

RESEARCH | TECHNOLOGY | EDUCATION

IN FOCUS

Resistance Welding in the DVS

The technical-scientific collaboration in the DVS

As a technical-scientific association the DVS is fully committed to joining technology. To that end DVS initiates and supports research activities for example, captures and documents the latest state-of-the-art technology and ensures that training and development programs offered by the DVS meet current requirements. This close network of research, technology and education is the core element of the technical-scientific collaboration work in the DVS. With this interdisciplinary approach, the association guarantees that its diverse work results are always based on current knowledge and are compatible with each other.

An impressive example of this successful work philosophy is the DVS technical code, consisting of more than 500 DVS technical bulletins and guidelines. The DVS technical code also sets high training standards and comparable qualifications in training and ongoing training, creating the basis for the highest level of uniform national and international acceptance and procedures.

The results of the DVS work are reflected in DVS events and are supported by DVS Media GmbH inter for example in specialist magazines, specialist books and other publications and made accessible to the professional world.

The booklet "In Focus" presents specific examples to illustrate the practical results of the scientific and technical community work in the DVS and invites you to participate in the various activities in the DVS. Each booklet is devoted to one topic and shows how the entire business location Germany benefits from the close linking in the DVS of research, technology and education to the respective industry.

Dipl.-Ing. Jens Jerzembeck
Head of Research and Technology



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Publisher:
DVS – German Welding Society
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September 2017

Title image: GSI SLV Duisburg

Resistance Welding – a modern pioneer in manufacturing

Resistance Welding, known for more than 150 years, is a proven technology with high added value. It is the dominant joining process in the field of thin sheet and wire and today, with its process variants, spot, projection and roller seam welding, stub and butt welding, finds applications in many areas of industrial manufacturing such as:

- Sheet metal processing industry (particular focus: automotive)
- Electrical industry (small parts and micro-welding)
- Manufacture of structural steel mats, industrial grids, rails and chains

Despite or even because of the long time that Resistance Welding has been in use, it is recognised as a proven and modern process. The actual process is proven and stable, the integration into production systems is variable and innovative. In the application area of Industry 4.0 in particular, Resistance Welding is not an unknown terrain, but is already being actively applied. Networked welding control systems are used in almost all body shell construction applications. These are centrally operated and give messages on the status, the process parameters or if deviations occur.

Dipl.-Ing. Ralf Bothfeld,

Harms und Wende GmbH & Co. KG

Chairman of the Working Group “Resistance Welding” (AG V 3) in the Technical Committee of DVS

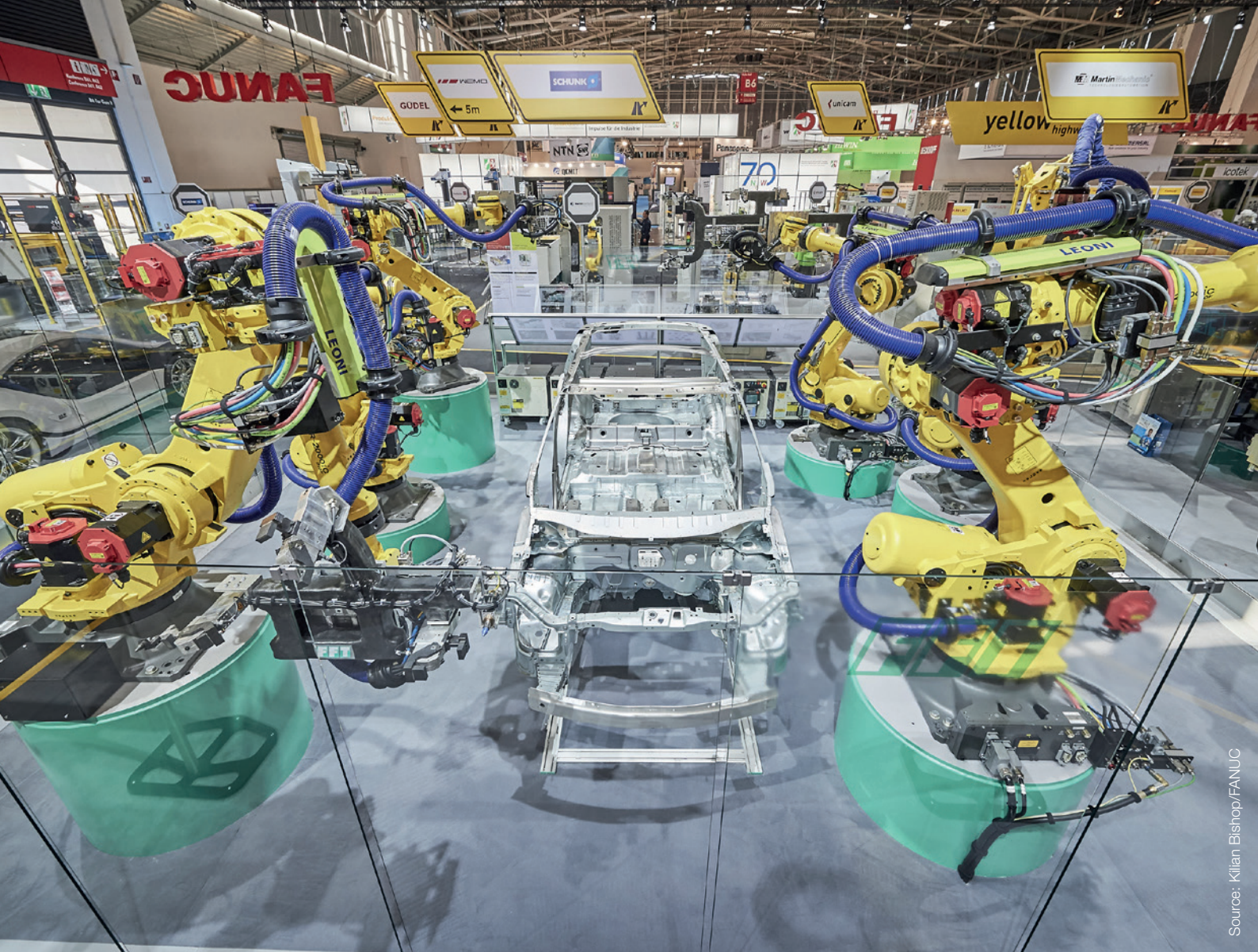
For several years innovative, adaptive current sources have been used in the production lines of automotive manufacturers and suppliers that regulate the process and keep it stable and also pass on the welding results. Not only as pure information, but also with regard to the operating state such as the spot-weld counter reading for wear compensation or trend information on the initial condition. The welding process data can be displayed, visualised and evaluated using the extensive database tools and analysis options of modern networked welding controllers. These possibilities give the operator important information about the welding process itself and also the process stability. Using this and particularly trend analyses, the essentials for the welding process are filtered out of the multiplicity of information and made useful.

One further aspect of the networking with respect to the Resistance Welding technique is that welding parameters or data sets of a material combination determined in the laboratory, can be stored and imported into any compatible control system via the data interfaces of the welding controllers. This is used in practice worldwide over the standardised interfaces of the inverter. Without a lot of “marketing hype” concerning Industry 4.0, resistance welders have used the computerisation of processes very successfully for some time.

Dr.-Ing. Karl Pöll,

Matuschek Meßtechnik GmbH, Alsdorf

Chairman of the Expert Committee “Resistance Welding” (FA 4) in the Research Association of DVS



Source: Kilian Bishop/FANUC

Example of the use of robots in automotive body construction.

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The DVS technical code

The DVS technical code for "Resistance Welding" offers extensive, application-oriented information on procedures, quality assurance, testing, design, training, materials, etc. and also defines the special requirements that are required of skilled workers in the area of Resistance Welding.

The interdisciplinary cooperation between the Research Association on Welding and Allied Processes e. V. of DVS, the Technical Committee (AfT) and the Education Committee (AfB), has resulted in a worldwide established and recognised set of DVS technical code, which represents a self-contained system.

DVS members have free access under: www.dvs-regelwerk.de



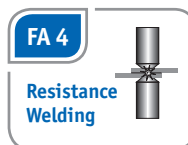
Resistance spot welding in automotive body construction.

Research in the DVS

The Research Association on Welding and Allied Processes e. V. of DVS

The research into joining technology in the DVS is a successful partnership between industry, research and the state. The Research Association on Welding and Allied Processes e. V. of DVS represents as a modern, professional and service-oriented institution for joining technology. As a research-promoting institution in the form of a non-profit association, it offers materials, process and industry-specific research focussing on joining, cutting and coating through its specialist committees in the professional world and the interested public. The specialist committees cover the entire value added and process chain of joining technology.

More than 500 experts from industry and science are successfully involved in the research association's network. More than 100 ongoing research projects are guided and supported annually. The research group is interdisciplinary oriented and open to different cross-industry research collaborations.



i Further and up-to-date information on the work of the Research Association of DVS is available at: www.dvs-forschung.de

The Expert Committees of the Research Association of DVS.

The Expert Committee 4 “Resistance Welding”

Principles/tasks of the Expert Committee

The Expert Committee (FA) 4 deals with the Resistance, Spot, Projection, Roll Seam Welding, Flash and Press Butt-Welding. The application range covers the sheet processing industry (automotive, ventilation, household appliances) through the wire industry (grids, sieves, structural steel mats, chains) to the electrical industry (contacts, lamps, motors).

The Expert Committee 4 is made up of experts from manufacturers and users of Resistance Welding as well as Germany's lead research centres. The FA 4 analyses the current research needs, initiates appropriate research projects and assesses new research ideas and research applications in close collaboration with the DVS (Working Group (AG) V 3 “Resistance Welding”). The needs of small and medium-sized enterprises in particular are taken into account to pursue application-oriented research. Ongoing research projects are supported by Expert Committee 4 and Working Group V 3.

In the autumn, a public colloquium is held for the transfer of current research results, in which there is a close exchange of information between the research institutes and industrial enterprises, and concluded research projects are evaluated. Half-yearly reports from the research institutes to the subgroups of the AG V 3 and lectures on the special “Resistance Welding” conference, which is held every three years complement the transfer of results as well as the cooperation with expert bodies such as the specialist SEMFIRA/EMF, the DIN – German Institute for Standardization e. V. and the German Commission for Electrical, Electronic and Information Technologies (DKE) in DIN and VDE. The research results are also incorporated into the creation and revision of the DVS technical code.



Research and focus areas (excerpt)

- Process optimisation for all process variants (e.g. Resistance Spot Welding, Projection and Roll Seam Welding as well as Flash and Press Butt-Welding) and hybrid joining technology such as spot weld bonding and welded rivets
- Influence of the welding systems on the welding process (welding tongs, electrodes, current sources, etc.)
- Questions on the availability of newly developed or modified materials and coatings (high-strength and ultra-high-strength steel materials in combination with soft steel materials, aluminium alloys, mixed construction)
- Quality assurance and non-destructive testing
- Welding process control and online testing
- Occupational safety (EMC/EMF/EMVU)
- Evaluation of the use of simulation methods and product optimisation



An overview of current or already completed research projects can be found under: www.dvs-forschung.de

How application-oriented research works

Research balance – transfer of results and implementation in the project

Non-destructive evaluation of the lens diameter during Resistance Spot Welding with magnetic test methods

(IGF-No. 17.539 B / DVS-No. 4.058)

Duration: 1st December 2012 - 30th November 2014

Prof. Dr.-Ing. habil Uwe Füßel, Professor of Joining Technology and Assembly, Institute of Surface and Manufacturing Technology, TU Dresden

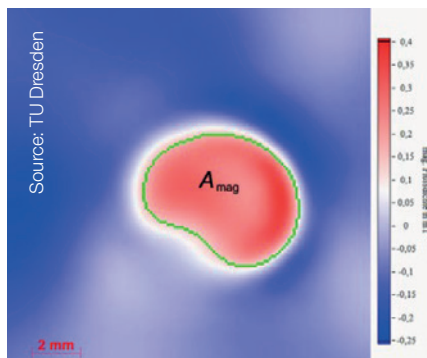
Within the framework of the research project, a new method for the non-destructive evaluation of Resistance Spot Welding was investigated. In this method, the joint is magnetized by magnetic coils and the magnetic field imposed (remanence) is then measured over a surface area. The magnetization can be applied during welding or later. Good results were achieved by magnetizing the joint after welding.

To validate the measurement results, the surface of the destroyed welding point A_{sp} is compared with the inner contour surface of the remanence measurement A_{mag} (Figure 1). A_{sp} is the result of the lens or point diameters measured according to ISO 14329. The samples were destructively tested by torsion. A_{mag} is determined from the measurement data of the surface remanence measurement by computer analysis. Figure 2 on

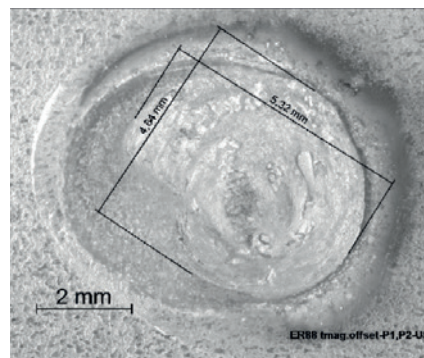
page 9 shows the results of the selected test series. It can be seen that good correlations between A_{sp} and A_{mag} are possible for material thickness combinations typically used in automotive engineering. This applies to both double and triple sheet joints. In the case of three sheet joints the respective cutting plane is measured on the surface. This enables both bonding surfaces to be evaluated separately.

Furthermore, as part of the project an attempt was made to automatically evaluate the lens diameter through the consistent and iterative use of numerical simulations and experimental tests. The results of the research project confirm the high potential promised by the new approach of non-destructive testing of Resistance Spot Welding joints using magnetic methods.

Remanence field of a welding point



Destructively tested weld spot



Comparison (true to scale)

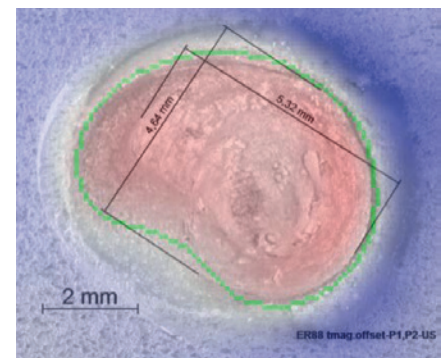
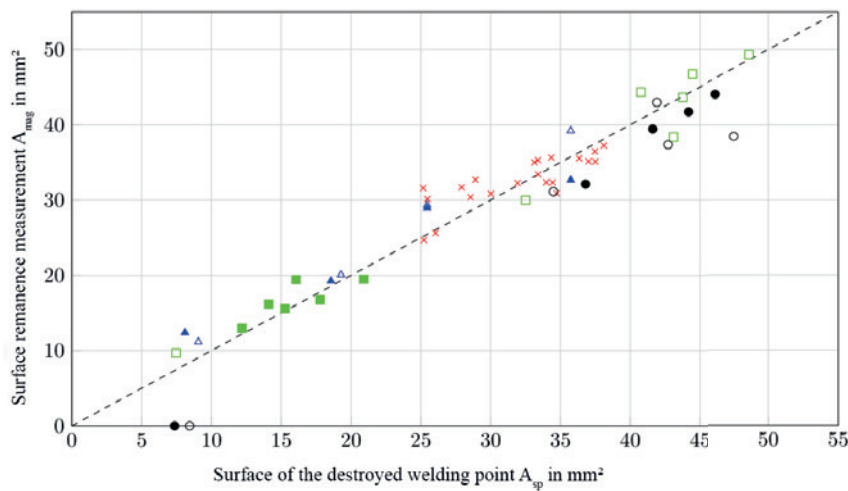


Figure 1: Comparison between non-destructive remanence measurement and destructively tested welding point.



- × $R^2 = 0,66$, DC04+ZE (0,65 mm) + HX220yD+Z (0,65 mm), OS
 - ▲ $R^2 = 0,95$, DC04+ZE (0,65 mm) + HDT780C+Z (2,0 mm), OS
 - △ $R^2 = 0,99$, DC04+ZE (0,65 mm) + HDT780C+Z (2,0 mm), US
 - $R^2 = 0,64$, DC04+ZE (0,65 mm) + 22MnB5+AS (2,0 mm) 22MnB5+AS (1,5 mm), OS
 - $R^2 = 0,96$, DC04+ZE (0,65 mm) + 22MnB5+AS (2,0 mm) 22MnB5+AS (1,5 mm), US
 - $R^2 = 0,99$, 22MnB5+AS (0,65 mm) + 22MnB5+AS (0,65 mm), OS
 - $R^2 = 0,94$, 22MnB5+AS (0,65 mm) + 22MnB5+AS (2,0 mm), US
 - $R^2 = 1$, perfectly linear relationship
- R: Correlation coefficient, OS: Top, US: Bottom

Source: TU Dresden

Figure 2: A comparison of the surface area of the destructively tested welding point A_{sp} and the associated contour surface of the remanence measurement A_{mag}

Outlook to the follow-up application DVS 4.070 “Destruction-free characterisation of the bonding surface during Resistance-Pressure Welding by imaging analysis of the remanence flux density”

This research project is based on the results of the completed research project “Destruction-free evaluation of the lens diameter in Resistance Spot Welding using magnetic test methods”. The aim of the next application is to develop an objective test method with less effort and shorter test times, the meaning and

application area of which are greater than that of the established ultrasound methods. This applies in particular to extreme and multi-section material thickness combinations as well as to projection welds.

Company opinions

Sabine Ritsche, voestalpine Stahl GmbH:

“The research project provides an interesting approach to the non-destructive determination of the lens diameter. The work so far has shown that this method is, in principle, applicable. Further practical research in this field should take account of practical applicability”.

Volker Arndt, Bosch Rexroth:

“Within the framework of the research project ‘Destruction-free evaluation of the lens diameter in the case of Resistance Spot Welding using magnetic test methods’, a new approach was

pursued, which provides information about the welding point similar to the established ultrasound test and that can also be automated. The results of the research project show the first successful steps towards the objectives mentioned above. The test statements must also be verified on other material combinations which are difficult to weld, also under the influence of disturbances, and the process limits shown. The implementation in a practical application of the procedure is absolutely necessary for a broad acceptance of the new test method in the industrial environment”.

Technology in the DVS



The Technical Committee (AfT)

Considering the currently more than 250 established joining processes, the technical-scientific collaboration work in the DVS can and must be systematic. This is guaranteed by the Technical Committee, which has more than 200 work councils. The AfT brings together more than 2,300 experts from business, academia, organisations and corporations who work together to capture and continually advance the state of the art. The fact that the DVS with this bundled expertise is also acknowledged on the international stage as a confident and competent partner in all assembly engineering issues is clear.

DVS is a major contributor to the international joining technology network through its involvement in the International Institute of

Welding (IIW) and the EWF – European Federation for Welding, Joining and Cutting. The work results originating from the AfT are published as DVS technical bulletins and guidelines.

At the national level, the AfT works very closely with the Normenausschuss Schweißen und verwandte Verfahren (NAS) des DIN e. V., in particular in the numerous community committees. The constructive cooperation with NAS enables optimum coordination of the DVS technical code with the normative requirements. The DVS technical code provides valuable application notes for practical application.

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DVS members benefit from free access to the DVS technical code under www.dvs-regelwerk.de. All the DVS technical bulletins and guidelines are available electronically.

Flash-butt welding.



Source: GSI-SLV Duisburg

Structure of the Technical Committee (Aft)



AG: Working Group, * Joint Working Group with NAS (Standardisation Committee Welding and Allied Processes of DIN e. V.), ** Joint Working Group with other Societies, ***SEMFIRA = Safety in ElectroMagnetic Fields, EMF = ElectroMagnetic Fields.

Working Group V 3 “Resistance Welding”

In total, approximately 300 experienced specialists in this Working Group (AG) V 3 are collaborating on DVS technical bulletins and guidelines as well as international standards on Resistance Welding. The DVS Working Group forms a joint committee with the DIN-Normenausschuss Schweißen und verwandte Verfahren (NAS) to develop standards.

The Working Group V 3 “Resistance Welding” of the DVS Technical Committee is divided into seven main subject areas, dealing with the wide variety of questions relating to resistance welding technology.

- AG V 3.1 “Flash Butt Welding, Butt-Welding and Pressure Welding with magnetically moving arc (MBP)”
- AG V 3.2 “Resistance Spot, Projection and Seam Welding”

- AG V 3.3 “Resistance Welding in electrical engineering and precision engineering”
- AG V 3.5 “Resistance Welding with capacitor discharge”
- AG V 3.6 “Measuring and process control”
- AG V 3.8 “Production equipment for Resistance Welding”
- AG V 3.9 “Testing of Resistance Welding”
- AG V 3.10 “Training in Resistance Welding”

The DVS technical bulletins and guidelines are summarised in the handbook of DVS technical bulletins and guidelines “Resistance Welding Technology”.

Events

AG V 3/FA 4 Community colloquium

The Expert Committee (FA) 4 “Resistance Welding” conducts an annual colloquium in cooperation with Working Group (AG) V 3 “Resistance Welding”.

The focus of the colloquium is the discussion and evaluation of completed research projects as well as the reporting on ongoing projects.

The extensive activities of the technical and scientific community work of the individual topics of Resistance Welding are also reported, in particular the DVS guidelines and technical bulletin work.

DVS special conference “Resistance Welding”

Working Group V 3 “Resistance Welding” organises the DVS special conference “Resistance Welding” every three years. Duisburg has established itself as the venue. The wide range of topics is aimed at those interested in research, development, planning, production or quality assurance relating to Resistance Welding.

The aim of this conference is to present to a broad specialist audience, in lectures and discussions, the latest research results in the field of Resistance Welding, which were developed with the support of the DVS and with public funds.

In addition, the accompanying “Specialist Exhibition on Resistance Welding” offers the opportunity to exchange experiences. Manufacturers of machines, devices and equipment have the opportunity to present their latest developments.

The next conference will take place in 2019.



Exchange of expertise at the conference “Resistance Welding 2016”.

DVS technical codes for practice

Technical bulletin DVS 2916-5 “Testing of resistance welding joints – Non-destructive testing of spot welded joints”

The technical bulletin DVS 2916-5 describes the non-destructive testing of resistance spot welding joints. The technical bulletin content refers exclusively to the non-destructive test methods for resistance spot welded joints of steels of up to 3 mm single sheet thickness. The technical bulletin describes the methods of visual inspection, magnetic powder testing, colour penetrant testing and transmission inspection.

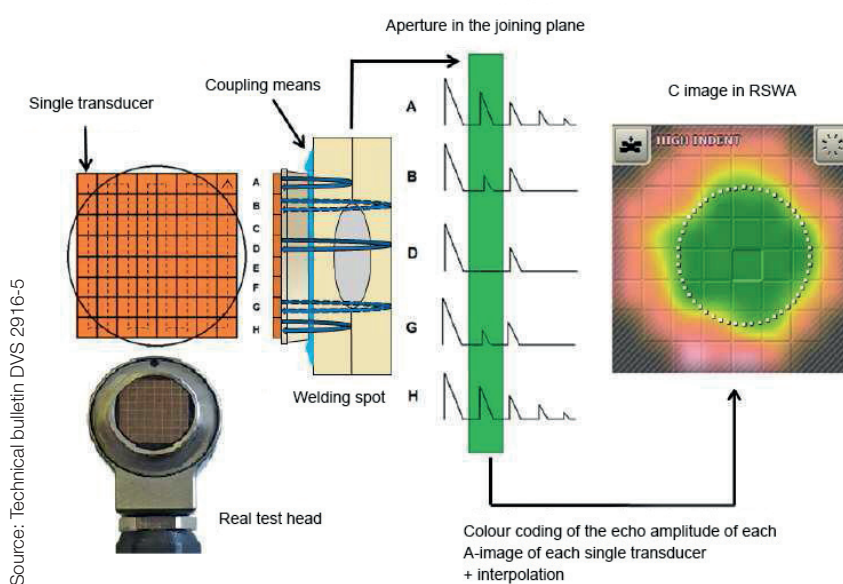
The visual inspection relates to the checking of the visible quality characteristics of a spot weld. With regard to the component the position of the spot weld, for example the distance from the edge of a flange, the distance between the spot welds, and the completeness of the number of spots is checked.

The rarely used magnetic powder test is used to detect defects or impurities close to the surface (for example cracks) in ferromagnetic materials. The method is based on the escape of magnetic stray flux into air on the surface of the pre-magnetized test piece if a defect is present. Iron or iron oxide powder, applied to the test piece, collects at the site of the defect or impurity. Only cracks perpendicular to the magnetic lines of force can be detected.

The colour penetrant test can only show irregularities which have a direct opening to the surface. In this case the penetrant, a liquid with a low surface tension, is drawn into the irregularities through capillary action, thereafter any excess is removed from the surface and the penetrant remains in the irregularity. A developer applied to the surface and draws the penetrant out of the irregularity. Any irregularity is shown by the colour contrast (red/white) or by illuminating the surface with an UV lamp if fluorescent penetrant dye is used.

Conventional radiographic testing is a non-destructive test method. With this method, pores, spatter, voids and cracks can be detected that lie parallel to the direction of irradiation. Bonding defects and cracks that lie in a plane perpendicular to the direction of irradiation cannot be detected since they do not effect the intensity attenuation of the radiation.

Another point of focus of the technical bulletin is the ultrasonic inspection of spot welded joints. In addition to general information and definitions for ultrasonic testing, there are references to the various systems, for example manual ultrasonic examination using the pulse echo technique – single transducer technique, manual imaging ultrasound, array testing techniques and mechanised imaging ultrasound testing.



Exemplary function principle according to the pulse-echo-method – multichannel technique.

Education in the DVS



The Education Committee (AfB)

The Education Committee initiates measures to adapt the training and certification offered by DVS to current developments and to prepare them for future requirements. The committee is supported by the Working Group "Training and Examination" (AG SP), which is responsible for training and certification, to create uniform training and testing materials within the framework of the qualification of technical specialists and managers. In doing so national and also current European and international requirements are implemented in the training and examination standards. The scope of responsibility of the AG SP is the development of the teaching and learning content of the technical training and further education as well as all other areas related

to the training and examination The DVS-PersZert, the personal certification body of DVS, ensures that these training and examination standards are ultimately adhered to and implemented nationwide.

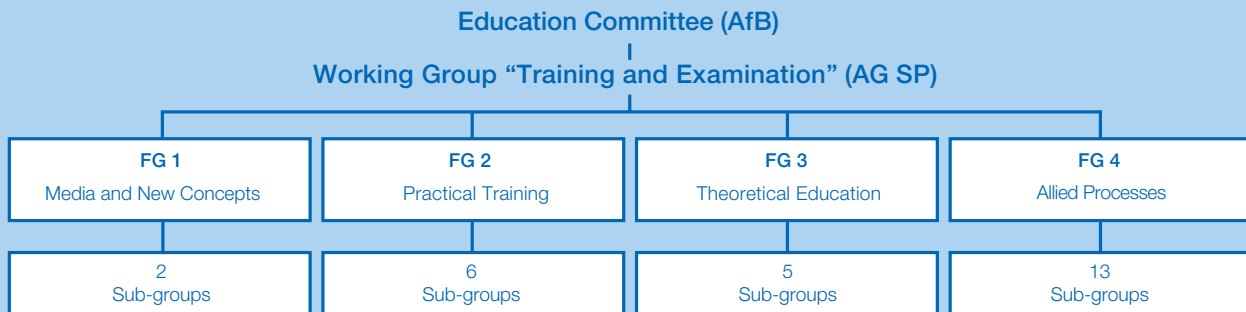
The Expert Group 4.8 "Resistance Welding" is responsible for the content of the training and further education courses on Resistance Welding. The experts (predominantly from the industry) are concerned with the development of DVS guidelines for the qualification and testing of personnel in the field of Resistance Welding.

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The current training and further education on offer from the DVS can be found under: www.dvs-bildungskatalog.de



Structure of the Education Committee (AfB)



FG: Expert Group

Training and career paths in the field of Resistance Welding

With the set of DVS training and examination guidelines, a self-contained system has been created that is widely acknowledged both nationally and internationally.

Guideline DVS-EWF 2940 “European Welding Practitioner for Resistance Welding (EWP-RW) – Training, Testing and Qualification”

This guideline for theoretical and practical training as a European Welding Practitioner for Resistance Welding was developed by members of the Technical Committee of the EWF.

It is designed in such a way that it conveys the essential basic knowledge in Resistance Welding that must be mastered by welding technicians who perform activities according to DIN EN ISO 14554-1 (section 6.3).

It is suitable for imparting basic knowledge such as that required by operators, inspectors, monitoring personnel, foremen, designers and technical sales staff.

The EWP-RW is also capable of supporting the welding supervision according to DIN EN ISO 14554-1 (section 6.4) in manufacturing operations.

It is possible that additional welding skills and/or experience will be required by the welding technicians for the performance of certain activities, which go beyond the teaching content of EWP-RW training. To meet these requirements additional training programs will be developed as required.

This guideline takes into account the minimum requirements for training in Resistance Welding from a European perspective by specifying objectives, content and the recommended teaching units assigned to them for each topic.

It is subject to a regular revision by the Technical Committee of the EWF – European Federation for Welding, Joining and Cutting to comply with the current “state of the art”.

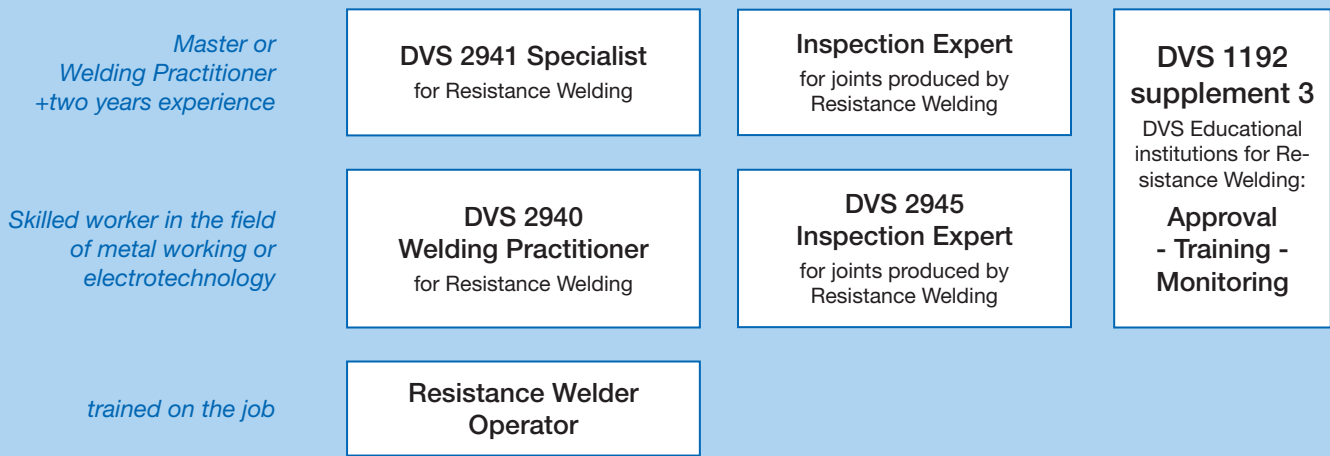
Guideline DVS-EWF 2941 “European Welding Specialist in Resistance Welding (EWSR) – Training, Testing and Qualification”

This guideline for the theoretical and practical training of European welding specialists for Resistance Welding was developed, evaluated and formulated by members of the Technical Committee of the EWF.

The directive describes a basic training in Resistance Welding, as required for welding personnel according to DIN EN ISO 14554-1 (section 6.4), monitoring, testing, documentation, technical sales, etc. In addition to this basic training, it may be necessary for the welding personnel to gain the qualification for the relevant tasks by means of further training and/or experience. Additional training programs will be developed to meet the requirements.

This guideline includes the minimum requirements for education and training in Resistance Welding, as agreed within the EWF, in the form of objectives, keywords and recommended time periods. They are subject to a periodical revision by the Technical Committee of the EWF to meet any changes relating to the “state of the art”.

Training and career paths in the field of Resistance Welding



Participants who have successfully participated in this course are expected to be able to use the welding technologies required by this guideline

Guideline DVS 2945 “Inspection expert for thin sheet joints”

This DVS course trains people as qualified specialists for the testing of joints in sheet metal structures.

The “Inspection expert for connections by Resistance Welding”, hereinafter referred to as the “Inspection expert”, is the expert worker in manufacturing for testing using “workshop testing procedures” and for ultrasonic testing. They are given the knowledge and skills required to carry out tests on joints in sheet metal structures.

The final examination is designed to provide proof of the knowledge and skills acquired during the course.

This guideline applies to the testing of joints in sheet metal structures produced by the joining procedures covered by this guideline (Resistance Spot Welding, Projection and Roll Seam Welding, Stud, Shielded Arc Welding and Laser Welding, Mechanical Joining and Bonding). It specifies the course contents and the examination of the knowledge and skills of the inspecting expert.

The training and testing provided for in this guideline should also be used as verification of the qualified personnel used as required by different regulations. This guideline is part of a structured overall training concept in the field of Resistance Welding.

Specialised media and teaching materials for “Resistance Welding”



The DVS Media GmbH

The DVS Media GmbH is the right starting point for comprehensive publications and media regarding joining, cutting and coating. The publishing program includes German and foreign-language trade journals, technical books, teaching media, DVS technical bulletins and guidelines, videos and software. The products from the DVS Media GmbH represent all the fields of activity of the DVS Association and all the results that they develop.

Numerous items of the DVS Media GmbH specialist media are devoted to the working results in the areas of research, technology and education around Resistance Welding: These include specialist books and periodicals, as well as training materials and individual or collections of DVS technical bulletins and guidelines.



Sources for the DVS technical codes

DVS members have free access to all DVS technical bulletins and guidelines under www.dvs-regelwerk.de. Interested persons who are not members of the DVS can refer to the DVS technical codes under www.dvs-media.info.

Your contacts for specialised media and teaching materials

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Publications regarding “Resistance Welding”

DVS-Fachbücher, Band 68/3:

USB-Stick: Taschenbuch DVS-Merkblätter und -Richtlinien „Widerstandsschweißtechnik“



The new, now sixth edition of Handbook 68/3 fully illustrates the DVS technical codes including all new developments. A large part of the technical bulletins became fundamentally overhauled, the others revised, especially with regard to the new international standards. The DVS 2911 “Capacitor Discharge Welding – Fundamentals, Processes and Technology” or DVS 2902-3 “Resistance Spot Welding of Steels up to 3 mm single-sheet thickness-design and calculation” have been newly created.

6th edition 2016

751 pages on a USB stick

ISBN: 978-3-945023-67-9



DVS-Berichte, Band 326:

Widerstandsschweißen Sondernatung in Duisburg

The “Resistance Welding” symposium is considered the source of knowledge of the latest state of the art. All the presentations from the 2016 conference are available as DVS reports, Volume 326 “Resistance Welding”. The publication focuses on practical contributions from welding procedures, process variants, materials, manufacturing, electromagnetic fields, testing, quality assurance, practical applications and regulations.

1st edition June 2016

272 pages, 487 images and illustrations, 19 tables

ISBN: 978-3-945023-75-4



DIN-DVS-Taschenbücher:

Schweißtechnik 9: Widerstandsschweißen (DIN-DVS-Taschenbuch 312)

With this DIN-DVS paperback, welding personnel, quality engineers and instructors are given a comprehensive collection of the most important Resistance Welding standards for their speciality field.

This standard collection is indispensable for anyone working in the field of Resistance Welding. The current reference book provides some 40 DIN (EN) (ISO) standards for the following areas:

- Terms, procedures and materials
- Quality assurance and personnel
- Testing of welded joints

4th edition 2017

864 pages, DIN A5, paperback

ISBN: 978-3-96144-002-3

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Working Group V 3 “Resistance Welding”

www.dvs-aft.de/AFT/V/V3

Chairman

Dipl.-Ing. Ralf Bothfeld,

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Vice-Chairman

Dr.-Ing. Christian Fritzsche,

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Education Committee

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Expert Group 4.8 “Resistance Welding”

Chairman

Dipl.-Ing. Stefan Schreiber, GSI – Gesellschaft für Schweißtechnik International mbH, Niederlassung SLV Duisburg

Vice-Chairman

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Research Association on Welding and Allied Processes e. V. of DVS

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