On the Possibility of Laser Pulse Characterization Based on Displacements and Temperatures at the Back Surface of the Target Body

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ABSTRACT

Lasers are used in science, medicine and industrial engineering [1]. The spatial distribution of energy of the laser beam is a key parameter in these applications. The beam profile must be stable during laser operation. Moreover, regular profiles are strongly preferred over irregular ones [1]. Numerous measurement techniques are applied to verify beam profiles and monitor their stability [1]. These techniques may be categorized as destructive and non-destructive. In destructive measurements, laser beams interact with solid targets (e.g. thermal paper, photographic films, acrylic blocks) and leave permanent changes which allow to identify some beam parameters. Nevertheless, these techniques are quite inaccurate and do not allow for continuous measurements. Non-destructive techniques are typically digitalized and make use of various methods of beam attenuation before it interacts with the sensor (e.g. various types of cameras) [1] but utilized apparatus are usually fragile and very expensive.

Recently, Kujawińska et al. [2] proposed a non-destructive method to retrieve laser beam parameters in which short laser pulse hits a thin metallic plate with circular hollow in the illumination area. In their paper measurements of temperature field at the rear surface of the plate (vis-à-vis the heated area) and its mechanical deformation (vector of displacements) were proposed to identify the laser beam profile. The schematic of the experimental stand incorporating the laser, thin aluminum plate, focusing lens as well as IR and CMOS cameras is presented in Fig. 1A. It was shown by Pietrak et al. [3] and Łapka et al. [4] that four spatio-temporal parameters of the laser pulse may be successfully identified by applying only temperature field measurement on the rear surface of the sample (e.g. registered using the IR camera), under the assumption that the beam profile is accurately described by the super-Gaussian distribution (mathematical form of the super-Gaussian function given in [5] was assumed). The recovered parameters were the laser pulse power, dimensionless shape coefficient of the super-Gaussian distribution as well as start and end times of exposition of target to the laser beam. In this paper, the development of the inverse algorithm described in [3] and [4] is continued and the results of the analysis of deformation of the metallic plate after the laser excitation is shown. The possibility of identification of laser beam parameters based on displacements (measured via Digital Image Correlation [6]) is investigated. Then the extended inverse algorithm is presented, including both finite volume model of heat conduction and finite element model of plate deformation (as shown in Fig 1B). The inverse procedure is based on the Levenberg-Marquardt least-squares minimization algorithm, employs software from the commercial CAE suite ANSYS Workbench, and is implemented in GNU Octave.

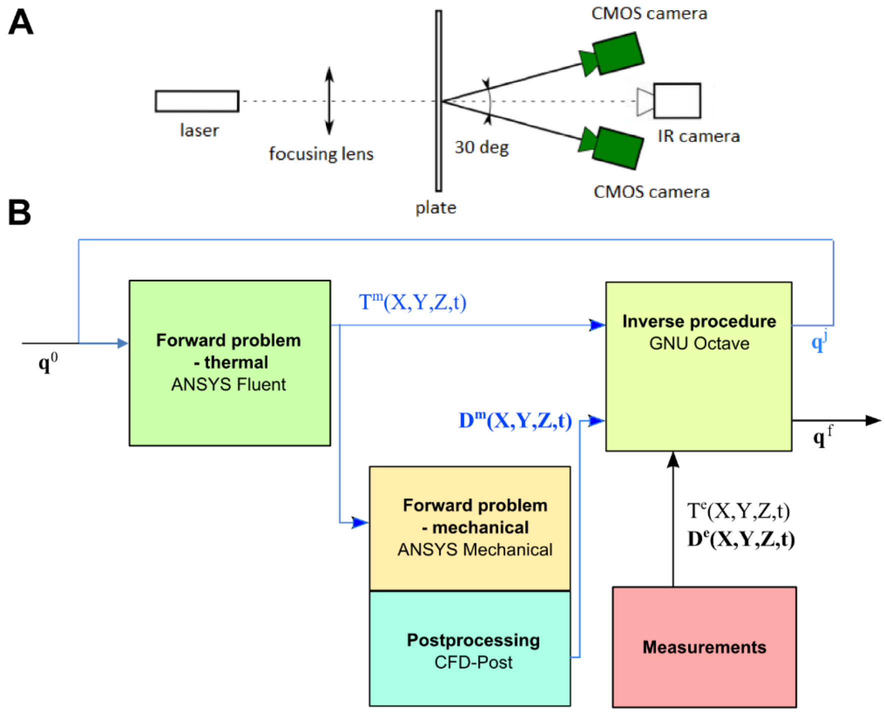

FIGURE 1. Schematic of the experimental stand (**A**); and data flow diagram for the implemented inverse algorithm (**B**), where: $\mathbf{q}^0$ – initial vector of unknown parameters, $\mathbf{q}^j$ – unknown parameters in j-th iteration, $\mathbf{q}^f$ – final calculated values of unknown parameters, $T^e(X,Y,Z,t)$ – measured temperature fields, $\mathbf{D^e(X,Y,Z,t)}$ – measured displacements, $T^m(X,Y,Z,t)$ – modeled temperature fields, $\mathbf{D^m(X,Y,Z,t)}$ – modeled displacements

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