TECHNOLOGY AND EXPERIMENTAL RESULTS OF METAL EXPANSION JOINTS FABRICATION

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Abstract

The authors presented the ideas and assumptions with regard to manufacturing and application of a new kind metal expansion joints. Mechanically assisted laser forming manufacturing technology was briefly discussed. Metal tube with appropriate diameter and wall thickness are used to manufacture metal expansion joints. The concept assumes using a CO_2 laser to implement such expansion joints. The incidence of laser beam on selected surface of the rotating tube, heating it. After reaching the plasticising temperature, the actuator compresses the tube. As a result, a bellow-lens shape is formed at the plasticization area. Initial experimental studies confirmed the validity of the concept. The bellow-lens metal expansion joint was obtained as a final result.

Keywords: Laser forming, metal expansion joints, laser treatment

1. INTRODUCTION

Each industrial pipelines installations work with variable parameters of the transmitted medium. These are changes of pressure and temperature parameters. As a result of changing working conditions, such an installation is exposed to damage related to a change in its geometry due to e.g. thermal expansion of the material. In order to avoid damage this installation must be compensated. The most natural solution is to compensate it by changing the direction of the pipeline, e.g. at elbows. However, it is not always possible, e.g. due to collisions with other installations, lack of space, etc. In this case, expansion joints integrated with installations are used. Depending on installation operating parameters these may be cloth, rubber or metal expansion joints. At high pressures and temperatures, metal expansion joints are used. They are made from a pipe, on which there are upsets in the form of a bellows or a lens. These upsets act as a kind of "spring" which compensate for the above-mentioned deformations. Their design ensures compensation of axial, lateral and angular deformations [1,2].

Standard metal expansion joints are made nowadays mainly by plastic cold working, using roller systems, hydroforming methods, etc. [1,2]. But there is an idea to produce metal expansion joints by a hybrid method called mechanically assisted laser forming [3,4]. Laser techniques are widely used actually, and they are very good known, e.g. cutting, welding [5], industrial coatings applications, creating textures on the material's surface [6], additive manufacturing, etc.

The laser forming method uses the phenomenon of distortion in the material as a result of the element's local temperature change [11-13]. The element is heated by the energy from the laser beam acting on it [14,15]. The appropriate geometry and trajectory of the laser beam leads to the desired shapes of the element [16,17]. In this case, the local change in the shape of the element is achieved due to the difference in thermal expansion of the "cool" and "warm" parts of the material [18,19]. Plastic deformation is obtained as a result of causing internal thermal stresses in the material without the participation of external forces, by means of three main mechanisms: temperature gradient mechanism (TGM) [20,21], upsetting mechanism (UM) and buckling mechanism (BM) [22-24]. During the heating process, it is very important to remember that incorrectly selected process parameters may result in changes in the structure of the material [25-28] and a decrease in the corrosion resistance of the processed materials [29-32].

The free-form laser forming method is, however, a very time-consuming process. That is why the idea of a hybrid method of mechanically assisted laser forming was born. In this method, in order to accelerate the process, apart from laser heating, external forces are also used to create plastic deformations. This approach significantly speeds up the forming process, the process becomes effective, and the method allows for obtaining complex shapes. An example of such an approach is, for example, shaping thin-walled elements made from pipes [7]. Of course, the ideas and assumptions should predict the experiment [8] and make the necessary macroscopic measurements of the obtained elements [9].

2. TECHNOLOGY

Metal expansion joints manufacturing process with a hybrid mechanically assisted laser forming method is based on the following assumptions and concepts:

- the laser beam heats a given area of the element to a certain, preset temperature, which improves the plastic properties in this area,
- evenly and uniformly heating of the element around its entire circumference is achieved by its quick rotation around its axis,
- an axial force acts on the element simultaneously, which causes its upsetting in the plasticized zone (heated by the laser beam),
- only the part of the pipe that is exposed to the laser beam at a given moment is deformed,
- the remaining part of the formed element, which has a lower temperature, does not deform.

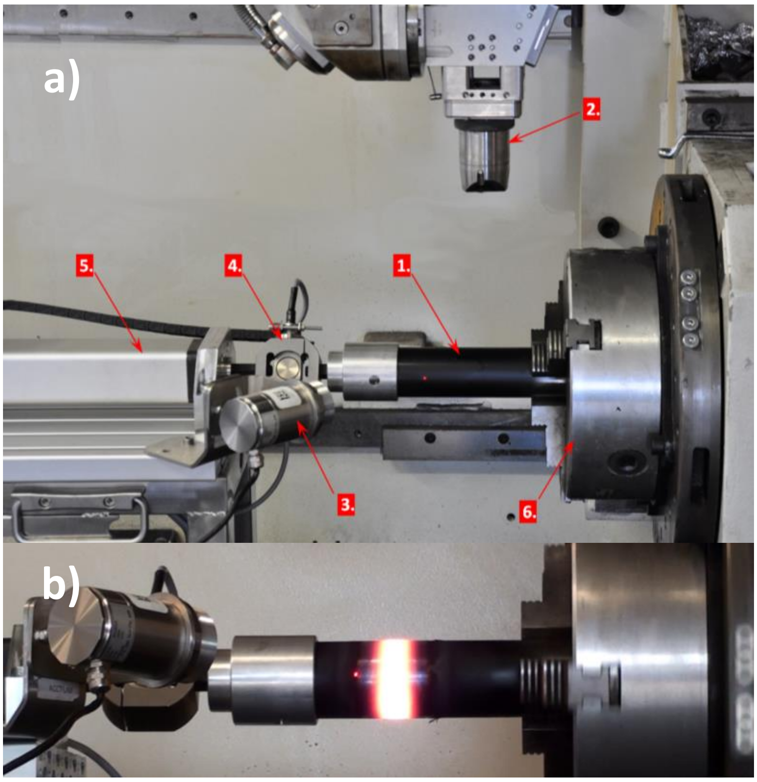

Figure 1 a) Real execution and measurement stand: 1 - quickly rotating pipe around its own axis, 2 - laser head (pipe heating), 3 - pyrometer, 4 - force sensor, 5 - axial thrust actuator, 6 - swivel handle. b) Execution stand during the process (heating stage DN50 pipe)

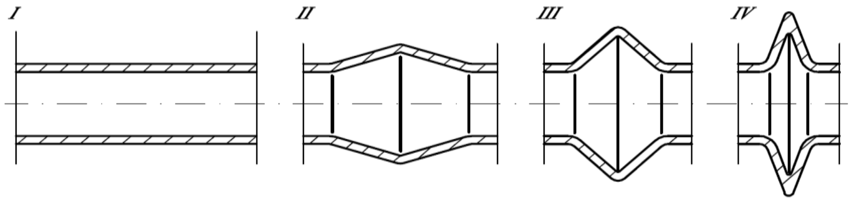

Figure 2 Individual steps of bellow-lens forming (concept): I - straight output pipe, II, III - pipe upsetting, IV - the final bellow-lens shape

The real execution and measurement stand is shown on **Figures 1a) and 1b)**, and the idea concept on **Figure 2**.

3. EXPERIMENT & RESULTS

Linear polarized laser beam was incident perpendicularly to pipe's surface so that the beam width coincided with the pipe axis. Pipe was made from X5CrNi18-10 grade stainless steel with dimensions ϕ20x1,0 and ϕ50x1,5 (in mm). The laser beam width on pipe's surface was about 20 mm for DN20 pipe and 40 mm for DN50 pipe, which at the same time was a heating and plasticizing zone of the pipe around its entire circumference. Simultaneously pipe was rotated at speed ω. After obtaining the appropriate plasticization temperature T, measured by temperature sensor (3), the actuator (5) was started. The actuator pressed on the pipe axially with the force F (4) applied at speed v. The experiment was performed for two actuator strokes s. The process was carried out with CO_2 laser TRUMPF TruFlow 6000 and parameters:

- laser power: P=900÷1100 W,
- process temperature: approx. T=1050÷1100 °C,
- pipe compressive force: max. F=600 N (for DN20), max. F=1200 N (for DN50),
- compressive length: s=20 mm (for DN20), s=40 mm (for DN50),
- pipe rotation speed: ω=1000 °/min,
- pipe compressive speed: v=10 mm/s,

After the process the elements were assessed and investigated. The shape measurement and macroscopic examinations were done. Final results are shown on **Figure 3 and Figure 4**.

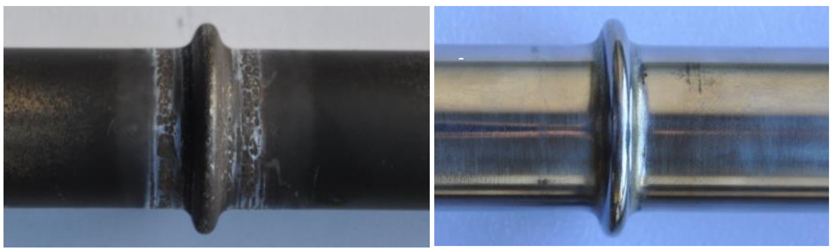

Figure 3 The final bellow-lens shape: a) just after process, b) after polishing

Figure 4 Cross sections of obtained bellows-lens shape (under different magnification)

4. CONCLUSION

According the experiment investigations proposed hybrid method of mechanically assisted laser forming is justified and effective. Moreover, validity of the concept was confirmed. Selection of the appropriate heating zone, process temperature, as well as the force and speed of compression lead to the formation of a bellow-lens expansion joint. Obtained results are reproducible, which confirm industrial application potential of the above-mentioned technology. Control of material temperature and compression length are essential elements of the investigated technology. Incorrect selection of those parameters will lead to burnout and/or burst bellow-lens rim. Output pipe excessive compression will lead to flat ring forming around the pipe, which will not fulfill the functions assigned to this elements type.

The improvement of the process will be the aid of further works planned in the future. Furthermore, it is planned to carry out a FEM analysis in order to recognize thermoelastic and thermoplastic phenomena occurring during the process. It is planned to study the microstructure of the obtained expansion joints. In order for the expansion joint to have the expected strength properties, the microstructure should not change and remain an austenitic. The selection of parameters (temperature) should ensure this, however, detailed research in this matter will give the answer what the real microstructure is. It is also planned to perform strength tests of the created expansion joints in order to determine their utilitarian suitability in industrial application.

The concept presented in this paper and performed investigations is protected by the patent law from April 11th, 2022; The Patent Office of RP; patent name: Method and device for the production of metal expansion joints (in polish); patent number: P.438965 [12].

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