INSTITUTE OF FUNDAMENTAL TECHNOLOGICAL RESEARCH
AND COMMITTEE ON MECHANICS
POLISH ACADEMY OF SCIENCES

7th European Conference on Structural Control

Book of Abstracts and Selected Papers

Editors:

Jan Holnicki-Szulc, David Wagg and Łukasz Jankowski

Co-editors:

Bartłomiej Błachowski and Piotr Tauzowski

since 1993 EACS

WARSAW 2022

INSTITUTE OF FUNDAMENTAL TECHNOLOGICAL RESEARCH
AND COMMITTEE ON MECHANICS
POLISH ACADEMY OF SCIENCES

7th European Conference on Structural Control

Book of Abstracts and Selected Papers

Editors:
Jan Holnicki-Szulc
David Wagg
Łukasz Jankowski

Co-editors:
Bartłomiej Błachowski
Piotr Tauzowski

WARSZAWA 2022

ISBN 978-83-65550-37-8

Institute of Fundamental Technological Research PAN
02-106 Warszawa, ul. Pawińskiego 5B
www.ippt.pan.pl

Committee on Mechanics, Polish Academy of Sciences
02-106 Warszawa, ul. Pawińskiego 5B
kmech.pan.pl

LASER MICRO BENDING MECHANISM FOR HIGH-PRECISION ADJUSTMENT IN MECHATRONIC SYSTEMS

J. Widłaszewski[1]

[1]Institute of Fundamental Technological Research PASc, A. Pawińskiego 5 B, Warsaw, Poland
e-mail: Jacek.Widlaszewski@ippt.pan.pl

1. Introduction

Application of laser technology makes it possible to perform highly accurate adjustment of components, which are difficult to access using traditional tools and are sensitive to mechanical forces. The energy input by the laser beam into the work-piece can be easily and precisely controlled. Adjustment of critical dimensions with micrometer or milliradian accuracy in small metallic components is applied during assembly stage in mass-production and it allows relatively large tolerances in the preceding production stages [1]. The potential of a laser beam as a means of energy transport for optothermal microactuation is intensively investigated to expand practical applications of micro-opto-electro-mechanical systems (MOEMS) [2].

Presented paper reports experimental and numerical investigations of a thermal micro-bending mechanism, which enables deformation either towards or away from the laser beam (a heat source), dependent on the applied processing parameters. A 3D finite element method (FEM) model has been developed to study the behaviour of a cantilever stainless steel beam heated by a laser beam. Experimentally-validated numerical model allowed an analysis of temperature, strain and stress fields during the heating and cooling cycle.

2. Experiments

Samples of dimensions 50 x 4.05 x 0.55 mm made of 18-8 type stainless steel, clamped in the cantilever arrangement, were heated with a stationary Nd:YAG laser beam (Fig. 1).

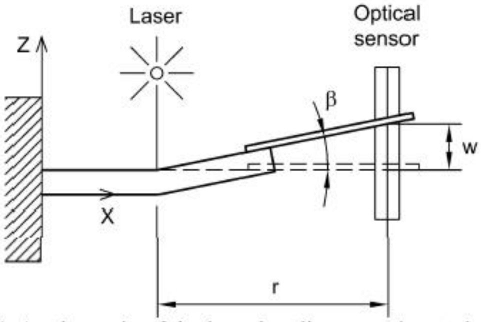

Fig. 1. A schematic of the laser bending experimental setup.
The definition of the positive angular deformation $\beta > 0$.

Non-contact deformation measurements were performed with a high-accuracy laser micrometer. In order to achieve a high accuracy of optical measurements, an additional element of high-quality surface and low mass was attached to the sample. Its displacement was measured and recorded during laser heating and after cooling down the sample to the initial material temperature. Angle β of the bending deformation induced by the laser pulse was calculated from the linear vertical displacement w (Fig. 1) measured with the micrometer.

3. Numerical simulation

Numerical simulations were conducted using the Finite Element Method (FEM). The thermal-mechanical sequentially coupled analysis was conducted in two separate steps: (1) determination of temperature field under prescribed heat load and boundary conditions, and (2) elastic-plastic incremental analysis of stress and strain due to the calculated temperature field. The calculations were performed with the ABAQUS system. Energy input from the laser beam was treated as a surface heat source, since the absorption of the infrared radiation by metals is typically confined to a layer several tens of nanometers thick.

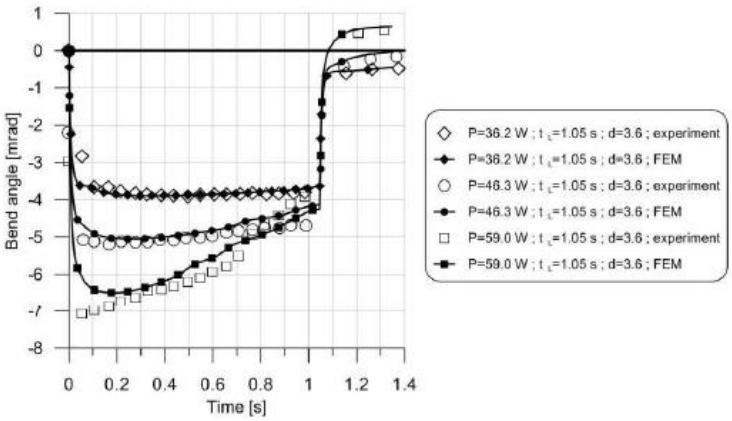

Fig. 2. A comparison of experimental and numerical time-runs of the angle of bend for various laser power P, time of laser heating 1.05 s and laser spot diameter 3.6 mm.

Thermal dependences of the following material properties were taken into consideration: thermal conductivity, specific heat, thermal expansion coefficient, Young's modulus, yield stress, Poisson's ratio and density. The Huber-Mises-Hencky yield criterion was employed.

4. Conclusions

Experimentally validated simulations explained the mechanism of laser-induced deformation. The studied mechanism of bending involves a significant positive longitudinal plastic strain in the edge regions of the beam. The deformation results from a considerable temperature gradient across the width of the beam, with some contribution of the temperature gradient in the thickness direction. Application of the mechanism opens up new opportunities for the laser-based micro-adjustment technology, particularly when the processed component is accessible from one side only.

References

[1] W. Hoving, *Accurate manipulation using laser technology*, in: M. Geiger, A. Otto (Eds.), Proceedings of the 3rd LANE 2001 (Laser Assisted Net Shape Engineering 3, International Conference) Meisenbach Bamberg, 2001, pp. 113-124.

[2] X. Han, H. Zhang, R. Xu, S. Wang, C. Qin, *Theoretical model of an optothermal microactuator directly driven by laser beams*. J. Micromech. Microeng. 25(7) (2015) 075012. DOI: 10.1088/0960-1317/25/7/075012.

Institute of Fundamental Technological Research PAN
02-106 Warszawa, ul. Pawińskiego 5B
www.ippt.pan.pl

Committee on Mechanics, Polish Academy of Sciences
02-106 Warszawa, ul. Pawińskiego 5B
kmech.pan.pl

7th European Conference on Structural Control

Book of Abstracts and Selected Papers

ISBN 978-83-65550-37-8