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Comparatives Determination of Thermal Field in Welded Components

This paper presents thermal field variation from the welded components considering electrical arc welded as moving source, with the help of the modelling and simulation software Ansys, and the comparison of simulated sizes with those resulting from the experimental determinations.

1. Introduction

The necessity of knowing the thermal field from the welded components has a special importance in studying the residual tensions and strains that appear in the welded structure when welded in a gas-shielded environment.

Mathematically speaking this means determining the function T(t,r) where t stands for a certain moment, and r is the value of the position vector of a certain moment on the welded component or in a Cartesian system, of the function:

$$T = (t, x, y, z) \tag{1}$$

2. Analysis.

After the modeling and simulation of the welding processes in a gas-shielded environment (Ar, CO_2) it is absolutely necessary to proceed to the confirmation of the theoretical premises by means of the real-life welding experimental program. Thus the temperature from three areas along the welded joint was taken.

Considering all this a program has been developed, program that aims at the evolution in time of the temperature in a certain point on the axis of the welded joint, placed at the beginning, the middle and the end of the welded joint.

For the experimental determination of the thermal cycles covered by the previously mentioned areas of the welding thermocouples type R 87%Pt-13%Rh/Pt were used, having the diameter of 0,5mm, that can measure temperatures up to 1800^0C, on a short period.

The measures were taken starting with the moment when the welding arc kindled for the beginning position of the welded joint, near the thermocouple on a normal direction, at the longitudinal axis of the joint, that was set a time origin. The temperature values were read after the time periods mentioned in table 1.
The values of the experimentally determined temperature was marked by $T_{M,}$ and the values of the temperature obtained using the soft Ansys programme, of modeling finite elements was marked by $T_{MEF.}$

The percentage deviation of the values obtained experimentally in proportion to those obtained by means of the simulation programme was calculated using the formula:

$$e = \frac{|T_M - T_{MEF}|}{T_M} \cdot 100 \ \% \qquad (2)$$

Table 1, table 2, table 3, present the effective temperature values, measured on the axis of the welded joint (T_M), and those deduced through previous mathematical modeling (T_{MEF}), for the measurement points placed at the beginning, the middle and the end of the process.

In these tables the moments of the measurements are also mentioned (t). The experimental values represent the average of three measures.

Table 1 The evolution in time of the effective temperature (T_M), and that deduced through previous mathematical measures (T_{EF}), in a point placed on the welded joint, at the beginning of the joint.

Timp(s)	0	2	4	6	8	10	12	14	16	18	20
T_M [^{0}C]	20	1133	1060	960	892	706	608	490	350	241	233
T_{MEF}[^{0}C]	20	1112	1025	965	871	754	643	550	434	311	231
Abatere(%)	-	2	3	1	2,3	6	5,7	10	11	4	0,8

The temperature variation in time in a point placed on the welded joint, and that in a point placed at the middle of the welded joint being represented in table 2.

Table 2. The evolution in time of the effective temperature (T_M), and of that deduced through previous mathematical measures (T_{EF}), in a point placed on the axis of the welded joint, at the middle of the joint.

Timp(s)	0	2	4	6	8	10	12	14	16	18	20
T_M [^{0}C]	20	1515	1466	1367	1250	1037	890	721	555	434	311
T_{MEF}[^{0}C]	20	1535	1421	1327	1200	998	851	673	505	400	278
Abatere(%)	-	1	3	3	4	4	4	6	9	8	10

Table 3. The evolution in time of the effective temperature (T_M), and of that deduced through previous mathematical measures (T_{EF}), in a point placed on the longitudinal axis of the welded joint, at the end of the joint.

Timp(s)	0	2	4	6	8	10	12	14	16	18	20
T_M [^{0}C]	20	1200	1008	998	877	735	611	404	308	235	200
T_{MEF}[^{0}C]	20	1211	1100	950	821	689	565	367	278	211	189
Abatere(%)	-	9	9	4	6	6	7	9	9	10	6

3. The comparison of the values of the measured results and those obtained through digital modeling with finite elements.

As reference values for the comparison of the results there were used the charts obtained through the usage of the modeling and simulation programme Ansys, dedicated to the discussed application (Fig. 2, 7.4, 7.6), of the temperature variation in time for different areas: at the beginning, the middle and the end of the welded joint. These values are compared to the results of the effective measures in charts 7.1; 7.2; and 7.3. Having this purpose in figures 7.3, 7.5, 7.7 the evolution charts of the temperature determined through mathematical modeling T_{MEF}, and that effectively measured T_M, are overlapped.

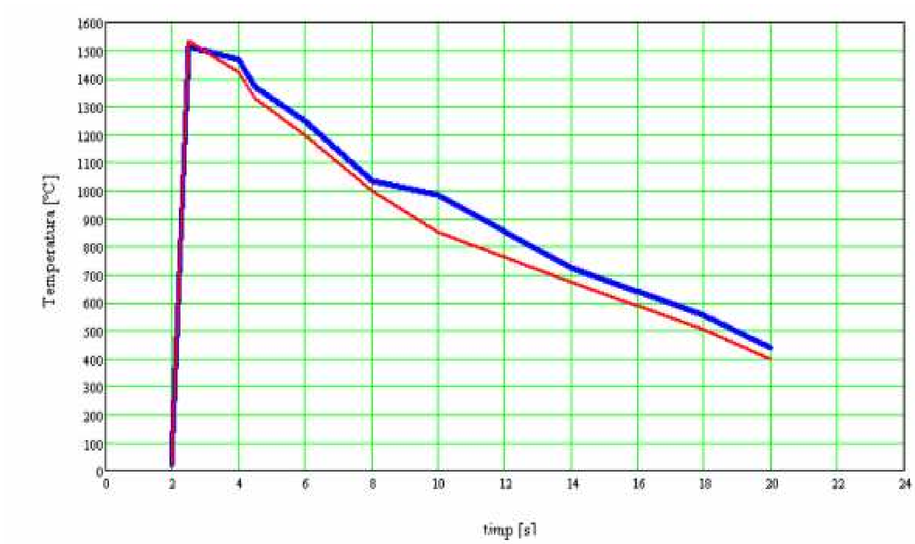

Figure 1 The comparison of the results regarding the measured temperature (T_M - red color) and simulated (T_{MEF} –blue color), at the beginning of the seam.

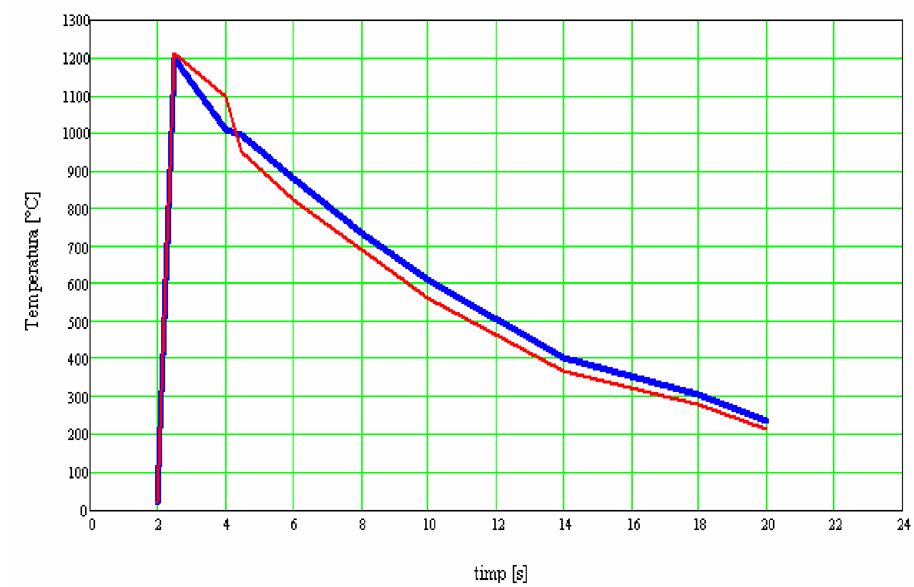

Figure 2 The comparison of the results regarding the measured temperature (T_M - red color) and simulated (T_{MEF} –blue color), at the middle of the seam

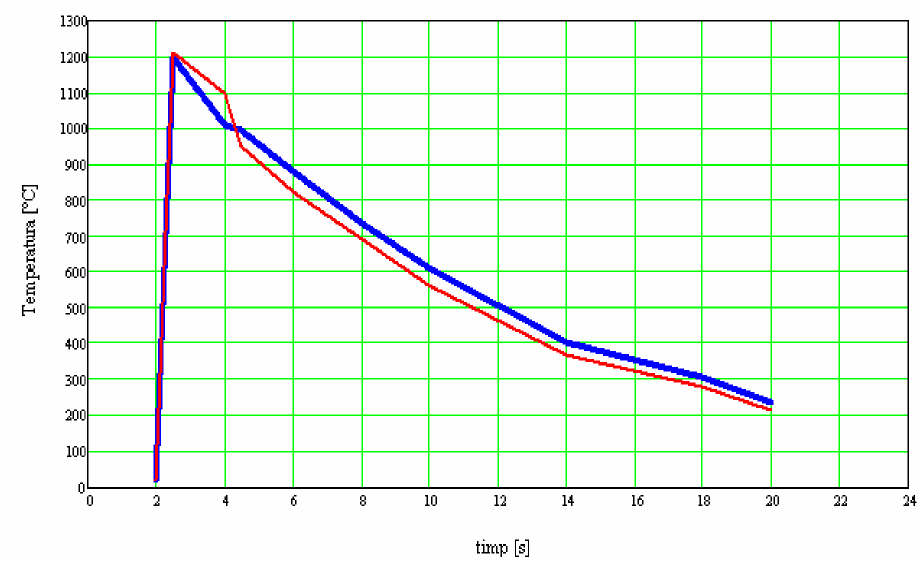

Figure 3 The comparison of the results regarding the measured temperature (T_M - red color) and simulated (T_{MEF} –blue color), at the end of the seam.

4. Conclusion

At the beginning of the seam a rapid heating is noticed till the temperature reaches a high value (Fig. 1).

Cooling takes place at a lower speed than that estimated, and that measured. As time passes the cooling speed is obviously decreasing.

It can be noticed that the values mathematically estimated were below the effective values registered during an effective welding. The highest difference was noticed after approximately 2 seconds from the beginning of the welding, when reaching top temperature.

Thus while the measured temperature which is actually the real one for this moment, reaches 1133^{0}C, the simulated temperature is of 1112^{0}C. Although the deviation is small (2%), it proves one more time the dependence of the material properties from the temperature. At following times of cooling, the mentioned difference of temperature is more reduced.

There can be noticed a better closeness between the values of the temperature determined through mathematical modeling (TM blue color), and that effectively measured (TR, red color). On some portions the curves for the two evolutions of the temperature even coalesce.

This allows the statement according to which there is a good correspondence between the values estimated through simulation and those experimentally registered. This stands at the basis of the validation of the mathematical model initially estimated.

The analysis of the values deduced through the simulation of the process at the end of the welding, brings in a new situation than the previous ones. On a short time, it was registered the emphatic increase of the temperature. Therefore, the welding components have been subjected to a big heating gradient. The evolution of the temperature is similar, with some small differences between the simulated and the effective values. The differences are mainly between 4-6 seconds, when the measured values have a bigger gradient than those obtained through simulation.

With distance increasing from the axis of the seam, the maximum temperature, rapidly drops at the beginning and then slows down. Touching the temperature tops is deviated in time. At the same time with distance increasing from the axis of the seam, the maximum level of the local temperature is reached later. At the same time the cooling speeds are smaller at a bigger distance from the axis of the seam. The maintaining duration of the materials at higher temperatures increases with the increase, in some limits, of the distance from the axis of the band put at the welding. An essential role is played by the involvement of the volume and the nature of the adjacent material.

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