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Experimental Study of Kerosene-Air Injection into a Model of a Detonation Chamber

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Abstract:-The paper presents the results of experimental research of kerosene-air injection into the model of a detonation chamber. The pulse detonation engine is similar to pulse jet engine with a major change in it which is the detonation part. To get proper detonation without flame holding, the fuel air mixture should be properly injected at precise pressure and atomization. The experimental study on atomizing nozzle of pulse detonation engine is concentrated in this paper. The atomizer position is varied to study the spray characteristics. The air is preheated rather than heating the fuel in this paper whereas the fuel is heated in other papers to increase the atomization performance. The increase in the atomization performance is studied in terms of flow velocity and atomization. The heating of fuel is complicated process which is difficult to carry out. Hence in this paper the air is heated to increase the performance of atomized air fuel mixture. The proper atomization at required pressure leads to better detonation without flame holding inside the pulse detonation engine.

***Keywords*—deflagration, detonation, two phase, shear force, aerodynamic force.**

I. INTRODUCTION

Pulse detonation engine (PDE) obtains thrust by generating detonations intermittently. The detonation cycle is thermodynamically attractive since it is an extremely rapid energy conversion process, and for a given amount of heat release, the entropy increase of the working fluid is minimized when compared to a deflagration event [1]. This provides the capability of extracting additional useful work from the cycle. Hence the thermodynamic efficiency of a detonation cycle is higher than a deflagration one. The typical shape of a PDE is a straight tube with one end closed and the other open and it can be operated even if there are no compression mechanisms such as compressors and pistons, which results in overall lower system cost when compared with turbo-machinery and certain rocket engine system. Atomization is a process where bulky liquid droplets are broken into collection of small fine droplets. This transformation goes through the break-up of liquid jet into number of filaments, which in turn transform into droplets [4]. The detonation tube is closed at head end and open at other end. The fuel injector is fixed at the head end of the detonation tube. The kerosene which is at room temperature and 2-3 bar pressure is mixed with the preheated air which is at room pressure at the exit point of the injector. The injector design is such that the kerosene and the preheated air mix at the exit point of nozzle.

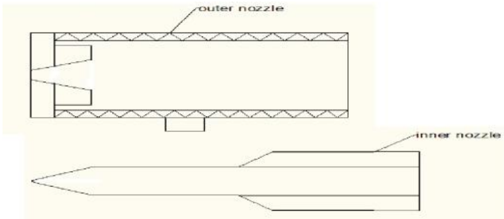

Fig 1: Atomizer

The injector got two casings, dividing the main injector into two sub compartments, the kerosene is passed in the inner injector and preheated air at the outside casing. The flow rate is measured before sending the fuel air mixture to the injector. The injector sprays the fuel air mixture at an angle of 5-18 degrees. The spray angle can be varied by moving the kerosene injector in the injector assembly. As the inside kerosene injector moves inside or outside of the main injector from the cross sectional plane where both kerosene and air injectors are placed and injected for maximum spray angle. The position of kerosene injector also affects on atomization of the kerosene. The detonation performance is increased by varying two component performances. One is by varying the atomizer characteristic and another is by heating the atomizing air. Atomizing characteristics can be variedby changing the atomizer position and by changing the position of fuel and air nozzles of the atomizer.

II. EXPERIMENTAL SETUP

Detonation is nothing but the rapid combustion by generating the shock wave. To achieve the transition from deflagration to detonation the flow rate and atomization of the fuel should be taken care. The outer nozzle exit diameter is 6 times the exit of the inner nozzle of main atomizer. The fuel which is at room temperature and 2-3 bar pressure is made to flow inside the inner nozzle of the main atomizer and preheated air is made to flow outside the inner nozzle. The fuel air comes in contact at the exit of the main atomizer which leads to atomization of the liquid fuel. As and when the fuel air come in contact, the fuel droplets break into fine particles and the preheated air help to considerable evaporation of the fine liquid kerosene. The fuel is made to flow axially in the direction of exit spray and the atomizing preheated air is made to flow in the direction perpendicular to the fuel flow just before entering the atomizer. The difference in angle between the fuel nozzle and air nozzle of the atomizer is 4-5°. The angle difference restricts the fuel nozzle to protrude outside .The atomizing air is heated using electric coil which is very simple to design and to use as good heat exchanger. The

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electric heat exchanger is two meter in length with very small cross sectional area. The thermal losses are made very small by using insulator material around it. The air supply of required pressure is taken from the air supplying source which is measured initially. The fuel is pressurized in the storage tank and the pressure is maintained during fuel delivery. The fuel is pressurized using air. The pressurized fuel is fed at required quantity to the atomizer and is made atomized using preheated air. Initially an experiment is carried out to study the behavior of atomization by heating the liquid fuel and using air of room temperature. The experiment is difficult to carry out as the auto-ignition temperature is very near to the boiling or vaporizing temperature. To avoid the auto-ignition difficulty the fuel should be pressurized using nitrogen replacing the air. The liquid fuel is being heated or vaporized in electric heat exchanger. Heating air is very easier than liquid fuel and the catastrophic effect can be avoided. Hence in this experimental study the air is being heated not the liquid kerosene. The air fuel ratio is kept stoichiometric with equivalence ratio unity. The spray velocity was found which was around 28-230 m/s for different air flow rate. The spray angle and the direction of spray vary based on the movement or the position of fuel nozzle from the atomizer exit. The ignition point of the spray is 12-23mm. In between these points the mixture catches fire from the conventional spark plug.

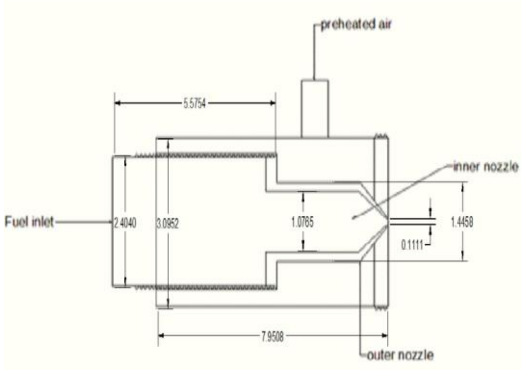

Fig 2: Both the Nozzles are at Same Cross Sectional Exit

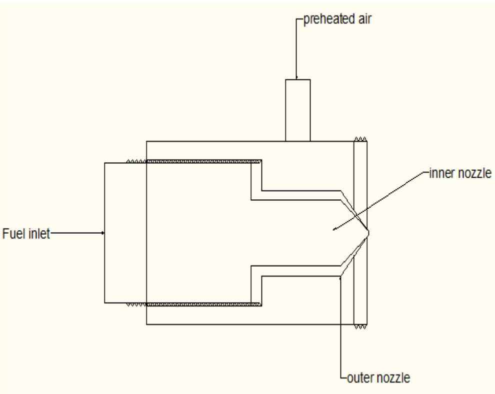

Fig 3: Inner nozzle moves 1mm outside

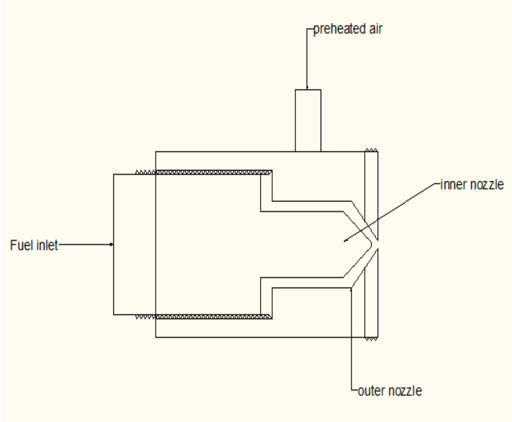

Fig 4: Inner nozzles moves 1mm inside

The air atomizes the fuel perfectly with very less creation of fuel droplets. The blockage ratio with respect to fuel nozzle position goes on increase as nozzle moves outside of the exit plane. As the inner nozzle moves inside, the blockage ratio decreases which results in the decrease in the exit velocity. To get maximum exit velocity, the nozzle tip should be at the cross sectional area of the outer nozzle. The increase in blockage ratio results in the higher velocity. The atomized fuel should be fine enough to avoid hot spots in combustor by which are known as Lean Premixed Prevaporized Combustion. The field of a spray created by a jet in cross flow can be divided into three modes: 1) Intact liquid column, 2) Ligaments, and 3) Droplets [2]. The liquid column develops hydrodynamic instabilities and breaks up into ligaments and droplets. This process is referred to as primary breakup. The location where the liquid column ceases to exist is known as the column breakup point (CBP) or the fracture point [7]. The ligaments breakup further into smaller droplets and this process is called secondary breakup. The liquid droplets are turned into fine droplets due to the two phenomena; one is due to the aerodynamic force and second is shear force. The intact liquid column is converted into ligaments due to the shear force which shear off the liquid droplet surface [5]. The air is then passed through the ligament of liquid droplet which creates the fine droplets of liquid due to the aerodynamic force.

III. RESULTS AND DISCUSSIONS

The liquid column can be converted into fine droplets if proper pressure and temperature of air and fuel is maintained. The positive results are found when the inner nozzle is at the exit cross sectional plane. The graph shows, the blockage ratio is good when the fuel nozzle is at the exit plane and it goes on decreasing as the inner nozzle moves inside or outside of the main nozzle. By moving the nozzle much inside, difficult of achieving the required velocity increases and if it is moving outside, the sufficient air supply cannot be obtained.

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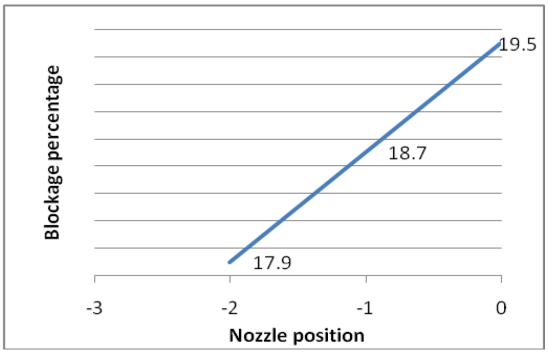

Fig 5: Blockage Ratio at the Exit of Atomizer

As shown in the graph, the blockage ratio is around 20% when both the nozzles are in same plane and it reduces by 1.5% as inner fuel nozzle moves 1mm inside of the outer air nozzle.

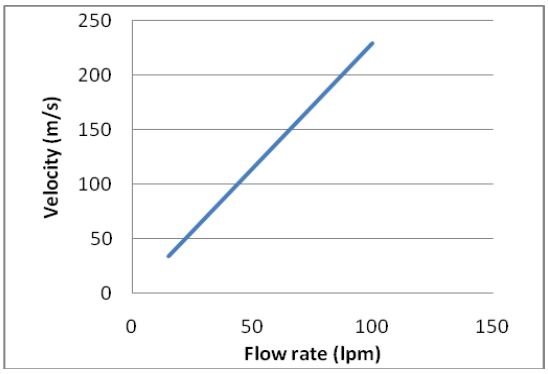

Fig 6: When nozzle at same plane

As shown in above graph, for a given flow rate and 100°c of air will get maximum results in velocity when both the nozzle exits are at the same cross sectional area. For minimum inlet flow rate it gives a better output velocity of 35m/s and for maximum inlet flow rate as per atomization air requirement, the output velocity will be more than the 230m/s.

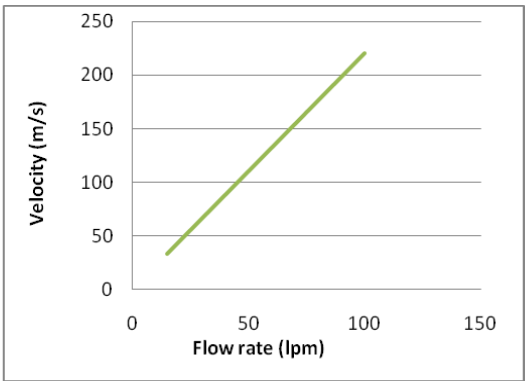

Fig 7: When nozzle at 1 mm inside

As shown in above graph, for the case where the inlet nozzle is 1mm inside of the outer nozzle, the velocity at the exit of the atomizer is not as better as the nozzles at the same cross sectional plane. The fig 8 represents a graph which is showing poor results than the previous one nozzle position as the inlet nozzle is 2mm inside the outer nozzle so that the output velocity is not much good. This shows the gradual decrease in the performance of the atomizer on basis of inlet nozzle position in the outer nozzle.

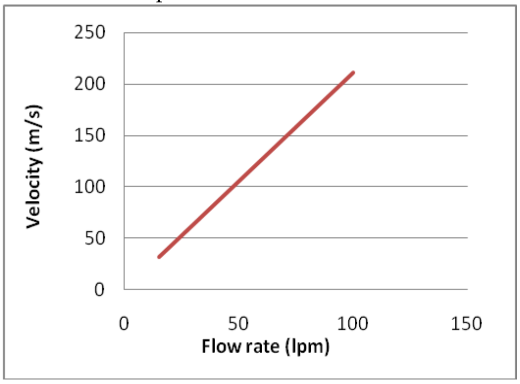

Fig 8: When inner nozzle is at 2mm inside

The atomization is better when the nozzle exits of atomizer are at same cross sectional area. The atomization is good for high flow rate of air which is preheated. The spray angle of the atomized fuel air mixture goes on increases as the fuel nozzle moves inside of the preheated air nozzle and it decreases when fuel nozzle move outside of preheated air nozzle. The flame catching range is more when both the nozzles are at same cross sectional area and the flame catching range is very small when the fuel nozzle moves inside or outside of the air nozzle. The pressure and temperature of the fuel and air affects a lot on atomization and velocity at the exit [6]. For complete combustion with very less release of toxic gases, equivalence ratio should be maintained. The equivalence ratio also effects on the flame catching distance.

IV. CONCLUSION

The atomization can be achieved by heating atomizing air rather than the liquid fuel. The heated atomizing air leads to shear type of fuel atomization. The high exit velocity from atomizer leads to the aerodynamic mode of fuel atomization. The performance of atomizer is good for velocity, spray angle and fine droplet formation only when both the nozzles of atomizer are at same cross sectional plane. The atomization can be achieved same as of the method where the fuel is being heated by heating the atomization air which is very simple than heating the liquid fuel.

REFERENCES

[1] "Fuel jet in a cross flow experimental study of spray characteristics" by E. Lubarsky, D. Shcherbik, O. Bibik, Y. Gopala and B. T. Zinn School of Aerospace Engineering USA ILASS Americas, 25th Annual Conference on Liquid Atomization and Spray Systems, Pittsburgh, PA, May 2013.

[2] "Experimental studies of kerosene injection into a model of a detonation chamber" by Jan Kindracki Institute of Heat Engineering, Poland Vol 92, No 2 (2012).

[3] "Operation of a Rotary-valved Pulse Detonation Rocket Engine Utilizing Liquid-kerosene and Oxygen" by Wang Ke, Fan Wei*, Yan Yu, Zhu Xudong, Yan Chuanjun School of

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 2, August 2013

Power and Energy China vol. 35 issue 1 January, 2011. p. 265-271.

[4] “Breakup and Atomization of a Kerosene Jet in Cross flow at Elevated Pressure” by Becker, J. &Hassa, C Vol. 11, pp. 49-67, 2002.

[5] “Shock tube investigation of the breakup of drops by air blasts” by Hanson, A. R., Domich, E. G., & Adams, H. S. Physics of Fluids Vol. 6, pp.1070-1080, 1963

[6] “The Thermodynamic and Fluid Dynamic Function of a Pulse Detonation Engine Nozzle” by T.A. Kaemming, R.S. Dyer, AIAA Paper 2004- 3916, 2004.

[7] “Experimental investigations on pulse detonation rocket engine with various injectors and nozzles “by Yu Yan, WeiFan n, KeWang, Xu-dongZhu, YangMu ENG STRUCT, vol. 33, no. 7, pp.2154-2161, 2011.