Materials Research Proceedings **5** (2018) 25-30 doi: http://dx.doi.org/10.21741/9781945291814-5

Mechanically-Assisted Laser Forming of Flat Thin Beams made of Inconel 627 and Inconel 718 Alloys

KURP Piotr

Kielce University of Technology, Faculty of Mechatronics and Mechanical Engineering Department of Terotechnology and Industrial Laser Systems, Aleja Tysiąclecia Państwa Polskiego 7, PL- 25314 Kielce, Poland

pkurp@tu.kielce.pl

Keywords: Laser Forming, Mechanically-Assisted Laser Forming, Thin Beams

Abstract. The authors of this paper presented the results of research on mechanically-assisted laser forming of flat thin beams made of Inconel 627 and Inconel 718 alloys. The method of applying external forces to beams and the way of conducting this process will be presented. The deflections of beams depending on a given load will be presented. The research presented in this paper will be arranged to develop the technology of thin-walled spatial elements bending, e.g.: tubular elements, which are made of the tested materials.

Introduction

Laser forming is one of contactless forming methods of elements made from various materials. Due to the fact that there is no physical contact between the tool and the workpiece, it can also be carried out remotely. This technology was developed already in the 80s of the last century and is being developed all over the world, including at Center for Laser Technologies of Metals Kielce University of Technology and Polish Academy of Science (CLTM PŚk&PAN) [1], [2]. However, this is a time-consuming method. Therefore, the idea of hybrid forming, i.e. mechanically-assisted laser forming, appeared. The first tests of hybrid forming were carried out at CLTM PŚk&PAN in 2016 for thin-walled beams made of X5CrNi18-10 acid-proof steel [3].

The Inconel 625 and 718 nickel superalloys are widely used to manufacturing heat-resistant and high corrosion resistance elements [4]. Inter alia, they are used in the aviation industry as material for turboprop engine chamber components [5]. The research on hybrid mechanically-assisted laser forming will be presented below.

Research stage and methodology description

The research stage for mechanically-assisted laser forming of flat beams was made based on the TRUMPF TruFlow6000 CO_2 laser. Specimens were made of Inconel 625 and Inconel 718 alloys with dimensions of 200x20x1 mm (specimen laser scanning length L=130 mm - for Inconel 625 and L=150 mm - for Inconel 718). The specimens were covered with a technical absorber in the form of black enamel (to increase the absorption coefficient of laser radiation [6]). A laser segmented head generating rectangular laser beam with dimensions of 20x2 mm was used for machining. The beam scanned specimens surface in such a way that the length of the beam coincided with the width of the sample. The laser treatment parameters were selected in such a way that the surface temperature of the specimen was within the range of <800°C; 900°C>. The scanning parameters were as follows: laser power P=500W, beam speed v=200 mm/min. The F force was obtained by means of suitable weights mounted on the loose end of the specimen. The range of tested loads was the following: 110, 160, 210, 260, 310, 360, 410, 460, 510 and 560G. Fig.1 shows the diagram of loading and deflection measurement.

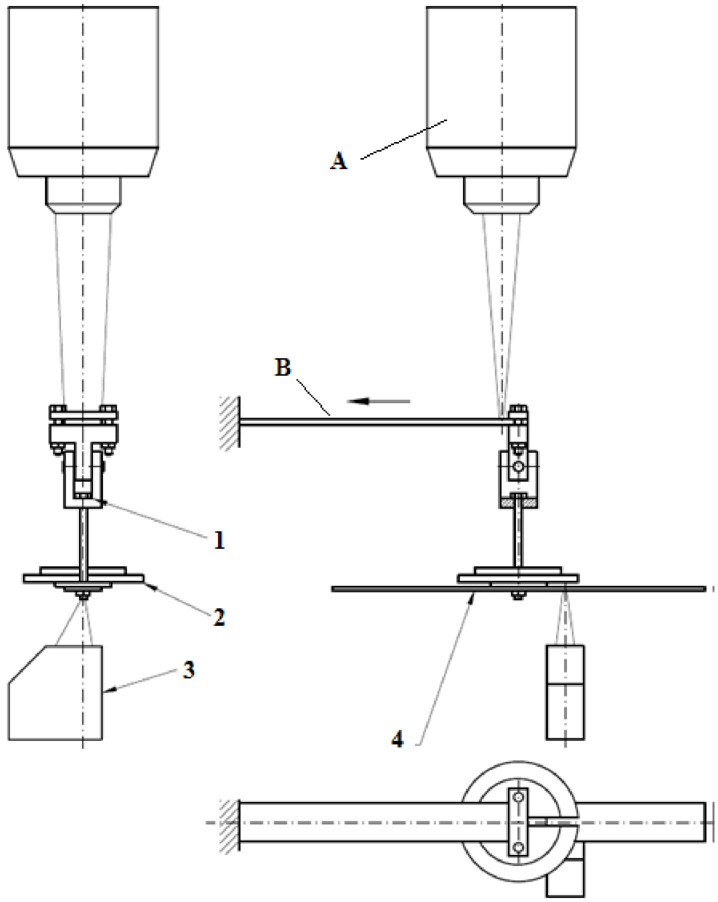

Fig. 1. Research stage diagram: A - laser segmented head, B - specimen tested, 1 - pivot suspension, 2 - weights (loads), 3 - deflection sensor, 4 - intermediate plate for deflection measurement.

Characteristics of the tested alloys and initial deflection values

The characteristics of the tested alloys are presented in Table 1 and Table 2 [7], [8].

Table 1. Mechanical and thermo-physical properties of Inconel 625 [7]

Constant	R_e [MPa]	R_m [MPa]	A [%]	E [GPa]	Thermal conductivity [W/m^{2}K]	Specific heat [J/kg^{o}C]
Value	≥664	986 - 996	≥ 46,3	~200	9,8	410

Table 2. Mechanical and thermo-physical properties of Inconel 718 [8]

Constant	R_e [MPa]	R_m [MPa]	A [%]	E [GPa]	Thermal conductivity [W/m^{2}K]	Specific heat [J/kgK]
Value	830-1030*	1030-1275*	12-20*	~200	11,4	435

* - depending on the type of finishing treatment

Before the mechanically-assisted laser forming process was performed, the initial deflections of the sample for given loads were measured with an altimeter. The results of the measurements were compared with the theoretical values calculated from the dependencies below:

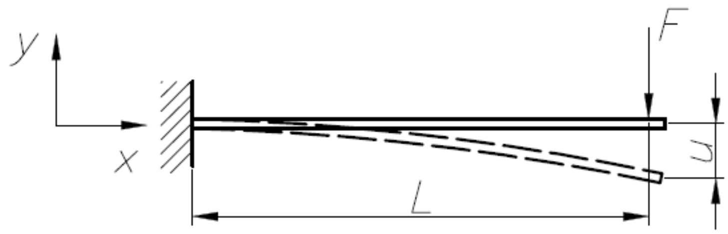

Fig. 2. Initial specimen deflection

The initial deflection of the *u* beam can be calculated from the following dependence:

$$u = \frac{F}{6 \cdot E \cdot I} \cdot x^3 - \frac{F \cdot L^2}{2 \cdot E \cdot I} \cdot x + \frac{F \cdot L^3}{3 \cdot E \cdot I} \tag{1}$$

The maximum deflection of the beam at the end of the interval is calculated for x = 0. Dependence (1) therefore takes the following form:

$$u = \frac{F \cdot L^3}{3 \cdot E \cdot I} \tag{2}$$

where:
E - modulus of longitudinal elasticity, I - inertia modulus of the beam cross-section:

$$I = \frac{g^3 \cdot s}{12} \tag{3}$$

Table 3 and Table 4 show the values for measured and calculated initial beam deflection.

Table 3. Initial deflection values for Inconel 625 alloy (L=130 mm)

load F, [G]	110	160	210	260	310	360	410	460	510	560
measured, [mm]	2,6	7,2	12,2	15,4	18,6	23,8	28,1	31,7	35,6	39,5
calculated, [mm]	3,6	5,2	6,8	8,4	10,0	11,6	13,2	14,9	16,5	18,1

Table 4. Initial deflection values for Inconel 718 alloy (L=150 mm)

load, [G]	110	160	210	260	310	360	410	460
measured, [mm]	5,8	8,5	10,9	13,9	17,8	19,1	22,8	25,4

calculated, [mm]	5,8	8,4	11,0	13,7	16,3	18,9	21,5	24,2

The experiment course and test results
The experiment course of mechanically-assisted laser forming for Inconel 625 and Inconel 718 alloys is shown in Fig. 3. The results of bending measurements during the process are shown in Fig. 4 and Fig. 5. The final bending values are tabulated in Table 5.

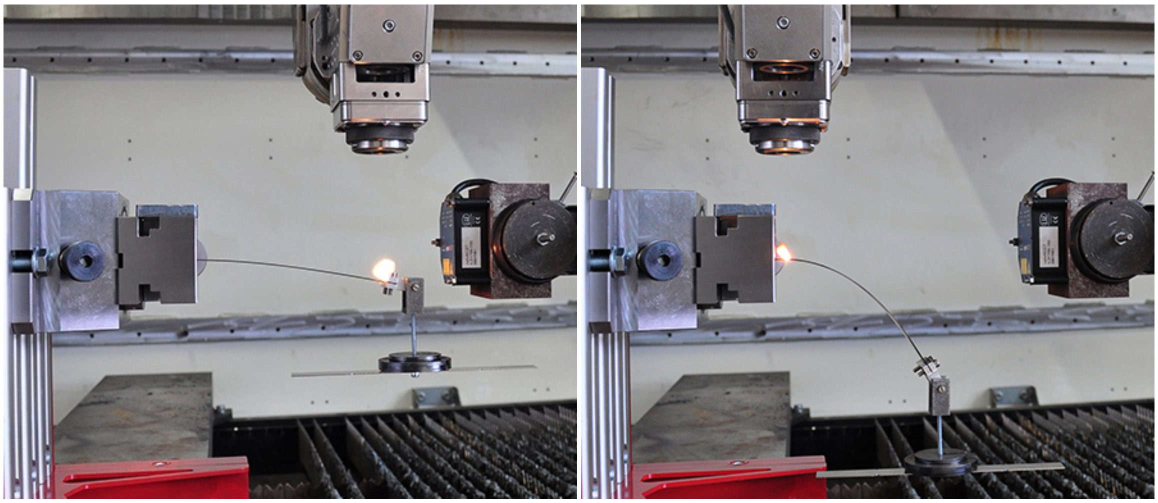

Fig. 3. Two extreme stages of mechanically-assisted laser thin beam forming for a total load of 360g (beginning and the finish of the process)

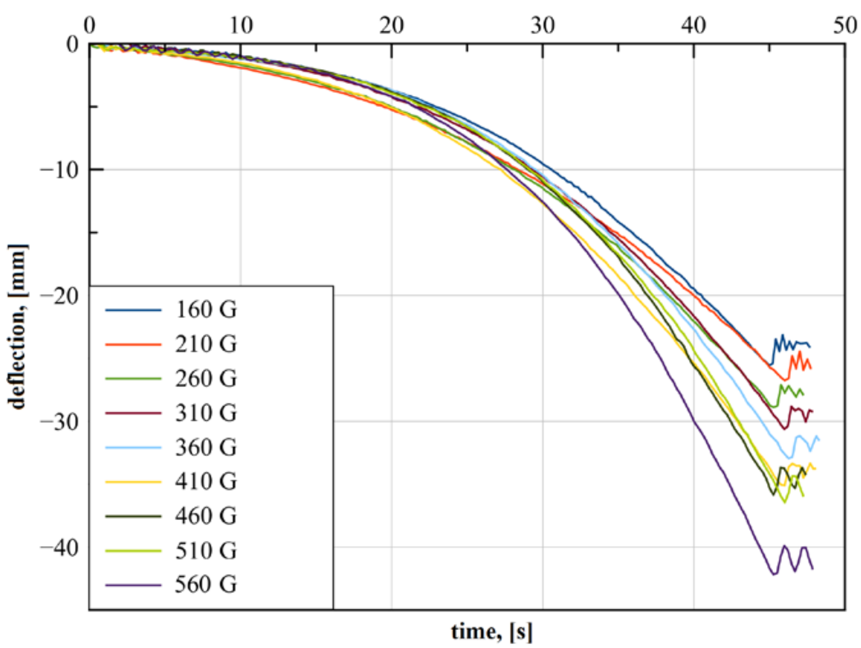

Fig. 4. Specimen deflection over time changes depending on the load. Values for Inconel 625 alloy.

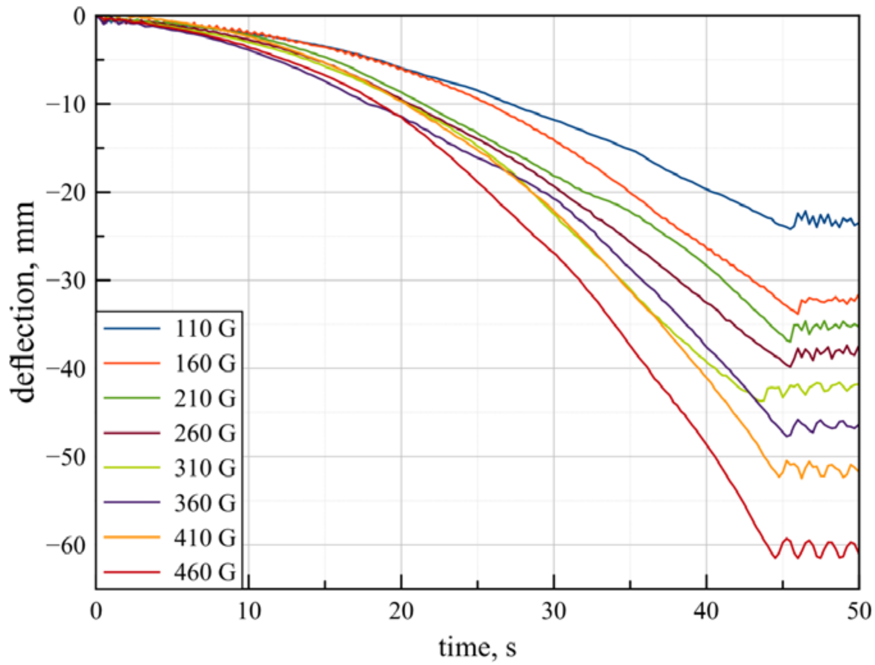

Fig. 5. Specimen deflection over time changes depending on the load. Values for Inconel 718 alloy

Table 5. Final deflection values of beam for given loads (tabular summary according to Fig. 4 and Fig. 5.)

load, [G]	110	160	210	260	310	360	410	460	510
(625) final deflection*, [mm]	-	23,05	25,01	27,02	28,91	32,21	34,01	35,11	36,15
(718) final deflection *, [mm]	23,5	32,5	35,0	37,5	42,5	47,0	51,5	61,0	-

* final deflection is plastic deflections after load removal

Summary

The test results indicate a good tendency for plastic deformation of the Inconel 625 and 718 nickel superalloy after reaching the appropriate temperature in element. The high content of alloying elements, in particular nickel, causes low thermal expansion of the material. However, by achieving the appropriate temperature of the beam, it changes the plastic properties of Inconel [9]. In addition, the bending process to the appropriate angle can be easily controlled by using additional, properly selected mechanical force. When supplying appropriate linear power density to the surface of formed specimens, which, however, must not liquefy the element, the force supporting the bending process may be small.

In the future research, structural studies will be carried out to determine structural changes in the material. The next stage of research will be mechanically-assisted laser forming of thin-walled elements in the form of pipes made of the above materials.

Acknowledgements

The research reported herein was supported by a grant from the National Centre for Research and Development (No. PBS3/A5/47/2015).

References

[1] D.L. Deacon, Material Degradation in Heavy Steel Plates Caused by Bending with a Laser. Master's thesis. Cambridge, USA: Massachusetts Institute of Technology, Dept. of Ocean Engineering, 1984.

[2] H. Frąckiewicz, Z. Mucha, W. Trąmpczyński, A. Baranowski, A. Cybulski, Sposób gięcia przedmiotów metalowych. Patent PL155358. Data zgłoszenia 26.11.1987.

[3] Z. Mucha, J. Widłaszewski, P. Kurp, K. Mulczyk, Mechanicallyassisted laser forming of thin beams. Proc. of SPIE 10159, Laser Technology 2016: Progress and Applications of Lasers, 2016, pp. 101590U-1–101590U-10.

[4] M. Scendo, N. Radek, J. Trela, Influence of laser treatment on the corrosive resistance of WC-Cu electrospark coatings, International Journal of Electrochemical Science, 8, 2013, pp. 9264-9277.

[5] J. Widłaszewski, M. Nowak, Z. Nowak, P. Kurp, Laser-assisted forming of thin-walled profiles. Metal Forming. XXVIII, 3, 2017, pp. 183–198.

[6] P. Kurp, Z. Mucha, K. Mulczyk, R. Gradoń, P. Trela, The influence of surface preparation on the absorption coefficient of laser radiation, Proc. of SPIE 10159, Laser Technology 2016: Progress and Applications of Lasers, 2016, pp. 101590M1-101590M8.

[7] Maher Limited, INCONEL® alloy 718 Data sheet, 2018 (http://www.maher.com/media/pdfs/718-datasheet.pdf)

[8] Special Metals Corporation, INCONEL® alloy 625 Data sheet, 2018 (http://www.specialmetals.com/assets/smc/documents/alloys/inconel/inconel-alloy-625.pdf)

[9] K.C. Miles, Recommended values of thermophysical properties for selected commercial alloys, Woodhead Publishing Ltd and ASM International, 2002. https://doi.org/10.1533/9781845690144