APPLICATION OF THE IMAGE CORRELATION SYSTEM TO DETERMINE THE MECHANICAL PROPERTIES OF WELDED JOINTS

DOMAŃSKI Tomasz [1]

[1]*Czestochowa University of Technology, Institute of Mechanics and Machine Design Foundations, Czestochowa, Poland, EU*

Abstract

The subject of the work is to present the possibility of using a non-contact optical system for measuring strains. Dantec's multi-unit Q-400 3D image correlation system was used. The aim of the study was to determine the distribution of displacements and strains on the surface of hybrid welded samples during the tensile test. The measurement was mainly used to estimate the mechanical properties of the welded joint, taking into account the change in the properties of the various joint zones. Measurement was carried out by tracing the displacement of the prepared surface of the tensile sample. In the paper, the results of the studies show the displacement and deformation fields for different tensile steps of flat samples to compare the effect of the process parameters selection on the mechanical properties of welded joints. Results were compared with the results of tensile test of the base material to determine the impact of the welding process change the mechanical properties of the investigated steel.

Keywords: Strains, displacements, 3D image correlation system

1. INTRODUCTION

The use of a non-invasive measurement method makes it possible to detect defects more quickly without the need for specialist preparation of test specimens. The advantage of using optical measurement methods of deformation or stress distribution is the ability to identify changes in the surface of the test material at microscale level this allows early identification of the process before its dynamic development. The digital image correlation method used images of the object taken at the same time by several optical cameras with high sensitivity to deformation and vibration of the object being observed. This method of measurement is currently used increasingly to determine the components of stresses, deformations or displacements in laboratory conditions, and to identify defects in machine construction components under the influence of static loads or dynamic variables over time [1, 2]. Measurement methods allow for easier adaptation to the measurement of parts of machine parts in their natural industrial environment under real operating conditions.

2. THE 3D SYSTEM OF IMAGE CORRELATION

The Q-400 system used with the ISTRA 4D software is a multifunctional non-contact tool for measuring the deformation of a tested object in both two- and three-dimensional coordinate systems. The principles of the system are based on relationships existing in the continuous mechanics. Dimensions and positions of the two points in the state before and after the deformation are considered. The correct operation of the system is based on the appropriate lighting and then the analysis of the light beam reflected from the surface of the observed piece before the load and in the subsequent steps of the load for consequence the deformations to appear.

The measurement method is based on the correlation of digital images, recorded with two or more cameras. The surface of the object is covered with a layer of white and black paint. The measurement is done by tracking spots coated surface of the object subjected to load. Using two digital cameras, it is possible to perform 3D analysis. When cameras record a test object from different pages, the position of each point of the object is focused on a specific point in the camera matrix. The position of each point of the examined object in a three-dimensional coordinate system can be calculated, when all the parameters are known recording, focal lenses and the position of the cameras are interrelated. In this way, every point of the object's surface, tracked by the camera, can be defined in all planes. Algorithms allow you to correlate the same point on the object plane to test all the cameras. Deformation of the object is determined by the observation of the image recorded by the CCD camera. Correlation algorithms allow for a maximum displacement of up to 1/100 pixel matrix [3].

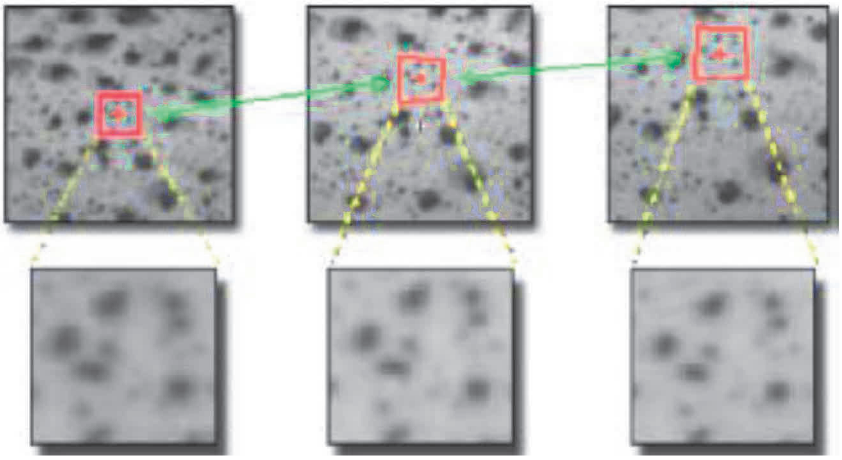

Figure 1 View of the surface [3]

The correlation algorithm tracks the position of the same points in the source image and the distorted image (**Figure 1**). To achieve this square surface containing a set of pixels, it is identified in the source image and in the position corresponding to the image after the deformation. There are many parameters that affect the accuracy of the results. They concern among other things, the size of the tracked spots, its density. Algorithm type the size of the set of points, the overlap of the set of points, etc. [4, 5]. Well optimized input parameters allow obtain very accurate results.

3. THE RESEARCH OF MECHANICAL PHENOMENA

Tensile test is one of the basic tests to determine the mechanical properties of materials. The research uses a universal testing machine Zwick & Roell Z100 with maximum load 100kN and precision 1N force / 0.01 mm elongation (without a touch extensometer, **Figure 2**). To carry out the tensile tests, samples welded at different technological parameters, shown in the **Table 1** below.

Table 1 Technological parameters of the process

Lp.	Power [kW]	Welding velocity [m / min]	Velocity of wire [m / min]	Current Intensity [A]	Current voltage [V]	Gap g [mm]
1	3	1	6	195	19	0
2	3	1	6	190	19	0.8
3	4	2	9	270	26	0.8

A modern disk laser was used in the studies Yb:YAG by focusing on the upper surface of the workpiece butt. In three tests carried changed laser beam power, the welding speed and the gap between the welded components. The first test was treated as a model test, at which correct welded joints with correct mechanical properties and mechanical properties were obtained. All samples were welded perpendicular to the rolling direction.

Figure 2 System of measuring

The test was prepared and performed according to standard PN-EN ISO 6892-1. In the figure we see an image correlation system coupled to a strength machine (**Figure 2**). Monotonic tensile test samples were made of steel S355. For each series of tests, three flat samples were prepared according to standard and cut off with water (Water Jet). The tests for base material and samples cut from welded hybrids sheets plate in a leading source of the laser beam, in the gas shield 82 % Ar + 18 % CO_2, inflatable with the speed 18 l / min and second source MIG. Distance mutual sources was constant for all tests and was d = 2mm. The laser beam was focused on the top surface of the joint (Z = 0). As a result of the tests, tensile diagrams were obtained (**Figure 3**), On the basis of which the mechanical properties of all analysed samples were determined. An increase in tensile strength and yield strength for 2 and 3 welding test can be observed (with gap) and a decrease in the strength of the first test compared to the base material (**Table 2**).

Table 2 Mechanical properties of tensile samples

	R_{eH}, [Mpa]	R_{eL}, [MPa]	R_m, [MPa]
Base material	**362**	**351**	**535**
Welded joint 1	**343**	**335**	**525**
Welded joint 2	**359**	**347**	**557**
Welded joint 3	**373**	**371**	**573**

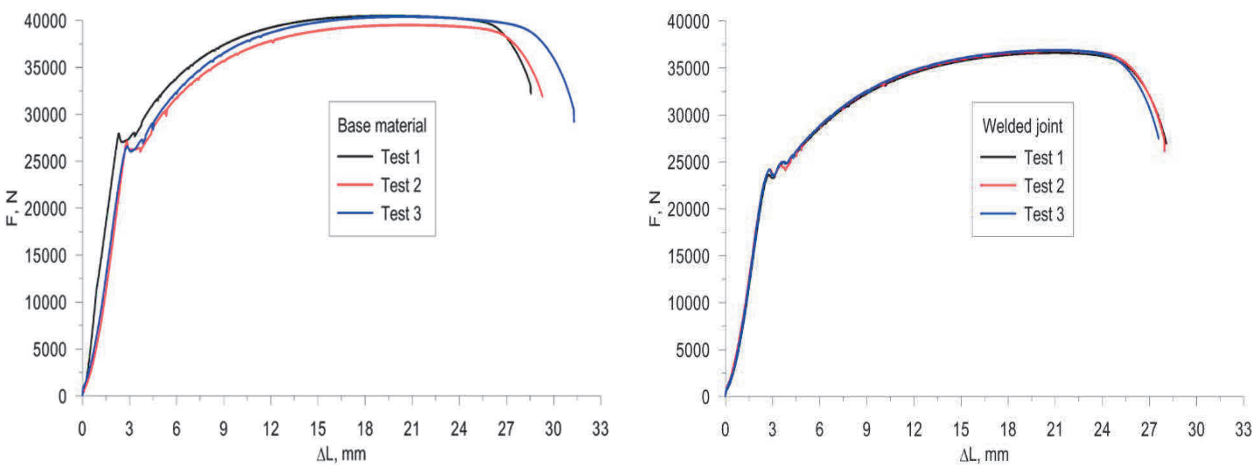

Figure 3 Tensile curves for the samples of the base metal and with the welded joint

Distributions of strain U_x and U_y in tensile sample of the base material **Figure 4** shows. Marked on the image line corresponds to a central axis of the sample, wherein the graphs are compared displacements and deformations for the welding tests carried out. The image was captured at the time that the necking in the tensile sample.

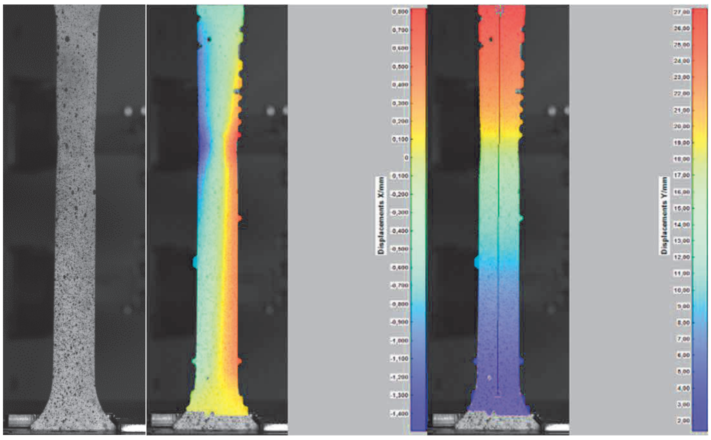

Figure 4 Distributions of longitudinal and cross displacement to the base material

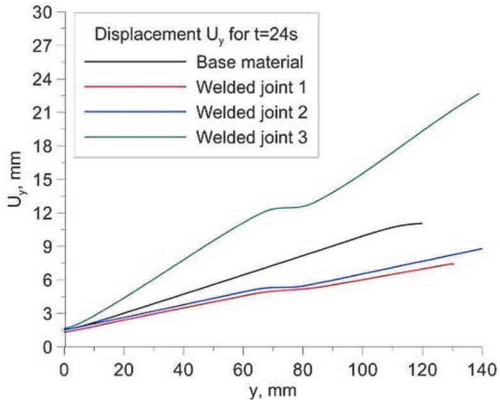

Figure 5 Distribution of displacements for t = 24 [s]

Comparison of distributions strain U_y for the 24 time [s] and at the moments of the appearance of the necking is shown below **Figure 5**. The last welded joint is characterized by considerably higher strain in 24 sec. compared to other results (**Figure 5**). This is due to the fact that the welded joint is much faster than the rest of the test that exceeds the yield point. In the case of achieving the establishment of the neck before the break, the maximum strain levels are similar for each of the trials.

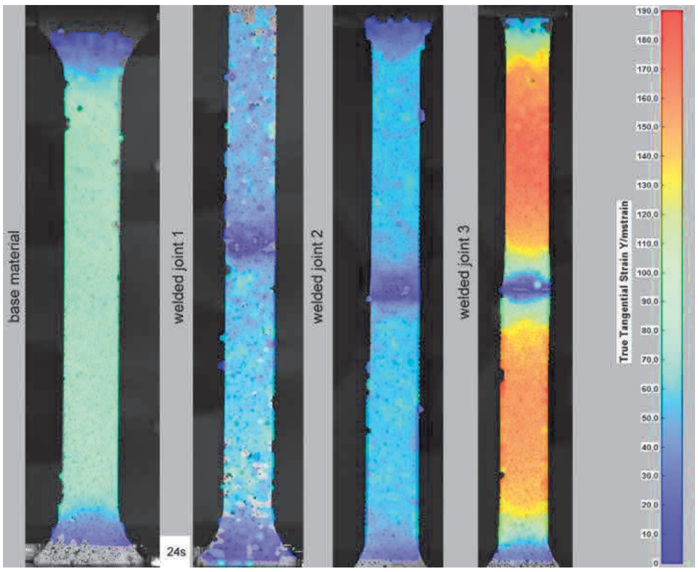

Figure 6 Comparison of longitudinal strain for time t = 24 [s]

The impact and the level of strain on the comparative figure for the central axis of the sample can be seen in **Figure 7** much better. Noticeable setoff in welded joints deformations occur in the weld and heat affected zone. It can be observed that the highest strain occur during the 24 s the last attempt for welding. This is directly related to the accepted sample parameters.

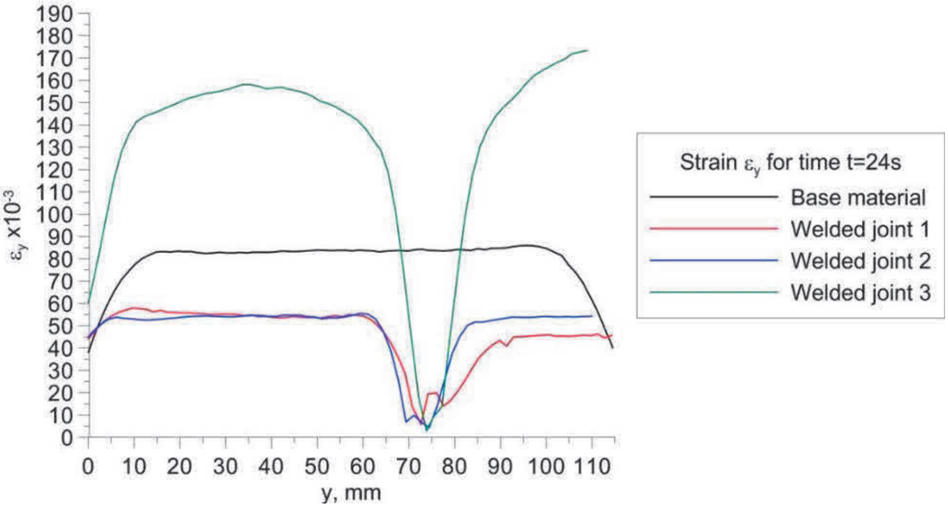

Figure 7 Strain distributions along the axis Y

4. CONCLUSION

After analysing the results, lower strain levels in the heat affected zone can be observed for the material compared to the base material as a result of structural changes in the weld and the HAZ of the joint. The results confirm the partial hardening of the welded joint. Visible increase in strain ε_y in the joint (all made attempts) it can be caused by providing additional material into the weld a slightly different chemical composition compared to the base material. The obtained results allow for a more accurate analysis of the mechanical properties of particular welded zones (joint, HAZ) not limited to the tensile test to determine the global value of the size and strength of the weld joint. Double increase in welding speed (joint 3) While simultaneously increasing the power of the heat sources of the laser beam and the electric arc completely changed the nature and size distribution of strains in the tension welded joint. While the gap between the welded components for particular technological parameters of the process does not significantly affect mechanical properties of the weld joint. The results can be very helpful in the experimental verification of mathematical models and numerical thermo-mechanical phenomena accompanying the process of welding and related processes.

REFERENCES

[1] CHU, T.C., RANSON, W.F., SUTTON, M.A., PETERS, W.H. Application of digital-image-correlation techniques to experimental mechanics. *Experimental Mechanics*, 1985, vol. 25, no. 3, pp. 232-244.

[2] LORD, J.D. *Digital Image Correlation (DIC), Modern stress and strain analysis. A state of the art guide to measurement techniques*. *1st. ed.* London: J. Eaton Evans, J.M. Dulie-Barton, R.L. Burguete, 2009. 128 p.

[3] Company materials DANTEC Dynamic.

[4] GOWER, M.R., SHAW, R.M. Towards a planar cruciform specimen for biaxial characterization of polymer matrix composites. *Applied Mechanics and Materials*, 2010, vol. 24-25, pp. 115-120.

[5] HERBST, C., SPLITTHOF, K. *Basic of 3D Digital Image Correlation.* Ulm: Dantec Dynamics GmbH, 2009. 12 p.