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Optimizing the Cost of Manufacturing Welded Thermo-resistant Steel Pipes

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The presence of stresses in the pipes of unalloyed and low alloyed steels with characteristics specified elevated temperature (high-temperature) can be put in the pipe-Dent the deformations occurring in the welded parts and the knowledge of their size allows to appreciate the ability of the test structures welded. To remove or reduce residual stresses and consequently to dimensional stabilization of the parts, use the thermal process. Comparisons have been made regarding the dimensional stabilization of the welded assembly by heat treatment of stress relief and dimensional stabilization by means of low frequency mechanical vibrations. Starting from the technological flow, two simulations were performed and the results obtained determined that the processing times were reduced in the case of vibration stabilization. The vibration stabilization system decreases thus reducing the manufacturing costs and consumes only a fraction of the heat demanded by the heat process, being one of the processes used predominantly for large welded assemblies, the intent being capable of being chipped at the place where the process of production.

Keywords: *thermos- resistant steels, de- tensioning, stabilising by mechanic vibrations, optimising the manufacturing costs*

1. Introduction

Weldable thermo-resistant steels with 0.15% C; 0.5% Cr; 0.5% Mo; 0.3% V are used in the manufacture of superheated and pressure vessel pipes in the energy and chemical industry and are part of the large-welded assemblies' category.

Considering the fields of use, these steels must provide creep resistance characteristics, namely ductility, especially elongation and cracking, at high, stable values during the use of the metal structure.

It is necessary that the defects occurring due to atom dislocations, or loops of marginal dislocations, cavities, etc. to be stabilized by thermal de-tensioning treatment, to ensure the mechanical characteristics of the steel for extended durations of use.

Several authors have stated the theory that the thermal degradation TD is due to the occurrence of ZIT of lesser or greater residual austenitic quantity, depending on the type of thermo- resistant steel (Cr-Mo-V) and the welding regime. If, however, this structure is subjected to post - welding treatments, the residual austenite begins to decompose during heating, being an unstable structure in addition to equilibrium. The decomposition phases begin by precipitation of carbides (Fe3C - cementite) and end with the decomposition of residual austenite in ferrite and perlite, and the precipitated carbons at the grain boundaries will reduce the plasticity of the ZIT.

If TD treatments (550 ... 650°C) are carried out in ovens without controlled atmosphere, precipitated carbides can oxidize, carbon having a high affinity for oxygen. Thus, the appearance of oxides causes a sudden decrease in plasticity and a local reduction in the resistance properties of heat-resistant steel, and the welded structure becomes heavily fragile.

Relaxation of stretch tension peaks is accomplished by lo-path plastic deformations. If these peaks encounter a fragile structure with a resilient Rm mechanical resistance, fine micro-fissures occur during TD treatments, rendering the welded construction unusable.

2. Thermic detensioning treatments of welded joints manufactured from thermos- resistant steels

In any welded structure there remain residual stresses, which can be diminished by thermal stress relief, TD, which has, among other things, beneficial effects such as: increasing the dimensional stability of the structure; reduction of corrosion sensitivity; decreasing the probability of producing fragile breakage by reducing triaxial stresses [1].

Thermal stress relief, TD, consists of heating, maintaining and cooling at well-defined temperatures. This is the most common treatment applied to welded joints.

The heating and cooling rates are chosen so that no additional stresses can be introduced into the welded structure which could further damage. Under these conditions, for low - alloy Cr - Mo welding steels, it is recommended that these speeds be max. 300°C/h.

Taking a decision on the application of stress relieving treatment, TD to a welded structure must consider the following factors but most importantly, some metals or metal alloys are fragile by TD.

In this case, the base metal (MB) tendency should be examined for strain relief. If the MB is fragile at TD, the welded structure will be strained by normalization. TD detensioning increases the manufacturing time and costs of the welded structure.

3. Comparative analysis of the welding structure's dimensional stabilization procedures

In the experimental program on electrically welded electric welding of 10CrMo9-10 alloy heat-resistant steel pipes, samples E3 and E3T, the following base and addition materials (coated electrodes) were used:

- 10CrMo9-10 (1.7380), 31 31.8 x 4.0 mm, 75 mm long, with chemical composition and mechanical characteristics specified;
- basic electrodes Cromobaz M, 2,5 mm, having the chemical composition and mechanical characteristics of the deposited metal specified. Prior to use, the Cromobaz M basic electrodes were dried for 2 hours at (250 ... 300)°C.

To establish the optimal parameters of the welding regimes, in this case preliminary samples were made which were then subjected to visual control and dimensioning. Following the preliminary experiments, the optimal welding parameters for the manual electric welding process with the Cromobaz M basic electrodes of Φ 2.5 mm (111), namely: welding current Is=(70...75)A, the arc tension U_a=(12...14V) and the welding speed v_s=(8...10) cm/min. After the welding cord was removed, it was cleaned of slag and splashed with the help of the slag cork and the wire brush. After cooling, each electrically welded electrically welded head sample was visually examined (with the naked eye and 5X magnifier), the welded joints being of adequate quality and without external defects [1].

Heat resistant point welded steel alloy 10CrMo9-10, F 31.8 x 4.0 mm (E3T), underwent a TD3 stress relief treatment according to Table 1.

In Figure 1 and Figure 2 there are presented the visual aspects of hand welded electrode welded samples with coated E3 and E3T electrodes.

Joints did not show welding defects on the exterior surfaces.

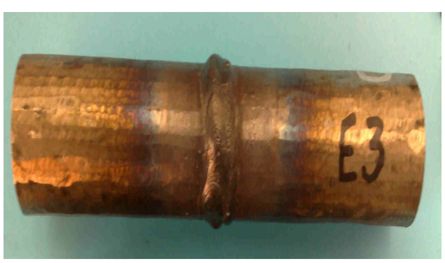

Figure 1. Point welded E3 sample, thermic untreated [1].

Figure 2. Point welded E3 sample, thermic treated [1].

Thermal stress relief of the welded structure increases the manufacturing time and costs of the welded structure.

In the case of large welded assemblies, because of the unevenness of the welding thermal field, internal stresses occur in welding materials, which in turn leads to their deformation, unless some thermal stress relief treatments are required. Remaining tensions can be viewed and calculated very hard, they are difficult to measure, and at high cost.

Table 1. Parameters of the thermic treatment de-tensioning regime [1]

De-tensioning treatment variant	Parameters of the thermic treatment regime, TD							Steel mark
	T_{min} ^0C	T_{max} ^0C	Heating speed, $v_{înc}$, ^0C/ hour	Cooling speed, $v_{răc}$, ^0C/ hour	Heating time, $T_{înc}$, hours	Stasis time, T_{men}, hours	Cooling time, $T_{răc}$, hours	
TD3	20	650	150	200	5,83	0,50	3,15	10CrMo 9-10 (1.7380)

Formula 62 is a resonance vibration resonance method developed by Stress Relief Engineering Co. (table 2.)

Table 2.

Nr. crt.	Name Welded ensemble	Revolution [rpm]	Initial current [A]	Final current [A]	Duration [min]	Observations
	SCANNING					
1	Welded pipes 1500 kg	0622	1.13			10 measurements were carried out. The revolution was increased constantly and step by step and the values were recorded in a table.
2.		0792	1.09			
3.		0874	1.11			
4.		1007	1.60			
5.		1162	1.73			
6.		1370	2.44			
7		1510	2.16			
8		1777	1.69			
9		1998	1.87			
10		2159	3.40			
VIBRATION						
1	Welded pipes 1500 kg	1777	1.69	1.49	10.00	5 revolutions were selected at which resonance spikes were found.
2		1370	2.44	2.24	05.00	
3		1007	1.60	1.42	03.47	
4		0792	1.09	0.98	01.07	
5		0622	1.13	1.02	01.32	

This allows reducing the residual stresses to a much lower level where the equilibrium of the superficially affected layer of metal is restored by modifying the positions of unstable atoms moving over very small distances to stabilize each crystal and at the same time the entire structure [2].

This process is ideal for large-scale applications with critical dimensions, which require very large furnaces to be thermally de-stressed, and for welded pipe assemblies used in power plants [4].

The dimensional stabilization of the metal structures was done in 3 steps:

1. Identification of the resonance spikes

The constant speed and vibration of the vibrator motor were constantly monitored by the A [%] - T [min], indicating the speed and the absorbed current at the occurrence of each spike on the accelerometer indicator A [%].

2. Selecting the revolutions correspondent to the resonance spikes

After the exploration has been completed and the resonance spike is recorded, 3 to 5 revolutions should be selected at which resonance peaks are found. To cover the entire range (500 ÷ 5000 rpm), one peak resonance, with the highest amplitude, is selected over an interval of 900 rpm. These speeds are those at which vibration will occur for dimensional stabilization.

3. Dimensional stabilising

Set the vibrator speed on the selected peak to the highest speed and let the vibrator work, following the alphanumeric device indications, stabilizing at this speed ending when the current value stabilizes [3].

4. Optimising the costs at welding thermo-resisting steels mark 10CrMo9-10

In the composition of the technological flow of production both the handling of the parts and their transport from one section to the other. By following the processes that contributed to the realization of this welded assembly, it was found that these components were made on two distinct machines, which resulted in a long manufacturing time, due to the discontinuity of the processes by the intervention of the operator but also the occurrence of the waiting times of the parts from one operation to another. All the factors involved in the assembly lead to an increase in manufacturing time and cost.

In the flow optimization analysis using WINQSB, two series of simulations were made, the first corresponding to the data in the data sheet and the second simulation by attempting to reduce the number of operations but also the number of operators involved in the manufacturing process of the assembly [5].

From the analysis of the production flow chart, where the welded assembly was de-tensioned for dimensional stabilization, in Fig. 3 resulted in a total required time of 1301.95 min respectively 21 hours and 42 minutes. Thermal detensioning treatment increases the manufacturing time and costs of the welded structure.

09-19-2017 15:36:14	Activity Name	On Critical Path	Activity Time	Earliest Start	Earliest Finish	Latest Start	Latest Finish	Slack (LS-ES)
1	Rec. mat.	Yes	2	0	2	0	1.9999	0
2	Debitare	Yes	2	2	4	1.9999	3.9999	0
3	Sanfrenare	Yes	190	4	194	3.9999	193.9999	0
4	Heftuire	Yes	100	194	294	193.9999	293.9999	0
5	Sudare	Yes	307.9500	294	601.9500	293.9999	601.9500	0
6	Transport	Yes	175	601.9500	776.9500	601.9500	776.9500	0
7	TT detensionare	Yes	350	776.9500	1126.950	776.9500	1126.950	0
8	Transport	Yes	175	1126.950	1301.950	1126.950	1301.950	0
9	Depozitare	no	10	776.9500	786.9500	1291.950	1301.950	514.9999
	Project	Completion	Time	=	1,301.95	mins		
	Number of	Critical	Path(s)	=	1			

Figure 3. Simulation of the manufacturing cycle of the welded assembly

Replacing the thermal stress relieving treatment with dimensional stabilization by means of low frequency mechanical vibrations, in figure 4 and 5, considerably reduce disruption during and after mechanical processing reduces the risk of cracking during welding and does not affect the mechanical properties of the welded assembly [3].

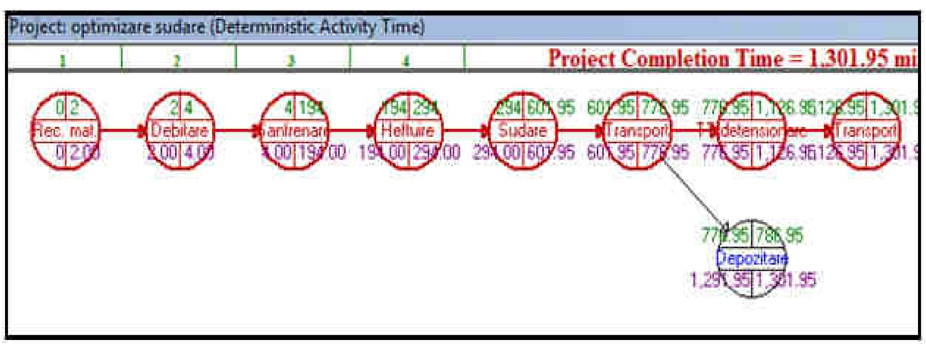

Figure 4. Graphic activity analysis I

Compared to the thermal relief treatment that has a long and long-lasting retention time, the duration of the application is in the order of tens of minutes, increasing production and reducing production times and costs.

From the two simulations, one can notice a time difference of approx. 4944 min respectively 8h 23 min. Graphic activity analysis with mechanical vibrations are shown in figure 6.

Activity Analysis for optimizare sudare cu VM

09-19-2017 15:53:57	Activity Name	On Critical Path	Activity Time	Earliest Start	Earliest Finish	Latest Start	Latest Finish	Slack (LS-ES)
1	Rec.mat.	Yes	2	0	2	0	2	0
2	Debitare	Yes	2	2	4	2	4	0
3	Sanfrenare	Yes	190	4	194	4	194	0
4	Heftuire	Yes	100	194	294	194	294	0
5	Sudare	Yes	307.9500	294	601.9500	294	601.9500	0
6	Control VM	Yes	20.86	601.9500	622.81	601.9500	622.81	0
7	Transport	Yes	175	622.81	797.81	622.81	797.81	0
8	Depozitare	Yes	10	797.81	807.81	797.81	807.81	0
	Project	Completion	Time	=	807.81	mins		
	Number of	Critical	Path(s)	=	1			

Figure 5. Assembly simulation with mechanical vibration control

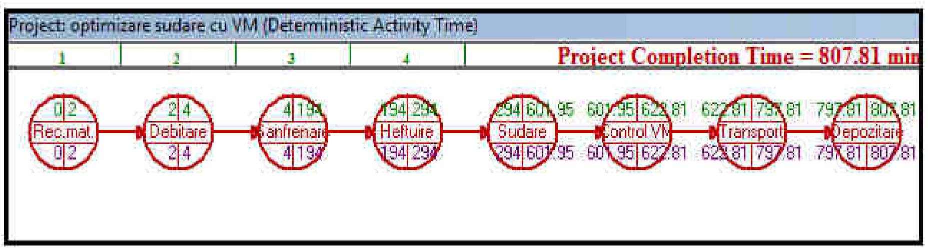

Figure 6. Graphic activity analysis with mechanical vibrations

4. Conclusion

Depending on the level and distribution of residual stresses, the volume of the weld structure and its complexity, it will be decided whether TD stresses will be made either totally or locally, i.e. in the adjacent areas. Local TD strain relief redistributes residual voltages to a larger volume in the structure, but reduces the voltage spikes. If both TD variants can be applied, total TD will be preferred;

TD detensioning increases the manufacturing time and costs of the welded structure.

The vibration stabilization system reduces distortion during and after mechanical processing and applies to a wide range of metals, reduces the risk of cracking during welding and does not affect mechanical properties.

In the case of series production, it can handle multiple parts at the same time, thus lowering manufacturing costs and consuming only a fraction of the energy demanded by the thermal process, being one of the methods used primarily for large welded assemblies.

The application time of the process is in the order of tens of minutes, this increasing productivity and reducing production times and costs.

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