ORGANIZATION AND TOPICS OF R&D IN THE FIELD OF JOINING TECHNOLOGIES CONDUCTED BY TWI AND DVS ASSOCIATION OF RESEARCHERS (Review)

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The paper gives information on organization and topics of investigations in the filed of joining technologies conducted by TWI and DVS Association of Researchers.

Keywords: *joining technologies, topics of R&D, TWI, DVS Association of Researchers*

Practice of «openness» of the investigation topics acquires a wide-accepted character under conditions of globalization of world economic development. The topics of planned scientific projects and programs of fundamental and applied investigations are published in the national editions as well as on the pages of web-sites by leading welding institutes, centers and welding societies of many countries, thus inviting to cooperation and mutual exchange of the scientific information.

The Institute Welding (TWI, Great Britain) and DVS Association of Researchers (DVS AR, Germany) are the leading European and world scientific centers in the field of joining technologies. Solution of specific and relevant tasks of the industry, i.e. development of new joining technologies, investigation of weldability of new structural materials, cut of industrial expenses in welding engineering, quality and safety of welding operations, increase of safety of welded structures, obtaining of scientific and experimental grounds to norm and standards etc. is the main direction of the investigation topics conducted in these scientific centers. High level of maturity of the developments sharply reducing time for technology transfer is provided for in the research programs of TWI and DVS.

TWI has been significantly growing its scientific-and-technical potential in the recent years. Number of researchers working in the Institute increased 1.3 times from 500 to 640 persons for the period from 2005 to 2010. A total gain from different areas of activities exceeded 53 mln GBP in 2010.

Researches on a plan of topics of Basic Investigation Program (CRP) make a basis of fundamental and applied scientific investigations in area of welding and related technologies of TWI. The budget of CRP Program made around 3.3 mln GBP for 2010–2012, and TWI income from results of the performed R&D was around 10 mln GBP in 2010.

TWI conducts significant volume of works on training, retraining and attestation of welding personnel, engineering and scientific stuff. A general fund for financing of this area of activity exceeded 14 mln GBP per year.

Membership fees from enterprises and individual persons from Great Britain as well as other countries of the world are the main source of financing of TWI scientific and production activities. Significant increase of a number of TWI members is observed in recent years. Thus, 110 companies became joint members in 2010 that allowed additionally obtaining around 1 mln GBP and the total gain from membership fees made around 7 mln GBP. Number of organizations and enterprises-joint members of TWI achieved 660 in 2010.

Industrial enterprises and firms (members of TWI) provide financial support at conductance of the specific topics and influence on direction of the performed investigations and developments. As a rule, the representatives of branches of industry reckon on obtaining of maximum benefit from the results of CRP Program for providing competitiveness of their production in the world market. Only commercial members of TWI which also can obtain additional information on CRP projects, including during the process of their execution, are provided with the final reports on results of R&D, performed in the range of CRP Program.

Organization of performance of the investigations in TWI is carried out on target projects. A scientific laboratory or department is organized for performance of works on that or another scientific direction for the time of conductance of R&D project and stops its existence after work on specific direction is finished.

TWI CRP Program for 2009–2012 includes 57 R&D projects which are grouped by five subject directions (strength of welded structures; metals and weldability; laser, arc and resistance welding; surface treatment; electron beam technologies and technologies of friction welding; plastics; glues, ceramics and electronics). Each research project is clearly oriented to one or several specific sectors of commercial production (airspace; motor car construction; welded structures and design; war industry; oil-, gas- and chemical industry; power engineering; railway transport; sensors and medicine; shipbuilding), where realization of obtained R&D results is supposed or which is a customer of given topic.

17 projects the topics of which can be divided on two main groups, i.e. mathematical modelling and visualization of physico-chemical and mechanical processes (6 projects) and methods for control of quality of welded joints (11 projects), have been performed/is performed in «Strength of Welded Struc-

tures» direction. The mathematical modelling and visualization find wider application in the investigations of welding processes replacing performance of multiple expensive experiments. A model for accurate forecasting of the residual stresses in circumferential welds of the pipelines is supposed to be developed and grounded in «Development of Progressive Methods for Evaluation of Circumferential Welds of the Pipelines» project. The project includes an investigation of changing of circumferential weld metal properties in the stress-strain state using stain-based failure assessment diagram, development and grounding of a model for accurate forecasting of the residual stresses in circumferential welds of the pipelines, development of a procedure for determination of influence of the residual stresses on crack formation for evaluation of crack resistance of circumferential weld. Development of a model for direct metal laser deposition using laser technologies that allows determining of the dependence between process parameters, material properties and resultant quality is the aim of «Progressive Methods of Modelling» project.

Large group of the projects is dedicated to development of methods of non-destructive testing of welded metal structures which, in particular, deal with evaluation of corrosion damage of steels in acid media, development of phased array ultrasonic testing, detection of small fatigue cracks. Computer X-ray tomography is interesting in application for testing and evaluation of porosity and undulation of black-reinforced plastic fiber.

Topics of the investigations in «Metals and Weldability» direction include 15 projects, aimed at investigation of weldability of structural, heat-resistant, stainless steels, nickel alloys and dissimilar materials using different welding technologies, i.e. electron beam, arc and TIG welding. In particular, the investigations are conducted on following R&D projects:

- Improvement of technology for welding of dissimilar materials — topic is relevant for nuclear-power engineering;
- Evaluation of weldability of ultrasupercritical materials for power units/power stations — for development of new structural materials designed for manufacture of turbogenerators of TPP with ultrasupercritical parameters of vapor;
- Repair of welded structures from heat-resistant steels with 9 % Cr without heat treatment — applicable to repair of turbosets and boiler units under conditions of TPP and NPP.

12 projects refer to the investigations in direction «Laser, Arc and Resistance Welding and Surface Engineering». They represent studies the topics of which are directed on development of new technologies, i.e. MIG/MAG, laser, hybrid laser-arc, welding of parts from carbon steel, corrosion-resistant alloys, dissimilar materials (steel and copper, steel and aluminum), heat-resistant steels, nickel, titanium and aluminum alloys.

The projects «Welding and Cutting Using New Generation Superpower Fiber Lasers and Single and Multipass Hybrid Laser Welding with Adaptive Control» are directly related with study of a peculiarity of interaction of laser and arc heating sources in hybrid process; selection of alternative combinations of laser with arc or plasma heating sources, providing high efficiency of welding and quality of the joint; investigation and development of hybrid laser-arc technology of welding of thin sheets from aluminum alloys and combination of dissimilar materials.

Such investigation topics as «High-Efficiency Layer-by-layer Laser Surfacing of Metal and Laser Spraying and Cladding» reflect direction of TWI investigation in the field of creation and development of processes of surfacing and deposition of special and protective coatings as well as development of consumables of improved quality with special physico-mechanical and tribological properties designed for coating deposition.

There are seven projects on investigation topics directed to «Technologies of Electron Beam and Friction Welding». The projects connected with development of new technologies of EBW and FSW of ferrite and austenite steels and high-strength aluminum alloys were represented in the program.

Number of serious research investigations in the field of development of new types of FSW tool and technique has not been reduced in TWI regardless that the FSW process was developed and realized back in the 1990s including by means of selling of a license for technology and equipment. Thus, a technology of microFSW of aluminum alloys from 0.2–0.3 to 1.5–2.0 mm applicable to performance of the longitudinal and spot welds were developed and has been already widely implemented following the TWI plans.

Additive technologies find greater application in commercial production, in particular, replacing casting techniques in ferrous metallurgy. Possibility of application of this technology for the friction welding process, especially, for development of tool, is supposed to be investigated in «Additive Technologies Applicable to Friction Welding» project.

There are 9 projects in topic of the investigations in «Plastics, Glues, Ceramics and Electronics» direction. The projects aimed at investigation and development of a technology of welding (laser welding, fusion butt welding) and deposition of coatings on the parts from plastics and composites are represented in the Program, in particular:

- Investigation of polymeric materials reinforced by carbon nanotubes and designed for operation under extreme environment conditions;
- Improvement of quality of welding for fiber-reinforced thermoplastics;
- Technologies of joining in medicine [1].

DVS — federal society (association), realizing management and coordination of scientific and technical, industrial and educational activity of different enterprises of Germany, dealing with the problems of welding and related technologies. DVS is included into Otto von Herike Association of Industrial Research Associations (AiF) and includes 14 land and 94 regional departments, 9 welding training-experimental centers (SLV institutes) and more than 12 training-welding centers (SL).

Number of DVS members (collective and individual) in 2010 was 18456, including 597 collective members.

According to the basic functions of DVS the following organizations were formed in its composition:

- DVS Association of Researchers;
- DVS Publishing house;
- Certification center DVS-ZERT;
- Commission on professional training AfB and independent body DVS-PersZert;
- Technical committee on standardization TC;
- National delegation in IIW and EWF.

To activate engineering research and to increase the efficiency of professional education the Association of institutes of welding technology (GSI) is functioning in DVS since 1999, which combines the welding educational-experimental centers (institutes): SLV Duisburg, SLV Berlin-Brandenburg, SLV Halle, SLV Munchen, SLV Felbach, SLV Hannover, SLV Saabrucken, SLV Bilefeld.

The of DVS AR forms program of topics of DVS research works, meeting the interests of industry and general strategy of development of research directions; realizes the annual distribution of funds for their performance, coordinates the integral developments. The selection of projects for inclusion into the plan of R&D of DVS AR is performed within the frames of 15 expert commissions (committees): FA1 — metallurgy and metals science; FA2 — thermal spraying and autogenous technology; FA3 — arc welding; FA4 — resistance welding; FA5 — special welding methods; FA6 — beam processes; FA7 — brazing; FA8 — adhesion bonding; FA9 — designing and calculation; FA10 — microbonding technology; FA11 — joining of plastics; FA12 — modeling of welding processes; FA Q6 — safety instructions and environment protection; FA V4 — underwater welding; FA13 — manufacturing methods, production technology.

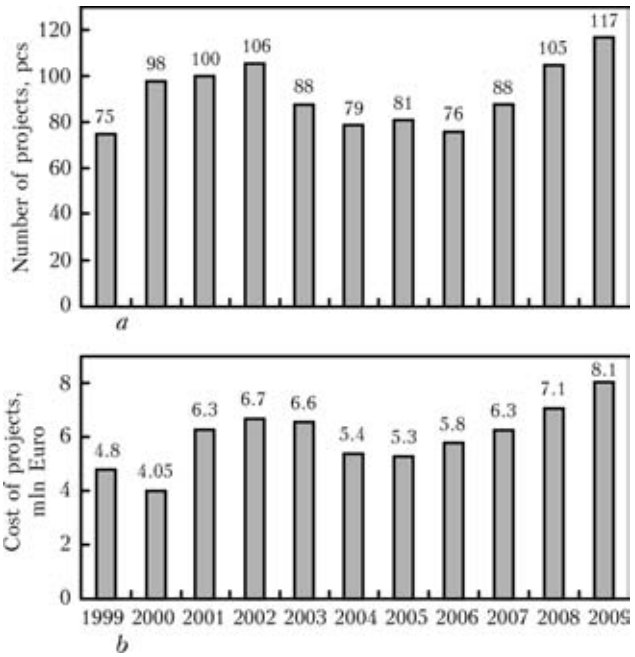
In 2010 the DVS AR performed R&D on 160 projects, with the total volume of financing of 11.5 mln Euro. The bulk of R&D projects is financed by AiF. In 2010 AiF financed 124 research projects at the sum of 8.8 mln Euro.

The Figure shows data on the number of R&D projects, performed by the DVS AR within the frames of financing of AiF in the period of 1999–2009 and their cost.

In 2009 the topics of DVS research works were distributed as follows: 86 % — research in the field of joining technologies and each 7 % — in the field of technology for spraying coatings and cutting technology.

The topics of DVS research works in the field of joining technology for different years are given in Table 1.

In the structure of topics of DVS research works the main part belongs to the research in the field of welding technologies, however their volume in the period of 2002–2009 decreased by 10 %. At the same period the volume of research on technologies of brazing joining increased practically by 3 times. The German scientists pay considerable attention to adhesion



Number (*a*) and total cost (*b*) of carried out DVS AR R&D projects

bonding technology, which is one of the most challenged at the technology market. It is predicted that along with the technology of laser welding the adhesion bonding will have the biggest growth. For example, in 2007 in EU countries more than 30 % of volume of production in the structure of production of welding equipment and rendering services belonged to adhesives and bonding equipment (about 6500 mln Euro).

The topics of DVS research works in the field of welding technology for different years are given in Table 2. As is seen from the Table, the arc fusion welding preserves the positions of basic welding technology. The volume of topics of research works in this field is high and amounts nearly 40 %. In the structure of DVS research works the volume of laser and hybrid technologies is growing.

The main material for welded structures remains steel (Table 3). After growth of volume of research works in the field of technologies of aluminium welding in 2002, 2007, 2009 the decrease of works in this direction is observed. In connection with increasing application of new materials, such as ceramics, composites in many fields of industry (transport, aircraft industry, etc.) and also increase in need in joining of dissimilar materials the volume of research works in these directions is increased.

Table 1. Topics of DVS research works in the field of joining technology, %

Type of joint	2002	2007	2009
Welding	73	62	64
Microjoints	11	14	12
Adhesion bonding	11	16	8
Brazing	5	8	16

Table 2. Distribution of DVS research directions in the field of welding technology, %

Joining technology	2002	2007	2009
Arc welding in shielding gas	45	37	38
Resistance welding	18	12	13
Electron beam welding	7	5	5
Hybrid welding	8	13	13
Laser welding	17	22	19
Other	5	11	12

Table 3. Structure of research works in the field of joining of weldable materials, %

Material	2002	2007	2009
Steel	40	28	34
Aluminium	28	36	21
Plastics	6	7	14
Glass/ceramics	5	5	7
Dissimilar materials	14	16	10
Magnesium	5	5	–
Other	2	2	14

Table 4. DVS R&D projects on separate topic directions

Topic direction	Name of the project
Metallurgy and materials science	Systems of alloying of flux-cored wires for shielded-gas welding of wrought aluminium alloys and alloys produced using die casting Improvement of weldability of aluminium by grain refining Investigation of prevention of hot cracks in austenite Cr–Ni steels and Ni-based alloys using optimization of temperature field
Thermal spraying and autogenous technology	Development of express-methods of NDT for measuring mechanic characteristics and porosity of thermal-sprayed coatings Thermographic methods of NDT for evaluation of thermal-sprayed coatings Improvement of quality of coatings deposited using arc method applying modified autogenous technology and high-velocity gas flows
Arc welding	Increase of stability of welding process in shielding gas using modified shielding gas flow Development of system of control of welding torch for automatic welding of steel and aluminium alloys in shielding gas Evaluation of efficiency of welding in shielding gas
Special welding methods	Investigation of FSW of steel and aluminium Development of conception of evaluation of fitness of installations for FSW and also determination of welding parameters Development of on-line control for FSW on the basis of sensors integrated into the tool
Beam welding methods	Application of multi-beam technology for decrease of internal stresses in the EB- and laser-welded parts Hybrid laser-arc welding of thick-wall precision pipes Hybrid laser-arc welding using low power arc methods
Designing and calculation	Experimental research and numerical modeling of deformation process of aluminium welded joints subjected to impact Calculation of micromagnetic characteristics of internal stresses in steels welded
Joining of plastics	Welding of plastics with heating by infrared radiation Laser welding of optically transparent plastics without using of absorber Automatic optimization and providing of quality on the basis of a new concept of machines for welding using a heating element
Modeling of welding processes	Rapid automatic reproduction of temperature field for modeling of welding deformations Digital diagnostics of cold cracks of parts of laser-welded high-strength steels Applying of modeling welding for calculation of load-carrying capacity of light steel structures of irregular shape

Quantitatively the topics of DVS research works on basic directions of R&D was divided in the following way: joining technologies, respectively, in 2007 — 42; 2009 — 38; materials — 27 and 17; calculation, designing, modeling — 13 and 28; automation — 10 and 7; safety regulations — 8 and 10 %.

The development of new technologies of joining occupies the major part (about 40 %) in the topics of DVS research works. However ever more attention is paid to studying of visualization of welding processes, including calculations, designing and computer modeling. The volume of research works, connected with safety regulations and environment protection, is increased (Table 4).

In conclusion it is necessary to note that familiarization with topics of R&D works carried out by leading world welding institutes, its analysis allows determination of scientific priorities in research works, clear out the problems at which the scientists are working by the orders of industry, personify the topics of research works, find possible partners, etc. The transparency of research topics gives possibility to realize the international coordination in the development of actual scientific trends [2].

1. Core research programme 2010–2012: Project summaries. TWI world centre for materials joining technology. *www.twi.co.uk*
2. Geschaeftsbericht 2010. Innovationen fur die Wirtschaft. Forschung in der Fuegetechnik. DVS. *www.dvs-ev.de*