РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЯ НОВЫХ ПРОЦЕССОВ, МАТЕРИАЛОВ, ИЗДЕЛИЙ

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COMBINING OF FUSION WELDING REGIMES PARAMETERS FOR OPEN BUTT JOINTS

Analysis of well-known regimes parameters factors of annular joints root pass automatic welding for pipelines coupled with open joint is presented. Possibility of weld pool parameters control by heating checking under action of reverse polarity and weld pool "cooling" during direct polarity is shown. By the example of well-known investigations the possibility of successful results obtaining for root pass welding by automatic welding and without support using, by combining of reverse polarity pulse welding current with direct polarity direct current only, is substantiated. There is proposed that for assigned task solution there is expedient to compare some groups of well-known welding methods united by the character of root pass realization by automatic method, including supports using or by means of heat input distribution.
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Introduction

Automatic welding of open butt joints, including pipeline joints root run welding, is frequently caused by the necessity of elimination of perturbations owing to the gaps size changing and joints edges displacement (high-lows). In the manual regime these inaccuracies of assembling for welding are overcome by the welders by means of weld pool dimensions change (either by increasing or decreasing, where it is expedient). Under conditions of automatic welding use, for elimination of dimensional inaccuracies of joints assemblies the supports are used usually, which often and most likely, as a rule, are complex and high-value mechanical equipment. Besides, the fulfillment of additional assembling operations for welding preparation is necessary. Another possible approach exists, which based on elimination of dimensional inaccuracies itself. Such solution of joint gap size non-stability problem is connected with toughening of requirements regarding to assembling operations results. In this case either the use of high-value operations for finishing of joints assembled for welding is necessary (as a rule, mechanized manual operations, which are individual for each joint), or the utilization of high-precision and high-value processing plant of blank production is necessary owing to which the dimensional inaccuracies of assembling are minimized.

Problem Formulation

Thus, fulfillment of automatic welding of butt joints with gaps, which are characterized with essential dimensional inaccuracies in gaps, originated due to assembling operations, and without utilization of additional mechanical or technological facilities (for instance, supports), all this is an actual problem [1]. There is a matter of convention, that the most rational solution of the problem, connected with the joint gap dimensions non-stability, which is under consideration in the present article, is the selection of combinations of automatic welding conditions parameters, ensuring optimal distribution of welding arc heat and pressure in the weld pool. That is, a maximum quantity of welding arc heat and pressure in weld pool should account for the joint edges, and a lesser quantity of heat and pressure should distribute in the center of the joint. The above mentioned problem solution should stimulate the melting of edges metal and simultaneously should facilitate the "cooling" of the joint center, avoiding and removing the weld pool burn-through and outflow. For such solution realization, among other well-known approaches, at present time the torch transversal oscillations are often used, which periods are synchronized with periods of welding current (of reverse and direct polarities). Other parameters, affecting the problem solution, are the shielding gas medium composition, edges cutting parameters, and welding joint position, which is actual especially under the pipelines joints welding.

Well-known approaches for the problem solution

There is well-known, that the typical welded joint, for which the solution of the investigated problem is actual, has the root pass, filling passes and facing pass (see Fig. 1).

The root pass is the origin of welded joint formation. This pass may be as a self-dependent seam (without filling and facing passes), and may be as a base for all subsequent passes of the joint. The welded butt joint root pass realized should meet the following requirements: to have a full melting of main metal edges, to have a small external convexity, and to have a minimum thickness, which should be enough for sustaining of all other joint passes without joint burning-through. At that, the main complexity during the root pass welding is connected with the gap constantly presence between edges, which results in unfavorable conditions for weld pool liquid metal keeping and stimulate its outflow or burning-through. There is possible to eliminate this problem by means of edges preparation quality increase, by forming the minimum size gap. In many industrial situations this way is inexpedient, because, as a rule, the individual debugging of each joint is necessary, which is unacceptable under mass production or under pipeline mounting in fiend conditions. In case of pipelines, mounted in field conditions, the gap presence between edges (2...3 mm) is allowed, which is usually non-constant. Simulta-
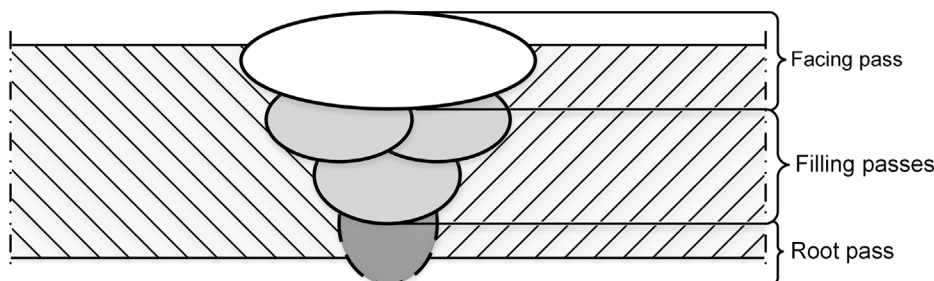

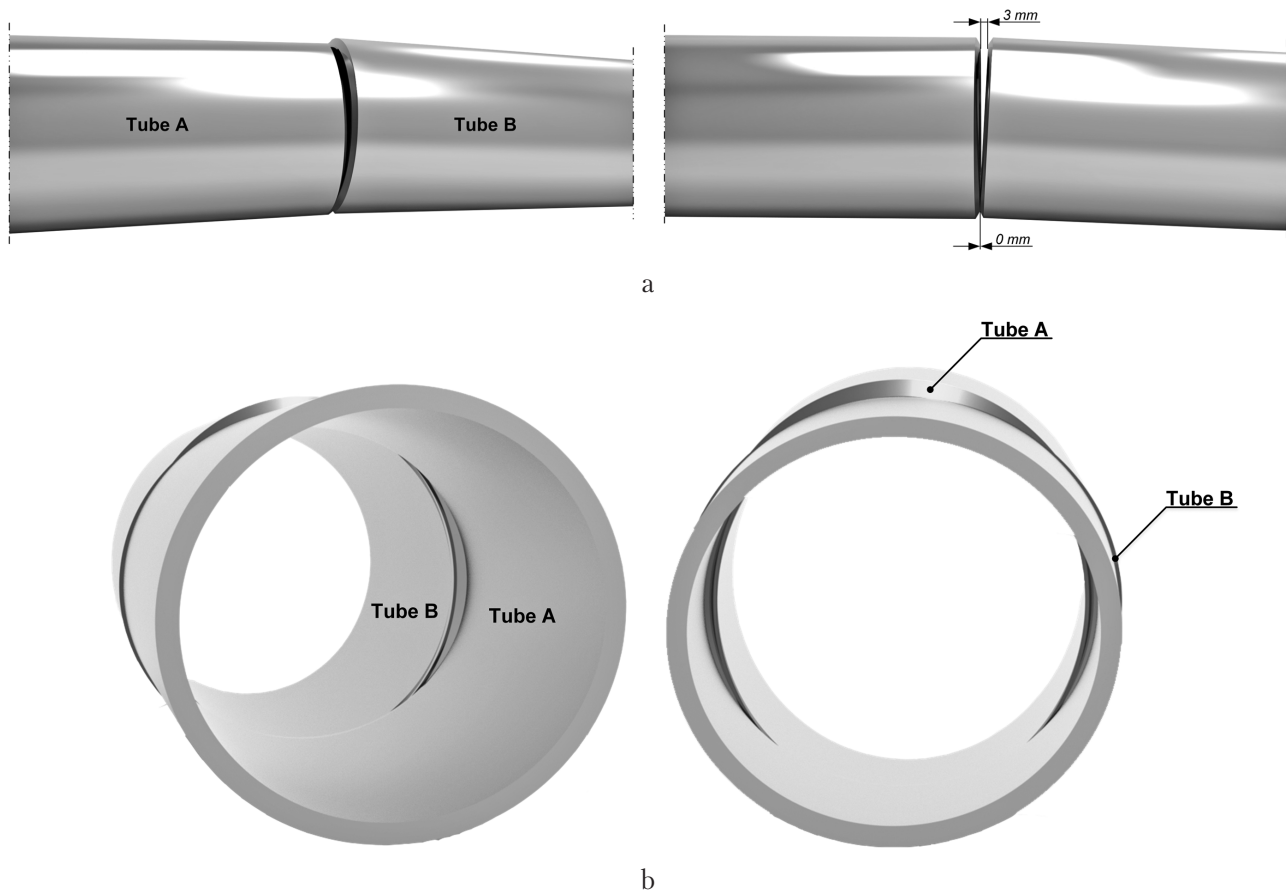**Fig. 1.** Schematic sketch of welded butt joint passes

a

b

Fig. 2. Schematic presentation of possible problems of dimensions non-stability during pipeline joints assembling:
a) variable gap; b) edges displacement

neously, other dimensional inaccuracy may be available (see Fig. 2) – edges relative displacement along the welded joint, which often results either in burning-through (at large displacement values), or in absence of edges alloying (at small values of its displacement). There is well-known, that the supports utilization (remained or strippable, removable) ensures full melting of butt joint, because it permits to use the increased level of heat input, but keeps the enlarged in dimensions weld pool away from outflow. During the trunk pipelines laying the tube internal clamps with removable supports for root seam are used. Nevertheless, not always the clamps may be used (usually, it may be used for straight part of pipelines with diameters more than 600 mm), besides, this is high-value high-technological equipment, which needs special adjustment and maintenance [2–5, 7–8, 13–14, 16–17, 20].

Thus, root seam welding fulfillment in trunk pipelines (not only for this cases, because the problem of pipelines joints welding is used in the present article as an example only) without supports utilization is more rational way, because it not demands complex high-value equipment and additional technological operations. Very often it is realized by means of manu-

al arc welding or by mechanized welding. In this case the absence of supports necessity during welding of joint seam with variable butt joint gap and edges mutual displacement is provided by professional experience of the skilled welder. On the other hand, there is well-known, that manual and mechanized welding has some limitations, including considerable metal splashing and harmful gases evolution, necessity to clean up the weld seam from slag in order to fulfill the subsequent passes, as well as productivity reduction of manual welding with stick electrodes in connection with necessity of electrodes frequent replacement. These and other factors make the manual welding process relatively slow and labor intensive. The productivity rather increases in case of mechanized manual welding utilization (MIG/MAG and flux cored wire), nevertheless, it always depends from the welder qualification and proficiency.

Unfortunately, transition to automatic welding means not only more complex and high-value equipment utilization, but requires also the permanent presence of welding operator. Thus, in most cases the automatic orbital welding is carried out with utilization of supports and internal clamps. In spite of the fact that the modern methods of automatic orbital welding

permit to fulfill the welding with assistance of systems of geometrical and technological adaptation, and remote control (changing the welding conditions parameters), these progressive welding technologies does not solve the main problem – the absence of possibility to control the weld pool parameters [6, 9–12, 15, 18–19].

There is well-known that MIG/MAG is such process, which gives considerable opportunities for weld pool control, first of all, for root seam welding and welding without supports utilization. For instance, MIG/MAG welding with alternating current is used with possibility to control the input heat quantity [19]. In this version of MIG/MAG process the modern shape of modulated alternating current wave (see Fig. 3) permits to match the advantages of both polarities, namely, considerable melting depth and stability of reverse polarity arc burning, with moderate heat input into main metal of reverse polarity welding arc. Metal transfer during alternating current welding is taken place at the moment of reverse polarity action, but drop size depends from duration of direct polarity action (drops are enlarge with direct polarity action time enlarge) [21]. As it well-known, this process was introduced by the KobeSteel, Japan (1980). The information is available [9] that during installation and fixation of one of polarities (stopping of poles interchange), particles outlet direction is change which result in asymmetry of weld pool temperatures values. There is well-known, that during action of the direct polarity, the wire electrode concentrates more heat and has increased melting rate, as well as less heat is transferred into the plate.

Elongation of welding arc length during direct polarity action is explained by the effect of thermal effectiveness increase due to "climbing out" of welding arc onto electrode (wire) tip for oxides searching in order to facilitate the cathode emission.

Thus, utilization of direct polarity interval during alternating current action promotes the electron flow passing to the plate and heat concentration onto electrode (wire) tip, which results in melting rate increase. Investigations of direct polarity duration effect on electrode tip elongation under melting process depending of welding current level [6] permits to clarify, that when electrode maximum elongation is reached, then melting rate become smaller and arc height become lower also and energy concentration take place on drops but not on electrode. Arc location on drops continues its heating, but stops the electrode melting. As a result, lesser quantity of heat is directed to the plate and welding pool become less hot, the wettability decreases, which results in lesser fusing and seam convexity increase. Usually the metal transfer is of macro-drop type, splashing level is high and welding arc stability is low, which is connected with welding current passing through zero point during alternating current welding fulfillment.

Pulse form of the current wave, as a constituent part of alternating current, is the technology with high ability to control the metal transfer (which taken place in free fall manner). Peculiarity of this technology is the presence of large current pulses and periods between them with small current (base current), which permits to control metal transfer; also to reach such metal transfer state, when at low value of average current one drop per pulse is generated. In order to ensure the metal steady transfer, the monitoring and control of welding current pulses are used (which ensure uniform heat input along the seam, reduce the
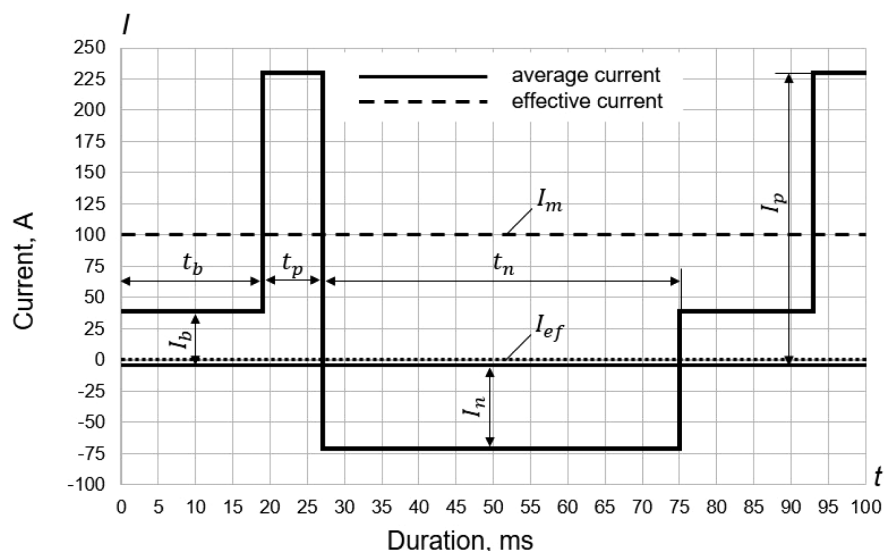

Fig. 3. Schematic sketch of electric current wave typical for MIG/MAG alternating current welding, were (I_p) and (t_p) are current and duration of reverse polarity pulse, (I_b) and (t_b) are current and duration of reverse polarity base, and (I_n) and (t_n) are current and duration of direct polarity; I_m – average current, I_{ef} – effective current

splashing and improve the seam outward appearance). Besides, this technology ensures relatively small volume of weld pool and, correspondingly, facilitates welding of thin plates or welding in various spatial positions with satisfactory seam outward appearance. On the other hand, drops falling during welding current pulses action results in the force creation acting on the weld pool and pushing it to collapse, which is negative factor during root pass welding with pulse current.

The main characteristics of pulse current welding is a deep penetration (which is determined by arc high pressure and increased heat input during each pulse), high stability of arc and metal transfer, low splashing of electrode metal.

There is known the methods for parameters stability increase during automatic welding with alternating current, based on utilization of special mixtures of shielding gas. For instance, $Ar + 5\% O_2$ ensures some improvements during the welding on direct polarity. With this mixture there is possible to reach the penetration improvement, decrease the splashing and improve outward appearance, as well as arc stability and metal transfer frequency are increased. There is noted [11], that oxygen addition to the argon is not significantly act on melting rate, but 1–5% of oxygen results in drop size decrease due to surface tension decrease in the area of drop-electrode surface contact, and melting rate during steel welding is increase. Also, there is known [21], that the mixture of argon and at least 5% O_2 or CO_2 is necessary factor for metal transfer stability increase during direct polarity.

Conclusions

1. By successful selection of regime and conditions parameters of automatic welding (direct polarity action duration and shielding gas mixture content), there is possible to control the weld pool parameters, namely, to check the heating under action of reverse polarity and to "cool" the weld pool during direct polarity action. Nevertheless, in order to copy the welder motions during root pass fulfillment there is necessary, that heating should be at joint edges and cooling should be above gap, that is at point of transition from one edge to another one. There is obvious, that such condition is complex for practical realization, because polarity change frequency is very high.

2. Taking into account all the above-mentioned factors, there is possible to reach successful results during root pass welding by automatic welding method even without support utilization, by combining pulse welding current of reverse polarity with direct polarity direct current, at that, in various combinations of current time action and current values, that is, using the principles of alternating current, but increasing action duration of each polarity (by frequency decrease) in order to increase heating/"cooling" effect and ensure

enough time in order to synchronize the polarity changes with welding electrode oscillations.

3. On the base of analysis conducted regarding the well-known root pass welding methods, first of all, comparison of various techniques for fulfillment of root seams with gap, there is expedient for further investigations to create some welding methods groups, united by the character of problem solution (fulfillment of root pass by automatic method), for instance, by the supports utilization or by heat input distribution.

Nomenclature

I – welding current, A
t – time, s

Subscripts

b – base of reverse polarity welding current
ef – effective current
m – average current
n – direct polarity of welding current
p – reverse polarity of welding current

Abbreviations

MAG – arc welding with metal (wire) consutrode in active shielding gas atmosphere with filler wire automatic delivery – Metal Active Gas Welding

MIG – arc welding with metal (wire) consutrode in inert shielding gas atmosphere with filler wire automatic delivery – Metal Inert Gas Welding

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КОМБИНИРОВАНИЕ ПАРАМЕТРОВ РЕЖИМОВ СВАРКИ ПЛАВЛЕНИЕМ ДЛЯ СТЫКОВЫХ СОЕДИНЕНИЙ С ЗАЗОРОМ

Представлен анализ известных факторов параметров режимов автоматической сварки корневого шва кольцевых стыков трубопроводов, собранных с зазором. Показана возможность управления параметрами сварочной ванны путем контроля нагрева под действием обратной полярности и «охлаждения» сварочной ванны во время прямой полярности. На примере известных исследований обоснована возможность достижения успешных результатов при сварке корневого прохода методом автоматической сварки и без использования подкладки, только комбинируя импульсный сварочный ток обратной полярности с постоянным током прямой полярности. Предложено, чтобы для решения поставленной задачи сравнивать несколько групп известных методов сварки, объединённых по характеру выполнения корневого прохода автоматическим методом, в том числе, с использованием подложек или с помощью распределения тепловложения. [dx.doi.org/10.29010/083.10]

Ключевые слова: сварное соединение; стыковое соединение с зазором; смещение кромок стыка; сварочная ванна; корень сварного шва.

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