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THERMAL EFFICIENCY OF THE TRUDISK 4002

The article presents the test results of thermal efficiency of the welded thin heat-resistant sheets of Inconel 718 nickel alloys using the Trudisk 4002 instalated in the TruLaser 5020 equipment. The thermal efficiency of the laser was determined using a water-cooled calorimeter. Thin sheet metal samples 0,7 and 0,9 mm, installed in the calorimeter were subjected to a laser beam with the power of 400 to 700 W, moved along the line at a constant speed Vs = 25 mm/s. The thermal efficiency was calculated as the quotient of the heat absorber by the welded sheets, determined calorimetrically, to the total amount of heat generated by the laser. The results show that thermal efficiency depends non-linearly on the laser power. The thickness of the plates to be welded does not affect efficiency. As the power of the laser increases from 400 to 600 W, thermal efficiency decreases three times from 21% to 7%, and with the increase of its power to 700 W, thermal efficiency increases to 28%.

Keywords: welding, Inconel 718 nickel alloy, thermal parameters

1. INTRODUCTION

The development of aviation technology is related to the development and application of new materials and the technology of their joining. Requirements imposed on metallic materials according to their working conditions, type of mechanical loads, temperature and environmental impact may vary [1].

The construction of modern aircraft engines requires metallic materials that can operate at temperatures up to 1200°C. Metals meeting the requirements of good heat resistance are nickel-based alloys, among which the Inconel 718 alloy is of great importance. This alloy has a good resistance to high-temperature corrosion and is one of the main materials used in PW4000 aircraft engines (manufactured by Pratt-Whitney) and CF6 engines (manufactured by General Electric).

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Compressor blades, shafts, turbines are made of this alloy, and parts of the combustion chambers and exhaust outlet are welded from metal sheets. Inconel 718 sheets are permanently joined by laser welding without the addition of a binder [1,2].

The main advantages of using a laser for joining sheet metal are: high quality of welded joints with a narrow heat-affected zone, minimal deformation and welding stress, as well as good performance, easy automation and robotization of the welding process. Additional advantages include the possibility of making joints that do not require further processing or significantly reduced finishing, limiting the harmful impact on the environment, and simple training and operation of the devices.

The main disadvantages of using a laser in the welding process include, apart from the high price, its low efficiency.

The basic laser parameters that determine the quality of the welded joints obtained are: beam power, energy and frequency of the light pulse, welding speed and the method of beam focusing.

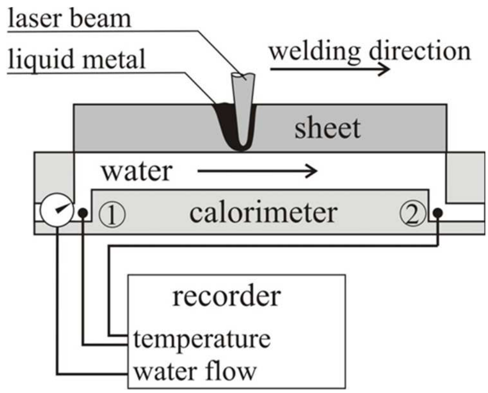
The aim of this study is to determine the thermal efficiency of the Trudisk 4002 in terms of the power used for welding thin sheets of heat-resistant alloy on the Inconel 718 nickel matrix.

2. THE MATERIAL AND METHODOLOGY

The material for the tests consisted of thin strips of Inconel 718 nickel matrix alloy sheet, 250 mm long, 50 mm wide and 0,7 and 0,9 mm thick. The chemical composition of the sheets, determined using the Q4 Tasman optical emission spectrometer (Bruker), was as follows: 19,0%Cr, 12,5% Fe, 5,2%Nb, 3,2%Mo, 0,87%Ti, 0,75 %Al, rest Ni.

The strands of these sheets were placed in a flow calorimeter [3]. The sheets were subjected to the influence of a laser beam with the power varying from 400 W to 700 W generated in the TruLaser 5020 laser head, moved along a line on a path with the length S = 200 mm, with a constant welding speed V_s = 25 mm/s. During the movement of the laser beam, the sheets were cooled with water with a constant flow rate of V_{H_2O} = 6 l/min. Using Ni-CrNi thermocouples installed at the points, at the beginning 1 and at the end of the laser beam path 2 (water inflow and outflow), the temperature difference ΔT was measured using a thermocompensator. The diagram of the thermal efficiency test stand and the view of the device with the TruLaser 5020 and calorimeter are shown in Figure 1.

a)



b)

Fig. 1. The scheme of the stand for testing thermal efficiency (a), view of the device TruLaser Robot 5020 with Trudisk 4002 and water-cooled calorimeter (b)

The amount of heat absorbed by the sheets subjected to a laser beam was calculated from the relation:

$$Q_k = m_w \cdot c_w \cdot \Delta T \tag{1}$$

where: Q_k – the amount of acquired by the heated sheets, J, m_w – the mass of water used to cool the sheet, expressed in kilograms, c_w = 4200 J/kgK, specific heat of water, $\Delta T = T_2 - T_1$ – temperature difference between the temperature of water flowing from the calorimeter at point 2 and the temperature of water flowing to the calorimeter at point 1.

The mass of water with a constant flow rate V_{H_2O}= 6 l/min (about 6 kg/min) used to cool the sheets while moving the laser beam along the line along the path S = 200 mm, with a constant speed V_s = 25 mm/s was calculated with:

$$m_w = t_s \cdot V_{H_2O} \tag{2}$$

where: m_w – the mass of water used to cool the sheet, kg,
t_s – time to move the laser beam, expressed in minutes

Laser thermal efficiency η_c was calculated from the quotient:

$$\eta_c = \frac{Q_k}{Q_c} \tag{3}$$

where: Q_c – the total amount of heat generated by the laser:

$$Q_c = \frac{P}{V_s} \cdot S \tag{4}$$

where: P – laser power, W; V_s = 25 mm/s; S = 200 mm.

The linear energy of E_L of sheet welding using the Trudisk 4002, taking into account its thermal efficiency, was determined from the dependence:

$$E_L = \eta_c \cdot \frac{P}{V_s}, J/mm \tag{5}$$

3. RESEARCH RESULTS

Tables 1 and 2 summarize the results of measurements of the thermal parameters of welding Inconel 718 sheets with using the TruLaser 5020. For a thinner sheet of 0,7 mm thickness, the thermal parameters were measured for three laser powers of 400, 450 and 500 W, and for a thicker sheet of 0,9 mm thickness, these parameters were measured for seven laser powers from 400 to 700 W, increasing the power by 50 W.

Table 1. Welding parameters, thermal parameters, thermal efficiency and line energy of welding E_L sheets from Inconel 718 alloys of 0,7 mm thickness

Lp.	**P, W**	**V_s, mm/s**	**t_s, s**	**Q_c, kJ**	**Q_k, kJ**	**ΔT, °C**	**η_c**	**E_L, J/mm**
1	400	25	8	3,2	0,76	0,2	0,21	3,36
2	450			3,6	0,62	0,2	0,17	3,06
3	500			4,0	0,38	0,1	0,10	2,00

Table 2. Welding parameters, thermal parameters, thermal efficiency and line energy of welding E_L sheets from Inconel 718 alloys of 0,9 mm thickness thin sheet 0,9 mm Inconel 718

Lp.	**P, W**	**V_s, mm/s**	**t_s, s**	**Q_c, kJ**	**Q_k, kJ**	**ΔT, °C**	**η_c**	**E_L, J/mm**
1	400	25	8	3,2	0,67	0,2	0,21	3,36
2	450			3,6	0,67	0,2	0,18	3,24
3	500			4,0	0,68	0,2	0,17	3,40
4	550			4,4	0,34	0,1	0,08	1,68
5	600			4,8	0,34	0,1	0,07	1,68
6	650			5,2	0,67	0,2	0,13	3,36
7	700			5,6	1,01	0,3	0,18	5,04

The results of calculating thermal efficiency η_c of laser beam welding of thin sheets of heat-resistant alloy on the Inconel 718 nickel matrix as a function of the laser power are presented in Fig. 2.

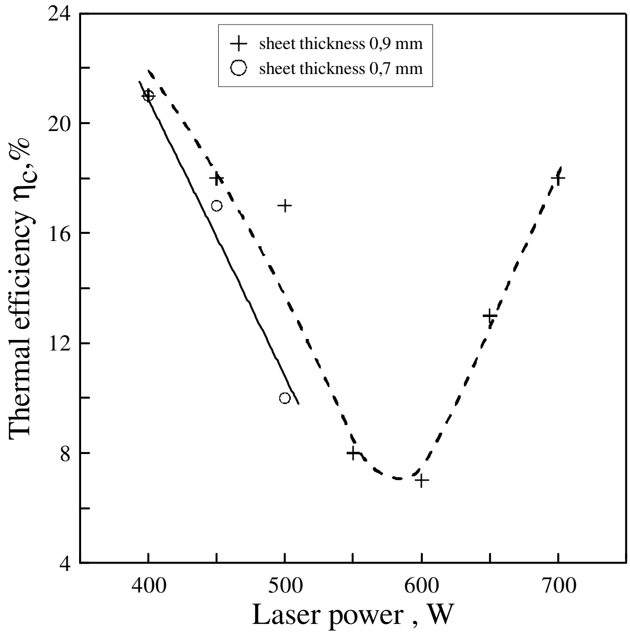


Fig. 2. The effect of the Trudisk 4002 laser power on the thermal efficiency of welding thin sheet from Inconel 718 alloy of 0,7 and 0,9 mm thickness

4. DISCUSSION OF RESEARCH RESULTS

The selection of laser welding parameters should be carried out in such a way as to maximize the thermal efficiency of welding. The thermal efficiency of the TruLaser 5020 strongly depends on the power used for welding. The presented research shows that the efficiency of this laser when used for welding thin sheets from the Inconel 718 nickel matrix varies within a wide range, from about 21% to 7%. The highest welding efficiency was achieved with the power of 400-450 W and 650-700 W. The laser power in the range of 500 - 600 W gave the lowest welding efficiency.

The amount of heat absorbed by the material at the point of incidence of the laser beam depends, among other things on the absorption (absorption) coefficient, which is determined by the geometric structure of the surface (SGP) (surface roughness). The surfaces of Inconel 718 alloy sheets were cleaned (tarnished) before welding and had the same SGP parameters.

Low thermal efficiency of the laser obtained in the power range of 500-600 W could be the result of the fact that the laser heating of the sheets took place in the air without the use of protective atmosphere. The formed oxides of the welded metal could cause a change in the absorbency of the incident laser beam, reducing its thermal efficiency.

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