

**MEASUREMENT OF TEMPERATURE OF
GASEOUS FLAMES USING DIGITAL
HOLOGRAPHIC INTERFEROMETRY**

by

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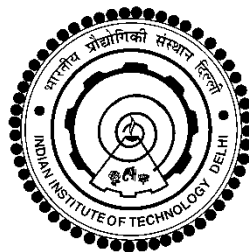
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**DEDICATED TO
MY
PARENTS**

CERTIFICATE

This is to certify that the thesis entitled “**MEASUREMENT OF TEMPERATURE OF GASEOUS FLAMES USING DIGITAL HOLOGRAPHIC INTERFEROMETRY**” being submitted by **Ms. SHOBHNA SHARMA** to the Indian Institute of Technology Delhi for the award of the degree of “**DOCTOR OF PHILOSOPHY**”, is a record of the authentic research work carried out by her under my supervision and guidance. She has fulfilled all the requirements for submission of this thesis, which to the best of my knowledge has reached the required standard.

The material contained in this thesis has not been submitted in part or full to any other University or Institute for the award of any other degree.

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ABSTRACT

Optical interferometric techniques are more sensitive, precise, accurate and whole field in comparison to other conventional measurement techniques. These techniques are non-invasive and non-contact type. Digital holography has made possible the quantitative measurement of phase from a single hologram. This has proved to be very powerful tool for optical metrology. Digital holography is free from the processing of recording material. It can make directly availability of phase from one digital hologram and thus have made interferometric process faster, robust and almost real time. In this thesis the measurement of temperature and temperature profile of gaseous flames (premixed, partially premixed and diffusion flame) using lensless Fourier transform digital holographic interferometry (LLFTDHI) is presented. The thesis is organized in five chapters-

Chapter 1 provides the basic knowledge about laminar premixed flames and laminar diffusion flames; intrusive and non intrusive techniques, those are used to measure the temperature of laminar flames. Also the brief details of interference, diffraction, conventional holographic principles and its types are presented. The chapter provides the description of digital holography, its development including the detail description of digital recording process and numerical reconstruction techniques along with the application of LLFTDHI in optical metrology. This chapter also gives the brief outline of the research work presented in this thesis.

Chapter 2 describes the measurement of temperature in axi-symmetric flames using LLFTDHI. LLFTDHI reconstruction technique is simple, easier to implement and need less optical components. Also, it can be used almost in real time. In this experiment the candle flame was used as an axi-symmetric object. Two digital holograms are recorded corresponding to two different refractive indices n_1 (without candle flame) and n_2 (with candle flame) respectively and used to calculate the phase difference between them. The line profile of the phase difference map is plotted which provides fringe number distribution by each pixel of the sensor with high spatial resolution. Then the summation of geometric path lengths is calculated by dividing the cross-section of the axi-symmetric flame at a particular position into numbers of annuli. The refractive index in each annulus is then calculated from the determined geometric path length through each annulus and the fringe-number of the ray which passed through the annulus. Hence, the temperature distribution is related using the Lorentz-Lorenz equation.

Combustion processes is well known to be influenced by magnetic fields. Magnetic field affects flame behavior because of the paramagnetic and diamagnetic nature of the constituent gases. The concentration of paramagnetic oxygen gas in air is much higher than that of paramagnetic chemical species in diffusion flame, for example ions, radicals, electrons etc. Therefore, oxygen plays an important role to determine the effect of magnetic field on the flames. Chapter 3 deals with the effect of uniform magnetic field on the measurement of temperature of axi-symmetric flame using LLFTDHI. Permanent magnets of rare earth are used to produce the uniform magnetic field. The investigation reveals that the combustion is promoted and hence enhanced the flame width under the applied magnetic field. This

observation is based on the paramagnetic characteristics of oxygen. The oxygen is drawn towards the magnetic field and thus more air is drawn towards the flame which promotes combustion whereas the other fuel and combustion products are diamagnetic those are efficiently repelled by the magnetic field. Since the oxygen is not concentrated at a particular point/area because of the uniform magnetic field, therefore the temperature is uniformly enhanced under the influence of magnetic field.

Butane gas is made up of carbon and hydrogen. It is a highly inflammable gas that is colorless, odorless and easy to liquify. These characteristics make it highly useful for certain applications. Butane torch is the most common application of butane gas so it is important to study the temperature and temperature behavior of butane torch flame. In chapter 4, the temperature and temperature profile of axi-symmetric flames (premixed, partially premixed and diffusion) generated by butane torch which is largely used by small scale industries, small glass blowing industry and by dentists is presented. By using butane/air flame of torch burner, three types of flames i.e. axi-symmetric premixed, partially premixed and diffusion butane/air flames are created corresponding to the supply of air percentage for the combustion through the nozzle burner and are investigated. On the basis of experimental results, it is investigated that as the supply of air is reduced, the premixed butane/air flame approaches towards diffusion flame and the measured temperature decreases.

Finally, chapter 5 provides the conclusion of the work presented in the thesis and suggestions for the future scope of the work.

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