Simulation of Piezoelectric Injectors on Rocket Engines

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Abstract **- For the past years a combined piezoelectric injector and fuel suitable for high pressure direct injection of particular small light weight aircraft. In this research, we are going to implement piezoelectric injectors for the rocket engines. Because a poor injector performance causes unborn propellant to leave the engine, giving extremely very low efficiency. The injector implementation in liquid rocket determines the percentage of theoretical performances of the nozzle that can be achieved. The principle of piezoelectric injector is defined to converting the applied mechanical energy into electrical energy. By using this principle, the liquid propellant is injected into the rocket engine for the combustion process. In this paper the injector is modeled using the CERO and three dimensional analyses to be carried out using ANSYS for different cases.**

Keyword- Piezoelectric Injector; Implementation; Rocket Engine; Convert; Design & Analysis

The nozzle that can be achieved. A poor injector performance causes unburnt propellant to leave the engine, Giving extremely poor efficiency. Injector can be classified into four types

1. Shower head
2. Self-impingement doublet
3. Cross impingement triplet
4. Shear coaxial
5. Swirl coaxial
6. Pintle

The injector implementation in liquid rockets determines the percentage of the theoretical performance of

Fuel is supplied to injector under high pressure by inlet pipe screwed to injector body whose magnitude depends on engine load and rotation speed. Next, it flows through inlet channel through the body of injector to atomizer and combine channel with steering chamber of injector work.

I. INTRODUCTION

A rocket is a missile, spacecraft, aircraft or other vehicle that obtains the thrust from the rocket engine. A rocket engine exhaust is formed from entirely from the propellant carried with in rocket before use. Rocket propellant is mass that is stored, usually in some form of propellant tank or casing, prior to being used as the propulsive mass that is ejected from a rocket engine in the form of a fluid jet to produce thrust. For chemical rockets often the propellants are a fuel such as liquid hydrogen or kerosene burned with an oxidizer such as liquid oxygen or nitric acid to produce large volumes of very hot gas. In the rocket engine, the propellant is burnt in the combustion chamber and the hot jet of gases (usually at very high Pressures, with combustion temperatures approaching 3000K) escapes through the nozzle at very high velocity. The propellant can be classified into,

i. Solid Propellant
ii. Liquid Propellant
iii. Gas Propellant
iv. Gel Propellant

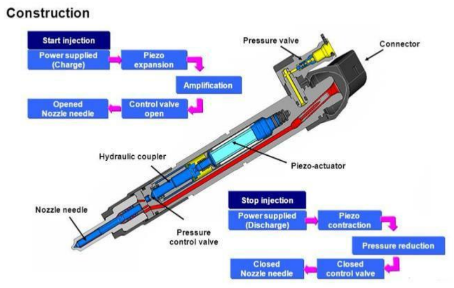

Figure 1

But when coil obtains voltage under the influence of electromagnetic field, raises unit shaft is raised and the valve starts to open. A time difference of pressure appears in the lower and upper part of injector. Higher pressure in the nozzle causes lifts the needle and begins injection of fuel to the combustion chamber. When the voltage disappears in the coil unit shaft comes back to the down position and closes the Steering injector valve. Pressure in lower and upper part of the injector adjustment and the needle under pressure the spring closes nozzle and finishes work of the injector.

II. ASSUMPTIONS

A. *Engine*

An aestus 2 (RS 72) engine has been assumed. It has been assumed that injector is placed at the end of the reservoir, where pressure is maximum and velocity is approximately equal to zero. Specifications of the engine are given below;

TABLE I. ENGINE SPECIFICATIONS

Parameters	specifications
Thrust	40 N
Chamber pressure	60 bar
Injector inlet velocity	0 m/s
Injector exit velocity	16.6m/s

Table 1

B. *Propellants*

Tokudome in [5] tested several propellant pairs and found Monomethylhydrazine and nitrogen tetroxide very efficient functionally

The propellant selection for the testing was done on the basis of the following three priorities;

1. Good operability (non-toxic and storable at room temperature),
2. Ready availability and cost effectiveness (commercial off-the-shelf and delivery system currently used)
3. Performance and originality (space application and the world's first study).

Monomethyl hydrazine (MMH) is a volatile hydrazine chemical with the chemical formula CH3 (NH) NH2. It is used as a rocket propellant in bipropellant rocket engines because it is hypergolic with various oxidizers such as nitrogen tetroxide (N2O4) and nitric acid (HNO3).

Nitrogen tetroxide is the chemical compound N2O4. It is a useful reagent in chemical synthesis. It forms an equilibrium mixture with nitrogen dioxide .Dinitrogen tetroxide is a powerful oxidizer that is hypergolic (spontaneously reacts) upon contact with various forms of hydrazine, which makes the pair a popular bipropellant for rockets.

A hypergolic propellant combination used in a rocket engine is one whose components spontaneously ignite when they come into contact with each other. The two propellant components usually consist of a fuel and an oxidizer. Although commonly used, hypergolic propellants are difficult to handle because of their extreme toxicity and/or corrosiveness. They can be stored as liquids at room temperature and hypergolic engines are easy to ignite reliably and repeatedly.

TABLE II. PROPELLANTS' SPECIFICATIONS

parameters	Specifications
Fuel	mono methyl hydrazine
density of fuel	870Kg/m3
oxidizer	nitrogen tetra oxide
density of oxidizer	1450Kg/m3
oxidizer/ fuel	1.6

Table 2

Figure 2

TABLE III. INJECTOR SPECIFICATIONS

parameters	specifications
fuel mass flow rate	3.78*10^-5 kg/s
oxidizer mass flow rate	4.89*10^-5 kg/s
pressure drop	12 bar
Required mass flow rate for fuel	0.005 kg/s
Required mass flow rate for oxidizer	0.008 kg/s
Injector height	45 µm
injector base	45µm
membrane thickness	37µm
membrane length	1.5mm
voltage applied to membrane	11.1v
number of fuel injector	132
number of oxidizer injector	164
injector plate diameter	4.1
optimal exciting frequency fuel	16500Hz
optimal exciting frequency oxidizer	9700Hz

Figure 3

III. METHODOLOGY

Firstly considering thrust and pressure drop across the injector, mass flow rates of the propellants are calculated. A particular injector design is selected and an initial 2D sketch is made on the CREO. The coordinates of the sketch is then transferred to the MATLAB®, where flow areas are found and adjusted from the centerline according to the mass flow rates. Parametric modeling of the design takes place in MATLAB®. Propellants (both fuel and oxidizer) flow rates are varied with the sleeve position and represented graphically. A reference fuel (internal) flow is taken and outer oxidizer flow is adjusted accordingly, keeping the operating point in the mid of the flow range. Difference in the required and obtained flow rates are calculated for both internal and external flows.

CREO DESIGN

Creo Elements/Pro offers a range of tools to enable the generation of a complete digital representation of the product being designed. In addition to the general geometry tools there is also the ability to generate geometry of other integrated design disciplines such as industrial and standard pipe work and complete wiring definitions. Tools are also available to support collaborative development.

A number of concept design tools that provide up-front Industrial Design concepts can then be used in the downstream process of engineering the product. These range from conceptual Industrial design sketches, reverse engineering with point cloud data and comprehensive free-form surface.

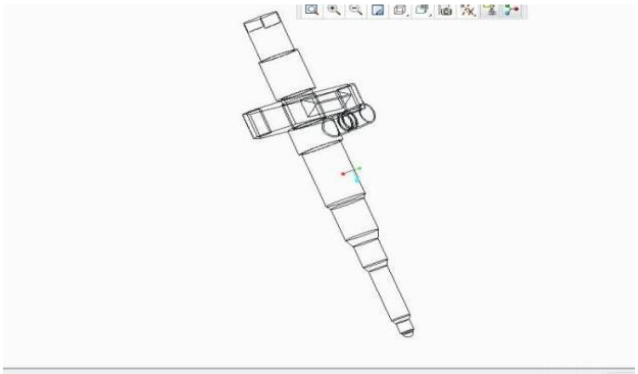

Figure 4 2D design

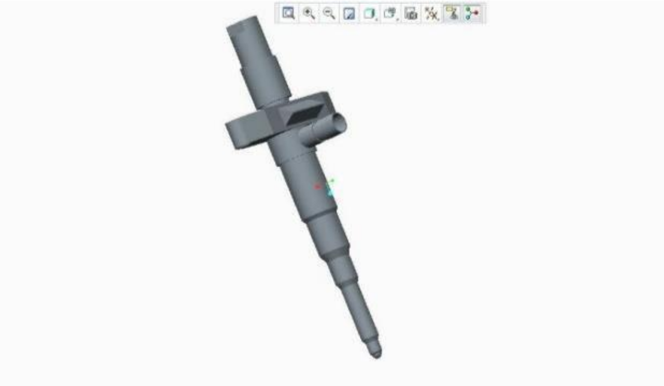

Figure 5. 3D design

Figure 4 and 5 are representing the two and three dimensional designs of piezoelectric injector correspondingly.

A RESULTS

A. Injector modeling

A piezoelectric injector has been modeled and analyzed successfully, right from the initial sketch and it will be prototyped in later stage, where experimentation will take place
.Author has worked on various designs, which has made the general design somewhat predictable, which will further help to design piezoelectric injector according to the required behavior.

Post design processing is very important, as required flow curves can only be achieved by tuning the designs in the Injector Design Tool.

B. Computational fluid dynamics (CFD)

A CFD analysis of the injector has been done in order to observe the resulting flow fields inside combustion chamber and circulations patterns have been observed. The circulations patterns are responsible for the flow stability and a unique flow pattern inside combustion chamber. The impingement points of the both the propellants have been highlighted in the, showing velocity and pressure contours of the flow.

Analyzing will be undertaken by two cases. Because of using separate injectors for fuel and oxidizer with respect to mass flow rate of fuel and oxidizer.

Case 1oxidizer mass flow rate

Case 2 fuel mass flow rate

Case 1: oxidizer mass flow rate results

By applying ideal boundary conditions in CFD-fluent and get the report from the software which we will be indicated as follows which is used for NTO mass flow rate as 4.89*10^-5 kg/s

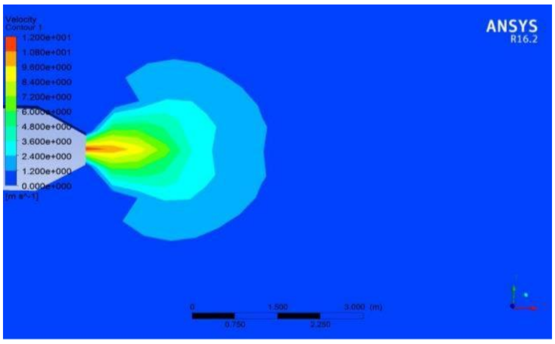

Figure 6 velocity contour

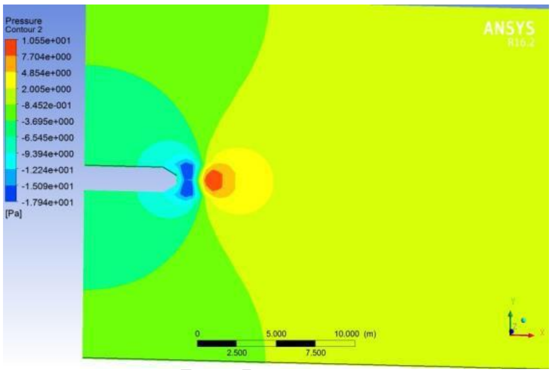

Figure 7 pressure contour

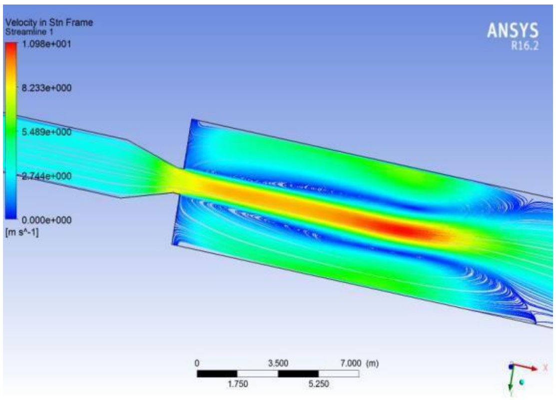

Figure 8 velocity flow path

Case 2 fuel mass flow rate

By applying ideal boundary conditions in CFD fluent and get the report from the software which we will be indicated

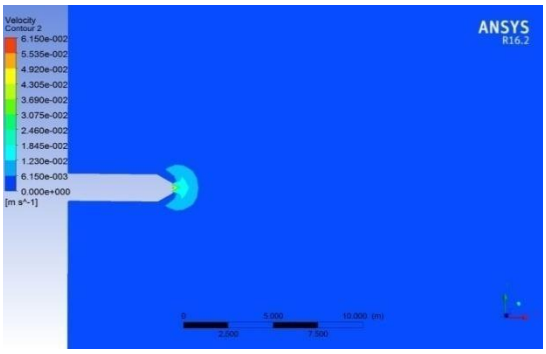

Figure 9 velocity

as follows which is used for MMH mass flow rate as 3.78*10^-5 kg/s.

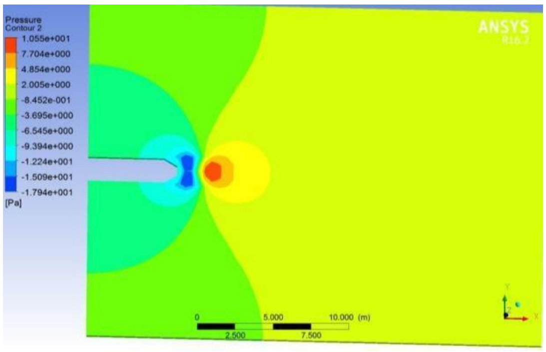

Figure 10 pressure

V.CONCLUSION AND FUTURE SCOPE

The principle of piezoelectric injector is to be defined as converting the applied mechanical energy into electrical energy. So that the piezoelectric injector will work efficiently by the way of quick response. The precise control over the injectors means that this type of technology offers the possibility of full throttling control, varying the mass flow rate (hence the thrust) from zero up to its maximum value, along with active control of combustion instabilities, and increased efficiency.

The injector implementation in liquid rocket determines the percentage of theoretical performances of the nozzle that can be achieved. A design concept has been proposed, along with some basic calculations to show its expected performance. Much further work is required to investigate this design fully. This kind of injection shows very attractive performance like no need of pressure drop along the injector plate, low power consumption, extremely small droplet, active control on mass flow rate and droplet size hence the possibility of performing throttling control and active instabilities control. Hence further theoretical and experimental work is to be required.

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