# STUDY OF SEQUENTIAL MULTIPOINT INJECTION NOZZLE EFFECT OF COMPRESSED NATURAL GAS ENGINE

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## ABSTRACT

The research and development of injection system has always been influenced by the availability and the form of fuel. In this project is about the study of the injection nozzle effect of compressed natural gas engine. This project study and simulate twenty types of sequential injection nozzle with different geometries using SolidWork and Cosmos FloWork software to find the best air and fuel mixing in the combustion chamber of the engine. The other effect of the modified injection nozzle is the velocities of the fuel in combustion chamber that can be determine using the software. The length of bore and stroke of the engine is base on the actual diesel engine and been model using SolidWork. As the result, the best injection nozzle is 10 degree nozzle. The air and fuel mixing is very good and better compare with the original injection nozzle. The velocity of fuel in combustion chamber is the highest compare with other design.

# ABSTRAK

Penyelidikan dan pembangunan system suntikan selalunya dipengaruhi oleh ketersediaan dan jenis bahan api itu. Projek ini adalah kajian tentang pengaruh muncung suntikan terhadap enjin gas asli termampat. Di dalam projek ini ada mengkaji dan membuat simulasi dua puluh jenis penyuntik dengan berlainan bentuk menggunakan perisian SolidWork dan Cosmos FloWork untuk mencari campuran udara dan bahan api yang terbaik di dalam ruang pembakaran pada enjin. Pengaruh lain perubahan muncung penyuntik adalah halaju bahan api itu di dalam ruang pembakaran yang dapat ditentukan menggunakan perisian tersebut. Ukuran diameter dan tinggi ruang pembakaran adalah berdasarkan enjin diesel yang sebenar dan dimodelkan menggunakan SolidWork. Keputusannya, muncung suntikan terbaik ialah 10 darjah kecerunan muncung itu. Udara dan bahan api bercampur dengan baik berbanding dengan muncung suntikan yang asal. Halaju bahan api di dalam ruang pembakaran adalah yang tertinggi berbanding muncung suntikan yang lain.

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| | |
|---|---|
| CAD | Computer-aided drafting |
| CFD | Computational fluid dynamics |
| CNG | Compressed natural gas |
| GGE | Gallon of Gas Equivalent |
| ICE | Internal combustion engine |
| LPG | Liquefied petroleum gas |
| SAE | Society of Automotive Engineers |
| SI | Spark Ignition |
| TDC | Top dead center |

# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

Natural gas is one of the most widely used forms of energy today. It is commonly used to heat and cool homes and businesses nationwide. In addition, more than 85,000 compressed natural gas (CNG) vehicles, including one out of every five transit buses, are operating successfully today. CNG's popularity stems, in part, from its clean-burning properties. In many cases, CNG vehicles generate fewer exhaust and greenhouse gas emissions than their gasoline- or diesel-powered counterparts.

CNG is odorless, colorless, and tasteless. It consists mostly of methane and is drawn from gas wells or in conjunction with crude oil production. CNG vehicles store natural gas in high-pressure fuel cylinders at 3,000 to 3,600 pounds per square inch. An odorant is normally added to CNG for safety reasons. Small compressors connected directly to the home's natural gas supply.

Nowadays, most of the engines are using fuel from petroleum. Fuel from petroleum becomes less and engineers work hard to find the alternative fuel for the engine. Natural gas is one of the alternative fuels that have potential to replace the petroleum fuel. This project will investigate about the injection nozzle effect for compressed natural gas engine. The injector will be simulated by Cosmos FlowWork software.

## 1.2 Background

In the internal combustion engines, there are any gasoline engines and diesel engines were used to generate the power in industries and transportations. The great problems of the world in the internal combustion engines usage until today are focuses on environment protection and economically fuel consumption. The problems need the new design, research and technology to find the new engines or its components so its can use of the alternative fuels another gasoline and diesel fuel, protect and friendly with the environment, high power and efficient in fuel consumption.

Some engine designers and researchers have been did any new design, new concepts and new ideas to found the new better engines, have a high power, friendly with the environment and efficient on fuel consumption using alternative fuel. The first choice of alternative fuel is compressed natural gas. By using compressed natural gas (CNG) as an alternative fuel for internal combustion engine will be reduce the engine performance, but the exhaust gas emission and economic operational by using compressed natural gas (CNG) as a fuel is lower than diesel fuel and gasoline fuel. This study will concentrate on enhance dedicated compressed natural gas (CNG) engine development based on computation and experimental. The project is to design and development of sequential injection dedicated CNG engine spark ignition based from four stroke direct injection diesel engine.

## 1.3 Problem Statement

The main problem of this project is in CNG engine that has low performance. The alternative fuel for the engine is low energy density and because of that, the performance of engine is low. Engine volumetric efficiency is also low because it is the gaseous fuel. The optimum air–fuel ratio changes with fuel properties. The problem will be low air fuel mixing.

## 1.4 Project Objective

Study about sequential multipoint injection nozzle effect in CNG engine performance. Do the computational model of sequential multipoint injection nozzle CNG engine flow and study.

## 1.5 Project Scope

The scope of this project is on design several types of injection nozzles for better air fuel mixing and the velocity of the fuel flow in combustion chamber. The computational design was using SolidWork and Cosmos FloWork. This project is studies and analyzes the effect of injection nozzle in CNG engine performance by using simulation.

## 1.6 Thesis Structure

This project is belonging to design and simulate the new improvement and development of the future design of the injection nozzle.

First chapter explains about the background of the study, problem statement, objective and scope of the project.

Second chapter is about the review of internal combustion engine in CNG, injection nozzle operation and importance process in the combustion engine which taken from the reference books and other related resources.

Third chapter explains on the concept and method being used for this project. It explain and show how to run the simulation of the project.

Fourth chapter shows the result of the project and discussion about the result. The result of the project is base on the simulation by Cosmos FloWork.

Fifth chapter is conclusions about the project that had been done and recommendation for future work.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

This chapter is about the review of internal combustion engine in CNG, injection nozzle operation, part with new improvement and importance process in the combustion engine which taken from the reference books and other related resources.

## 2.2 Internal combustion engine

The internal combustion engine is an engine in which the combustion of fuel and an oxidizer (typically air) occurs in a confined space called a combustion chamber. This exothermic reaction creates gases at high temperature and pressure, which are permitted to expand. Internal combustion engines are defined by the useful work that is performed by the expanding hot gases acting directly to cause the movement of solid parts of the engine [6] [7].

The term Internal Combustion Engine (ICE) is often used to refer to an engine in which combustion is intermittent, such as a Wankel engine or a reciprocating piston engine in which there is controlled movement of pistons, cranks, cams, or rods [6] [9].

Internal combustion engines are also an important source of noise [1]. There are several source of engine noise: the exhaust system, the intake system, the fan used for cooling, and the engine block surface [1]. The noise may be generated by aerodynamic effect, may be due to forces that result from the combustion process, or may result from mechanical excitation by rotating or reciprocating engine components [1] [5].

The motion of internal combustion engines is usually performed by the controlled movement of pistons, cranks, rods, rotors, or even the entire engine itself [6] [9].

## 2.3 Four stroke engine

The four strokes refer to intake, compression, combustion (power) and exhaust strokes. The cycle begins at top dead center (TDC), when the piston is furthest away from the axis of the crankshaft. On the intake or induction stroke of the piston, the piston descends from the top of the cylinder, reducing the pressure inside the cylinder. A mixture of fuel and air is forced (by atmospheric or greater pressure) into the cylinder through the intake (inlet) port. The intake (inlet) valve (or valves) then close(s), and the compression stroke compresses the fuel–air mixture [1] [11].

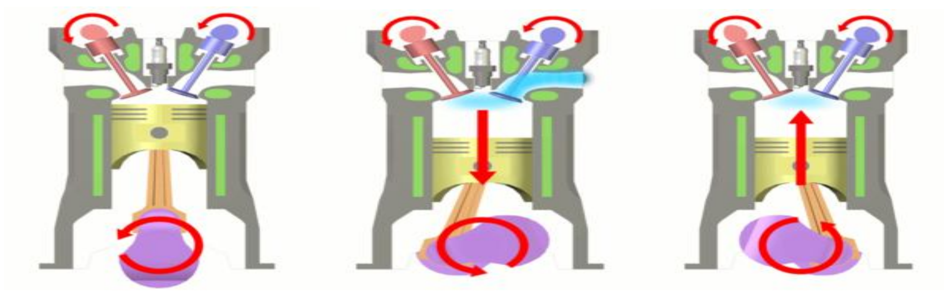

**Figure 2.1**: Starting position, intake stroke, and compression stroke.

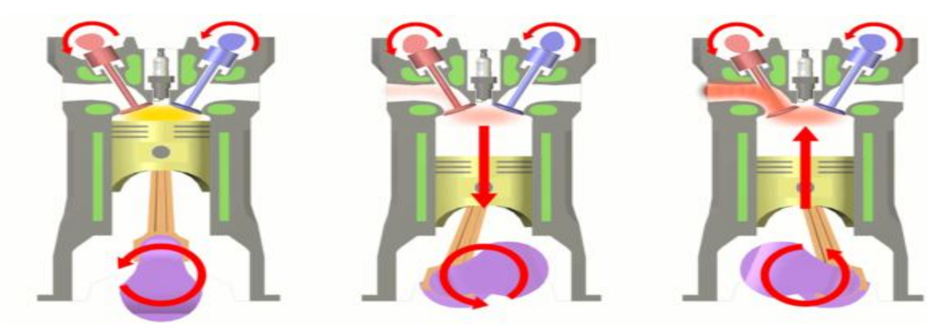

**Figure 2.2**: Ignition of fuel, power stroke, and exhaust stroke.

## 2.4 Spark-ignition engine operation

In spark-ignition (SI) engines, the air and fuel are usually mixed together in the intake system prior to entry to the engine cylinder, using a carburetor of fuel-injection system [1] [5]. The term spark-ignition engine is normally used to refer to internal combustion engines where the fuel-air mixture is ignited with a spark. The term contrasts with compression-ignition engines, where the heat from compression alone ignites the mixture [12]. Spark-ignition engines can be either two-stroke or four-stroke, and are commonly referred to as "gasoline engines" in America and "petrol engines" in Britain. However, these terms are not preferred, since spark-ignition engines can (and increasingly are) run on fuels other than gasoline, such as liquefied petroleum gas (LPG), methanol, ethanol, compressed natural gas, hydrogen, and (in drag racing) nitro methane [12]. A four-stroke spark-ignition (SI) engine is an Otto cycle engine [1] [12].

## 2.5 Compressed natural gas

Compressed Natural Gas is a fossil fuel substitute for gasoline (petrol), diesel, or propane fuel. Although its combustion does produce greenhouse gases, it is a more environmentally clean alternative to those fuels, and it is much safer than other fuels in the event of a spill [3] [8].

CNG is made by compressing natural gas (which is mainly composed of methane [$CH_4$]), to less than 1% of its volume at standard atmospheric pressure. It is stored and distributed in hard containers, at a normal pressure of 200–220 bar (2900–3200 psi), usually in cylindrical or spherical shapes [8].

The main component in CNG fuel is methane gaseous, about 75% methane. The chemical reaction of CNG fuel is therefore given by:

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

## 2.6 Compressed natural gas engine

Compressed natural gas can be used in Otto-cycle (gasoline) and modified Diesel cycle engines. The equipment required for CNG to be delivered to an Otto-cycle engine includes a pressure regulator (a device that converts the natural gas from storage pressure to metering pressure) and a gas mixer or gas injectors (fuel metering devices). Often assisting the gas mixer was a metering valve actuated by a stepper motor relying on feedback from an exhaust gas oxygen sensor. Newer CNG conversion kits feature electronic multi-point gas injection, similar to petrol injection systems found in most of today's cars [8].

Compressed natural gas engine require a greater amount of space for fuel storage than convention gasoline power vehicles. Since it is a compressed gas, rather than a liquid like gasoline, CNG takes up more space for each Gallon of Gas Equivalent (GGE). Therefore, the tanks used to store the CNG usually take up additional space in the trunk of a car or bed of a pickup truck which runs on CNG [8].

This project investigate about internal combustion engine using compressed natural gas as an alternative fuel to reduce the pollution from exhaust gas emission and the operation cost of the engine [3].

To improve of compressed natural gas (CNG) nozzle holes geometries and understand of the processes in the engine combustion is a challenge because the compression-ignition combustion process is unsteady, heterogeneous, turbulent and three dimensional, very complex and the nozzle fuel injector hole is can be variation with any hole geometry [10].

## 2.7 Injection nozzle operation

In sequential injection compressed natural gas (CNG) engines, natural gas fuel is injected by fuel nozzle injector via intake port into combustion chamber and mixing with air must occur before ignition of the gas fuel. Once ignition occurs, there is a rapid energy release resulting from the combustion of the fuel mixed during the ignition delay followed by a slower energy release limited by the availability of gaseous fuel and its mixing rate with air [1].

To improve the perfect of mixing process of compressed natural gas (CNG) fuel and air in combustion chamber, for example with arranging of nozzle hole geometry, modification of piston head, arranging of piston top clearance, letting the air intake in the form of turbulent and changing the compressed natural gas (CNG) fuel angle of spray [10]. The compressed natural gas (CNG) fuel spraying nozzle is the level of earning variation so that can be done by research experiment and computational of engine power, cylinder pressure, specific fuel consumption and exhaust gas emissions which also the variation of them have been researched the sequential injection of compressed natural gas (CNG) offers several advantages to increase the compressed natural gas (CNG) engines performance [8] [10].

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

This chapter will explain on the concept and method being used for this project. For that, an overall structure of methodology has been illustrated in a flow chart.

## 3.2 Overview of the methodology

The project started with the objectives and problem statement that had been defined. The project cannot be done if the knowledge regarding on the topic itself is not adequate. First of all, the concepts regarding the project must be clear. This can be done by searching related information through the journals in the net, reference book, etc. With the information acquired from the literature review, a clear concept and idea should already in mind. Hence, the next process which is design and modeling are carryout. In this process, computer-aided drafting (CAD) software, Solidworks used for design the multi holes injection nozzle while the flow motion modeling of the injector done by computational fluid dynamics (CFD) software, Cosmos FloWork.

### 3.3 Project Methodology

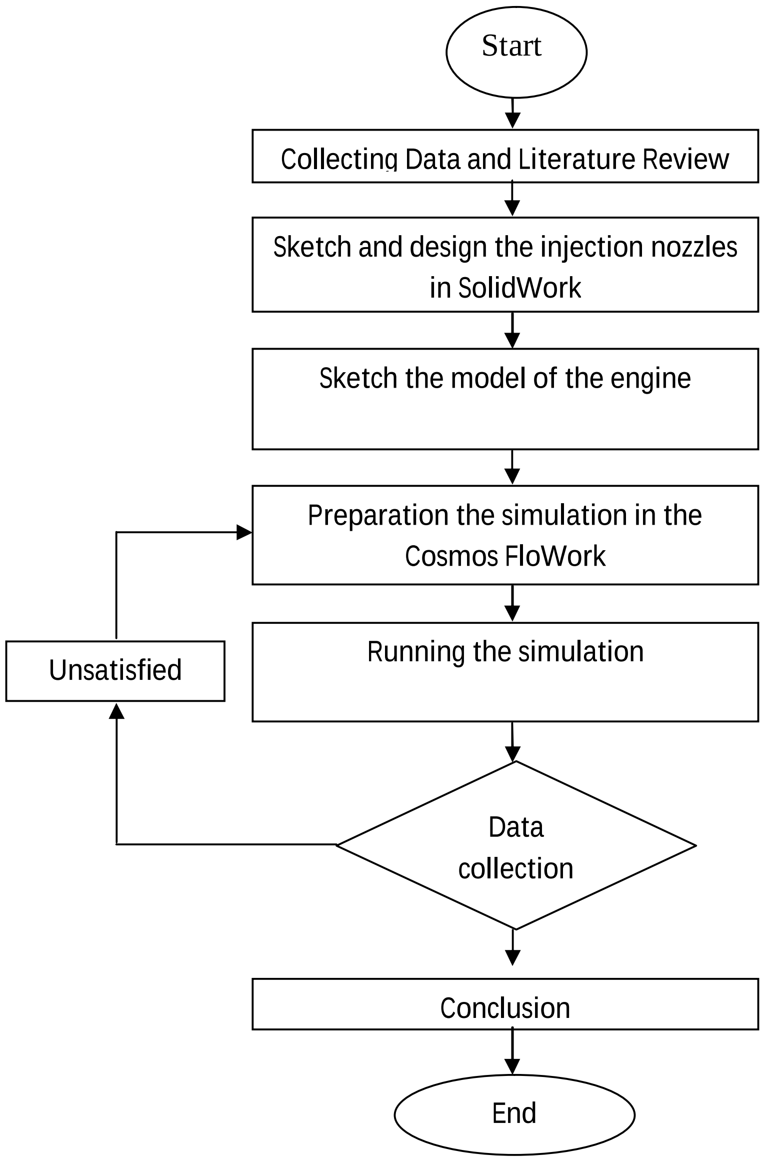


**Figure 3.1**: Flowchart of final year project

## 3.4 Description of the methodology

### 3.4.1 Injection nozzles

The beginning of this final year project, literature review were collected from book, journal and other references to understand about the project. After that, the original injector was designed by SolidWork 2005.

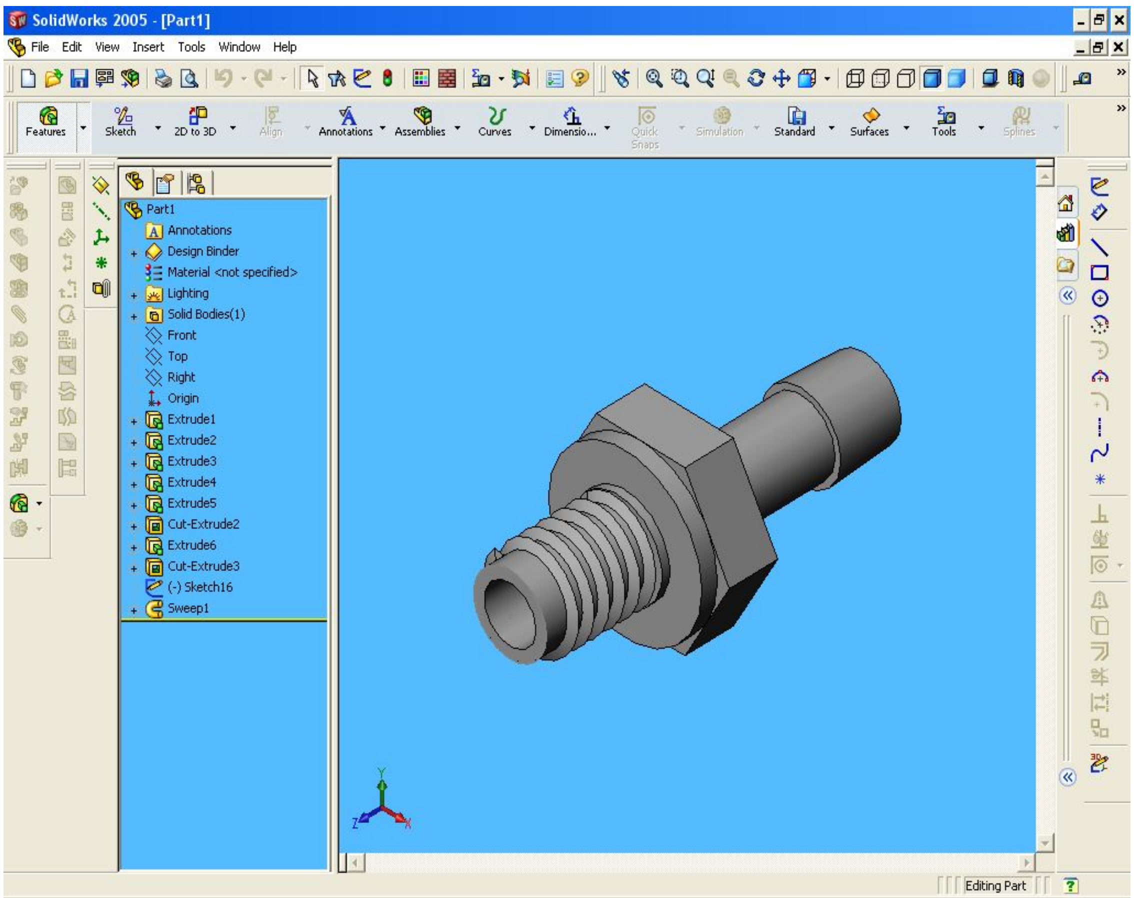


**Figure 3.2**: Original Injection Nozzle

The main purpose of this project is to design the injection nozzle and analyze the flow at maximum valve lift before ignite. The figures below are the modified injection nozzles that used in this project.

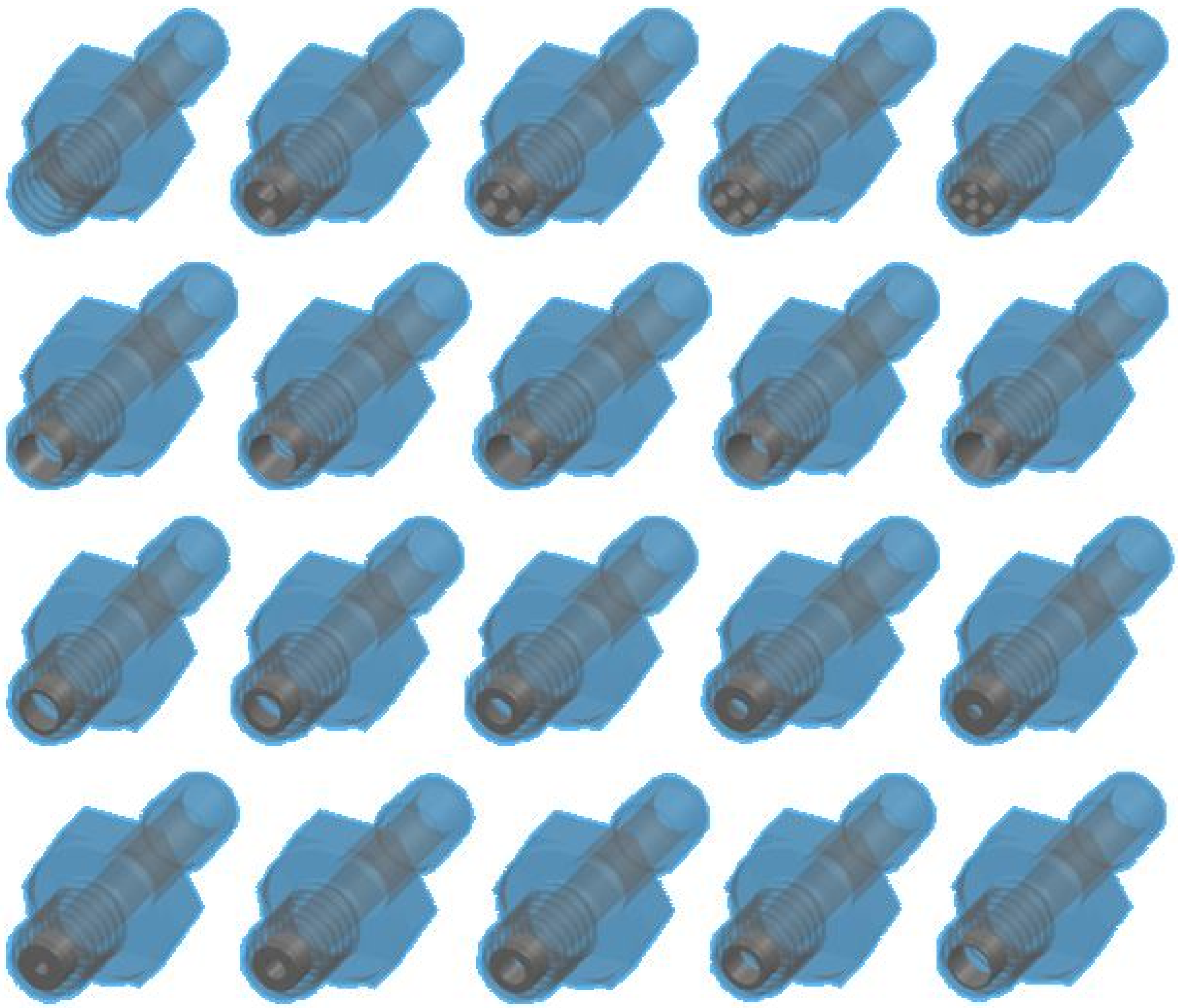

**Figure 3.3**: Modified Injection Nozzles from SolidWork 2008

To find the best design, nozzle must be create in different size, degree and number of nozzles. So that, the best design can be choose after simulate the flow of the nozzle in CNG engine using Cosmos FloWork software. In this project use 20 types of injection nozzles in difference diameters, angel of nozzle and sum of holes. Then, analyze each of the injection nozzles using the CNG engine SolidWork model. The figure below is the detail design.

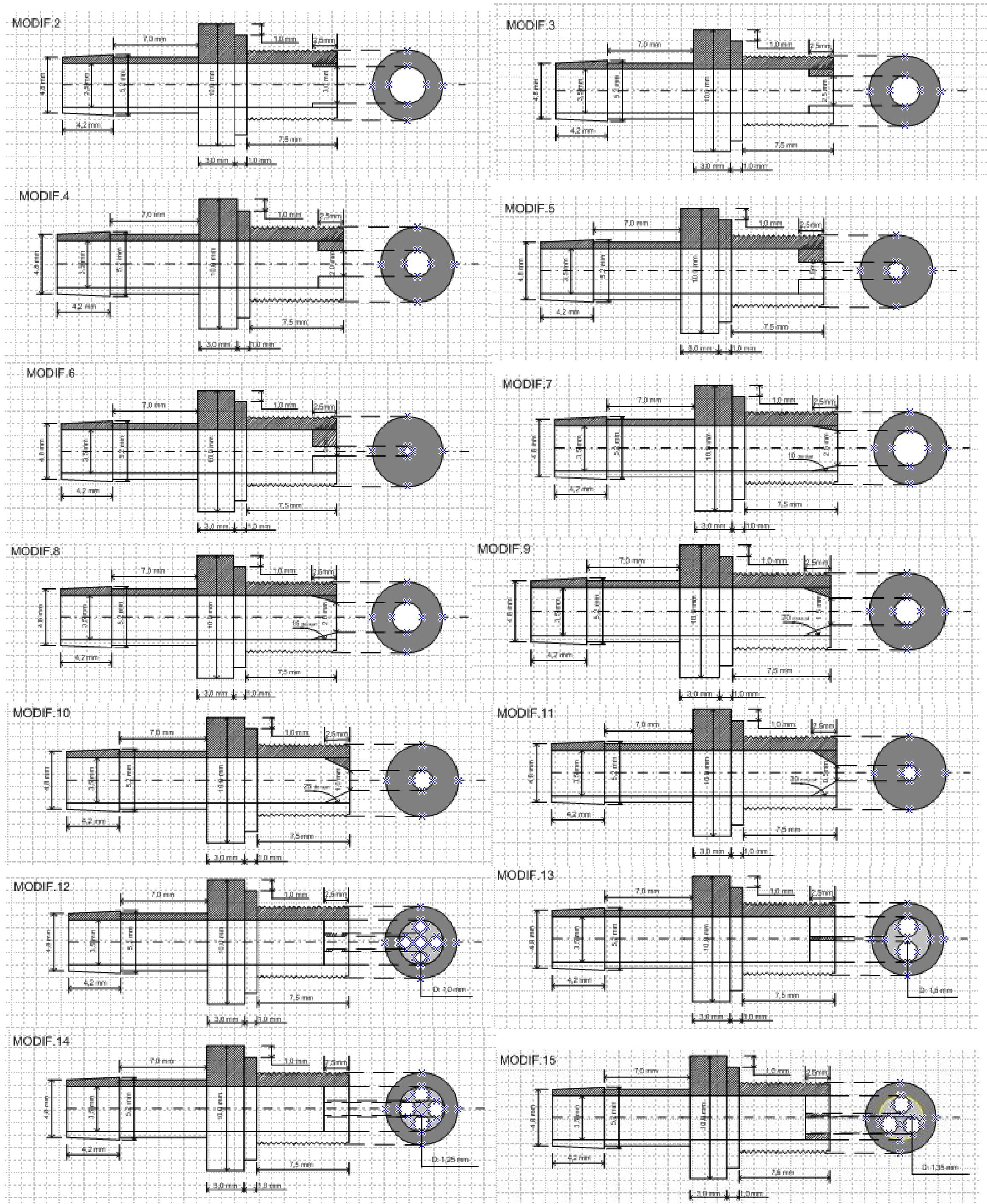


**Figure 3.4**: Modified Injection Nozzles from Microsoft Visio 2007

### 3.4.2 Compressed natural gas engine model

The model of the CNG engine in figure below is base on the actual engine in term of bore, stroke and intake valve. The diameter of the bore is 86 mm and the length of the stroke is 70 mm. The valve lift is 7.11 mm. The injection nozzle is at the intake manifold.

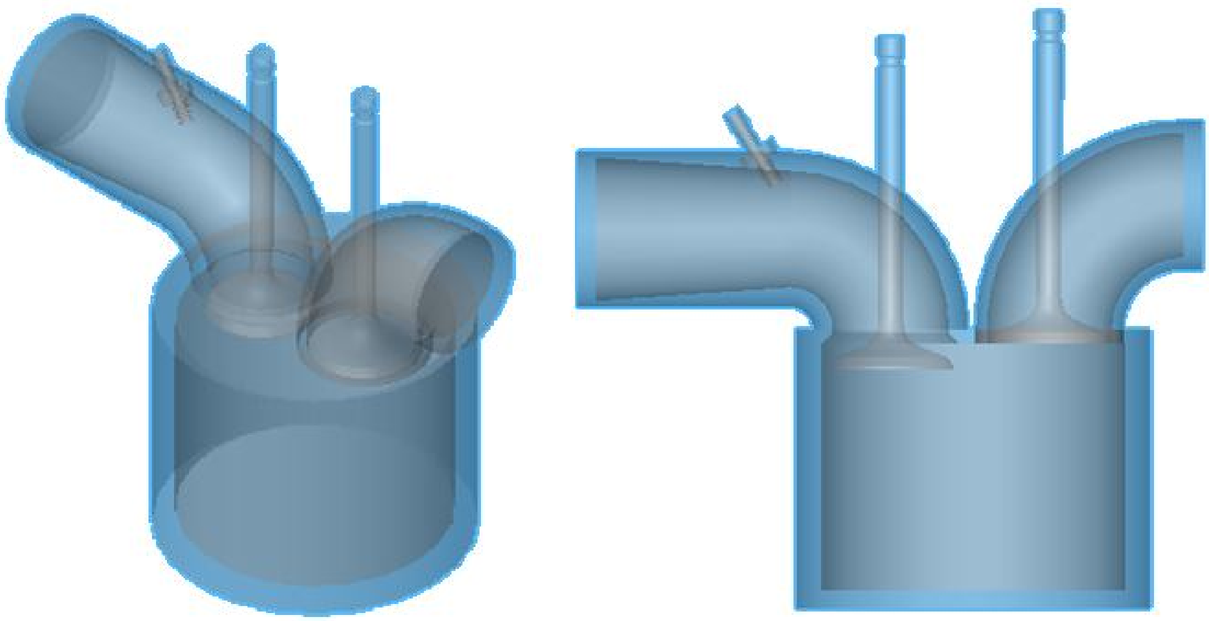

**Figure 3.5**: CNG Engine Model