

## **Biodata**

**Name:** H S Mukunda

**Academic qualifications:** B.E. Mechanical, 1963, Mysore University, Mysore, M.E. (Aeronautical), 1965, Indian Institute of Science, Bangalore, Ph.D. (Engineering Sciences), 1970, Indian Institute of Science, Bangalore

**Current positions:** Chairman, Advanced research Center – Jain university, Jain University, Global campus, Kanakapura Road, also, Hon. Advisor, ABETS, Combustion, Gasification & Propulsion Laboratory, Department of Aerospace Engineering, Indian Institute of Science Bangalore 560 012,

### **Teaching**

About half a dozen courses in the areas of Rocket Propulsion, Liquid Propellant Rockets, Aircraft as a total system, Mechanics and Thermodynamics of Aerospace Propulsion, Mathematical Techniques in Reacting Flows, Fundamentals of Combustion, Statistics and some of the courses have been delivered over several years.

### **Research**

Research interests span from computational and experimental investigations on combustion of propellants and propulsion systems to those on wood and cellulose. 25 Ph.D and 25 Masters Dissertations have been completed. The research activities have resulted over 80 Journal publications and 50 conference proceedings. Some of the research projects have originated from sponsored R & D projects. Have been the principal investigator for more than a dozen sponsored projects and a co-investigator for another six sponsored projects. The total financial outlay for the projects handled exceeds 50 million Rupees. The projects handled are for Aeronautics Research & Development Board (AR & DB), Ministry of Non-conventional Energy Sources (MNES), Department of Science & Technology, Karnataka State Council for Science & Technology, Department of Space (Indian Space Research Organisation), Aeronautical Development Establishment ADE), the most extensive in terms of effort and funds being AR&DB and MNES.

### **Significant Contributions to Science and Technology**

The professional career has focused on the study of combustion processes in Aerospace propulsion and civilian industrial systems that include gaseous, liquid and the more difficult solid fuels, namely, agro-residues and other bio-fuels. The central theme of these studies to uncover methods of controlled burning fuels with efficiency and minimal gaseous emissions – clean combustion processes. The key aspect of his work is to combine fundamental investigations leading to publications in prestigious journals along with technology development of

relevance to aerospace as well as civilian community in India and other countries. This unusual ability has allowed him to create a unique group at the Institute that is continuing to take forward concepts and ideas to technologies of national and international significance.

He and his colleagues have competed and participated in the bi-annual International symposia on combustion for the last twenty years by presenting refereed papers and placing India on the international combustion science map. In the aerospace area, the contributions are significant in respect of understanding and development of hybrid propulsion systems, erosive burning in solid rocket propellants and combustion instability in solid rockets. He has participated extensively the reviews of propulsion systems of ISRO – PSLV and GSLV and tactical rocket systems of DRDL – Prithvi, Akash, Nag, B-5 (PJ10) and others.

Two important areas are in the understanding and the development of combustion devices and biomass gasifiers to generate electric power by using the combustible gas to run reciprocating engines in dual fuel compression ignition mode or gaseous fuel spark ignition engines.

Both basic research and technology development on these devices have been successfully completed; technology transferred and deployed for the benefit of rural energy services as well as urban poor.

The motivation for the work was derived from the considerations that

- (i) India's economy is strongly affected by the import of petroleum resources from overseas,
- (ii) India has a vast biomass resource estimated at 100-150 million tonnes per year (net) which remains to be tapped for the finest form energy namely, the electrical (the estimated installed capacity is about 10000-15000 MW),
- (iii) such an effort should note the localised and distributed availability of the resource, and
- (iv) the basic sciences of combustion and gasification have not progressed adequately enough to tackle the variety and variability in the physical and chemical properties of biomass.

The work performed in the laboratory has led to

- the understanding as to why biomass stoves have lower thermal efficiency compared to kerosene and gas stoves,
- the development of efficient designs for woody as well as powdery biomass stoves for a range of power level of 4-50 kW and utility patterns of domestic and community kitchens as well as industrial conditions.

Gasification systems for 25, 300, 450, 500 kg/hr thermal applications have been designed and built in India for industries to run the systems to run on 24 hour per day basis and several of them have clocked 4000 hours in less than ten months.

Systems for electrical applications have been designed tested and built for 3.7, 20, 50, 100, 300 kWe and 1000 kWe are in use both in industrial sector and the rural sector.

In recent times, highly efficient and emission-free bio-fuel based combustion systems for domestic cooking, community cooking and bathwater heating and other semi-industrial applications using electricity (about 2 to 3 Watts) have been designed, tested, and patented. They are being commercialized currently.

### **Impact**

The work has resulted in developing indigenous technology to meet the requirement of the country. Further, the technology has been transferred to Europe, Japan and Brazil. The technology package developed has a significant contribution to the oil economy in this country and also key role to play in the CDM's.

### **Intellectual Property rights and Technology Transfer**

Patents have been taken on both the design of Wood stoves and Open Top Gasifiers as well as cyclone gasifiers for Pulverised fuels. These patents have been taken in India, European countries, Sri Lanka, Japan, Thailand, and Brazil for the present. These have been taken in several countries since technology has been transferred to Four technology transferees in India, one to Switzerland (Xylowatt).

### **Recognitions/Awards**

1. Karnataka Rajyotsava Award 2005
2. DRDO Academic Excellence Award 2002
3. Life time achievement award of Solar Energy society of India.
4. Om Prakash Bhasin Award for Energy, 1994.
5. Award for Excellence in Research in Engineering, 1994.
6. Fellow of Indian Academy of Sciences, 1984.
7. Fellow of Indian National Academy of Engineering, 1995.
8. Life time contribution Award by Solar Energy Society of India, 1999
9. Member, International Board of Directors of Biomass Energy Network, 1995.
10. Fellow of the Aeronautical Society of India, 1994.
11. Member of several policy and R&D committees of Bioenergy Utilisation in DNES (MNES) from 1985.

12. Nominated Indian Representative on the World Energy Society, 1993 - 1996.
13. Member, ISPRES (under ICSU, Paris), 2005+
14. Sir M. Visweswariah award for outstanding science and technology, Karnataka Government, 2006

### **International Travel**

1. Israel for attending the 19th (Int.) Symposium on Combustion (1982).
2. USSR as a member of delegation on Heat and Mass Transfer (1983).
3. China to attend the Second Asian Congress on Fluid Mechanics (1983).
4. USA to attend the 20th (Int.) Symp. on Combustion and Labs. in USA, Germany, Holland and France (1984).
5. Japan to deliver invited lecture on Computational Mechanics at the International Congress (1985).
6. Germany to attend the 21st (Int.) Symp. on Combustion in Munich and visit to Laboratories in Sweden (Royal Swedish Laboratories), and Holland (1986).
7. Visit and Stay at NASA Langley Research Center, Hampton, USA as National Research Council Associate for two years (June 1987- June 1989).
8. USA to attend the 22nd (Int.) Symp. on Combustion (August 1988).
9. USA as visiting scientist to Institute for Computer Applications to Science and Engineering (ICASE) during the summers of 1990, 1991 and 1993.
10. France to attend the 23rd (Int.) Symp. on Combustion at Orleans (July 1990).
11. Visit to Switzerland for presentation of Joint Indo-Swiss Test on IISc gasifier at ETZ, Zurich, 1994.
12. Irvine, California (USA) to participate in the 25th (Int.) Symp. on Combustion and also to Royal Institute of Technology, Stockholm (Sweden) to discuss the collaborative project on gasification, 1994.
13. University of Rome, Rome to record lectures of biomass utilisation for use in UN universities, 1994.
14. USA to attend the Biomass Users Network meetings as a Board of Directors at New Jersey in 1995.
15. Naples to attend 26<sup>th</sup> International Symposium on Combustion and visit several institutions in Germany and Switzerland (July – August, 1996)
16. USA to attend 27<sup>th</sup> International Symposium on Combustion and hold discussions with NREL, Golden, Colorado and Paul Scherer Institute, Zurich in Switzerland (August 1998).
17. Warwick, U.K. to participate in Indo-U.S. programme on “Electric Power Technology Assessment” during 24-27 Sept. 1999
18. Australia and New Zealand for study tour under UNDP/GEF related project on “Development of high rate biomethanation processes as means of reducing green house gases emission, April 10-21, 2000

19. Brazil – University of Itajuba, (EFEI), to deliver a course to students on bioenergy and examine the possibility of cooperation on small scale biomass to power with other universities – Uni. Paraiba, Joao Passoa and the governmental organization, ANEEL at Brazilia during 03 – 21 November 2000
20. Brazil – Specialist conference at Rio-de-Geneiro to examine the status of small scale biomass gasification 28 – 30 June 2001
21. China – as an expert on an FAO sponsored study tour to Kunming and surrounding areas for South East Asian countries from 10 - 15, Sep. 2001.
22. Myanmar – as an expert to advice Myanmar Government on biomass gasification and power generation from biomass in rural areas arranged by the Indian Embassy in Myanmar, 7 to 11 January 2002.
23. University of Hokaido, Sapporo, Japan during July, 2002 to attend the 29<sup>th</sup> International on Combustion. Also visited M/s Satake Corporation, Japan with whom technology transfer agreement has been signed for manufacturing of gasifiers developed in this laboratory.
24. Cuba – during 2001 and 2002 as an international expert for a GEF project.
25. Paris, France to participate in ISPRES (ICSU) meetings, 2005, 2007, 2008.

### **Administrative Positions Held**

1. Convener, Space Technology Cell (1982-1983).
2. Convener, Joint Advanced Technology Programme (1983-1987).
3. Chairman, Center for Scientific and Industrial Consultancy (1989-1991).
4. Convener, Action Research Center for Biomass Gasification and Combustion (1992-1999).
5. Hon. Secretary, KSCST (1995-1997).
6. Chairman, Department of Aerospace Engineering (1995-1999).
7. Chairman, Center for Schemes and Projects (1996-2003).
8. Chief Programme Executive, Advanced Bioresidue Energy Technologies Society (1998-2003)
9. Chairman of the Board of Directors of International Biomass Users Network.
10. Indian Representative of World Energy Society.
11. Advisor, Advanced Bioresidue Energy Technologies Society (2004+)
12. Chairman, Advanced Research Center and Fire and combustion research center (2015+)

### **Elsevier's citations of the publications:**

YOUR 20 ELSEVIER PUBLICATIONS: **12,938**

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United States	<b>1,633</b>
China	<b>1,052</b>
Thailand	<b>720</b>
United Kingdom	<b>491</b>

## **Publications**

### **Books:**

1. Understanding Combustion, Macmillan, India, 1990 (1st edition), 2009 (2<sup>nd</sup> edition)
2. Recent advances in biomass gasification and combustion. edited by P J Paul and H S Mukunda, 1992
3. Biomass to Energy, The S&T of the IISc Bio-energy Systems by ABETS, IISc, 2003
4. Understanding clean energy and fuels from biomass, Wiley India, 2011
5. Understanding Aerospace Chemical Propulsion, Interline Publishing, 2004; reprinted by IK International publishing, 2017
6. Understanding Air and Space Vehicles, Jain university publishers, Bangalore, 2017

### **Journals and others**

*(Note: Most pdfs can be accessed at <http://cgpl.iisc.ernet.in>)*

### **1965-1974**

- V. K. Jain and H. S. Mukunda - On Ignition and Extinction Problems in Forced Convection Systems, Int. J. Heat Mass Transfer, 11, p.419, 1968.
- H. S. Mukunda and V. K. Jain - Structure of a Diffusion Flame in the Presence of a Wall with One Step Reversible Chemical Kinetics, Astronautica Acta, 14, p.629, 1969.
- V. K. Jain and H. S. Mukunda - The Extinction Problem in an Opposed Jet Diffusion Flame with Competitive Reactions, Combustion Science and Technology, 1, p.105, 1969.
- H. S. Mukunda - Effect of Interaction between Chemical Kinetics and Fluid Mechanics in a Stagnation Point Boundary Layer, Combustion Science and Technology, 3 p-267, 1971.

H. S. Mukunda - Evaluation of Some Definite Integrals Involving Repeated Integrals of Error Function, Bulletin of Calcutta Math Society, 66, p.39, 1974.  
H. S. Mukunda and B. N. Raghunandan - Burning Constant Stoichiometry Ratio Relation - Some Clarifications, AIAA JI, 12, p.1430, 1974.  
H. S. Mukunda and B. N. Raghunandan - Rocket Propellant Combustion Studies in a Constant Volume Bomb, Combustion Science and Technology, 9, p.149, 1974.  
H. S. Mukunda, S. M. Deshpande, H. R. Nagendra, A. Prabhu, S. P. Govindaraju - A Critical Study of the Work 'Vyamanika Shastrai, Scientific Opinion, p.5, 1974. ([PDF](#))  
H.S.Mukunda, V.K.Jain, , P.J.Paul – A Review of Hybrid rockets: present and future potential, Proc Indian Acad Sci., Vol C2 1979 ([PDF](#))

### 1975-1984

B. N. Raghunandan and H. S. Mukunda - Transient Processes in Liquid Droplet Combustion, Letters in Heat Mass Transfer, 3, p.213, 1976.  
B. N. Raghunandan and H. S. Mukunda - Liquid Droplet Combustion - A Re-examination, Combustion and Flame, 30, p.71, 1977. ([PDF](#))  
A. G. Marathe, H. S. Mukunda and V. K. Jain - Some Studies on Hydrogen-Oxygen Diffusion Flame, Combustion Science and Technology, 15, p. 49, 1977. ([PDF](#))  
B. N. Raghunandan and H. S. Mukunda - Combustion of Polystyrene Spheres in Air, Fuel, 56, p. 271, 1977.  
H. S. Mukunda, A. Subhananda and M. Sambashivarao - Combustion Science and Technology Flow Studies in Non-Circular Tubes with Wall Injection Vol.15.PP.21-30,1977.([PDF](#))  
H. S. Mukunda, V. K. Jain and P. J. Paul - A Review of Hybrid Rockets - Present Status and Future Potential, Proc. Indian Acad. Sci, C2, Part I, May 1979, 21, pp.215, 1977.  
H. S. Mukunda - A Comprehensive Theory of Erosive Burning in Solid Propellants, Combustion Science and Technology, 18, p.105, 1978.  
P. J. Paul, H. S. Mukunda, H. K. Narahari and V. K. Jain - Regression Rate Studies in Hypergolic Systems, Combustion Science and Technology, 26, pp.17-24, 1981. ([PDF](#))  
P. J. Paul, H. S. Mukunda and V. K. Jain - Regression Rates in Boundary Layer Combustion, Proc. 19th International Symposium on Combustion, pp. 717-729, 1982.  
P. Ram Prasad, B. N. Raghunandan and H. S. Mukunda - Some Experiments on Model Composite Solid Propellants, Propellants, Explosive and Pyrotechnics, 8, pp. 53-55, 1983.  
U. Shrinivasa and H.S. Mukunda\* - WOOD GAS GENERATORS FOR SMALL POWER (-r5 hp REQUIREMENTS.1983 ([PDF](#))  
U. Shrinivasa and H. S. Mukunda - Wood Gas Generators for Small Power (5HP) Requirements, Sadhana, Proceedings of the Indian Academy of Sciences, I, pp.137-154, 1984.

H. S. Mukunda, P. J. Paul, U. Shrinivasa and N. K. S. Rajan, Combustion of Wood Spheres - Experiments and Model Analysis, Proceedings of the 20th Symposium (International) on Combustion, 1984.

H. K. Narahari, H. S. Mukunda and V. K. Jain - A Comprehensive Model for the Combustion of Ammonium Perchlorate, Proceedings of the 20th Symposium (International) on Combustion, pp.2073-2082, 1984.

H.S. Mukunda, P. J. Paul , U. Srinivasa and N. K. S. Rajan - Combustion of Wooden Spheres - Experiments and Model Analysis - Twentieth Symposium on Combustion/The Combustion Institute , 1984/pp. 1619-1628 ([PDF](#))

### 1985-1994

S. Dasappa, V. Reddy, H. S. Mukunda and U. Shrinivasa - Experience with Gasifiers for 3.7 kW Engines, AMBIO, pp. 275-279, 1985.

A. T. Bhashyam, S. M. Deshpande, H. S. Mukunda and G. Goyal - A Novel Operator Splitting Technique for One Dimensional Laminar Flames, Combustion Science and Technology, 46, Vol. 46, pp.223-248, 1986.

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B. Sekar and H. S. Mukunda - A computational study of direct simulation of high speed mixing layers without and with chemical heat release, Proceedings of the 23rd symposium (international) on Combustion, pp 707-713, 1990.

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S. Dasappa, H. V. Sridhar, P. J. Paul, and H. S. Mukunda - On the combustion of wood char spheres in O<sub>2</sub>/N<sub>2</sub> mixtures - Experiments and Analysis, Proceedings of the 25th symposium (international) on Combustion, pp 569--576, 1994.

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D. P. Mishra, P. J. Paul and H. S. Mukunda - Stretch effects extracted from propagating spherical premixed flames with detailed chemistry, *Combustion and Flame*, p 379--386, 1994 ([PDF](#)) .

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#### 1995-2004

G. Sridhar, H. V. Sridhar, S. Dasappa, P. J. Paul, N. K. S. Rajan, U. Shrinivasa and H. S. Mukunda -Technology for gasifying pulverised biofuels including agricultural residues, *Energy for Sustainable Development*, pp. 9--18, v.III, no. 2, 1996.

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H. S. Mukunda, S. Dasappa, P. J. Paul, N. K. S. Rajan, U. Shrinivasa, G. Sridhar, and H. V. Sridhar - Fixed bed gasification for electricity generation, *Biomass Gasification and Pyrolysis, State of the art and future prospects*, pp. 105--116, European Commission, CPL Press, 1997.

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s. Dasappa, P. J. Paul, H. S. Mukunda And U. Shrinivasa - Wood-Char Gasification: Experiments And Analysis On Single Particles And Packed Beds, Twenty-Seventh Symposium (International) On Combustion/The Combustion Institute, 1998/Pp. 1335--1342.([PDF](#))

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## 2005-2010

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