

**Study of Combustion Characteristics of Premixed and
Diffusion Flame with Hydrogen and Methane Fuel**

A THESIS

submitted by

PUNIT KUMAR (S14004)

for the award of the degree

of

MASTER OF SCIENCE

(by Research)



School of Engineering

INDIAN INSTITUTE OF TECHNOLOGY MANDI

August 2017

Declaration by the Research Scholar

This is certify that the Thesis entitled “**Study of combustion characteristics of premixed and diffusion flame with hydrogen and methane fuel**”, submitted by me to the Indian Institute of Technology Mandi for the award of the Degree of Master of Science (by research) is a bonafide record of research work carried out by me under the supervision of ***Dr. P Anil Kishan***. The content 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.

Place: IIT Mandi

Signature:

Date:

Punit Kumar

Declaration by the Research Advisor

This is certify that the Thesis entitled “**Study of combustion characteristics of premixed and diffusion flame with hydrogen and methane fuel**”, submitted by ***Punit Kumar*** to the Indian Institute of Technology Mandi for the award of the Degree of Master of Science (by research) is a bonafide record of research work carried out by him under my supervision. The content 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.

Signature:

Dr. P Anil Kishan
Assistant Professor
School of Engineering
Indian Institute of Technology Mandi

Date:

Acknowledgement

Foremost, I would like to acknowledge Dr. P Anil Kishan for all the support and guidance which he has provided me at times. In absence of his insights and directions, this work could certainly not be completed. I would also like to thanks Dr. Atul Dhar for all the support, brainstorming sessions and time with which he has helped me to carry out this research. Annual progress committee members: Dr. Vishal Singh Chauhan, Dr. Dhiraj Patil, Dr. Arpan Gupta and Dr. C S Yadav, are also appreciated for their timely suggestions and directions.

I would also like to mention and thank the lab members and my dear friends Mr. Priybrat Sharma, and Mr. Sarthak Nag. Their technical discussion and insight have always helped to resolve the issues at hand. It is always fun to work in the lab with them.

Special thanks to all my friends at IIT Mandi, Davinder Singh, Sumeet Sharma, Ajay Bhardwaj, Arpit Bhardwaj, Manoj Dhiman, Tushar Kant Swain, Abhishek Banagunde, Neha Thakur, for all the moral support and for bear with me and my boredom. All the trekking trips and bike rides will always be memorable. Lastly I would like to thanks my parents, brothers and sisters to support me and believe in me.

Punit Kumar

Contents

Acknowledgement	v
Contents	vii
List of Figures	ix
Nomenclature	xi
Abstract	xii
1 Introduction	1
1.1 Theory and Literature Survey	3
1.1.1 Combustion and Flame	3
1.1.2 Premixed Flame	4
1.1.3 Flame front	5
1.1.4 Flame Stretch	8
1.1.5 Diffusion Flame	13
1.2 Objective	16
1.3 Thesis Outline	16
2 Design and Development of Constant Volume Combustion Chamber (CVCC)	19
2.1 Introduction	19
2.2 Design Methodology	20
2.2.1 Sizing	21
2.2.2 Visual System	21
2.2.3 Fuel Supply System	23
2.2.4 Temperature control system	23
2.2.5 Ignition and Camera Triggering System	25
2.2.6 Pressure measurement System	25
2.3 Experimental Sequence	26
2.4 Image Processing and flame velocity measurement	27
2.5 Schematic Diagram and Setup	30
3 Experimental and numerical studies of flame characteristics of premixed combustion	33
3.1 Introduction	33
3.2 Flame kernel growth study of spark ignited hydrogen air premixed combustion at engine conditions	33
3.2.1 Numerical Modeling	34
3.2.2 Results and Discussion	36
3.3 Numerical Investigation of Pressure and Temperature Influence on Flame Speed in CH₄ – H₂ Premixed Combustion	45
3.3.1 Numerical Approach	45

3.3.2	Results and Discussion	48
4	Diffusion Flame characteristics of H₂ – CH₄ in coflow burner	66
4.1	Introduction	66
4.2	Computational Details	67
4.3	Boundary Conditions	69
4.4	Validation	71
4.5	Effect of H ₂ on CH ₄ flame	73
4.6	Effect of Fuel inlet velocity CH ₄ – H ₂ flame structure and emissions in JHC (Jet in Hot Coflow) burner	77
4.6.1	Effect of fuel inlet velocity on structure of the flame	77
4.6.2	Effect of fuel inlet velocity on Emission	85
4.7	Investigation of Recirculation of burned gases on CH ₄ – H ₂ diffusion flame in a Jet in Hot Coflow (JHC) burner	92
4.7.1	Effect of oxygen concentration on emissions	92
4.7.2	Effect of dilution with CO ₂ concentration on emissions	98
5	Conclusion and Future Plan	102
	REFERENCES	106
	APPENDIX	111
	List of Publications	118