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Technological innovations – a basis for the increase of competitiveness of welding industry in the USA

The threat of losing its position as leader in the global economy causes an increasing concern to the US government and business community. In recent years the USA has lost its leadership in competitiveness, moving from first place in 2009 to fifth in 2011, and in 2010 the USA lost its position as number one in industrial production to China [1].

Industrial production, being the bedrock of the US economy, makes up 11% of the country's GDP, with the export of industrial products constituting over 60% of total export. Industry employs approximately 13.4 m people, i.e. almost 9% of the total number of people employed. Remunerations in the industrial sector are over 20% higher than in other extra-industrial sectors of the economy.

Since 2008 the economic crisis has remained the major issue of the US economy. Yet negative tendencies could be observed as early as 2001 when 2.5 m jobs were cut in the industrial production sector in just over a year. Experts indicate the following worrying trends in the US industrial production:

- decreasing industrial production; share of industrial production in GDP in 2000-2010 fell from 17 to 11%.
- employment reductions; in 2000-2010 the industry saw a decrease in employment by 37% (6.5 m),
- decrease in foreign trade; the US global market share went down from 19 to 11% (2000-2010), which has caused a foreign trade deficit,
- growing prices of industrial products; increasing outlays related to industrial safety, environmental protection, taxes, remunerations, complaints etc. affected prices of finished products, which has decreased US competitiveness in the global market,
- shortage of skilled labour [2].

Technologies for joining materials are an indispensable part of the economy's industrial sector. Welding engineering and related technologies are closely integrated with production processes in basic sectors of the industry. They are of key importance and cannot be replaced by other alternative solutions. Having in mind the significance of joining technologies for the economy, in 2010 Edison Welding Institute (EWI) in conjunction with the American Welding Society (AWS) initiated extensive investigation into the condition and possible ways of improving the competitiveness of industrial production using materials joining as an example. Within the project "Future trends in materials joining in the USA", manufacturers representing six core industrial sectors were surveyed in order to uncover the major problems of these sectors and their needs related to materials joining. The results of the investigation were published in February 2011 at the sum-up conference "Strengthening Manufacturing Competitiveness: the Future of Materials Joining in North America, attended by the representatives of scientific, governmental and social institutions as well as of the welding engineering market leaders – Lincoln Electric, Trumpf, Miller Electric and others. The final conference document outlines the main problems in the field of materials joining and the tasks for the next five year.

In today's globalised economy there is

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only one possibility of increasing industrial competitiveness, namely, through the development of innovativeness, i.e. increasing the level of solutions, shortening the time for industrial implementation of technical innovations and improving personnel skills. The innovative development of the economy also entails intense relations between science, education and personnel training. According to the aforesaid survey carried out by EWI, the problems appearing in the area of materials joining are closely connected with solving the tasks mentioned above. The results of the survey are presented in Tables 1 and 2 [3].

The results presented in the tables reveal that in all industries, new structural materials and their composites are becoming increasingly popular (Table 1). This is a major task in the automotive industry and power engineering. It also tops the tasks lists of other industries. Research workers, designers, constructors and manufacturers are more and more interested in applying new materials improving technical characteristics of elements and reducing their production costs. For instance, the necessity of reducing a car body mass increased the expansion of high-strength steels, aluminium, magnesium alloys and composites. An increase in the use of new structural materials requires the development of new joining technologies (Table 2). This problem is

Table 1. Problems and the most important tasks in US materials joining engineering in the next five years (the first 4 issues vs. industries)

Problems and tasks	**Order of importance in industries**					
	Automotive industry	Petrochemical industry	Military industry	Space industry	Heavy machinery industry	Power engineering
Shortage of highly qualified engineers and specialist in joint quality inspection		1	4			
Shortage of skilled welders and workers of other professions		3			1	
Greater competition from countries with lower labour costs	3					
Greater outlays on developing and implementing new processes, products and methods				2		2
Increase in time needed for assessing the quality of joints					3	
Increase in use of new materials and their composites	1	4	3	4	4	1
Implementation of new technological processes			2	1		
Shortened time between the development of a solution and its industrial implementation			1	3		4
Development of on-line systems reporting the latest technologies and methods, and providing access to them	2					3
Increased requirements related to the quality of joints	4	2			2	

Table 2. Materials joining technologies and other works essential for industry (the first 4 issues vs. industries)

Required technologies/works	**Order of importance in industries**					
	Automotive industry	Petrochemical industry	Military industry	Space industry	Heavy machinery industry	Power engineering
Development of technologies for joining wend advanced materials	1	3	1	1	3	3
Increasing the number and improving qualifications of engineers and constructors dealing with in joining technologies		2	2			1
Development of arc welding processes (efficiency, quality etc.)		1	3		1	
Development of new methods for joining dissimilar materials	2			2		2
Providing on-line access to databases with materials joining technologies		4				
Development of more sensitive, accurate and failure-free NDT methods	3		4	4		
Development highly efficient technologies for welding materials of great thickness					2	
Improvement (updating, channelling and making cheaper) methods for training welders					4	
Development of policy for development of new joining processes						4
Modernisation of resistance welding technologies (quality, reliability etc.)	4					
Development of additive (supporting) industrial technologies				3		

mentioned by the representatives of all the surveyed industries, and in the military and space industries it is particularly visible. The respondents also maintain that it is necessary to shorten the time for implementing new solutions in industrial production, find ways to reduce the costs of developing and implementing innovations, and develop on-line databases with new solutions related to materials joining. In short, it is necessary to develop policies allowing the development of joining technologies (Table 2).

The second task in the order of importance for all the representatives is to ensure qualified personnel specialised in joining technologies. According to the Office of Statistics, in the USA between 2002 and 2009 the number of workers of all welding-related jobs dropped from 1 076 498 to 968 037 or, expressed in percentage, by 10.08%. However, this number may be higher, as requirements concerned with the professional skills of a welder are higher than in 25 other jobs.

The data obtained by means of the survey and confirmed by the statistics reveal that individual US industries suffer from a shortage of skilled welders, welding engineers, and other joining and quality control specialists. For instance, the main issue in the petrochemical industry is the shortage of qualified engineers and specialists in joint quality inspections, whereas the heavy machinery industry has an insufficient number of welders (Table 1). The shortage of qualified personnel is strictly connected with the problem of personnel training system improvement as well as with the development and implementation of the system ensuring permanent improvement of qualifications of specialists representing all professions [4].

The major source of innovation is research and scientific, experimental and design engineering works. American experts believe that the total global outlays on research funding in 2012 will increase by 5.2 % and an amount of 1.4 trillion USD, where the US share will be 36%, i.e. 436 billion USD. Research is financed by industry (64%) and the federal government (29%). Table 3 presents data related to the structure of financing research and scientific, experimental and design engineering works in the USA, broken down into the main financing sources and contractors.

Research in the USA, similarly as the world over, is an area open to collaboration. The data from Table 3 show that industry increasingly finances its own research as well as basic research conducted by scientific institutions for the industry. The federal government also puts considerable funds into research activities initiated by industry and institutions. According to the results of a survey conducted by the R&D Magazine, 80% of industrial companies finance research carried out along with research centres and other organisations. It should be emphasized that not only industry but the federal government also shows a growing interest in profiting from outlays on research. A few years ago only 10% of companies planned and calculated profit from such "investments". Today, over 50% of businesses consider this factor as a key indicator of their activity.

The Bayh-Dole Act of 1980 created the basis for a new US research and technical policy, the aim of which is to increase the competitiveness of the national economy. The law allowed passing the right of intellectual property financed from governmental resources to other non-federal research institutions such as universities, private businesses

Table 3. Ratio "fund source – research contractor", 2012, m USD (change in relation to 2011- %)

Fund source	**Contractor**					
	Federal government	Governmental funds, national centres and laboratories	Industry	National science fund and other academic institutions	Non-profit organisations	**Total**
Federal government	29 152 -2,51%	14 666 -3,69%	37 577 -2,42%	37 440 0,93%	6 817 -2,29%	**125 652 -1,61%**
Industry		202 2,20%	237 487 3,37%	3 868 26,49%	2 129 8,89%	**279 685 3,75%**
National science fund and other academic institutions				12 318 2,85%		**12 318 2,85%**
Other governmental institutions				3 817 2,72%		**3 817 2,72%**
Non-profit organisations				3 491 2,70%	11 055 2,80%	**14 546 2,70%**
Total	**29 152 -2,51%**	**14 868 -2,36%**	**311 063 2,63%**	**60 934 2,85%**	**20 001 1,55%**	**436 018 2,07%**

and other entities as well as enabled making invention licences available on the basis of exclusivity, which is the primary condition for their commercialisation.

This law, other governmental decisions adopted later, and state-run programmes stimulated the integration of basic and applied research, increased industrial companies' interest in basic research, contributed to the expansion of interdisciplinary research and changed the attitude to research infrastructure [5, 6].

In order to stimulate technological research related to materials joining, strengthen mutual relations between science and industry, significantly shorten implementation time and expand areas of innovative solutions, EWI together with the US Institute for Industrial Productivity worked out a successful model of developing and industrial implementation of technological innovations related to joining technologies. The basis of the model is the idea of creating new organisational structures favouring closer integration of all the participants in the innovative process – from concept to development, commercialisation and extensive industrial implementation of innovation. Such structures can be the following: Focused Industry Consortia, and Manufacturing Technology Application Centres.

The Consortium is a temporary union of industrial companies interested in the development of new advanced technologies. The Consortium members specify the basic technological problems which must be solved, agree on the programme of a project and choose the management of the consortium group. In order to solve various special tasks the Consortium can invite centres for the development and implementation of industrial technologies, research laboratories, commercial companies and other organisations as collaborating contractors. The state supports the development of innovations until their commercialisation by means of state programmes. Industrial implementations of innovations require significant involvement of industrial and other resources. Table 4 presents the scheme of collaboration for the Consortium and centres for the development and implementation of industrial technologies.

Table 4. Scheme of collaboration of the Focused Industry Consortium and centres for the development and implementation of industrial technologies

Focused Industry Consortium	**Centres for the development and implementation of industrial technologies**							
	Automation	Casting	Electronics assembly	Press forming	Quality control	Joining	Additive technologies	Treatment
Production of metal for aviation industry using additive technologies	X				X	X	X	X
Car body mass reduction		X		X	X	X	X	
Quick assembly of batteries	X		X		X	X		
Environmentally friendly production of electronics	X		X			X		
Production of units for nuclear power stations		X			X	X	X	X
Automation of production of machines for heavy machinery industry	X				X	X	X	X

The scheme above presents one of the main ideas related to the functioning of the Consortium, i.e. the possibility of involving specialised centres for the development and implementation of industrial technologies, supported by their highly qualified experts and possessing necessary funds, to solve specific tasks during the development of specific innovations.

The purpose of the consortium model developed by EWI is to demonstrate a demand for new materials joining technologies, invent such technologies and create a programme of partnership-based collaboration for the development and quick industrial application of new technologies. An example demonstrating how this model functions in practice is the Additive Manufacturing Consortium and Nuclear Fabrication Center created by EWI in 2010.

For instance, the Additive Manufacturing Consortium joined efforts of large US space industry corporations taking advantage of the research provided by EWI and other private, non-profit and state organisations interested in the development and widespread industrial implementation of leading additive technologies. The consortium included 24 industrial companies and research centres. The industrial partners of the consortium were users and manufacturers, whereas the research partners included universities and such organisations as the Army, the Air Force, the Navy, NIST and NASA. The development and implementation of this model was supported by the state. In order to implement the project, the state of Ohio established a multimillion dollar grant.

If the purpose of the consortia is to solve strategic and organisational tasks aiming to develop new technologies, the main collaborating contractors in given projects are centres dealing with the development and implementations of industrial technologies. Such centres should be global market leaders in their sectors, possessing cutting-edge equipment and employing highly qualified personnel. An example of such a centre in materials joining is EWI, which within the scope of its activity collaborates both with universities and industrial companies. Such an approach favours the development of innovative solutions successfully implemented in production. Since 1984 EWI has been taking advantage of state aid within the confines of the Ohio Edison Programme. Permanent development, efficient solutions and high return on outlays are the factors which attract private investors. In 2010 private investments in the research works of EWI were almost 20 times higher than the contribution from the state [7].

The model of developing and implementing technologies has been approved by the US government. In 2011, on the basis of this model, the National Institute of Standards and Technology at the US Department of Commerce adopted a new national programme for supporting the development of technological innovations in the USA named ”Advanced Manufacturing Technology Consortia (AMTech)”. In 2012 the budget of this programme amounted to 12 m USD. The aim of the programme is to support innovation-oriented tasks such as robotics technology, nanomaterials, new advanced materials and new production technologies. In total, in 2012 the state supported innovative programmes with a sum of 75 m USD [8].

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