Vysoká škola báňská-Technická univerzita Ostrava, Fakulta stavební
VŠB-Technical University of Ostrava, Faculty of Civil Engineering

2. MEZINÁRODNÍ KONFERENCE SPOLEHLIVOST KONSTRUKCÍ 2018

2nd INTERNATIONAL CONFERENCE STRUCTURAL RELIABILITY 2018

16. MEZINÁRODNÍ KONFERENCE MODELOVÁNÍ V MECHANICE 2018

16th INTERNATIONAL CONFERENCE MODELLING IN MECHANICS 2018

Sborník rozšířených abstraktů • 24. - 25. 5. 2018 • Proceedings of the extended abstracts

ESRA

ACCURACY ASSESSMENT OF FORMULAS FOR COOLING TIME ($t_{8/5}$) CALCULATION DURING THE WELDING OF CARBON STEELS

Vukić Lazić[1], Dušan Arsić[2], Aleksandar Sedmak[3], Ružica Nikolić[4], Mirjana Opacic[5]

Abstract

During the welding and weldability assessment of certain materials, the cooling time in the temperature range 800 to 500°C is a very important parameter, based on which one can predict characteristics of the welded joint. Today, for calculating the $t_{8/5}$ time there is an increase of use of analytical and empirical formulas. The aim of this paper is to compare results of those formulas to experimental results (measured by thermocouples).

Keywords

Cooling time, empirical formulas, carbon steel, model plates

1 Introduction

Execution of the adequate welded joint is, in majority of cases, accompanied by voluminous experimental or numerical investigations. However, today exist ways to predict the weldability and expected properties of the welded joint by application of the analytical and empirical expressions [1, 2]. If the satisfying results of those calculations are obtained, the process can be significantly shortened by eliminating the expensive and tedious experimental research. The objective of this paper is to point to possibilities to predict weldability of material, as well as to accuracy of empirical formulas. Research presented in this paper was conducted on examples of hard-facing of the carbon and tempered steels, while the formulas of Rikalin, Ito and Bessyo and formula based on limiting thickness [1, 2] were analyzed and their results were compared to experimental ones. Samples for experiments (measurements of temperature) were actually the plates made of carbon steels (one structural and four tempering steels): S355J2G3, C15, C35, C45 and C45E, with various thicknesses (s = 7.4, 8, 10, 20 and 30 *mm*). The thermocouples were placed and fixed in drilled holes of diameter $1.7^{\pm 0.05}$ mm. For that purpose, experiments were performed with various electrode diameters (Ø3.25 - PIVA 430 B (ISO, E1-300), Ø4.0 - PIVA 440 B (ISO, E1-400) and Ø5.0 - PIVA 460 B (ISO, E2-60) [3].

[1]Vukić Lazić, PhD, Professor, University of Kragujevac, Faculty of Engineering, Sestre Janjić 6, 34000 Kragujevac, Serbia, E-mail: vlazic@kg.ac.rs

[2]Dušan Arsić, MSc, Research associate, University of Kragujevac, Faculty of Engineering, Sestre Janjić 6, 34000 Kragujevac, Serbia, E-mail: dusan.arsic@fink.rs

[3]Aleksandar Sedmak, PhD, Professor, University of Belgrade, Faculty of Mechanical Engineering, Kraljice Marije 16, 11000 Belgrade, Serbia, E-mail: asedmak@mas.bg.ac.rs

[4] Ružica Nikolić, PhD, Professor, University of Žilina, Research Center, Univerzitna 8215/1, 010 26 Žilina, Slovakia *and* University of Kragujevac, Faculty of Engineering, Kragujevac, Serbia, E-mail: ruzicarnikolic@yahoo.com

[5]Mirjana Opacić, MSc, Innovation Center of the Faculty of Mechanical Engineering, Kraljice Marije 16, 11000 Belgrade, Serbia

***Table 1.** Comparative values of the cooling time $t_{8/5}$ (s = 10 mm)*

Electrode diameter d_e, mm	Hard-facing driving energy q_l, J/cm	Preheating temperature T_o/T_p, ℃	Cooling time $t_{8/5}$, s				Base metal
			$(t_{8/5})^J$	$(t_{8/5})^{Sgr}$	$(t_{8/5})^{EXP}$	$(t_{8/5})^R$	
4.00	20082	20	19.6	57.7	20.5	31.0	C15
4.00	17650	20	16.1	44.6	18.5	25.5	
5.00	29400	138	54.6	245.4	44.5	79.0	
5.00	24758	36	28.3	95.3	29.0	44.0	
4.00	18200	20	16.9	47.4	15.5	26.8	C45E
4.00	19413	36	19.6	58.6	20.0	31.5	
5.00	16736	96	19.7	61.1	20.5	34.0	
5.00	40551	80	69.8	326.3	57.5	84.0	S355J2G3
5.00	34087	62	50.3	208.2	47.5	68.0	
5.00	34588	20	44.2	171.2	40.0	60.0	
4.00	19809	20	7.6	14.0	8.5	10.0	C45 (s= 20 mm)
4.00	17975	50	7.3	13.5	7.5	10.1	
4.00	21101	20	8.4	15.9	9.5	12.1	
5.00	28356	71	13.1	16.1	12.5	11.5	C35
5.00	38667	97	23.0	36.4	19.0	16.2	
5.00	34027	20	14.3	18.4	14.7	11.2	
5.00	34255	20	14.4	18.7	17.5	11.5	
5.00	26863	20	10.0	11.5	10.3	9.0	

$(t_{8/5})^J$ – Ito-Bessyo formula; $(t_{8/5})^{Sgr}$ –Limiting thickness formula; $(t_{8/5})^{EXP}$ - experiment; $(t_{8/5})^R$ – Rikalin's formula.

2 Conclusion

In calculating the cooling time $t_{8/5}$ a dilemma arises which formula to choose. In other words, until now it was not known which formula gives results that are the closest to the experimental cycle, or the curve of temperature cycle obtained by other methods. By analyzing results from table 1 one can notice the unacceptable differences between the cooling time calculated from the formula $t_{8/5}= f(s_{gr})$ and experimental results. The best agreement with experimental results was obtained by the Ito-Bessyo formula. This conclusion is valid for hard-facing of the flat plates, while results for hard-facing of other surfaces were not considered.

Acknowledgements

This research was financially supported by the Ministry of Education, Science and Technological Development of Republic of Serbia trought project TR 35024.

References

[1] ARSIĆ, D., LAZIĆ, V., SAMARDŽIĆ, I., NIKOLIĆ, R., ALEKSANDROVIĆ, S., DJORDJEVIĆ, M., HADZIMA B. Impact of the hard facing technology and the filler metal on tribological characteristics of the hard faced forging dies. *Technical Gazette*. Osijek, Croatia: Editor Pero Raos, 2015, vol. 22, no. 5, pp. 1353-1358. ISSN 1330-3651

[2] LAZIĆ, V., SEDMAK, A., ŽIVKOVIĆ, M., ALEKSANDROVIĆ, S., ČUKIĆ, R., JOVIČIĆ, R., IVANOVIĆ, I. Theoretical-experimental determining of cooling time (t8/5) in hard facing of steels for forging dies. *Thermal Science*. Belgrade, Serbia, Editor: Simeon Oka, 2010, vol.14, no.1, pp. 235-246. ISSN 0354-9836.

[3] Catalogue of Filler Materials (in Serbian), SŽ Fiprom, Jesenice, Slovenia, 2015.