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The Mechanism of Undercut Formation and High Speed Welding Technology

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1. Introduction

With the economic integration and technological globalization, intensified competition in the manufacturing sector. Welding technology as an important means of processing, has become such as vehicles, shipbuilding, container, steel and many other fields in the core competitiveness of enterprises to improve the most important factor, especially as one of the assembly process, usually arranged in the manufacturing process the late or final stage, which has a decisive role in the quality of products.

Improve the welding speed is the subject of research for many years, but in recent years, with welding automation, especially in promoting the use of welding robots, along with the increasingly fierce market competition, making the welding process efficiency is particularly prominent, has become a constraint welding a key factor in productivity, a welder can not play a major potentials obstacle. Thus, how to improve the welding speed once again become a hot research topic.

While there arc welding speed to improve stability of the process parameters of the problem, but still the ultimate prerequisite is to ensure there are no welding seam welding quality defects. Thus, the case study high-speed welding of weld defects is to increase the welding speed of the mechanism of the important aspects of the process.

Welding speed is a key parameter of high speed welding when joining thin sheets. Undercut is one of the most important problems which restrict welding speed.

So this will be generated during welding undercut mechanism and high-speed welding technology to give detail.

2. Mathematical model of weld pool

2.1 Welding pool mechanics research situation

2.1.1 The force affected on pool

As the pool under the effect of the arc, it makes stress state complicated. The pool suffers not only gravity, surface tension, buoyancy, but also the arc force. In the melting pole gas shielded welding, it will suffer the droplet impacting when transfer.

Studies have shown that, among all of the forces, when the welding current under 200A, the arc force will be little shown in the figure 1. In relevant analysis, its effect is little, which can be ignored. Therefore, the force in the pool is the gravity, surface tension, buoyancy arc force and so on.

Studies have shown that, when the current is 150 A, welding speed is 3.33cm/s, the pool flow rate is 0.01m/s magnitude which caused by the buoyancy, electromagnetic force and the both showed the reverse flowing. The role of buoyancy promote the liquid of pool center upward movement from the bottom and push the liquid of the surface to edge from the centre, which make the melting width increase.

Electromagnetic force forces the surface liquid flow to centre from the edge and then to the bottom, which will impact the bottom so that the penetration increases. The vortex strength caused by the electromagnetic force is not only related with the current size, but also with material properties, the arc moving speed. Under the same current, moving faster, the greater the thermal conductivity, and the effect of electromagnetic force is more small.

Under the action of surface tension, the liquid flow at the rate of 1.0 m/s magnitude, the flow direction is related with the temperature coefficient of surface tension. The combined results of the pool owing to the forces , when the welding current is less than 200A, the size and distribution of the surface tension play a decisive role to moving speed and direction of the liquid.

2.1.2 The law that surface tension roles in liquid flowing in the pool

When small current (Ia < 200A) welding, electromagnetic force and buoyancy are small, which can be ignored, liquid metal flow of the pool is main related with surface tension and gravity. The gravity's law is sample, so the relationship between surface tension and temperature is the main influence on the liquid metal flowing. If the surface tension σ reduce with the increase of temperature T, that is $\partial\sigma / \partial T$ <0,the distribution of surface tension

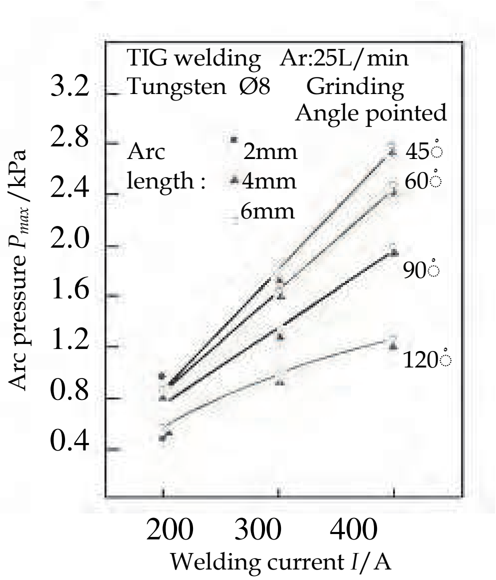


Fig. 1. Relation of pressure and current of arc.

on the pool surface is small near the center and large next to the edge, so the flow direction is from center to edge, that is the flow direction is from high temperature to low temperature. Shown in the figure 2 a 、b .At the same time, the flow of liquid metal will take the arc heat to pool edge from pool center which will form shallow and wide weld. If the surface tension increases with the temperature increased, that is $\partial\sigma / \partial T$ >0,the distribution of surface tension on the pool surface is large near the center and small next to the edge, therefore, the liquid metal will flow to center from pool edge. That is flow to high temperature from low temperature, shown in the figure 2 c, d. The heat of arc will be taken into pool bottom, which will form narrow and deep weld.
Generally believed that，surface tension can be measured roughly with affinity strength of free surface atom. For most of substances, temperature coefficient of surface tension is

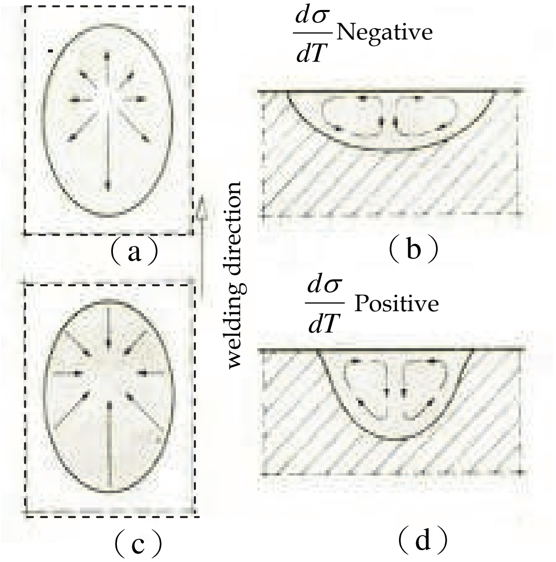


Fig. 2. Effect of surface tension on weld pool flow.

number, that is to say, surface tension reduces as the temperature increases. That is because high temperature led to affinity between atoms reduced. When it exists surfactant(such as oxygen, sulfur and so on), surfactant can enhance the affinity between the surface atoms as temperature increases, which will cause $\partial\sigma / \partial T$ in a positive state. That is increasing as the temperature rises. This means that because the temperature distribution is high in the middle and low close to the edge in the pool, which causes surface tension distribution large in the middle and small close to the edge, leading to the liquid metal flow to middle from edge.
The rules in A-TIG process has been confirmed.

2.1.3 Variation law of surface tension temperature coefficient

The variation of surface tension in the pool under the arc force is a complicated problem. This is not only because of the high arc temperature, the large temperature gradient distribution, the short welding time which results pool in a severe non-equilibrium, but also because non-uniform temperature distribution in the pool causes trace elements assemble, especially the surface active elements. All of these make distribution and variation of surface tension complicated.

Temperature distribution determined by the arc characteristics are high around the center and low close to the edge. It makes surface tension distribution of liquid metal show corresponding change. However, there is a more complicated problem. That is surface tension of liquid metal is not only related with temperature, but also related with its composition, especially related with the distribution and content of surface active elements. According to P.Sahoo and others findings, When the metal has surface-active substances (expressed by i) ,we can get the temperature coefficient by follows:

$$\frac{\partial\sigma}{\partial T}=-A-R\Gamma_s\ln(1+Ka_i)-\frac{Ka_i}{(1+Ka_i)}\frac{\Gamma_s(\Delta H^0-\Delta\overline{H}_i^M)}{T} \tag{1}$$

In the formula: Γ_s-The super saturation of element i in the metal; K- absorption coefficient;ai-activity of element in the metal; ΔH^0 -Standard enthalpy; $\Delta\overline{H}_i^M$ -distribution enthalpy of element i in the metal. T-temperature.

From (1)we can see, $\partial\sigma/\partial T$ is a function of temperature but also a function of composition, and for pure metals, it is minus. When the surfactant concentration exists certain content, K a_i <<1, (1)will become:

$$\frac{\partial\sigma}{\partial T}=-A-\frac{Ka_i\Gamma_s(\Delta H^0-\Delta\overline{H}_i^M)}{T} \tag{2}$$

When ΔH^0 is minus, $\partial\sigma/\partial T$ will become a positive number in (2). Figure 3、4 are the sulfur content in Fe-S system, oxygen content in Fe-O system and temperature on the influence of the surface tension.

We can see in the figure surface tension coefficient of Iron-based liquid metal increases and it curves gets upward with oxygen, sulfur content increases. Yet surface tension coefficient decreases with increasing temperature in each curve. More importantly, each curve with increasing temperature will come through the most important point: $\partial\sigma/\partial T$ =0. This is a turning point. When a point is above it, $\partial\sigma/\partial T$ >0,that is to say the surface tension of liquid metal will increase with temperature rising. While a point is under it, $\partial\sigma/\partial T$ <0, the surface tension of liquid metal will decrease with temperature rising. The turning point of the temperature range between roughly 2000K-2800K.

2.2 Liquid flowing in the pool

2.2.1 Liquid flow in pool when temperature coefficient of surface tension changes

As is mentioned earlier, surface tension is the main force on liquid flowing, yet the distribution and direction of surface tension are determined by temperature distribution of surface metal. In non-melting fixed-point arc welding conditions, if arc temperature distribution is in line with Gaussian distribution, because of it, the temperature next to the edge of pool is lowest(About the metal melting temperature),and the metal in the middle of pool is highest temperature(Up to the boiling temperature of the metal). When there is no

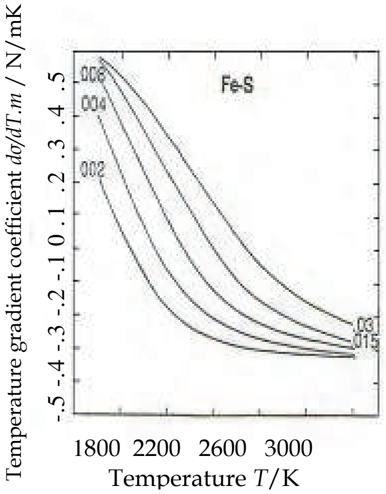


Fig. 3. Variation of temperature coefficient of surface tension as a function of temperature and S%.

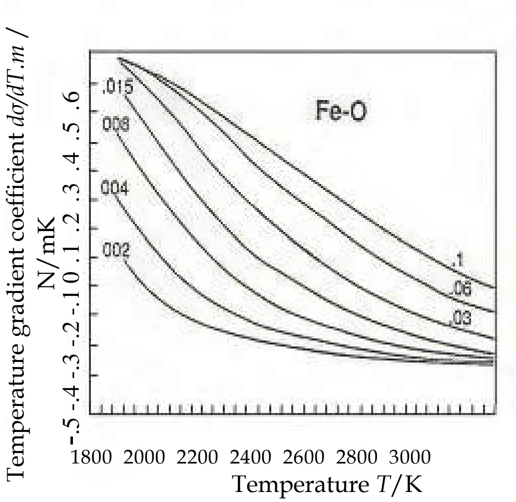


Fig. 4. Variation of temperature coefficient of surface tension as a function of temperature and O%.

surface active element, the temperature coefficient of surface tension $\partial\sigma / \partial T$ <0, just as figure 5 show us, the metal in pool will flow from the center of pool where the surface temperature is high and surface tension is small to the edge of pool where the surface temperature is low and surface tension is large, shown in the figure 5.

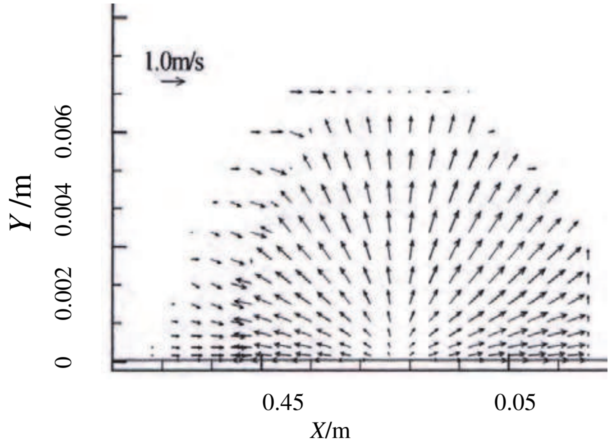


Fig. 5. Simulation of flow field as the change of $\partial\sigma / \partial T$ sign in welding pool.

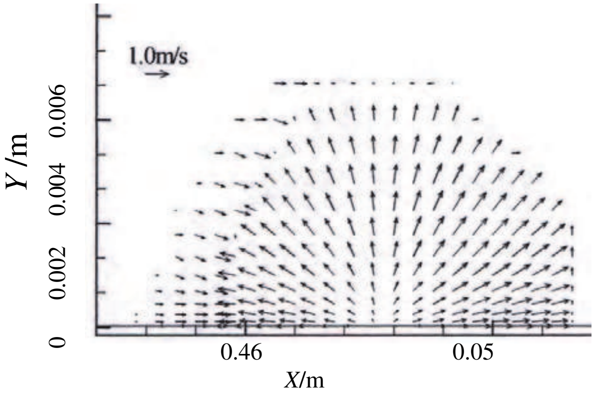


Fig. 6. Simulation of flow field as the change of $\partial\sigma / \partial T$ sign in welding pool.

However, when it exist surface active elements, the temperature of a certain part in pool surface is just the temperature in which the sign of $\partial\sigma / \partial T$ changes .It will form two areas, $\partial\sigma / \partial T$ is positive in one area, and negative in another. Therefore, it will produce two or more circulations in the internal pool. The figure 6 show us that it formed two circulations in the internal pool. The liquid in pool flows from the middle (where the temperature is high) to the edge in one area ,where the temperature is above the temperature that $\partial\sigma / \partial T$ changes its sign. Yet it flows from the edge (where the temperature is low) to the middle in another area, where the temperature is below the temperature that $\partial\sigma / \partial T$ changes. Literature is studying the corresponding law, which is the flowing of pool influence of penetration ,because temperature change lead to surface tension change. Thus in their simulation prerequisite, pool is assumed to be rigid surface. It is obviously a big gap between the actual situation, but it can be accepted to study penetration of pool. For this article, the main goal is study the influence that surface tension with temperature change impact to undercut. Obviously, the above assumption is unreasonable. But the simulation results, which is about flow state of liquid metal in pool affected by surface tension, to explain the cause of undercut has a theoretical significance.

2.2.2 Numerical simulation of pool free surface

M.S.Tsai in university of Wisconsin has studied the liquid convection in pool and pool shape of TIG under the assumption of the free surface. In order to describe the edge of pool surface, he used orthogonal curvilinear coordinates and determined morph of pool surface based the following formula:

$$P_a - \sigma_{22} - P + C = -\gamma\left[\frac{h^{''}}{(1+h^{'2})^{3/2}} + \frac{h^{''}}{r(1+h^{'2})^{1/2}}\right] \tag{3}$$

The above formula:

σ_{22} --Normal stress, N/ m^2 ；

P-- Environmental pressures，N/ m^2 ；

Pa-- The pressure from the equations of motion, N/ m^2 ；

C-- Undetermined coefficient；

γ --Surface tension coefficient, N/m；

h-- Surface deformation function.

Tsai who applied the Laplace equation, Ohm's law and Maxwell's equation calculated the flow velocity field and bath temperature in condition that the welding current is 150A and the distribution of arc is in line with Gaussian, just as the figure 7 shows us. In the picture, the surface next to pool center rises. The area near the outer part of the fusion line has a small concave. The explanation Tsai has given us is that the liquid metal near the surface flow inward, and the liquid metal near the pool center is forced flowing vertically downward, that caused the surface near the pool center being pushed up. The result is that the pool forms bump in the middle and concave near the edge. This is the first time to explain the reasons for the formation of undercut at the perspective of metal flowing in the pool.

3. Fixed-point arc welding results and analysis

3.1 TIG welding of fixed-point finite element analysis and experimental study

3.1.1 The same energy when the temperature and temperature gradient

In order to study the same energy, different welding current and welding time of pool behavior, we conducted a fixed-point arc TIG welding experiments, the following parameters.

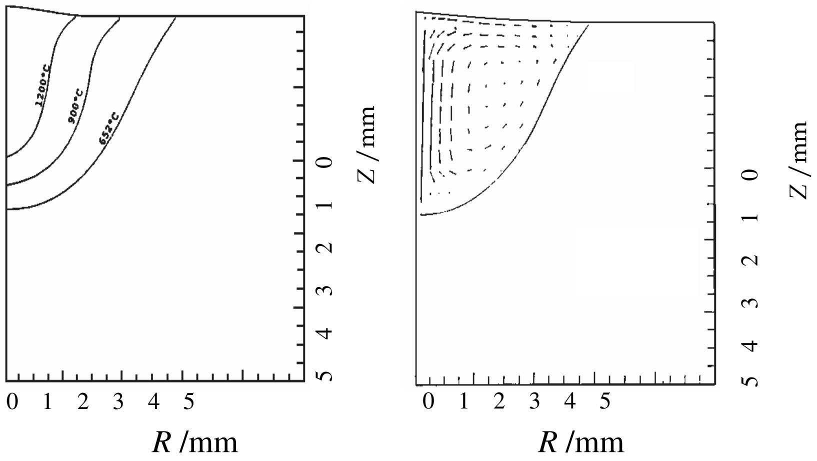


Fig. 7. Temperature, flow field and surface deformation under Gauss distribution of heat source (150A)

Shielding gas flow rate: 101/min, tungsten to the base metal distance: 5mm, length of tungsten out: 5mm, pre-aspirated time 1s, air time delay off: 4s, current rise and fall times of 0. Welding current and time relationship as show in the table 1.

number	1	2	3	4
current I （A）	190	150	110	70
time t （s）	2.4	3.4	5	9

Table 1. Parameters for equal energy standstill weld.

The same input energy, welding current and heating time is not calculated while the temperature gradient as shown in figure 8. It can be seen from the figure, the welding current large temperature gradient larger short time, while the small current for a long time heating the temperature gradient smaller.

In order to verify the results, this paper uses thermal imaging to measure the temperature field. Thermal imager which technical parameters are as follows:

Thermal imager model: HRX thermal imaging system
Manufacturer: Beijing Century Knight Technology Co, Ltd.
Detector spectral response range :8 - 14μm
Pixels: 256 × 256
Grayscale images: 256
Temperature measurement range :1550 - 2100K
Temperature measurement precision :2%
Data acquisition time:10ms

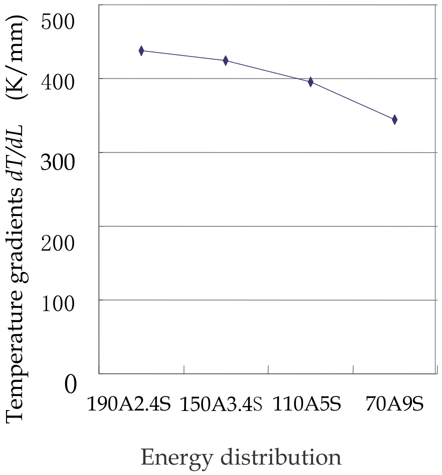


Fig. 8. Comparison of temperature gradients in same input energy

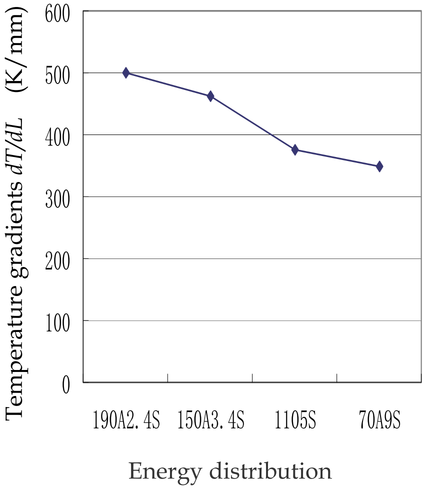


Fig. 9. Temperature distribution of welding pool surface in same input energy.

Experiments have shown temperature gradient in figure 9. From figure 9, we can see that although the same input energy there are, but when the way using small current had a long time heated, the fusion of the online temperature gradient is smaller. Instead, when changed large current for a short time heated, the temperature gradient is bigger.

As shown in figure 10 when it have the same energy input and different heating time, that is to say the calculated value depth-to-width ratio of the solder joints when energy distribution is not the same as the way. From the graph may safely draw the conclusion that, under the condition of the same energy input, the way using small current for a long time welding can get a more to big depth-to-width ratio value

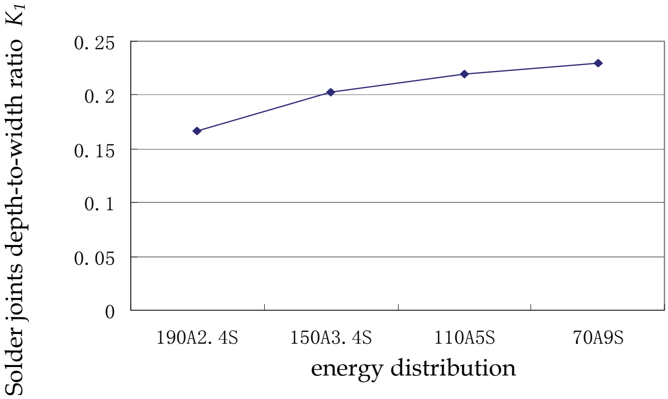


Fig. 10. Ration between depth and width of the bead.

3.1.2 The temperature and the temperature gradient of the same current

Figure 11 is the calculated temperature curve when the molten pool is cooling under the welding current 190 A, heating 2.4 seconds. Figure 12 is the calculated temperature curve when the molten pool is cooling under the welding current 190 A, heating 1.4 seconds.

From the figure 11 and 12, we can see when arc is burning in a long time, the molten pool is obviously bigger. But compared to two graph of the temperature change we can found the temperature change speed in the center parts of molten pool is far outweigh the pace of change in the surrounding. That is to say, in the cooling process of molten pool, though in the midst of the liquid metal finally solidified, but its temperature down than the temperature of the surrounding reduced much faster.

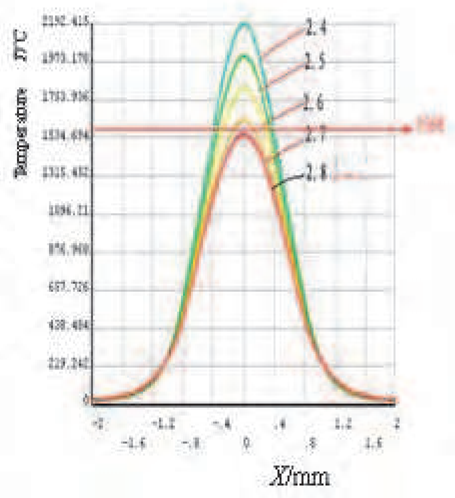


Fig. 11. Calculated result of temperature of welding pool surface as cooling (190A, 2.4S).

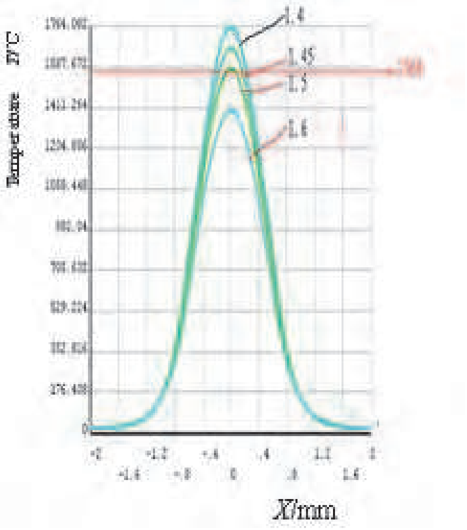


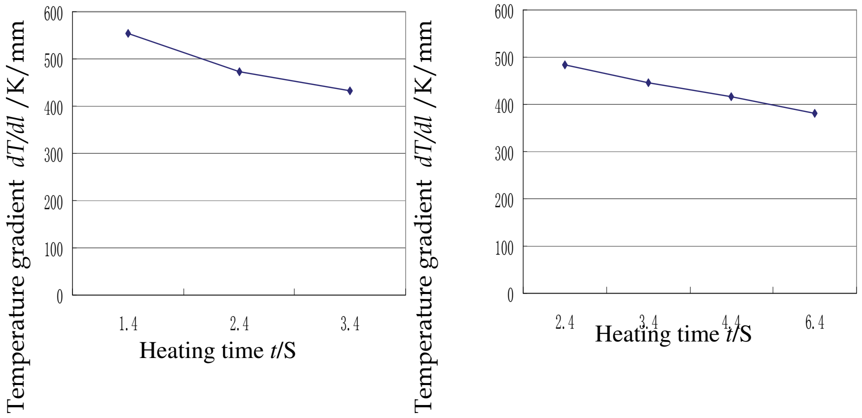
Fig. 12. Calculated result of temperature of welding pool surface as cooling (190A, 1.4S).

In figure 13 we can also see, with the time of heating extended, the fusion line near the temperature gradient decreased. It can be concluded, small standard slow welding can reduce the fusion line near the temperature gradient.

3.2 Designated welding experimental results

3.2.1 Experiment conditions and welding standard

Experiment mainly carried out from three aspects: one basic situation of contrast is the different welding current, different welding time, but heat input is the same; the second



a) current is 190A

b) current is 150A

Fig. 13. Relationship between temperature gradient and arc time.

situation it is the same, but the welding arc burning time different changed; the third is under the same welding standard but welding materials is not the same as the sulphur content is different.

The specimens uses the Q235 steel plate. The actual weldedtestspecimen respectively in two kinds with sulphur content in the 0.02% and 0.05%. Table 1 is designated welding experimental parameters. The welding conditions: TIG welding dc electric reverse connect, Ar gas protection, gas flow 101/min, tungsten extreme view of 60 °, 6 mm distance to the workpiece.

The numbers in table 2 is the value of the welding current multiplied the welding time, because of the actual welding arc current difference can cause energy loss different and it can not stand of the truely welding heat input, but its can indirectly reflect the quantity of welding heat input. In the experiment, strictly control arc burning time and using thermovision and infrared thermometer measuring the temperature distribution of welding pool and some point of the heat cycle, especially near the fusion line of thermal cycle. After the specimen cooled, with precision surface measuring instrument measuring the surface shape of the solder joint we can get bite edge data.

The experiments in table 2 must be repeated at least three times, ×in the table stand for the test have not done. Some are due to welding current is too small, the time is short, basically the specimens does not melt to form a molten pool; some are due to welding current is too large, time is long, the measurement can not be carried out because of the specimen got burning through.

Time(s) Current(A)	2	3	4	5	6	7	10	13	16
70	×	×	×	×	×	490	700	910	1120
110	×	330	440	550	660	×	×	×	×
150	330	450	600	750	×	×	×	×	×
190	380	570	760	×	×	×	×	×	×

Table 2. Parameter of standstill arc welding.

Note:

1. The × express the experiment have not done.
2. The corresponding numerical listed in the table express the product of multiplication of the current and the time.

Surface shape measuring instrument Hommel-Links PM2000 technical indexes are as follows: the vertical resolution 0.25 microns, level 1 micron, resolution for tip radius of 20 microns ± 5 microns.

3.2.2 Experiments results

(1) The same heat input experiment results. When the welding current is different and different welding time, but the same heat input, Welding undercutting depth will increase with the increased of the welding current and the reduce of the time. That is to say, large current and short time welding condition can produce the depth of undercutting more big, figure 14 is the actual measurement result. This is because large current and short time condition input can have a lager welding temperature gradient, surface tension is bigger, the

tendency of liquid metal near to the fusion line flow to the center of the molten pool increased, then undercutting depth increased.

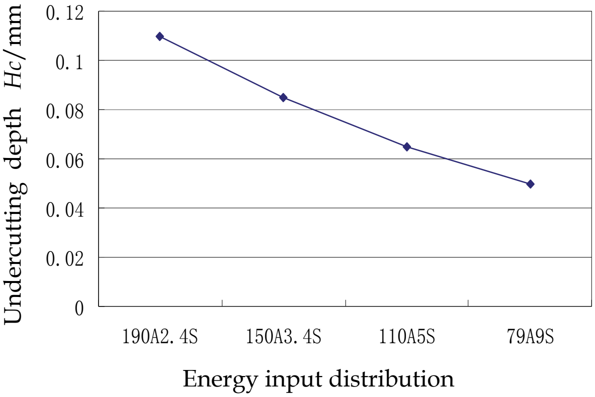


Fig. 14. Undercut depth of different welding current under the same input energy.

(2)The same welding current experimental results. When the welding current is the same, but the welding time is different, the welding undercutting depth will increas as the extension of welding time, as figure 15 shown. When the welding current is same, the molten pool size will increase as the extension of welding time, but the basic flow mode of molten pool is not change, still from the fusion line to pool center, so the welding undercutting depth increased.

(3)Different specimens in sulphur content experiment results. By the analysis above in this chapter shows that when the surface activity element proportion existing in the specimen is different, it will have an important impact on the flowing behavior of liquid metal. This experiment selected two kinds of Q235 steel specimens with the sulphur content in 0.02% and 0.05%. The actual welding test results in figure 16.

The figure 16 shown, with steel in different content was elected as the specimens, inthe same welding standard conditions the undercutting depth varies significantly. In 190A welding current conditions, the welding time is 2s, the specimens undercutting depth of 0.02% in sulfur content is almost three times of 0.05% . When the welding time for 4s, it still nearly twice. Therefore, the surface activity substance of the mother material has an important influence to the flowing of the welding molten pool, thus it can affecting welding results, lead to significantly change of the undercutting tendency.When the proportion of surface active substances rises, the absolute value of the surface tension get lower, but the regulation of the surface tension changing with temperature distributionare still the same.

In the experiment, the specimens with sulphur content in 0.02%, without exception are undercutting, and it is clearly visible with naked eye, as figure 17 shows. The background of the figure is under the currence is 70 A, 3 s TIG flat welding arc, the photo of looking down at the welding spot, the lower part is the cross section along the welding spot diameter and the measuring curve by the surface shape measuring instrument.The figure shows that, in the cooling process of the welding pool, the liquid metal have obviously tendency to gathering, formed the surface shape that among the middle convex and concave around.

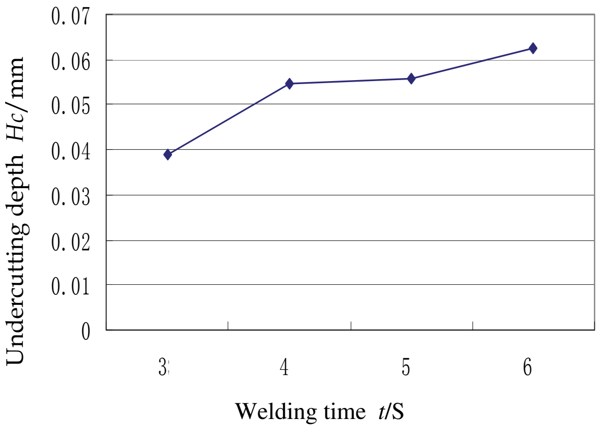


Fig. 15. Undercut depth of different time under the same current

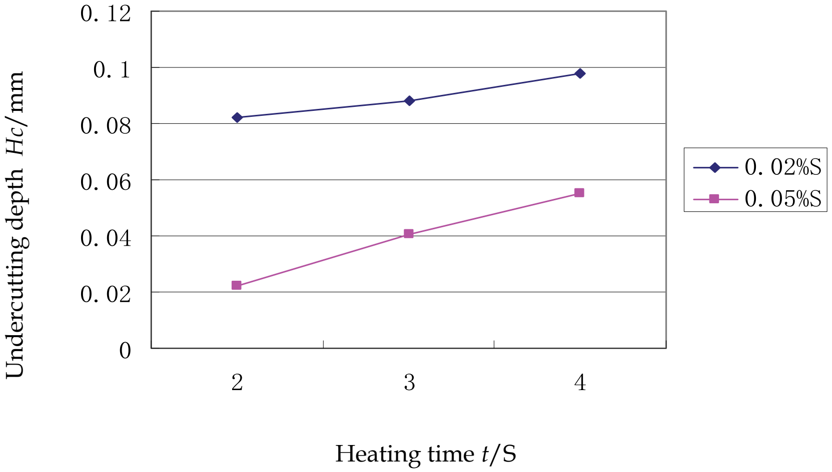


Fig. 16. Comparison of undercut as different S%.

Figure 18 shows the the welding spot under different welding parameters, including (a) photos for welding current 150 A, 4s welding results, (b) phptos for 190 A, 3s welding results, they have the same undercutting.

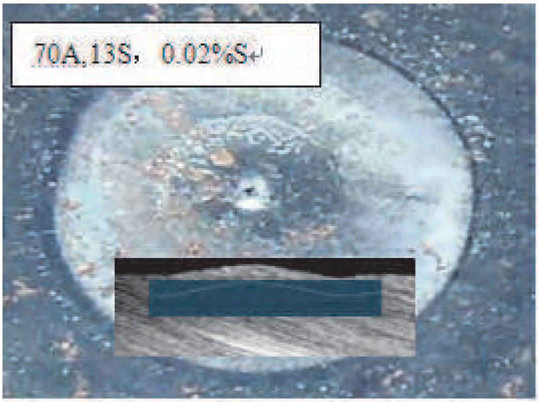
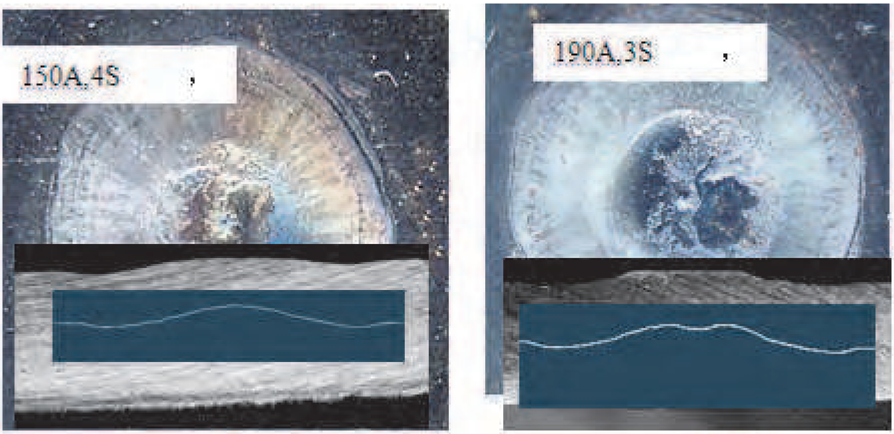


Fig. 17. Photo of welding spot.

3.2.3 Contrast experiments

For support the surface activity elements action mechanism and the conclusion above, the mother material lower in sulfur content (S content 0.01%, 0.004%) was chosen to do the contrast experiments, the experimental results shown in figure 19. We can see well spot surface didn't happened undercutting phenomenon. Observe carefully we will find, welding spot surface is tiny ripples, it is mainly because of the surface wave when molten pool



(a)150A、4s (b)190A、3s

Fig. 18. Photos of welding spots.

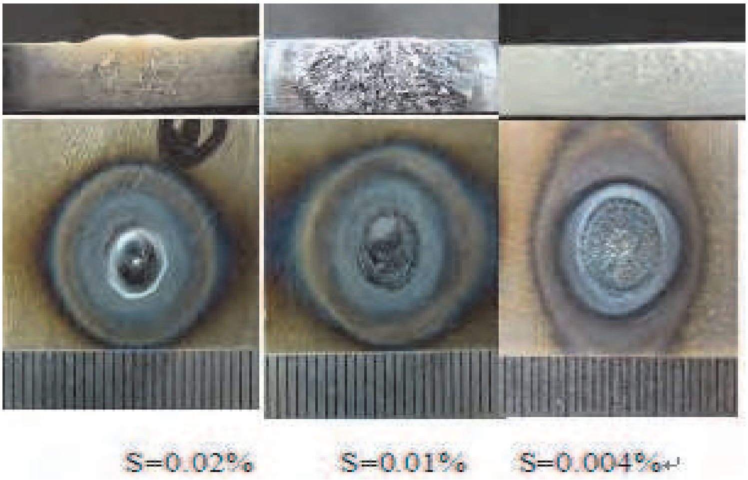


Fig. 19. Appearance of weld spot under the same welding condition.

freezes, but no middle convex phenomenon. This proved the fact that the metal surface activity elements can influence the direction of the metal flow, thus affects the undercutting when welding.

By the experiments above we can come to the conclusion: for the metal which contain very low surface active element content or no active surface elements, the metal surface tension temperature coefficient is less than zero in the range of above its melting point, liquid metal flow direction of molten pool is from the center point to fusion line, and it won't produce undercutting phenomenon in the designated welding.

To the metal contain active surface element, the degree of undercutting will get increase with the temperature gradient rise.

4. Experimental mobile welding results and analysis

4.1 Experimental study of a single TIG welding arc

To simplify the experimental conditions, comparison test has been done using the results which is got in different weld speeds in TIG welding process, shown in Figure 20. Experimental parameters are as follows: welding current is 190A, shielding gas flow is 10l/min, base metal thickness is 3mm, tungsten to the workpiece distance is 5mm, welding speed, respectively is 0.51m/min, 0.54m/minand 0.57m/min.

As can be seen from figure 20, when the welding speed is 0.51m/min (figure a), undercut doesn’t exist; when the welding speed reaches to 0.54m/min time (figure b), undercut sometimes have sometimes no, in a transitional state; when the welding speed comes to 0.57m/min time (figure c), there is a clear continuous undercut phenomenon. Thus, the critical welding value of producing undercut is in 0.54m/min so in this welding conditions.

4.2 Study of single TIG transverse electromagnetic compression arc

To study the impact of the welding heat source shape on undercut, this passage uses magnetic control method to compress the single arc to make circular arc cross-sectional shape into the oval-shaped, as shown in figure 21.

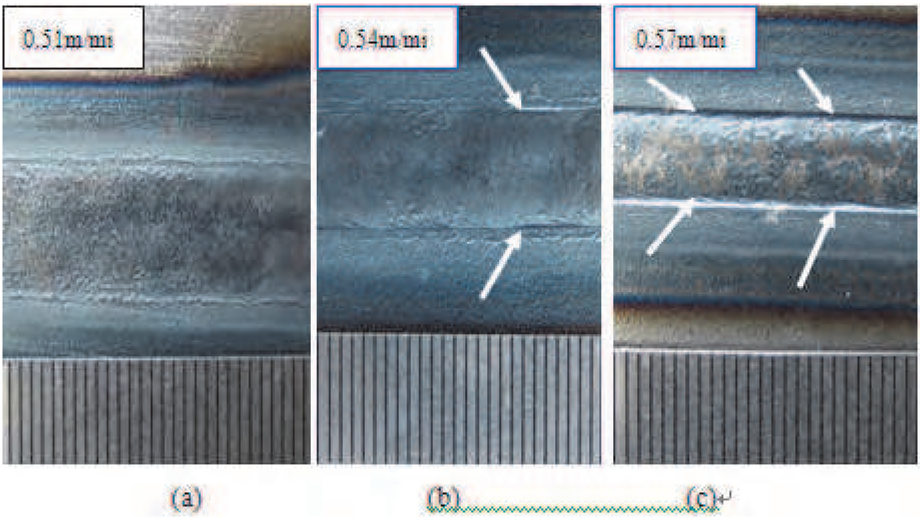
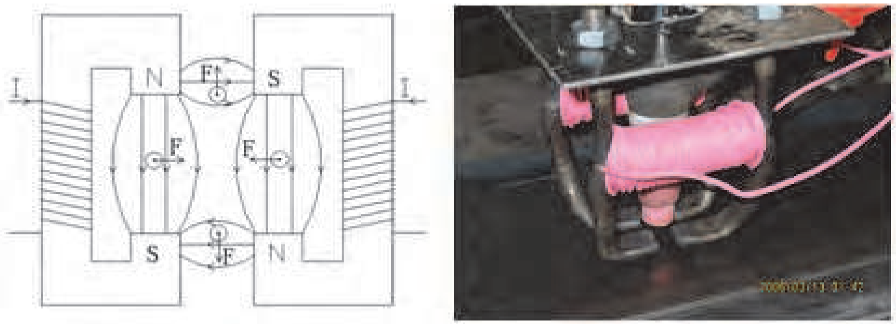


Fig. 20. TIG welding experiments.



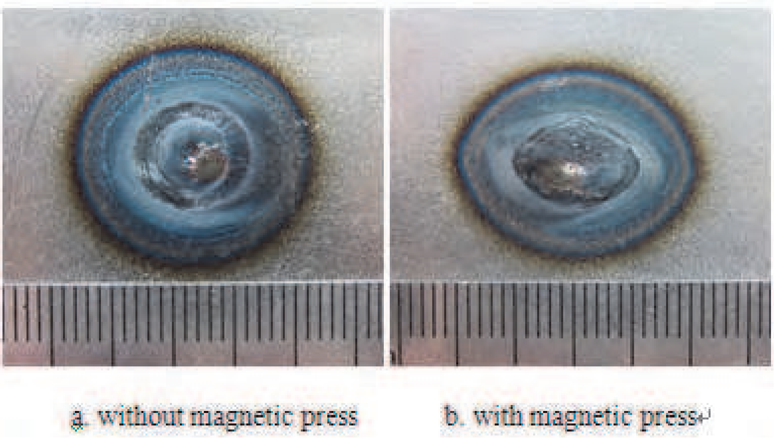
a, mechanism b, appearance

Fig. 21. The principle of electric magnetic field control and instrument photo.

4.2.1 Magnetic devices and experimental conditions

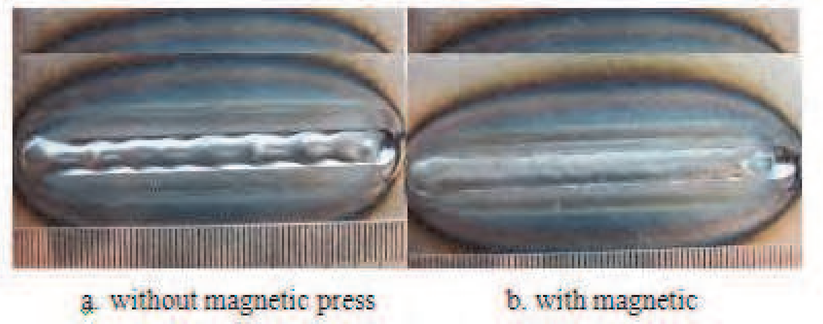
In this paper, arc electromagnetic control device has been designed using the principle of electromagnetic control, as shown in figure 21b. The coil turns is 100 turns, the control current is 3A, the magnetic pole spacing is 10mm, the magnetic pole area is 10mm×3mm, the distance between two pairs of poles is 10mm.

It can be seen from figure 21a, there is transverse magnetic field all around the arc, this magnetic field can compress the arc into an oval-shape.



a. without magnetic press b. with magnetic press

Fig. 22. Welding spot of magnetic pressed arc or not pressed.



a. without magnetic press b. with magnetic

Fig. 23. Welding results of magnetic press arc or not press.

4.2.2 Magnetic compression fixed-point welding experiments

To verify the effect of magnetic arc compression, first fixed-point welding experiments have been done. Experimental conditions are as follows: welding current is 190A, welding time is 2.4s, shielding gas flow is 10l/min, and base metal thickness is 3mm. Fixed-point welding spot is shown in figure 22, a is the spot not applying magnetic compression, b is the spot applying magnetic compression. It can be seen that after magnetic compression fusion pool becomes oval-shape, magnetic compression effect is obvious.

4.2.3 Mobile welding magnetic compression arc experiments

Continuous welding experiments have been carried out along the long axis of oval in magnetic compression, welding current is 190A, welding speed is 0.63m/min, the results is shown in figure 23.

Figure 23, a is the result of no magnetic compression, weld undercut is serious and there is a clear trend of bead hump. b is the result of applying magnetic compression, weldment is continuous and neat.

The temperature gradient is the most important factor of affecting the undercut extent. If setting the equivalent diameter d of circular welding arc, welding speed V_w , shown in the figure 24. The time that through cross-section A of welding arc is:

$$t = \frac{d}{V_w} \tag{4}$$

If the arc diameter d is a constant, and ignoring the deformation of the arc move，seen by the formula 4, the time t through cross-section A is inversely with the welding speed. In other words, actually, the welding speed increasing is achieved through the time t decreasing, which is similar to high current short time fixed-point welding, and it leads to temperature gradient increased, the tendency of undercut and extent arise.

If using oval-shaped heat to weld along the long axis of the b direction, shown in figure 24, when the welding speed is constant, because the heat distribution is larger along the welding direction, the time t1 is:

$$t_1 = \frac{b}{V_w} \tag{5}$$

Figure 24 shows, b>d，then，t1>t, it can be seen, when using elliptical arc to weld along with the long axis, the time which arc through the cross-section A increases and it equivalent to reducing the welding speed, and it can reduce the temperature gradient effectively and

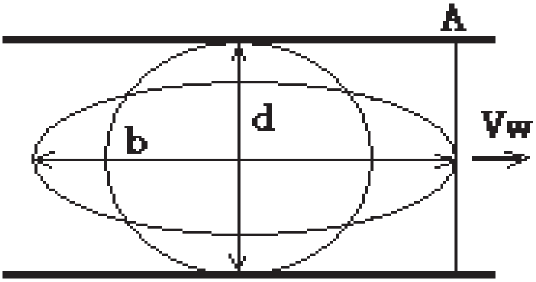


Fig. 24. Schematic diagram of arc.

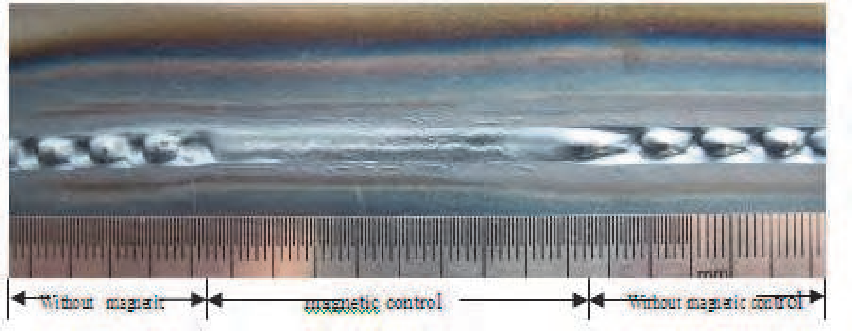


Fig. 25. Result of welding by magnetic control arc.

the tendency of undercut extent.

Secondly, when using the elliptical welding arc along the long axis, due to the width direction of the weld arc is compressed smaller, weld width will inevitably reduce, shown in figure 24. Thus, it can effectively improve the weld depth-with ratio, also help to inhibit the emergence of undercut.

Alternating magnetic arc welding results shown in figure 25. Thus, using of magnetic compression arc can effectively reduce weldment temperature gradient, inhabit undercut and increase welding speed.

5. Conclusion

The flowing direction of liquid metal is the main factor that depends on whether to produce undercut in the pool area near the fusion line. When the area's liquid metal flows from the pool center to the fusion line ,the undercut will not be produced; But when the area's liquid metal flows from the fusion line to t the pool center the undercut may be produced.

The temperature property and distribution of the pool liquid surface tension are one of the most important factors ,which affect the flowing direction of the liquid metal near fusion line area. When the existence of Surface Reactive Materials (sulfur or oxygen) makes the surface tension temperature coefficient become from negative to positive, the pool surface liquid will flow from the fusion line to the poll center, if the region can not be replenished by the metal in time, the undercut will be produced.

Temperature gradient is the most important factor that affects the degree of undercut of welding spot, the size of temperature gradient depends on the size of the surface tension gradient, and the latter directly affects a driving force of the pool metal . Under other unchanged conditions, undercut of the weld will increase with temperature gradient increasing.

Numerical simulation of the arc of movement shows that, with the welding speed increases, molten bath temperature gradients near the fusion line area increases, the dynamic aspect ratio decreases, both will increase the tendency of undercut. When increase the preheating temperature, reduce the thickness of welded parts, improve cooling conditions, can reduce the temperature gradient and improve the dynamic aspect ratio, help to curb the undercut.

When using electromagnetic compressed arc into an oval shape and welded along its long axis can effectively reduce the temperature gradient of direction perpendicular to the weld pool, increasing the dynamic aspect ratio, help to curb undercut generation, achieve higher speed welding.

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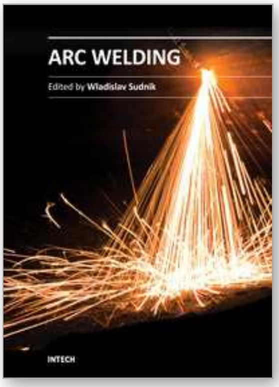

Arc Welding
Edited by Prof. Wladislav Sudnik

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Ever since the invention of arc technology in 1870s and its early use for welding lead during the manufacture of lead-acid batteries, advances in arc welding throughout the twentieth and twenty-first centuries have seen this form of processing applied to a range of industries and progress to become one of the most effective techniques in metals and alloys joining. The objective of this book is to introduce relatively established methodologies and techniques which have been studied, developed and applied in industries or researches. State-of-the-art development aimed at improving technologies will be presented covering topics such as weldability, technology, automation, modelling, and measurement. This book also seeks to provide effective solutions to various applications for engineers and researchers who are interested in arc material processing. This book is divided into 4 independent sections corresponding to recent advances in this field.

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