LASER FORMING IN THE USE OF HELICAL METAL EXPANSION JOINTS MANUFACTURING

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Abstract

In the paper, the author presented the technological assumptions for the production of a helical metal expansion joint. Currently produced expansion joints have bellows or lens shapes. These types of expansion joint can only carry lateral, angular and axial deformations. A helical metal expansion joint is a new type of expansion joints that can compensate for torsional deformations of industrial pipelines, which are the result of the installed armature in the piping system. The authors presented a method of mechanically assisted laser forming, which was used as a manufacturing technology for this type of element. This technology combines laser heating of an element in the form of a pipe (implemented with a carbon dioxide laser along a given trajectory in order to plasticize the heating zone), with the simultaneous application of an external force, which is intended to plastic deform the element on its circumference. The carried out experiment consisted of the selection and control of the process temperature using an integrated optical pyrometer, based on which the laser power was controlled. According to the preliminary experiments, the compression speed of the element was selected. Compression was carried out using a mechanical actuator. During the process, the compression force that caused the deformation of the element was recorded. Experimental results obtained during the manufacturing of helical metal expansion joints are presented. Mainly, the results are presented and discussed, such as: obtained geometry, forces needed to manufacture the element, processing temperature, strain rate and others.

Keywords: Laser forming, metal expansion joints, laser treatment

1. INTRODUCTION

Metal expansion joints are pipeline elements designed to compensate for system deformations related to changes in operating parameters, such as temperature and pressure. Without compensating for this type of deformation, the piping system will fail quickly. In addition, compensators help to eliminate dimensional inaccuracies during the assembly of such an installation.

Currently, two basic types of metal expansion joints are manufactured [1,2]:

- bellows expansion joints,
- lens expansion joints.

These components compensate for the following deformations [3-6]:

- lateral deformation,
- axial deformation,
- angular deformation.

The mentioned components do not compensate for deformations generated by torques, which are the result of the operation of fittings, main pumps, etc. installed in the pipeline. To come up with the idea of manufacturing helical metal expansion joints, a task should be used to compensate for this type of deformation.

The listed elements do not compensate for torsional deformations that are the result of the operation of equipment, e.g. pumps, etc. installed in the pipeline. That is why the idea of creating helical metal expansion joints was born, whose task is to compensate primarily for this type of deformation.

The manufacturing of this type of elements is mainly carried out by various types of cold-forming methods [3]. The author of this publication will present the results of testing the performance of metal expansion joint using the mechanically assisted laser forming method. Laser processing is now a widely used manufacturing method. It covers a whole range of various types of technologies such as: cutting, welding, surfacing, surface treatment, micromachining, additive machining and many others [7-9].

Laser forming involves the introduction of internal stresses into the material. These stresses are the result of the temperature difference between the areas of the element heated by the laser beam and the rest of the material. The phenomenon of thermal expansion is involved in this process. Differences in expansion between areas of different temperatures (locally heated and unheated) lead to the desired shape change of the element. Three basic mechanisms of laser forming are known [10]:

- Temperature Gradient Mechanism (TGM),
- Upsetting Mechanism (UM),
- Buckling Mechanism (BM).

The mechanisms described above apply to free laser shaping, i.e. without the participation of external forces. This method, however, is a very time-consuming and energy-intensive process. Hence, the idea of manufacturing screw compensators with a hybrid method of mechanically assisted laser processing was born.

2. DESCRIPTION OF TECHNOLOGY

The technological assumptions for the manufacturing of the helical expansion joints are presented in the paper [11]. To introduce the reader to the issue, a synthetic description of the technology is presented below.

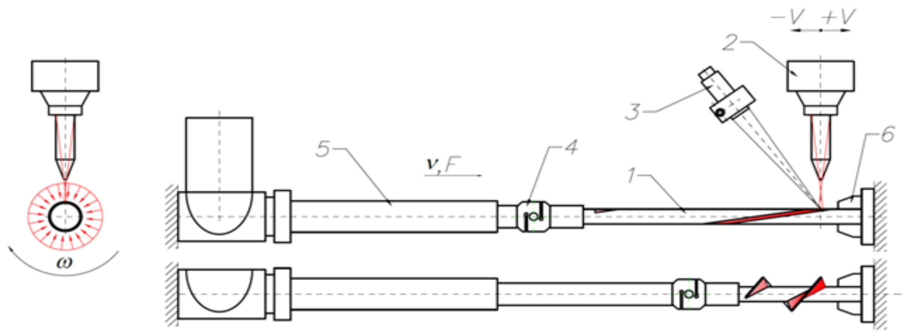

Figure 1 Idea of helical expansion joints manufacturing (two main steps: upper diagram - heating path with marked elements and technical parameters; down diagram - element after heating and compressing): 1 - rotating pipe, 2 - laser head (pipe heating), 3 - pyrometer, 4 - force sensor, 5 - axial thrust actuator, 6 - chuck

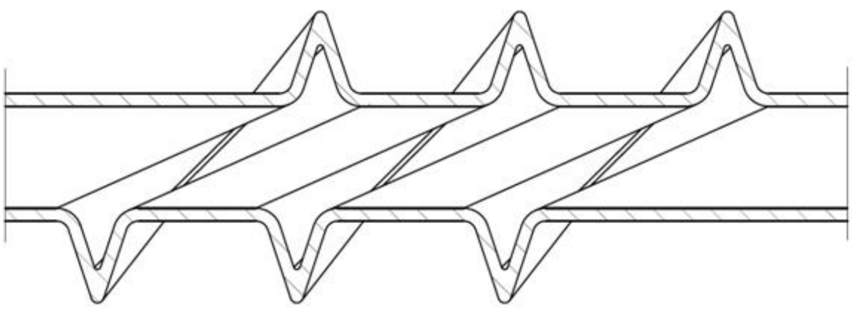

Figure 2 Cross section of final element

Figure 1 and **2** shown idea and final element after manufacturing. The helical compensator has bellows in the form of a helix around its circumference, resembling a thread. It can be either right or left handed. In order to manufacture this type of expansion joint using the mechanically assisted laser forming hybrid method, it is necessary to bring part of the pipe to the plasticizing temperature by heating it around the perimeter in a helix, and then compress the element with the appropriate force.

3. EXPERIMENTAL RESULTS

The TRUMPF TruCell 1005 with TruFlow 6000 CO_2 laser was used for the experiment. The output element in the form of a pipe was installed between the actuator and the rotary chuck. The pipe material was X5CrNi18-10 grade stainless steel. The process temperature was controlled by a monochromatic pyrometer. The pyrometer was integrated with the laser driver. This made it possible to control the laser power in feedback with the pyrometer indications. Thanks to this, the temperature of the heated zone was kept constant. The surface of the specimen was covered with a special absorber (matt black enamel) to increase the laser radiation absorption coefficient. The parameters of the laser processing are listed below:

- laser wavelength of λ = 10.6 µm,
- process temperature: approx. T =1,100°C,
- laser power: $P \in$ <900, 2500> W (depending on element temperature),
- pipe rotation speed: ω = 200 rad·s^{-1},
- pipe compressive speed: v =10 mm·s^{-1},
- initial beam pitch: p = 80 mm,
- maximum compressive force: F =6 kN (depending on output element geometry).

The final result of the experiment was the helical expansion joint manufacturing shown on **Figure 3**.

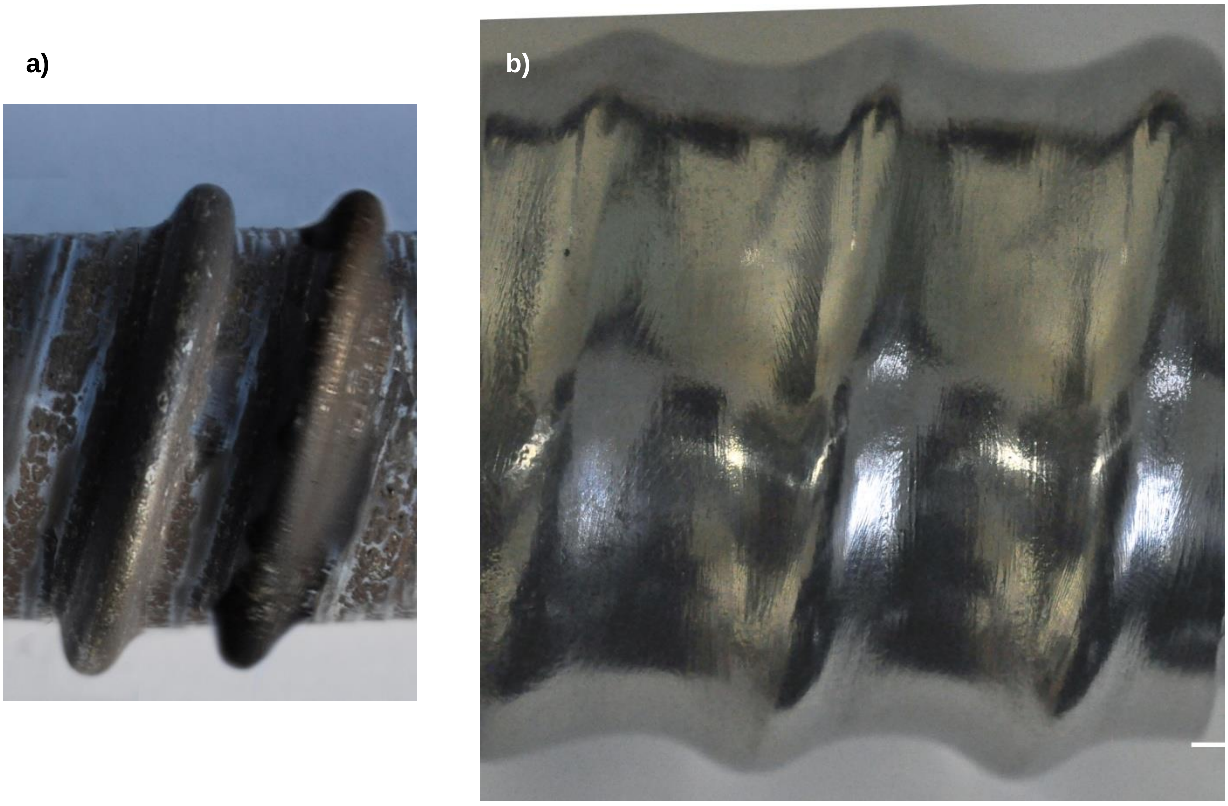

Figure 3 Final elements: a) helical metal expansion joint DN20, b) helical metal expansion joint DN50 (scale not kept)

4. CONCLUSION

The experimental study confirmed the legitimacy of the idea and confirmed the possibility of producing helical expansion joints proposed by the mechanically assisted laser forming hybrid method. The processing parameters were selected experimentally so as to obtain the expected effects, i.e. the shape of the expansion joint. The macroscopic examinations carried out showed that the obtained helical expansion joint was manufactured correctly. The geometry of the elements was very well done. No cracks, kinks, unfavourable corrugations and other geometric deviations were observed on the surface. The helix obtained is symmetrical and repeatable, no defects in the upset geometry were noticed. To check the ability to compensate for torsional moments by the compensator, additional tests should be carried out. Such research is planned for the future.

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