SELECTION OF WELDING TECHNOLOGIES IN CONSTRUCTION OF LARGE-DIAMETER MAIN PIPELINES

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The advantages and disadvantages of different technologies of pipes joining applied in construction of main pipelines are considered. It was noted that the method of flash-butt welding has advantages as compared to the arc, beam and hybrid methods of welding. 1 Table, 8 Figures.

Keywords: *welded pipelines, electric arc processes, beam welding methods, flash-butt welding, economic efficiency*

The industrialized countries which are in need of a large volume of natural gas are actively planning and constructing the main pipelines from gas-extracting centers to the sites of consumption. Especially it concerns such countries as Brazil, Algeria, Australia, Russia, countries of Caspian region and Middle East.

Welding is the most responsible technological operation in construction of pipelines and rate of construction depends on the efficiency of welding works fulfillment, therefore the development of welding technologies is the decisive factor, determining the quality and efficiency of construction and assembly works.

The welding processes and technologies can be divided into the following groups: electric arc, beam and press, including flash-butt welding and friction welding. The application of these technologies should provide high-quality welded joints of a new generation of pipelines of steel of higher strength category, such as X65, X70, X80 at the diameters of up to 56 inches.

Electric arc processes. Since the 1960s the manual electric arc welding (MAW) using electrodes of cellulose type for root weld and basic electrodes for filling layers. This technology is also used at present for steels of conventional class of strength. It requires high skills of welders-operators at keeping the temperature conditions of welding to remove hydrogen from the welded joint. The MAW technology will be also further used on the small areas of pipelines under the restricted conditions and repair-welding works.

The MIG/MAG welding process for producing of weld root with a controllable electrode metal transfer according to the STT method with the following filling of a groove at the conventional process is presented in Figure 1. At present this method is widely used, moreover the filling after producing of a root layer, except of using MIG/MAG process, can be performed also by electrodes with a basic type of coating. The peculiarity of this process is achievement of the very high quality of a multilayer weld, if welding was completely performed from the external side of a pipe.

To produce a weld using only MIG/MAG process (Figure 2) a number of companies carried out the research works and designed equipment

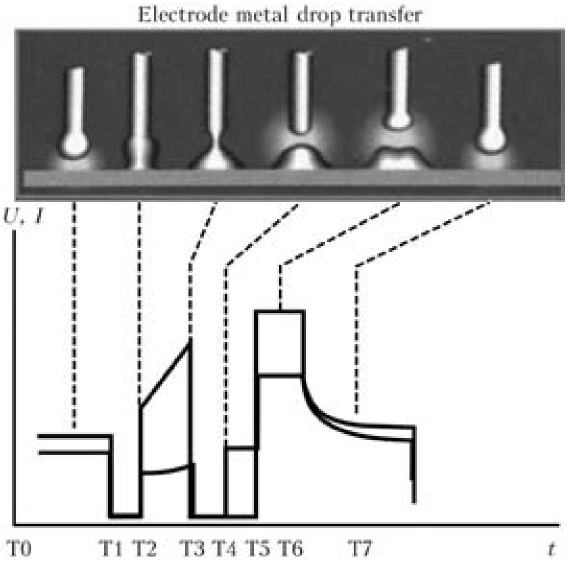

Figure 1. Scheme of MIG/MAG process (STT method)

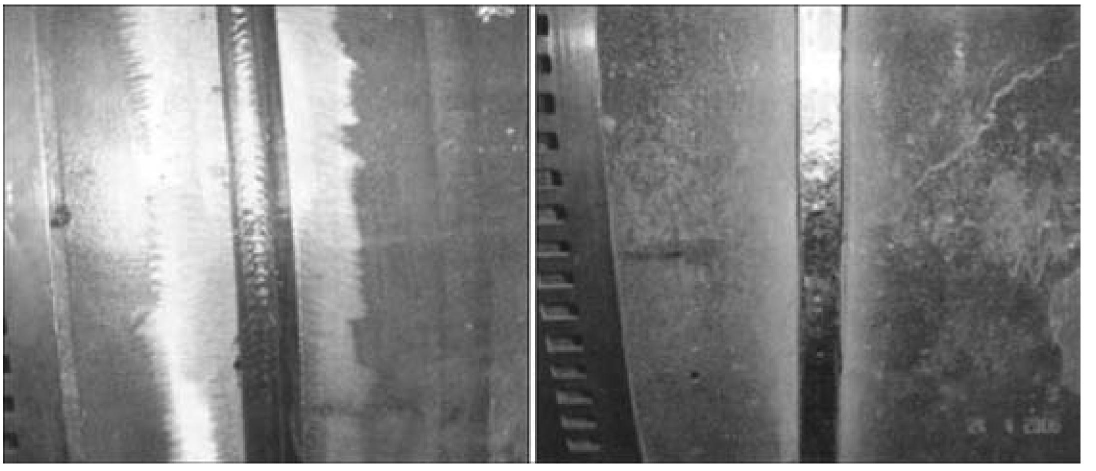

Figure 2. Appearance of welded joint produced using MIG/MAG process

for automatic orbital welding («Proteus» machines).

There are modifications, when orbital equipment is operating with two torches (Figure 3), which reduces the time of weld filling. Especially interesting is the modification of tandem MIG/MAG process representing new possibilities for the growth of efficiency. In this case one welding torch with two contact nozzles provides feeding of two wires into one common welding pool. At the present time its application under the construction and assembly conditions is restricted, first of all, due to instability of the process and, secondly, because of need in welding operators of a high skill.

For MIG/MAG process the technology with use of a welding column (Figure 4) of CRC Evans company (USA, Huston) is the most updated one. According to this technology the welded joint is produced using welding heads, arranged inside and outside of welded joint of appropriate pipes.

Requirements to circumferential welded joints produced by MIG/MAG process are specified as to very accurate geometry of abutting the pipe ends and accurate control of welding parameters. As far as deposited layer has a 3 mm thickness on one welding station, then for the thick-walled pipes, for example of 24 mm, it is necessary to organize eight welding stations to preserve the calculated cycle during performance of one welded butt. At the present moment this technology is widely used. However it requires the staff of more than 60 people attending the welding column for welding pipeline of 1420 mm diameter at the wall thickness of up to 24 mm.

Beam welding methods. Among the beam welding technologies, the most developed is the technology of hybrid laser welding. The machines developed in SLV Halle (Germany) show promising results under the laboratory conditions (Figure 5). However, to implement this technology it is still necessary to apply much efforts to modifying the equipment (Figure 6) and development of assembly and welding fixtures.

Press methods. At the regional congress of the International Institute of Welding, held in Sophia in October 20–24, 2010 all the welding

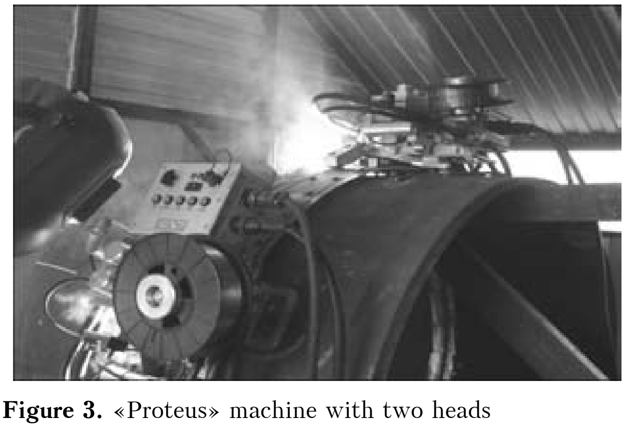

Figure 3. «Proteus» machine with two heads

Figure 4. CRC column on the route

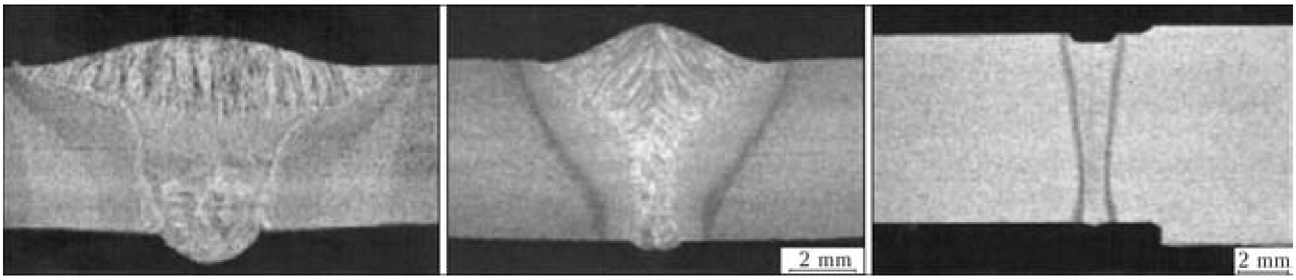

Figure 5. Macrosection of pipe steel joints produced using different power sources: *a* — MIG/MAG; *b* — MIG/MAG + laser; *c* — laser

technologies applied in construction of main pipelines were discussed.

The technology of flash-butt welding (FBW) was recognized as the most successful from the point of view of efficiency, small number of attending personnel and the lowest influence of subjective human factor. Resolution of the congress advised it as a priority implementation.

In practice the technology of FBW represents the process which provides the supply of voltage between the two ends of pipes which are aligned according to the certain program, as a result of which the flashing occurs. The power of passing current of a high value (hundreds of thousands amperes) heats the ends of pipes, after quick compression of which the permanent joint is provided.

This technology was developed at the E.O. Paton Electric Welding Institute under the supervision of B.E. Paton, S.I. Kuchuk-Yatsenko, V.K. Lebedev together with the organizations of the Ministry of Oil and Gas Industry of the USSR in the 1970s. Further, the welding machine «Sever 1» was designed on its base, with the use of which more than 1 mln. welded joints of pipes of 1420 mm diameter were produced and after 30 years of their service there was no a single case of emergency situation.

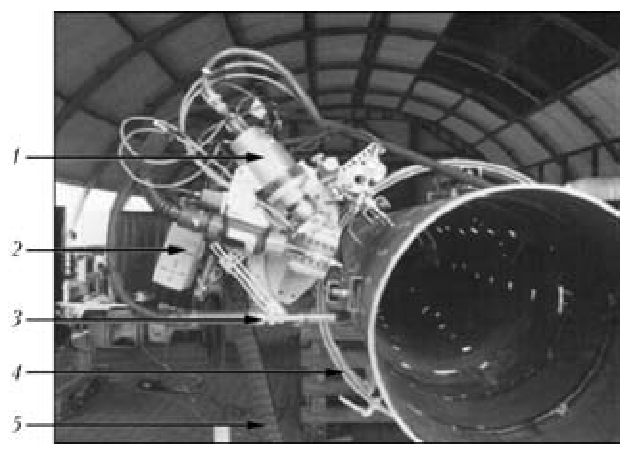

Figure 6. Welding complex for hybrid laser welding: *1* — head for hybrid welding; *2* — moving tractor with control sensor; *3* — torch in the position of groove filling; *4* — ring; *5* — hose

After 2009 the plant CJSC «Pskovelectrosvar» together with the E.O. Paton Electric Welding Institute carried out the modification of this equipment for application of this technology in welding of large-diameter pipelines. The KSS-004 complex was developed (Figure 7) which at the present time is planned to be widely used in many areas of invested pipeline system both in Russia as well as in other countries.

In accordance with the above-mentioned resolution of the IIW, some experimental welded joints of large-diameter pipes were produced, which later were tested in the laboratories of CJSC «Pskovelectrosvar» and also in the laboratories of the Institute of Materials Science of the Bulgarian Academy of Sciences. Using the computer system of control, the parameters of welding mode and modes of the following heat treatment and also parameters of removal of external and inner flash for the next automatic ultrasonic testing were precisely preset.

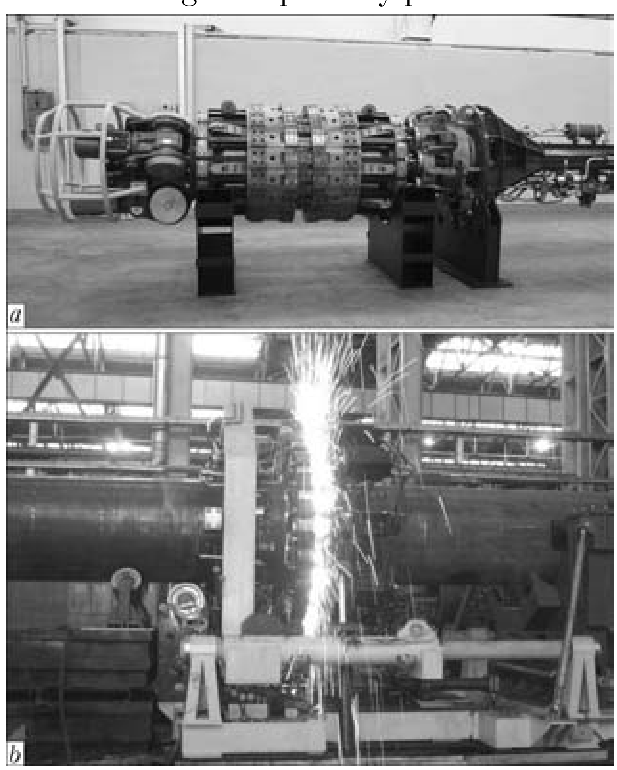

Figure 7. KSS-04 complex: *a* — appearance; *b* — in the process of operation

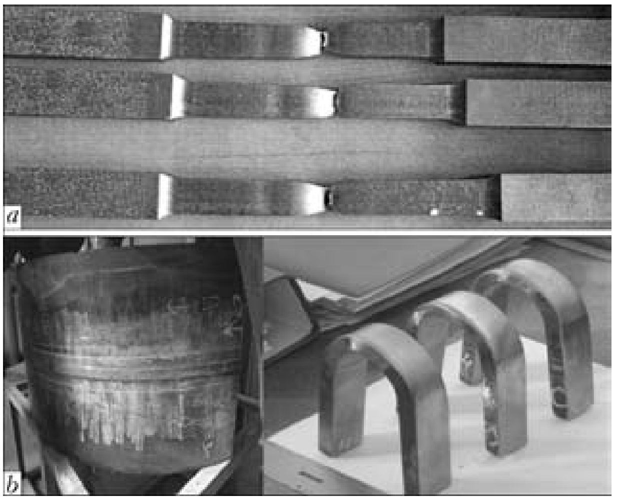

Figure 8. Appearance of specimens of pipe welded joints DN 1220×27 mm after tensile (*a*) and bending (*b*) tests

In the experiments, steel of strength category X65 of «Europipe» company (Germany) of the following chemical composition, wt.%: 0.071 of carbon, 0.237 of silicon, 1.51 of manganese, 0.005 of sulfur, 0.009 of phosphorus, 0.04 of chromium, 0.15 of nickel, 0.07 of molybdenum, 0.04 of vanadium, 0.037 of aluminium, 0.012 of titanium, 0.02 of niobium, 0.002 of boron, 0.03 of copper was used. Its mechanical properties in as-delivered state are the following: $\sigma_{0.2}$ = 490 MPa; σ_t = 553 MPa; δ = 26.5 %; KCV_{+20} = = 335.8 J/cm^2; KCV_{-40} = 334.9 J/cm^2. After tests of specimens the following strength characteristics were obtained, MPa: 538, 545, 541 and 540.

Appearance of specimens of welded joints of pipes DN 1220×27 mm after the tensile and bending tests is given in Figure 8.

Let us outline the advantages of FBW:

• Process is performed in one station;

• High rate of construction of pipelines due to a small period of welding of one butt in one station is provided, which amounts to 60–200 s depending on type and sizes of pipes, being welded, from 114 to 1420 mm diameter with up to 30 mm wall thickness. Great industrial experience of FSW in construction of different-purpose pipelines under on-land conditions was gained;

• All the process from beginning to the end is performed in automatic mode according to preset program which eliminates the subjective influence of welder on the quality of joints;

• Low level of residual stresses in welded joints is achieved, that considerably increases the corrosion resistance of such joint; mechanical properties meet the requirements of standards of industrialized countries (for example, the standard AP1-1104, USA);

• The quality of welded joints is efficiently evaluated by computerized processing of real values of welding mode parameters, created on the basis of real existing dependence «welding mode–joint quality», which is predetermined by physical peculiarities of FBW process; the validity of detection of possible defects is practically equal to 100 % including also the use of automated ultrasonic testing;

• The pipes of all the classes of strength are welded at any ambient temperature without preheating;

• Weather factors do not influence the quality of welded joints;

• The speed of pipeline construction is increased;

• Material expenses for pipeline construction are decreased.

Comparison of economic efficiency of implementation of flash-butt welding complex of KSS-04 type and welding column CRC Evans

Characteristic	CRC Evans	KSS-04
Pipeline extension, km	100	
Pipeline diameter, mm	1420	
Pipeline wall thickness, mm	≤25	
Cost of one complex, USD	5,750,000	3,930,000
Total number of butts on the whole pipeline considering the possible rejections, pcs	9,180	9,116
Number of project personnel, persons	68	16
Cost of welding of one butt, USD	874	579

The data given in Table have a significant evidence of advantages of application of KSS-04 complex as compared to the welding column CRC. The comparison of such factors as number of attending personnel, cost of one welded joint is especially demonstrative in favor for KSS-04 complex.

Basing on this fact, the companies, for example Bulgarian ones, which deal with realization of projects on construction of large-diameter pipelines, will be oriented to further application of KSS-04 complexes.

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