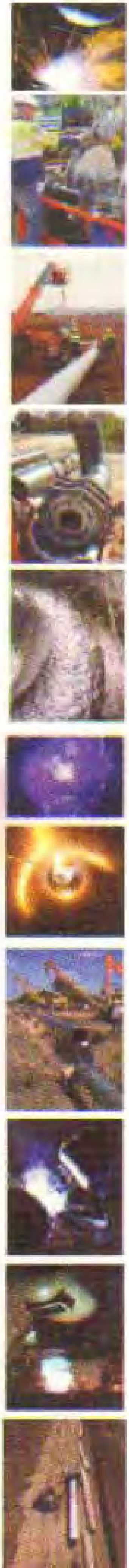

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The 2nd South East European IIW International Congress

PROCEEDINGS

PIPELINE WELDING CURRENT TOPIC OF THE REGION

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Welding – HIGH-TECH Technology in 21st century

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PROCEEDINGS

ISBN 978-954-9322-25-5

CONTENTS

KEY TECHNOLOGIES WELDING AND JOINING

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Abstract: *Welding of advanced and modern materials and joining of material combinations make new demands on the welding and joining technologies.*
During the last ten years new processes and process variations have been developed, particularly in the fields of arc and beam welding, with the aim to increase the economic efficiency, to reduce the energy input and to assure the quality of the welded joints.
The so-called "cold joining technologies", as, e.g. mechanical joining and adhesive bonding, have increasingly gained in importance.
The lecture presents an outline of those recent advancements of the welding and joining technologies, and specifies their technical and economical potentials

Keywords: *Key Technologies, Arc Welding, Electron Beam Welding, Non Vac EB-Welding, Laser Beam Welding, Laser-MIG-Hybrid Welding, Spot Welding, Mechanical Joining, Adhesive Bonding, Commercial Relevance of Joining Techniques*

1. INTRODUCTION

There are not many things in our natural environment which have a monolithic structure. Most things of our environment are, for that matter, composed of many individual parts and these parts must be joined to one piece - be it immovable or movable – in order to fulfil their function as a structural part.

These recognized key technologies and their relatedness to joining techniques shall be considered.

Fig. 1: Key technology "Traffic and Transport"

The first key technology is "Traffic and Transport", Figure 1:

A car is composed of many single parts which are kept together by thousands of welding spots and many metres of weld seams and, nowadays, more and more by hundreds of meters of adhesive bonds. Vehicles which are used for rail traffic like, for example, an ICE high speed train wagon, are, of course, welded. The ICE wagon has a length of more than 2[illegible] metres and is composed of more than twenty individual extrude[illegible] profiles which are welded together with the suitable joinin[illegible] technologies. Interestingly, the window openings are cut out wit[illegible] the laser only after the wagon has been welded completely. In ai[illegible] traffic the mainly used technique is riveting; for the new airbu[illegible] 380, however, a large part of outer hull elements has bee[illegible] welded, for the first time with the laser. A cruise ship consists o[illegible] more than 300.000 single parts, and 900 km of welding seam[illegible] must be welded for assembling the ship. Welded pipes in an[illegible] form are able to transport great quantities of goods, gaseous[illegible] liquid and solid. Nowadays, but also when looking ahead, the ke[illegible] technology "traffic and transport" is, in conclusion, no[illegible] imaginable without the application of welding.

The second key technology is "Power- and Civil Engineering"

A power plant produces energy. For the generation of profitabl[illegible] and that means highly efficient energy the so-called stea[illegible] parameters are important: a highest possible pressure with, at th[illegible] same time, high steam temperatures. The boilers, pipes an[illegible] turbines must be capable to tolerate those high pressures an[illegible] temperatures. This is only possible through the selection o[illegible] suitable materials and joining techniques. In the field of chemica[illegible] apparatus engineering, corrosion susceptibility creates extremel[illegible] challenging tasks. Aggressive media, like acids and bases, mainl[illegible] in processes with extremely high pressures and extremely low o[illegible] high temperatures, are dealt with only through the application o[illegible] special materials which again make extremely high demands o[illegible] the joining technique. It also applies to the field of civi[illegible] engineering that steel structures are of course, not accomplishe[illegible] without welding, as the picture of the Öresund bridge shows. Bu[illegible] even if the used steel is not visible, think of concrete high-ris[illegible] flats, massive steel structures inside the high-rise flats ar[illegible] responsible for the strength and safety of those buildings, and i[illegible] goes without saying that the steel has been welded. Withou[illegible] welding, power- and civil engineering would also be impossibl[illegible] to realise .

espect to the voltage is defined. An experimental method for alculating the partial derivatives of the Taylor expansion is resented. Using the obtained model, the bead widths can be alculated for a specified variation in voltage. Finally two practical xperiments are done in order to testify the precision of the method.

According to the results of the experiments, relative error does ot exceed 7% in each angle which is a proof of the appropriate recision of this method. As the result of the process is significantly ffected by angle, the other common methods can not be used in the whole span of 0 to 180 degrees. As a result the presented method round the central working point offers a suitable model of the ystem behavior. Mathematical base of the model provides the apability of the generalization of the method for the other outputs.

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MODEL OF WELDING TECHNOLOGY FOR RECONSTRUCTION OF HEATING STATION SYSTEM

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Abstract: : *In this paper is shown model of welding technology and reduced form which may serve as example for production of welding technology for heating station system at reconstruction of town system for heat supply. The main aim is on preparation of joints which will be welded, and conditions for welding and control of welding and welded joints, as well as achieving prerequisite to gain demanded quality. This way of defining welding technology is several times verified in practice.*

Keywords: RECONSTRUCTION, HEATING STATION SYSTEM, WELDING, CONTROL, EXAMINATION, TECHNOLOGY

1. Introduction

The basic document of the documented quality achieved during construction or reconstruction of welded constructions is a Project of Welding Technology. Project of Welding Technology consists of analysis of the base metals, welding procedure selection, filler metal selection, welding parameter's selection and control. Project and constructive demands of construction, given in technological and constructive documentation, reflecting on the shapes and dimensions of welds have to be mandatory fulfilled during welding processes. Otherwise, it is necessary to ask for the change and departure of the project. Paper gives an example/model Project of Welding Technology for reconstruction of the water heat distribution system.

Project described in this paper is about reconstruction of the magisterial city hotwater pipeline. Reconstruction considers removing the old pipeline and montage of the new one (Figure 1a and 1b).

Figure 1a: Details from the building cite

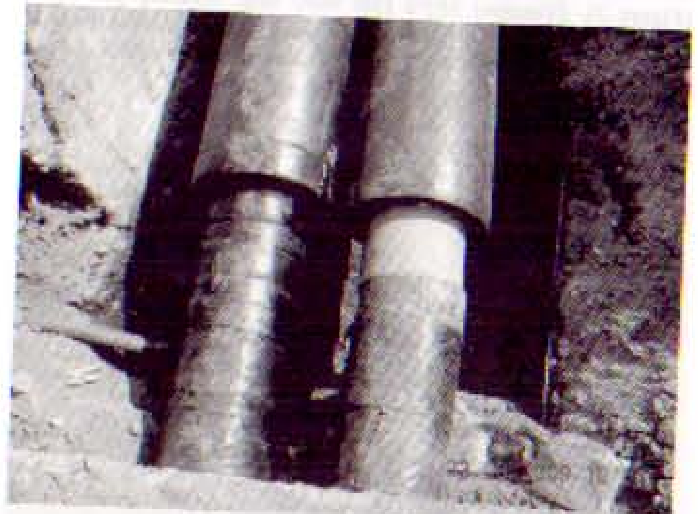

Figure 1b: Details from the building cite

2. Base material

According to the project and constructive documentation, for object called Central Magisterial Hotwater Pipeline (CMHP), is assumed to use materials capable to withstand high temperatures, materials with significant anti-ageing properties and low alloyed constructive steel. Base material, mostly used for pre-isolated pipes, is P235GH. Comparative descriptions of this steel, adequate qualities according to the different standards, chemical constitution and mechanical properties with technological properties and usage are:

P 235 GH (EN 10028/2) - **Č 1202** (SRPS C.B4.014) - **HI** (DIN 17155, WNr 1.0345) -**12 K** (GOST 5520)

2.1. Properties of the base material

Base material for pre-isolated pipes is steel P235GH which is the material capable to withstand high temperatures, non ageing, applicable for steam boilers, high pressure reservoirs and armatures. This material is applicable for large pipes and other steel structures. Properties of this material are given in Tables 1 and 2.

Table 1: *Chemical constitution - material P235GH*

Nº	Material	C (%)	Mn (%)	Si (%)	P_{max} (%)	S_{max} (%)	Mo (%)	Cr (%)	Al_{min} (%)
1	Č 1202	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]

Notation: Values for C, Mn, Si are given as mean values

Table 2: *Mechanical properties of P235GH*

Nº	Material	Ultimate strength R_m (N/mm²)	Yield strength R_{eH} (N/mm²)	Elongation A5 (%)	Ductility A [illegible]
1	Č 1202	360-480	[illegible]	[illegible]	[illegible]

Notation: Yield strength, ultimate strength and elongation are determined normal to the rolling direction and ductility is determined for 0°C.

Weldability: Steel P235GH can be welded with every common welding procedure. Preheating is not necessary.

2.2. Preparation of base material for welding

Preparation of base material for welding consists in weld joint preparation. Shape and dimensions of the joint, just like type of its preparation depend on several factors: material thickness, type of weld, quality of the weld, position of welding, welding technique, welding type etc.

2.3 Selection of the welding groove type

Type of the welding groove depends on properties of the base material, dimensions, welding process, exploitation conditions etc (Figure 2). (Standard SRPS ISO 9692 title: Welding and allied processes – Recommendations for joint preparation – Part 1. Manual metal-arc welding, gas-shielded metal-arc welding, gas welding, TIG welding and beam welding of steels.

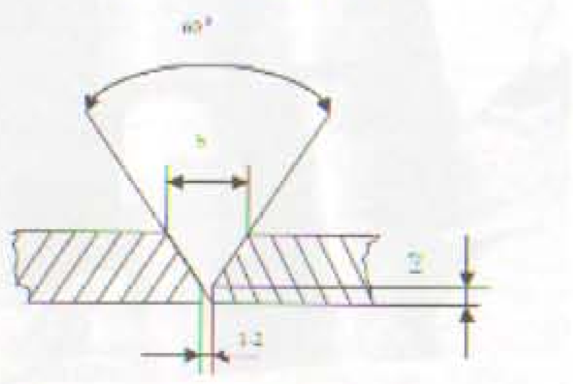

Figure 2: Preparation of the V butt joint

Welds on drawings and in Welding Procedure Specification (WPS) are in accordance with ISO 2553.

2.4. Base metal cutting and preparation for welding

Surface and groove preparation is important factor and operation that significantly involves in quality of the welds. Bad surface and groove preparation, in general, gives bad quality of the joint. Considering technological possibilities of the welding joints manufacturer, there is proposed technology, adequate for surface and groove preparation.

For development of the CMHP several different types of pipes are used. Pipes are different diametrically, and there are sub assemblies made of pipes and plates and profiles – for carrying structure of heat water pipeline. Blacksmith anticorrosive layer of "shop primer" has to be compatible with anticorrosive protection put on the structure. During preparation of pipes, pre montage and welding it is important to take care about the protection layers and isolation. Protection with "shop primer" is made after cutting and welding on positions and assemblies.

Welding profiles, pipes and other materials are cut with oxy-acetylene process, on plasma machine etc. Cutting surfaces have to be machined, especially grinded. Surfaces have to be clean, metal shined, with no oils, grease, corrosion or any other impurities. Surface cleaning can be chemical or mechanical (grinding, steal mops etc.).

Following the demands from the technology, if not specified differently, all butt joints on the structure, including technological welds on steel sheets, are welded to confine quality "B" (old quality "S"), and all T-joints in quality "C" (old quality "I"). All demands from the standard SRPS C.T3.010. have to be fulfilled.

3. Welding process selection

Following demands from the standard, regulations and project documentation there are proposed welding techniques that will enable welding of this pipeline. Pipes Ø D80 mm are welded with oxy-acetylene process, and pipes Ø D > 80 mm are welded with metal arc welding (MMA) process.

With the demand of achieving weld quality, welding speed, economic welding a welds that have adequate mechanical properties, based on assumed quality of base metals, it is approved to use:

- metal arc welding (MMA) process
- oxy-acetylene process.

Considering technological capabilities of the welding manufacturers, working conditions, weldability of applied materials, previously mentioned processes are approved. It is approved to use oxy-acetylene for heating with the goal of deformation removal.

4. Welding consumables

Welding consumables consider: coated electrode, wire feed electrode for MAG welding, wire feed electrode for FCAW welding, shielding gases, shielding powders, etc.

4.1 Selection of welding consumables

Depending on quality of the applied base metals, selected welding processes and recommendations of the manufacturer, welding consumables are chosen.

4.2 Properties of welding consumables

Coated electrode for MMA

CELEX is coated cellulose electrode it recommended for pipeline welding, reservoir and various object that suffer pressure of fluid. It is applicable in all welding positions. Its properties are given in tables 3, 4, 5 and 6.

Table 3: Coated electrode for MMA welding

Name	SRPS C.H3.011	ISO 2560	EN 499	DIN 1913	AWS A 5.1
CELEX		E 43 5 C 19	E 35 2 C 21	E 43 53 C 4	[illegible]

Table 4: Chemical constitution

Name	C (%)	Si (%)	Mn (%)
CELEX	0,12	0,15	0,60

Tabela 5: Mechanical properties

Name	Ultimate strength R_m (N/mm²)	Yield strength R_e (N/mm²)	Elongation A5 (%)	Ductility Av min (J)
CELEX	450-550	›390	›22	›70

Table 6: Welding parameters. Current I (A) depends from the diameter of the torch Ø d (mm)

Ø d (mm)	2,0	2,5	3,25	4,0	5,0	6,0	8,0	Current polarity
CELEX	-	50-65	90-120	110-140	140-200	-	-	[illegible]

4.3. Shielding gases. Gasses used for cutting, preheating or distortion removing

Gas welding process, preparation of joints, preheating or distortion removing process release heat which is the product of violent burning of acetylene/oxygen or propane /butane mixture. Mixture acetylene/oxygen generates temperatures at about 3150 °C. Propane /butane mixture gives approximately 2400 °C.

4.4 Preparation of welding consumables

Welding consumables used for cutting and welding (coated electrodes, wire feed electrode, shielding gases etc.) have to be stored in original packages in dry and ventilated warehouse. Gases should be kept in original and faultless tanks or gas stations with faultless installation.

Coated basic electrode have to be dries before consumption at temperature of t=200-250°C, 2 to 3 hrs in electrical dryers (furnace or moveable electrode dryer). Furnace capacity should be adequate to fulfill daily consumption of welding consumables. It is suitable that every welder has its own small, moveable dryer for keeping constant temperature and dryness of the torches.

5. Welding machines

For MMA welding it is suitable to use electrical transformer, inductors i invertors, which consist from current source with commands for parameters regulation, cables for electricity distribution and welding clamps. All electrical welding equipment must have approvals and attests from certified control body about properties and usability. Safety always comes first.

In order to achieve homogeneity and symmetry of welding parts, nice visual look, constant weld, to ease welder's job, to achieve wanted shape and dimension it is necessary to use special tools and mechanization that is demanded in project documentation.

6. Welding personnel selection

For welding jobs, consumed and planned with the welding project, welding manufacturer must have sufficient and trained welding personnel which will guarantee quality of welds in correspondence to the project, constructive and technological documentation.

Every welder must have his personal welding stamp. Welder is obligated to mark his welds with his personal stamp at 35 to 50 mm from joint. All welders have to be fully informed about the welding technology.

Welding manufacturer must have welding specialists or welding engineers.

Welding manufacturer must provide a team that will investigate and control manufactured welds. Another scenario is to hire other company that is capable and certified to do such a job.

7. Working conditions

Welding has to be done in safe conditions but has to fulfill demands of the project. Welding can be done only in the area which is protected from the atmospheric showers, wind, low temperatures etc. Welding processes are best to be done in the most adequate welding position.

7.1. Atmospheric conditions

Welding on a open space can be done without any special precautions if temperature is higher than 0°C, if there is no wind or rain. For protection from rain and wind it is necessary to use canopies, paravans, tents etc. Temperatures between 0 and -5 °C require preheating of the base material and constant, slow cooling after welding. With temperatures below -5 °C it is necessary to stop welding.

7.2 Welding work place

On the welding work place, every welder must have: adequate, safe and functional power supply, functional welding machine, differently from process to process, adequate equipment, tool, accessories, controllers, clamps, safety equipment, personal safety equipment, necessary constructive and technological documentation etc.

8.0 Welding sequence

Welding sequence assumes: supervisions and finishing welding parts, pre welding ("heft"), welding according to the technological lists with special attentions on welding plan, welding sequence, welding parameters and pre measures for errors avoiding, electrical arc starting, after welding cooling etc.

Before welding, welder and controller or welding coordinator must complete all parts (positions, assemblies) for weld and to control quality of the preparation of the base material for welding.

During montage of the pipes in pipeline and preparation for welding it is important to pay attention to put pipes horizontally and coaxial to avoid weld shearing between the pipes (Figure 3).

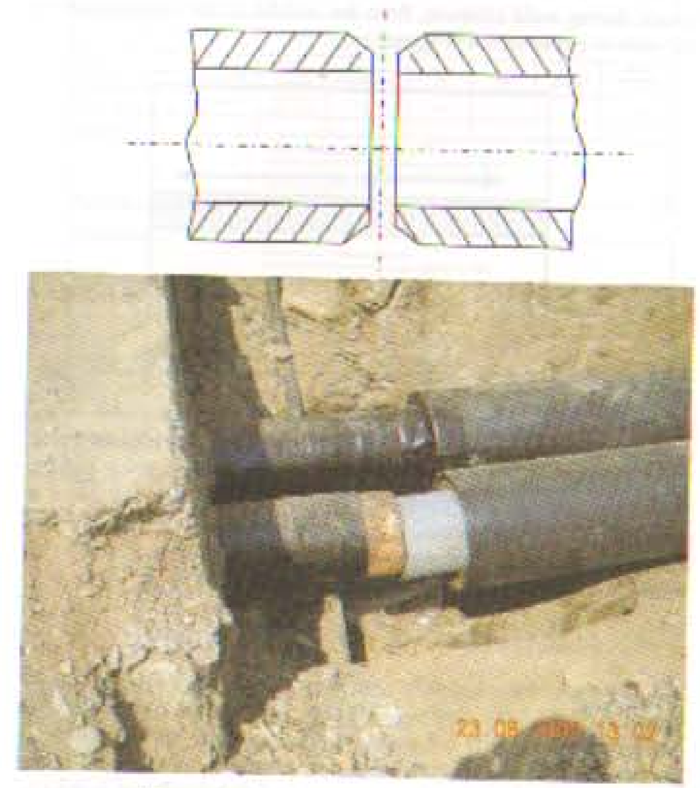

Figure 3: It is important to make pipes coaxial

8.1. Pre welding ("heft")

It is important to pre weld two parts before the welding. That is important part of the welding process because parts that are about to be welded have to stay positioned one to another during welding. "Heft" makes that possible. Pre welding is done according to the project documentation. Position for pre welding has to be the most adequate and easiest to manipulate with. Pre welds have to be minimally 5 mm high and minimally 50 mm long. Pre welds have to be on equal distance one to another. Welding consumables for the pre welding have to be the same quality as consumables for the welding. Pre welding are made only by welders with attest since root "heft" is very important for the weld. If not, pre welds have to be removed completely. Otherwise, only start and end parts of the pre welds are being removed.

8.2. Welding technique

Welding technology describes montage welding on the worksite. Technological lists give technological parameters for the most suitable welding positions for welds. Welding plans are given for every single weld, for every type of weld. Since most of the welds are butt welds, in order to decrease number of deformations and imperfections, it is important to make symmetrical welds, from the middle of the profile, pipes to the middle of the perpendicular side on plate (if there is a plate), without stops or continues at the ends of the corners (Figure 4). Welds have to be created simultaneously from the middle to the ends of the construction.

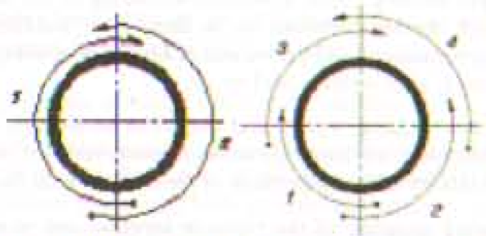

Figure 4: Welding sequence during circular welding

In order to decrease deformations it is used principle of more passes during weld creation, from the middle of the construction to the ends of construction (Figure 5).

Figure 5: Line welding, welding sequence from the middle to ends of the construction

Every pass requires slack cleaning and all impurities removal. Root weld is machined from the back side and slack on the top surface of the weld is being removed with the hammer. Face is cleaned with the steel brush. It is not permitted to start arc out of the weld on base metal or other details that make assembly. During root welding it is important to reduce shaking of the arc to the minimum.

8.3. Starting the electric arc

Start and end of electric arc during welding requires special attention, especially during welding with coated electrode with basic coating. Electric arc during welding with coated electrode is started in front of the crater of the previous weld. After start, electrode is slowly guided to the crater and slowly after is moved to the direction of the weld. Stop of the electric arc cannot be fast and, especially, cannot be stopped with picking up the electrode from the weld. Electrode has to be guided all the time, laid low and slowly moved back to the weld, on softened material and there electrode can be taken up and arc is stopped. Length of the arc cannot be larger than the diameter of the electrode. Electric arc is always started and stopped on the weld.

8.4. Recommendations for welding parameters

Welds creations is done according to the technological parameters given in the WPS for characteristic welds in the pipeline. MMA process requires from welders to strictly obey and use parameters given in WPS or given by the manufacturer of the electrodes.

8.5. Cooling of the welds

After finish of the welding it is necessary to make possible easy cooling on a steady air (without wind). The goal is to avoid fast cooling what might result in creation of rigid and stiff large scaled structures in base metal or heat affected zone (HAZ). It is possible that cracks might appear.

8.6. Reparation of joints

All welds that after controlling appear to have imperfections (non correct welds, post damaged, have cracks etc.) have to be repaired. Activity plan is:

- Part of the weld with a defect has to be removal.
- Welding on that area has to be done by the same procedure given in WPS.
- Weld has to be homogenous and symmetrical.
- All impurities and slack have to be removed with the hammer and surfaces have to be brushed with the steel brush.
- Inspection of the weld has to be done as control documents have proposed.

If following inspection of the weld makes no suggestion and concludes that there are no imperfections of the weld or there are satisfactory imperfections, reparation was successful.

9. Quality control

In order to get quality demanded by project it is important to have systematic quality control on welds. This control includes:

- Pre welding control
- Welding control
- Post welding control

Quality control methods have to, single or in combination, to enable detailed overview on quality of the weld.

9.1. Pre welding control

Pre welding control has task to control welding equipment, base metal, working conditions, consumption materials, preparation of base metal (shape, dimensions, surface conditions), pre welding (joints, montages, "hefts"), certificates for welders (attest control).

9.2. Welding control

Welding control consists of: process control, welding parameters, start/stop of the electric arc, root layer control, following welding control, impurities removal, preheating control, slow cooling control, working place control. This control has to be 100% done.

9.3. Post welding control

Post welding control includes: visual inspection of welds, non destructive testing, destructive testing, control of weld marking (welder's stamps).

9.4. Visual inspection

Visual inspection of welds includes existence of welds inspection, and following: weld dimensions imperfections, cracks in weld or base metal, segregations, cuts in the area of HAZ etc. This control has to be 100% done for every welded structure.

9.5. Non destructive testing

For this Project it is decided that non destructive testing has to be conducted. It is decided to do: magnetic flux testing, ultrasound and radiographic testing. All demands for testing are given in the technological documentation. After conducted testing, it is necessary to create adequate reports that completely describe conditions of welds. If NDT finds some imperfections of welds, that has to be noted in the report. Reparation has to be done and testing is repeated.

9.6. Destructive testing

On a demand of supervisor it is possible to do destructive testing on samples taken from the pipeline. Mechanical, destructive testing can confirm following properties of the weld:

- bending angle cannot be smaller than 180°
- yield strength of weld has to be the same or greater than yield strength of base metal.

Certified institution or organization capable to conduct these testing has to make a report and send it to the manufacture/investor of the object. The results from testing have to be included into the elaborate about the Project realization.

9.7. Control of the weld's marking

Every welder, after finished welding, has to clean the weld from the slack and impurities and to mark the weld with his personal welding stamp. Stamp has to be put near the weld, at the distance of 30-50 mm from the center of the joint line.

9.8. Central Magisterial Hotwater Pipeline weld's control

For welds on the Central Magisterial Hotwater Pipeline and its control, it is planned to do following:

All welds have to be measured, controlled and tested. All welds have to be 100% visually tested for shape and dimensions. All welds have to be homogenous, weld burns, with qualitative starts and ends of arc and without surface imperfections. Allowed distortions are given by the demands of project and $h_{r\ max}$ = 1,6 -2,6 mm, and maximal width of the weld face can be max 2 mm from face h max = 2+b+2 mm (Figure 6).

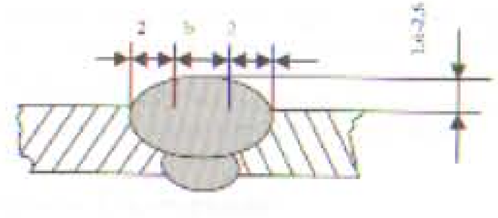

Figure 6: Allowed distortion of butt weld's dimensions

If it is possible, it is suitable, but not mandatory, to investigate surface imperfections. This can be done with penetration fluid or magnetic flux.

All welds have to be tested 100% with x rays (radiography).

All welds have to be tested for linkage. Volume of testing is 100%. Investigations have to be conducted in accordence to the project documentation. Test are conducted with water, pressure 13 to 16,9 bar, during 8 hrs. During this time period, pressure has to remain the same.

All welds, joints have to be marked with two numbers. First one is the number of section, second number is number od the joint, weld in that section.

10. Welding diary

Welding diary has to be present in every company, for every object that is being welded. Diary is written in 3 copies always. Two copies go to the investor and one copy stays in the company. Diary is kept by the welder's coordinator, manager of the welding blacksmith or specially appointed person.

11. Changes in welding technology

Changes in the proposed welding technology can be done only on demand of investor with written statement of welding technologist. Otherwise, no one can guarantee the quality of welded structure.

12. Welding technology lists

For every type and dimension of the weld joint, there is technological list welding procedure specification (WPS). All important parameters for welding are given there. Plans of welding, schemes of welding, directions of welding are given in documentation as well. An example of such a list is given in Figure 7.

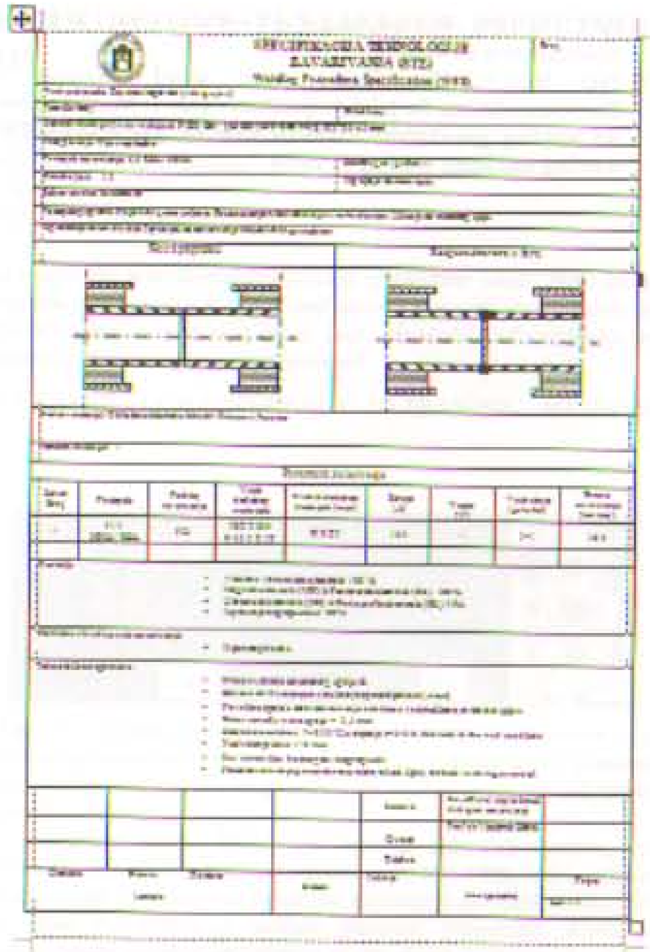

Figure 7: WPS – Welding Procedure Specification (on example)

13. Appendix

Appendix gives a;; documents that are main parts of the Project. These documents are: attests of welders, certificates of material and equipment, WPS, reports, conclusions etc.

14. Conclusions

Project of Welding Technology is basic document on which plans, control and qualify construct or reconstruct welded structure in this case hot water pipeline. It is important that Project is done clearly, qualitative and by experts in welding. This paper is an attempt to describe the process and to ease experts in area of welding to make their project basing on the experience of this Project.Introduction

15. References

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ALTERNATIVE SOLUTIONS FOR NONDETRUCTUVE TESTING OF PIPELINE WELDS

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Abstract: The paper presents new and non-traditional methods and means for non-destructive testing of pipeline welds. Data on the employment of ultrared thermography, digital radiography, a low-frequency ultrasonic method and electro-acoustic transducers are provided. Their advantages as compared to the traditional methods of weld testing, considering speed, cost, adaptivity and sensitivity, are analyzed. Some new testing techniques developed by the Ukrainian Academy of Sciences are also presented.

Keywords: INFRARED THERMOGRAPHY, DIGITAL RADIOGRAPHY, LOW-FREQUENCY ULTRASONIC METHODS, ELECTRO-MAGNETIC ACOUSTIC TRANSDUCERS

1. Introduction

The intensive development of digital, computer-aided and semiconductor technique essentially contributes to the development of means and technologies for nondestructive testing (NDT). Part of the solutions outlined below are implemented in the nondestructive testing of pipelines during their assembly and exploitation [1].

2. Infrared Thermography

The basic advantages of the method are its capability of remote operation, high sensitivity (parts of °C) and capability of overlapping the visible image and the thermographic one. Fig. 1 shows a thermogram [2] of the American Space Shuttle where a discontinuity has been recorded. Note that it has not been registered by any of the NASA traditional techniques employed for that purpose.

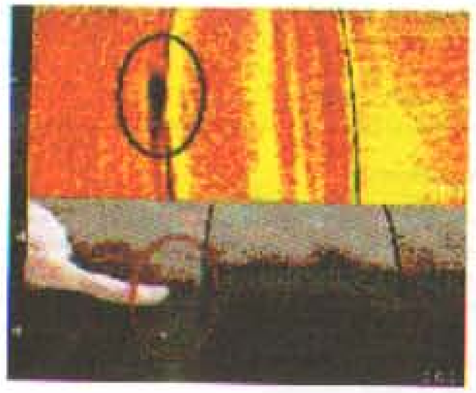


Fig. 1. Discontinuity in the Space Shuttle skin registered via thermography and missed by the traditional methods of control

Modern systems of control enable one to locate sub-surface discontinuities in composite materials, metals and ceramics. The infrared thermography (IRT) is used to control coatings (their density, adhesion, thickness), corrosion effects, thickness and mechanical damage of pipelines and tanks. It is a highly sensible method to assess quality. As expected, the preparation of the necessary documents for IRT registration will be soon completed.

Fig. 2 shows three images of a cell panel containing inclusions, fabricated from aluminium, graphite and epoxy resin. As seen, (a), (b) and (c) denote registration performed by thermography, radiography and ultrasonic tomography. Note that the thermographic registration is the most informative one. IRT is used to control the state of overground and underground pipelines.

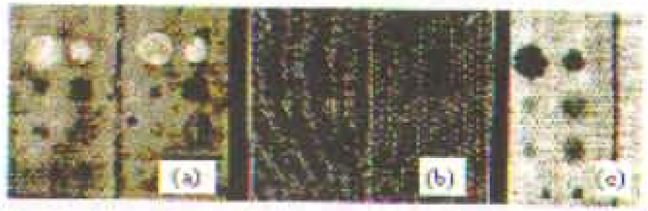


Fig. 2 Comparison of the results for the registration of inhomogeneous inclusions in a 5-layered graphite epoxy laminate for cell panels: (a) thermography, (b) radiography, (c) ultrasonic tomography

Impulse lamps, lasers and heating inductive systems can provide appropriate heating regimes. On the other hand, surface cooling can be monitored using the techniques outlined above. This is done by assessing surface physical properties, depth of discontinuity location and change of the object thickness. A scheme of the method of active thermography is shown in Fig.3, where 2 denotes the ITR camera and 3-a laser heating object 1.

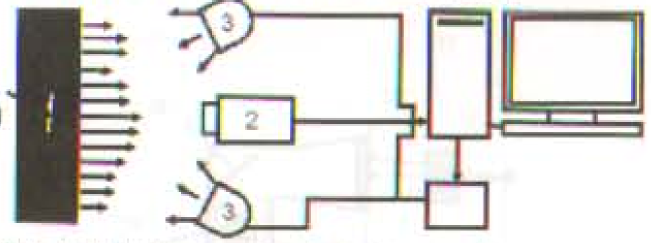
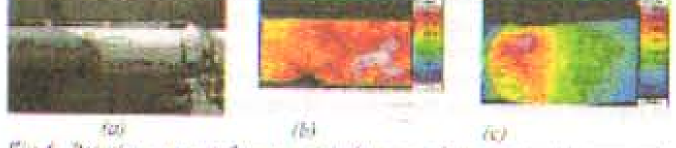


Fig. 3. A scheme of the operation of active thermography

Note also a new trend in measurement techniques known as vibro-infrared thermography (VIRT) which enables one to locate subsurface cracks. The samples under control are treated by ultrasonic waves with frequency of 15-30 kHz and power of 0.5-3 kW, yielding heating due to friction between crack banks. The increased temperature is registered via thermovision, and it is an indication of the existence of a crack.

An example for the application of remote infrared thermography in the control of a rotating cement furnace is shown in Fig. 4 [3]. Fig.4.a shows a furnace after repair while Fig.4.b and Fig.4.c – furnace areas with damaged insulation and weld defects.



(a) (b) (c)

Fig.4. Rotating cement furnace: (a) furnace after repair, (b) area with damaged insulation, (c) area with weld defects

Defects are due to poor exploitation, local exceed of temperature and poor repair.

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