

PAPER • OPEN ACCESS

Application of combined laser processing in welding of heat-treated parts

To cite this article: P Ogin 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **537** 032028

View the [article online](#) for updates and enhancements.

Application of combined laser processing in welding of heat-treated parts

P Ogin

Togliatti State University, 14, Belorusskaya St., Togliatti, Russian Federation

E-mail: fantom241288@yandex.ru

Abstract. The article deals with the questions of the end connections of heat-treated precision machine parts having a low stiffness, in particular, assembled Camshaft cars. To reduce the residual stresses that occur when welding heat-treated parts, it is proposed to perform preheating of heat-treated elements in the welding zone using a laser. Also, to reduce the deformations that may occur when welding axisymmetric structures with low stiffness, such as assembled Camshaft, it is proposed to use pulsed laser welding, and welding is performed only on the site previously processed by the previous laser. A laser machine based on two sources of laser radiation DLR-200-AC and YLR 150/1500-QCW-AC was used for experimental studies. The technological heads of lasers are coaxially arranged and have a single output lens, this allowed to calculate the processing program and the necessary laser power for the first and second laser source in a single technological window, as well as to synchronize the work of two laser sources. As samples were used assembled Camshafts, which consisted of a shaft with a Central hole, and heat-treated Cams. The shafts were made of steel 20 (WNR 1.0402), Cams of steel 40X (WNR 1.7034). Heat treatment of Cams was carried out by induction method. Analytical and technological features of processing are described. The cyclic combined process is described. The result is shown. Using the proposed methodology it is possible to use the technology of connecting axisymmetric parts with low stiffness both at the stage of analysis and modernization of existing designs, and at the stage of development of advanced designs.

1. Introduction

The final connection of welded parts with the help of laser is increasingly used in the automotive industry. The tightening of environmental requirements for cars makes designers continuously optimize its elements to reduce the weight and size indicators.

One of these parts is the Camshaft of the car. This part operates under cyclic loads. It is subject to the most stringent requirements for the accuracy and relative position of the individual surfaces. Reduction of weight and size parameters for this part is an urgent technical task.

One of the options for reducing the weight of this part is the use of an assembled structure [1-6]. This will allow you to change the design of existing elements, in particular will allow you to apply a hollow shaft. For different configurations of Cam shafts may reduce the weight and size by 10-50%. In addition, the designer is able to control the properties of individual wear surfaces of the part through the use of a variety of combinations of structural materials. Economic benefits can be achieved when used for low cost materials.



However, obstacles to the creation of such shaft designs are high requirements for the location of the working surfaces of the Cams, shaft deformation during welding by standard methods, as well as the need to perform welding of heat-treated parts.

The use of multi-component materials, complex configuration, low stiffness, and different thickness in the weld area make technologists constantly look for new ways and varieties of welding. This is due to the complexity of the structures used and constantly growing technical requirements for parts.

In works [7-9] the analysis of deviations of mating details at laser welding, in particular for axisymmetric details is carried out. Minimal deviations in the application of laser welding were revealed. In [10-12] it is shown that the preheating of the treatment surface leads to an improvement in the stability of the welding process. In particular, the work [13] shows the possibility of using induction current as a heating source. However, these methods are mainly applicable to high stiffness parts that are not subject to deformation during welding. Therefore, the search for technological solutions for welding of heat-treated axisymmetric parts with low stiffness is an urgent task. The work [14, 15] describes the use of a laser beam for preheating the welding zone, in particular in friction welding. Laser two-beam welding reduces the temperature gradient during welding, improves the stability and quality of the welded joint [16-18]. Therefore, as a source of local heating and welding of heat-treated parts, the use of a laser beam is permissible. In this paper, it is proposed to preheat and weld using two different lasers.

2. Research methodology

During the experimental work, the preheating of the heat-treated area was carried out by short-term exposure to a continuous medium-power laser. The final connection of the Cams and the shaft by welding using a pulsed laser. This allowed minimizing the deformation of the structure during welding. The laser combined treatment experiment was performed using two lasers, DLR-200-AC and YLR 150/1500-QCW-AC. Optical laser heads are mounted coaxially (figure 1).

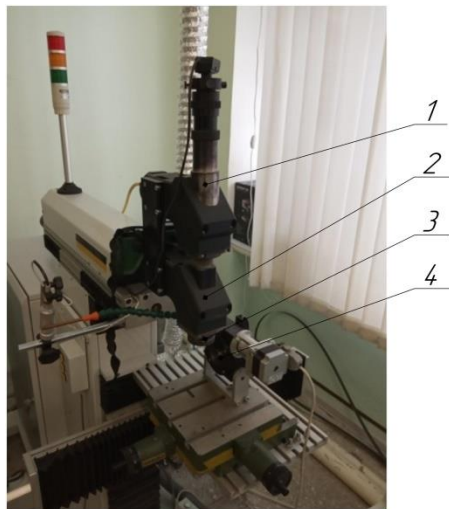


Figure 1. Optical laser heads. 1 - Optical head DLR-200-AC; 2 - Optical head YLR 150/1500-QCW-AC; 3 - the output lens; 4 - rotational device.

This made it possible to apply the original cycle during processing (figure 2). The processing technology is as follows. The first laser (DLR-200-AC) performs preheating in the weld area. After that it is switched off, the laser head returns to the middle of the treated area and the second laser (YLR 150/1500-QCW-AC) is switched on. Working in pulsed mode, it produces welding treated with the first laser phase. After this cycle repeats itself.

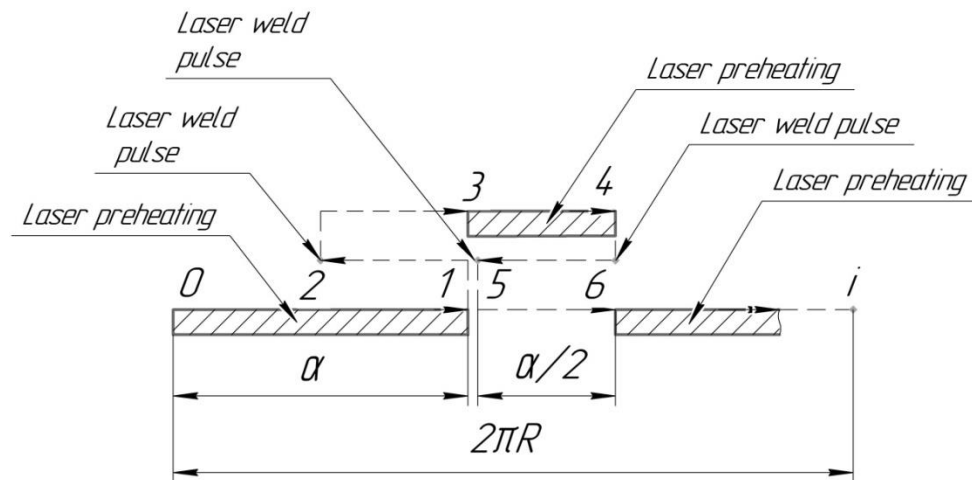


Figure 2. Cycle combined processing.

For experimental work a set of Cams of steel 40X (WNR 1.7034) and a hollow shaft of steel 20 (WNR 1.0402) were used. The Cams have been heat treated to a hardness of 45 HRC. Installation of Cams on a shaft was carried out in specialized technological equipment. Landing Cams was carried out to provide the necessary clearance GOST 28915-91 "Laser impulse welding. Main types, design elements and dimensions", type T1.

The papers [19, 20] give the theoretical data for calculating power density in the treatment area while creating on the surface of temperatures at which the processes of heat treatment of the material (hardening, temper, anneal), as well as welding and evaporation processes. Based on available data, power densities for preheating and welding have been analytically calculated. The power density for preheating was $7.07 \cdot 10^4 \text{ W/cm}^2$, for welding $5.3 \cdot 10^5 \text{ W/cm}^2$.

To obtain the required overlap ratio ($k_p=0.5$), the angular velocity of the shaft rotation is calculated (figure 3). The initial data was taken as the diameter of the contact spot (d) of the laser in the treatment zone – 0.3 mm.

Calculation of the angle of rotation to meet the conditions of combined treatment was carried out from the condition $\alpha=d$.

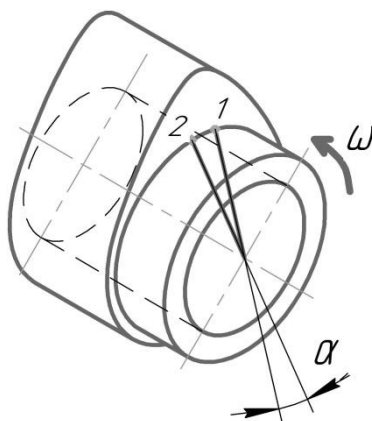


Figure 3. Scheme of calculate velocity of the shaft rotation for combined processing.

The velocity ω was chosen based on the solution of the inequality (1):

$$\omega = \frac{9}{R} \leq k_p \cdot d \quad (1)$$

After calculation, the speed ω is made up 0.134 rad/sec .

3. Practical significance

Camshaft after combined (preheating + weld) processing illustrated in figure 4.



Figure 4. Camshaft after combined (preheating + weld) processing.

4. Conclusions

The methodology of complex laser processing of high-precision heat-treated machine parts with low stiffness is proposed. The technology of Assembly of heat-treated parts on the example of camshaft is proposed. The possibility of reducing residual stresses in the welded joint of heat-treated parts due to preliminary local laser treatment is shown.

5. Judgments and prospects of research development

At the stage of further analysis of the proposed technical solutions, it is advisable to use virtual and mathematical modeling tools, for example, Ansys, MathLAB/Simulink, including simulation and parameterization of technological parameters of laser processing (for example, by the criteria of thermal balance, calculations of stress-strain state, accuracy characteristics, reliability and durability criteria, dynamic performance, etc.).

In addition, further work will describe the structure of the welded joint, as well as the results of endurance tests of the proposed design of Camshafts.

References

- [1] Horvat G L and Surface S C 1989 Assembled Camshafts for Automotive Engines *J. Materials Shaping Technology* **3** 133-6
- [2] Chen J T and Yang L F 2013 State-of-the-Art of Joining Technologies for Assembled Camshaft *Advanced Materials Research* **602-604** 2118-22
- [3] Yuan Y, Mingcheng W, Zhaoying L, Fengchi S, Wei W, Peihe Z, Ming C, Xiaoyi L and Min Z 2014 Lightweighting development by means of laser welding in China automaker faw *35th FISITA World Automotive Congress* **9**
- [4] Zhai Z, Yang L, Ma J and Zhang M 2017 An evaluation of the assemblability of two novel assembled camshaft configurations by tube hydroforming *AIP Conference Proceedings* 1896
- [5] Meusburger P 2005 Assembled camshafts for commercial vehicles *ThyssenKrupp techforum* 54-9
- [6] Kou S, Yang S, Zhao Y and Zhang C 2004 Engine assembled camshafts-competitive technologies for camshaft manufacture *Zhongguo Jixie Gongcheng/China Mechanical Engineering* **15** 474
- [7] Buschenhenke F, Hofmann M, Seefeld T and Vollertsena F 2010 Distortion and residual stresses in laser beam weld shaft-hub joints *Physics Procedia* **5** 89-98
- [8] Denkena B *et al* 2018 Surface integrity of turned laser-welded hybrid shafts *Production Engineering* **13** 79-87

- [9] Buschenhenke F, Seefeld T and Vollertsen F 2011 Distortion control during laser beam welding of shaft-hub joints within a process chain *Journal of Laser Applications* **1** 427-34
- [10] Turichin G, Kuznetsov M, Pozdnyakov A, Gook S, Gumenyuk A and Rethmeier M 2018 Influence of heat input and preheating on the cooling rate, microstructure and mechanical properties at the hybrid laser-arc welding of API 5L X80 steel *Procedia CIRP* **74** 748-51
- [11] Sokolov M and Salminen A 2014 Methods for improving laser beam welding efficiency *Physics Procedia* **56** 450-7
- [12] Zhang L J, Liu J Z, Bai Q L, Wang X W, Sun Y J, Li S G and Gong X 2019 Effect of preheating on the microstructure and properties of fiber laser welded girth joint of thin-walled nanostructured Mo alloy *International Journal of Refractory Metals & Hard Materials* **78** 219-27
- [13] Kügler H and Vollertsen F 2013 Inductive preheating in laser beam welding of multimaterial joints of 22MnB5 and AA6016 *Physics Procedia* **41** 41-8
- [14] Wada T, Morisada Y, Sun Y, Fujii H, KaWahito Y, Matsushita M and iKeda R 2018 Friction Stir Welding of Medium Carbon Steel with Laser-Preheating *Tetsu-to-Hagané* **104** 23-30
- [15] Sun Y F, Konishi Y, Kamai M and Fujii H 2013 Microstructure and mechanical properties of S45C steel prepared by laser-assisted friction stir welding *Materials and Design* **47** 842-9
- [16] Chen W and Molian P 2008 Dual-beam laser welding of ultra-thin AA 5052-H19 aluminum *Int J Adv Manuf Technol* **39** 889-97
- [17] Bergmann J P, Bielenin M and Feustel T 2015 Aluminum welding by combining a diode laser with a pulsed Nd:YAG laser *Weld World* **59** 307-15
- [18] Harooni M, Carlson B and Kovacevic R 2014 Dual-beam laser welding of AZ31B magnesium alloy in zero-gap lap joint configuration *Optics & Laser Technology* **56** 247-55
- [19] Duley W W 1983 *Laser Processing and Analysis of Materials* (Springer, Boston, MA) p 464
- [20] Kovacs T 2018 Laser welding process specification base on welding theories *Procedia Manufacturing* **22** 147-53