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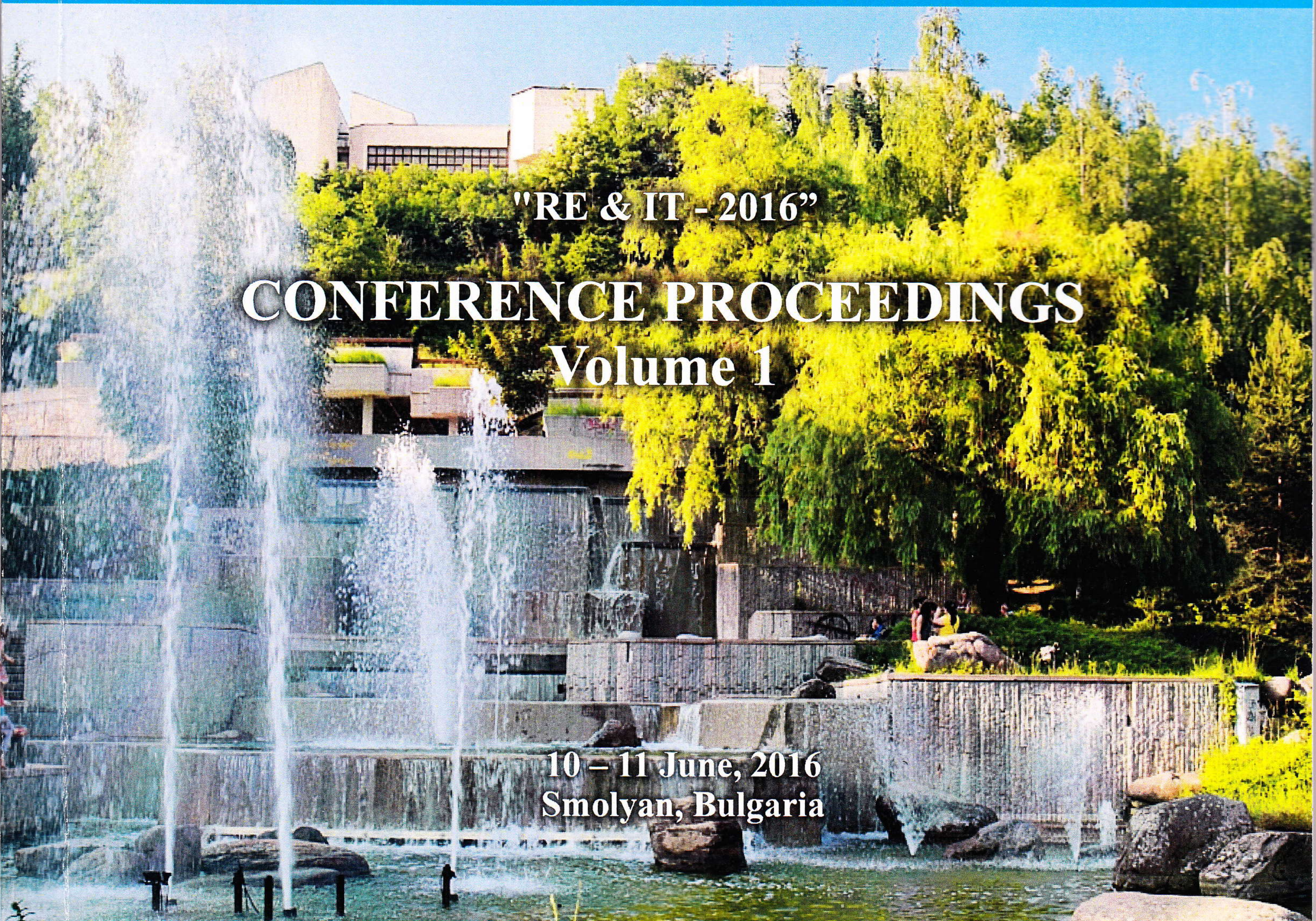

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LIQUID PHASE MODIFICATION METHODS THROUGH NANOPOWDER AL_2O_3 AND TICN INJECTION IN TIG AND IMPULSE TIG WELDING METHODS

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Abstract: *In practice there are several known methods of inserting the nanopowder Al_2O_3 and TiCN to the welding layer, they are specified according the conditions needed for the welding process. This article examines some new and innovative opportunities of liquid phase modification through insertion of nano-sized particles without being melted, according to TIG and Impulse TIG overlay welding methods.*

Keywords: *Nanopowder, Al_2O_3 and TiCN, TIG, Impulse TIG, Overlay Welding*

1. Introduction

Overlay welding is a technology where a layer of metal alloy is being laid on the work piece. The overlay welding with different kinds of metal with specific chemical and mechanical properties performed on the working surfaces of the parts, increases their durability and reduce the weariness [6].

The area of operation of the overlay welded surfaces are defined by the chemical composition of the layer. The alloy is being produced by melding the main metal and by adding other metal, powder or flux. Main principles to evaluate the alloy are: homogeneousness of the composition in the welded volume, cost effectiveness, application capability of the alloying method and other. To insert alloy elements in to the base metal, following methods are being used[4]:

- Use of solid electrode wires or tapes – traditional method of becoming an alloy with particular chemical composition in wide scope of welding conditions where the alloying elements are well distributed in the volume.
- Alloying with use of electrodes – the most widely spread method. The overlay metal is homogeneous by composition, well formed, lack of pores and slag and also the chemical composition is fully based on the electrode.
- Another method of overlay welding uses low carbon wires or tapes and ceramic flux or flux mixtures, from which the alloying elements are being transferred to the overlay metal. In this method the flux is the main source of alloying and the more the volume of the melted flux the bigger is the quantity of the elements inserted in to the overlay metal. That is why the composition of the metal is dependent of the welding regime, the mass and composition of the used flux.
- Alloying using pastes which are being deposited on the welded layer and then melted with or without additional low carbon wire. The chemical composition of the welded metal is determined by the quantity of the paste and also by the quantity of the melted alloying material. (Figure 1).
- The alloying of the surface layers with carbide powders, nitrides, oxides, etc. whitch have the size of nano paricles could be observed as another innovative method (nano particles have the size 1.10^{-9}m). By melting thise powders, the alloying is similar to the method with the pastes (Figure 1). On the other hand, if the nano particles are inserted in the lower temperature area of the weld seam without being melted, they will take places in the crystal lattice of the melted metal and will make the structure refined,

which will lead to better mechanical properties of the overlay layer (Figure 2). The new metal will be then a composite material, obtained by matrix consistent of construction steel and particles of nitrides, carbides and other which contains the welding powder [2].

The materials that we create that way are called metal matrix nano – composites MMNCs [7]. For that purpose usually powders of 1nm to 100nm are being used. The mechanical properties of the modified layer have maximum improvement at medium levels of nanoparticles concentration , which can be explained with the finer microstructure.

The innovation of the method lie on the fact that the powder maintain it's state, it is not being meltd and so the liquid phase is being modified [5]. Because of the low power of the arc, the use of TIG and impulse TIG welding preocesses is not very efficient compared to the plasma powder welding method. On the other hand it could be used to weld smaller parts (blades, wear resistant plates, etc), where a smaller amount of heating is requiered, so that the deformations could be avoided.

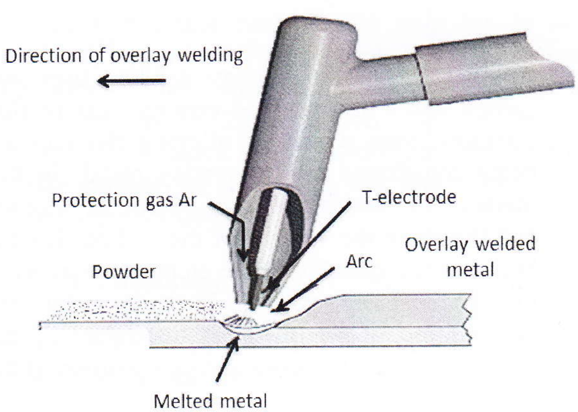


***Figure 1:** Welding with melting of powder*

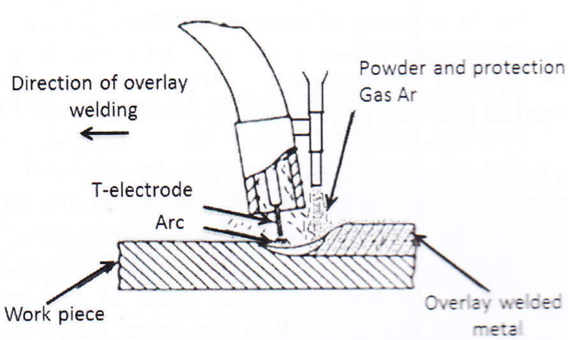


***Figure 2:** Welding without melting of powder*

2. Methods for modification of the liquid phase using Nano-powders without melting them.

It will be observed shortly the tested methods of modifying the liquid phase with Nano powders (*Figure 3*), without being melted, as well as some of their features.

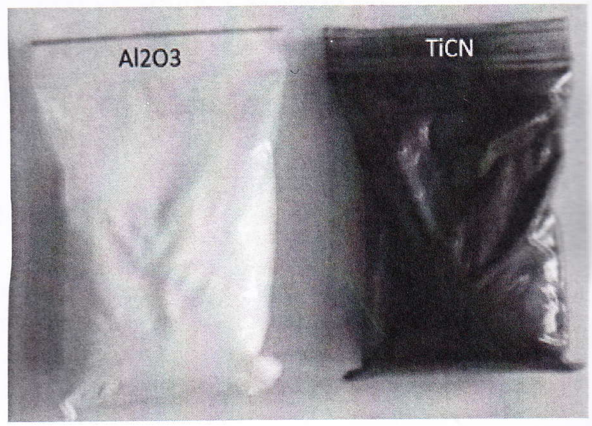


*Figure 3: **Nano-particles Al2O3 and TiCN size 45nm – 55nm.***

A. The powders could be inserted at the end of the weldseam using proper additional device mechanism (

Figure 4). It points 35°- 45° in relation to the direction of welding, it has the shape of bended wire 2mm in diameter and at the one end it has the contour of the weldseam (elliptical). The devise is being attached and "towed" by the gas nozzle. A few millimeters parallel to the welding line there is the powder trail which is being pulled in by the device to the weldseam. The powder trail is laid on the work piece in safety distance from the heat so that it could not be melted. It is 2-3mm wide and 2mm high. By the movement of the nozzle the powder is being pulled to the end of the weldseam. The powder is additionally pushed from the additional device so that it can penetrate better in to the seam.

TIG overly welding is flexible because of the manual movement of the nozzle, the arc is very powerful in gas environment and there is no need of additional materials in case of welding thin sheet metal layers. These characteristics make the method universal. Other advantages of the process are: inert-gas protection and T-electrode have no effect on the chemical composition of the metal; there is no slag and splashes; the arc is being observed; fine adjustment of the welding regime is possible; mechanizing and automation is also possible; nano-particles could be inserted in different temperature zones of the weldseam. With the time the bended wire bends because of the heat, deforms and it could not push the nano-powder proper any more to the melted metal.

B. Figure 5 shows an innovative method for insertion of nano-powders with or without melting. The devise is designed to deliver a mixture of inter gas and powder. It ensures a control over the amount of powder being used for the welding. The inert gas goes in through inlet 1, then enters the injector 3 and creates vacuum in channel 7. This leads to sucking the particles out from the reservoir 5.

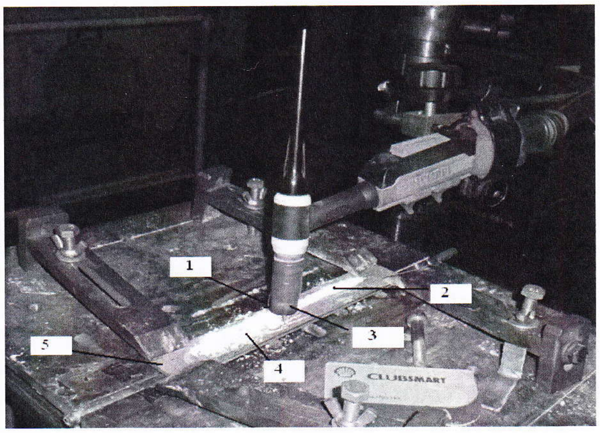


Figure 4: *TIG and impulse TIG welding without melting the nano-powder. 1 – wire, with weldseam contour bend; 2 – powder on the side; 3 – nozzle ; 4 – powder after welding ; 5 – work piece.*

The control over the amount of the powder that has been sucked out is ensured through the valve 6. Inlet 2 is also supplied with inert gas so that air can't get to the mixture and from there to the weldseam. That way the particles that enter the weldseam make its structure refined.

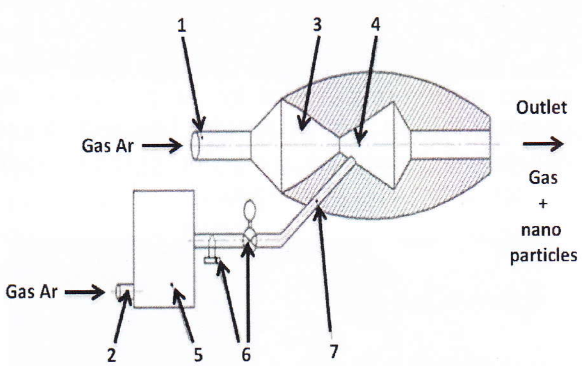


Figure 5: *Principle view of device for Nano-powder insertion with or without melting. 1,2 – intert gas insertion nipples; 3 – injector; 4 - mixture chamber; 5 – powder reservoir ; 6 – valve for controling the amount of powder ; 7 – channel*

Figure **6** shows the insertion of nano-particles in to the melted metal direct after the arc, in the area of lower temperature. The end of the device is positioned in an angle according to the nozzle 1 and the melted metal 5. The inert gas goes in through inlet 4 and passes through the nano-powder reservoir 3 which is being sucked out and transported behind the welding arc. The direction of overlay welding is from right to left.

The problem in here is that the pressure of the inert gas is not higher than 0.6 bar. At this low pressure the nano-particles are not always transported. If we increase the pressure at constant powder insertion the result is unwanted form of the modified seam (

Figure **8**). The device could be also positioned in front of the nozzle, in which case the powder will melt and a modified layer with special features will be created – hardness, wear and heat resistance, etc.

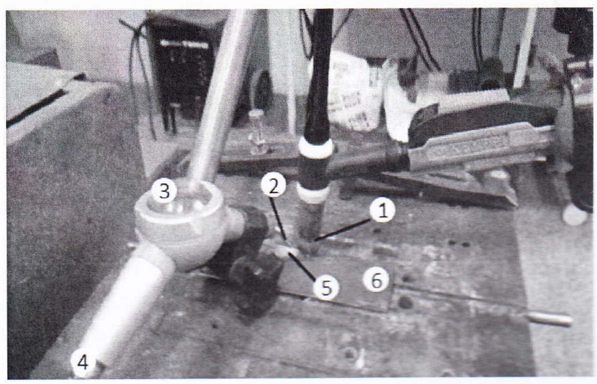


Figure 6: *Insertion of nano-powders behind the weldseam in the low temperature area 1 – nozzle; 2 – insertion tube for nano-powder and inert gas; 3 – nano-powder reservoir; 4 – inlet for the protection gas argon; 5 – heated metal right after the arc goes out; 6 – work piece.*

Figure 7 shows another way of insertion of nano-powders. The working principle is shown on Fig.5. The inert gas is being fed through the reservoir 3, the transport gas correspondingly through inlet 5. In the body 4 there is a needle which is being pushed back thought the button 7. After releasing the button a spring pushes the needle back to the initial position. That way the needle goes back and forward and prevents the blocking of the hole which delivers the powder after the arc. The pressure of the inert gas that goes through the reservoir is in this case of most importance. It is possible that at high pressure the powder could be squeezed in and that could lead to blocking the hole of the reservoir from which the mixture of powder and inert gas should go out.

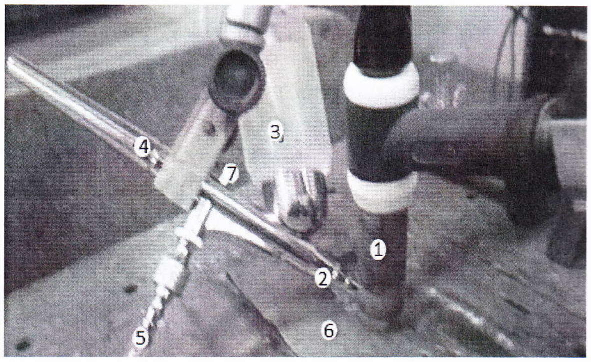


Figure 7: *Insertion of nano-powder behind the arc of welding in the low temperature area. 1 – nozzle; 2 –device outlet; 3 – nano-powder reservoir; 4 – body of the device; 5 – inert gas inlet; 6 – work piece; 7 – control button*

Figure 8: *Melted seam created at higher pressure of the transport gas*

C. On Figure 9 is shown the most appropriate method to feed the nano-powder after the arc, in the low temperature area of the liquid seam. It is being used an inclination backwards to the arc direction. That way the layer is created exactly in the same way like using a vertical electrode. The front 5 of the nano-powder TiCN is pointed to the back end of the seam.

The gas nozzle of the torch 1 is №7 with diameter d = 11m, where the thickness of the protection gas is 6-7l/min. It is used the minimal possible amount of protection gas, so that the negative effect of the high pressure towards nano-powder can be reduced. TiG electrode Wl 20 with diameter d = 2,4mm is being used. Angle of inclination is 28-30 degrease. The distance to the nozzle in front is 6mm at 2mm height which is exactly the length of the seam. This length is equal to the voltage of U_{arc}=10-12V. The distance from the electrode projection over the work piece and the center of the nano-powder spray mark 3 is in limits of 10-12mm. The tip of the injector has a distance of 10.5-11.5mm to the work piece. The pressure of the gas that is being used for the transport of the nano-powder is 0.8-1.0 bar.

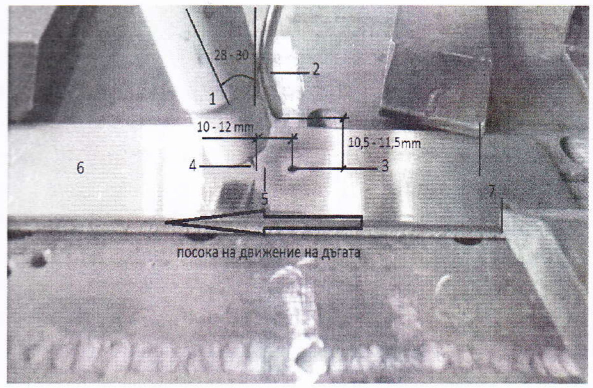


Figure 9: *Position of the nozzle and the injector at the powder insertion process. 1 – nozzle; 2 – outlet for gas and nano-powder insertion; 3 – nano-powder TiCN; 4 – W electrode; 5 – nano-powder insertion towards arc; 6 – work piece; 7 – support*

It's one of the most important factors and it should be controlled so that no deformation at the end of the liquid metal seam could occur (Figure **8**), in that case 1 bar shouldn't be overstepped. But on the other side under 0,6 bar it can't be achieved a constant and steady insertion of the nano-powder. The pressure could be raised up to 1,2 bar under the circumstances that the overlay welding is being done through melting the nano-powder. In that case a line with the nano-powder is being laid on preliminary on the work piece surface (Figure **10**), which is being melted on the welding process. The line has a width of 1,5mm – 2mm and height of 0.5mm – 0.6mm. The grip is based on a mechanical adhesion (griping of the particles). There is no need to use a bonding substance (liquid glass, glue, etc.). Sputtering of the nano-powder is not observed at the TiG welding method under influence of the arc or the gas pressure. By using the impulse TiG method, a small sputter could occur caused by the pressure of the impulse. In that case a powder line with bigger dimensions should be used, for example width 2,5mm - 3mm and height 1mm.

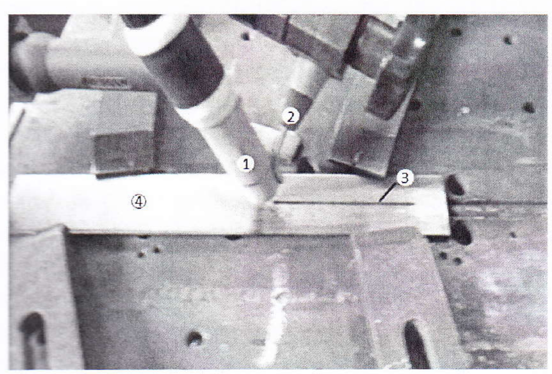
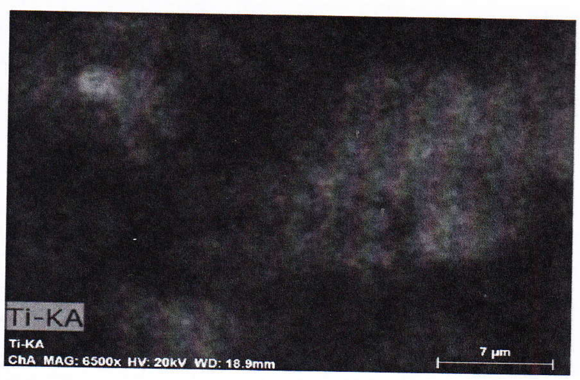


Figure 10: Preliminary deposited nano-powder for melting. 1 – nozzle; 2 – injector; 3 – deposited line of powder TiCN; 4 – work piece

Two methods are being used for melting of the surface layer, which parameters are shown below. They are being determined preliminary, where consistent powder lines, no knots and sufficient amount of liquid metal are observed.

- TiG: I = 80A, U_{arc} = 10,5 V ÷ 11,5V, $V_{weld.}$ = 2,5 mm/sek., Q_{gas} = 6÷7l/min (Ar). Tungsten electrode – lanthanum Wl 20, $d_{electrode.}$ = 2,4mm, injector №7 – diameter 11mm, electrode output L_{out} = 6÷7mm, electrode inclination – angle backwards 28° ÷ 30°.
- Impulse TiG: impulse current I_{imp} = 120A, background current I_b = 40A, average current I_{avg} = 80A, impulse length and pause a 50% ergo $t_{imp} = t_p$ = 50%, impulse frequency – 4 Hz, U_{arc} = 10,5V ÷ 11,5V, V_{weld} = 2,5mm/sek., Q_{gas} = 6÷7l/min. (Ar), Tungsten electrode – lanthanum Wl 20, $d_{electrode.}$ = 2,4mm, injector №7 – diameter 11mm, electrode output L_{out} = 6mm, electrode inclination – angle backwards 28° ÷ 30°.

Two types of nano-powders have been used for the experiment - Al_2O_3 and TiCN with particle size 45 - 55nm. It was established the size of the grain, the wear resistance of the new surfaces and their hardness.



Surface distribution of titanium, determined through characteristic x-ray observation TiKa. The study with electron microscope shows the distribution of TiCN over the surface and depth of the modified layer.

3. Conclusions

1. There have been made experiments with all methods for insertion of nano-powders behind the welding arc in to the low temperature area.
2. The Best result was produced with the method described on Figure 9 where the protection and transport gases are being fed from the same source.
3. The distribution of TiCN is relatively even and the structure has the size 4 without melting nano-powders up to 7-8 with TiCN insertion after the arc.
4. The results are shown on Figure 11. It shows the overlay welding of one, two on ½ from the width overlapping or tree also overlapping lines. There are no visible defects, the lines are consistent and well formed.
5. That gives us reason to continue the research of these methods for insertion of nano-powders in the area behind the welding arc.

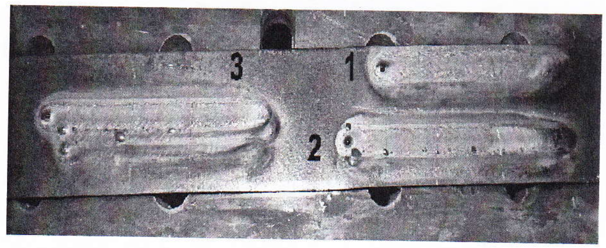


Figure 11: *overlay welded lines. 1 – one line ; 2 – two overlapping lines; 3 – tree lines*

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