MECHANICALLY ASSISTED LASER FORMING HYBRID METHOD IN METAL EXPANSION JOINTS MANUFACTURING

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Abstract

The author of this paper presented the concept of manufacturing metal expansion joints using a hybrid method of mechanically assisted laser forming. An experiment was carried out based on the presented concept assumptions.The parameters used in the experiment and the final effect are presented. With the appropriate selection of the process parameters, the authors managed to confirm the validity of the presented concept and the final result of the experiment.

Keywords: Laser forming, metal expansion joints, laser treatment

1. INTRODUCTION

Typical metal expansion joints (MEJ) [1] are made nowadays by plastic cold working, using roller systems, hydroforming methods, etc. The laser technologies are commonly used nowadays in wide range of manufacturing processes. [2-6]. There will be presented a concept to manufacture MEJ with the hybrid mechanically assisted laser forming method (HMALFM) [7]. Classical laser forming method uses the phenomenon of distortion in the material as a result of the element's local temperature change. The element is heated by the energy from the laser beam acting on it. The appropriate geometry and trajectory of the laser beam leads to the desired shapes of the element [8-12]. MEJ with combined bellow-lens shape, are made of a metal tube with an appropriate diameter and wall thickness. The concept assume the use of a CO_2 laser to implement such a expansion joints. The laser beam heats selected area of the rotating tube, which is mounted on swivel handle on one side and in the actuator handle with the other end. After reaching the plasticizing temperature, the actuator compresses the element. As a result, a bellow-lens shape like is formed at plasticization area. Initial experimental studies confirmed the validity of the concept. As a final result, bellow-lens metal expansions joint was obtained.

2. CONCEPT

The concept of expansion joints by mechanically assisted laser forming hybrid method manufacturing is based on the assumption that only part of pipe that is subjected to the laser beam at a given moment is deformed. The laser beam heats selected area of the pipe to a certain, preset temperature, which improves plastic properties of heated region. The element is evenly and uniformly heated along its entire circumference by quickly rotating around its axis. At the same time, an axial force acts on the element, which causes pipe upsetting in the plasticized zone (heated by the defocused laser beam). The remaining part of formed pipe, which has a lower temperature, does not deform. De facto, only "selected girdle" of an element is upset at this time.

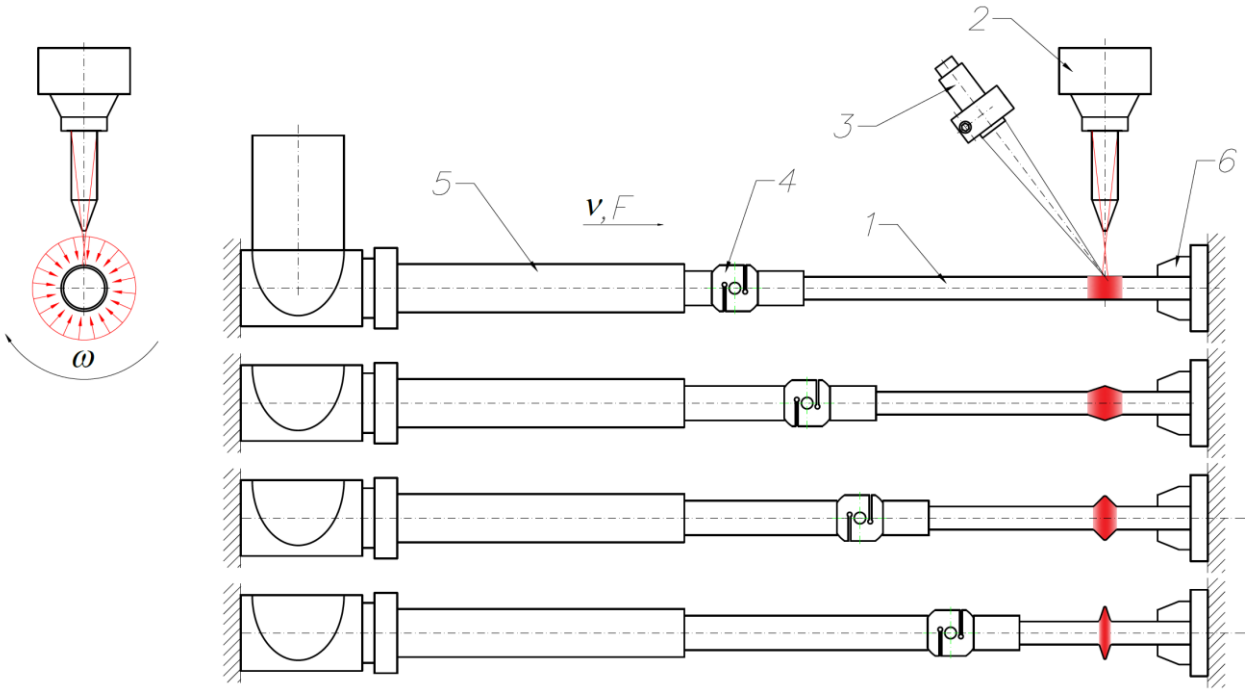

Figure 1 Individual stages of the metal expansion joint forming and the scheme of the execution and measurement stand: 1 - pipe quickly rotating around its axis, 2 - laser head (pipe heating), 3 - pyrometer, 4 - force sensor, 5 - axial thrust actuator, 6 - swivel handle

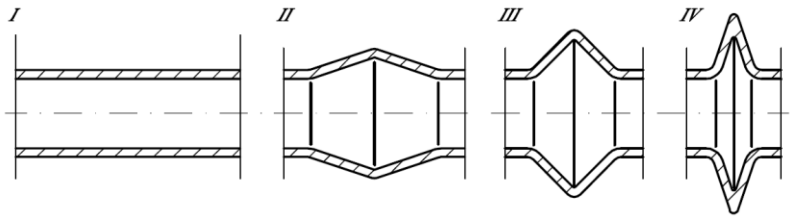

Figure 2 Individual steps of metal expansion joint forming (concept): I - straight output pipe, II, III - pipe upsetting, IV - the final bellow-lens shape

The width of this "girdle" depends on laser beam focal point dimensions incident on element's surface. This, in turn, effects on possibility of obtaining the appropriate geometry of manufactured expansion joints. The conceptual analysis was illustrated on **Figure 1** and **Figure 2**.

3. EXPERIMENT

Material used in experiments were pipes made of stainless steel grade X5CrNi18-10, with dimensions of ϕ20×1 mm (diameter × wall thickness) and 250 mm length. The pipe was installed between axial actuator with a maximum pressure force of 5kN (4) and swivel handle (6). The surface of the sample was covered with a special absorber (matt black enamel) in order to increase and uniform absorption coefficient of laser radiation. The experiment was performed by using the CO_2 laser TRUMPF TruFlow 6000 with maximum output laser power equal to 6kW. The treatment parameters were as follows:

- laser wavelength: λ=10,6 μm,
- CW laser mode,
- laser power: P=900÷1100 W,

- process temperature: approx. T=1050÷1100°C,
- pipe compressive force: max. F=600 N,
- compressive length: s=10÷20 mm,
- pipe rotation speed: ω=10000 °/min,
- pipe compressive speed: v=10 mm/s.

The final product after laser forming is shown of **Figure 3** and the process description is below.

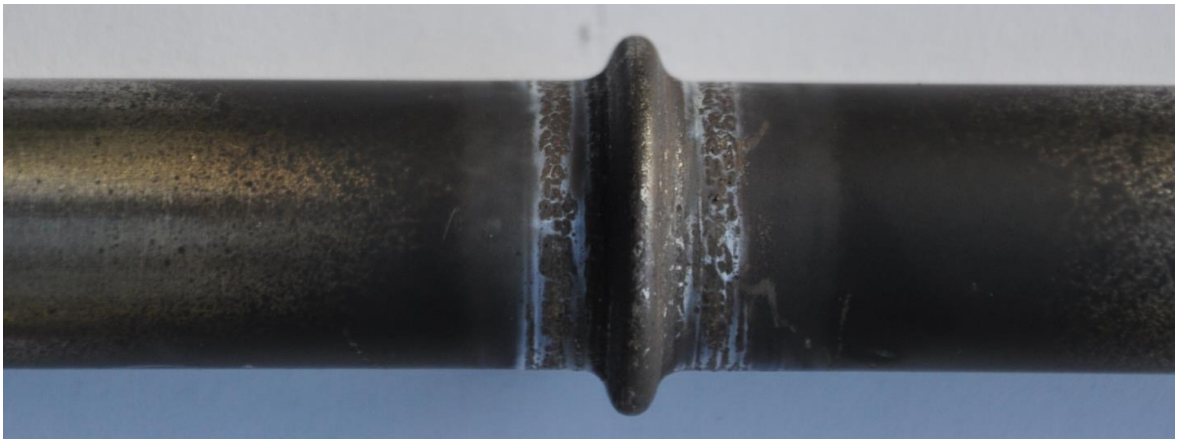

Figure 3 The final element manufactured during experiment (compressive length s=10 mm)

Linear polarized laser beam was incident perpendicularly to pipe's surface so that the beam width coincided with the pipe axis. The laser beam width on pipe's surface was about 20 mm, 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.

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 concept presented in this paper and performed investigations is protected by the patent law from April 11, 2022; The Patent Office of RP; patent name: Method and device for the production of metal expansion joints (in polish); patent number: P.438965 [13].

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