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Tests of Hot Crack Resistance Using the Transvarestraint Tests – Specialist Automated Test Rig

Abstract: The significance of the Transvarestraint test as one of the most reliable tests enabling the assessment of the susceptibility of materials and welds to hot cracking when exposed to imposed strains aimed to assess the susceptibility of steels and welds to solidification cracking as well as research-related needs inspired Instytut Spawalnictwa to develop, design, provide related software and implement an automated test rig examining hot crack susceptibility using the above-named method. The article presents the design and operation of the test rig. The adopted design and software solutions make the station user friendly as regards the entering of all data and welding head movement trajectory as well as the recording of data and measurement results in the form ready to print and archive. The solution also ensures the obtainment of the repeatability of the entire technological process.

Keywords: tests of welded joints, hot cracking, Transvarestraint test, automated test rig

DOI: *10.17729/ebis.2016.6/5*

Introduction

Assessments of hot crack susceptibility of steels can involve technological tests utilising the self-fixing of a specimen or machine tests with variable bend rates, e.g. Transvarestraint test. This test, enabling the assessment of the susceptibility to hot cracking triggered by imposed strains, is one of the most reliable methods assessing the susceptibility of steels, aluminium alloys and welds to solidification cracking. The assessment of hot cracking triggered by imposed strains makes it possible to determine the range of high-temperature brittleness, critical joint deformation rate and critical temperature-related deformation intensity, i.e. hot cracking criteria [2-8]. The significance of the test as well as research-related needs inspired Instytut Spawalnictwa to develop, design, provide related software and implement a specialist automated test rig examining hot crack susceptibility using the above-named method [1].

Test Rig Design

The Transvarestraint test rig was made in accordance with the following technological assumptions:

- welding technology: TIG without a filler metal (142),
- bend rate: up to 300 mm/s,
- specimen thickness: up to 20 mm,
- welding rate setting: up to 99 cm/min,
- setting of a delay time preceding the initiation

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of bending (counted after welding process termination): 0-99 s,
- setting of a delay time following the termination of bending: 0-999 s,
- welding torch positioning system accuracy: up to 0.1 mm

Test rig technical data:
- test rig supply voltage: 3 × 400 V,
- hydraulic system supply: 21.0 MPa,
- pump efficiency: V = 1.3 l/min.

The automatic test rig examining hot crack resistance using the Transvarestraint consists of the following components (Fig. 1):
- welding unit,
- specimen bending hydraulic unit,
- welding head drive unit,
- welding current and arc voltage measurement unit,
- control system with a data reading and recording computer,
- specimen fixing unit.

The welding units consists of a Fronius MW 300 inverter welding power source (TIG), welding torch and welding fixtures. The welding head drive unit (Fig. 3) features an EzM-60L-A stepper motor with an EzM-PD-60L-A stepper motor controller and a welding torch movement drive system mounted on a special structure fixed to the actuator housing.

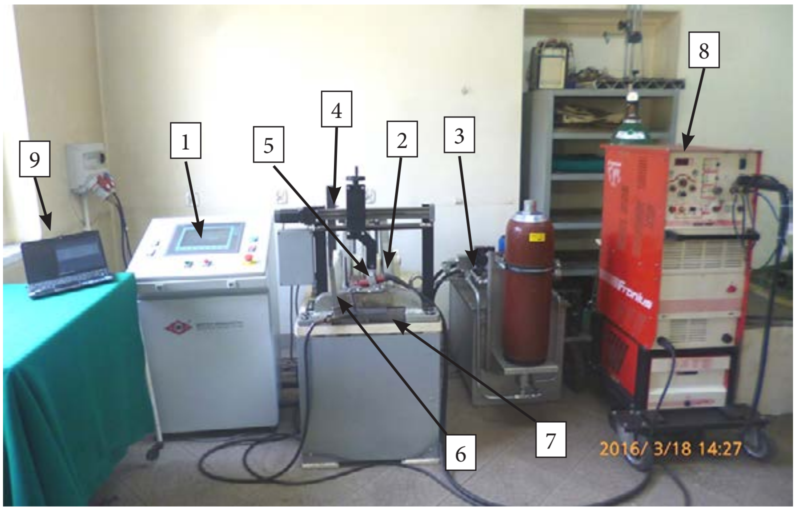

Fig. 1. Specialist automated rig for testing hot crack resistance using the Transvarestraint test – main view. 1: Control system (with control panel and control cabinet); 2: Hydraulic actuator; 3: Actuator supply system; 4: Welding head motion unit; 5: Welding torch; 6: Specimen fixing unit; 7: Test specimen; 8: Welding unit; 9: Computer for the recording and archiving of data

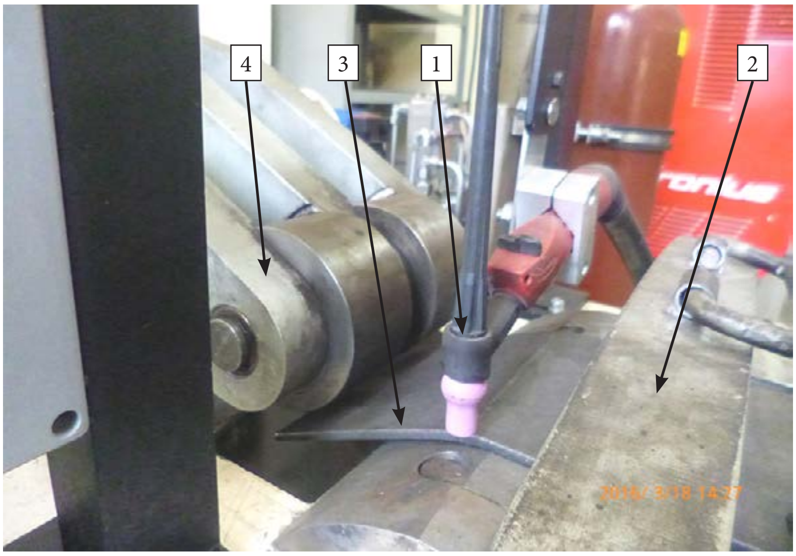

Fig. 2. Bending of the specimen after the completion of the welding process 1: Welding torch 2: Specimen fixing system; 3: Test specimen; 4: Actuator arm; 5: Specimen bending die

The hydraulic unit consists of a hydraulic actuator and a hydraulic supply system (SHZ 084/14) (Fig. 4). The hydraulic supply unit is controlled using a touch control panel installed in the control cabinet. Using the touch panel, the operator can set a bend rate as well as the rate of an actuator return to its original position (after bending). The rate of actuator bending movement can be set up to 300 mm/s. For such rate values, it is possible to bend specimens having thicknesses of up to 20 mm. The actuator is provided with electromagnetic sensors transmitting information about actuator positions to the control system. The technical data of the hydraulic unit include a power supply of 3 × 400 v, a hydraulic system supply of 21.0 MPa and a pump efficiency of 1.3 l/min.

The specimen fixing unit is composed of clamps fixing a specimen using bolts and between ten and twenty exchangeable dices made of steels blocks having assumed curvatures corresponding to specimen bending radiuses and made on one of the block edges. Each die has its own identification number. After the fixing of an appropriate die and a specimen, the unit is ready for the programming of a test cycle.

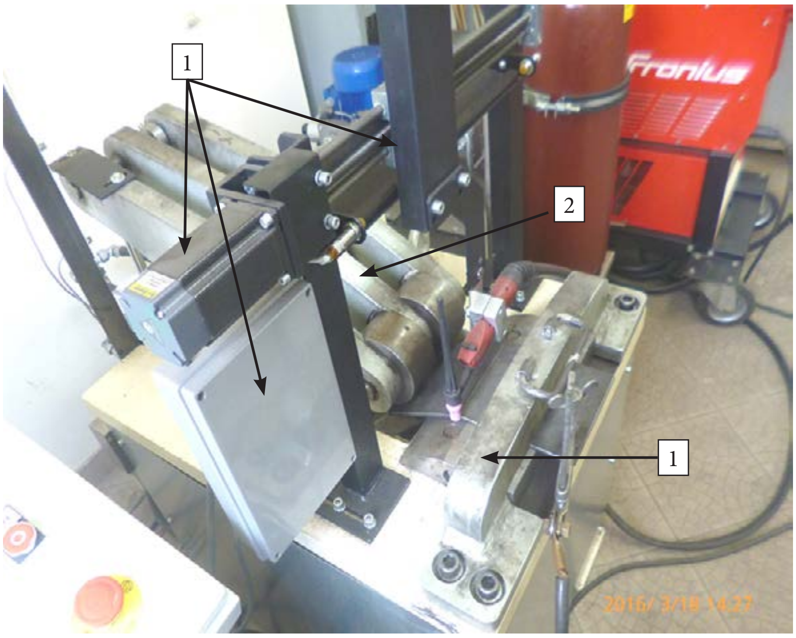

Fig. 3. Units for the driving and positioning of the welding torch (1), specimen bending (2), specimen fixing (3)

Fig. 4. Supply system of the SHZ 084/14 hydraulic actuator

The units responsible for power supply, measurements, protections, control of drives, rig operation and monitoring as well as units for communicating with the operator are installed in the cabinet containing the operator panel. The panel contains elements connected with the manual operation of the rig and the operator panel informing about the ongoing operation of all the rig elements and about their malfunction along with its reasons. The operation rate of each drive is controlled independently. The drives are automatically stopped in the event of their overload. In addition, the rig is provided with the system of programme, power, temperature (monitoring the operating temperature of the units) and electromagnetic (signalling the position of the hydraulic actuator and welding torch) protections.

The basic components of the control system include a Siemens S7-1200 (CPU1414) programmable controller provided with modules containing digital and analogue inputs/outputs as well as operator touch panel (Siemens KTP 1000 colour). The programmable controller processes signals coming from all the rig units. The logical appropriately structured algorithm of rig operation is used to generate output signals for all drives and failure signals read by the operator on the terminal screen. The control system (operator terminal combined with the Siemens controller) enables the operation of the rig both in the automatic and manual mode. To move between terminal screens of various functionalities, the operator needs to touch related pictograms visible on the screen. The screens available to the operator include the screen of operation mode (automatic/manual) selection, rig operation control, settings of technological parameters, process data, counter of specimens and time setting. Each of the above-presented screens displays a current date and time. Failures and their reasons are communicated by appropriate messages.

The terminal is also used for the monitoring of the number of tests performed in a 24-hour cycle and the total number of tests. The control cabinet is provided with a measurement system built based on transducers (LEM), i.e. a current transducer (LT 1000-SI) for electronic measurements of welding current and a voltage transducer (LV25-P) for electronic measurements of welding arc voltage. The transducers are combined with a NI9215 measurement card (National Instruments) provided with analogue inputs.

The control and measurement systems transmit data to a computer reading out identification and measurement data of a test specimen; readouts are available in a ready-to-print form.

Manual Control and Programming

In the manual control mode, the operator undertakes the responsibility for the operation of the rig. The manual mode allows switching on individual units and drives of the rig in any sequence. However, to prevent improper operation or even damage to the rig, it was necessary to implement programme protections stopping certain drives in situations posing threats, e.g. leading to failures. The manual rig operation mode is intended for the following activities:

– verification of the correct operation of the drives of individual rig units,
– activities connected with the setting and maintenance of rig elements,
– programming of the initial welding torch position and welding trajectory,
– programming of a safe welding torch position during the bending of the specimen,
– programming of the welding torch position following the termination of a test cycle and enabling the problem-free removal of the specimen,
– setting the initial position of the actuator preceding the automatic cycle of operation,
– entering data concerning the identification of a test specimen, and
– entering all other data concerning the technological parameters of rig operation necessary for the performance of a test in the automatic cycle.

The pictograms of drives related to the actuator, power-on, resetting and the power-off of the motor are visible on the manual operation control screen of the operation panel. The initiation or the stopping of the above-named drives requires the touching of appropriate icons. The pictograms of the welding torch movement drive (in the fast or precise mode) make it possible to programme (and ultimately reach) the points of welding process initiation and termination. The control systems enable the reaching of the above-named points at accuracy even higher than the adopted value of +/- 0.1 mm. To move the welding torch to a previously programmed point of welding process initiation (from any other position/location) the operator should touch a related icon.

The entering of the identification data of a given test specimen as well as other data concerning test processes is performed using appropriate icons. The system allows the automatic movement of the welding torch to the welding process initiation point from any other positon/location of the torch (by selecting an appropriate icon) as well as the verification (without welding) of a programmed trajectory at a preset welding rate (by the automatic movement of the welding torch).

Before starting a test, the operator should enter the following data (using the terminal touchscreen):

– specimen identification: specimen no., designation, specimen material, yield point and material strength,
– bend die-related data,
– welding process-related data: welding rate in cm/s, welding process initiation and termination point. After the programming of welding trajectory, the screen displays the length of a welding path,
– data related to the operation of the hydraulic actuator: the setting of a delay time preceding the moment of post-weld bend initiation within the range of 0 to 99 s, the setting of a hold time following the termination of bending within the range of 0 to 999 s and bending rate up to 300 mm/s.

Automatic Control

The automatic operation is possible after satisfying all the conditions necessary for the initiation of operation in the automatic mode; such conditions must be confirmed by related statuses of sensors and protections of test rig units.

The presence of irregularities precluding the operation of the test rig is signalled by appropriate communications displayed on the terminal.

The cycle starts with the movement of the welding torch at a preset rate and with assumed welding parameters; the cycle starts from the starting point being also the point of welding initiation. After reaching the previously programmed point of welding trajectory termination, the process of welding is finished and the welding torch is moved outside the specimen area. The reaching of the welding process termination point is followed by the metering of a previously programmed delay time preceding the initiation of bending performed at a programmed rate. The completion of bending is followed by the metering of a previously programmed delay time following the termination of bending and the return of the actuator to its upper position (at a preset rate). Once the actuator arm has reached its upper position, the welding torch is moved to a point located outside the specimen area enabling its problem-free removal.

Based on data coming from non-contact sensors fixed on the hydraulic actuator, the control system displays values concerning the duration and rate of bending on the terminal screen and sends them to the computer.

Reading and Recording of Data

The screen of the operator panel and that of the computer for reading and recording test-related data also display information about the satisfaction of initial conditions necessary for the initiation of an automatic test process, data of test specimens entered in the control system as well as process data calculated and measured during an automatic test cycle.

The reading of specimen and test-related data requires the selection of the process data icon on the operator panel screen. The data are also accessible following the completion of the test using a computer combined with a controller made by Siemens (connected via an Ethernet cable) enabling the recording and archiving of complete specimen-related data sets as well as measurement data concerning welding current and arc voltage. After the performance of a test, data are automatically archived in the form enabling their printout.

Concluding remarks

The solutions concerning the designs and software programmes related to the Transvarestraint test rig ensure the following:

- high and repeatable quality of tests,
- high precision of parameter settings,
- complete recording of specimen test-related data,
- automatic archiving of test results in the form ready to print out,
- user friendly environment enabling the programming and controlling of the process as well as the entering and recording of data.

The TIG welding method (without a filler metal) adopted for the above-named test rig can also be replaced by MAG, MIG and TIG welding with a filler metal. In such cases, some minor modifications involving the welding power source or welding fixtures could be necessary. The TIG welding method with a filler metal will make it possible to test the hot crack resistance of weld deposits or of specific material systems, e.g. filler metal – base material [8].

The above-presented tests confirmed the accuracy of the assumptions concerning design-related solutions, test rig operating software programmes as well as the technological and economic attractiveness of adopted solutions ensuring high repeatability, precision of parameters settings and easy operation of the rig in relation to the entire automation of testing processes. The adopted design and software-related solutions make the rig user friendly as regards the entering of all data and welding head movement trajectory programming as well as the recording of data and measurement results in the form ready to print and archive.

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