Effect of intake In-homogeneity on the mixture formation and combustion process in natural gas engine

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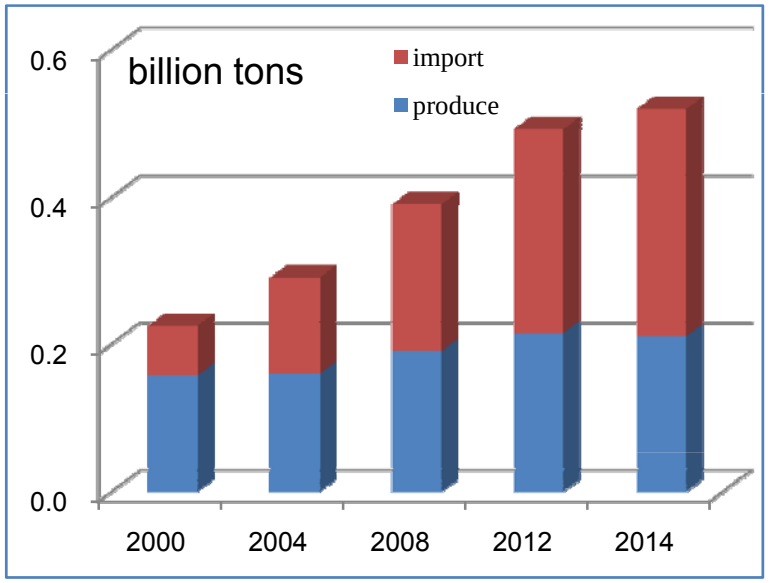
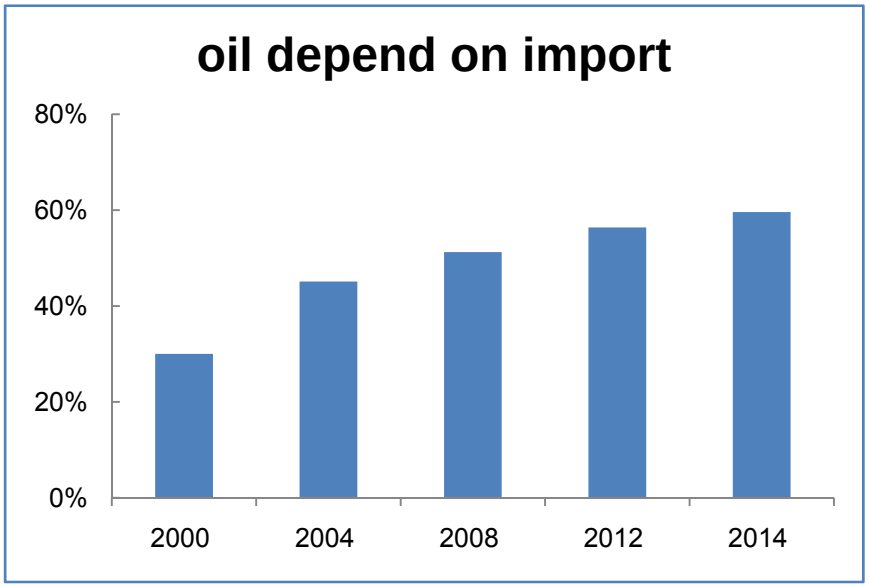
1.Introduction

Oil shortage problem is becoming an main obstacle restricting china's economic development.





1.Introduction

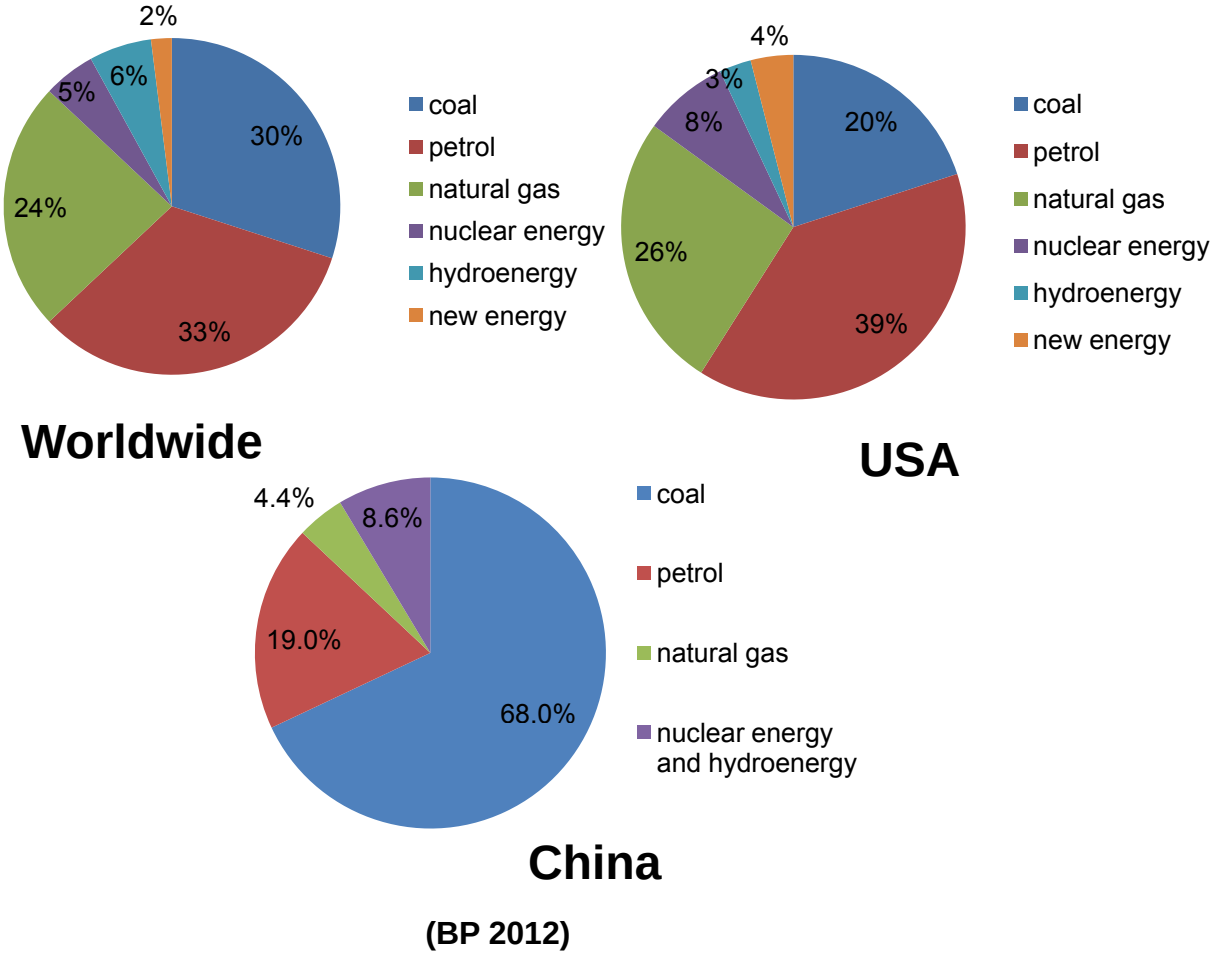
the proportion of coal is more than 60%

Lower fuel efficiency; Higher pollution

The proportion of natural gas is no more than 5%,far lower than the world's average of 24%

To optimize the Energy consumption structure

Energy consumption structure



(BP 2012)

1.Introduction

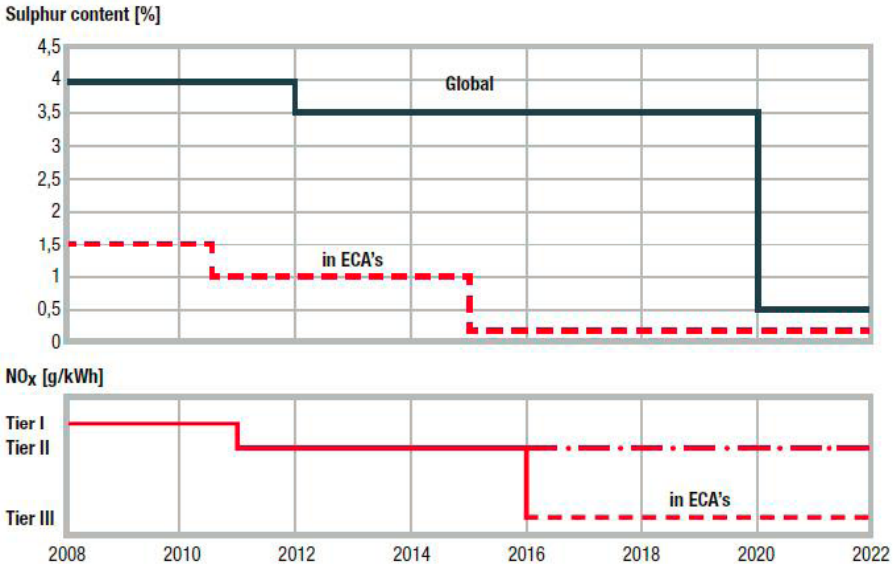
In China, the total number of inland river ships is very large ,more than 230 thousand. Therefore, the emissions from marine diesel engine is one of the most important pollution source. which leads to the damage of inland river and surrounding.

1.Introduction

the International Maritime Organization (IMO) has proposed increasingly strict regulations through lower thresholds for SOx and NOx emissions, the number of ECA zones is increasing. this is a serious challenge for china's engine manufacturers.

IMO emission legislation, the big challenges for international shipping

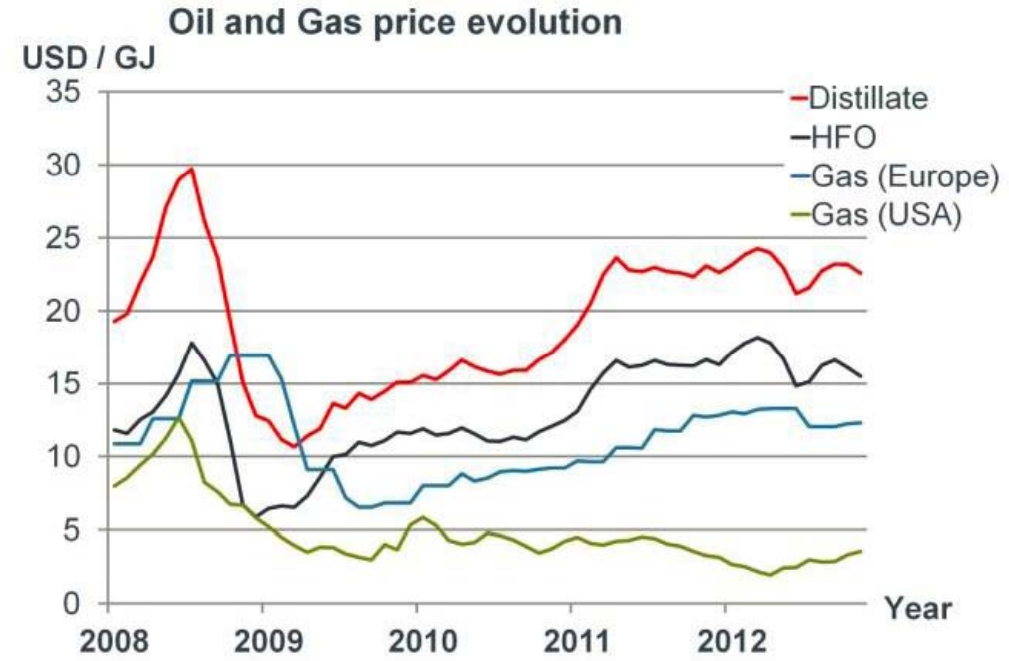
SOx: Regulation decided
NOx : Regulation decided
ECAs: Not decided
CO2: Items discussed
CO_2: **Design index EEDI**
CO_2: **Operational Index EEOI**
Market based instruments:
Global bunker **levy** (tax)
CO_2 credits



1.Introduction

To promote the application of natural gas is an effective measure to release the pressure from energy and environment.

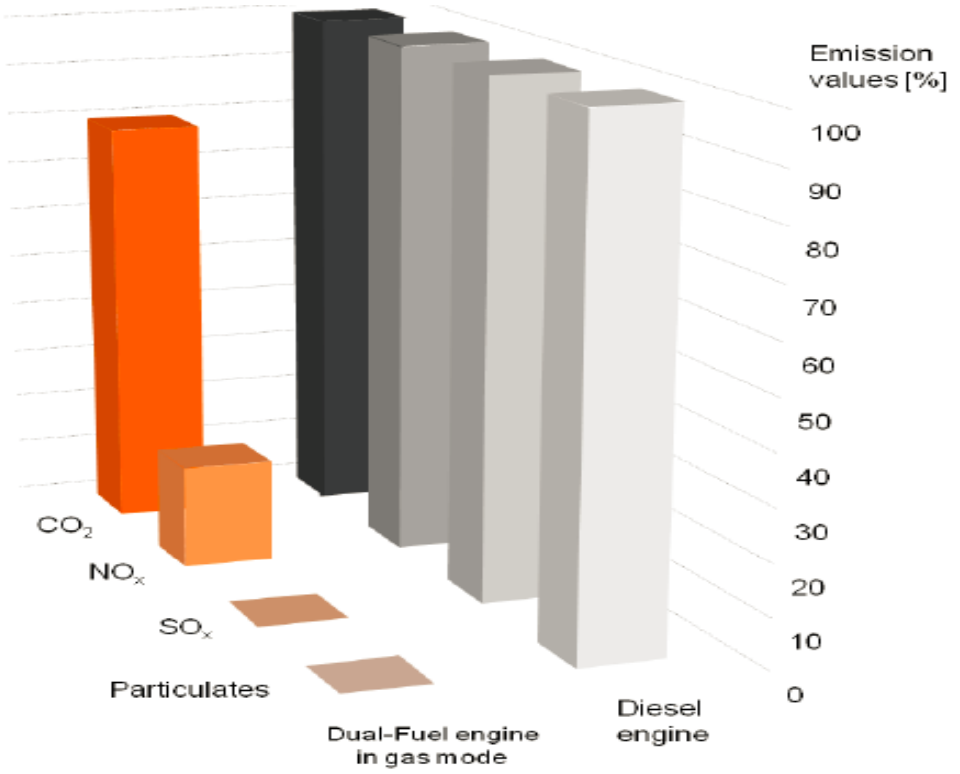
- Abundant resource
- Clean combustion
- Lower price



[Kunkel, S., et. al. (2013)]

1.Introduction

Comparing to traditional diesel engine, gas and dual fuel engine can produce lower emissions, NOx, SOx and PM, so no additional exhaust gas treatment system is needed to meet the Tier III NOx requirements.



(CIMAC Congress 2013,Wärtsilä)

1.Introduction

- policy and funding support

  -Develop alternative energy

- Large demonstration projects

  -Gasify Yangtze river

  -Gasify canal

Ship with dual fuel engine

1.Introduction

◆Multi-point gas injection technology

-Faster response to load variation

-Cylinder to cylinder balance

-satisfactory safety, etc

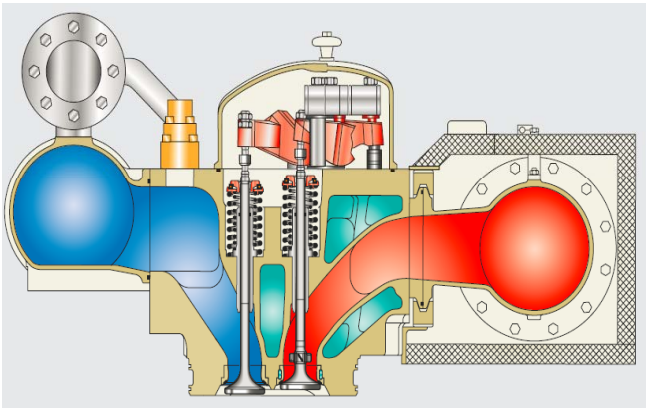
◆Problem of the technology

-Shorter mixing time of gas fuel and air

-inhomogeneous mixture in intake port

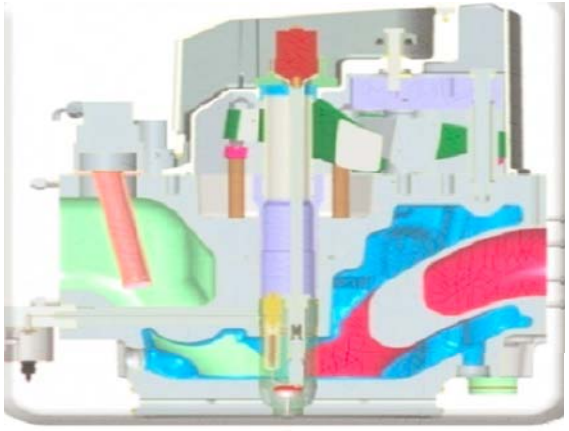
2. 3D-model and design of gas nozzle

The shapes of common gas nozzle



(a)No gas nozzle

(b) Vertical gas nozzle



(c) inclined gas nozzle

2. 3D-model and design of gas nozzle

◆ Marine gas engine

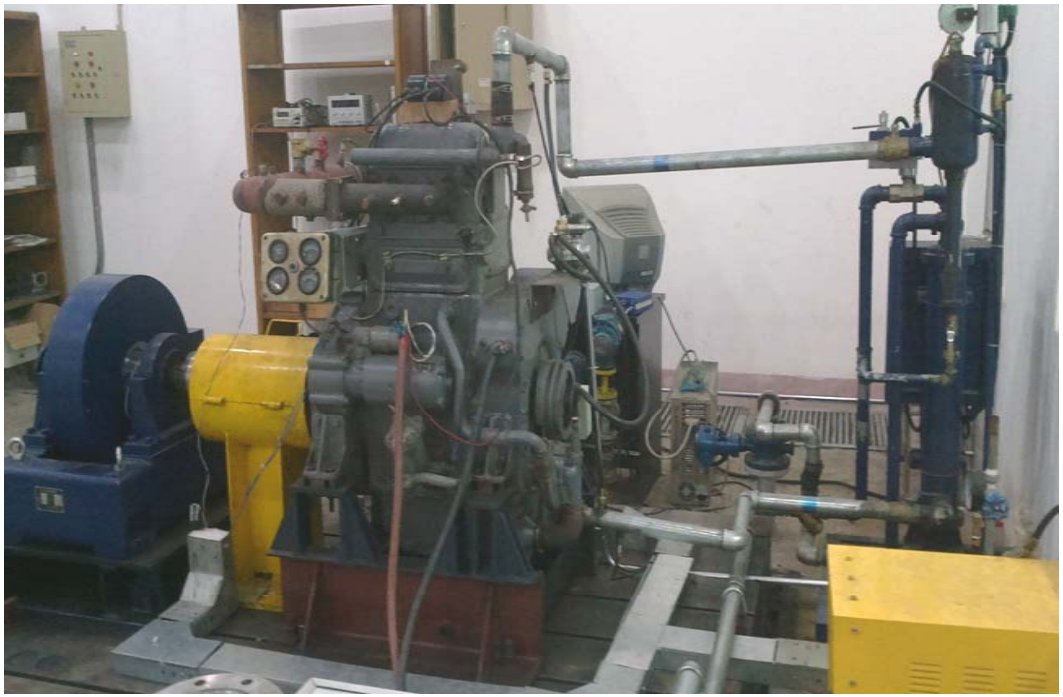
-new combustion chamber

-Compression ratio：16.5→11

-Electronic gas injector

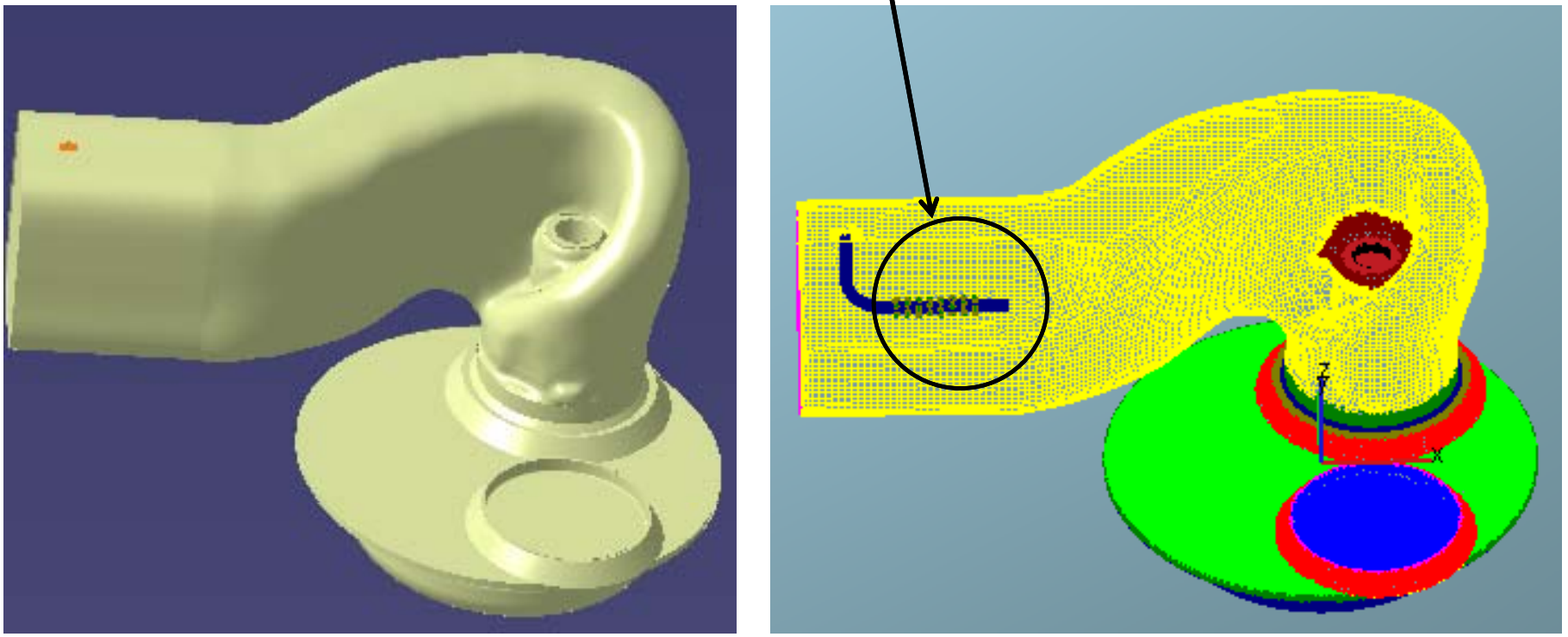
- ECS

Fundamental research



2. 3D-model and design of gas nozzle

3D-model



geometry model and its mesh of the gas engine

2. 3D-model and design of gas nozzle

◆design of gas nozzle

-single-hole gas nozzle

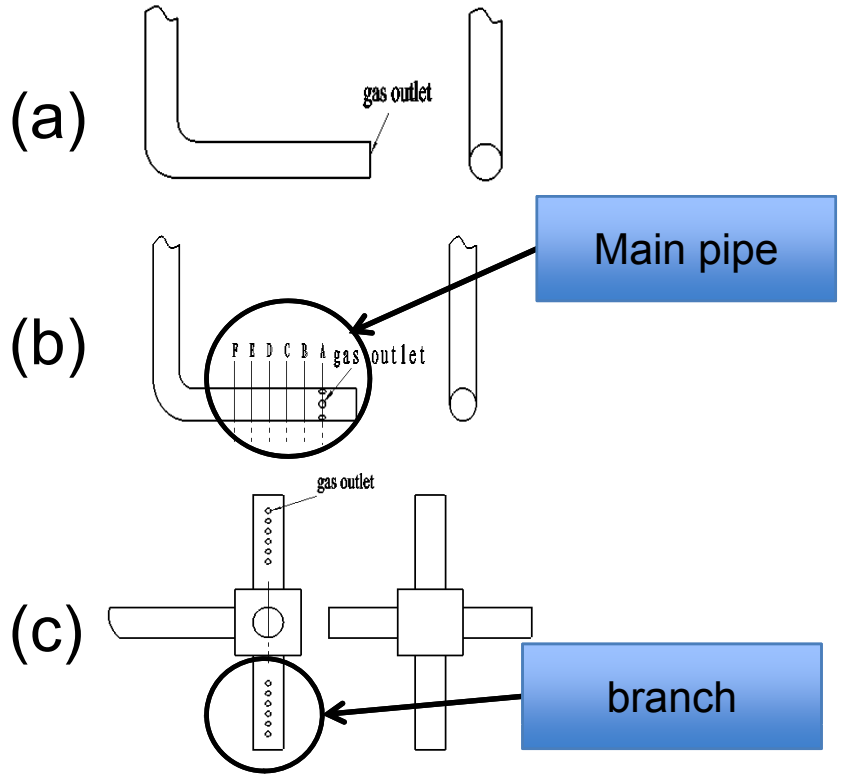
Only one outlet at the end of pipe

-multi-hole gas nozzle

Many holes on the main pipe

-cross multi-hole gas nozzle

Four branch , different distribution



3. Calculation conditions

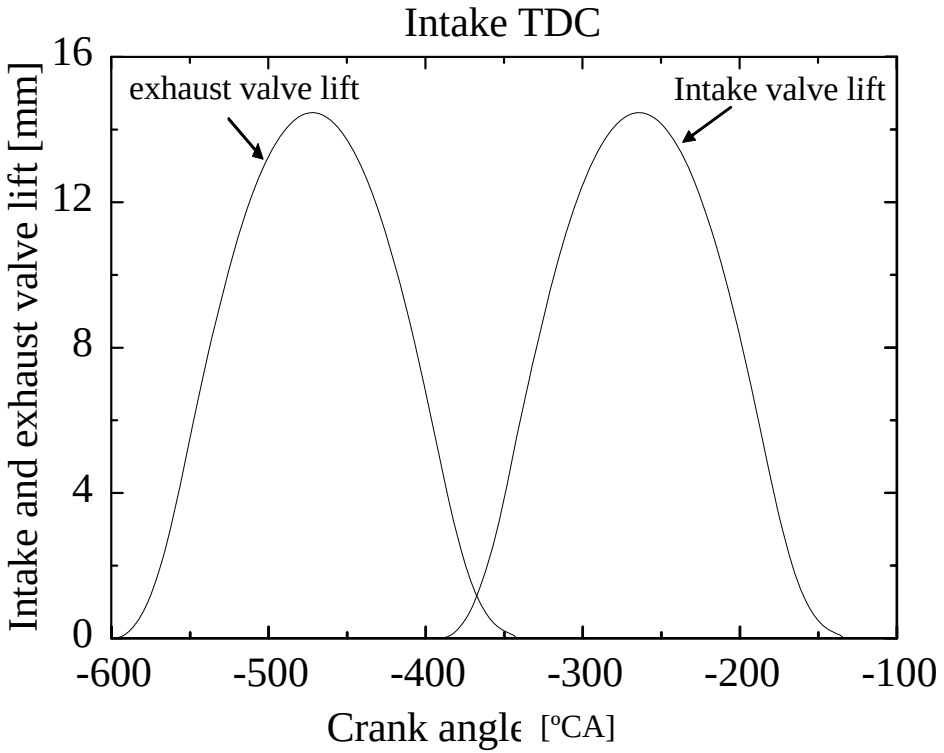
- Engine speed :1000rpm
- Engine load : Wide Open throttle
- Lean burn : excess air coefficient=1.6
- Gas injection timing：intake TDC

3. Calculation conditions

-The period of intake valve opening：248ºCA

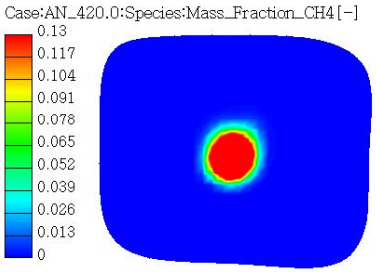
-The period of gas injection：110ºCA

Ignition timing: 30ºCA BTDC



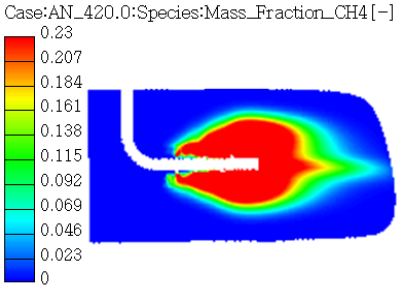
4. Results

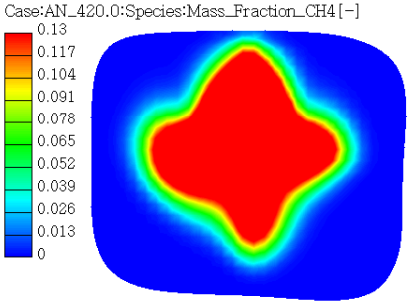
single-hole gas nozzle



Faster flow speed, small interaction area

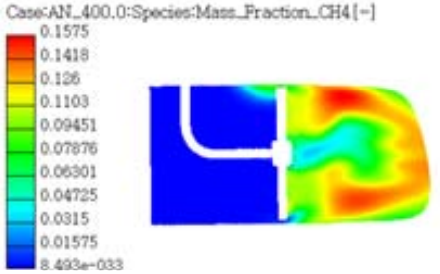
multi-hole gas nozzle

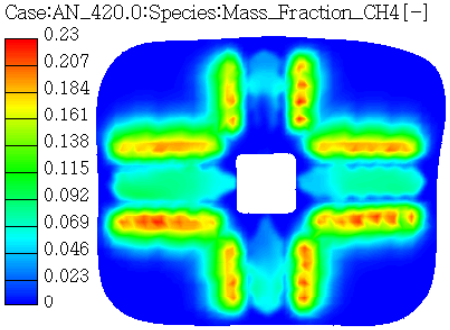




Perpendicular to the direction of air flow

cross multi-hole gas nozzle



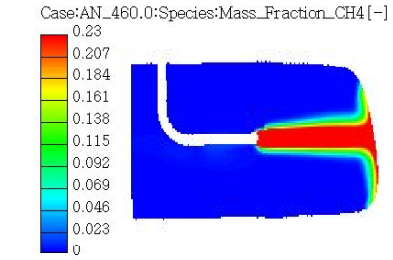


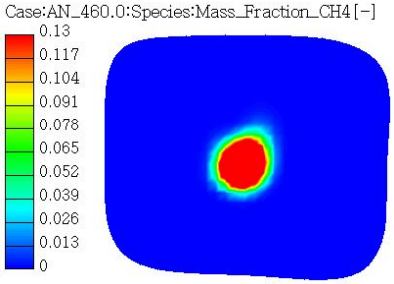
Most homogeneous

Gas injection process

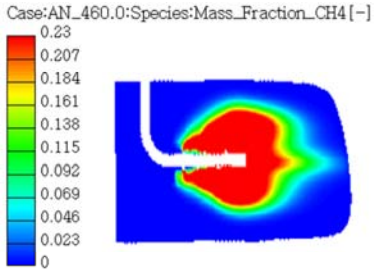
4. Results

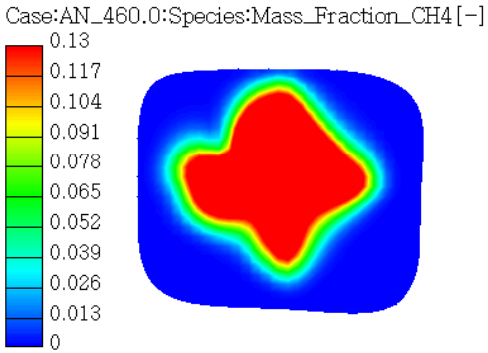
single-hole gas nozzle



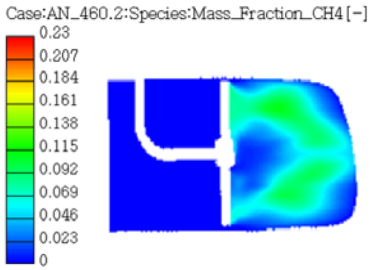


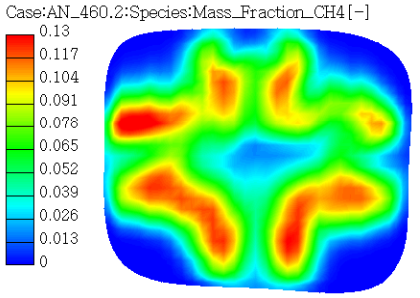
multi-hole gas nozzle





cross multi-hole gas nozzle



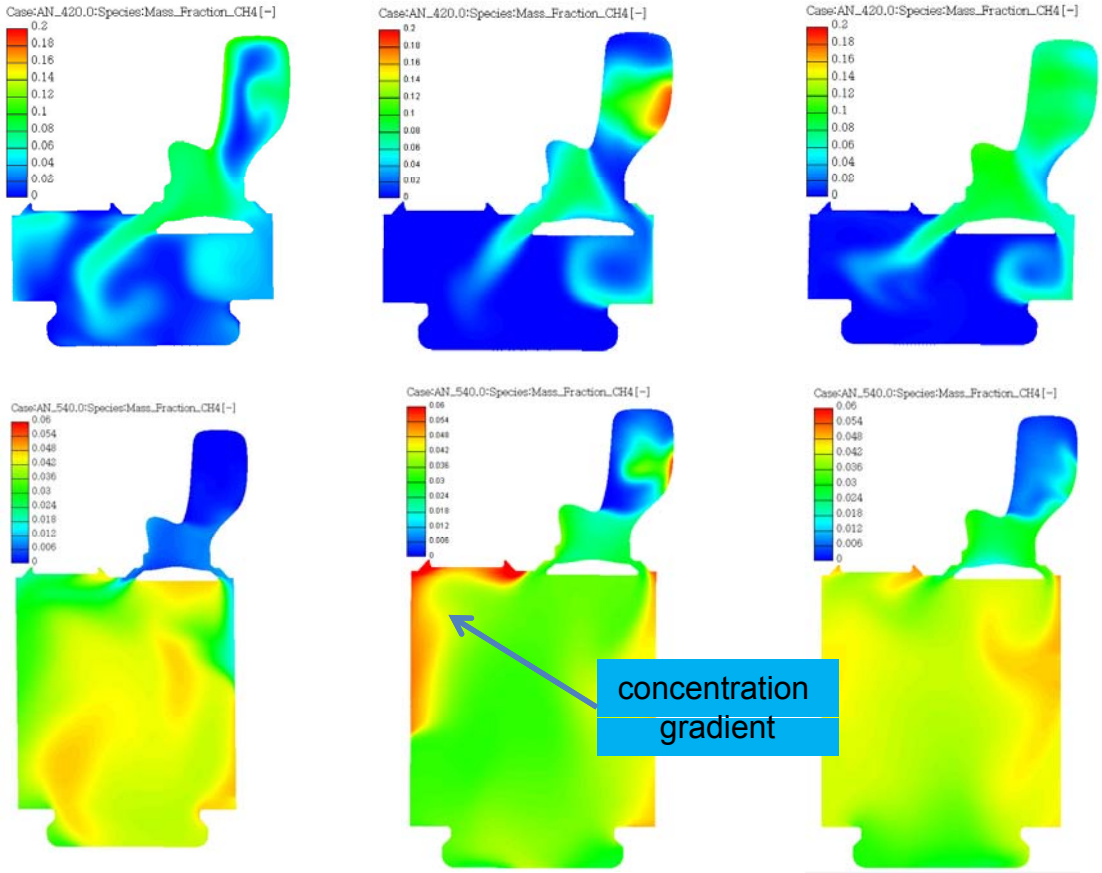


Gas injection process

4. Results

Comparing to case 2, the mixture for case1 and case 3 is more homogeneous, but no obvious rule

single-hole gas nozzle | multi-hole gas nozzle | cross multi-hole gas nozzle



Intake process

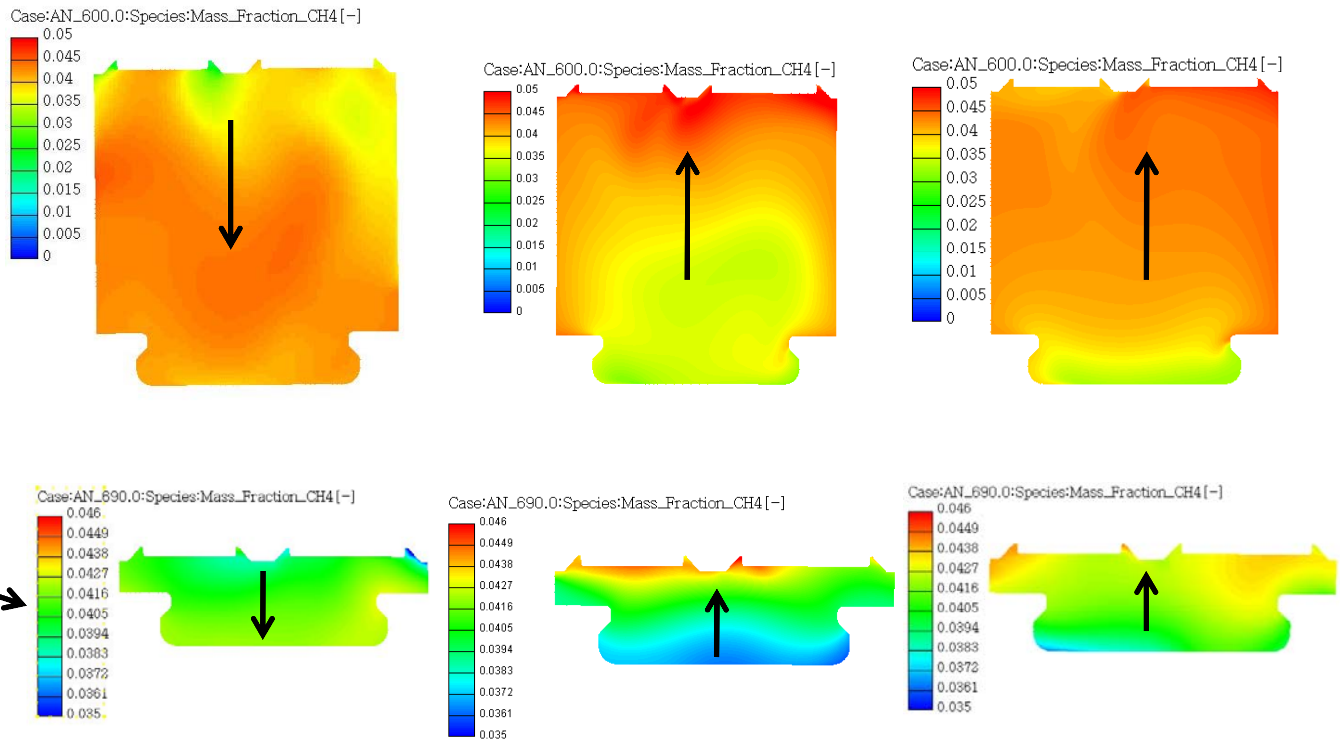
4. Results

single-hole gas nozzle | multi-hole gas nozzle | cross multi-hole gas nozzle

stratification of air

and fuel mixture

Start ignition

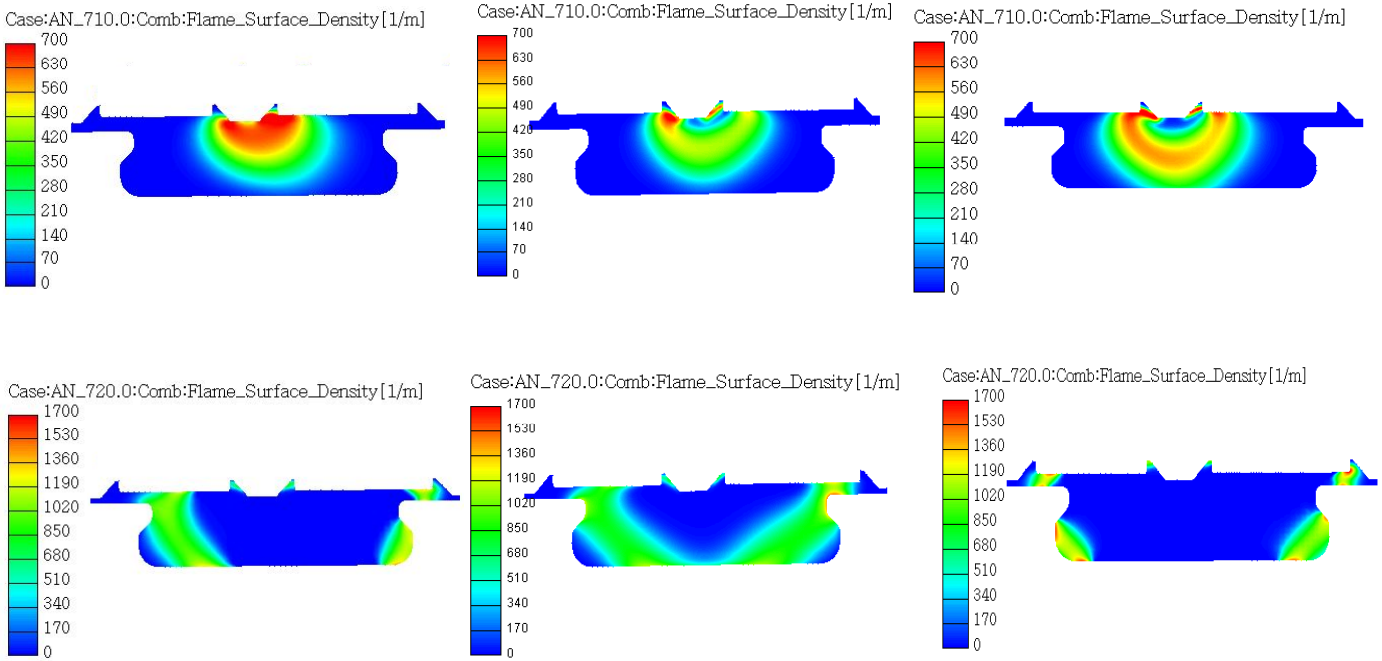


compression process

3. Results

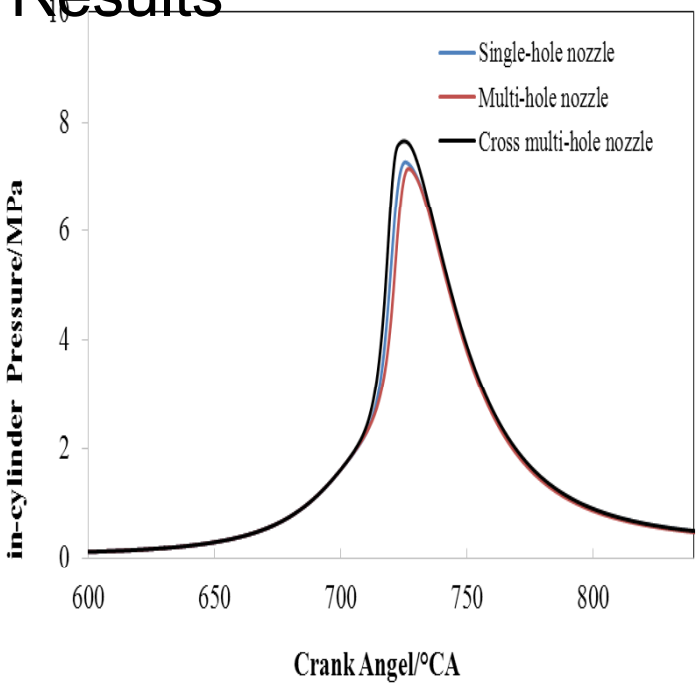
Case 3 and case 1 can produce faster combustion.

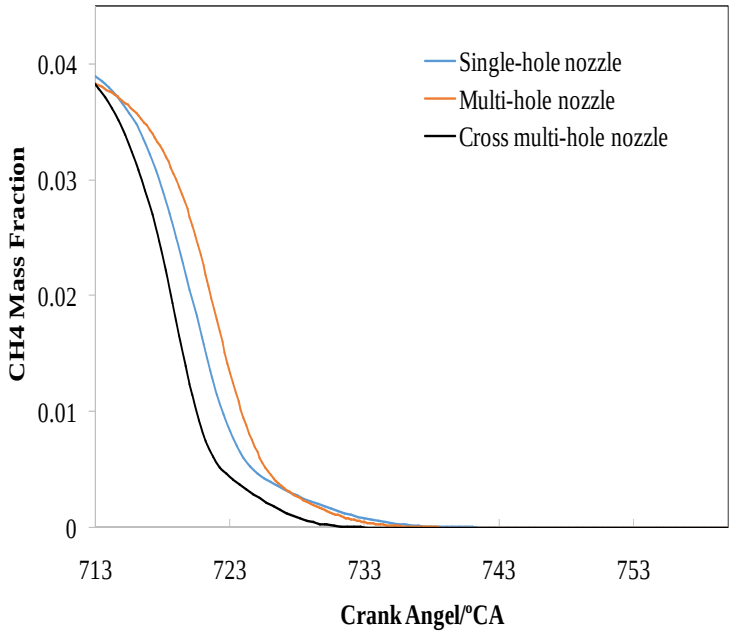
single-hole gas nozzle | multi-hole gas nozzle | cross multi-hole gas nozzle



combustion process

3. Results

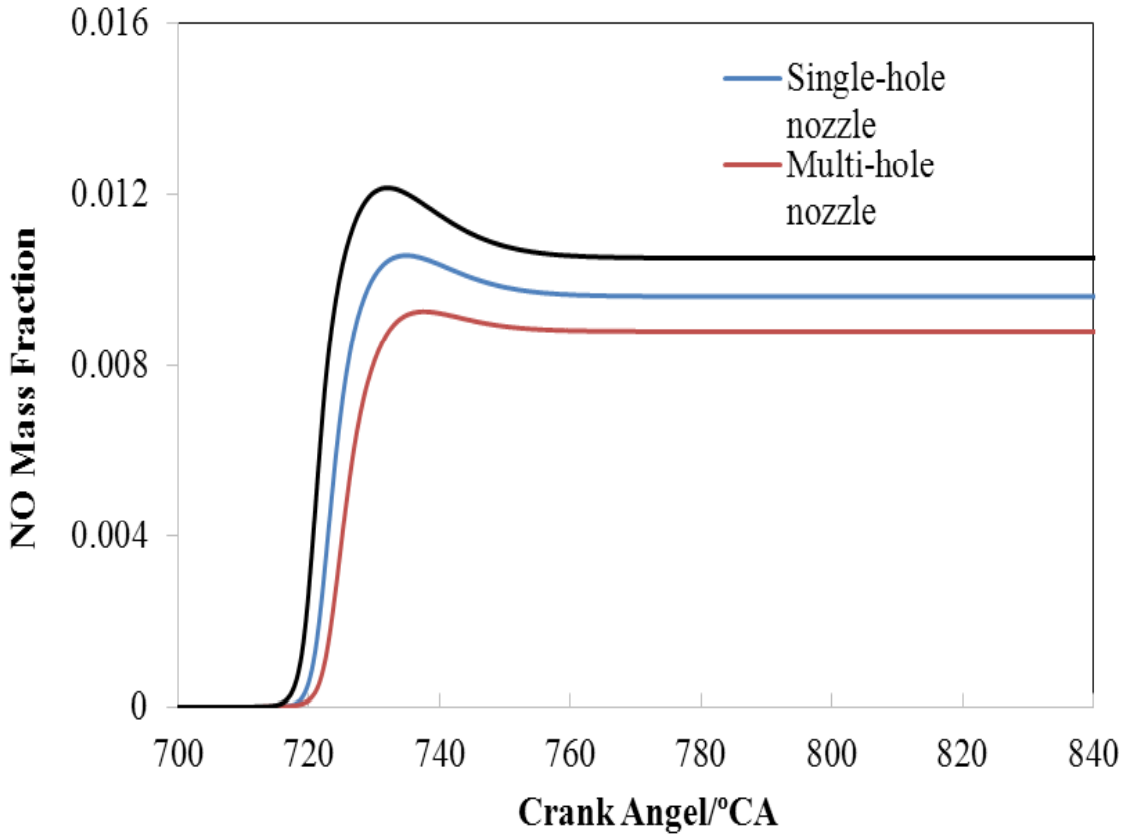




The peak pressure and the rate of methane combustion are highest using cross multi-hole gas nozzle, followed by case1 and case 2.

3. Results

Faster combustion also leads to higher NOx emission for case 3



5. Conclusions and suggestion

◆The design of gas injection nozzle can realize the reasonable stratification of gas fuel and air mixture and improve combustion of lean burn natural gas engine;

◆The structures of gas nozzles may be not optimum and simple, but they can help us to understand the intake mixture process and their effect on combustion and emission formation process, furthermore provide a direction of performance optimization of natural gas engine

◆In order to further optimize the combustion of natural gas engine, except for optimizing structure of gas nozzle, other factors need to be comprehensively considered such as gas injection timing, gas supply pressure, and combustion chamber, etc.

Thank you