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Temperature Change Calculation at Welding Products

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Abstract: Thermal calculation of the welded seams was conducted, made from heat resisting austenitic steel 10X11H20T2P by argon-arc welding. Schedules of temperature increment are constructed during various time moments on mode parameters existing on technology manufacture and on offered welding conditions. Structure forecasting opportunity and mechanical properties of welded connection various zones is shown: a welded seam, weld lines, zones of thermal influence and basic metal by calculation of temperature field changing in time. Calculation data are received at use of standard methods of calculation and under general formulas. Basic methods of experimental temperature test are considered at welding and computer application in calculations of temperature fields. Recommendations are given at the welding modes choice for prevention of hot cracks formation, namely, welding speed reduction up to 6 km/h is recommended.

Key words: Thermal processes · Welded connections · Austenitic class steel · Mechanical properties

INTRODUCTION

A basis for calculations of heating and fusion of metal at welding are the equations and formulas which use for quality assessment of temperature fields and also for quantitative calculations at testing of thermal cycles of welding, cooling speeds, thermal influence zone sizes, etc. In some cases real processes and the phenomena proceed more difficultly, than it describes by formulas. Character of thermal influence at welding, conditions of heat distribution and heat emission from welded details are complex and nondescript and calculation of temperature is complicated and inexact [1]. With the purpose of calculation accuracy increase temperature fields of welded connections experimental researches are additionally done [2, 3].

Procedure. Calculation procedures of temperature field test are based on the equation of heat conductivity for a case of a three-dimensional body with surrounding space:

$$\frac{\partial T}{\partial t} = \frac{\lambda}{c\rho}\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2}\right) = a\nabla^2 T$$

Where $\nabla^2 T$-Laplas operator; a = $\lambda/c\rho$-thermal diffusivity coefficient.

Along with Calculation procedures of temperature field test in practice experimental methods are used which find wide application in various branches of mechanical engineering.

In calculations of thermal processes [3-10] at welding the dependences received by a schematization and simplification of heat distribution actual processes are widely applied. The specified assumptions allow receiving the harmonious theory of temperature distribution in bodies at heating by various moving sources of heat. This theory actually reflects a qualitative picture and in some cases gives sufficient for technical calculations accuracy of welding processes description. In points where there are concentrated sources, the specified temperature can reach infinitely great values. The greatest errors in the description of temperature fields are observed in zones close to sources of heat [1, with. 158-173].

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The equation of temperature increment in a plate in a heat saturation stage:

$$\Delta ?_{??} = \frac{q}{2\pi\lambda\delta} e^{-vx/(2a)} K_0\left(\frac{vr}{2a}\sqrt{1+\frac{4ba}{v^2}}\right),$$

Where K_0-Zeroth order Bessel function of 1st kind, q-quantity of heat, [delta]-thickness of a plate, $r=\sqrt{x^2+y^2}$ - distance to a considered point from the beginning of co-ordinates, a-thermal diffusivity, [lambda]-heat conductivity coefficient, t-time, b-temperature emission coefficient, v-speed of welding.

Thermal calculation was made by means of MS Excel.

The Basic Part: At welding by austenitic steel fusion the main problem is a correct choice of welding modes for prevention of hot cracks in metal of a seam and a zone of thermal influence. In this connection, welding operation is considered in the paper as at this stage of technological process there can be some defects.

Initial data for calculation are the following: the material is a steel 10X11H20T2P, heat conductivity coefficient [lambda] is 0,29 watt/(cm·K), volumetric heat capacity is 4,75 joule/(cm^3·K.), temperature conductivity coefficient is 0,06 cm^2/ sec, efficiency is 0,85, welding current strength is 160 ± 20 A, voltage is 22 V, welding speed is 0,26-0,3 m/min (0,43-0,5 cm/sec), thickness of parts in a zone of welding is 2,5 mm, butt welding for one run. Electrodes of 4 mm in diameter are applied.

Initial body and environment temperature was accepted as a temperature reference point. As welded connections in their sizes have rather small thickness and are close to a plate, they are considered as semi-infinite plates. Temperature distribution on a sheet thickness is uniform; heat spreads only in a plain face of a part. With some assumptions the heating source was accepted to a linear continuously operating heat source and thermal calculation was made under convective heat exchange condition. 2,5 mm chrome-nickel steel sheets are welded in a butt. On the chosen mode of welding the following was required: 1) to create a temperature field of a limiting state; 2) to find maximum temperature distribution depending on distance from a seam axis.

For creating a temperature field of the limiting state corresponding to the chosen welding mode, we use the scheme of a powerful fast-moving linear source in a plate with heat emission. We choose calculated coefficient values of thermo physical properties for average process temperature T = 500°P. Temperature distribution curves are built across a seam depending on a distance y_0 from a seam axis from 0 to 5,0 cm for time moments t from 1 to 36 sec after arch centre passing through the given section. On Figure 1 on X-axis the distance y_0 from a seam axis is laid and on Y-axis are calculated temperatures during the corresponding time point t. Temperature distribution in certain time points t = const are presented by isochrones.

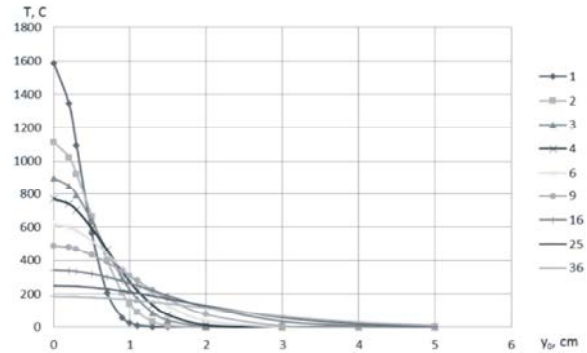

Fig. 1: Temperature calculation at butt welding of 2,5 mm sheets; temperature distribution curves on Y-axis during different time points

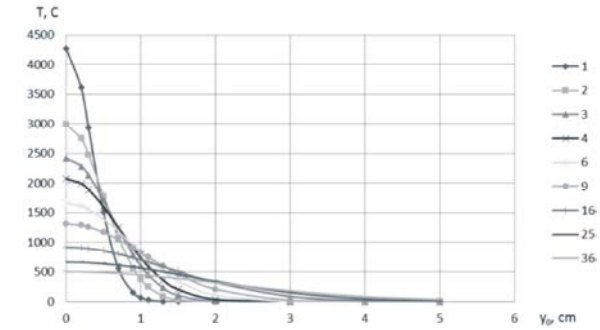

Fig. 2: Temperature distribution graph in welded connection at welding speed of 6 m/h on Y-axis during different time points

Having reduced welding speed to 6 m/h we will make a graph of a temperature distribution in a welded connection (Fig. 2).

With increase in capacity of a heat source q the length and width of zones increases on planes x0y. The increase in zone length occurs faster, than its width. The simultaneous increase in capacity of a source and welding speed at constant welding heat input qualitatively influences the form and the zone sizes the same as at welding of plates. Heat conductivity increase is equivalent to simultaneous reduction of source capacity and welding speed at constant heat input. Heat capacity increase also influences on increase of welding speed, i.e. zones are narrowed, but temperature distribution on a negative semi axis remains constant [1, p. 205-208].

Use of computers for temperature field calculations at welding can be various depending on an assigned task. In common cases computers are used for calculations under known formulas. If expressions do not contain any special functions the result can be found even on the low power computer. If calculation is carried out for a series of points under the same formula there is a necessity of a program, notifying initial data for specific calculation. Use of computers is rather effective in problems of optimization of welding mode parameters, for example, on cooling speed in the set temperature interval.

Experimental temperature test at welding has the advantages over calculating one though concedes to it in possibility of obtaining and analysis of the general regularities. It is necessary to consider as a true the approach at which both methods supplement each other and the decision on use of this or that method is accepted taking into account specific conditions and tasks. There are several experimental temperature test methods by means of thermal paint or thermal stickers [1, 2]. However, more often for a temperature measurement at welding thermocouples are used. Considerable EDS give thermocouples: chromel-alumel thermocouple, chromel-copel thermocouple, iron-constantan thermocouple.

Investigated heat resisting austenitic steel 10X11H20T2P is notable for high coefficient of thermal expansion, small heat conductivity and high relaxation resistance at high temperatures. It leads to high level of pressure and deformations at welding, tempering and at thermal cycling operation. The basic possible reasons of crack development in a welded seam are exhaustive metal plasticity of a seam as a result of a seam shrinkage and welded work pieces shift; intergranular character of high-temperature welding deformation.

For prevention of hot cracks development it is necessary to consider value of welding current force and speed of welding. According to received data most effective is control of welding speed, which can be reduced to 6 m/h (0,16 cm/sec) at welding of the steels inclined to hot cracks development.

CONCLUSION

The carried out calculation of temperature fields at welding and their subsequent analysis has shown applicability of a method for decrease in probability of hot cracks development at welding of parts from heat resisting austenitic steels 10X11H20T2P. Operating temperature comparison at welding of parts with condition diagrams allows to predict structure after cooling and hence, mechanical properties of welded connections (seams, thermal influence zones and the basic metal).

Summary:

- Calculation of temperature fields is carried out at argon arc welding of gas-transfer station compressor drive combustion chamber outboard housing, made from austenitic steels 10X11H20T2P.
- It is established that for prevention of hot cracks development at argon arc welding of flange forging and shell plate and also at backing run of defects it is necessary to consider value of welding current force and welding speed.
- For prevention of defects it is offered to reduce welding speed to 6 m/h.

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