Some considerations on the welding heat flow

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Some considerations on the welding heat flow

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Abstract. The modelling of a weld is not only related to the heat flow in the thermal part of the simulations. Addition of additive material and the simplification of thermal and mechanical behaviour should be considered. The basic idea is to replace a complex physical process with a much simpler one. This brings not only approximations, but also the need for calibration procedures to determine the heat flow. In the present paper we aim to model the relationship between welding temperature variation depending on the time and depth, and to model the relationship between stress and distance from the heat source (welding).

1. Introduction

Welding is a joining process used in production. For an efficient performance of welded joints, the influence of heat loss and thermal stresses that accompany the welding process cannot be emphasized too much. Many authors have conducted welding modeling and analysis studies. Other authors have also worked exclusively in the areas of heat flow during welding processes. A good understanding of the control factors in solidifying and cooling welding pool will ensure efficient design of welding technologies.

The heat provided by the source, irrespective of its characteristics, generates in the body an energy field different from that of the body, the thermal flow of welding. The heat flow differs from source to source and material to material (considering both physical properties and geometry). The thermal flow of welding comprises all the heat transfer phenomena through the materials, during the welding process. The temperature distribution, the duration of the material's high temperature maintenance, the cooling rates will influence many aspects of the performance of the joint. The thermal field also develops at the level of the filler material, causing it to melt. It is worth noting that the melting welding processes have the following features: o heating of the joint materials depends significantly on the type of source, heating is often complex (conduction and radiation); a temperature field in the liquid pool is influenced by the convection in the pool; a heating of materials that do not undergo phase transformations is done by conduction. It can be said that the heating phenomenon is predominantly conductive.

The heat source generates a quantity of thermal energy. This energy is transmitted to neighboring areas through an energy transfer process, modifying the temperature. The temperature and space temperature variation is different depending on the source-material relative size.

By adapting the welding limit conditions, it is possible to determine the temperature distribution in space and time, the cooling rate at a given point, the length of the liquid pool, etc, [1]. The form of isotherms generated by small-sized sources for massive pieces is hemispherical in the depth of the piece, having the same centre as the welded point (with the source). This is the case most commonly encountered in the welding practice, namely welded electrode welding, semiautomatic or automatic welding with a fusible / non-fusible electrode in a gas atmosphere. The deviation from the theoretical outline is the consequence of the turbulence in the metallurgical pool under the effect of gas dynamics and the temperature gradient. On the surface of the piece, the isothermal shape is elliptical, having the centre of the liquid bath, with the length and width influenced by the material characteristics and the welding technology (energy used, welding speed). Isotherms in solid material depend on material characteristics and technological parameters.

The area adjacent to the liquid pool is heated by conduction at temperatures that vary depending on the relative position relative to the stitch axis, is the limit of the liquid pool.

Depending on the maximum temperature reached, the time the material is at maximum temperature and the cooling rate, the area of thermal influence is subdivided into fine areas which have been indirectly thermally treated.

The material in this area exceeded the conventional heating limit, entering the overheating area (over 1100ºC). As a result, grains suffer an increase on the lower grains. Grain growth has the effect of reducing mechanical properties, increasing hardness, and increasing the risk of hot cracks, [2]. The size of this area is rarely 1.5 mm thick.

The normalized sub-area is characterized by fine grains. The area is a weak point for previously extruded materials (hardened by cold plastic deformation) when austenitic heating results in recrystallization, thus loss of properties previously obtained. The size of this sub-zone is comparable to the previous one.

The material is austenitized incompletely to the heating, here there is a reduction in the hardness of the material compared to the thermally unaffected base material. Softening is due to relaxation due to heating.

The return sub-area is the area where the material did not exceed the critical temperature, so there were no phase transformations. It is the largest area in the heat-affected zone (HAZ).

2. Research on the area that is affected by welding

Figure 1 shows a schematic diagram of the welding pool following analysis of 1018 steel welding technology, [3]. The welding pool is usually treated as a problem of spherical coordinates close to a hemisphere. Using the concept of conserving the energy relationship in a field and assuming that there is no mass transport with temperature-dependent thermal properties, the temperature distribution in the welding pool can be modeled by ensuring mass conserving the volume of the welding pool, as well as preserving pulse.

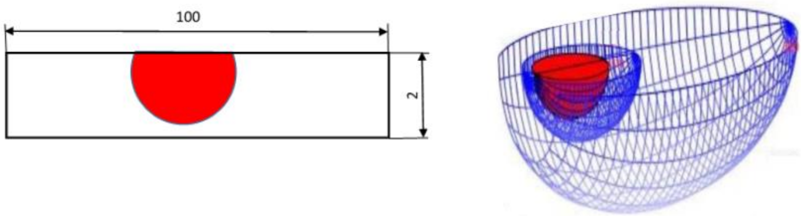

Figure 1. Approximate representation of the welding pool.

Before the tests, a test plan was prepared. The objective of the test plan was to cover the entire temperature range and input parameters encountered during normal welding. An infrared camera for measuring temperatures has been used.

Measurement of residual stresses can be achieved by the cutting method. The principle of the method is to isolate the cutting of the assembly made up of small elements fitted structure in advance bonded strain gauge bridges forming surface of the workpiece and whose dimensions are a few millimeters. A measurement of the deformations between the initial state and the final state allows the return to the residual stresses to which the element was subjected. The method is commonly used for welding. The longitudinal residual stresses produced by the potential deformations are estimated by measuring the deformations in the longitudinal sections whose faces are parallel to the welded points.

It is possible to perform the analysis of the residual stresses in the depth and by the diffraction of the neutrons in the presence of a voltage gradient as in the case of strong gradients of welding stresses. Neutrons offer an advantage that their penetration depth is higher than X-rays. Typical penetration values are 2cm in nickel alloys, 3cm in steels and up to 5cm in aluminum and its alloys.

3. Results and discussions

The results related to temperature measurement over time can be seen in table 1.

Table 1. Temperature variation depending on time.

t -Time (sec)	T- Temperature (°C) (Upper surface)	T -Temperature (°C) (1mm below surface)	T -Temperature (°C) (Lawer surface)
1	2450	1600	1000
3	2300	1550	980
5	2200	1500	950
7	1900	1400	930
9	1700	1300	900
11	1400	1100	870
13	1200	950	840
15	900	800	780
17	850	750	740
19	800	700	690
21	750	650	650

The variation in temperature over time is shown in the graphs in figures 2, 3 and 4. In this figure it can observed and functions that pass closest to the experimental points.

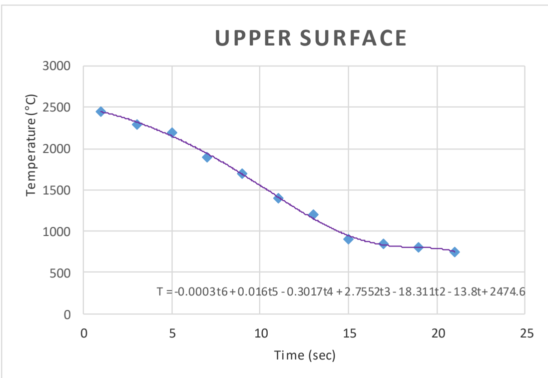

Figure 2. Heat transfer on the upper surface of the plate.

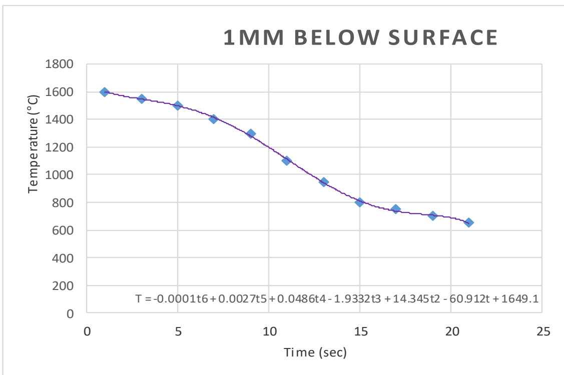

Figure 3. Heat transfer on the 1mm below surface of the plate.

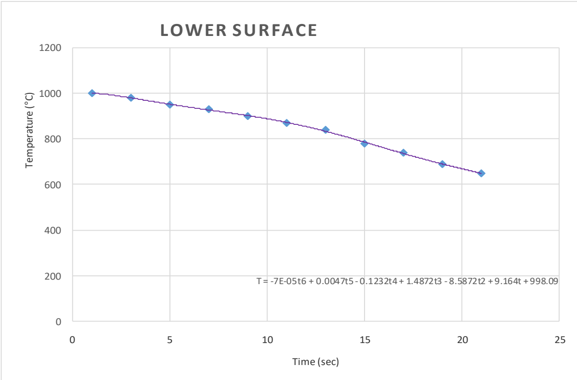

Figure 4. Heat transfer on the lower surface of the plate.

The profile of the temperature graph obtained is in close agreement with those obtained in the literature, [4, 5].

Results related to transvers stress depending on distance from the source welding are shown in table 2.

Table 2. Transvers stress depending on distance from the source welding.

DISTANCE (mm)	STRESS (MPa) - top surface	STRESS (MPa) - bottom surface
-50	50	49
-40	98	98
-30	149	145
-20	170	165
-10	215	180
0	210	163
10	220	135
20	140	110
30	130	95
40	110	98
50	95	95

The variation in transvers stress over distance from the source welding is shown in the graphs in figures 5 and 6. In this figure it can observed and functions that pass closest to the experimental points.

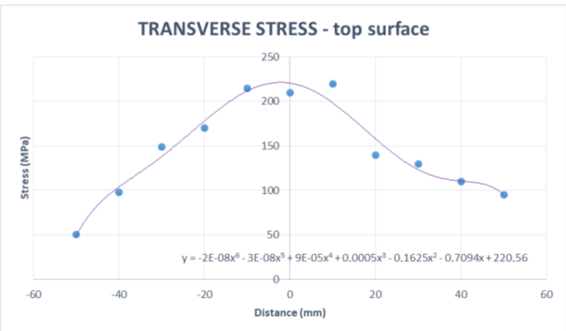

Figure 5. Transvers stress over distance from the source welding on top surface.

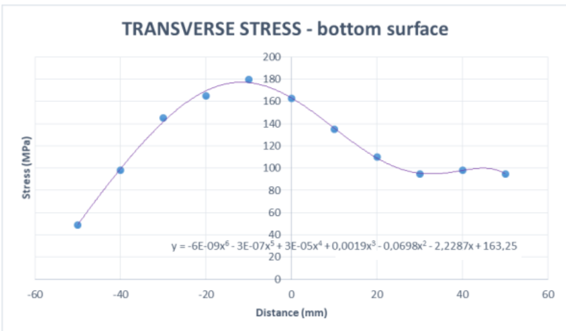

Figure 6. Transvers stress over distance from the source welding on bottom surface.

Results related to longitudinal stress depending on distance from the source welding are shown in table 3.

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Table 3. Longitudinal stress depending on distance from the source welding.

DISTANCE (mm)	STRESS (MPa) - top surface	STRESS (MPa) - bottom surface
-50	0	0
-40	100	100
-30	280	270
-20	310	300
-10	420	410
0	470	460
10	510	500
20	510	490
30	520	510
40	385	385
50	110	110

The variation in longitudinal stress over distance from the source welding is shown in the graphs in figures 7 and 8. In this figure it can observed and functions that pass closest to the experimental points.

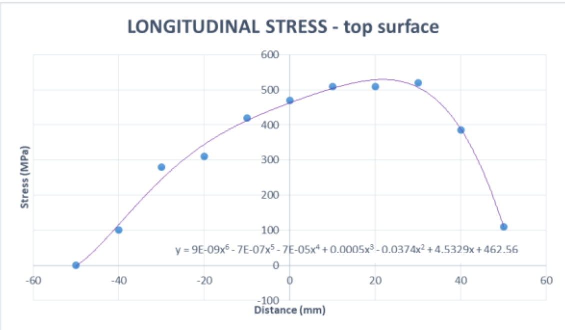

Figure 7. Longitudinal stress over distance from the source welding on top surface.

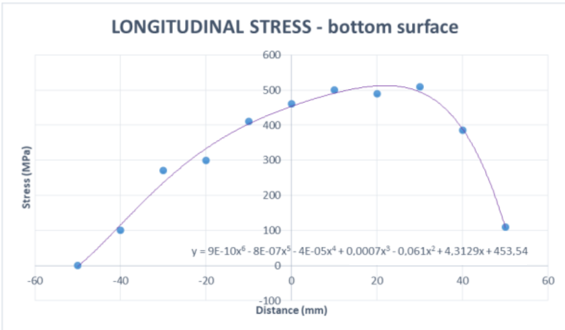

Figure 8. Longitudinal stress over distance from the source welding on bottom surface.

4. Conclusions

From figures 5, 6, 7 and 8, the stress distribution shows that the effect of the stress is higher near the heat source, which is the point of application of the electrode. This effect extends over the area covered by the welding pool as can be seen from the graph. This variation of the demand distribution is a common phenomenon in the case of welds. The figures show that the high transverse stresses obtained for the top of the plate (figure 5) are the result of the phase transformations involved in the welding pool. The variation of plate stress thickness is not uniform as expected (figures 7, 8). The high stresses faced by the welding pond and the surface of the plate can be achieved by heat treatment. The quality of the welding joints and the productivity of the processes used are directly influenced by the thermal processes that occur during the corresponding welding operations. Technological welding option is an important advantage in reducing the thermal effects and negative phenomena resulting from them in the metal which more difficultly dissipates the heat developed by the electric arc and is more sensitive to the action of the welding process.

5. References

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