FIZIKAI SZIMULÁCIÓ ÉS MATEMATIKAI MODELLEZÉS A SICO-VIZSGÁLAT KEMÉNYSÉGELOSZTÁSI FELTÉTELÉVEL

PHYSICAL SIMULATION AND MATHEMATICAL MODELIZATION WITH HARDNESS DISTRIBUTION MAPPING OF SICO TEST

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ABSTRACT

Hot cracks occur when thermal shrinkage, along with restraint-induced deformation, cannot be accommodated by plastic deformation. That usually happens during welding to some alloys, which segregate on heating and cooling at near-solidus temperatures. When low-melting and mechanically weak phases form and occur over a wide range of temperatures, this is significant. Hot tensile testing can be used in conjunction with a thermal cycle resembling that of real welding to inspect for susceptibility to liquation cracking caused by the low-melting, weak phases. This procedure can be performed on a thermal-mechanical simulator using GLEEBLE 3500; It involves the tensile testing and determination of the hot strength and ductility of many cylindrical samples at temperatures below solidus. The Strain- Induced Crack Opening (SICO) test is an alternative to the hot tensile test during the simulated welding period.

1. INTRODUCTION

The GLEEBLE 3500 is a modern physical simulator; more precisely, it is a multifunction thermo-mechanical system experimental series. GLEEBLE is able to simulate a wide range of processes in real-time [1].

The material used is ZF50 unalloyed structural steel from which I use chemically tested cylindrical specimens to perform a cracking deformation test. The GLEEBLE 3500 heats the specimen and then compressed on elevated temperature. The cross-section of the volume fraction subjected to deformation increases considerably as a consequence of the sealing. Using DEFORM (FEM) finite element software, the test is modelled and analyzed.

2. PRESENTATION OF GLEEBLE 3500 AND THE SICO TEST DESCRIPTION

Physical simulation of material treatment processes means modelling in laboratory conditions that accurately replicates the thermal and mechanical processes which reach the material during actual phenomena. By establishing the conditions of final use, the material or structure's behaviour can be investigated, and the effects can be analyzed.

At the University of Miskolc, Institute of Materials Science and Technologies exists the GLEEBLE 3500 which is a fully integrated, digitally controlled thermomechanical testing scheme with Windows-based software computer support that allows extensive thermo-mechanical simulation and testing.

The GLEEBLE can be divided into three main units: mechanical, thermal unit and digital control system.

When a simulation or a scan takes place, the results are automatically inserted into the Origin software, which is a part of a compelling and flexible data analysis platform that comes with GLEEBLE 3500. Origin offers numerous built-in math functions for data analysis and includes the LabTalk coding language that can be used to evaluate and process comparative, comprehensive simulations and test data [2].

Fig. 1. GLEEBLE 3500 thermomechanical simulator

3. SICO TEST

The cracking caused by the deformation called SICO test is used to test materials that are susceptible to crack during hot forming. The experiment can be divided into two phases, heat resistance to the coveted temperature of the material, and compression of the material to the fracture initiation [3].

In the test, the heated sample is released using the GLEEBLE system. Consequently, the diameter of the workpiece increases in the center, and in the part of the deformation, a so-called dud is formed on which the cracks appear [4, 5].

Fig. 2. the SICO test specimen demonstrates the crack formation

The experiment is done on the GLEEBLE 3500 system at the Institute of Materials Science and Technology at the University of Miskolc; the physical simulation is called the SICO test. During the experiment, the

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workpiece is heated up and then installed in the GLEEBLE. The tested material is ZF50, the exact dimensions of which are as follows:

- 85 (+ 0.2) mm long
- 10 (+ 0.2) mm in diameter.

Fig. 3. Test specimens after a SICO test

The specimen is heated to 1150 °C by resistance heating, then cooled to 950 °C and 23-25 kN compression at 13 mm / s deformation speed. The size of the seal is 13 mm. At the end of the experiment, the data obtained using thermocouples are evaluated [6].

4. RESULTS

For symmetrical purposes, on the specimen's longitudinal axis, only four pairs of thermocouples were welded at 3 mm apart from the 25 mm section between the jaws only on the 12.5 mm section. Consequently, the positions of the thermocouples TC1, TC2, TC3, and TC4 were placed at a distance of 0 – 3 – 6 and 9 mm from the midpoint. Also displayed in Figure 4 The data collected by the machine was then evaluated by using ORIGIN 8.5 software. In the four tests, the temperatures measured by the four thermocouples shown as a function of time [8, 9].

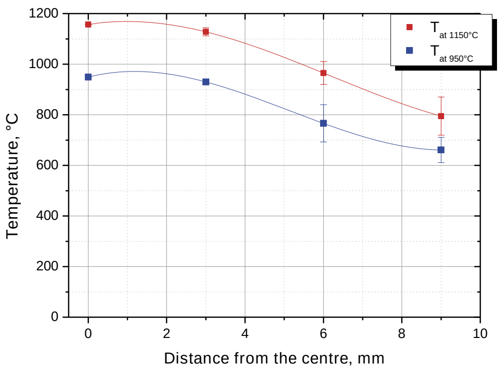

Fig. 4. Temperature determined by thermocouples along the longitudinal axis of the specimen at four positions at 1150 ° C and 950 ° C

In the diagram, at each distance, the red curve indicates the maximum of 1150 ° C, while the blue curve indicates the average of the temperatures measured at the start of the test.

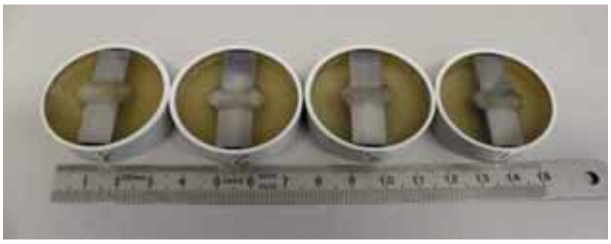

Fig. 5. Test specimens are embedded after etching, prepared for structural testing

I tested the hardness with an MVK tester of hardness (1 kg load) HV1. Performing the test, a 136 ° angle diamond was pressed into the specimen in the same way as in the Brinell. The square-shaped pyramid leaves a trace on the test piece's surface, so it is measured off the diagonal, and then determined by the Vickers hardness. During the measurement of hardness, the distance between the lines is 2 mm; the distance between the columns is 1.5 mm depending on the target's location [7].

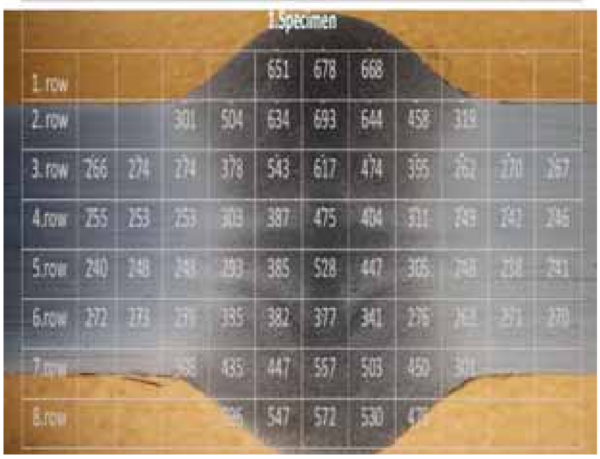

Fig. 6. the hardness result values for the specimen 1

Each hardness value can be obtained in accordance with their exact position a three-dimensional hardness map that can be used to detect hardness distribution on the cross-section examined, that is in the specimen's center. The three hardness distribution maps corresponding to the three samples are shown in Figure 7.

The hardness distribution for 1st and 2nd are almost the same. However, in the last case, morphology is similar, but in this case, there are more hardness values along the symmetry axis than in the first two cases.

In the case of SICO 3, the thermocouple of the TC2 and TC3 are detached, and afterwards, the results cannot be counted, so I neglected these results not to affect the successful experiments.

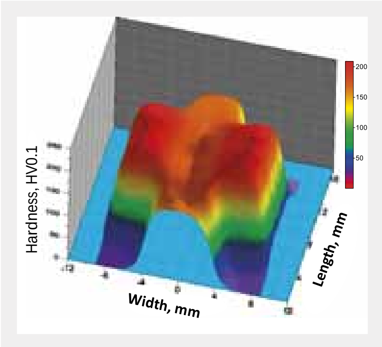

Fig. 7. a) SICO 1

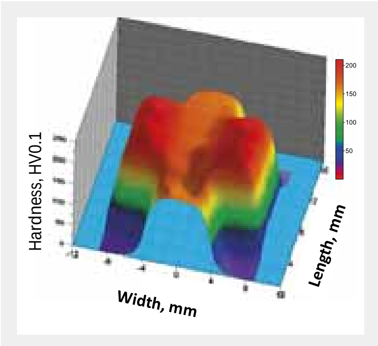

Fig. 7. b) SICO 2

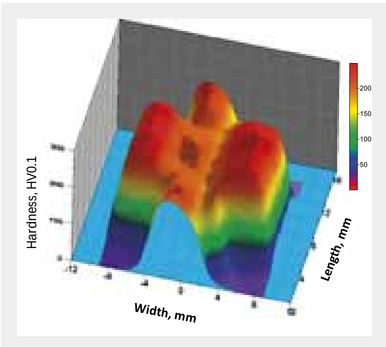

Fig. 7. c) SICO 4

Fig. 7. (a,b and c) Hardness distribution maps of the test pieces

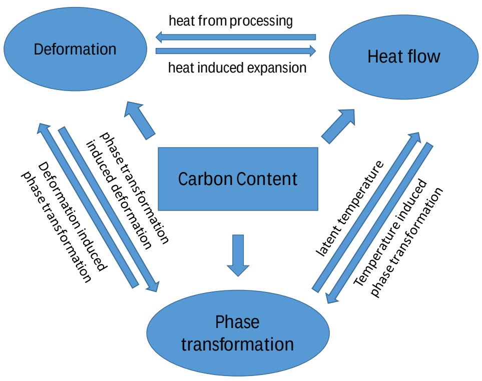

Fig. 8. The logical structure of DEFORM [10]

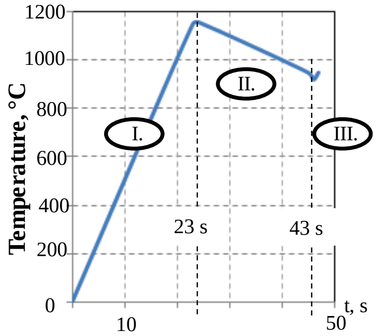

Fig. 9. The stages of modelling as a function of time

5. THE DEFORM NUMERICAL MODELING OF SICO TEST

I defined the three processes by Roman numbers. First, the heating cycle was modelled (I) at 1150 ° C using thermocouple number 1. My aim is that I approach the field of inhomogeneous temperature created by the GLEEBLE system in the workpiece as much as I can during this step of modelling, as shown in Figure 9.

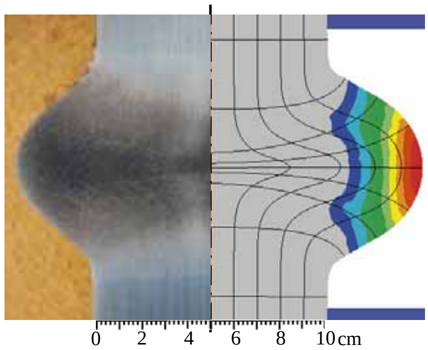

Figure. 10. Comparison of the post-formation thread run

In Figure 10 above, we can see that the right and the left material flow lines show a good match on the basis of a geometric comparison.

Overall, it can be stated that if the measured and calculated results are compared in a number of respects, then many results variables in numerical modelling are likely to give good results to the process.

6. CONCLUSION

- Physical simulation and mathematical modelling of the SICO (Strain-Induced Crack Opening) test on ZF50 steel grade were carried out in my dissertation, and the results obtained were validated.
- I conducted a short heat treatment period on the GLEEBLE device after the cylindrical specimens made of ZF 50 steel were prepared,

and four thermocouples were welded, heating up with DC current until 1150 °C keep for 2 seconds, then it cools down to 950 °C, which is the experiment's temperature when we apply the compression.

- THE DEFORM FEM program was used for the mathematical modelization of temperature's distribution which has empirical models, so the result we have is extremely close to the real phenomena. That is why we chose it during my dissertation work.
- As for validation, I chose parameters that can be measured in both processes. These two parameters were temperature distribution all along the specimens and grain orientation after deformation.

REFERENCES

[1] LUKÁCS J., NAGY GY., HARMATI I., KORITÁRNÉ F. R., KUZSELLA LÁSZLÓNÉ K. ZS.: Szemelvények a mérnöki szerkezetek integritása témaköréből, Miskolci Egyetem, Miskolc 2012., 210-218.

[2] http://www.muszeroldal.hu/news2/Fizikai%20szimulacio%20a%20Miskolci%20Egyetemen.pdf?type=INFOM

[3] Adonyi Y.: Heat-Affected Zone Characterization by Physical Simulations, Welding Journal (October 2006) p. 42-47.

[4] R. Kuziak, M. Pietrzyk, Interpretation of SICO Test, Iron and Steelmaker, 2002, 39-44, E. Oñate and D. R. J. Owen (Eds) CIMNE, Barcelona, 2005.

[5] Testing for Susceptibility to Hot Cracking on GleebleTM Physical Simulator S.T. Mandziej DUNAÚJVÁROS REGIONAL MATERIAL SCIENCE AND RESEARCH KNOWLEDGE CENTER DURATT 25-DRTT/2009 — Irt.: 2009/10/1 15th February, 2009, Dunaújváros

[6] R. Kuziak, M. Pietrzyk, Interpretation of SICO Test for Rod Steels

[7] Cseh-Bognár Sándor METALLOGRÁFIAI VIZSGÁLATOK, 2012 JANUÁR

[8] Dr. Tisza Miklós, Kovács Péter Zoltán, Lukács Zsolt: Számítógépes technológiatervező rendszerek folyamatmodellezése Oktatási segédlet, Miskolci Egyetem, Miskolc, 2010, Lukács Zsolt: Integrált tervező rendszerek II.

[9] SZABÓ JÁNOS Szálfutás elemzése kardánperem előgyártmány süllyesztékes kovácsolási technológiájánál, 2014. május 5.

[10] Jeffrey Fluhrer DEFORM TM 2D Version 8.1 User's Manual.