fabricated mainly in Poland. Presently, Instytut uses a state-of-the-art electron beam welding machine manufactured by Cambridge Vacuum Engineering. The above-named machine enables the performance of welding processes with and without filler metals, surfacing, surface alloying, surface texturisation etc. Because of its relatively high power of 30 kW and the capacity of the working chamber amounting to 5 m3, the machine is used to develop technologies enabling the welding of crucial structures utilised in the aviation and automotive industries.

Instytut's early experience of laser beam welding was connected with laser beam welding performed using a CO_2 laser welding machine characterised by continuous emission and a low power of 200 W. The machine was made by Wojskowa Akademia Techniczna - Military University of Technology in 1968. Many years of research and experimental work have resulted in the development of numerous technologies in the scope of cutting, welding and surfacing of complex structures. Presently, tests performed at Instytut involve the use of state-of-the-art equipment including Trumph TLC-1005CO_2 lasers, Nd:YAGTruPuls 103 pulsed lasers, Yb:YAGTruDisc 12002 disc lasers having a power of 12 kW and provided with the entire technological package, including laser welding heads, remote welding heads, (laser + MIG/MAG) welding heads and the system for the monitoring of laser welding processes. The modern equipment is successfully used by the team of experienced researchers to develop and implement new and very efficient welding technologies in the national industry.

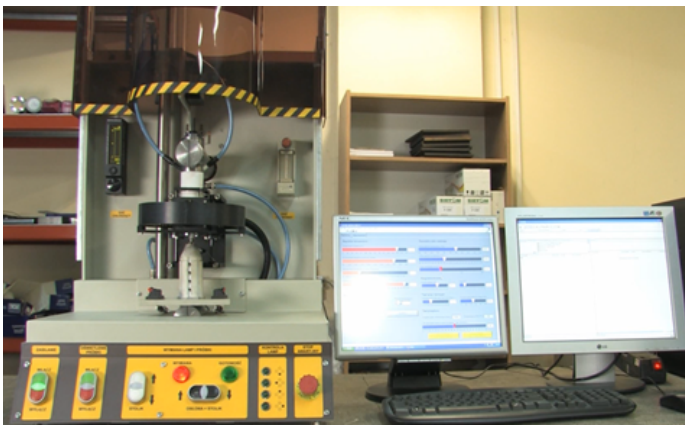
Electron beam welding SE 20-10/60 developed and made at Instytut Spawalnictwa

Another important area of Instytut's activity includes expert opinion concerning reasons for failures or breakdowns of welded structures such as containers, bridges, pipelines, etc. as well as



Laboratory robotic laser welding station equipped with a TruDisk 12002 TRUMPF YAG laser having a power of 12 kW

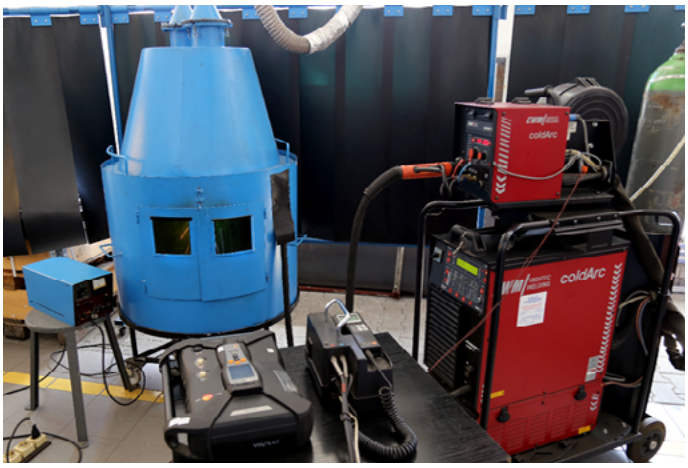
the determination of weldability of materials used in power engineering equipment or of unknown materials in repairs of old bridge and hydraulic structures. Zakład Badań Spawalności i Konstrukcji Spawanych - Testing of Materials Weldability and Welded Constructions Department, currently addressing the above-named issues, continues to perform weldability-related research work initiated in 1950. It was the time of becoming familiar with issues related to welding (hot, cold, brittle, lamellar and annealing) cracks, the effect of welding stresses on operation properties, the weldability of high-strength steels, structural transformations in steels under conditions of welding thermal cycles and many other issues, the knowledge of which is indispensable for the proper preparation of welding processes. Presently, Instytut's research teams use technologically advanced simulators of thermal cycles and FEM-based software programmes enabling the modelling of welding processes. The continuous development and implementation of new materials and increasingly complex structures require the application of state-of-the-art testing equipment and experience gained by Instytut's researchers over the years of its existence.



Station for the testing of structural transformations (developed and made at Instytut Spawalnictwa)

Because of the specific nature of welding processes leading to structural changes in metals, welded structures must be subjected to thorough checks concerning their fabrication and the quality of welds. Some of the most important tests of, particularly crucial, structures are non-destructive tests (NDT). As early as in the late 1940's, it was possible to perform (at Instytut) non-destructive radiographic, magnetic particle, ultrasonic and penetrant tests. The year 1958 saw the creation of a shop enabling the isotopic testing of welded joints. Works focused on the development of non-destructive testing techniques and equipment have been performed incessantly for all the years of Instytut's activity, with some techniques going down in history and others being created and developed. The 1980s saw the design and making of a device enabling the performance of leaktightness vacuum checks. Today, the aforementioned technique is referred to as the bubble method-based leak test with a vacuum cup (UKS) and proves excellent in test concerning the integrity of welds in power engineering equipment. Presently developed testing techniques involve the use of digital radiography and ultrasonic systems (TOFD and Phased Array), particularly when developing techniques which enable the making of welded joints in thin sheets or austenitic steels. The experience of Instytut's research workers and collaboration with specialists from other research centres make it possible to extensively share NDT-related knowledge during specialist courses. Until June 2020, Instytut issued approximately 15 800 certificates for NDT personnel (trained by Instytut).

Another important area of Instytut's activity includes the health and safety at work connected with welding processes both in terms of personnel health and environmental protection. As early as in the 1960s, Instytut actively participated in works aimed to provide safe conditions at work during the performance of welding and allied processes. The first stage of works was focused on how work conditions are affected by fumes, gases, radiation and noise emitted during plasma cutting and welding, CO_2 and argon-shielded welding, brazing, pressure welding and many other processes commonly used in production. Related information is available to industrial partners via a dedicated internet platform named I-EcoWelding.



Station for measuring and recording the concentration of pollutants emitted during welding processes

As stated above, since the very beginning of its existence, Instytut cared for the level of education provided to Poland's welding personnel. To assist local educational centres and, at the same time, to ensure an appropriate level of training provided to welders in Poland, Instytut, through its Ośrodek Obsługi Spawalnictwa Krajowego - Polish Welding Service Centre carries out the substantive monitoring of training for welders in the whole of Poland. The Polish Welding Service Centre's scope of activities includes the certification of Polish welder training centres (over 300 centres in Poland), the verification of licensed examiners of welders (licensed by Instytut; over 200 examiners in Poland) and, on the basis of examination reports sent to Instytut, issues documents to welders (certificates of welder's qualification examination in accordance with PN-EN ISO 9606 and the Welder's Book). In turn, Instytut's seat is the place of training provided to all levels of welding personnel in accordance with IIW and EWF: I/EWE, I/EWT, I/EWP as well as I/EWS and I/EWIP schemes, based in accreditation granted to Instytut in 1996 owing to efforts by the then Director Jan Pilarczyk. In terms of "international" training, Instytut cooperates with leading technical universities. The Table below presents the numbers of international diplomas issued by the Institute's Certification Centre until June 2020.

Number of diplomas	**I/EWE** 3 025	**I/EWT** 384	**I/EWP** 236
	I/EWS 882	**I/EWIP** 898	**Other** 605

Nowadays, Instytut's scope of activities also includes the qualification of welding technologies, the certification of companies fabricating welded structures, the testing and certification of welded structures, the testing and certification of welding engineering products as well as the development of technological instructions/specifications and guidelines. In recent years, Instytut's specialists have actively participated in preparations for the construction of Poland's first nuclear power plant. The researchers were commissioned by the government to develop guidelines for Polish companies concerning: ASME and AFCEN regulations, canons related to quality assurance systems and regulations governing the training of welding personnel and NDT personnel.

The article only outlines Instytut's activities; it does not attempt to "make an inventory" of Instytut's all-important achievements. The idea behind the study was to present the Institute which, for 75 years of its existence, has consistently searched for and carried out tasks

resulting from the needs and expectations of the economy. Since 1 April, 2019, after restructuring addressing the objectives formulated in the Europa 2020 policy, Instytut Spawalnictwa, along with 36 other research institutes, has composed Sieć Badawcza Łukasiewicz (the Łukasiewicz Research Network). In spite of organisational changes and incessant adaptation to the ever-changing national and global economy, Łukasiewicz – Instytut Spawalnictwa offers today nearly all what modern industry needs in terms of welding engineering. Presently, contact with Polish welding engineers is also possible through Informatyczna Platforma Spawalnicza (Instytut Spawalnictwa Computer Welding Platform).

Since the very beginning, i.e. for 75 years, all works performed by Instytut's researchers have been undertaken not so much to gain any credit or recognition but to productively serve Polish welding engineering sector, and, consequently, the entire Polish society being the actual end user and target customer of various welded structures present in nearly all common objects of everyday use. The workers of Łukasiewicz - Instytut Spawalnictwa wish to further develop the welding engineering sector and continue to contribute to the growth of safety and reliability of welded structures.

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