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WELDING TODAY AND TOMORROW

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It has been presented the huge changes in the Polish welding engineering which occurred in the last 20 years: in ownership among producers of welding equipment and materials, in investments which have been carried out, in the influence of free market, in the importance of knowledge and in the emerging of the people's own potential. These factors enabled to decrease the distance between the Polish and world welding level. 8 Ref., 5 Tabls, 10 Figures.

Key words: survey, Polish welding engineering, world welding level, changes in the last years, new factors, eliminating of lag

Introduction

While talking about contemporary welding engineering and pondering over its future development, one must also evoke its rich history and refer to its considerable achievements in earlier days, in particular, in the interwar time (1918 – 1939) as well as during the forty years that followed (1945 – 1985).

The interwar period witnessed the construction of the world's first fully welded road bridge on the river Słudwia near Łowicz in Poland in 1929 (Fig. 1). The bridge has been in its place ever since in spite of wear and tear and destruction caused by the war.

In the interwar period the first buildings (tall buildings as well as exhibition and production halls) were constructed on the basis of welded steelwork. The production works manufacturing welded structure were set up in numerous existing steelworks, which produced considerable amounts of structural steel, in the region of Silesia. Although the production plants of welded steelwork were relatively small, the number of produced structures was imposing. Even today's design engineers and production engineers would not feel ashamed of some of the solutions applied then. It should be also emphasised that many constructions came into being within a very short time.

The post-war period in Poland was the time of rebuilding the country after the ravages of war and starting up numerous industrial plants. In that period the amount of produced structural steel was colossal. It was connected practically with all fields of regenerating civil life as well as rebuilding and developing industry. Steelworks, coal mines, power stations, shipyards, chemical plants are just examples of the biggest consumers of welded steelwork.

Remembering and appreciating '***yesterday's***' achievements, one must nevertheless admit that it has been the last two decades of political, economic and commercial transformations in Poland, Europe and the world that have had the greatest impact on the '***today***' of Polish welding engineering.

The factors which made it possible to decrease or even eliminate the gap between the Polish and world's welding engineering are the privatisation among manufacturers of welding materials and equipment as well as manufacturers of welded products and structures, all kinds of investments, free-market awareness, access to knowledge as well as the possibility to develop and improve one's own skills and abilities.

Today's Polish welding engineering has a potential which lays the strong foundations for the welding engineering of '***tomorrow***'.

The image of Polish welding engineering is created by the following:

- manufacturers and distributors of welding materials and equipment
- applied welding technologies and level of their automation
- welding sector personnel

Figure 1. The world's first fully welded road bridge and commemorative plaque affixed by the American Welding Association

- users of welding technologies
- scientific and research establishments

Manufacturers of welding materials and equipment

Privatisation of domestic manufacturers of welding materials and equipment by such companies as ESAB and LINCOLN has opened the world's market (through their perfectly organised distribution networks).

The most fundamental issue now is the access to new manufacturing techniques and technologies. They usually require high financial outlays for research and industrial applications. Finding an investor in Poland is no easy task. Thanks to the investments made by foreign companies the market sector of welding materials and equipment has considerably strengthened its position. A recent decision of the ESAB company to move the production of welding equipment from Sweden to the city of Opole seems only to confirm this trend (Opole is going to have the biggest production plant of ESAB welding equipment in Europe). Also the investments made by the LINCOLN company and its subsidiaries in the scope of production of flux-cored wires or welding torches. The gas companies that have located their investments in Poland include LINDE, MESSER, AIR LIQUIDE and AIR PRODUCT.

It should be clearly emphasised, however, that apart from large international companies there are over a dozen Polish big and small companies manufacturing welding materials and equipment, such as ASPA, ZBUS, ECKERT, ZASO, ELKO, MULTIMET, METALWELD, TECHNIKA SPAWALNICZA and others. These manufacturers supplement the large companies' offer with specialist materials and equipment for welding engineering.

Over two thousand distributors and servicing points in Poland provide their services to the customers of welding engineering companies. Thanks to investments made, privatisation process and organizational changes, there has been a steady growth in the potential and competitiveness of Polish welding engineering on the global markets. This can be seen

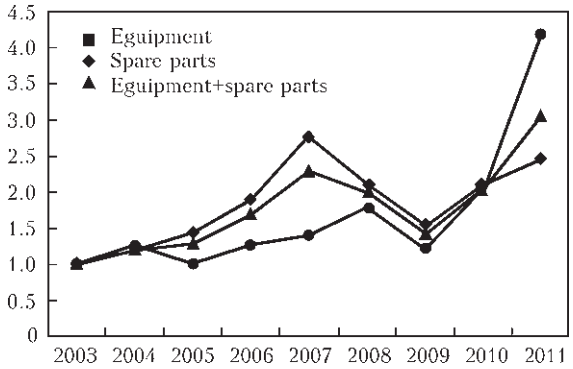

Figure 3. Dynamics of export of welding equipment and spare parts in the years 2003 – 2011

in the figures relating to the dynamics of the market of welding materials and equipment.

The year 2003 was adopted as the basis for the analysis of the market dynamics, of both welding materials and equipment. That was the year of the sale growth after the economic slump in the years 2000 – 2002.

After the period of a boom in the economy in the years 2003 – 2007 (Fig. 2 and Fig. 3) the impact of the world's crisis on the domestic market of welding equipment became visible. The total production of equipment and spare parts sold in 2007 was twice as much as in the year of 2003, whereas in 2009 it approached the level of the year 2003. The years 2010 – 2011 saw the recovery of the economy. The total value of the export of equipment and spare in 2011 exceeded the level of the year 2007, which was a very good year for the market of welding engineering.

Thanks to a perfectly developed distribution network, including networks of the ESAB and LINCOLN companies, the equipment manufactured in Poland is exported to over 100 countries all over the world. The biggest number of devices is exported to Belgium (16%), Russia (15.3%), USA (9.9%) and Germany (7%).

The dynamics of the market of electrodes and flux-cored wires shows that there has been a considerable export growth in both fields. The export of covered electrodes in the years 2003 – 2010 increased over

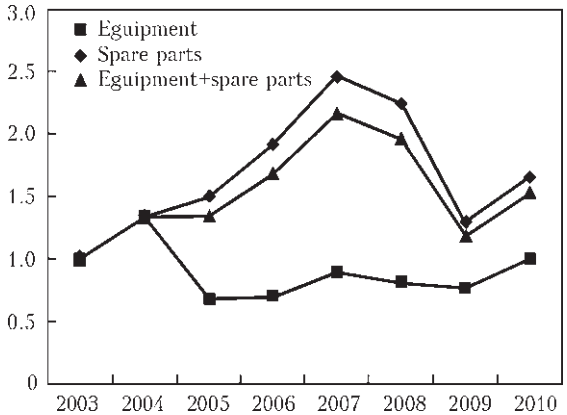

Figure 2. Dynamics of sales of domectic welding equipment in the years 2003 – 2010

Figure 4. Dynamics of the market of covered electrodes in the years 2003 — 2011acc. to mass

10 times, whereas that of flux-cored wires over 7 times (Fig. 4 and Fig. 5). Similarly as was the case with equipment, the world's crisis of 2009 caused a decrease in export of covered electrodes and of flux-cored wires. However, the domestic use of covered electrodes remained at the level of the year 2003. The use of flux-cored wires was gradually growing. In 2007 it was over 3 times greater, and in 2010 it was twice as high as in the year 2003 (Fig. 5).

The dynamics of import of welding equipment was either stable or of a declining character. In the years 2003 – 2010 the value of import did not exceed the level of the year 2003. The highest activity of the manufacturers of welded products and steelwork in the purchase of new welding equipment took place in the years 2007 – 2008. It resulted, among other things, from a long and arduous effort to build the financial stability of the companies.

The import of welding materials and equipment has taken place in the past and today, and what should be emphasized, from various countries. In 2011 Poland's most important partners in the scope of the purchase of welding equipment were Germany 28.8% as well as China and Italy with a respective share of 15.3% and 14.3% of the total purchase value.

The greatest import of electrodes as far as the mass is concerned has come from Portugal, Hungary and China, whereas electrodes of a relatively higher price and quality have been imported from Sweden, Germany and Holland.

The import of flux-cored wires from China in 2011was comparable in terms of quantity with the import from Germany. However, the quality of German wires was 2.5 times higher, which indicates their better quality and specialist properties.

Analysing the structure of the total use of weld metals in Poland in 2010, it was possible to observe that the weld deposit coming from solid wires (MIG/MAG) constituted approximately 53%, from flux-cored wires (FCW) approximately 20%, whereas from covered electrodes (MMA) and from welding consumables for submerged arc welding (SAW) 18% and 9% respectively. Both the increase in the use of flux-cored wires and the declining tendency in the use of covered electrodes follow the tendency taking place in developed countries, where in the years 1976 – 2004 the participation of weld deposit obtained during manual welding with covered electrodes decreased from 51 to 12% in Western Europe, from 49% to 12% in the USA and from 70% to 13% in Japan.

Applied welding technologies and level of their automation

General trends in the scope of welding technologies applied in Poland do not diverge from those in the developed countries in Europe and in the world. In the general hierarchy of applied methods, manual

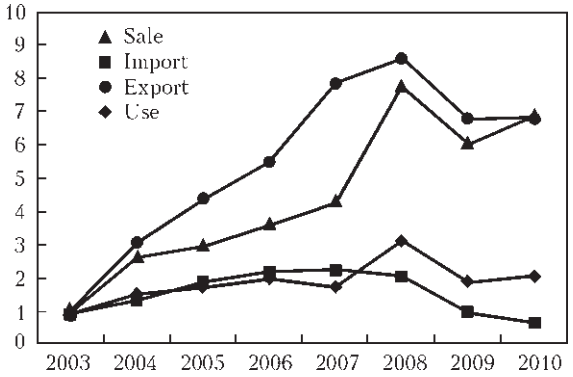

Figure 5. Dynamics of the market of flux-cored wires in the years 2003 — 2011acc. to mass

welding with covered electrodes is relatively rarely applied, while the application of flux-cored wires and semi-automatic MIG/MAG welding is on the increase. However, nowadays the state-of-the-art methods and cutting-edge welding technologies are laser welding and cutting, hybrid welding, electron welding, welding with several wires, low-energy processes as well as automatic and robotised welding.

All of the above-mentioned processes are known and applied in Poland, however, the scope of their use is different from the one observed in the developed countries. The world's production of industrial lasers in 2008 amounted to 41700 units. About 36% of this number, i.e. over 15 000 items were installed in Europe. If one assumes that 22% of lasers were used for cutting and 12% for welding, then 5100 lasers were used in welding processes in Europe solely in the year 2008. According to estimates, around 2000 units were installed in Poland, including several dozen intended for welding. Hybrid welding is already a subject of research and experimental testing. There are some single industrial applications of hybrid welding but still a lot needs to be done in this area.

A similar situation is in the case of robotisation of welding. There is over a million of robots installed all over the world, with 30% of this number being made up by welding robots. Among welding robots a dominating position is taken by robots for welding and fusion welding, whereas robots for brazing and, in particular for laser welding, have prospects of development.

As the measure of robotisation level one uses the number of robots per 10 thousand people employed in all industries or in the automotive industry. It is estimated that in the world there are approximately 50 robots per 10 thousand employees in all industries. However, in such countries as Japan and Germany there are respectively 1436 and 1130 robots per 10 thousand workers employed in the automotive industry and 191 and 134 robots in all industries. In Poland in 2010 there were 5158 robots installed in all industries, with 2559 robots used in the automotive industry. Therefore, there are 19 robots per 10 thousand employees in all industries and approximately

Table 1. Welding robots installed in different countries in 2010

Country	Number of pcs.	Country	Number of pcs.
China	8 000	India	446
Germany	4 129	Slovakia	396
North America	3 883	Brazil	246
South Korea	3 800	Great Britain	197
Japan	3 609	Poland	171
Spain	563	Portugal	131
France	496	Russia	115

176 robots per 10 thousand employees in the automotive industry.

The number of welding robots installed annually in different countries is worth emphasising. The potentate is China where in the year 2010 eight thousand welding robots were installed. In Germany, North America, S. Korea and Japan this number fluctuates around four thousand, whereas Poland, with 171 robots, takes one of the last positions in terms of the number of installed welding robots (Table 1).

Welding sector personnel

The personnel employed in the welding sector is one of the greatest assets of Poland's welding engineering; this being due to the level and organisation of educational processes, practical training and experience in manufacturing critically important structures by domestic producers. The international system of educating welding personnel implemented by Instytut Spawalnictwa enables obtaining international certificates (Table 2) and European diplomas (Table 3). Instytut Spawalnictwa collaborates with the European Welding Federation as well as the International Institute of Welding and contributes significantly to their work.

Vocational training is run in Poland by approximately 400 centres supervised by Instytut Spawalnictwa. Several dozen thousand documents are issued every year (Table 4). It is estimated that approximately 130 – 150 thousand people are involved in work for the welding engineering sector, including 60 – 80 thousand of welders.

Users of welding technologies

Depending on the economic situation, in Poland, in over 100 industrial sectors there are between 6.5

Table 2. The total number of the international diplomas acquired by the welding personnel in the years 1999 – 2011 was 2,400

	IWE	IWT	IWP	IWS	IW	IWIP
Number of diplomas	1,418	200	150	362	31	239

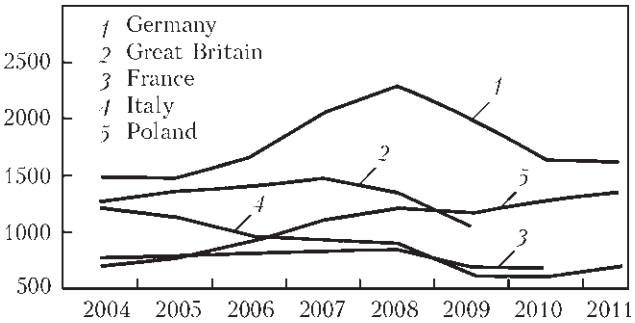

Figure 6. Production of steelwork in thousands of tons in the countries of the greatest production output in Europe

and 7 thousand companies using welding and related technologies in production processes. Such companies create about 50% of the added value. Poland comes second in Europe as far as the quantity of steelwork production is concerned (1.35 m tons). There is also a high share of export in the structure of production. In 2010 export amounted to 630 thousand tons, while import reached 195 thousand tons (Figure 6). All this is a clear indication of the strong position of companies connected with the welding engineering sector.

Domestic manufacturers make the most reliable and responsible welded steelwork for power engineering, aviation, building engineering, petrochemical sector, gas engineering, transport, automotive industry, ship building, etc. Their export and price relations show Poland as a country with a very competitive offer.

What is insufficient, however, is the outlays incurred by industrial companies for innovative activity. The companies allocate over 80% of their financial resources for purchasing equipment and just merely 10% for research and development.

Scientific and research potential

The expert institutions dealing with welding engineering in Poland are Instytut Spawalnictwa (the biggest establishment in Poland, with 165 employees), chairs or departments at 16 universities (employing from several to a dozen or so workers), the Polish Academy of Sciences, some research institutes as well as large industrial plants with their testing and research facilities. Industrial plants with a foreign capital usually carry out their research in their own scientific centres, sadly, outside Poland.

For the past 20 years the laboratories conducting research for the welding engineering sector have been

Table 3. The total number of European diplomas acquired by the welding personnel in the years 1997 – 2011 was 1,734

	EWE	EWT	EWP	EWS	EW
Number of diplomas	1,108	179	158	72	91

Table 4. Documents issued every year

	2004	2005	2006	2007	2008	2009	2010	2011
Welders Qualification Test Certificates	20,566	22,487	34,576	42,423	43,789	46,199	44,454	42,499
Welder's Books	8,740	10,580	15,474	21,524	17,604	14,736	13,918	13,662

Table 5. Financial outlays for research projects in welding engineering

Description	Projects financed by MNiSW in the following years				NCBR Projects	Developmental Projects
	2002 – 2007		2008 – 2010		2010 r.	Years 2007 – 2008
	Own	Superv.	Own	Superv.	Initech	
Number of projects	28	10	21	9	3	4
Financial outlays in thousands PLN	6 567,9	414,7	6 325,3	463,1	10 877,0	2091,0
Average outlays in thousands PLN per 1 project	234,6	41,5	301,2	51,4	3 625,7	522,7
MNiSW – Ministry of Science and Higher EducationNCBR – National Centre for Research and Development Superv. – Supervisory Initech – Innovative Technology.						

equipped with the state-of-the-art lasers, robotised welding equipment and modern testing machines.

Table 5 presents financial outlays for research projects in welding engineering financed from the budgetary resources.

The structure of research issues and financial outlays for research shows that despite limited outlays the scope of the research carried out in Poland has covered the majority of problems essential to modern welding engineering, such as laser welding (including hybrid welding), plasma welding, welding (including FSW), materials of poor weldability, nanomaterials, calculations and simulations of processes etc. (Fig. 7 and Fig. 8).

The assets of today's welding engineering:

- powerful and quickly developing production and distribution facilities of welding materials and equipment
- highly skilled welding personnel thanks to the international system of vocational education and training as well as owing to experience gained at production of reliable steelwork of critical importance
- welding technologies hierarchy applied in accordance with the world's trends
- great potential and production capacity of the manufacturers of welded products and steelwork
- powerful research and testing facilities and experienced researchers as well as the range of research-related issues taking into consideration the world's latest trends.

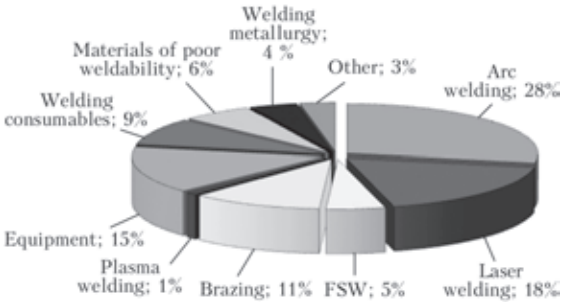

Figure 7. Structure of research projects financed from the budget in the field of welding engineering in Poland in the years 2000 – 2007

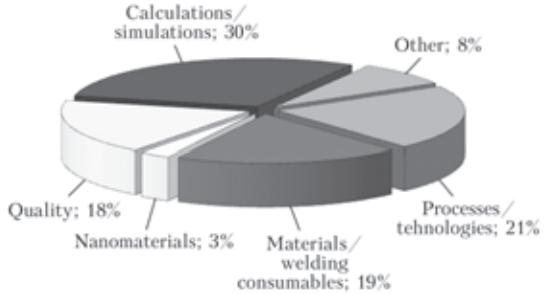

Figure 8. Structure of outlays for research projects financed from the budget in welding engineering in Poland in the years 2007 – 2011 (acc. to value)

Welding of the future

Welding engineering of the future will depend on research conditioning the development of structural materials and technologies to join them, educational and vocational background of the welding personnel, the level of innovation at companies and a general economic situation.

Research in the area of structural materials

The research of materials processed by means of welding technologies will include:

- parent metals: steel, aluminium, magnesium and plastics
- new materials: titanium and its alloys, composite and ceramic materials, multi-materials
- materials of the future – nanometals.

As can be seen in Figure 9, the production of steel is four times higher than that of other structural materials. For this reason the use of steel is and, in the nearest future, will continue be a fundamental indicator of the condition and development of individual industrial sectors, including welding engineering.

The research related to the development of structural materials has been addressed in many publications and research programmes such as European Strategic Energy Technology Plan (referred to as the SET Plan) developed by the Polish Steel Technology Platform (Polska Platforma Technologiczna Stali) as well as the programme 'Horizon 2020' being prepared

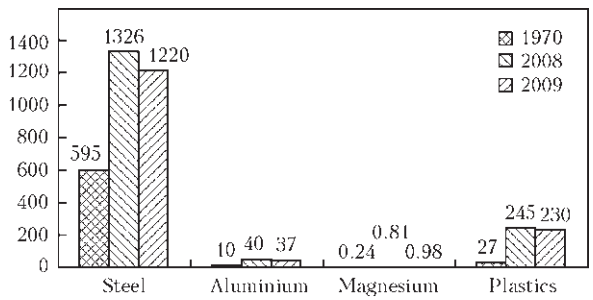

Figure 9. World's production of major structural materials

by the European Union. The latter programme is supposed to be in operation from 2014 to 2020 and provide approximately 80 bn PLN to finance European research and innovations.

Welding technology development

New structural materials of poor weldability pose a real challenge for welding engineers. These include:

- materials resistant to high temperature
- multi-materials in the form of sheets, shapes and casts
- high-strength steels + soft steels, aluminium steel + carbon fibre reinforced plastics (CFRP)

Technologies of the future are:

- laser, hybrid and electron beam welding
- remote controlled welding using concentrated energy
- always relevant electric arc welding: Cold Metal Transfer, STT (Surface Tension Transfer), Cold Arc, SCW (Synergic Cold Wire), two-arc MAG welding, submerged arc welding with multiple electrodes and thin wires as well as TIME methods

The growth in the productivity and quality of welded joints is conditioned by the automation and robotisation of high-efficiency welding processes as well as by computerised control of welding processes, first of all due to high current parameters and welding rate values.

Innovative solutions

'Being innovative' is the ability to create and use in practice new and ***effective solutions*** which have become feasible owing to research and experience gained during production.

Effective solutions bring the following advantages:

- increase in quality and efficiency
- reduction of costs
- reliability and competitiveness of manufactured welded products and structures.

Innovation is the most effective method to enjoy competitive and economic success. '**Innovation means knowledge turned into money'**. All too often one can see only expenditure related to the implementation of new solutions. In fact, costs are borne only once, whereas benefits keep coming in for years.

Innovation obviously does cost, and poses a great problem in countries like Poland. Welding engineering companies have been arduously building their financial stability, investing in fixed assets, building or renovating production halls, purchasing welding machinery and equipment. This phenomenon is very positive and important as these areas have been neglected for many years. However, the foregoing is insufficient to boost efficiency and competitiveness. ***The future and competitiveness of Polish welding engineering will, to a much greater extent, depend on the companies' activity in the field of innovation.***

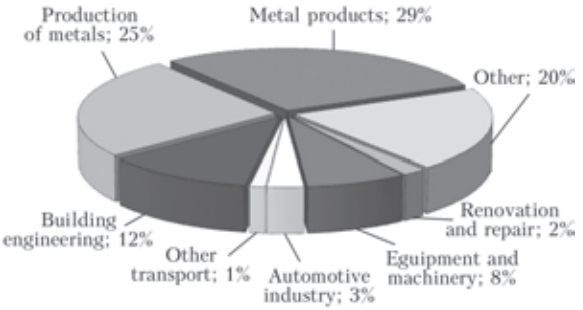

Figure 10. Structure of the use of rolled goods in Poland by sectors related to welding engineering in 2010

Influence of economic situation on Polish welding engineering

The globalising economy increases international competition. If the welding engineering industry is to play an important role in it, it will have to face up to this challenge. It is difficult, though, to predict what shape the economy will take in Poland and in the world.

Welding engineering needs a good economic situation in sectors being the main users of welding techniques i.e. metal products (for power engineering), building engineering, automotive and transport industries (including shipbuilding), equipment and machinery, renovation and repair (Fig. 10).

Examples of investments which may positively influence the economic situation of the welding industry in the domestic market

1. The construction of the north–south gas pipeline is due to begin in 2014. It will connect the terminal in the city of Świnoujście with gas distribution grids in the Czech Republic, Slovakia, Ukraine and other south-European countries. The pipeline is going to be 2000 km long and its construction is to be completed in 2020. Parallel to the above-mentioned investment, there are plans made for the Odessa–Brody–Gdańsk pipeline.

2. According the document 'Power Engineering Policy for Poland until 2030' approved by the Cabinet, the power engineering sector is going to be the driving force for the development of Polish economy (including welding engineering sector). One of the factors affecting the development of power engineering is the requirements issued by the European Union in relation to the reduction of CO_2 emissions, making it necessary to modernise the existing power units and transmission grids as well as to build new ones, diversify Poland's power generation by building nuclear power plants and implementing renewable energy solutions connected with wind, water, solar or biofuels. All the investments connected with the excavation of shale gas will also be of importance to the welding engineering sector.

3. All the above-mentioned changes will not be possible without new technologies and solutions in welding engineering.

4. The prospects of the development of wind power engineering: at the premises of one of Polish shipyards ('Gryfia') a modern 'off-shore' unit is being built. It is a joint venture of three companies: German Bilfinger Berger, Gdynia's Shipyard's "Crist" and MARS Closed-end Investment Fund (belonging to ARP — Industrial Development Agency). The target production is to bring 80,000 ton of steelwork making up foundations for off-shore wind turbines, with the main customers being German and British companies.

5. Gdańsk Shipyard has started the production of wind turbines. The target production aims at 300 turbines annually making the shipyard the biggest manufacturer of offshore wind turbines in Europe.

6. In Goleniów Dutch Glasfiber has set up a plant manufacturing blades for wind power plants.

7. As many as 32 application forms have been submitted to Poland's authorities requesting permission to locate off-shore wind farms.

8. There is a slowdown in the building sector. However, taking into account the needs of the whole infrastructure and planned subsidies from the European Union funds, the building sector still has a chance to favour the development of the welding engineering industry.

9. Planned investments in renewable sources of energy, waste incineration plants, railway sector and further investment in road infrastructure bode well for the welding sector.

10. There has been 3 bn PLN allocated for the modernisation of railway lines so far but this amount will be probably increased to about 10 bn PLN.

11. The automotive and aviation sectors are the driving force for the progress in welding engineering. The share of the automotive sector in creating the added value constitutes 5% of the general added value of the industry. This is far less than in developed countries but there is some success in this area too.

12. Poland is a number-one manufacturer of buses in Europe.

13. The aviation industry in Poland has numerous relations with the world's aviation companies. The companies that have opened their branches in Poland include Meyer Tool — an American manufacturer of spare parts for aviation industry, Sandvik — a Swedish producer of cutting tools, acid-resistant steel, electroresistant materials and conveyor belts, Pratt&Whitney Canada — the world's leader in the production of engines, Vac Aero International Canada. At present, most of the companies in this sector belongs to foreign investors. The aviation industry in Poland is represented by the association 'Dolina Lotnicza' ('Aviation Valley') which encompasses 77 companies employing 22 thousand engineers and technicians.

Conclusions

Assets of contemporary welding engineering

- reliable production and distribution base of welding materials and equipment
- welding personnel's high qualifications and extensive experience in production
- structure/hierarchy of applied welding technologies consistent with the world's trends
- big potential and manufacturing capacity of the manufacturers of welded products and steelwork
- excellent research and testing facilities as well as experienced researchers
- broad scope of research taking into account the world's trends

Weaknesses of contemporary welding engineering

- inadequate level of automation and robotisation
- insufficient application scope of the latest technologies
- inadequate participation of companies in financing innovative solutions
- too low outlays for R&D and too low share of R&D in innovative activity

The future of welding engineering will depend on:

- research conditioning the development of structural materials and technologies of joining them
- level of welding personnel
- innovative approach of companies
- general economic situation

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