NUMERICAL SIMULATION OF RADIATION LOSSES IN A DECAYING LASER SPARK USING LBL METHOD

A Thesis

Submitted by

Ankit Sharma

For the award of the degree

Of

MASTER OF SCIENCE (by RESEARCH)

School of Engineering

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I dedicate my thesis to my loving family, teachers and friends.

Declaration by the Research Scholar

I hereby declare that the entire work embodied in this thesis is the result of the investigations carried out by me in the School of Engineering, Indian institute of Technology Mandi, under the supervision of Dr. Ankit Bansal and Dr. P. Anil Kishan, and that is not submitted anywhere for the award of the degree. In keeping the general practice, due acknowledgements have been made wherever the work described is based on the finding of other work.

I.I.T. Mandi (H.P.)

Date: 16 September, 2015

Ankit Sharma

Indian Institute of Technology, Mandi
Mandi, Himachal Pradesh - 175005 मण्डी,

भारतीय प्रौद्योगिकी संस्थान, मण्डी
हिमाचल प्रदेश - 175005

THESIS CERTIFICATE

This is to certify that the thesis titled "**Numerical Simulation of Radiation Losses in a Decaying Laser Spark using LBL method**" submitted by **Ankit Sharma**, to the Indian Institute of Technology Mandi for the award of the degree of **Master of Science (by Research)**, is a bona fide record of the research work done by him under our supervision. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

Dr. Ankit Bansal
Thesis Supervisor
Assistant Professor
Department of Mechanical and Industrial Engineering
IIT Roorkee.

Date: 16 September, 2015

Dr. P. Anil Kishan
Thesis Co-Supervisor
Assistant Professor
School of Engineering
IIT Mandi.

Date: 16 September, 2015

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ANKIT SHARMA

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ABSTRACT

An investigation has been done to numerically simulate the radiation losses which occur due to laser energy deposition. Although the fluid dynamic effects due to laser energy deposition has been studied by a number of researchers independently but the effect of radiation has either been neglected or has not been highlighted effectively. When a laser beam is focused on a small focal volume of gas, the energy is absorbed by the gas causing breakdown of gas resulting in collision of energetic electrons which results in very high pressure and temperature gradients at the end of plasma formation. These gradients lead to fluid dynamic phenomenon such as formation of detonation, and the propagation of the pressure wave into the surrounding gas. Chemical changes also occur which result in dissociation, ionization and recombination of different species as N_2, O_2, NO, N, O, etc. At such high temperature, the diatomic air species may become highly dissociated and emission from the resulting two mono atomic species N and O cannot be neglected and is the major source of radiation loss. An Open Source CFD software Open Foam has been used to study the above effects. To define the chemistry model five species namely O_2, O, N_2, N, NO and eleven elementary reaction steps are considered for dissociation and recombination of air. For radiation modeling, detailed line by line spectral model has been developed. Accurate simulation of radiation heat transfer is carried out by line-by-line radiation modelling which requires very accurate absorption coefficient data at hundreds of thousands of wavelengths. The RTE must be solved at each wavelength, and the total intensity is calculated by applying a suitable integration scheme in wavelength space. Spectroscopic data required for the calculation of

emission and absorption coefficients was taken from NIST database. This model includes features as thermodynamic data from Gordan and McBride, Boltzmann distribution, line broadening effects, absorption and emission coefficients calculations. It has been integrated with OpenFOAM to solve RTE using P1 solver. Radiation losses obtained are almost *500 times* higher as compared to the past reported data but still these losses are very less as compared to the deposited energy. Since the most accurate method LBL also showed that radiation losses are negligible so our study validates the assumption of neglecting the radiation losses which was assumed in all previous studies without any proper validation.

Keywords: Lasers, Radiation, Blast wave, Plasma, Line by line, Spectral modelling, P1 solver

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