

# Improvement in Ignition Delay Characteristics of Diesel Engine Combustion by Varying Combustion Chamber Air Pressure



Tushar Gupta, M. Emran Khan

**Abstract;** Complete and clean combustion is always desirable for better performance of engine and less emissions. An experimental work is carried in constant volume combustion chamber for getting conditions like diesel engine combustion to study the ignition delay characteristics of diesel engine combustion by varying combustion chamber air pressure. In this experimental work, air pressure of combustion chamber varied from 10 to 25 bar, hot surface temperature inside the combustion chamber varied from 350°C to 550°C and fuel injection pressures varied from 100 to 200 bar for hollow cone spray and solid cone spray. For this work a set-up is made in which the flame detection is done by digital storage oscilloscope using an optical method. The findings of the work suggests that combustion chamber air pressure and injection pressure are significantly varies the values of ignition delay at a particular hot surface temperature. It is also find that on increasing the values of combustion chamber air pressure and injection pressure, ignition delay values are decreases although the variation in ignition delay is less at higher injection pressure and combustion chamber air pressure.

**Keywords:** Ignition Delay, Diesel Engine, Combustion, Combustion chamber, Cylinder air pressure, Spray.

## I. INTRODUCTION

Time, money and health are the essential need of a person in present world. Automotive industry plays very important role as a means of transport in time saving for public at large. As health of the population is an essential factor for a country. Therefore different countries adopted various norms regarding the safety of health of its population. Emissions librated from the automotive engines are of major concern. Diesel engines have many advantageous over petrol engines and contribute to a major proportion of automotive industry as these are main source of power for the heavy duty vehicles like large trucks, buses and marine engines [1]. Diesel engines are fuel efficient and economic but also a prime contributor to the environmental pollution. Now a day's government of any country is more concerned about the pollution emitted from the engines rather than its cost effectiveness. In India also Bharat stage IV norms are going to be replaced by Bharat stage VI norms to check the emissions generated from the engines [2]. Therefore researchers are very keen to find the ways to reduce the emissions librated from the engines.

For improving performance enhancement and emission characteristics of diesel engine many researchers and engineers are doing research to make better engine design and simultaneously improving the combustion process by optimizing the various parameters. One way to get the better fuel efficiency and lesser emissions is the occurrence of clean combustion inside the engines. Quality of fuel spray, it's mixing with air and its distribution inside the combustion chamber mainly governed the combustion process of diesel engines. Combustion chamber air pressure, injection pressure, injector geometry, inside cylinder temperature and density are primarily governed the breakup and distribution of the spray [3]

Emissions from the engine mainly rely upon its combustion process, nature of fuel, combustion chamber design, temperature and air: fuel ratio etc. Ignition delay in the combustion process of diesel engines is directly or indirectly affected by all these parameters. Therefore understanding of ignition delay is very important to improve the combustion process. In diesel engines, ignition delay of the fuel is defined as the time interval between start of fuel injection to the start of combustion [4].

It is subdivided into two parts:

- Physical delay
- Chemical delay

The part in which fuel-air mixing takes place and the resulting mixture is raised in temperature is physical delay and chemical delay involves pre-flame reactions until ignition occurs. Ignition delay needs to be reduced for reducing emissions generated ion diesel engines. At higher temperature chemical delay is prominent over physical delay and it is affected by fuel properties. These chemical properties of fuel are much more important as fuel molecular structure is depending on Cetane number. Since ignition quality of the fuel is defined by its Cetane number therefore it will affect the ignition delay prominently [5]. Figure1 illustrates these effects.

**Revised Manuscript Received on December 30, 2019.**

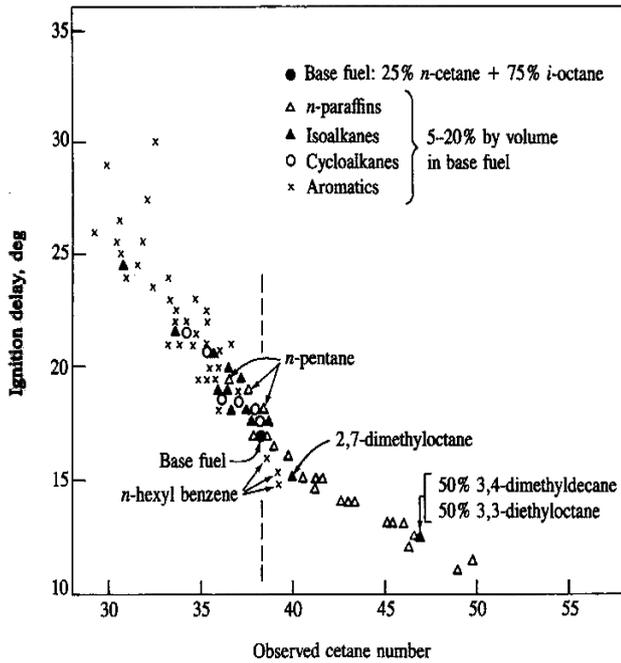
\* Correspondence Author

**Tushar Gupta\***, Research Scholar, Deptt. Of Mechanical Engg., Jamia Millia Islamia, Delhi, India. Email: [tgupta1987@gmail.com](mailto:tgupta1987@gmail.com)

**M. Emran Khan**, Professor, Deptt. Of Mechanical Engg., Jamia Millia Islamia, Delhi, India. Email: [emran\\_jmi@yahoo.com](mailto:emran_jmi@yahoo.com)

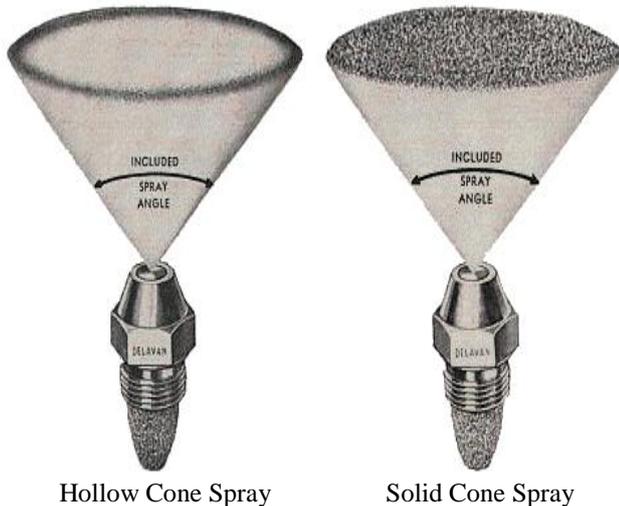
© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an open access article under the CC-BY-NC-ND license <http://creativecommons.org/licenses/by-nc-nd/4.0/>

# Improvement in Ignition Delay Characteristics of Diesel Engine Combustion by Varying Combustion Chamber Air Pressure



**Figure 1: Effect of Hydrocarbon Structure on Ignition Quality of Diesel Fuel**

This paper includes the experimental work carried for two types of spray patterns (Hollow cone and solid cone) for conditions like diesel engine combustion. Each has certain advantages depending on its use. Pintle nozzle is used for getting hollow cone spray while Single hole nozzle is used for getting solid cone spray in this work.



**Fig2: hollow cone spray and solid spray**

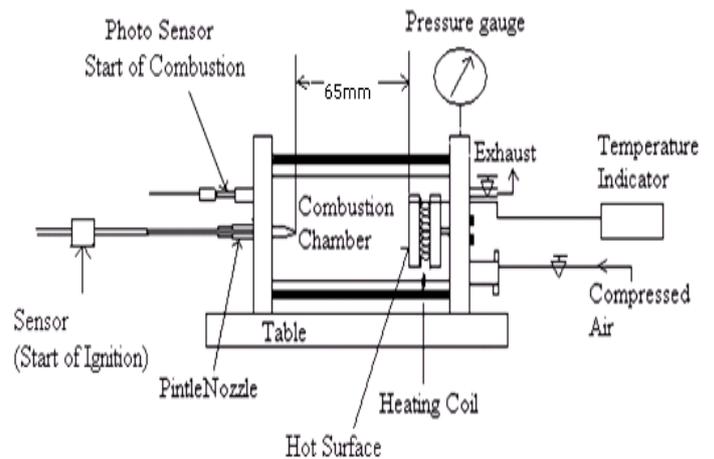
A lot of research and experiments have been performed to improve the diesel engine combustion and librated emissions. Some of the findings of these researches and experiments are as follows.

Fuel injection pressure and fuel spray pattern are significantly responsible for the generated emissions [1]. At higher injection pressure and hot surface temperature, variation in ignition delay is less [2]. Too high injection pressure lead to very short ID and decreases the possibilities of homogeneous mixing [3]. Higher ignition delay generates high rate of heat release and NO<sub>x</sub> emissions [4]. By introducing the efficient after treatment systems for particulate and NO<sub>x</sub> emissions control high Injection Pressure are advantageous for heavy duty engines [6]. Increased injection pressure reduces soot emissions

significantly [7]. Solid cone spray allows more variation in the values of ignition delay rather than hollow cone spray [8]. Luminous ignition delay is reduced by increasing hot surface temperatures [9].

Detection of the nonvolatile nucleation mode (core) emission depends on the variation in load. The core emission have not seen at low loads but at medium and high loads it increased as injection pressure raised [10]. ID is a decreasing function of pressure and temperature while conducted experiment in rapid compression machine [11]. At higher injection pressure ID of impinging spray flame is longer [12]. Ignition delay is shortened with increase in pressure [13]. Advancement in injection timing and higher injection pressure lead to better combustion [14].

## II. EXPERIMENTAL SETUP AND ITS COMPONENTS



**Figure 3: Block Diagram of Combustion Chamber**

**Table 1: Specification of Combustion Chamber**

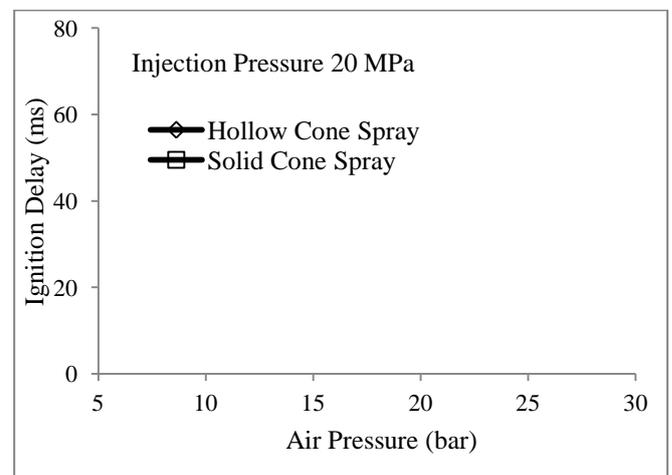
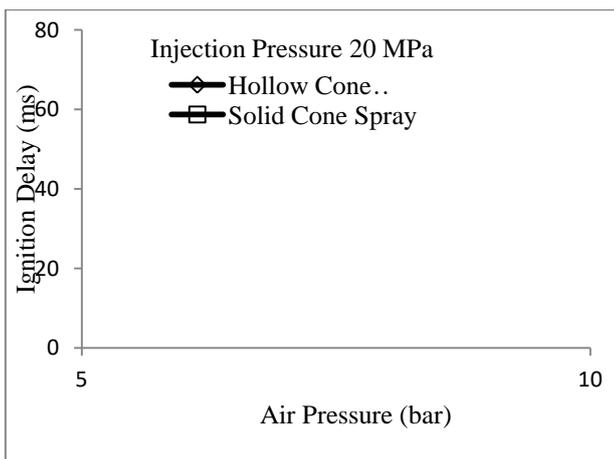
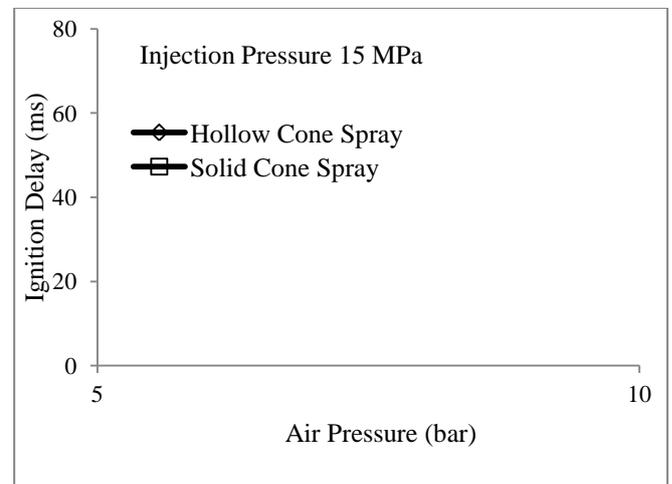
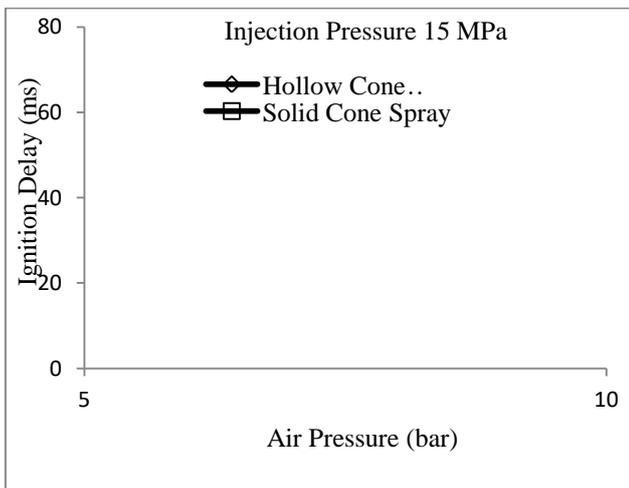
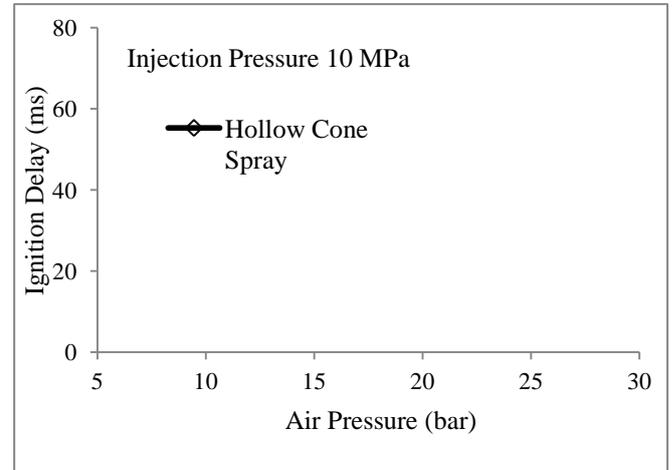
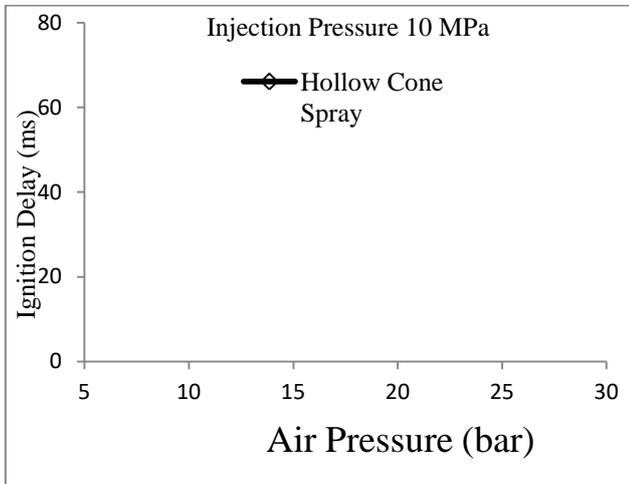
Dimensions	Length = 14 cm Diameter = 90 mm
Material	Stainless Steel
Nozzle	Pintle Nozzle
Temperature Controller	Universal Temperature Controller
1) Start of Injection	Piezo-electric Sensor
2) Start of Combustion	Photo Sensor
Maximum Temperature	800°C
Maximum Pressure	200 bar

### Various Components of Experimental Set Up

1. Bosch Fuel Injection Pump
2. Pump Plate:
3. Striking Pin
4. Rocker and Lever Arm

5. Fuel Metering
6. Piezo-electric Sensor
7. Photo Sensor
8. Injection Nozzle
9. Combustion chamber
10. Digital Oscilloscope
11. Temperature-Controller
12. Air Compressor
13. Temperature Indicator

**III. RESULT AND DISCUSSION**

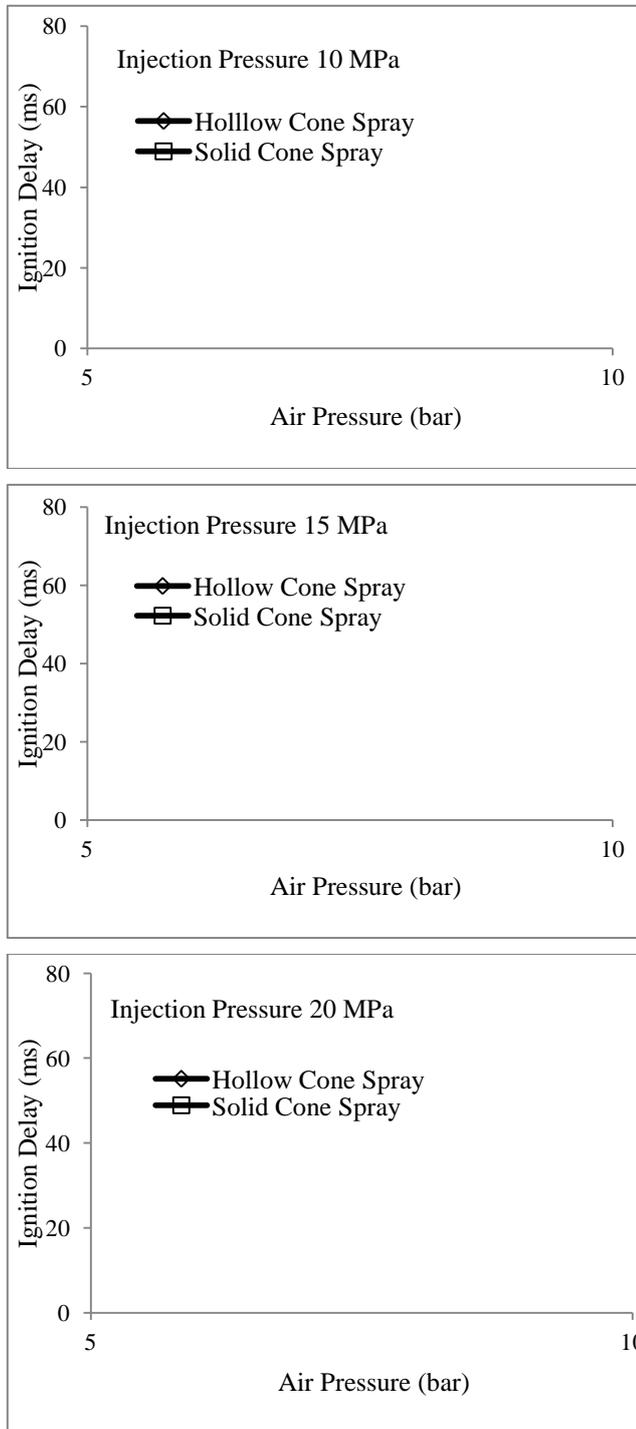


**Figure 4:** Effect of Variation of Air Pressure on Ignition Delay Characteristic of Fuel Sprays for Hot Surface Temperature 350°C at Different Injection Pressure. From the above figure it is clear that at 350°C ignition delay is always higher for solid cone spray than hollow cone spray at all air pressure and for all injection pressures. On increasing the air pressure value of ignition delay are generally decreases at all injection pressures. but from 15 bar to 25 bar air pressure ignition delay values of hollow cone spray is marginally affected at all injection pressures.

## Improvement in Ignition Delay Characteristics of Diesel Engine Combustion by Varying Combustion Chamber Air Pressure

**Figure 5:** Effect of Variation of Air Pressure on Ignition Delay Characteristic of Fuel Sprays for Hot Surface Temperature 450°C at Different Injection Pressure.

From the above figure it is clear that at 450°C on increasing the air pressure, values of ignition delay are slowly decreases at all injection pressures. Ignition delay is lower for solid cone spray than hollow cone spray at all air pressure on 10 MPa and 15MPa injection pressures but at 20 MPa injection pressure ignition delay values are almost same and even lower for hollow cone spray than solid cone spray.



**Figure 6:** Effect of Variation of Air Pressure on Ignition Delay Characteristic of Fuel Sprays for Hot Surface Temperature 550°C at Different Injection Pressure.

From the above figure it is clear that at 550°C on increasing the air pressure, although values of ignition delay are marginally decreases at all injection pressures but the variation in the values of ignition delay obtained from both sprays is very less or we can say that at higher temperatures the effect of different sprays is diluted. We can also see that for higher injection pressures ignition delay is lower for both types of sprays.

### IV. CONCLUSION

On increasing the combustion chamber air pressure, ignition delay is continuously decrease for both types of spray at all injection pressure and all hot surface temperatures although the difference is lesser at higher hot surface temperatures.

Higher injection pressure leads to shorter ignition delay at all hot surface temperature and air pressures.

At low temperature of 350°C the performance of hollow cone spray is better than the solid cone spray while at 450°C solid cone spray gives better result for ignition delay values.

At 550°C the effect of different sprays is diluted and both sprays almost give same result for ignition delay values.

For low temperature (i.e. 350°C) the suggested nozzle type is pintle nozzle while for moderate temperature suggested nozzle type is single hole nozzle.

At high temperatures there is not clear cut barrier on the use of any nozzle from present study. So we can use any nozzle.

The effect of air pressure on ID is significant at low temperatures but at high temperature its dependency on ID is marginal.

The dependency of type of spray is also good on ID and this dependency is more in lower temperature ranges compared to higher temperature ranges.

### REFERENCES

1. Kannan K. and Udayakumar M., "Experimental study of the effect of fuel injection pressure on diesel engine performance and emission", ARPN Journal of Engineering and Applied Sciences, Vol. 5, No. 5, May 2010.
2. Gupta Tushar and Khan M.Emran, "Variation In Ignition Delay With Changing The Environment Inside The Combustion Chamber For Different Sprays", International journal of innovative technology and exploring engineering, Vol.5, Issue 10, 2019.
3. Crua C., "Combustion Processes in C.I. Engines", PhD Thesis, School of Engineering, University of Brighton collaboration with Ricardo Consulting Engineers, December 2002.
4. Heywood, J.B., "Internal Combustion Engines", Second Edition. McGraw Hill International, New York, 1988.
5. Prakash V., "Measurement of the ignition delay of oxygenated fuels blend sprays at high pressure", M. Tech. Thesis, Department of Mechanical Engineering, Z H College of Engineering & Technology, Aligarh Muslim University, Aligarh, India, May 2011.
6. Morgan R., Banks A., Auld A. et al., "The Benefits of High Injection Pressure on Future Heavy Duty Engine Performance," SAE Technical Paper 2015-24-2441, 2015.
7. Wang X. et al, "Effect of injection pressure on flame and soot characteristics of the biodiesel fuel spray", Taylor and Francis Group, March 2010.
8. Gupta Tushar and Khan M.Emran, "Comparison Of Ignition Delay Measured For Sprays Ejected From Pintle And Single Hole Nozzle", International journal of research and analytical reviews, Vol. 5, Issue 4, 2018.



9. Hot surface ignition and combustion characteristics of sprays in constant volume combustion chamber using various sensors, Sanaur Rehman, Cogent Engineering (2018), 5: 1464879.
10. Lahde T. et al, "Effect of Fuel Injection Pressure on a Heavy-Duty Diesel Engine Nonvolatile Particle Emission", Environmental Science and Technology, 2011.
11. Ribaucour M. et al, "Ignition of isomers of Pentane: An experimental and kinetic modeling study", Proceedings of the Combustion Institute, vol.28, 2000.
12. Wei du at el, "effect of injection pressure on ignition and combustion characteristics of impinging diesel spray", Applied Energy, Volume 226, 15 September 2018.
13. Yao C et al, "Effects of injection pressure on ignition and combustion characteristics of diesel in a premixed methanol/air mixture atmosphere in a constant volume combustion chamber" Fuel, Volume 206, 15 October 2017.
14. Sameer P.M., Ramesh K., "Assessment on the consequences of injection timing and injection pressure on combustion characteristics of sustainable biodiesel fuelled engine" Renewable and Sustainable Energy Reviews, Volume 81, Part 1, January 2018.

### AUTHORS PROFILE



Tushar Gupta is an eminent research scholar in JamiaMillialIslamia, Delhi, India. He has been worked as assistant professor in G.L.A. University (India), Galgotias University (India), Sharda group of Institutions (India) in past few years. He has been completed his graduation and post-graduation from A.M.U. (India).



Professor M. Emran Khan is Head of the department of Mechanical Engineering in JamiaMillialIslamia, Delhi, India. He has been published so many research papers in reputed international journals and no. of books and book chapters in reputed publishers. He has teaching and research experience of 34 years. He is a member of NBA, planning commission of india and many selection committees.