

## Contributions regarding increasing reliability of beer industry installations using weld cladding in ultrasonic field

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**Abstract.** Paper presents a new technology for availability increasing of different installation parts used in beer industry – ultrasonic activation of metal deposition by welding. The dilution phenomenon is studied linked on its influence upon material technological and functional properties in the three distinct zones of resulted couple (filler material, influenced thermal zone, base material). Experimental results performed on unidirectional valve are presented regarding variation of chemical composition concentration and dilution variation in three zones influenced by ultrasonic wave.

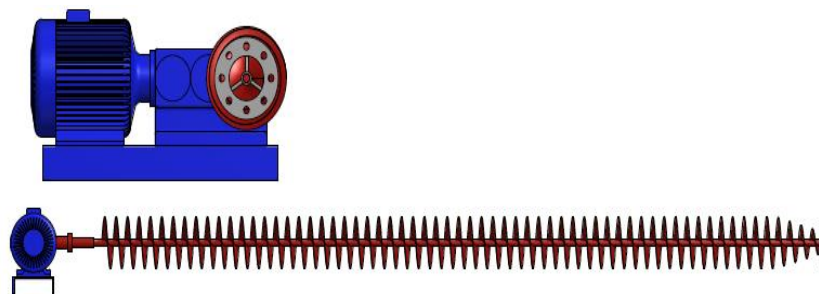
### 1. Introduction

The spent grains is a byproduct resulting from the manufacturing process of beer, high humidity (over 70%), high protein components lightly fermented and has a strong action on all componentelor corrode in contact with the plant. Corrosion affects most elements that transport spent grains (fig. 1). These are the pushing and discharge screw 4, backflow valve and its components (fig. 2) and the pipeline which transports mash (fig. 3) for silage bunkers.

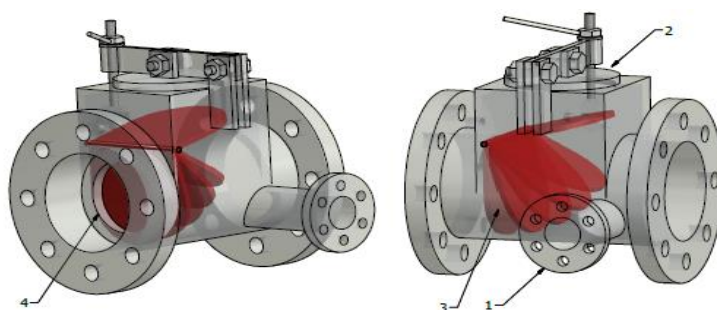
All these components are strongly affected by corrosion so that their life sometimes drops below 18 months requiring replacement with new, fairly expensive and inefficient operation, as it happens, for example, with the pipeline (fig. 4). To increase the lifetime of these components are more technological methods, the most important being refurbishing them through various technological processes by offering a number of clear advantages of the processes for reconditioning known and applied, the most effective in the present case, the refurbishment weld cladding because it presents significant advantages [7]:

-significant savings of expensive materials (on normal and cheap materials surfaces, corresponding expensive materials with suitable properties at corrosion and/or abrasion are deposited).





**Figure 1.** Schematic diagram of the exhaust system of the spent grains:  
1 - electric motor; 2 – gear; 3- motor support and reducer; 4 – screw; 5 - bush.



**Figure 2.** General view of a unidirectional valve:  
1-flange for connection to the air supply pipe; 2- manhole; 3- flap;  
4 - sealing.



a.



b.

**Figure 3.** General view of pipeline transportation of spent grains:  
a- inside the factory; b- outside the factory



a.



b.

**Figure 4.** General view of pipeline transport marc:  
a new; b-after one year of operation

-simplifies the overall technological achievement for that part, requiring only a few related technological operations;

-confers functional, technological and economic characteristics in the section, consistent with the role of functional requirements;

-achieved significant energy savings and labor because it concerns only related operations plating, not the whole technological process of manufacturing new parts;

-pollute far less than the material work on developing and manufacturing new parts;

-is particularly effective due energy savings, labor, materials, time and financial.

Reconditioning by plating and welding are however a number of disadvantages:

- the need for compatibility between the filler material and the support material;

- lack of adhesion or uneven adhesion between the coating and base material;

- the emergence of a heat affected zone in which they develop some nonconformities;

- need a good cleansing of the area uploaded to eliminate grease, oxides and impurities;

- tower deposition rates and thus low efficiency;

- the impossibility of certain complex surfaces;

- the emergence of many types of defects, especially at the intersection of welds;

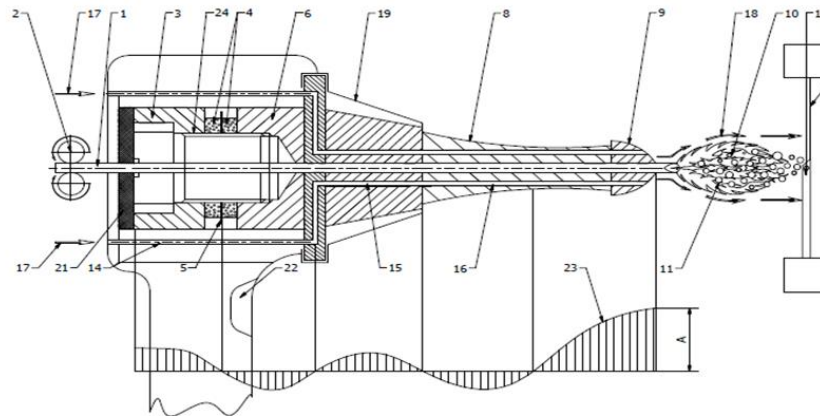
- deposited layers are uneven and inhomogeneous;

- postplacare require heat treatment;

- the phenomenon of dilution and modifying the properties of functional and technological section.

To eliminate these disadvantages and substantial reduction of some of them paper proposes a new method for reconditioning components of the transport system of the spent grains namely reconditioning plating ultrasonic welding field [5], [6]. The schematic is presented in the fig.1.

Wire electrode 1, made of filler material is driven by the drive rollers 2 and passes through the reflector Acoustic 3 discs piezoceramic 4 radiant acoustic 6, the amplifier ultrasonic concentrator 7 ultrasonic energy 8 and the active concentrator ultrasonic energy 9 unlike the arc 10 which melts in the form of very fine droplets 11, which are projected on the surface of the clad 12, after solidification, resulting in the coating 13. Ultrasonic system is introduced in the housing 19 and fixed through nodal flange 20, 21 being acoustically isolated and cooled continuously. The ultrasonic transducer is electrically polarized by the polarizing electrode 5 and the polarized electric screw driver through prepolarizare 24. The shielding gas 17 is introduced through the holes 14, 15 and 16, thereby forming a protective curtain 18, for the electric arc 10, as well as spray-coating 13. Ultrasonic system is so calculated and designed as to work under resonance with maximum amplitude A, in the melting of the wire electrode, chart particle velocity amplitude variation along the form 23. System Initial operation and stopping torch is an on-off valve 22.



**Figure 5.** Schematic diagram of a gun reconditioning weld cladding field ultrasonic activation wire electrode:

1-wire electrode; 2-driving roller; 3-acoustic reflector; 4- piezoceramic discs; 5-electrode electric polarization; 6-acoustic radiant; 7- acoustic the amplifier; 8 concentrator ultrasonic energy; 9-active part of the concentrator; 10- electric arc ; 11- drops of liquid filler; 12- plated surface; 13-deposited layer; 14,15,16-holes leading to the protective gas; 17- protective gas; 18-curtain protection; 19- carcass; 20- nodal flange; Insulation 21; 22- actuator; 23-diagram of variation of particle velocity amplitude; 24-prepolarize mechanical system.

According on the size of ultrasonic energy concentrator and the shape of the active part, the torch can also be used for reconditioning plating interior surfaces, such as curved areas of the pipes used to transport the spent grains [4].

## 2. Technological equipment used in plating in ultrasonic field

Plating efficiency of ultrasonic welding field depends primarily on the input mode power ultrasonic welding bath [1], [2], [3]. The research showed that spread of ultrasound in liquid metal bath has significant influence over the process of transfer of filler material by the arc and the metallization process, influences due ultra-acoustic cavitation and accelerated diffusion. The paper has been attempted many versions, but the best results were obtained using the following methods:

- ultrasonic activation of filler material in the spraying process and design the metallic surface;
- activation of ultrasonic welding bath or reconditioned piece plating (base material);
- a simultaneous activation and ultrasonic weld material and the base material ultrasonic cavitation and accelerating the process of diffusion.

Experimental research of the work was performed using ultrasonic activation of the filler material in the form of wire electrode through a welding torch design and implementation of the reconditioning cladding by welding with protective gas environment in the principle diagram in Figure 5. The ultrasonic activation of the material the addition wire electrode in the form of the following advantages are obtained [8], [9]:

- accelerates the process of ionization space arc;
- increases arc stability;
- substantially increase the transfer of the base material on the surface to be reconditioned by plating;
- to homogenize the liquid metal particles projected on the surface of the plated by a more intense spray;
- obtain a fine grain structure, due to the action-symmetrical regular and alternate ultrasonic waves;
- increase the speed of cooling and the degree of subcooling of the beginning of cavitation due to ultrasonic crystallization;

- accelerates the diffusion process;
- ultrasonic cavitation occurs in welding bath, which increases the cooling rate influencing the solidification process;
- substantially lowers the dilution phenomenon deposited layer and can be more easily controlled;
- disappear precipitation of grain boundary interface material - filler;
- there is an increased release of gas welding bath;
- cleaning is performed almost perfectly plated surface due to cavitation;
- internal thermal stresses disappear and no heat treatment is required postplacare;
- to obtain a structure with more improved functional properties and technology.

### 3. Experimental results

To highlight the effectiveness departure in ultrasonic field and its advantages compared to plating welded without activation ultrasonic were done experiments under the following conditions: the base material was a steel pipes OLT 60 to the chemical composition shown in Table 1 and the main mechanical properties shown in table 2; the filler material used was Fe Inconel 625, worked as a wire electrode with a diameter of 1.2 mm  $\phi$ , the chemical composition shown in table 3, and the main mechanical properties shown in Table 4; plating was done using welding in the environment of protective gases (Ar 100%) by depositing a single layer or multiple layers, and even without activation by ultrasonic welding regime using the parameters listed in table 5.

**Table 1.** Chemical composition of the base material [%].

The material basic	The components and content [%]										
	C	Si	Mn	S	P	Ni	Cr	Mo	Al	W	Fe
OLT 60	0.145	0.250	0.480	0.002	0.010	0.130	1.20	0.86	0.025	0.003	Restul

**Table 2.** The main mechanical properties of the base material.

The material basic	Temperature [°C]	R <sub>p0.2</sub> [MPa]	R <sub>m</sub> [MPa]	A [%]	Z [%]	kV-46 [J]	HB [HB]
OLT 60	20°C	875.0	987.0	22	37	178.9	234

**Table 3.** The chemical composition of the filler material.

The filler material	The components and contents [%]						
	C	Ni	Mn	Cr	P	S	Si
Inconel 625 Fe	0.018	64.10	0.027	21.96	0.0005	0.001	0.070
	Mo	Al	Nb	Ti	Cu	Fe	-
	8.57	0.38	3.35	0.25	0.01	0.51	-

**Table 4.** Main mechanical properties of filler material.

The filler material	Propeties						
	Temperature [%]	R <sub>p0.2</sub> [MPa]	R <sub>m</sub> [MPa]	A [%]	Z [%]	kV-46 [J]	HB
Inconel 625 Fe	20°C	645	761	19.9	76.5	277.2	237

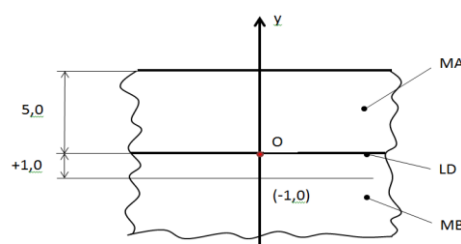
**Table 5.** Regime value parameters plating welding environment Ar 100%

Sample	Plating scheme parameters									
	$U_a$ [ V ]	$I_s$ [ A ]	$v_s$ [cm/min]	El [kJ/cm]	$I_u$ [W/cm <sup>2</sup> ]	f [kHz]	A [μm]	Tip [sarma]	Gas [l/min]	flow
without ultrasonic activation	15	320	52.5	7.30	-	-	-	cold wire φ1.2	15.0	
	20	280	48.4	7.50	-	-	-	cold wire φ1.2	17.0	
	24	260	41.6	6.57	-	-	-	cold wire φ1.2	19.5	
with ultrasonic activation	15	320	56.7	9.85	7.8	20	35	cold wire φ1.2	15.0	
	20	280	52.3	7.35	9.6	22	58	cold wire φ1.2	18.0	
	24	260	48.7	7.55	12.3	25	72	cold wire φ1.2	20.5	

Ultrasonic waves influence on the main technological and functional properties of the couple resulting from coating and without ultrasonic activation was done analyzing the following: chemical composition and modifications to it in the base material, heat affected zone and the addition material; main functional properties and technological base material, heat affected zone and the addition material; structural analysis and structural changes in the base material; heat affected zone and the addition material; possibilities of determining non conformities that may appear in three distinct zones and analyzing the stress and strain in the plated piece.

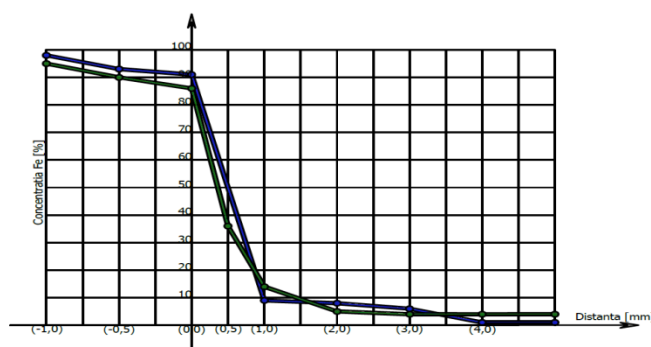
### 3.1. Determination of chemical composition and the changes to it after plating process.

As a result of thermal cycle which is subject to the base material and filler material (heating-melting-cooling-solidification) chemical composition changes occur, due to the phenomenon of dilution and modifications of functional and technological, due to structural changes occurring in the three distinct zones around the demarcation line (filler material, heat affected zone and base material). The measurements were done from the outer surface of the layer deposited on the inside of the base material, as shown in figure 6, step 1.0 mm (zero point marking the separation between the base material and the filler material).



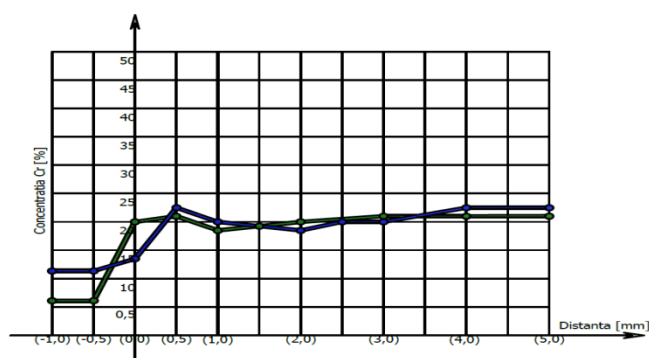
**Figure 6.** The scheme for measuring the chemical composition around the demarcation line; MA-material the addition; LD-the demarcation line; MB- base material

Samples were taken from unidirectional valve, marked and processed and subjected to chemical analysis by fluorescence X-ray, according to STAS 11464-1980 (ISO 9556/2002), to give the results in table 6. Figure 7 shows the change in the content of Fe to the depth measurement to give a sudden increase in the concentration in the heat affected zone in the case of cladding by welding without activating the ultrasonic and in the case of cladding by welding with the activation of the ultrasonic deposited material increase in the concentration of Fe it is more accelerated because it accelerated the process of diffusion from the base material into the filler material under the action of ultrasonic waves.



**Figure 7.** The variation of the concentration of Fe, measured from the outside of the deposited layer (Inconel 625 Fe) to the base material (OLT 60):

- without ultrasonic activation - green line;
- with ultrasonic activation of the material file- blue line



**Figure 8.** Variation in the concentration of Cr layer is measured from the outside (Fe Inconel 625) to the base material (OLT 60):

- for plating without activation by ultrasonic waves – green line
- for coating enabled by ultrasonic welding filler material – blue line

**Table 6.** Changes in the concentration of chemical elements picture in plating welded components in the environment of argon 100% area: filler-affected zone thermal-base material

No. crt	marking test tube	C	Mn	Si	S	P	Cr	Ni	Mo	Nb	Al	Ti	Cu	Fe	Plating nature
1.	layer 5,0 mm	0,018	0,025	0,070	0,001	0,005	21,96	64,10	8,57	3,35	0,38	0,25	0,09	0,95	without ultrasonic activation
2.	layer 4,0 mm	0,018	0,025	0,060	0,001	0,005	21,00	63,50	8,00	3,30	0,35	0,25	0,09	0,90	
3.	layer 3,0 mm	0,018	0,025	0,050	0,001	0,005	20,90	62,60	7,50	3,00	0,35	0,20	0,09	1,0	
4.	layer 2,0 mm	0,04	0,030	0,040	0,001	0,004	19,8	60,60	6,89	2,80	0,30	0,20	0,08	1,6	
5.	layer 1,0 mm	0,05	0,150	0,07	0,001	0,004	19,5	55,50	6,02	2,50	0,25	0,18	0,08	12,3	
6.	layer 0,5 mm	0,07	0,30	0,10	0,001	0,008	3,05	2,86	5,75	2,25	0,10	0,15	1,07	37,3	
7.	layer 0,0 mm	0,08	0,45	0,15	0,002	0,10	2,55	0,92	2,35	0,010	0,090	0,050	0,090	85,2	
8.	layer - 0,5 mm	0,10	0,45	0,20	0,002	0,10	1,40	0,25	1,05	0,001	0,030	0,010	0,080	90,4	
9.	layer - 1,0 mm	0,12	0,46	0,250	0,002	0,010	1,20	0,13	0,86	0,001	0,025	0,002	0,080	92,3	



10.	layer - 5,0 mm	0,018	0,027	0,070	0,001	0,005	21,96	64,10	8,57	3,35	0,38	0,25	0,09	0,51	with ultrasonic activation of the wire electrode
11.	layer - 4,0 mm	0,018	0,027	0,050	0,001	0,005	21,10	64,00	8,50	3,00	0,38	0,25	0,09	0,51	
12.	layer - 3,2 mm	0,018	0,027	0,030	0,001	0,004	20,00	63,50	7,90	2,55	0,35	0,25	0,09	0,51	
13.	layer - 2,0 mm	0,010	0,070	0,030	0,001	0,003	19,50	62,8	7,10	2,30	0,30	0,20	0,08	0,60	
14.	layer - 1,0 mm	0,010	0,10	0,170	0,001	0,002	19,00	60,1	6,90	2,06	0,25	0,20	0,07	2,40	
15.	layer - 0,5mm	0,02	0,40	0,270	0,002	0,075	2,60	4,50	3,06	2,95	0,20	2,15	0,07	4,55	
16.	layer - 0,0 mm	0,130	0,45	0,260	0,002	0,010	1,40	1,27	2,25	0,010	0,10	0,012	0,080	92,0	
17.	layer - 0,5 mm	0,135	0,46	0,260	0,002	0,010	1,25	0,35	1,15	0,005	0,050	0,002	0,080	92,5	
18.	layer - 1,0 mm	0,140	0,47	0,250	0,002	0,010	1,20	0,13	0,86	0,001	0,025	0,002	0,080	93,4	

Uniform distribution of carbides of Cr around the demarcation line is explained actuation ultrasonic waves during solidification process leading to a fragmentation of the structure and obtain a grain structure of fine mechanical properties and technology much better and more homogeneous section, where coating by ultrasonic welding filler material enabled. Similarly, there is a change in the contents of Ni, Si, Mo and Ti to form carbides which may weaken the coating, but are broken up and uniformly distributed when using the plating by welding with the activation of the ultrasonic wire electrode.

### 3.2. Determination of dilution.

Dilution is the main phenomenon that occurs in weld plating with special influence on the functional properties of the deposited layers and technology in general, the couple obtained, it can be taken as objective function when making plating process optimization. The experimental result that as the dilution increases, technological properties and functional layer is getting worse, therefore, to control and manage the phenomenon of dilution to an analysis of the factors influencing its factors occurring during the plating process.

A summary of the results is presented in table 7.

**Table 7.** Influence of dilution plating process parameters

Nr. crt.	The parameters of the plating process	The influence of process parameters on dilution plating
1.	The intensity of the welding	When intensity increases, the dilution increases as penetration increases
2.	The tension electric arc	Electric arc voltage increases, increase the width of the deposited layer decreases penetration and therefore decreases dilutions
3.	Linear welding energy	Increase energy linear increase penetration, increase the dilution
4.	Welding speed	Welding speed decreases, increases penetration, decreases the amount of molten material and therefore decreases dilution
5.	Nature protective gas	100% argon requires low voltage arc stability for a good, low penetration and therefore less dilution. 100% helium requires a higher welding speed so a lower penetration and therefore less dilution. Ar + He mixture should lead to greater penetration and thus greater dilution.
6.	The nature of the base material	Different influences on the chemical composition, the physical, chemical and electrical components; compatibility with the filler material and crystal structure.
7.	Nature of filler material	It has a different influence on the chemical composition, compatibility with amaterialul basic functional properties and crystal structure.
8.	Penetration	Key parameter influencing dilution when penetration increases, the dilution increases.
9.	The number of layers deposited	When the number of layers deposited increases, the dilution increases.
10.	The initial surface roughness	Influence the process of attaching the filler material depends on the



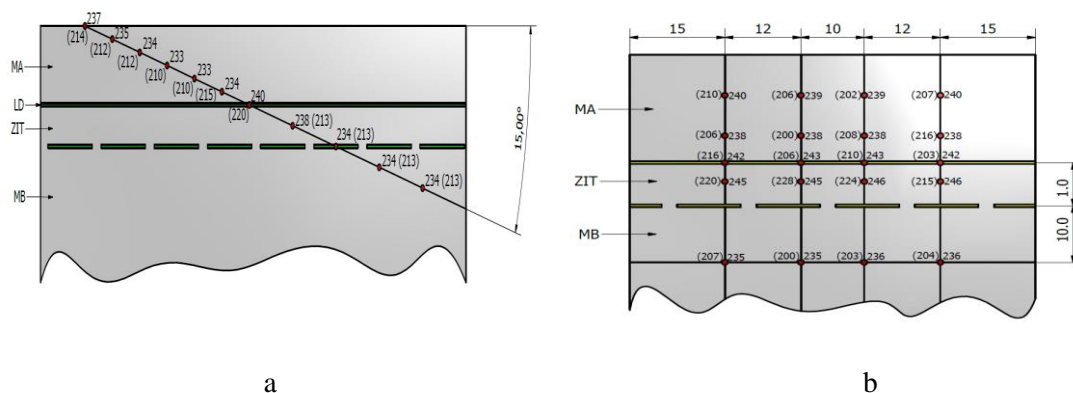
		base material and dilution.
11.	Ultrasound intensity	When intensity increases, and increases the diffusion process dilution increases
12.	Ultrasound frequency	The frequency increases, the speed of subcooling is high, the solidification speed is increased, dilution decreases.
13.	Particle velocity amplitude	Amplitude increase cure speed increases, crystallization and solidification process of dilution increases and decreases.
14.	The duration of ultrasonic activation	Time increased activation increases crumbling structure occurs and determine the deposited layer, dilution decreases.
15.	Type ultrasonic waves excited in the ultrasonic system	Longitudinal waves accelerate the solidification, radial waves accelerates the diffusion process, so dilution increases and the combination of longitudinal waves and where radial leads to a lower dilution.

The experimental results on different tracks and different configurations of surfaces revealed the phenomenon of dilution and its importance.

### 3.3. Determination of technological and functional properties of coated parts by welding

The purpose of the plating process of the components surfaces in the beer industry technology, is a substantial increase in corrosion resistance and wear resistance properties that depend in the first place structural changes taking place in three distinct zones of the couple result.

Resistance to wear depends in the first place increase hardness and grain structure of the deposited layer in three distinct zones. Determination of hardness HV10 on samples of the coated pieces were made by the diagrams in figure 9 a and b, to yield better values in the case of coating by activation of the ultrasonic welding filler material.



**Figure 9.** a - Determination of hardness HV10, ISO 15614-7 plated on a specimen by ultrasonic welding, and even without activation: MA - addition material; LD- the demarcation line; HAZ - heat affected zone; MB - the base material; Past values in parentheses are those obtained by plating without activation ultrasonic welding.

b - Determination of hardness HV10, ASME, a specimen plated by ultrasonic welding and without activation: MA - addition material; LD-the demarcation line, MB - magerialul base, ZIT-heat affected zone. The values in parentheses are those obtained by plating ultrasonic welding without activation

Analyzing the obtained results, presented in fig. 9 and 10, shows that weld cladding in ultrasonic field produces base material hardness increases by 10... 18%, 11.... 20% of filler material, while the heat affected zone increases by 3...5 / times [10]. This can be explained by structural changes taking place in three areas distincte torque resulting from the coating. Structural changes taking place in three distinct areas of the couple resulting from the coating. The properties are homogeneous section and

along the area where plating activation ultrasound because the process of diffusion is much faster and occurs and a relaxation of tensions internal heat due to the propagation of ultrasound through the three zones of the couple result after plating.

#### 4. Conclusions

1. Variation of the concentration of chemical elements in the three areas distinct components (heat affected zone base- material - filler material (different consisting in an increase of the content of C, Mn, Si, S, P, Cu and Fe, while a decrease in the content of Cr, Ni Nb, Mo, Al and Ti measured from the outside inwards;
2. The following parameters have a significant effect on dilution, as the most important phenomenon that occurs when using weld cladding in ultrasonic field: the electrical current of welding; voltage electric arc; linear welding energy; welding speed; nature protective gas; Basic material nature; filler material nature; penetration; the number of layers deposited; Initial surface roughness plated; intensity ultrasound; frequency ultrasound; the amplitude of the particle velocity; Ultrasonic activation time and the type of the ultrasonic waves in the excited ultrasonic system;
3. Weld cladding in ultrasonic field provides an increase of 10.... 18% of mechanical properties in the base material, 11 ... 20% in the filler material and 3....5% of the heat affected zone compared to plating without activation ultrasonic welding;
- 4- Changes in the functional properties filler material, heat affected zone and base material is explainable phenomena occurring due to the propagation of ultrasound through the three media, notably ultrasonic cavitation accelerate the diffusion, increasing the speed and acceleration of crystallization supercooling , leading in the end to obtain a fine grain structure with equiaxed grains of a size much smaller than in the case of plating without activation of the ultrasonic welding filler material.
5. Action during propagation of ultrasound, stretching - compression in the process of solidification leads to fragmentation and mixing grain carbides their section by ultrasonic oscillation amplitude and frequency ultrasound.

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