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Modelling and study of the thermo-mechanical behaviour of the head of a gasoline internal combustion engine

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Thanks

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strengths to accomplish this work.

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Finally, we have the great honor of dedicating this modest work to:

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The whole **KHALOUA** family and **BELLMAHI**

To all our friends

To all our comrades in the mechanical engineering group

To all study friends

To all the teachers who contributed

To our training throughout our study lives.

Abstract

The engine cylinder head is an essential part in the operation of the automobile. it undergoes great stresses under thermal and mechanical stresses.

The current study presents the thermomechanical analysis of the engine cylinder head with the use of a finite element software « ANSYS-Workbench. »

The choice of materials to develop the engine cylinder head is a major factor for a good functioning. therefore, in the present work, Aluminum alloy is chosen. however, the results are not perfect. Despite the results, they indicate the importance of cylinder head design

Résumé

Le culasse moteur est une pièce maitresse dans le fonctionnement de l'automobile, il subit de fortes contraintes sous sollicitations thermiques et mécaniques.

Le présent travail est relatif à l'analyse thermomécanique de la culasse moteur à l'aide d'un logiciel éléments finis « ANSYS-Workbench. »

Le choix de matériaux d'élaboration du culasse moteur est un facteur principal pour le bon fonctionnement, pour notre étude on a choisi l'alliage d'aluminium mais les résultats ne sont pas tellement parfaits.

ملخص

تعد كتلة المحرك جز ًءا مهًما في تشغيل السيارة. يتعرض الهيكل او كتلة المحرك لضغوط كبيرة منها حرارية ميكانيكية

نقدم الدراسة الحالية تحليل الميكانيكي الحراري الاسطوانة المحرك باستخدام برنامج العناصر المحدودة

« ANSYS-Workbench. »

اختيار المواد المناسبة لتطوير كتلة المحرك هو عامل رئيسي ألداء جيد. لذلك، في عملنا هدا الحالي، قمنا باختيار " سبائك الألومنيوم ". ومع ذلك، فإن النتائج لم تكن ليست مثالية

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GENERAL INTRODUCTION

GENERAL INTRODUCTION

The vehicle's propulsion is usually obtained by means of engines, to know mechanical devices capable of converting the chemical energy of a fuel into mechanical energy.

The cylinder head has mechanical and energy performance in the automobile engine petrol as also in most heat engines (diesel, LPG, hydrogen ...), with different arrangements and forms but has a single operating principle.

The objective of this study is to study the thermomechanical modeling of a cylinder head engine in a heat engine and represent performance, in order to do the simulation.

The first chapter describes the operating principle of motors, their different types, the operating principle and the advantages and disadvantages and consumption of each type.

The second chapter gives an identification of the engine cylinder head (Different types of cylinder head and Classification, thermal stresses and mechanical, choice of processing materials, defect inspection and repair)

The third chapter constitutes a modeling and simulation of an engine cylinder head, first sizing and design of the engine cylinder head part using software (SOLIDWORKS), and then we engage with a software publisher specializing in numerical simulation which is (ANSYS WORKBENCH 16.2) where we made the fine mesh with the application of conditions thermal and mechanical limits.

The fourth chapter contains the results of the chapter calculations preceding it. So, in this chapter we will compare between the two cases of our material used "aluminium alloy", the first, normal case (with coolant) and the second, accidental case (without cooling liquid). The objective of this study is to see the influence of coolant liquid on the variation of the thermomechanical stress in our engine cylinder head

chapter 1

The Different Types Of Engines

Introduction:

In this chapter, we will present a general overview of the different types of engines, we will see different classification of engines and we will introduce the operating principle of each engine as well as the efficiency, and the advantages and disadvantages of each type. these engines are used in different areas such as in automotive industries, aircraft industries, marine industries, etc. So, let's discuss about different engines types one by one.

1. Internal Combustion Engines:

In internal combustion engine, the combustion of fuel takes place inside the engine. Two stroke and four stroke petrol and diesel engine are the examples of internal combustion engine. Internal combustion engines are heat engines. They burn fuels to produce heat. The heat increases the pressure of the gases contained in the engine. This pressure then produces motion. Heat engine convert chemical energy (fuel) into mechanical energy (motion).

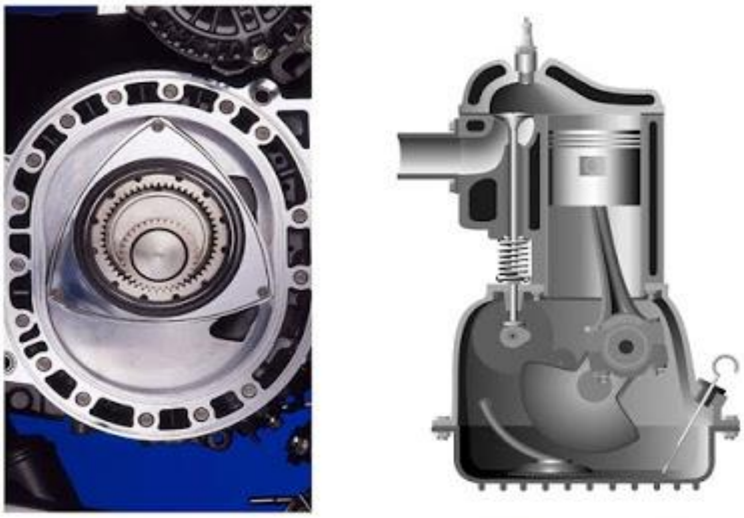
Internal combustion engine can produce motion in three different ways (**reciprocating motion**, rotary **motion**, **linear motion**)

Different kinds of engines produce different kinds of motion [1]

1.1. Engine Classification:

We can classify automotive engines by different methods.

1.1.1 . Types of Design:



Wankel Rotary Engine Reciprocating Petrol Engine

Fig 1: Rotary engine and reciprocating engine. [2]

(I). Reciprocating engine: In reciprocating engine, there is a piston and cylinder, the piston does reciprocate motion within the cylinder. Due to the reciprocating motion of the piston, it is called reciprocating engine. 2 stroke and four stroke engines are the common examples of reciprocating engine.

(ii). Rotary engine: In rotary engine, the rotor does rotary motion to produce power. There is no reciprocating motion. A rotor is present in the chamber which does rotary motion inside a chamber. Wankel rotary engine, turbine engines are the rotary types of engine.[2]

1.1.2. Types of Fuel Used:

On the basis of types of fuel used, the engine is classified as petrol engine, diesel engine and gas engine.

(I). Petrol engine: The engine which uses petrol for its working is called petrol engine.

(ii). Diesel engine: The engine which uses diesel for its working is called diesel engine

(iii). Gas engine: An engine using gas fuel for the working is called gas engine.

1.1.3. Number of Strokes:

On the basis of number of strokes, the types of engine are:

(i). Four Stroke Engine: It is an engine in which the piston moves four times two upward (form BDC to TDC) and two downward (from TDC to BDC) movement in one cycle of power stroke is called four stroke engines.

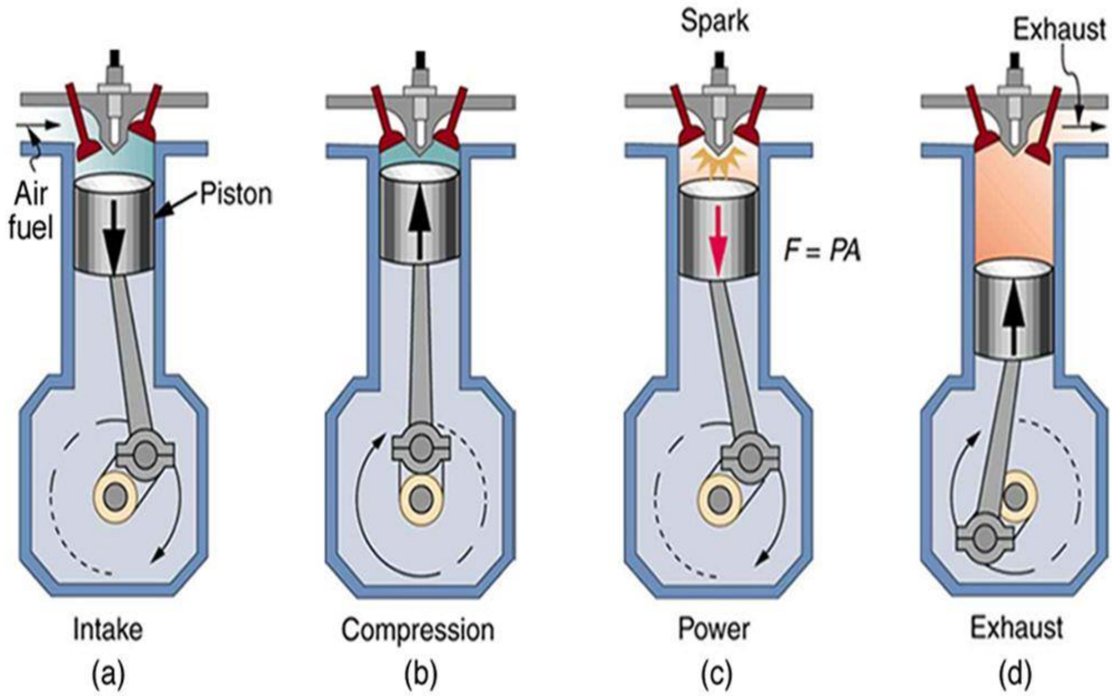


Fig 2: Four-Stroke Engine [3]

(ii). Two Stroke Engine: The engine in which the piston does two times motion i.e. one from TDC to BDC and other from BDC to TDC to produce a power stroke is called two stroke engines.

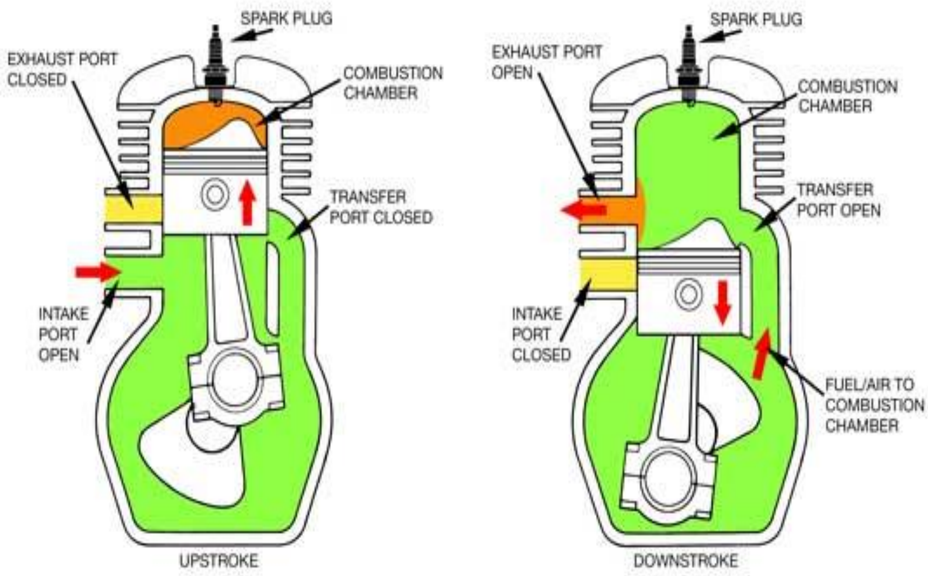


Fig 3: Two Stroke Engine [4]

1.1.3. Type of Ignition:

On the basis of ignition, the engines are classified as:

(i). Spark ignition engine (S.I. engine): In spark ignition engine there is a spark plug which is fitted at the engine head. The spark plug produces spark after the compression of the fuel and ignites the air fuel mixture for the combustion. The petrol engines are spark ignition engine.

(ii). Compression ignition engine (C.I. engine): In Compression ignition engine there is no spark plug at the cylinder head. The fuel is ignited by the heat of the compressed air. The diesel engines are compression ignition engine.[2]

1.1.4. Arrangement of Cylinders:

On the basis of arrangement of cylinders, the engines classification is:

(i). Vertical engine: in vertical engines, the cylinders are arranged in vertical position as shown in the Fig 4.

(ii). Horizontal engine: In horizontal engines, the cylinders are placed horizontal position as shown in the diagram given below.

(iii). Radial engine: The radial engine is reciprocating type internal combustion engine configuration in which the cylinders radiate outward from a central crankcase like the spokes of a wheel. When it is viewed from the front, it resembles a stylized star and is called a 'star' engine. Before the gas turbine engine is not become predominant, it is commonly used for aircraft engines.

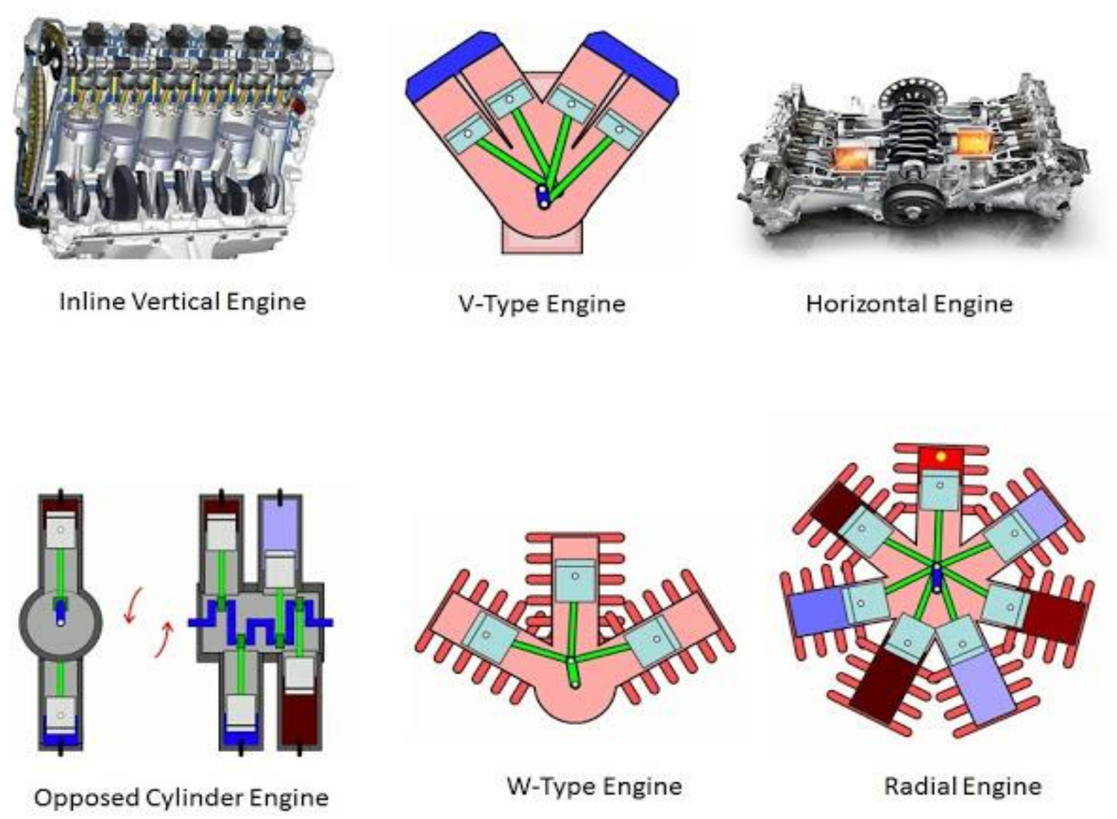


Fig 4: different types of arrangement of cylinder[2]

(iv). V-engine: In v types of engine, the cylinders are placed in two banks having some angle between them. The angle between the two banks is keep as small as possible to prevent vibration and balancing problem.

(v). W type engine: In w type engines, the cylinders are arranged in three rows such that it forms W type arrangement. W type engine is made when 12 cylinder and 16-cylinder engines are produced.

(vi). Opposed cylinder engine: In opposed cylinder engine, the cylinders are place opposite to each other. The piston and the connecting rod show identical movement. It is runs smoothly and has more balancing. The size of the opposed cylinder engine increase because of its arrangement.

1.1.5. Valve Arrangement:

According to the valve arrangement of the inlet and exhaust valve in various positions in the cylinder head or block, the automobile engines are classified into four categories. These arrangements are named as ‘L’, ‘I’, ‘F’ and ‘T’

(i). L-head engine: In these types of engine, the inlet and exhaust valves are arranged side by side and operated by a single camshaft. The cylinder and combustion chamber forms and inverted L.

(ii). I-head engine: In I-head engines, the inlet and exhaust valves are located in the cylinder head. A single valve actuates all the valves. These types of engine are mostly used in automobiles.

(iii). F-head engine: It is a combination of I-head and F-head engines. In this, one valve usually inlet valve is in the head and the exhaust valve lies in the cylinder block. Both the sets of valves are operated by the single camshaft.

(iv). T-head engine: In T-head engines, the inlet valve located at one side and the exhaust valve on other side of the cylinder. Here two camshafts are required to operate, one for the inlet valve and other one is for the exhaust valve.[2]

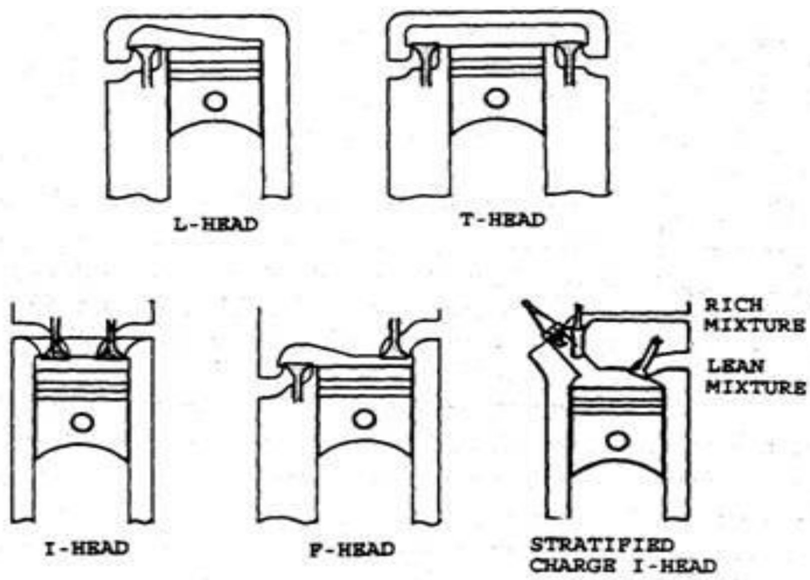


Fig 5: different types of arrangement of valve.[5]

1.1.6. Types of cooling:

(i). Air cooled engines: In these engines, the air is used to cool the engines. In air cooled engines the cylinder barrels are separated and metal fins are used which provides radiating surface area that increase cooling. The air-cooled engines are generally used in motorcycles and scooters as shown in Fig 6.

Fig 6: A cylinder from an air-cooled aviation engine (Continental C85).[6]

(ii). Water cooled engines: In water cooled engines, the water is used for the cooling of engine. Water cooled engines are used in cars, buses, trucks and other four wheeled vehicles, heavy duty motor vehicles. An anti-freezing agent is added in the water to prevent it from freezing during cold weather. Every water-cooled engine has radiator for the cooling of hot water from the engine.[2]

1.2 Constructional features of engine:

1.2.1 Fixed organs:

a) cylinder head:

A cylinder head is usually located on the top of the engine block. It serves as a housing for components such as the intake and exhaust valves, springs and lifters and the combustion chamber.

b) block engine:

It's the side walls of the cylinders. The cylinder block formed of a single piece is more resistant to the forces produced,

1.2.2 movable organs:

b) Piston:

The piston of an engine is the first part to begin movement and to transmit power to the crankshaft as a result of the pressure and energy generated by the combustion of the fuel. The piston is closed at one end and open on the other end to permit direct attachment of the connecting rod and its free action.

c)Piston Rings:

The primary function of the piston rings is to retain compression and at the same time reduce the cylinder wall and piston wall contact area to a minimum.

The other important functions of piston rings are the control of the lubricating oil, cylinder lubrication, and transmission of heat away from the piston and from the cylinder walls.

Piston rings are classed as compression rings and oil rings depending on their function and location on the piston.

Compression rings are usually plain one-piece rings and are always placed in the grooves nearest the piston head. Oil rings are located either in the lowest groove above the piston pin or in a groove near the piston skirt. [9]

e) Connecting Rod:

This is the connection between the piston and crankshaft. The end connecting the piston is known as small end and the other end is known as big end

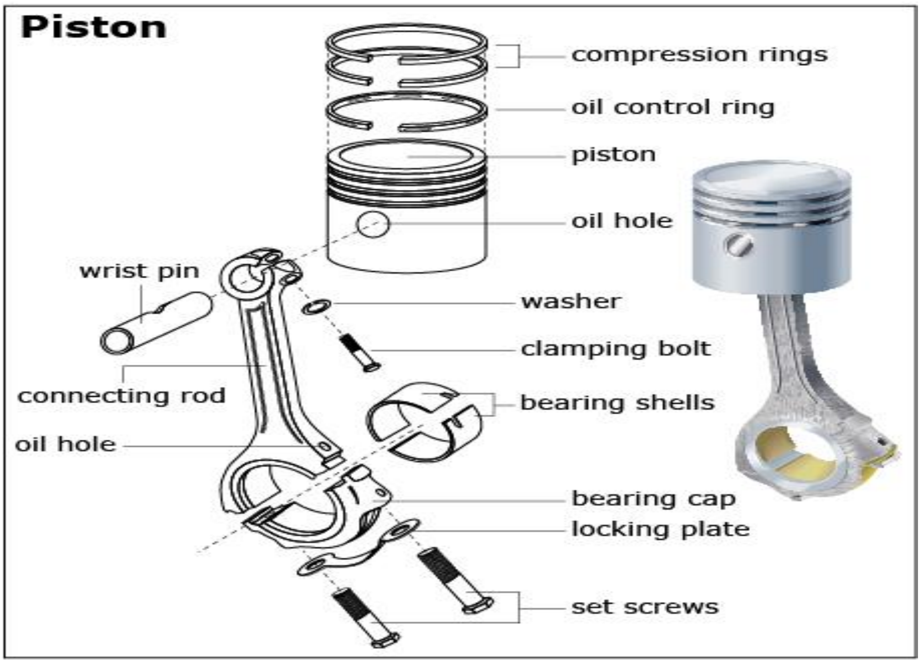


Fig7: different parts of the piston.[7]

f) Crankshaft:

This is connected to the piston through the connecting rod and converts the linear motion of the piston into the rotational motion of the flywheel.

h) Valves:

To allow the air to enter into the cylinder or the exhaust, gases to escape from the cylinder, valves are provided, known as inlet and exhaust valves. The valves are mounted either on the cylinder head.

I)Camshaft:

The valves are operated by the action of the camshaft, which has separate cams for the inlet, and exhaust valves. The cam lifts the valve against the pressure of the spring and as soon as it changes position the spring closes the valve. The cam gets drive through either the gear or sprocket and chain system from the crankshaft. It rotates at half the speed of the camshaft.

j) Flywheel

This is usually made of cast iron and its primary function is to maintain uniform engine speed by carrying the crankshaft through the intervals when it is not receiving power from a piston. The size of the flywheel varies with the number of cylinders and the type and size of the engine. It also helps in balancing rotating masses.[9]

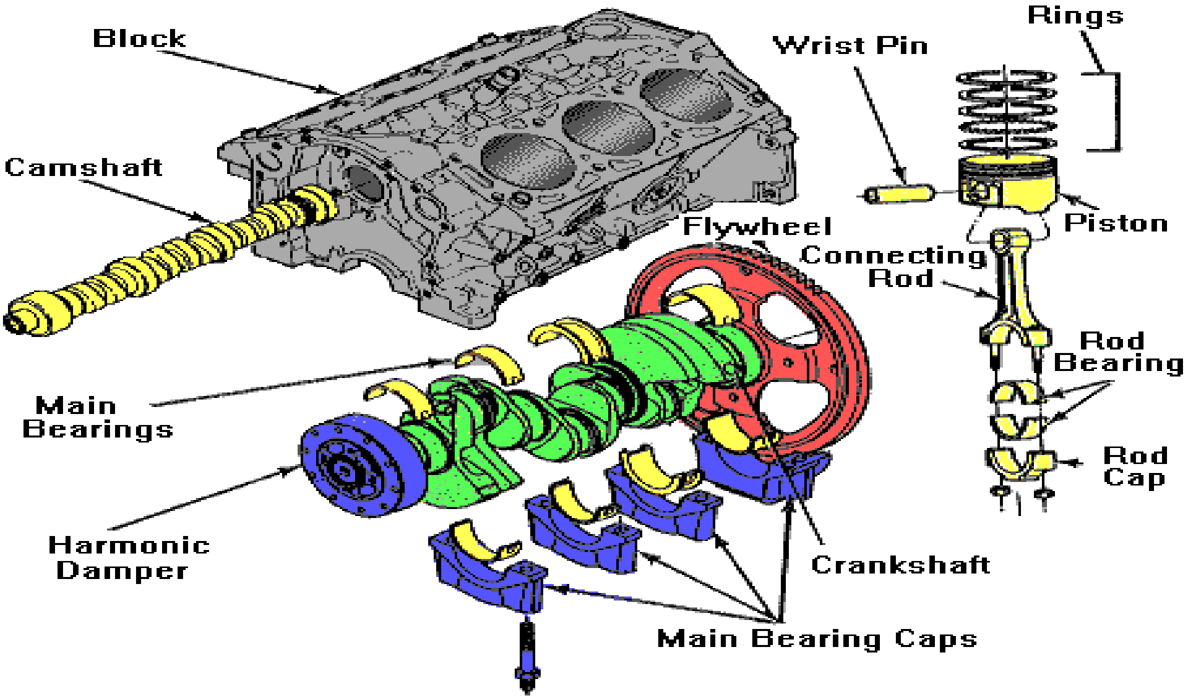


Fig 8: different part of an engine

Materials used for engine parts:

S. No.	Name of the Parts	Materials of Construction
1.	Cylinder head	Cast iron, Cast Aluminium
2.	Cylinder liner	Cast steel, Cast iron
3.	Engine block	Cast iron, Cast aluminum, Welded steel
4.	Piston	Cast iron, Aluminium alloy
5.	Piston pin	Forged steel, Casehardened steel.
6.	Connecting rod	Forged steel. Aluminium alloy.
7.	Piston rings	Cast iron, Pressed steel alloy.
8.	Connecting rod bearings	Bronze, White metal.
9.	Main bearings	White metal, Steel backed Babbitt base.
10.	Crankshaft	Forged steel, Cast steel
11.	Camshaft	Forged steel, Cast iron, cast steel,
12.	Timing gears	Cast iron, Fiber, Steel forging.
13.	Push rods	Forged steel.
14.	Engine valves	Forged steel, Steel, alloy.
15.	Valve springs	Carbon spring steel.
16.	Manifolds	Cast iron, Cast aluminium.
17.	Crankcase	Cast iron, Welded steel
18.	Flywheel	Cast iron.
19.	Studs and bolts	Carbon steel.
20.	Gaskets	Cork, Copper, Asbestos.

1.3. Different Types of Engines:

1.3.1. Gasoline Engine:

1.3.1.1. History:

The first petrol engine was built in 1876 in Germany by Nikolaus August Otto, although there had been earlier attempts by Étienne Lenoir, Siegfried Marcus, Julius Hock and George Brayton.[10]

1.3.1.2. Definition:

A **petrol engine** (known as a **gasoline engine**) is an internal combustion engine with spark-ignition(S.I. engine), designed to run on petrol (gasoline) and similar volatile fuels.
These engines are the most common ways of making motor vehicles move

Fig 9 : W16 petrol engine of the Bugatti Veyron.[12]

1.3.1.3 Working cycles:

Petrol engines may run on the four-stroke cycle or the two-stroke cycle

1) A four-stroke spark-ignition engine

The four-stroke cycle petrol engines operate on Otto (constant volume) cycle shown in Figure 10. The four different strokes are:

a)suction or intake stroke
b)compression stroke
c)expansion or power stroke

d)exhaust stroke

Each stroke consists of 180 degree rotation of crankshaft rotation and hence a four-stroke cycle is completed through 720 degree of crank rotation.

The construction and working of a four-stroke are shown in fig 2 above.

a) intake stroke :

the bottom dead centre by the crank shaft. The crank shaft is revolved either by the momentum of the flywheel or by the electric starting motor. The inlet valve remains open and the exhaust valve is closed during this stroke. The proportionate air-petrol mixture is sucked into the cylinder due to the downward movement of the piston

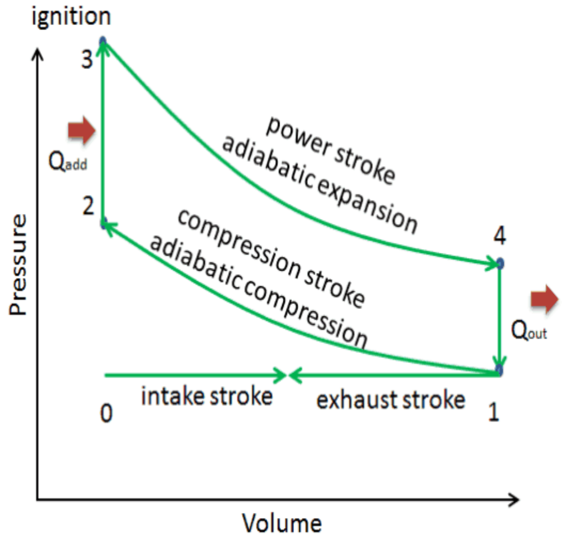


Fig10 : Theoretical Otto cycle

b) compression stroke :

During compression stroke, the piston moves from bottom dead centre to the top dead centre, thus compressing air petrol mixture. Due to compression, the pressure and temperature are increased Just before the end of this stroke the spark - plug initiates a spark, which ignites the mixture and combustion takes place at constant volume as shown by the line(2-3). Both the inlet and exhaust valves remain closed during this stroke.[9]

c) power stroke :

The expansion of hot gases exerts a pressure on the piston. Due to this pressure, the piston moves from top dead centre to bottom dead centre and thus the work is obtained in this stroke. Both the inlet and exhaust valves remain closed during this stroke.

d) exhaust stroke :

During this stroke, the inlet valve remains closed and the exhaust valve opens. The greater part of the burnt gases escapes because of their own expansion The piston moves from bottom dead centre to top dead centre and pushes the remaining gases to the atmosphere.

When the piston reaches the top dead centre the exhaust valve closes and cycle is completed

2) A two-stroke spark-ignition engine :

The principle of two-stroke cycle petrol engine is shown in Figure 3 above.

The two different strokes are:

a) Upward Stroke

b) Downward Stroke

1.3.2.4 The pros and cons of Gasoline Engine:

Gasoline pros:
-Gasoline engines are both quieter and smoother than diesel engines.
-Cost of repairs are cheaper than diesel engines due to more simple construction.
-Gasoline engines are lighter than diesel engines due not needing strong alloys and components diesel engine requires. This is important in racing where less weight is better.
-Have no problem starting in cold weather because of spark-ignition system.

Gasoline cons:
-Gasoline engines consume more fuel than similarly performing diesel engines.
-They emit up to 20 times more CO_2
-Longevity of gasoline engines are relatively short. 300,000 km (200,000 miles) is upper limit for engine failures and breakdown. However, there are always exceptions, but don't expect 400,000 km (300,000 miles) from gasoline engine.
-Although gasoline is cheaper in US, in most of the world gasoline is more expensive than diesel.
-Have limit in turbo boost, because when boost is too high, it be haves like diesel engine which is very damaging to engine itself.

1.3.2 Diesel Engine:

1.3.2.1. History:

Rudolf Diesel developed the idea for the diesel engine and obtained the German patent for it in 1892. His goal was to create an engine with high efficiency

1.3.2.2. Definition:

The diesel engine is a compression-ignition heat engine. the high compression of air in each cylinder creates enough heat for ignition. fuel is injected into the cylinder. the heat of the compressed air immediately causes combustion, Diesel engine have long been the source of power for heavy duty trucks, trains, and ships.

Fig 11: BMW four-cylinder Diesel engine.[13]

1.3.2.3 Working cycles:

1)Four Stroke Compression Ignition Engine (C.I):

The four-stroke cycle diesel engine operates on diesel cycle (constant pressure)

a) intake stroke :

During suction stroke, the piston is moved from the top dead centre to the bottom dead centre by the crankshaft.

The inlet valve remains open and the exhaust valve is closed during this stroke. The air is sucked into the cylinder due to the downward movement of the piston. The line (e-a) on the P- V diagram represents this operation.

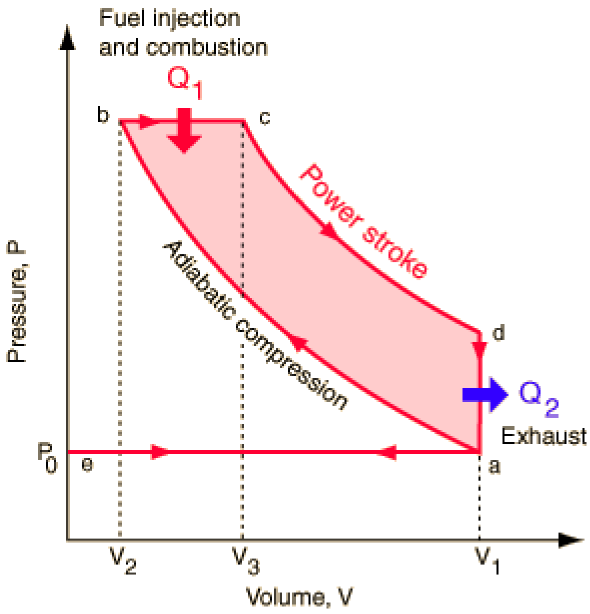


Fig 12: Diesel cycle

b) compression stroke:

The air drawn at the atmospheric pressure during suction stroke is compressed to high pressure and temperature as piston moves from the bottom dead centre to top dead centre. This operation is represented by the curve (a-b) on the P- V diagram. Just before the end of this stroke, a metered quantity of fuel is injected into the hot compressed air in the form of fine sprays by means of fuel injector. The fuel starts burning at constant pressure shown by the line (b-c). At point c

c) power stroke :

The expansion of gases due to the heat of combustion exerts a pressure on the piston. Under this impulse, the piston moves from top dead centre to the bottom dead centre and thus work is obtained in this stroke. Both the inlet and exhaust valves remain closed during this stroke. The expansion of the gas is shown by the curve (c-d).

d) exhaust stroke :

During this stroke, the inlet valve remains closed and the exhaust valve opens. The greater part of the burnt gases escapes because of their own expansion. The vertical line (d-a) represents the drop in pressure at constant volume. The piston moves from bottom dead centre to top dead centre and pushes the remaining gases to the atmosphere.

When the piston reaches the top dead centre the exhaust valve closes and the cycle is completed.[9]

2) A two-stroke Compression Ignition engine :

The principle of two-stroke cycle diesel engine is shown in Figure 3 above.

The two different strokes are:

a) Upward Stroke

b) Downward Stroke

1.3.2.4 The pros and cons of Diesel Engine:

Diesel pros:

-Greater efficiency. Up to 40% less fuel consumption than similarly performing gasoline engine. This is because of their much bigger compression ratios and due to diesel fuel having greater energy content than gasoline.
-Greater torque at low RPM's. This is very useful when towing heavy load or going uphill, makes accelerating easier. This is because of their longer strokes, which extort more leverage on crankshaft.
-More than double longevity. Diesel engines generally cover more than 600,000 km (400,000 miles) without rebuild. Of course, oil and filter changes are mandatory. This is because diesel engines are made with stronger components to withstand high compression ratios and temperatures. There are recorder diesel engines covering more than 1 million km (750,000 miles) without rebuild
-They have no high voltage electrical ignition system, resulting in high reliability and easy adaptation to damp environments.
-Diesel engines can accept super- or turbo-charging pressure without any natural limit, constrained only by the strength of engine components. This is unlike gasoline engines, which inevitably suffer detonation at higher pressure.
-Emits around 27 times less carbon monoxide than gasoline engines.

Diesel cons:

-Average new diesel car will cost around 5–15% more than same car with gasoline engines
-Are more noisy. This is because of its combustion cycle introducing high pressure fuel into highly compressed air and sudden combustion.
-Average cost for repairs cost more than repairs for gasoline engine.
-Despite lower CO2 emissions, diesel engines emit more sulphur, NX1 and particles which affect human health. Some particles are even known to cause cancer.
-Difficulty starting in cold weather

1.3.3 LPG Engines:

1.3.2.2. Definition:

Internal combustion engines running on liquid petroleum gas (LPG) are well-proven technologies and work much like gasoline-powered spark-ignition engines. When LPG (liquefied petroleum gas) is used in LPG vehicles with internal combustion engines or for stationary engines, like generators, it is called Autogas. Autogas is a varying mixture of propane and butane.

1.3.2.3 Working principle

LPG works in an engine is fundamentally the same as a petrol-powered internal combustion engine. The engine block, pistons, spark plugs, ignition system, lubrication system and electricals all work the same on LPG fuel.

Fig13: Dacia Duster Gains TCe 100 Eco-G Three-Cylinder Running On Gasoline And LPG.[11]

1.3.2.4 PERFORMANCE:

Bi-fuel LPG cars can reduce greenhouse gas (GHG) emissions by 15% as compared to petrol operation. The energy efficiency of engines running on natural gas is generally equal to that of gasoline engines, but is lower if compared with modern diesel engines. When running on LPG or NG, CO2 emissions are at least 10% or 20% lower, respectively, if compared to gasoline.

The pros and cons of LPG Engine:

LPG pros:

-Cost: The main reason for driving LPG is the cost of the fuel. Of course, very dependent on the country, but typically less than half the cost of petrol.
-LPG is the cleanest fossil fuel available

LPG cons:

-Less range: LPG has less caloric content then gasoline, . Also, the tank never gets filled to more than 80%, again reducing effective range.
-LPG being less safe, LPG is more volatile then petrol, and thus potentially more dangerous.
- LPG being less powerful. That was true with the old LPG system (G). The modern G3 system is just as powerful as petrol.
- Some cars do not handle the LPG system well, for a multitude of reasons.

2. electric motor:

2.1 History:

In 1828, the Hungarian Ányos Jedlik invented an early type of electric motor, and created a small model car powered by his new motor. Between 1832 and 1839, the Scot Robert Anderson built a crude electric-powered carriage, powered by non-rechargeable primary power cells.

During the 20th century, the main manufacturers of electric vehicles in the US were Detroit Electric and others. Unlike gasoline-powered vehicles, the electric ones were less noisy, and did not require gear changes

2.2 Definition:

An electric motor is an electrical machine that converts electrical energy into mechanical energy. Most electric motors operate through the interaction between the motor's magnetic field and electric current in a wire winding to generate force in the form of rotation of a shaft. Electric motors can be powered by direct current (DC) sources, such as from batteries, motor vehicles or rectifiers, or by alternating current (AC) sources, such as a power grid, inverters or electrical generators. An electric generator is mechanically identical to an electric motor, but operates in the reverse direction, converting mechanical energy into electrical energy.

2.3 Basic Components of Electric Motor:

1)Rotor:

In an electric motor, the moving part is the rotor, which turns the shaft to deliver the mechanical power. The rotor usually has conductors laid into it that carry currents, which interact with the magnetic field of the stator to generate the forces that turn the shaft. Alternatively, some rotors carry permanent magnets, and the stator holds the conductors

2) Bearing:

Supporting part of the rotating shaft of the rotor

3) Stator:

The stator is the stationary part of the motor's electromagnetic circuit and usually consists of either windings or permanent magnets

4) Bracket or end plate:

Bearing supporting part integral for the stator

5) Lead wire:

Wire connected to the drive circuit supplying power to the motor or wire connected to the power supply.

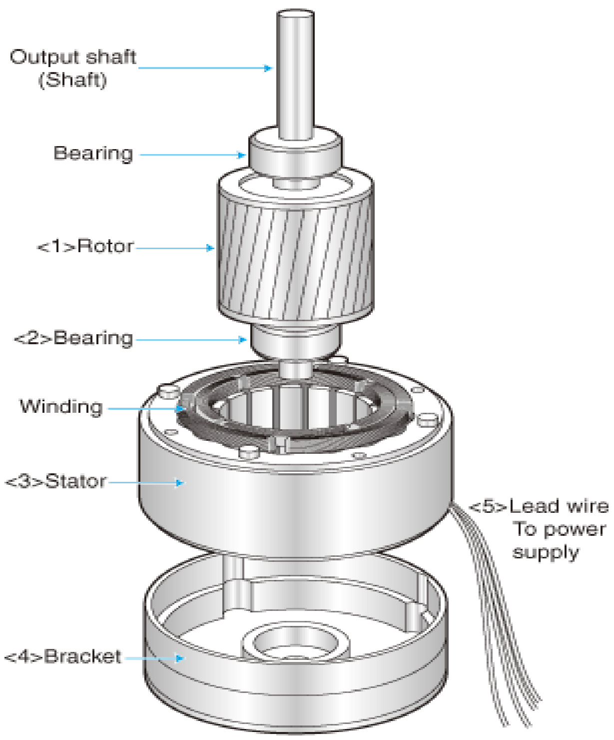


Figure 14 : Motor components. [14]

6) Windings:

Windings are wires that are laid in coils, usually wrapped around a laminated soft iron magnetic core so as to form magnetic poles when energized with current.

2.4 Types of Motors used in Electric Vehicles:

1) DC Series Motor:

High starting torque capability of the DC Series motor makes it a suitable option for traction application. It was the most widely used motor for traction application in the early 1900s. The advantages of this motor are easy speed control and it can also withstand a sudden increase in load. All these characteristics make it an ideal traction motor. The main drawback of DC series motor is high maintenance due to brushes and commutators. These motors are used in Indian railways. This motor comes under the category of DC brushed motors.[15]

2. Brushless DC Motors:

It is similar to DC motors with Permanent Magnets. It is called brushless because it does not have the commutator and brush arrangement. The commutation is done electronically in this motor because of this BLDC motors are maintenance free. BLDC motors have traction characteristics like high starting torque, high efficiency around 95-98%, etc. BLDC motors are suitable for high power density design approach. The BLDC motors are the most preferred motors for the electric vehicle application due to its traction characteristics.[15]

Fig15 :KUNRAY BLDC 650W Brushless DC

3. Permanent Magnet Synchronous Motor (PMSM):

This motor is also similar to BLDC motor which has permanent magnets on the rotor. Similar to BLDC motors these motors also have traction characteristics like high power density and high efficiency . PMSM is the best choice for high performance applications like cars, buses. Despite the high cost, PMSM is providing stiff competition to induction motors due to increased efficiency than the latter. PMSM is also costlier than BLDC motors. Most of the automotive manufacturers use PMSM motors for their hybrid and electric vehicles. For example, Toyota Prius, Chevrolet Bolt EV, Ford Focus Electric, zero motorcycles , Nissan Leaf, Hinda Accord, BMW i3, etc.[15]

Fig16: Permanent Magnet Synchronous motor of Toyota Prius 2004.[16]

4. Three Phase AC Induction Motors:

The induction motors do not have a high starting toque like DC series motors under fixed voltage and fixed frequency operation. But this characteristic can be altered by using various control techniques like FOC or v/f methods. By using these control methods, the maximum torque is made available at the starting of the motor which is suitable for traction application. Squirrel cage induction motors have a long life due to less maintenance. Induction motors can be designed up to an efficiency of 92-95%. The drawback of an induction motor is that it requires complex inverter circuit and control of the motor is difficult.[15]

5. Switched Reluctance Motors (SRM)

Switched Reluctance Motors is a category of variable reluctance motor with double saliency. Switched Reluctance motors are simple in construction and robust. The rotor of the SRM is a piece of laminated steel with no windings or permanent magnets on it. This makes the inertia of the rotor less which helps in high acceleration. The robust nature of SRM makes it suitable for the high speed application.[15]

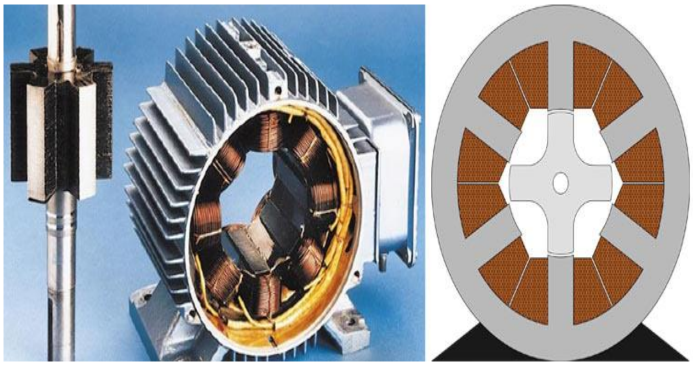


Fig 17:Switched Reluctance Motor

2.5 The pros and cons of Electric Motor in vehicles:

1)Pros Electric Motor:

-The initial cost of an electric motor is much lower than a fossil-fuel engine with the same horsepower rating.

-Electric motors have relatively few moving parts, which means they have a longer lifespan.

-electric motors require minimal maintenance service.

-electric motors are highly efficient.

- Electric motors don’t require fuel, so there is no engine oil maintenance .

-they don’t freeze in sub-zero temperatures.

2)Pros Electric Motor:

-Electric cars take longer to “refuel. Fully recharging the battery pack with a Level 1 or Level 2 charger can take up to 8 hours, and even fast charging stations take 30 minutes to charge to 80 percent capacity.

-High temperatures can shorten battery life, and very low temperatures can reduce the useful capacity of the battery.

- The battery packs within an electric car are expensive and may need to be replaced more than once over the lifetime of the car.

3. Increase Engine Performance And Power:

there are ways we can increase the horsepower, maximizing the performance and speed.

3.1 Add Cold Air Intake:

Adding cold air intake will lower the temperatures of air entering the engine and decrease restriction. Colder air is denser and produces more power. A cold air intake can boost power by up to 10 horsepower.[17]

Fig 18: Cold Air Intake

3.2 Change Exhaust System:

Changing an exhaust system can improve the efficiency of air leaving the system. The better the air leaves the better it can enter. This can increase engine performance in a way similar to how adding a cold air intake does. The principle is simple: Increasing oxygen levels allows a better burn.

3.3 Add a Turbocharger:

adding turbocharger can increase power but up to 50 horsepower. Turbochargers force air and fuel into the system faster than could occur naturally. Again, more oxygen equals better burn. Adding a turbocharger often means adding other upgrades to keep up with the boosted performance which can get expensive.[17]

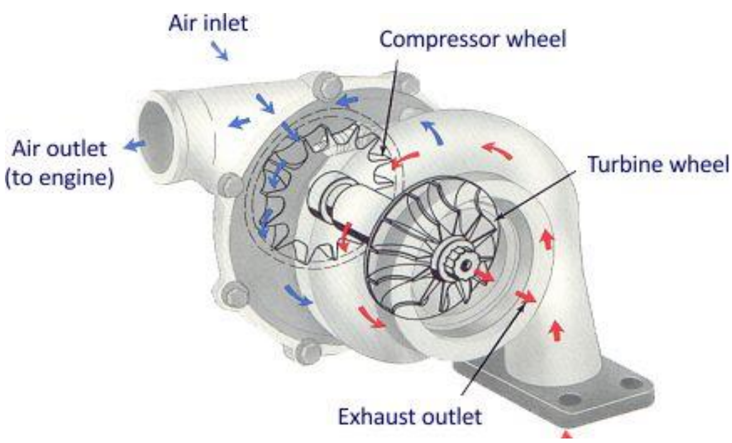


Fig19: Turbocharger Construction

3.4 Spark Plugs:

Over time, spark plugs get dirty, corrode and eventually wear out. They might still do their job, but not as efficiently as when they were new. changing spark plugs regularly until get the best possible performance from your engine

Conclusion:

In this chapter we have seen the different types of engines and the most used ones and we touched on the principle of their work and their classification.

We conclude from this:

An engine, it is a machine for converting any form of energy (chemical, electrical) into mechanical force and motion.

REFERENCE

[1] The book of: Power: Mechanics of Energy Control (ralph C.Bohn and J.Macdonald), Publisher : McKnight & McKnight Pub. Co; 1st Edition (January 1, 1970).

[2] https://www.mechanicalbooster.com/2016/08/different-types-of-engine.html

[3] https://www.pinterest.com/pin/16536723607172153/

[4]https://www.gasenginemagazine.com/gas-engines/2-stroke-cycle-zm0z19djzhur

[5] http://what-when-how.com/automobile/arrangement-of-valves-automobile/

[6] https://educalingo.com/en/dic-en/air-cooled

[7] http://resource2.rockyview.ab.ca/math203/m5/m20_3_m5_s3_sum.html

[8]http://carpartsforsalea.blogspot.com/2013/01/engine-diagram-engine-information.html

[9] https://www.coursehero.com/file/24977021/Lecture-3-Enginepdf/

[10] https://www.thoughtco.com/who-invented-the-car-4059932

[11] httpswww. Carscoops.com202001dacia-introduces-tce-100-eco-g-three-cylinder

[12]https://busy.org/@powercouple/car-engines-my-top-6-of-best-engines-in-the-world

[13] https://www.motor1.com/news/221804/bmw-four-cylinder-biturbo-diesel/

[14] httpswww. Nidec. comentechnologymotorbasic00002

[15]https://circuitdigest.com/article/different-types-of-motors-used-in-electric-vehiclesev

[16]https://circuitdigest.com/sites/default/files/inlineimages/u1/Permanent-MagnetSynchronous-Motor-of-Toyota-Prius-2004.jpg

[17] https://boostperformanceproducts.com/blogs/boost-engine-performance/increase-engineperformance-and-power

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CHAPTER 2 :

Presentation of cylinder head

1.1. Introduction:

Cylinder Head is one of the most critical components and holds complicated configuration of the entire engine assembly. The cylinder head of engine has to perform multiple functions like bringing charge air through intake ports, taking exhaust gas out from the cylinder with minimum pumping losses, maintaining coolant flow across critical points with retained thermal loads, and holding the integrity of the structure under compression and tensioning of bolts on account of varying loads. The principal dimensions and construction of cylinder head depend on intake and exhaust port layout, an actuation system, bolt pattern, fuel injector positioning, coolant flow, and more rigorously on the shape of combustion chamber. The prime job of a cylinder head is to:

1. Withstand high thermal and mechanical stresses.
2. Support actuation system for valves opening and closing.
3. Holds integrity of entire engine unit by means of bolted joints.
4. Contain injectors, spark plug, intake and exhaust ports along with valves, valve seats, and valves guiding tubes.
5. Maintain cooling of components as it contains complicated cooling passages.
6. Maintain combustion and peak firing pressure.
7. Path for fluids (oil, coolant, and delivering fuel to injectors). [1]

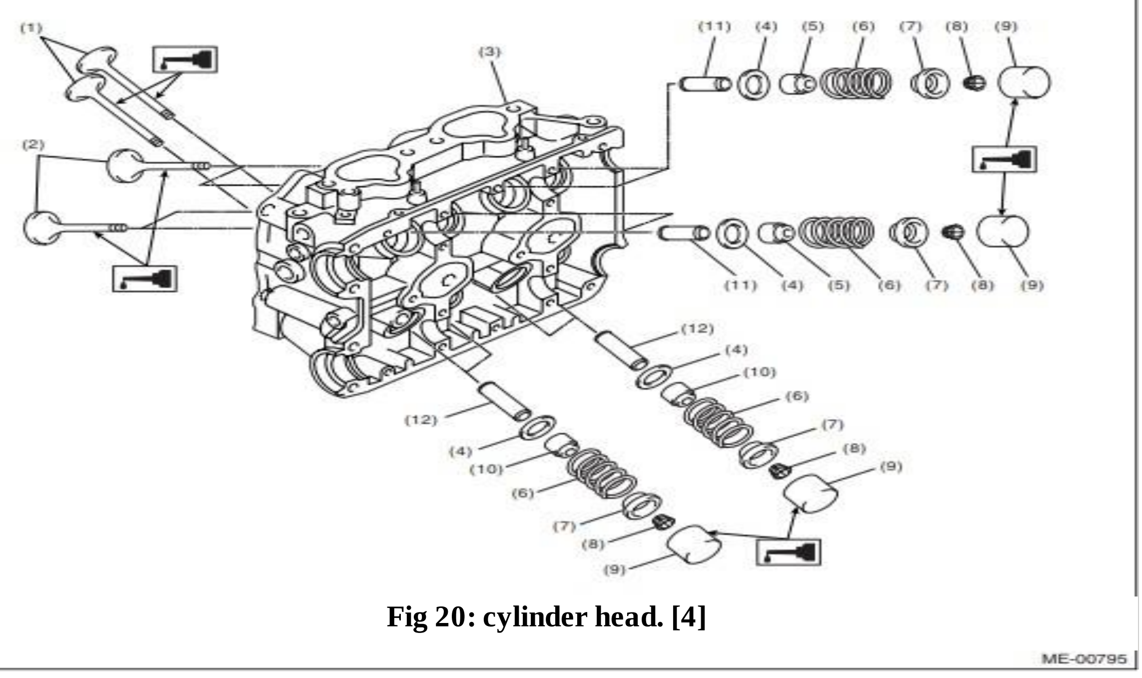


Fig 20: cylinder head. [4]

(1) Exhaust valve
(2) Intake valve
(3) Cylinder head
(4) Valve spring seat
(5) Intake valve oil seal
(6) Valve spring
(7) Retainer
(8) Retainer key
(9) Valve lifter
(10) Exhaust valve oil seal
(11) Intake valve guide
(12) Exhaust valve guide

1.2. Function of the cylinder head:

1.2.1. Principal Functions:

1.2.1.1. Cylinder head, with the intake and exhaust ducts:

- Part of the combustion chamber.
- The intake ducts, with associated ventilation, and exhaust ducts, with associated thermal.
- Injection systems (carburetor, single point injection).

1.2.1.2. Air supply system:

- The cylinder head ensures the cylinders are evenly filled with air, in desired quantity and with the desired level of turbulence.

1.2.1.3. Combustion chamber:

- The cylinder head participates in defining the shape of the combustion chamber.

1.2.1.4. Exhaust system:

- Exhaust of burnt gases.

1.2.1.5. Distribution system:

- Integration of valve control device (camshaft fixing, spring supports…).

1.2.2. Secondary functions:

A. Cooling system:

- Cooling of hot or sensitive areas (combustion chamber, exhaust pipes…).

B. Lubrication:

- Provides lubrication of moving parts (camshaft, bearing, vacuum pump or pressurizing the hydraulic play take-up elements).

C. Fluides circulation:

- Communications with the low engine.
- Integrates other circulations, for example recirculation of exhaust gases or injection Support exhaust air.

D. Support or receive other components or accessories:

- Injection pump.
- Air injection pump.
- Power steering pump.
- Shaft Balancing.
- Candle engine.
- Oil separator. [2]

1.3. Different types of cylinder head:

The cylinder head may be classified depending upon the layout of valves and ports. There are three basic types of cylinder heads:

1.3.1. Flathead Cylinder Heads (FHV):

These were the first type of cylinder heads. Flathead cylinder heads simply protect the cylinder block and have no moving parts. These cylinder heads do not allow for an efficient air flow, and thereby provide a poor engine performance. [3]

Exemple: Cadillac V8 engine 1927.

Advantages:

- **Simplicity.**
- **Robustness.**
- **Low part count.**
- **low mechanical engine noise**

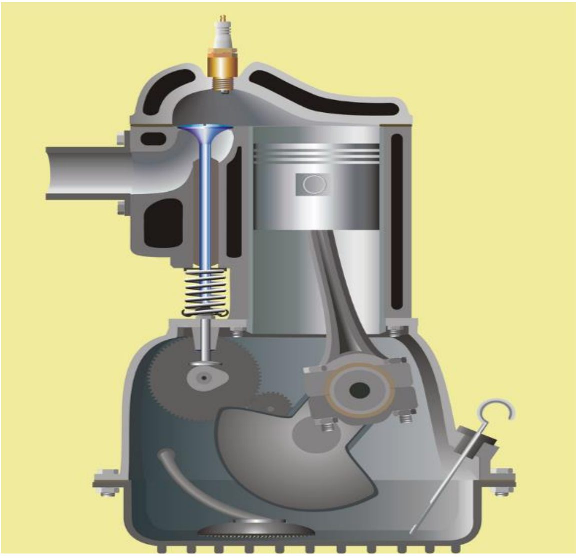


Fig *21*: flathead cylinder heads. [5]

Disadvantages:

- **Weakness gas flow and poor combustion chamber shape (engine efficiency is low).**

- **Difficult maintenance.** [9]

1.3.2. Overhead Valve Cylinder Heads (OHV):

These cylinders heads are superior to flathead cylinder heads. Overhead valve cylinder heads have the camshafts above them. These heads have their pushrods and valves connected to provide a smooth airflow. [4]

Exemple: Chevrolet Corvette Z06 engine.

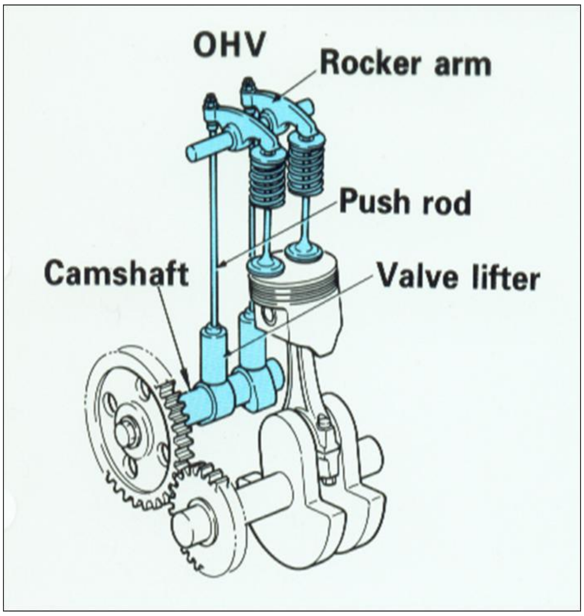


Fig *22*: over-head valve (OHV). [6]

Advantages:

- **Robustness.**
- **The lubrication requirements for OHV cylinder heads are much less and easy.**
- **Easy dismantling of the cylinder head.**
- **OHV engines have a less complex drive system for the camshaft when compared with OHC engines.**

Disadvantages:

- **Due to the position of the valves the efficiency of the engine is low.**
- **Difficult maintenance. [7]**

1.3.3. Overhead Camshaft Cylinder Heads (OHC):

These are the most advanced designs of cylinder heads. Overhead camshaft cylinder heads have the camshafts inside the cylinder head, eliminating the need of pushrods. This provides a better airflow, and in turn, increases the efficiency of the engine, and have two terms. [7]

A. Working of a Single overhead cam (SOHC):

SOHC simply stands for single overhead cam. This type of engine comes with only one camshaft located in the engine head. The cam rod is responsible for operating the intake and exhaust valves. [8] . **Exemple:** engine Renault 4.

B. WORKING OF A DUAL OVERHEAD CAMSHAFT (DOHC):

DOHC is a synonym for dual overhead cam, and this means you have two cams operating the exhaust and intake valves. The engine has one header but with two cam rods. Unlike the SOHC, the DOHC has 4 valves with each camshaft per cylinder, operating either the exhaust valves or the intake valves. The cams are often tied together by a short chain. Some cars have different valve configurations – 3 intakes and 2 exhausts. [8]

Exemple: Ford Mustang 5.2L V8 Supercharged , Mercedes-Benz Inline-6 engine.

Advantages:

- **The advantage of the OHC design is that valves are operated almost directly by the camshaft (Simplicity of valve control).**
- **It's also possible to install three or four valves per cylinder.**
- **Motor performance is strong.**

Disadvantages:

- **Expensive to manufacture (more parts).**
- **difficulté valve clearance.**
- **The lubrication requirements for OHC cylinder heads difficult. [9]**

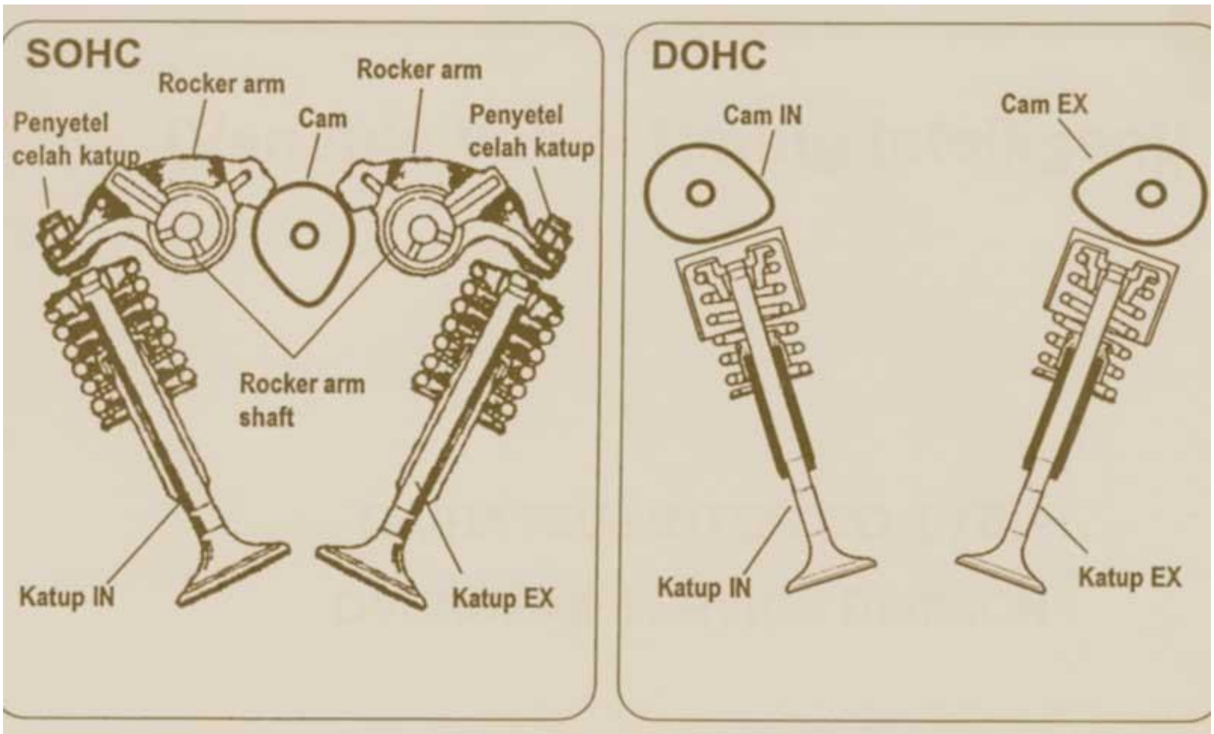


Fig 23: SOHC versus DOHC. [10]

1.4. Classification of cylinder head:

Engines are classified into four types on the basis of their shape. In every type of engine, the cylinder head and the combustion chamber are in different positions. The shape of the engine appears more or less like the letters I. l, F and T. Accordingly, engines are classified as:

I-head engine combustion chamber.

L-head engine combustion chamber.

F-head engine combustion chamber.

T-head engine combustion chamber. [3]

1.4.1.I-head engine combustion chamber:

In the I-head engine, the cylinder and the cylinder head appear roughly .The inlet and exhaust valves are placed in the cylinder head of this engine, just above the piston. Therefore this engine is called the overhead valve engine. There are two camshafts to operate these valves, as against a single camshaft present in many engines.

1.4.2. L-head engine combustion chamber:

The shape of the engine with the combustion chamber and the cylinder appears similar to the letter l. The inlet valve and the outlet valve are seated beside each other on one side of the cylinder. These valves are not placed on the cylinder head, instead they are placed in the cylinder block. A single camshaft operates these valves. The L-head engines are mainly used in buses and lorries.

1.4.3. F-head engine combustion chamber:

F-head engine is a combination of the I-head engine and the L-head engine .The inlet valve is placed in the cylinder head and the outlet valve is placed in the cylinder block near the cylinder. These valves are operated by the same camshaft.

1.4.4. T-head engine combustion chamber:

In the T-head engine, the combustion chamber is slightly elongated on both sides of- the cylinder. The shape of this engine appears similar to the letter T. The inlet valve and the ex-haust valve are placed on the two sides of the cyl-inder in this engine. An inlet camshaft operates the inlet valve, and an outlet camshaft operates the outlet valve separately. If the two camshafts are placed under the valve stems, the valves can be opened by the cams pushing directly against the valve stems. for this arrangement, push rod and rocker arms are not required. However, in some T-head engines, the two camshafts are placed above the valves.

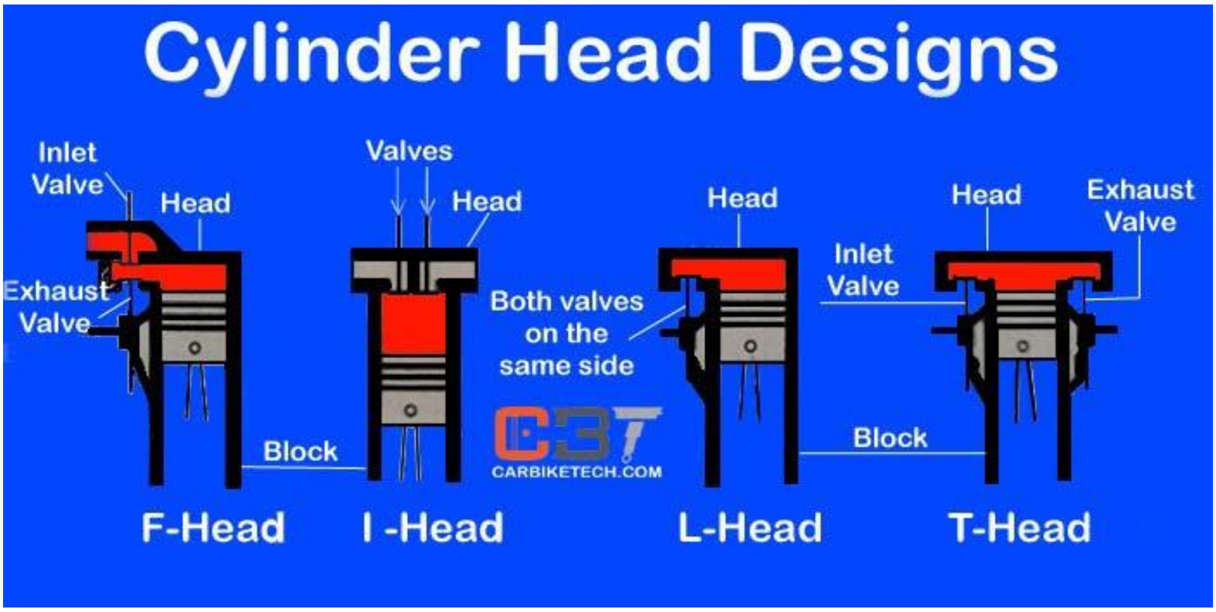


Fig 24: cylinder head classification. [11]

1.5. Design features:

The development and production of engine blocks and cylinder heads is often considered to be a core competence of the car manufacturers. With the ongoing substitution of iron by aluminium, the heads and blocks market segment has grown, but there are nevertheless only a limited number of independent competitors besides the OEMs. The reasons are the strong entry barriers that exist for potential competitors. [6]

1.5.1. Engine type:

Conventional engines with an „in-line" array of the cylinders have one cylinder head. V-engines generally need two cylinder heads, which may have identical or differing geometry. Provided that the angle between the two cylinder axis planes is not too big (<= 15°), V-engines can also be equipped with only one cylinder head. In this case, the cylinder axis is not perpendicular to the joint face.

1.5.2. Integration of valves:

The cylinder head holds the intake and exhaust valves, thus there may be many designs according to the number and positioning of the valves and the form of combustion chamber. In general, two valves are adequate for engines developing up to 35 kW/l, but above this level of power density, more valves are desirable. The increased number of valves offers distinct advantages:

- The spark plug can be more easily positioned close to the centre of the chamber, i.e. the flame path is short and complete combustion is easier to attain. Also the ignition timing can be retarded so that the dwell of the gases at high temperature in the cylinder is reduced.
- The interaction of the two incoming streams of gas can greatly improve mixing, again leading to more complete combustion.
- With two exhaust valves instead of one, the ratio of seat length to area exposed to the hot gases is higher and, therefore, the rate of cooling by conduction through the seats is also higher.

Thus, in modern cylinder heads for high performance engines, three, four or even five valves and possibly two spark plugs have to find place in the flame deck resulting in a continuously decreasing space between the valves. This area also sees the highest temperatures and is exposed to severe thermal fatigue effects when the engine warms up or cools down. In addition, pressed-in valve seat inserts - generally made from sintered powder metal - are essential for aluminium cylinder heads. Consequently, special care has to be taken to avoid local failure due to fatigue cracking. The geometry of the flame deck and the inserted valve seats as well as the surface condition and porosity of the aluminium material play a crucial

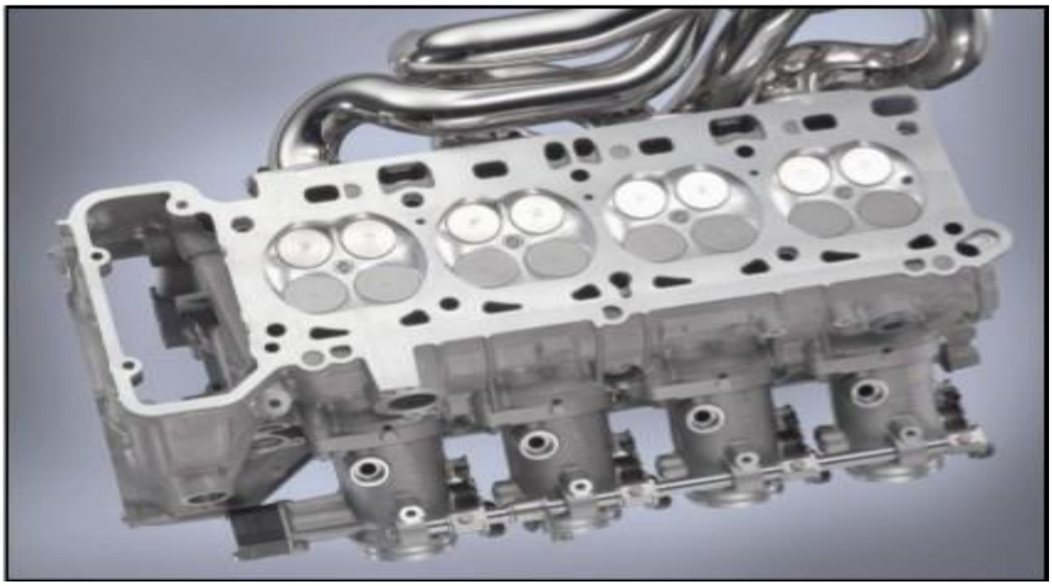


Fig 25: Cylinder head with individual throttle bodies and exhaust manifolds.

role regarding crack initiation within that area.

1.5.3. Type of engine:

Cylinder head design should help to improve the swirl or turbulence of the air fuel mixture and prevent fuel droplets to set onto the piston surface or the cylinder wall. Combustion must always take place within a turbulent flow field since turbulence increases the mixing process and enhances combustion.

The shape of the flame deck depends very much on the type of engine. Gasoline cylinder heads have bowl shaped cavities in the flame deck, whereas direct injection diesel heads usually have a flat and machined surface which is beneficial when looking at thermal fatigue crack initiation.

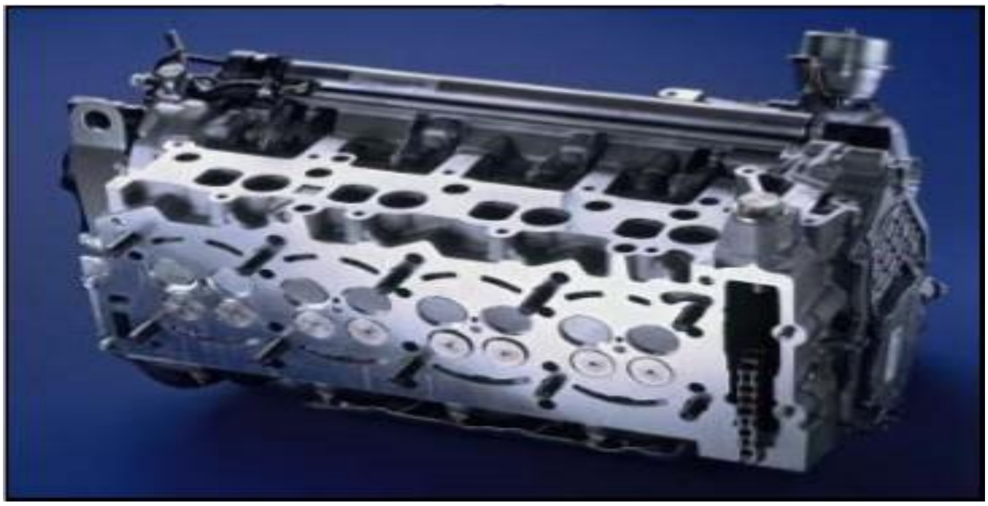


Fig 26: Cylinder head of the diesel engine of the Mercedes Benz A class.

1.5.4. Camshaft bearings:

The seats for the camshaft bearings may be incorporated into the cylinder head casting. For specially designed heads the camshaft bearings may be incorporated also as a second component produced by high pressure die casting.

In order to reduce fuel consumption, recent research activities have concentrated on variable valve actuation. The BMW Valvetronic technology, for example, replaces the conventional throttle butterfly with an electrical mechanism that controls the amount of lift of the individual intake valves on each cylinder. FEV's patented Electromechanical Variable Valve Timing System (EMVT) allows fully variable operation of the intake and exhaust valves with minimal changes to the cylinder heads of gasoline engines. As a result, the conventional camshaft is not anymore necessary for the control of the valves.

Fig 27: Cylinder head with camshafts and intake trumpets

1.5.5. New technical developments:

As a consequence of the current engine development trends, in particular the tendency to downsize the engines, the cylinder head must meet additional requirements:

- Enable further weight reduction.
- Permit increased power densities; future expected performance values are up to 65 kW/l for direct injection diesel engines and up to 75 kW/l for boosted gasoline direct injection engines.
- Allow the introduction of advanced combustion systems for both spark (SI) and compression (CI) ignition engines.

Thus the specifications for aluminium cylinder head castings are becoming more and more severe:

- Higher operating temperatures (due to the high power density).
- Increased combustion pressures, meaning higher mechanical stresses (static and dynamic) on the material that combined with thermal cycles may cause significant reduction in fatigue life of the component.
- Designs with multi-port layouts and application of advanced combustion systems, leading to very complex geometries and thin cooling water passages.

In the next generation engines, the combustion pressure is expected to rise to the 180-200 bar range for CI engines and to 100-120 bar range for boosted SI engines, while the maximum combustion chamber wall temperatures, usually found at the bridge between the exhaust valves, might rise well over 250°C and even approach 300°C.

1.6. Choice of cylinder head materials:

1.6.1. Material requirements:

As a result of the permanent increase of combustion pressures and temperatures, the potential of the common aluminium cylinder head alloys is almost fully exploited. In order to satisfy all the product requirements, optimised casting alloys and a proper control of the as-cast microstructure by the application of sophisticated casting processes are generally. [6]

a.Strength:

The applied aluminium alloys have to offer sufficient strength and hardness at room temperature for machining and assembly. Furthermore, high strength at elevated temperatures (up to 250°C) is crucial to ensure that the engine block-cylinder head assembly can withstand the combustion forces and the forces resulting from thermal expansion and contraction during service cycles without losing tightness of the cylinder head gasket. Creep strength is required in particular for the head gasket area.

b.Thermal conductivity:

The cylinder head can support the high combustion temperatures only due to an efficient cooling. A decisive characteristic for the cylinder head material is therefore a high thermal conductivity. On the other hand, any addition of alloying elements to aluminium for the purpose of increasing strength or creep resistance results in a decrease of the thermal conductivity. Hence, a compromise between the two counteracting targets has to be found.

c.Surface quality:

An unimpeded flow of the incoming gas is of major importance for the combustion process. Thus, high demands are made on the smoothness of the surface of inlet and outlet channels. The roughness of the flame deck surface should be minimized as well, because any notches can lead to the initiation of fatigue cracks.

D.High and low cycle fatigue:

Cylinder heads are exposed to high-cycle fatigue (HCF) due to the combustion cycles and to low-cycle fatigue (LCF) resulting from thermal expansion and contraction during start-up and stop of the engine. Critical HCF areas are on the water jacket side of the flame deck wall because of the prevailing cyclic tensile stresses, while LCF may primarily cause cracks in the thin-walled valve bridge areas which are at the same time exposed to the highest temperatures within the cylinder head.

LCF strength is partly related to the static strength at high temperatures which in turn is strongly influenced by the alloy composition. However, HCF strength can only be slightly influenced by the alloy composition. In this case, the cast microstructure, the presence of casting defects (in particular porosity) and the surface quality are the dominating parameters. The application of an alloy with defined ductility seems to be advantageous since some studies indicate that better low cycle fatigue behaviour is related to a higher ductility when small material plastifications are allowed.

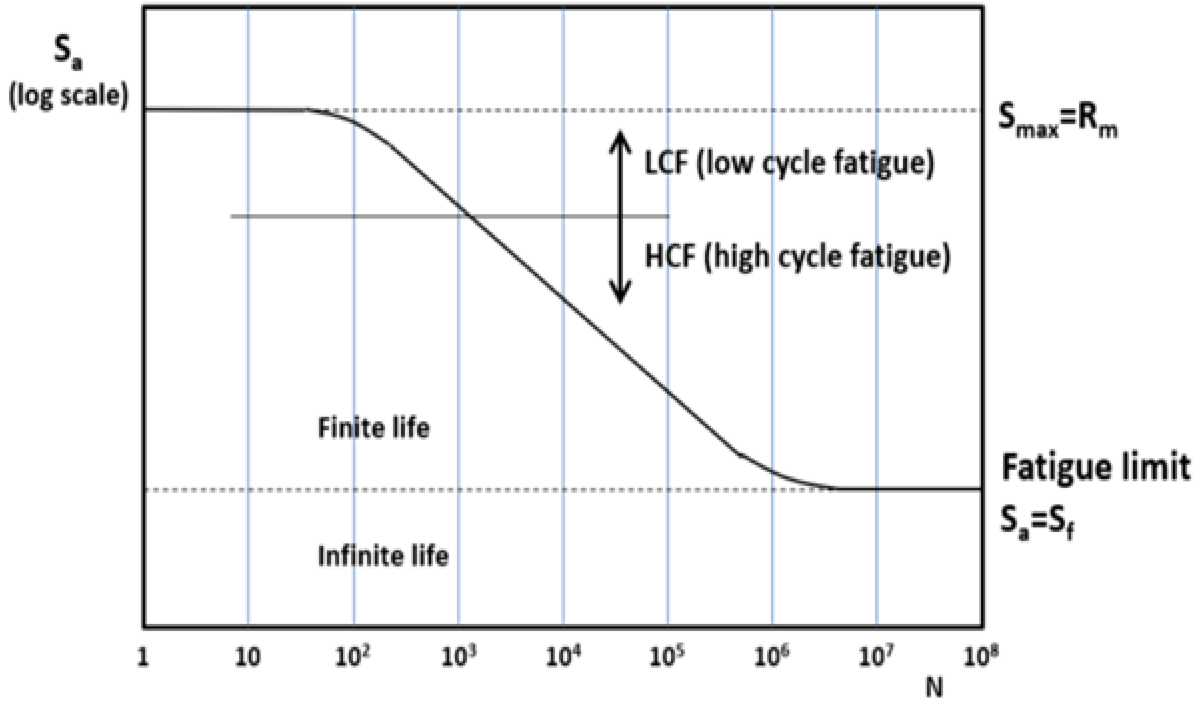


Fig 28: The difference between low cycle fatigue (LCF) and high cycle fatigue (HCF). [3]

f.Castability:

The castability of an alloy is generally improved with increased Si content, while Cu additions, which are required for high temperature strength, have a negative effect on the feeding behaviour. Insufficient feeding could lead to defects in the as-cast structure, in particular porosity. The presence of such defects would be critical in those regions of the cylinder head which are exposed to high cycle fatigue, i.e. the area between the valves in the flame deck or the walls between the flame deck and the water jacket

1.6.2. Alloy composition and heat treatment:

The alloy selection for cylinder head castings requires the consideration of various criteria, some of them similar to those used in case of engine blocks. Many cylinder head castings undergo a heat treatment with a subsequent aging. In this case, potential aging effects during operation of the engine over a long period have to be considered too.

The best combinations of strength and ductility are offered by casting alloys with low iron content such as AlSi7Mg0.3 (A356). Therefore, in the past, most cylinder heads were made from primary aluminium alloys. But also alloys which can be produced using recycled aluminium (i.e. with a slightly increased impurity content) such as AlSi10Mg or AlSi7Mg still provide sufficient ductility. Due to the poor high temperature performance of this type of alloys, new Cu- or Ni-containing alloys have been developed specifically for high performance diesel cylinder heads (e.g. AlSi7MgCu0.5, AlSi9Cu1Mg and AlSi7MgCuFeNi). They provide higher strength at elevated temperatures while maintaining ductility and fatigue performance. Cylinder heads produced with these alloys are usually applied in the T6 condition.

For moderately loaded cylinder heads of gasoline engines, also foundry alloys like AlSi8Cu3 or AlSi6Cu4 (similar to A380.2 and A319, respectively) can be considered. They are widely used for cylinder heads produced in the gravity casting processes. The T4 and T5 conditions are favoured whereas the as-cast (F) condition may cause problems due to insufficient dimensional stability and hardness, the latter being most important for ease of machining.

Properties	Value	Unit
Density	2770	Kg m^-3
Coefficient of Thermal Expansion	2.3E-05	C^-1
Young's Modulus	7.1E+10	Pa
Poisson's Ratio	0.33	
Bulk Modulus	6.9608E+10	Pa
Tensile Yield strength	2.8E+08	Pa
Compressive Yield strength	2.8E+08	Pa
Tensile Ultimate strength	3.1E+08	Pa

Table 2: represents properties of aluminum alloy. [3]

In practice, the applied alloy composition is optimized depending on the specific cylinder head design and casting conditions. It is important to find a compromise between high temperature strength, ductility and fatigue performance while maintaining reasonable material cost by tolerating certain levels of impurities.

The performance requirements of highly loaded cylinder heads have pushed the suppliers of aluminium castings to develop new process solutions with the aim of increasing the quality of the cast components, minimizing the number of casting defects (porosity, inclusions etc.) and improving the microstructure of the material (dendritic arm spacing). Nevertheless, the current engine development trends leading to higher operating temperatures and increased combustion pressures ask for new alloy developments. Although the performance of the standard Al-Si casting alloys could be significantly improved by the addition of Cu (and other alloying elements) to obtain better resistance at high temperatures (up to 250°C), these improvements might not be enough to meet future engine performance targets. The application of alternative aluminium alloy systems with better high temperature properties (e.g. Al-Cu alloys) will have to be considered, although their applicability is limited by their poor castability which makes it difficult to manufacture complex castings, like cylinder heads, at high production rates. [6]

1.6.3. Applicable casting processes:

Different casting processes using sand moulds or, preferentially, metal dies are applied for the production of aluminium cylinder heads, each offering advantages and disadvantages. The channels for the combustion gas, the coolant and the lubricating oil are cast hollow using sand cores installed in the holder mould. For this reason, the high-pressure die casting cannot be used because the sand cores are fragile and would not endure the high injection pressure of molten aluminium.

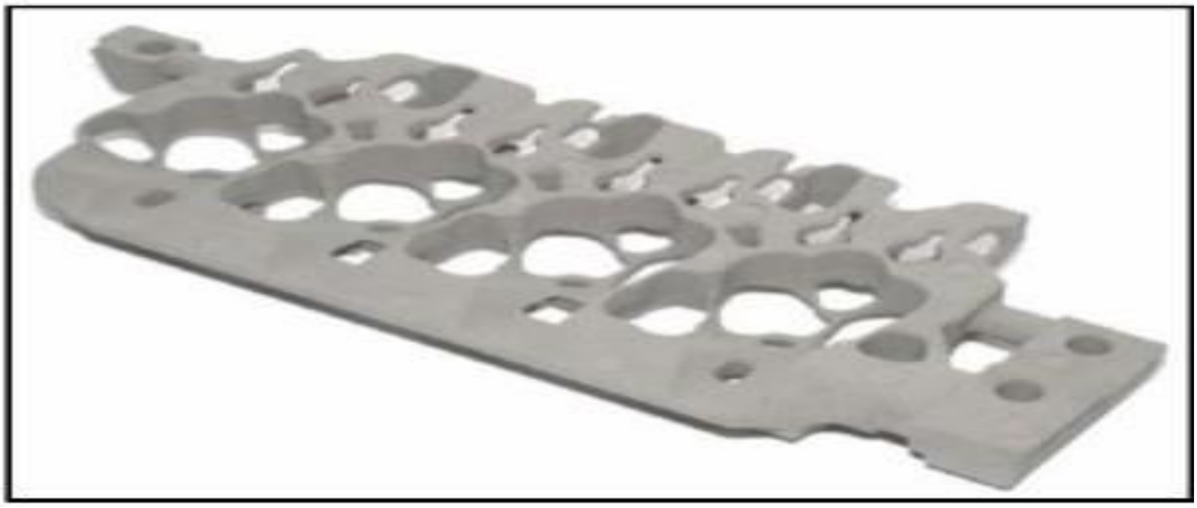


Fig29: casting processes using sand moulds. [12]

Gravity die casting is worldwide the traditional casting process for cylinder heads. Depending on the position of the casting in the mould, the process enables to achieve a high solidification rate in the flame deck region resulting in a fine microstructure with low porosity, and hence good mechanical properties. With the application of sand cores, a very sophisticated cooling water-jacket with a complex geometry of can be realised. in the flame deck area and at the same time a higher productivity due to a smaller volume of feeders and runners.

fig30: Isuzu diesel 4-cylinder head produced with the Rotacast process, alloy EN-AC- AlSi7Mg / T6 temper. [13]

Low pressure die casting provides similar benefits as the conventional gravity die casting process. Additionally there is nearly no process scrap (feeder, etc.). However, due to the fact that the machinery is blocked during the entire solidification time, the total cycle time is relatively high, which in turn decreases productivity.
The lost foam casting process is predestined for castings with very complicated and complex geometries which is in fact the case for water jackets in cylinder heads. But apart from the need of perfect mastering of the process, the safe avoidance of porosity in important areas (e.g. flame deck) can be a problem, because the implementation of local cooling in the lost foam process is difficult.

1.6.4. Future developments:

Application-specific optimizations of aluminium alloys and casting processes, including an improved control of the local solidification conditions, are ongoing and will enable continuous improvements of the performance characteristics of the cylinder head.
Another approach looks for an improvement of the quality of the casting by the subsequent elimination of defects. Hot isostatic Pressing (HIP) is a well known method that employs high pressure and high temperature to "heal" porosity and other casting defects. In the conventional HIP process the pressurizing medium is typically a gas and the process is carried out at elevated temperatures for specific time periods (normally several hours per cycle). Another possibility is Liquid Hot isostatic Pressing (LHIP) where the medium used to apply the isostatic pressure is a liquid (molten salt bath).
A further idea is to split the cylinder head into two parts, each one made by using the best combination of material and manufacturing process. The lower part of the cylinder head facing the combustion chambers could preferably be realized with a high temperatures resistant alloy. Without the necessity to use sand core, a high performance alloy such as AlCu4TiMg, which is not easily castable in complex forms, could be used. For the upper part of the head, it is then possible to use an aluminium alloy with excellent castability. In comparison to a traditional single casting, it would also be possible to simplify and strengthen the sand core that make the passages in the upper part of the head and to draw passages for the cooling fluid that optimizes the cooling in the critical zones (for instance between the valves).
Considering the many advantages offered by aluminium in cylinder head applications, a substitution of aluminium by other materials is not likely for the moment. [2]

2. Cylinder head parts and service:

2.1. Head disassembly:

Heads are easier to work on if they are clean. After hot-tanked heads have cooled, be sure to rinse them thoroughly with water. Following cleaning, lubricate all machined surfaces immediately to prevent rust. Be especially certain to lubricate valve springs that have been hot-tanked. Springs can lose their protective coating during hot-tanking and will rust quickly. Rusted springs should be discarded because rust creates stress raisers and changes spring tension.

Some OHC camshafts act directly on the valve, whereas others use rocker arms. Before removing the valve and spring from some OHC heads, it is necessary to remove the rocker arms. Pry against the spring retainer and remove the rocker arm as shown in (Figure 31). Then the camshaft can be removed.

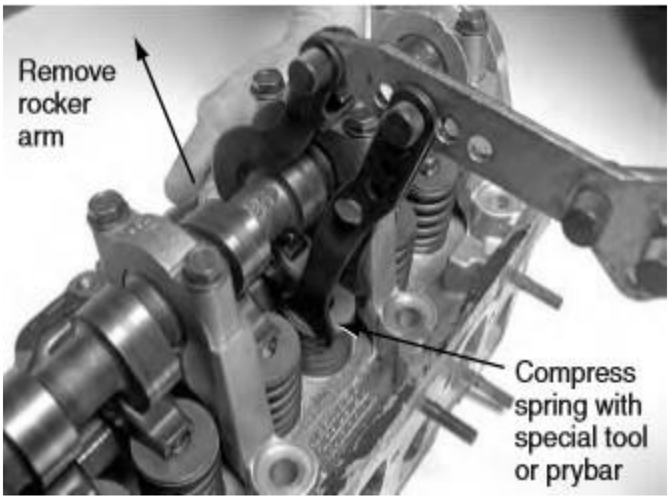


Fig 31: Remove OHC rocker arms before disassembling the valve and spring.

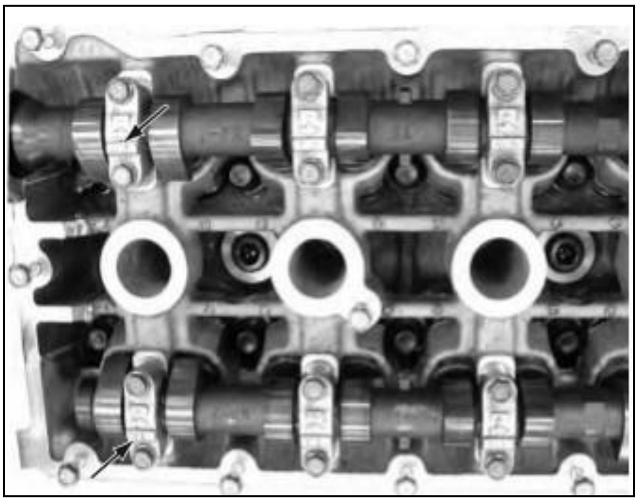


Fig33:Strike the retainer with a piece of pipe,

Verify that camshaft caps are correctly numbered before removing them (Figure 32). On DOHC heads, number the exhaust caps E-1, E-2, and so on, and number the intake caps I-1, I-2, and so on.

Valve retainers are sometimes stuck to the valve locks (keepers) by varnish buildup. Before using a spring compressor, strike each spring retainer with a rubber dead-blow hammer and a short length of pipe, an old piston pin, or a special tool (Figure 33). If this is not done, the jaws of the spring compressor can be bent or broken. [1]

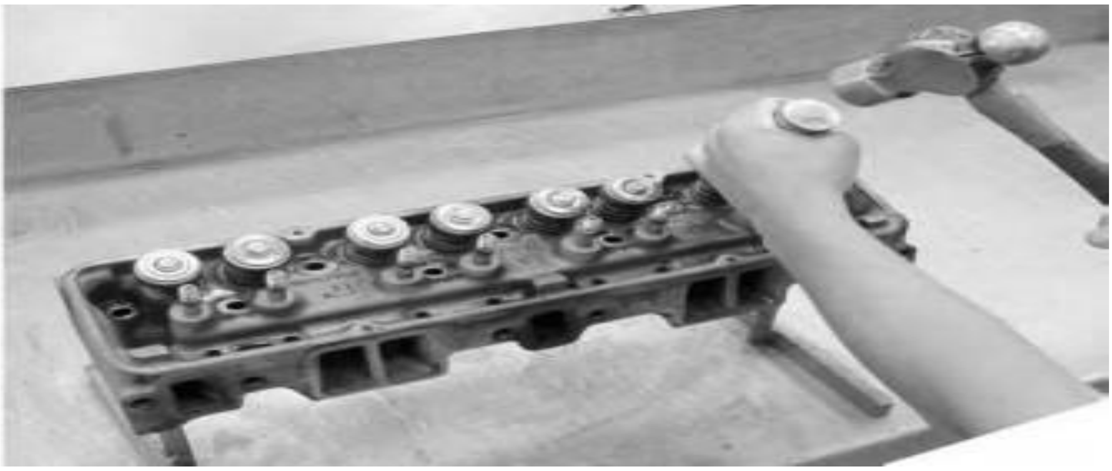


Fig32: Verify that the cam caps are correctly numbered before removing them

2.1.1. Spring Removal Tools:

One of the oldest types is the manually operated spring compressor (Figure 34). Its jaws are adjusted to fit the spring retainer. Also, adjust the compressor travel so that the spring will be compressed just enough to allow the keepers to be removed. There are also spring compressors that are air operated (Figure 35). Be careful not to accidentally pinch your fingers when using this tool. [1]

Fig 34: Valve spring compressors. A common type of valve spring compressor in use.

Fig 35: An air-operated spring compressor.

2.2. Crack inspection:

Cracks are sometimes found in combustion chambers, between combustion chambers, and also, rarely, on the valve spring side of the head (Figure 36). There are a number of ways to detect cracks. Sometimes after the head has been cleaned, cracks will be apparent to the eye. Glass bead blasting can be especially helpful in highlighting cracks. [1]

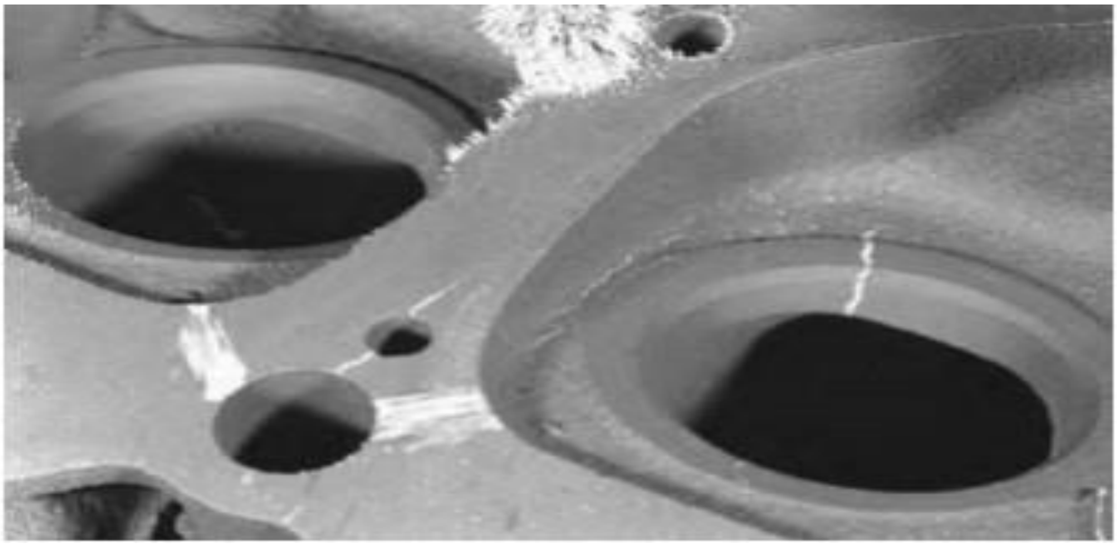


Fig 36: Examples of cracks in a cylinder head

2.2.1. Magnetic Crack Inspection:

Crack inspection on iron heads can be performed using a simple magnetic crack detector, which is shown in (Figure 37).

- The electromagnet is turned on, which sets up a magnetic field.
- The head is dusted with iron powder and the powder lines up with the magnetic lines of force. A crack interrupts these lines of force, causing the powder to gather around the crack.
- The magnetic field must be broken for the test to work. Magnetic crack detection works best when the crack runs between the poles of the magnet. If the crack is parallel to the magnetic poles, the crack might not show up. Turn the magnet 90° after the first test; the lines of force will move, possibly revealing a crack that did not previously show up.
- Put chalk on the crack so you can find it after the magnetic powder has been removed.
- Magnetic powder is available in different colors.

- Be sure to check the top side of the head for cracks, too. [2]

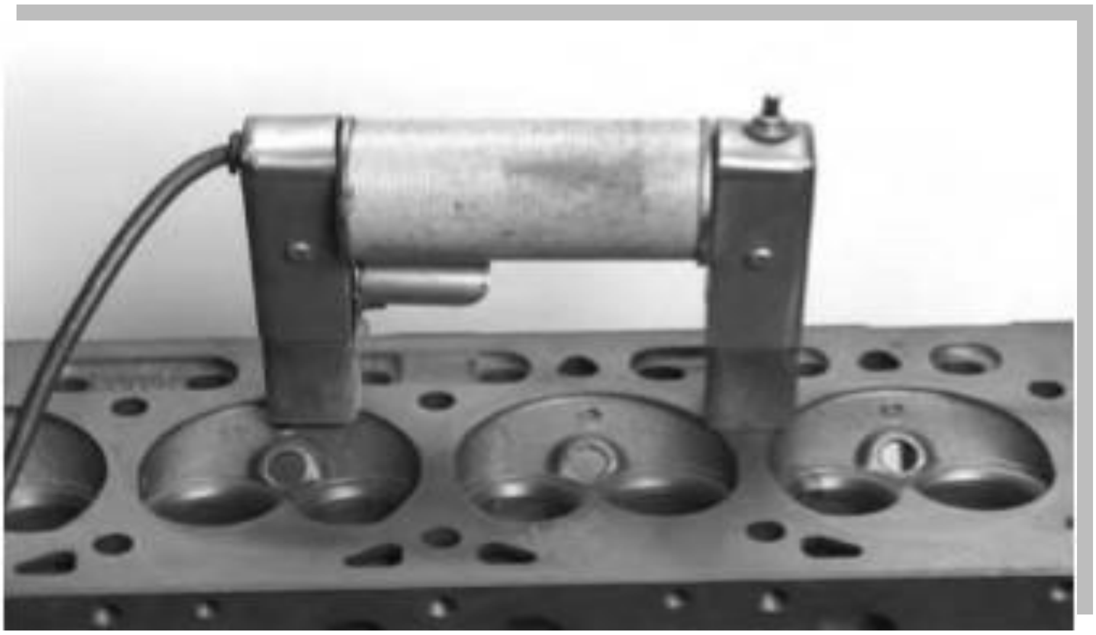


Fig 37: A magnetic crack detector.

2.2.2. Dye Penetrant:

Dye penetrant can be used to detect cracks in any metal (Figure 38). It is usually used on aluminum castings but not on iron because of its expense compared to magnetic detection. It is important that all grease and carbon be removed from the head prior to crack checking with penetrant because carbon can hide a crack.

- First, spray the surface with cleaner and allow it to dry (Figure 38a).
- Next, spray a red dye onto the cleaned surface. Allow the dye to soak in for 5–30 minutes.
- Then wipe the excess dye from the surface (Figure 38b). A shop towel moistened with the cleaning solution works well, but do not soak the surface with cleaner.
- Finally, spray a light coating of the white developer to make cracks visible to the eye (Figure 38b). Cracks show up as red or pink lines on a white background.

A black light crack detector works in a similar fashion. Shine the black light on the surface after spraying a special solution on the head. [2]

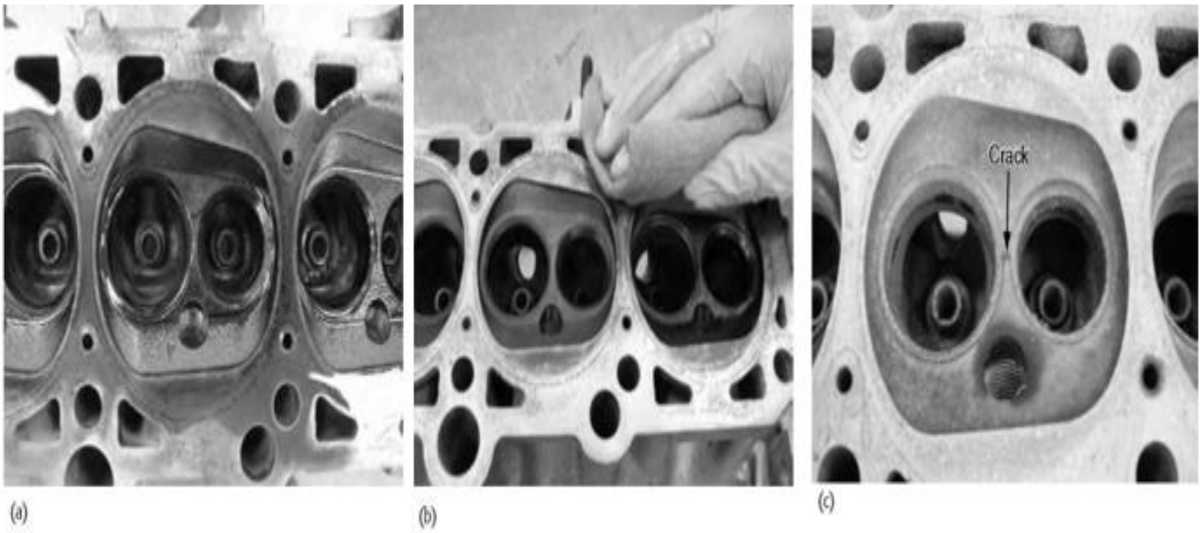


Fig 38: Checking for cracks with a dye penetrant. (a) Spray on penetrant. (b) After 5 minutes, clean the surface. (c) Spray on developer to highlight the crack.

2.2.3. Pressure Testing:

Another popular way of testing for cracks is pressure testing, which is very effective. All openings in the head are plugged before filling it with water or air. The head is outfitted with a custom-fitted pressure tester (Figure 39) or a universal pressure tester, which is more time consuming.

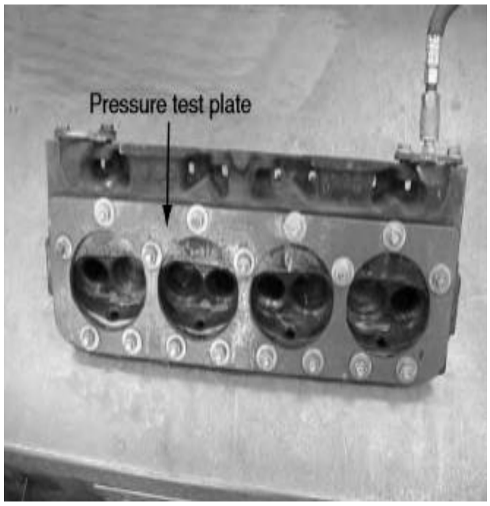


Fig 39: A custom-fitted pressure test plate installed on a cylinder head.

Heated water can be used to simulate actual running conditions. Some heads require cylinder head and/or cam bolt torque as well as heated water before they reveal a leak.

If air is used, soapy water is sprayed over the head surface, or the head is submerged in water to check for air bubbles. A very small percentage of aluminum heads have porosity problems from the casting process and are vacuum-impregnated with resin to seal them during manufacturing. This process is also done in castings of brake master cylinders, power steering pumps, and automatic transmissions. Excessive temperatures in heat cleaning can cause leaks in vacuum-impregnated heads, which can be found during pressure testing. [1]

2.3. Crack repair:

Cracks are sometimes repairable, but the repair is only practical if the cost of a bare head is more than twice the cost of the crack repair. If there is any question whatsoever as to the effectiveness of a crack repair, it is not worth taking a chance. A new or used head should be obtained. Also, factory aluminum heads are heat treated. The heat treatment is lost during welding. [3]

2.3.1. Tapered Plugs:

Cracks in iron heads can be repaired with tapered, threaded plugs. This process is known in the industry as pinning a crack or stitching a crack. The plugs are usually made of iron, but sometimes brass plugs are used.

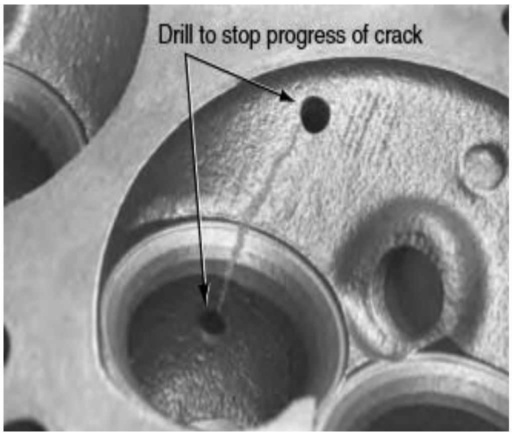


Fig 40: Pinning a crack. Drill both ends of the crack.

Fig 41: Install the pins one at a time and then cut them off.

Fig 42: Grind and clean the chamber.

- After drilling, recheck with a crack detector to be sure that the ends of the crack have been found. If both ends of the crack cannot be seen, scrap the head.
- Drill holes along the crack.
- Ream the holes with a tapered reamer and then tap them with a tapered tap.
- Dip the plugs in a ceramic sealer before installing them.
- Install and cut one plug, and then drill the overlapping hole for the next one. Each plug overlaps about one-third of the next plug all along the crack. Start at the lowest point and work your way up the crack.
- Install the plugs at different angles so that they will interlock above and below the surface. For illustration purposes, the plugs in (Figure 41) were not cut off as each one was installed.
- Cut the plugs with a jab saw to about one quarter of their diameter.

- Then peen the plugs with an air chisel.
- Last, grind and finish the surface (Figure 42).

Cracks between the seats are difficult to repair. Manufacturers often state that these kinds of cracks are acceptable, provided they do not leak coolant. [3]

2.4. RESURFACING HEADS:

Heads that are excessively warped must be surfaced to ensure proper head gasket sealing.

2.4.1. Checking Flatness:

Clean the head surface before checking for flatness. Use a straightedge and feeler gauge (Figure 43a) diagonally, vertically, and horizontally on the head (Figure 43b). When checking for warp on the ends of a head, be sure to rock the straightedge to the opposite side of the head. If you do not do this, you will only get half of the warp reading. A round straight bar is also available for checking straightness (Figure 44a). The round bar is more suited for checking the alignment of bearing bores (Figure 44b). [3]

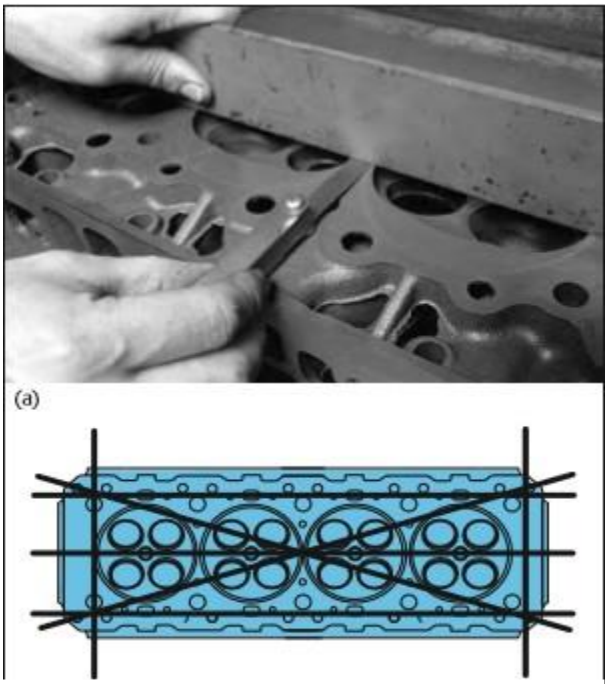


Fig 43: Check for excessive warpage. (a) Use a feeler gauge and straightedge. (b) Check diagonally, vertically and horizontally.

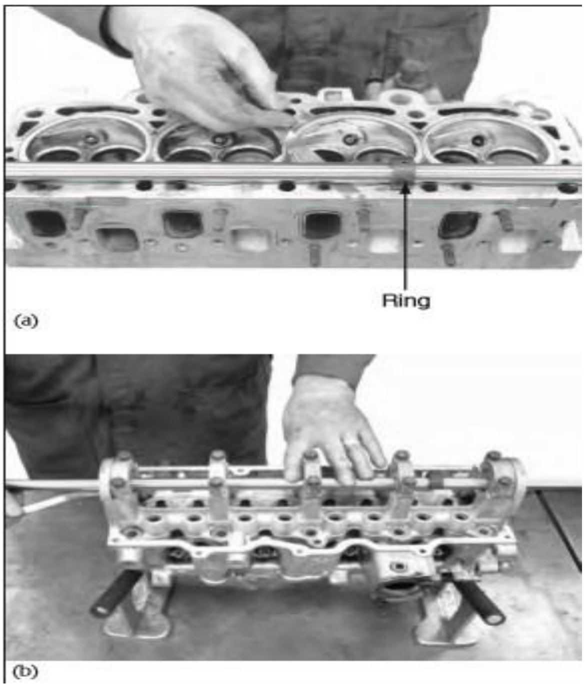


Fig II 44: (a) A round bar for checking flatness. The ring has a machined flat surface to prevent the bar from rolling. (b) Using a round bar to check cam bore misalignment.

2.4.2. Cast Iron Heads Warpage:

When checking cast iron heads, as a general rule:

- Heads warped more than 0.006" on in-line sixes, and more than 0.004" on four or eight cylinders, need to be resurfaced.
- Heads should not be warped more than 0.002" in any 6" length or 0.0015" within a 3" diameter.
- Flatness across the width of a head should not vary by more than 0.002".
- When checking head flatness on a four cylinder, try to fit a 0.004" feeler gauge under the straightedge. If it fits, but a 0.005" does not, then it is okay. Also, aluminum heads with corrosion around water passages must be resurfaced. Some may require welding first if more than 0.010" material removal is anticipated. [3]

2.4.3. Aluminum Head Warpage:

Aluminum heads can have no more than 0.002" of warp in any direction.

2.4.4. Resurfacing by Grinding or Cutting:

Resurfacing is accomplished either by "fly cutting" the head on a milling machine or grinding the head on a head grinder. Factory broach marks usually run from end to end on the head. A
head may have been surfaced previously. Heads that have been milled or ground in a machine shop will have a circular (Figure 45) or crosshatch surface pattern.

Head resurfacing can increase compression, so remove as little metal as possible.

Fig 45: A circular pattern left on the head during machining.

- Grinding is slower than cutting because more passes must be made with the grinding wheel.
- Grinding is better than cutting for removing hard spots in the metal.
- When cutting a head surface with a multiple cutter head, the carbide cutters must be within ±0.0005" of each other (one-half of one- thousandth of an inch). If one cutter

is adjusted improperly and is higher than the others by only 0.001", it will be doing all the work and a rough cut will be the result.

- If a head was milled or ground, check the head after resurfacing for twist that might have occurred when clamping the head in the surfacer.

Many surfacers use water for coolant. Watersoluble oil is added to the water. This keeps rust from accumulating and also acts as a lubricant when surfacing aluminum heads. Kerosene or a spray lube can also be applied to aluminum heads before surfacing.
Aluminum is not all the same and it can machine differently, depending on the manufacturer and country of origin. To do a satisfactory job, carbide cutters must be sharper for aluminum than for cast iron. Overheating can harden aluminum. [14]

2.4.5. After Machining:

When a head is resurfaced, some shops stamp the amount of metal removed on a head boss with a number stamp to alert the next machinist who works on it. When measuring head thickness, measure at all four corners if possible. Deburr any sharp edges left on the combustion chamber by machining. Sharp edges can cause preignition. Holes in the head for the head bolts can be deburred with a tapered reamer. [14]

CONCLUSION:

In this chapter, we explained the cylinder head and its functions. We seen the different types of cylinder heads and their classifications, and we discussed their materials, properties, and how to disassemble and repair them. And from this we conclude, the cylinder head An important part of the engine.

REFERENCES

[1] the book of: Automotive Engines: Diagnosis, Repair, Rebuilding [Tim Gilles], Publisher: Cengage Learning; 006 Edition (February 1, 2010).

[2] the book of: How to Port and Flow Test Cylinder Heads (David Vizard), Publisher : CarTech; Illustrated Edition (February 23, 2012).

[3 the book of: A TEXTBOOK OF AUTOMOBILE ENGINEERING (R K RAJPUT) Publisher : Laxmi Publications Pvt Ltd; Second Edition (June 30, 2007).

[4] http://www.ac-6.co.uk/cylinder_head_assembly.htm.

[5]https://aaltodoc.aalto.fi/bitstream/handle/123456789/28972/master_Hassan_Ghulam_2017.pdf?sequence=1&isAllowed=y.

[6] https://www.buyautoparts.com/howto/what_is_a_cylinder_head.htm.

[7] https://www.samarins.com/glossary/dohc.html.

[8] https://mechanicbase.com/engine/dohc-vs-sohc/.

[9] https://themonarchwriters.wordpress.com/2018/12/20/overhead-valve-engines-theiradvantages-and-disadvantages/.

[10]https://www.answers.com/Q/What_are_the_advatages_and_disadvantages_of_overheadcamshaft.

[11] https://carbiketech.com/cylinder-head-what-are-its-types-classification/.

[12] https://en.wikipedia.org/wiki/Flathead_engine.

[13] https://www.tvsmotor.com/blog/sohc-vs-dohc-differences-explained/.

[14] https://www.autobutler.co.uk/wiki/cylinder-head-functions-repairs.

Chapter 3:

MODELING AND SIMULATION OF A cylinder head

1.Introdiction:

This chapter presents the modeling and simulation part of our dissertation

This is the most important part of our work. So, we start with the sizing and design of the cylinder head using the Solid works software, then we will start the numerical simulation part by (Workbench ANSYS 16.2), where we will make the fine mesh with the application of conditions thermal and mechanical limits on our cylinder head.

2. The design of the cylinder head:

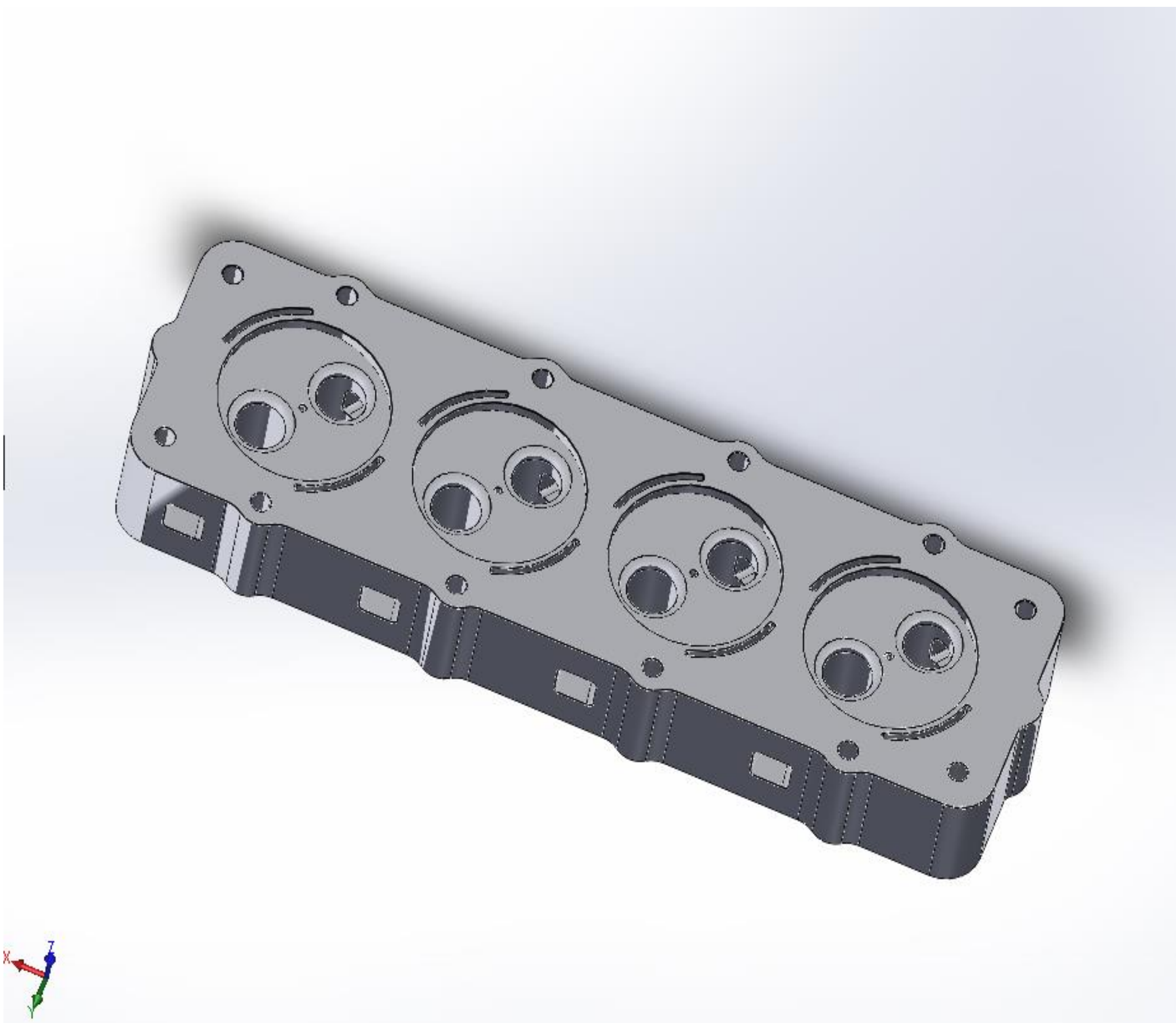


Fig46: design of cylinder head in solid works 2015

3. Simulation of the cylinder head in ANSYS 16.2 (workbench):

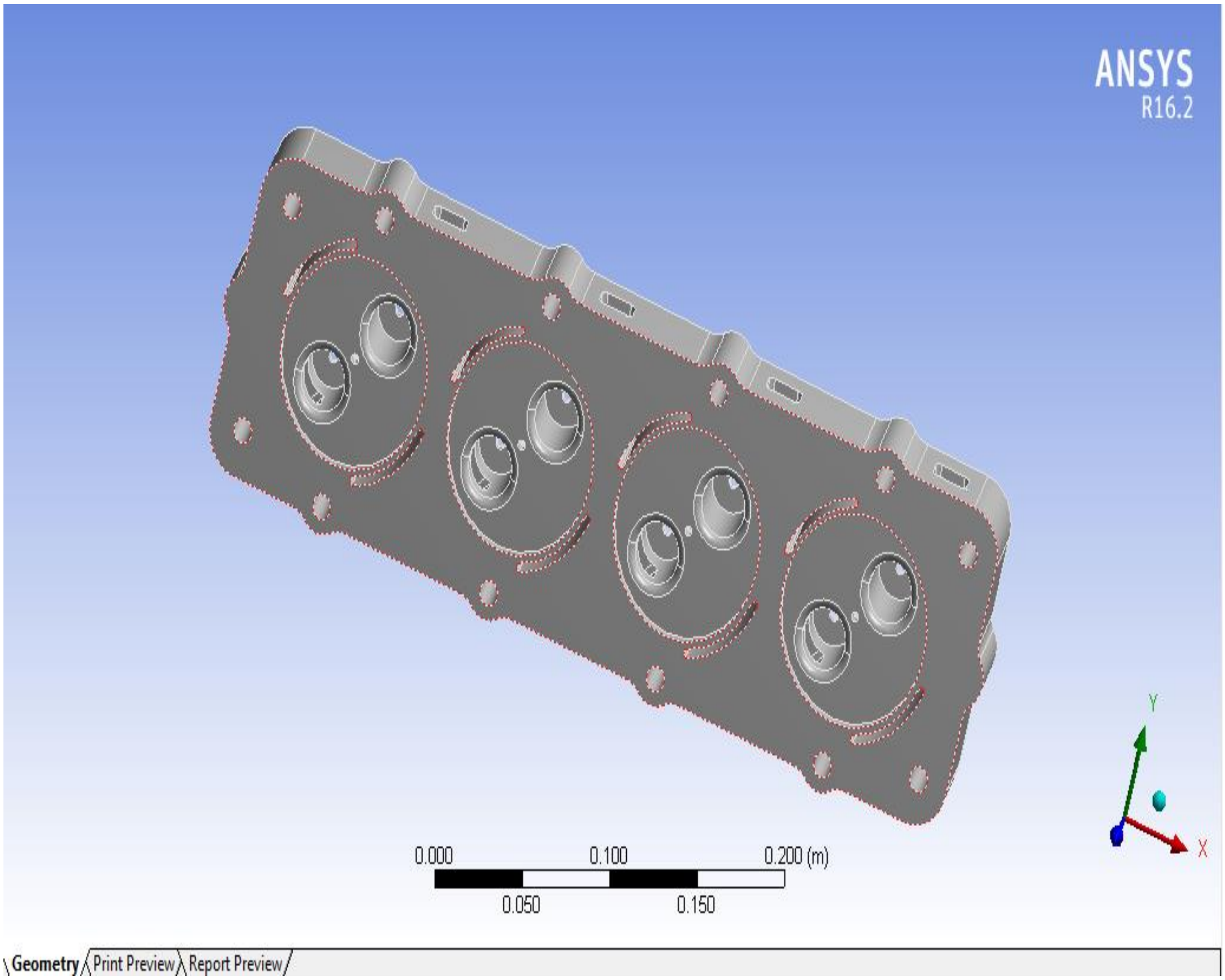


Fig47:Simulation of the cylinder head in ANSYS 16.2

4.Sizing and geometry of the cylinder head:

In this study, the model created by solid works represents a cylinder head with following dimensions:

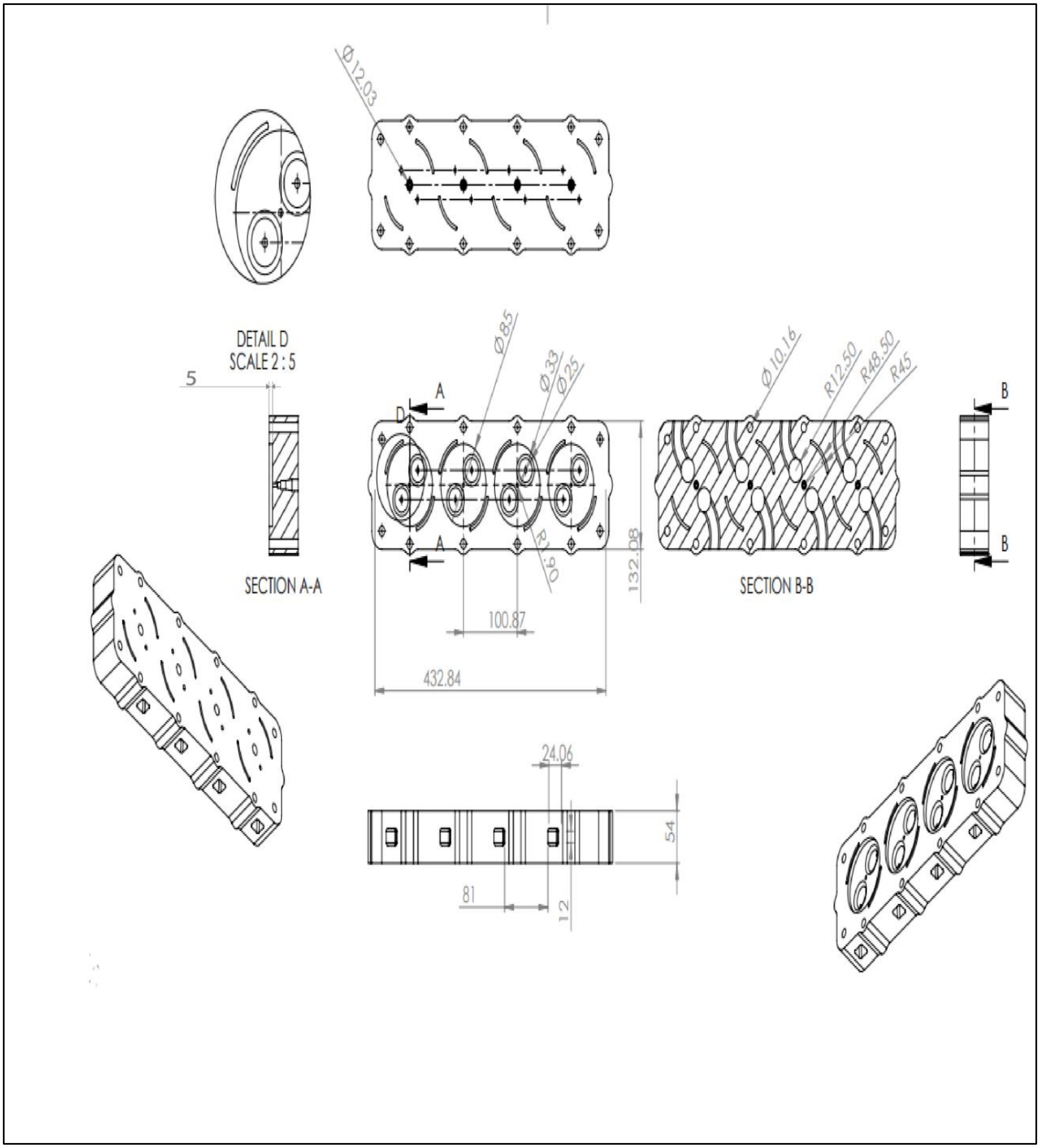


Fig48: cylinder head drawing identification (mm)

5. Material properties:

In our simulation we will use Aluminum alloy

property	*value*	
Temperature	***0***	***2000***
Density (Kg m^-3)	*2770*	*1900*
Young s modulus (Pa)	*7.1E+10*	*1.1 E+10*
Poisson s ratio	*0.33*	*0.33*
Bulk modulus (Pa)	*6.9608E+10*	
Tensile yield strength (Pa)	*2.8E+08*	
Compressive yield strength (Pa)	*2.8E+08*	
Tensile ultimate strength (Pa)	*3.1E+08*	
Thermal expansion coefficients α (10-6 K ^-1)	*23*	*33 in (600°C)*
Thermal conductivity λ (W/mK)	*147*	*175(in 220°C)*
Melting temperature Tf (°C)	*500 to 638*	
Elasticity limit** Re **(MPa)	*280*	

Table 3: Aluminum alloy properties[2]

6. The physical properties for this cylinder head:

Material	**Aluminum Alloy**	
Bounding Box	Length X	458.24 mm
	Length Y	142.72 mm
	Length Z	54. mm
Properties	Volume	2.6198e+006 mm^3
	Mass	7.2568 kg
	Centroid X	151.08 mm
	Centroid Y	-4.3628e-003 mm
	Centroid Z	25.89 mm

Table 4: The physical properties for this cylinder head

7. Mesh:

The creation of the geometry as well as the mesh are done under the software "ANSYS". The latter offers extended solutions for the most geometries complicated.

The quality of the mesh plays a significant role in the precision and stability of the numerical calculation. So attributes like node distribution, nature smoothness and the obliquity of the elements are very important. For this study, the quadratic tetra hydric element was suitable with a quality of "Fine" mesh**.**

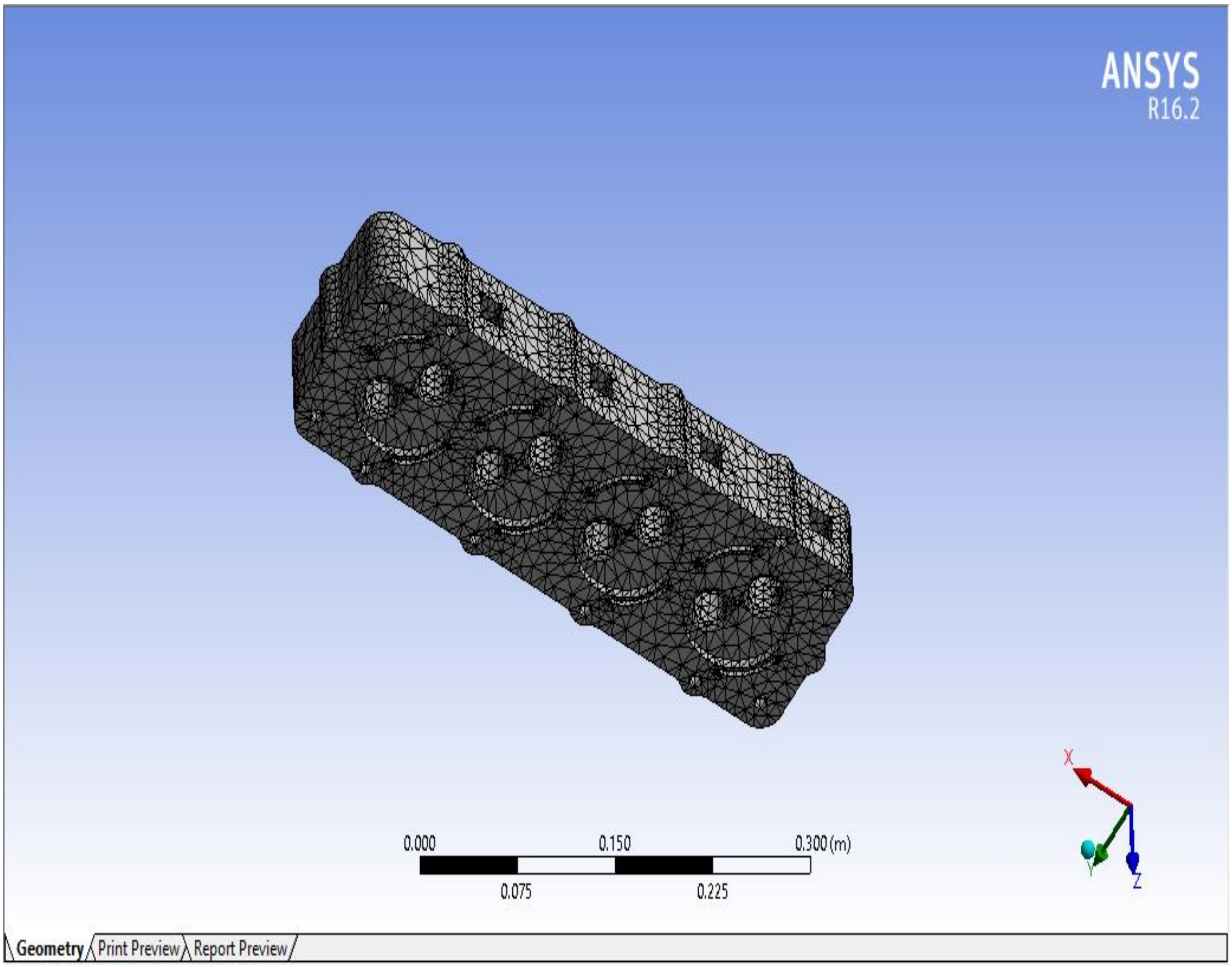


Fig 49: Fine quadratic tetra hydric mesh of the cylinder head

Statistics	
Nodes	93985
Elements	55922
Minimum Edge Length	0.26180 mm

8.The firing order (1342 four-stroke engine):

The firing order is the sequence of power delivery of each cylinder

This is achieved by sparking of the spark plugs in a gasoline engine in the correct order.

Or by the sequence of fuel injection in a diesel engine. When designing an engine, choosing an appropriate firing order is critical to minimizing vibration and achieving smooth running, for long engine fatigue life and user comfort, and heavily influences crankshaft design.

The firing order				
1.cylinder	work	exhaust	Intake	Compression
2.cylinder	Intake	Compression	work	exhaust
3.cylinder	exhaust	Intake	Compression	work
4.cylinder	Compression	work	exhaust	Intake

Table 5: the firing order in petrol engine

Intake: in the cylinder #1

Compression: in the cylinder #3

Work(power): in cylinder #4

Exhaust: in the cylinder #2

9. Thermomechanical calculation procedure:

We will do a stationary thermal calculation at the beginning to determine the distribution of temperature throughout the cylinder head, then we will do a structural calculation

in which we will import the temperature results (previously calculated on the model) to be able to make a thermomechanical calculation to be able to make a thermomechanical calculation

9.1.Thermal boundary conditions:

The initial temperature is 22 ° C

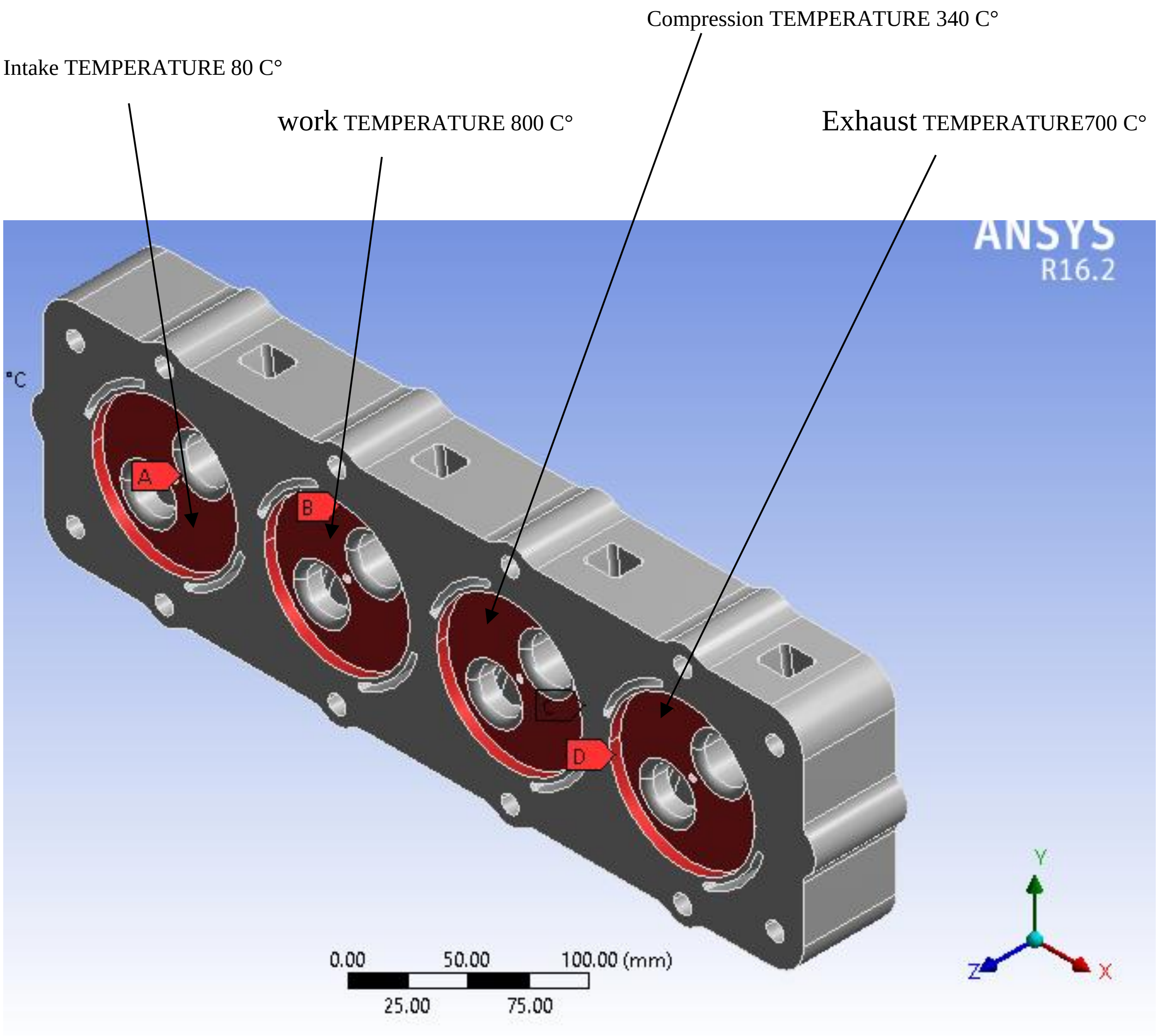


Fig 10: The temperatures applied on our cylinder head

fuel	GASOLINE ISO-OCTANE
Intake TEMPERATURE C°	80
Compression TEMPERATURE C°	340
Work TEMPERATURE C°	800
Exhaust TEMPERATURE C°	700

TABEL 6 : The temperatures applied on our cylinder head[3]

9.1.1. temperature of intake and exhaust chamber:

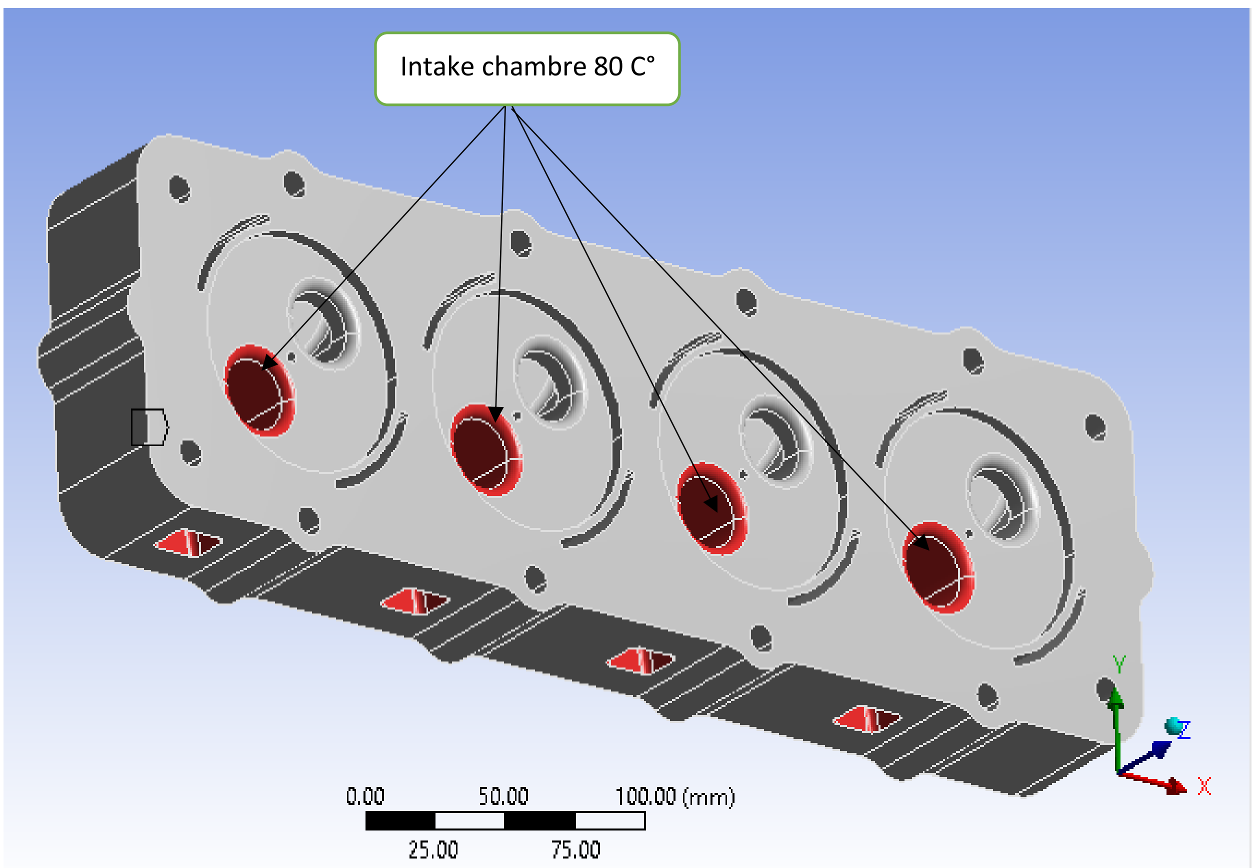


Fig 51: the area with red represent intake chamber

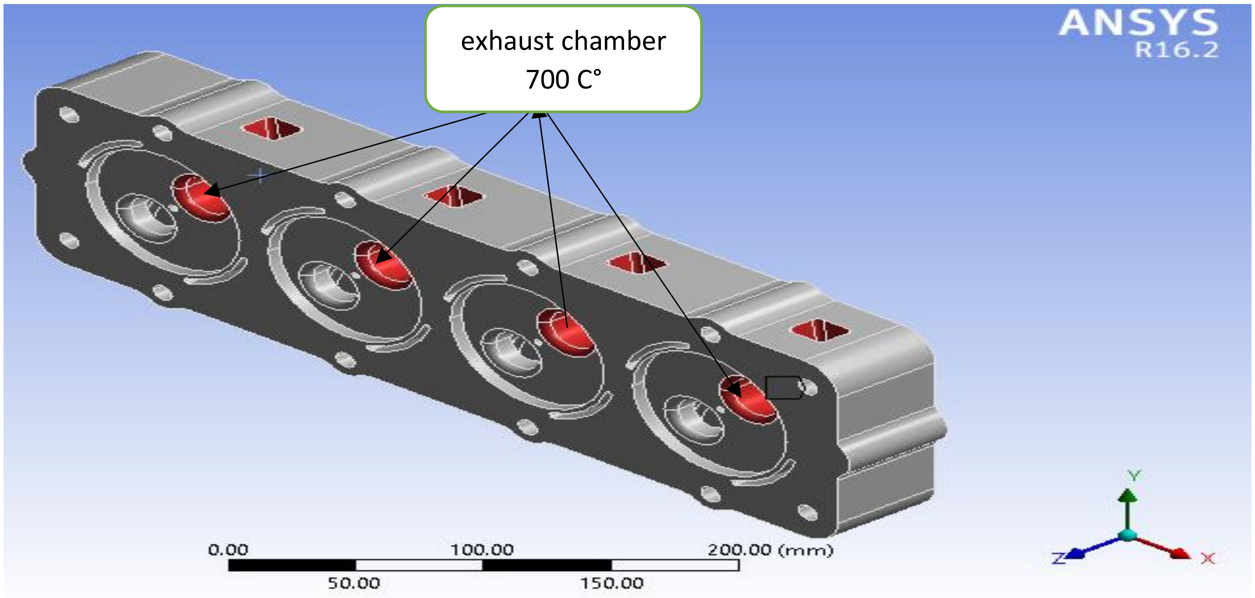


Fig 52:the area with red represent exhaust chamber

9.1.2 cooling zone:

The coolant temperature is 80 ° C. and the coolant pressure has been neglected

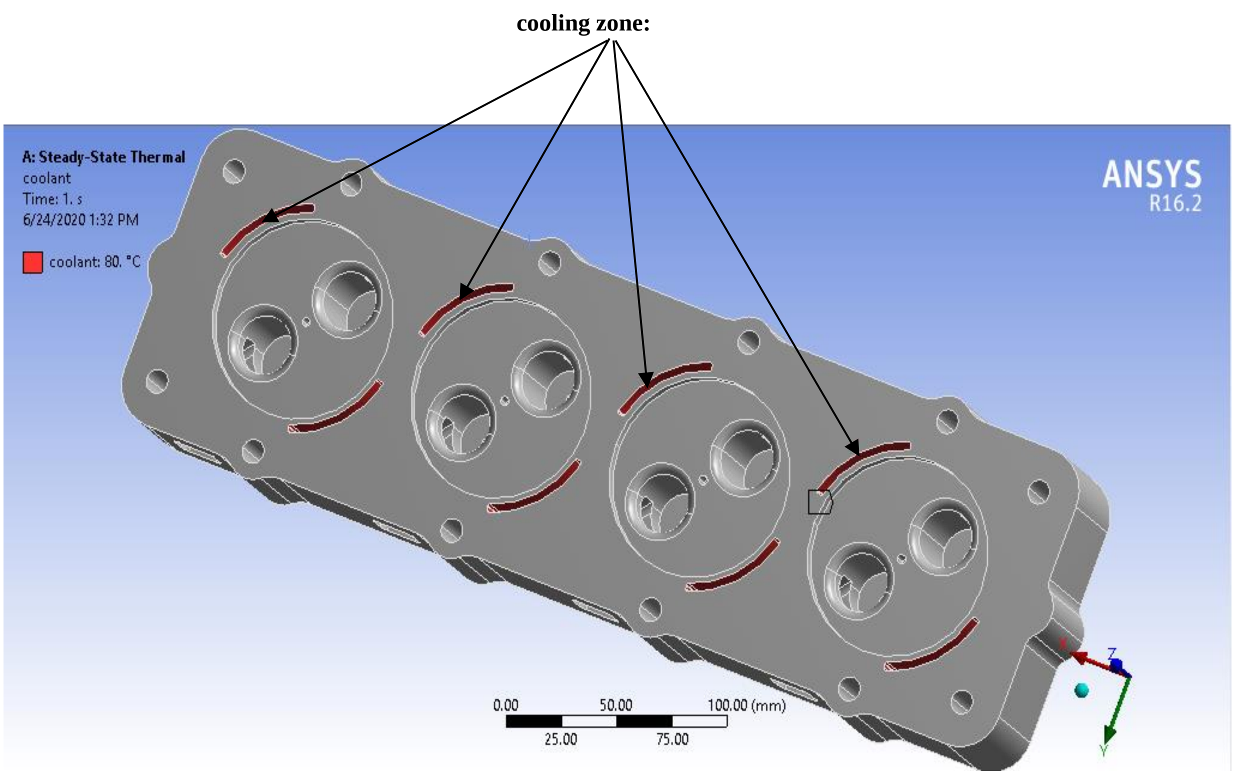


Fig 53: cooling zone

9.1.3 Heat equation:

$$\Phi = \lambda * \Delta T \quad (1)$$

the equation of heat is written

$$\rho Cp\ \Delta T\ \Delta t = div(\lambda\ .gradT) + q \quad (2)$$

With: Φ: heat flux (W / m).

Cp: is the mass thermal capacity at constant pressure (J / kg.K).

ρ: is the density of the material considered (kg / m3).

λ: is the thermal conductivity of the material (W / mK).

q: is the internal heat ratio W / m3

9.1.4 Thermal expansion:

Thermal expansion is used to calculate the thermal deformation for a specimen of length L according to the following formula:

$$\Delta L = \alpha . L .\ \Delta T \quad (3)$$

Implies that $(\Delta L ther / L) = \varepsilon\ thermal = \alpha . \Delta T = \alpha . (Tf - Ti)$ (4)

ΔL (mm): Expansion due to a change in temperature.

α (1 / K): Coefficient of thermal expansion.

L (mm): Characteristic length.

ΔT (K or ° C): Temperature difference

The total deformation is given by

$$\varepsilon\ total = \varepsilon\ elastic + \varepsilon\ thermal \quad (5)$$

$$\Delta L\ total = \Delta L\ mec + \Delta L\ ther \quad (6)$$

Finite element formulation of the heat equation:

$$[K\ ther]\ \{T\} = \{Q\} \quad (7)$$

[K ther]: The stiffness matrix it depends on the geometry and the thermal properties of the material.

{T}: The vector of the temperature.

{Q}: The vector of the heat flow.

9.2. Mechanical boundary conditions:

- **Fixed support :**

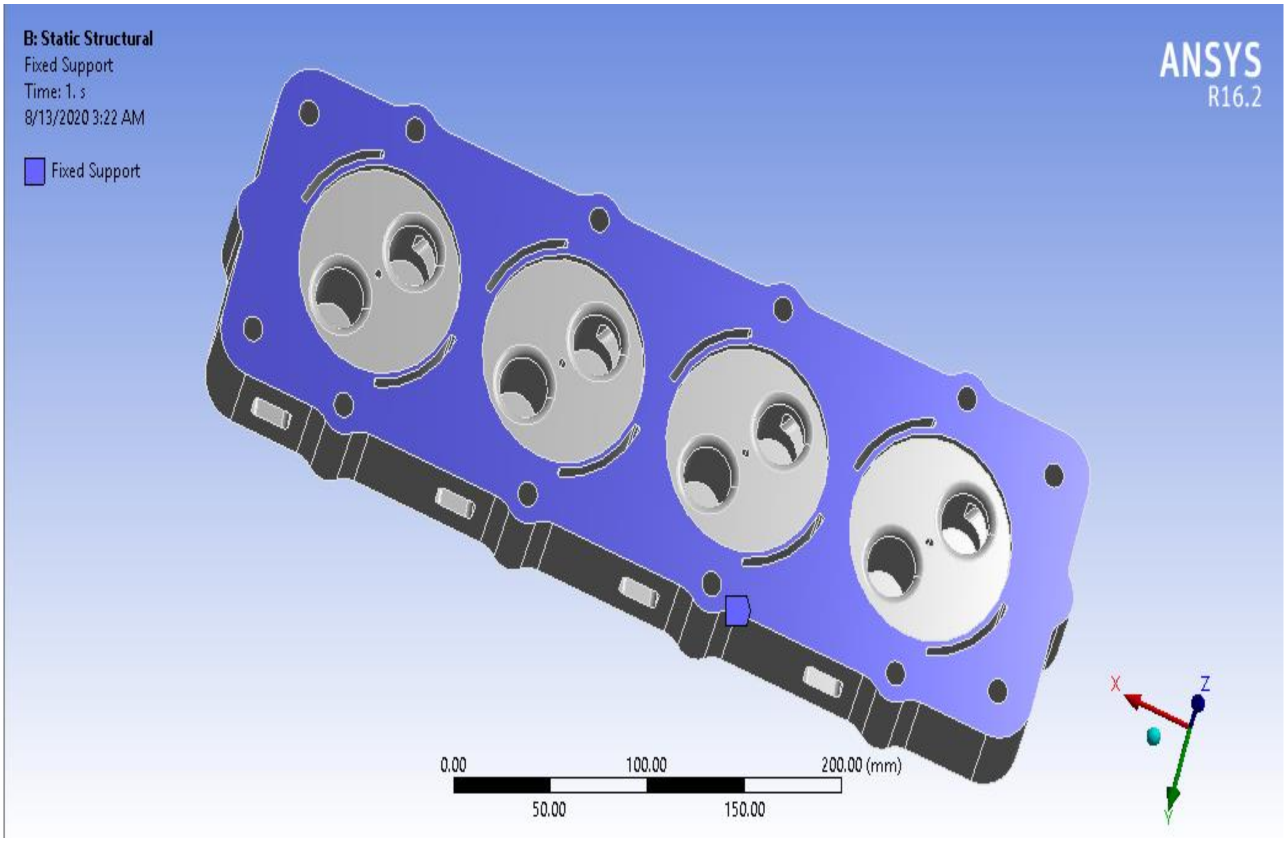


Fig 54: Fixed support

9.2.1 The pressure applied in each cylinder:

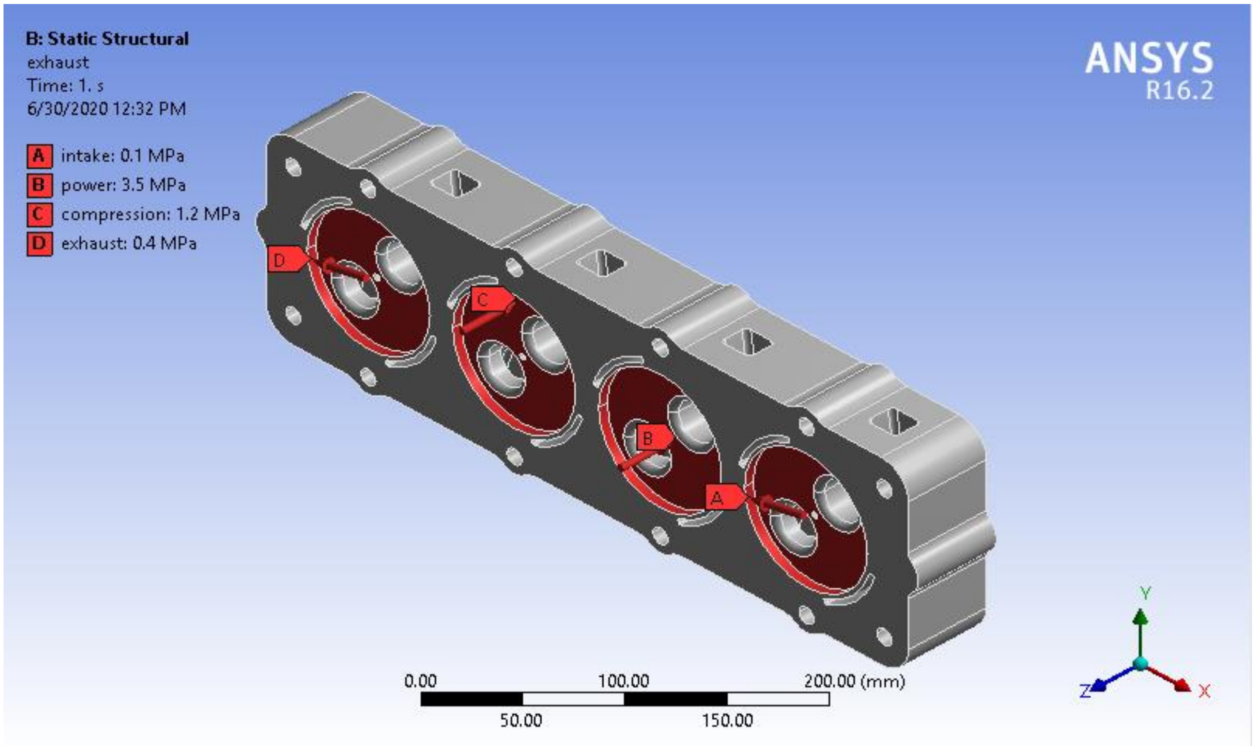


Fig 55 : The pressure applied in each cylinder

	Value MP
Intake TEMPERATURE C°	0.1
Compression TEMPERATURE C°	1.2
Work TEMPERATURE C°	3.5
Exhaust TEMPERATURE C°	0.4

Tabel 7: The pressure applied in each cylinder[3]

Finite element formulation of the heat equation:

[K mec] {U} = {F} **(8)**

[K mec]: The stiffness matrix it depends on the geometry and the mechanical properties of the material

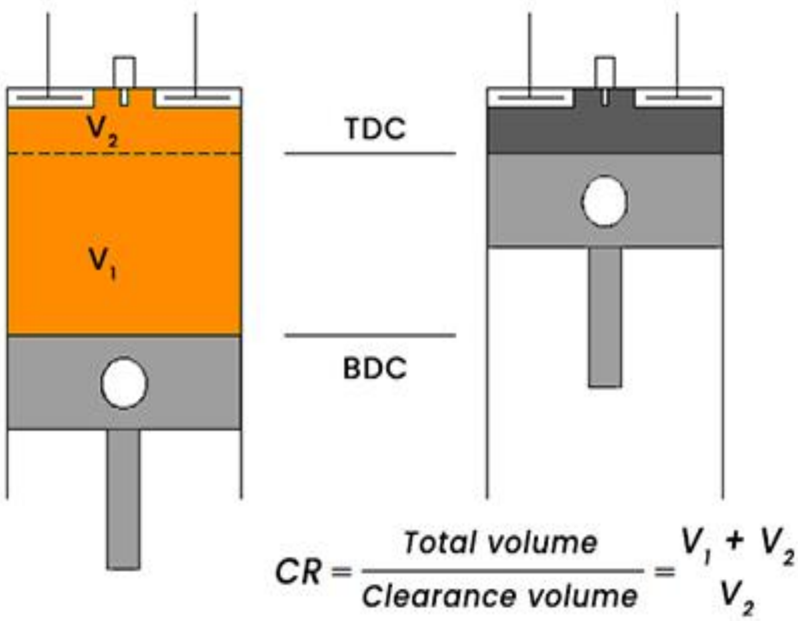
{U}: The displacement vector.

{F}: The vector of the force (deduced from the pressures)

10 . Compression ratio:

The compression ratio (CR) of an IC engine is a ratio of the total volume of the combustion chamber to the volume left after complete compression-like clearance volume.

It is calculated by the formula



REFERENCE

[1] : https://www.ansys.com/fr

[2] : Métaux et alliages, matériaux magnétiques et multi matériaux www.techniquesingenieur.fr)

[3] : J.Chagette, Technique d'automobile, le moteur, Ed Dunod, 1977.

CHAPTER 4 :

RESULT OF THE ANALYSIS

Introduction:

The structural analysis of the cylinder head was performed in a thermomechanical analysis.

In the beginning the thermal analysis was carried out to obtain the temperature distribution in the cylinder head.

We will use two cases for Aluminum Alloy:

Normal case: The coolant is present in the cylinder head with an 80°C temperature.

Accidental case: There is no coolant in the cylinder head

1.Normal case:

1.1. Temperature:

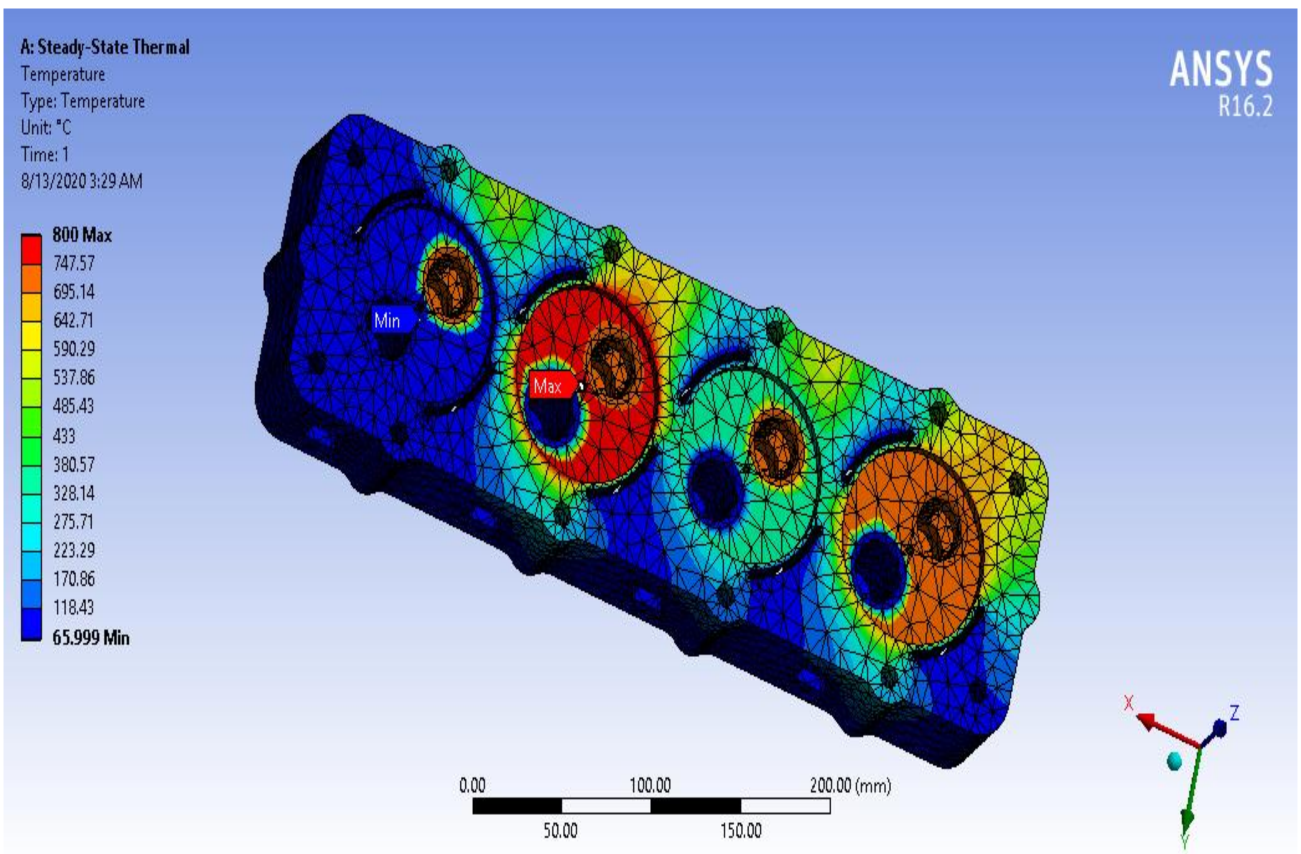


Fig 56: Distribution of temperature in cylinder head

We notice that:

The maximum temperature = 800 ° C (located in the combustion zone).

The minimum temperature = 65.99 ° C.(located in cooling zone).

The coolant is effective for our cylinder head, because it prevents temperatures (work or power, compression, exhaust) to spread throughout the body of the cylinder head.

1.2.Total heat flux:

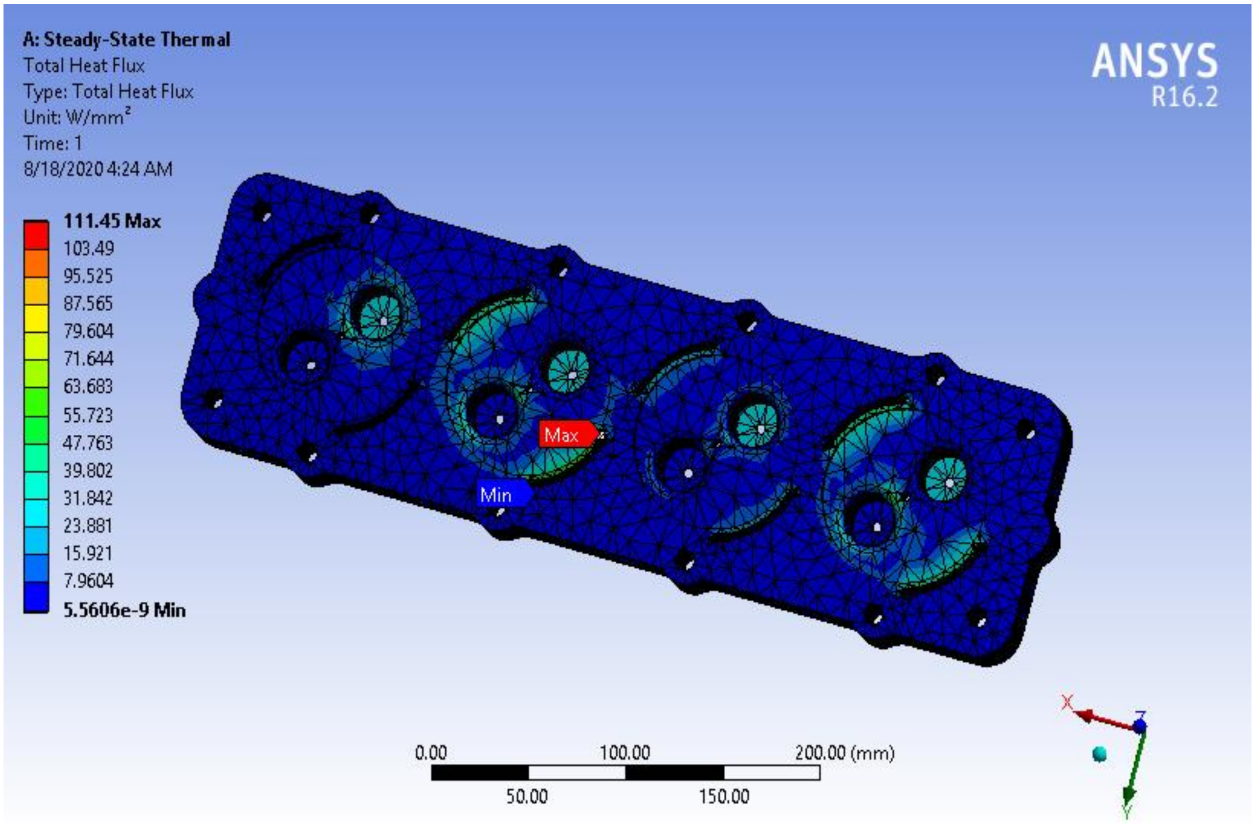


Fig 57 : Total heat flux in this model

Maximum value: 111.45 W / mm2

1.3.Thermal deformation (thermal strain):

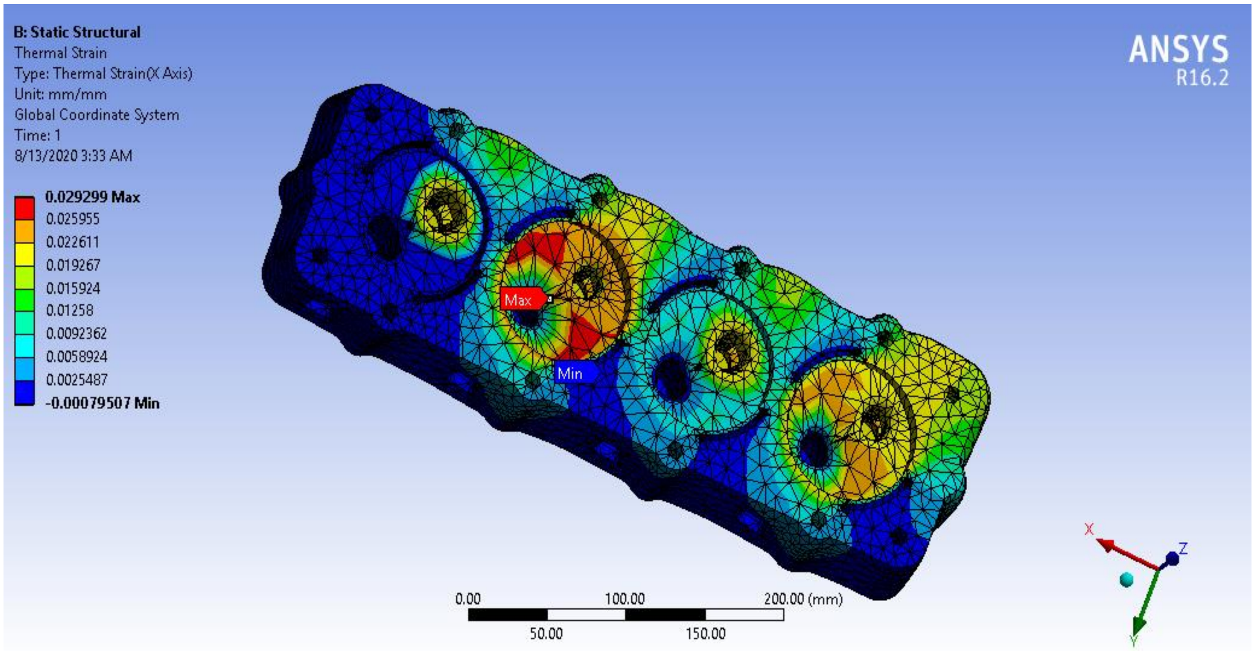


Fig 58*:* thermal strain

Maximum value: 0.029299mm / mm =2.9 %

1.4.Total equivalent deformation:

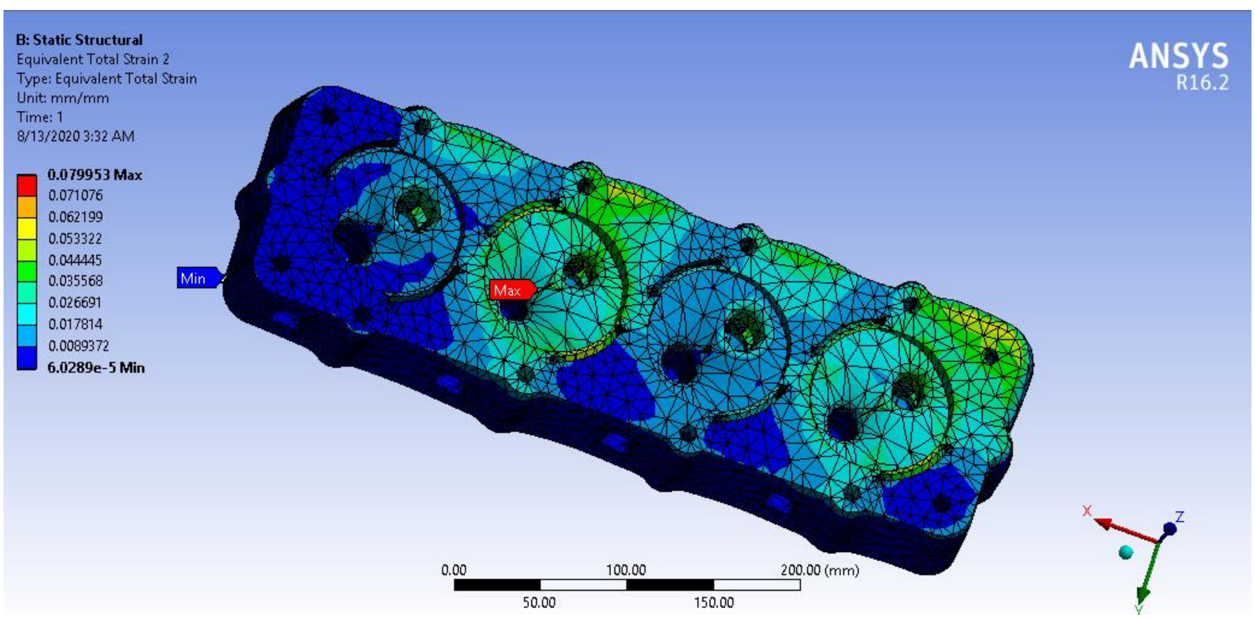


Fig 59 :Total equivalent deformation

From the results obtained we see that the stresses and strains

are located at the combustion zone level (the combustion temperature

equals 800 ° C).

1.5. Equivalent stress (Von-Mises):

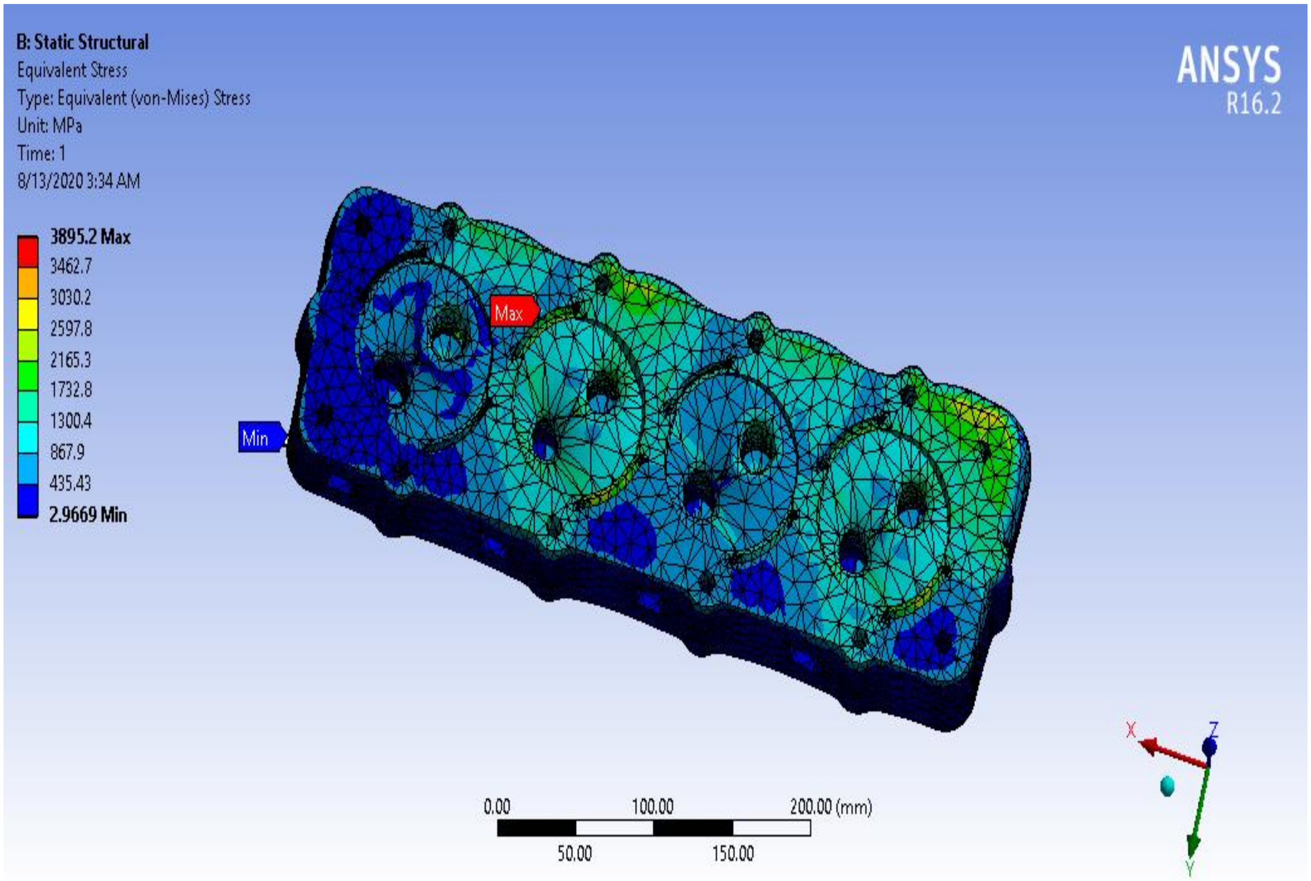


Fig 60: Equivalent stress Von-Mises

The maximum stress is located at the combustion zone (where the temperature is the highest), the maximum value obtained is very high (3895.2 MPa). This forces us either to use a material with an elastic limit higher than 3895.2 MPa (which is rare to find such a material),

1.6. Total displacement:

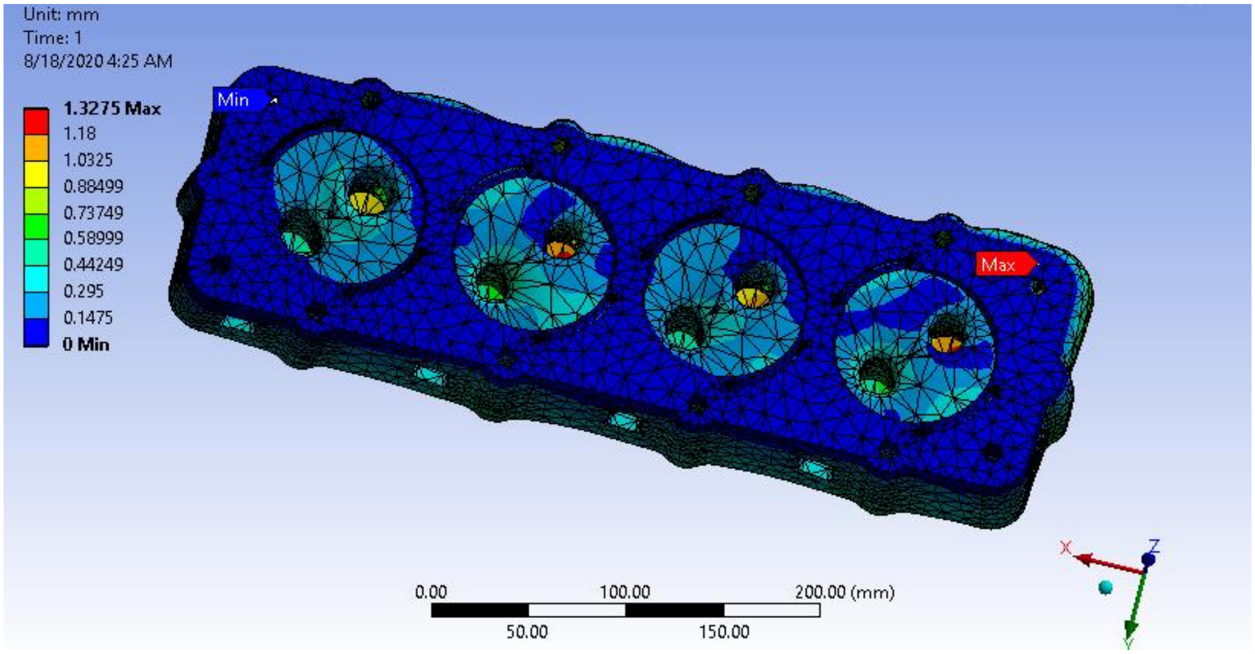


Fig 61: total displacement

The maximum displacement (1.3275 mm)

1.7.path:

To draw our curves we need a path.

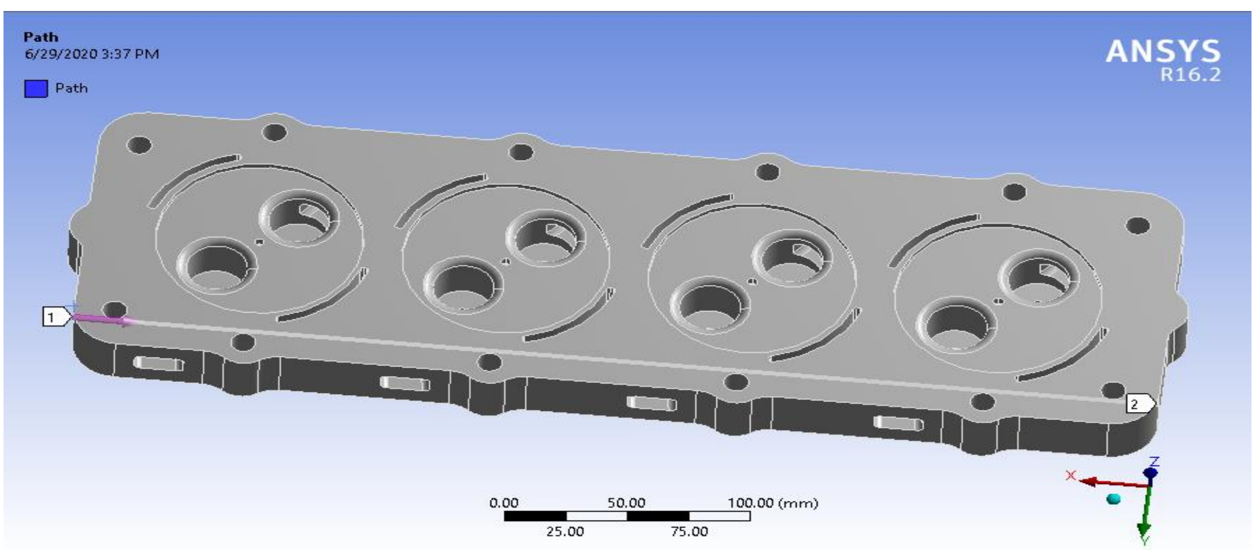


Fig 62: path

Coordinates	Start	End
X Coordinate (mm)	373.5	-71.10
Y Coordinate (mm)	53	53
Z Coordinate (mm)	54	54

Table 8: Path coordinates (mm)

The following figures represent the curves of the path (length Scale 1=9mm) :

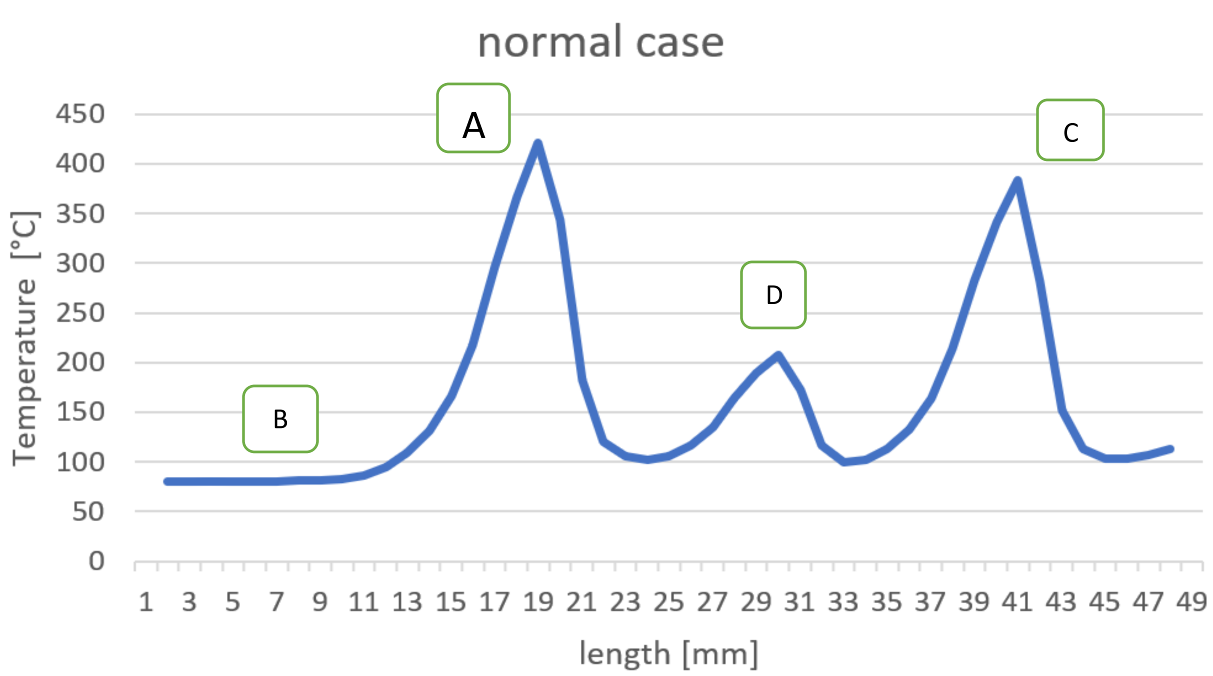


Fig 63 : Temperature as a function of the length of the path

Point A: Maximum temperature equal 422 ° C, this is the combustion temperature.

Point B: Minimum temperature equal to 84 ° C, this is the intake temperature (this is the same temperature of the coolant).

Point C: Temperature equal to 385 ° C, this is the exhaust temperature.

Point D: Temperature equal to 208 ° C, this is the compression temperature.

Because of the cooling of the cylinder head, we notice that:

Point A temperature <combustion temperature (800 ° C).

Point B temperature = inlet temperature (80 ° C).

Temperature of point C <exhaust temperature (700 ° c).

Point D temperature <compression temperature (340 ° C).

So the coolant is very effective in cooling the cylinder head

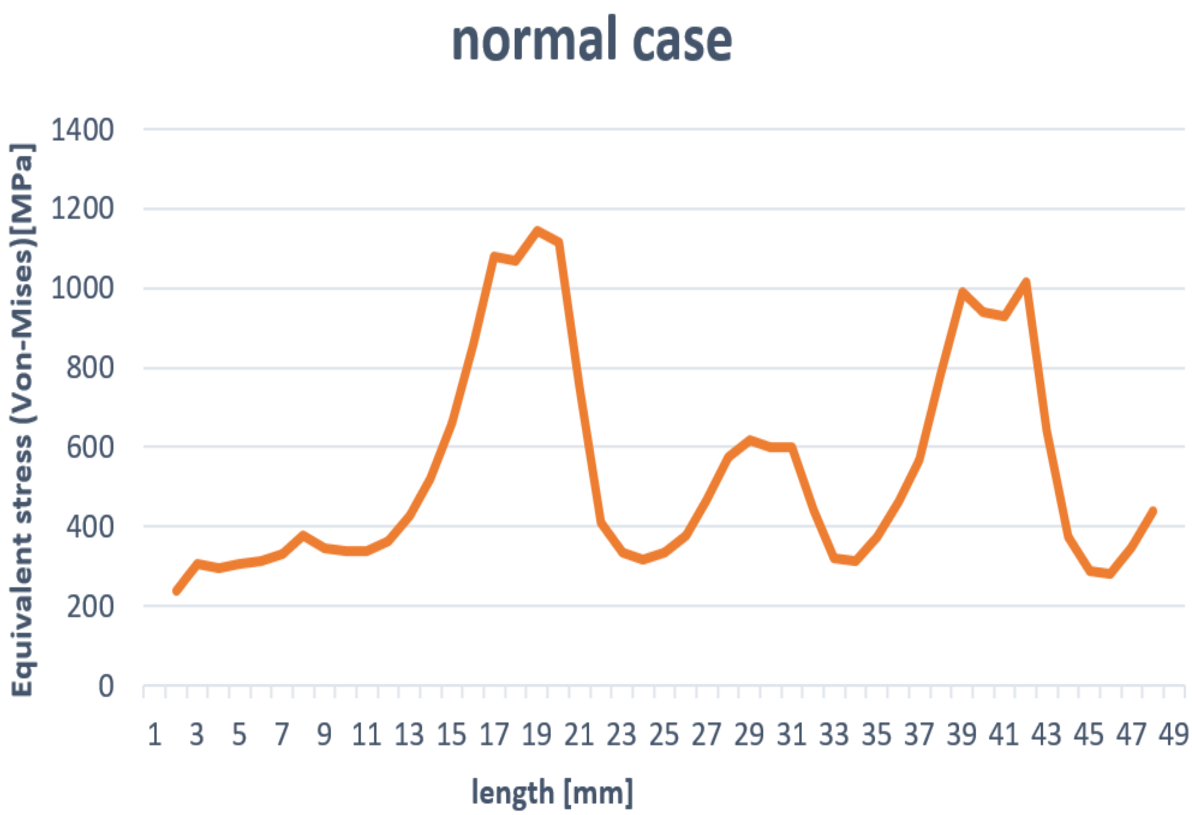


Fig 64: The equivalent stress (Von-Mises) as a function of the length

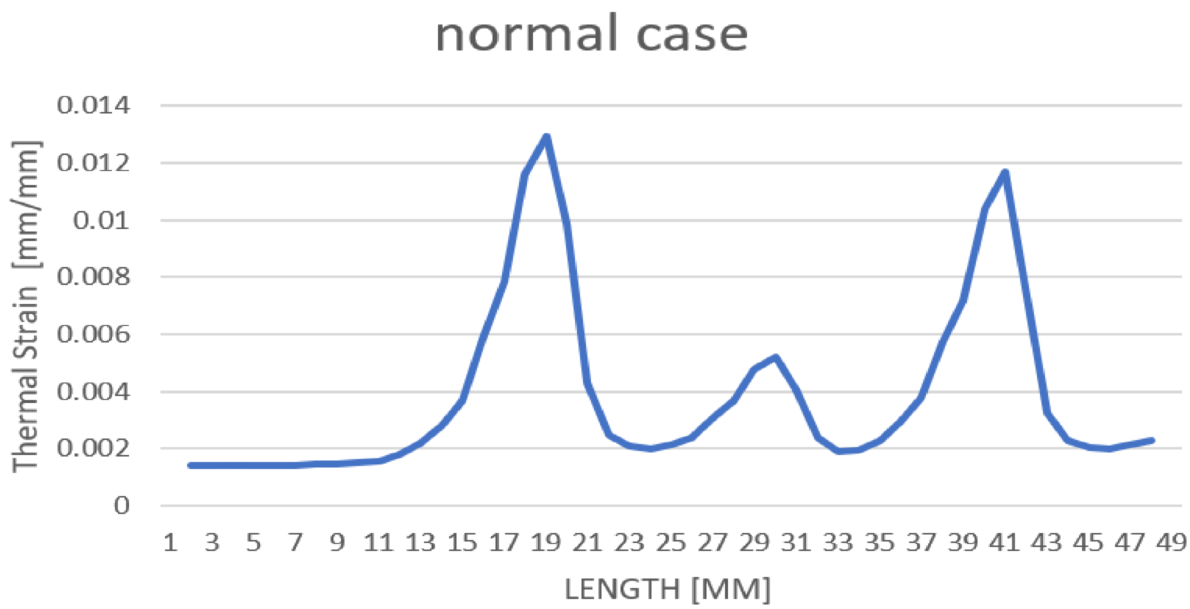


Fig 65:Thermal deformation as a function of length

The maximum thermal deformation is in the combustion zone due to the high temperature which deforms the combustion zone. In addition, the coefficient of expansion of **Aluminum alloy** increases proportionally with the increase in temperature

The minimum thermal strain is in the intake area because the intake temperature is low.

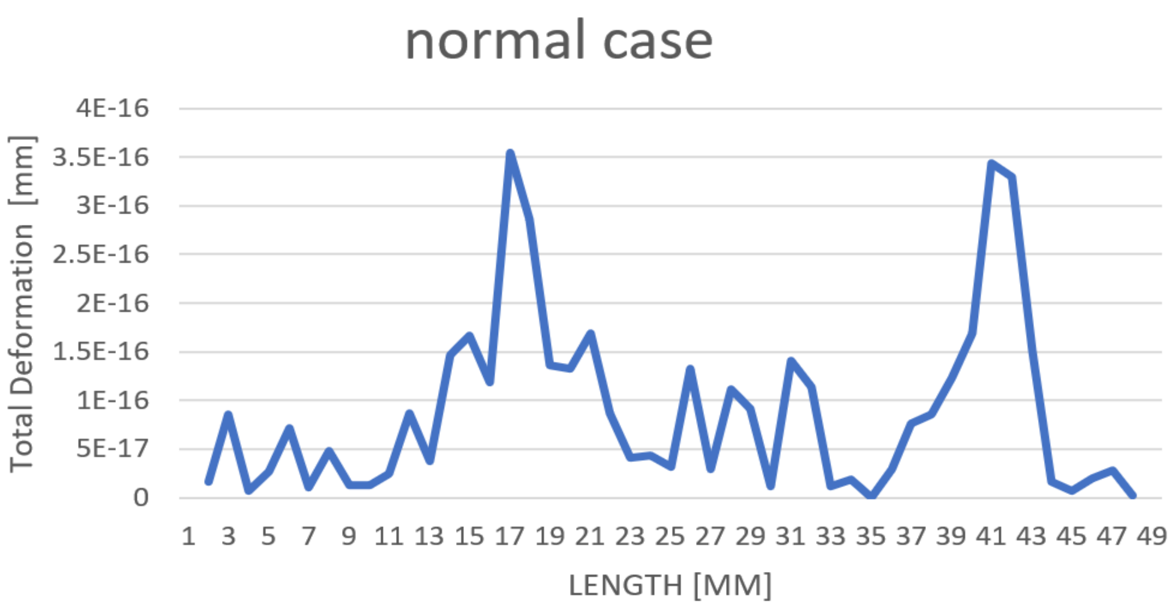


Fig 66:Total deformation as a function of length

2.Accidental case

2.1.Temperature:

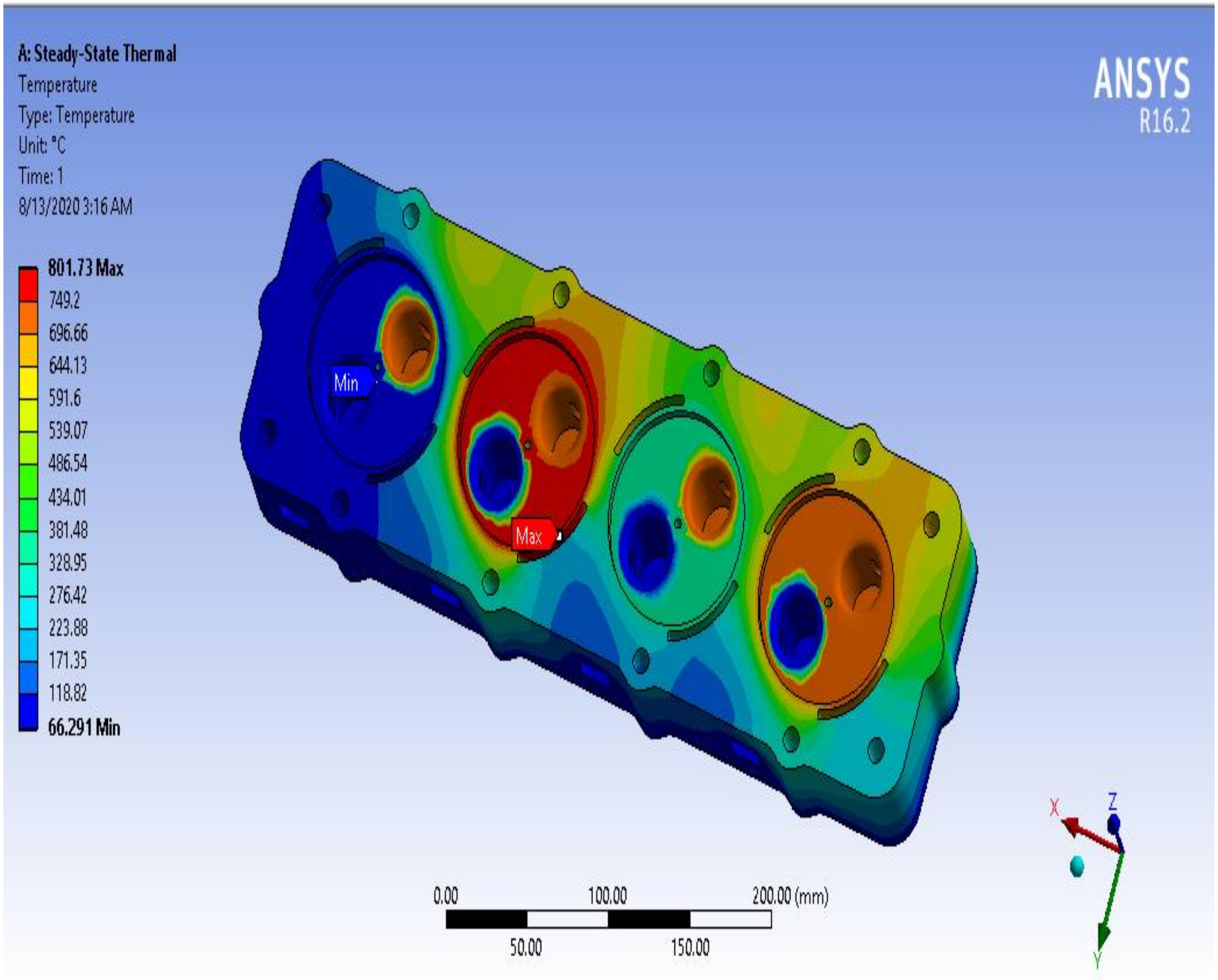


Fig 67: Distribution of temperature in cylinder head

Note that the maximum temperature is equal to 801 ° C which is located in the combustion zone, on the other hand the minimum temperature is 66 ° C.

The combustion, exhaust and compression temperatures are propagated throughout the body of the cylinder head due to the absence of coolant.

2.2.Total heat flux:

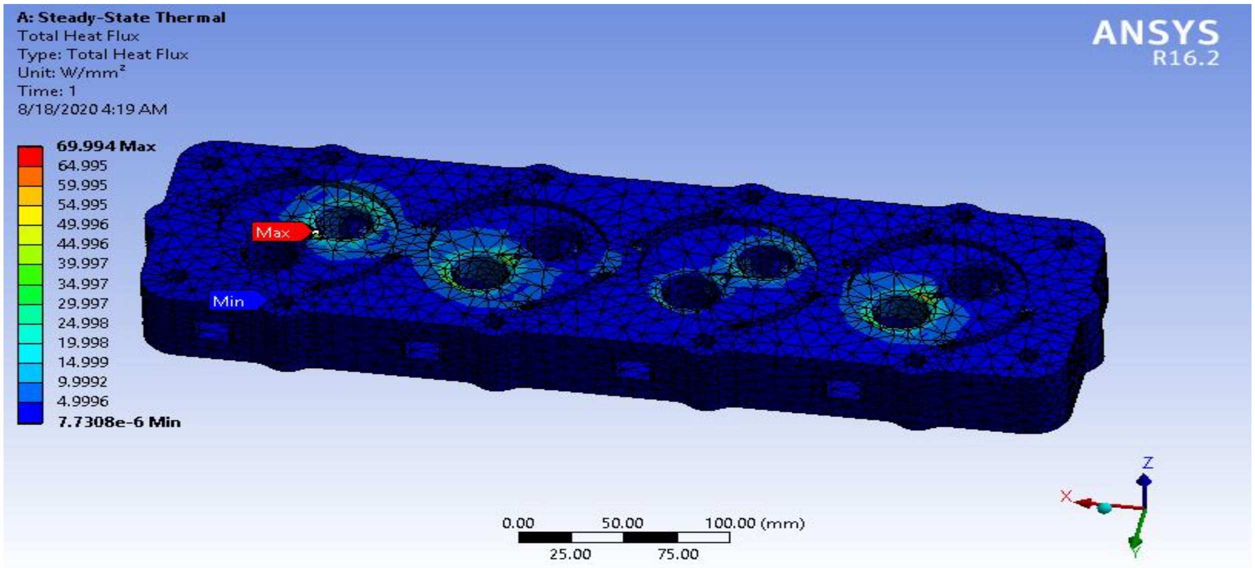


Fig 68: Total heat flux in this model

Maximum value: 69.995 W / mm2

Minimum value: 0.0007730 W / mm2

2.3.Thermal deformation (thermal strain):

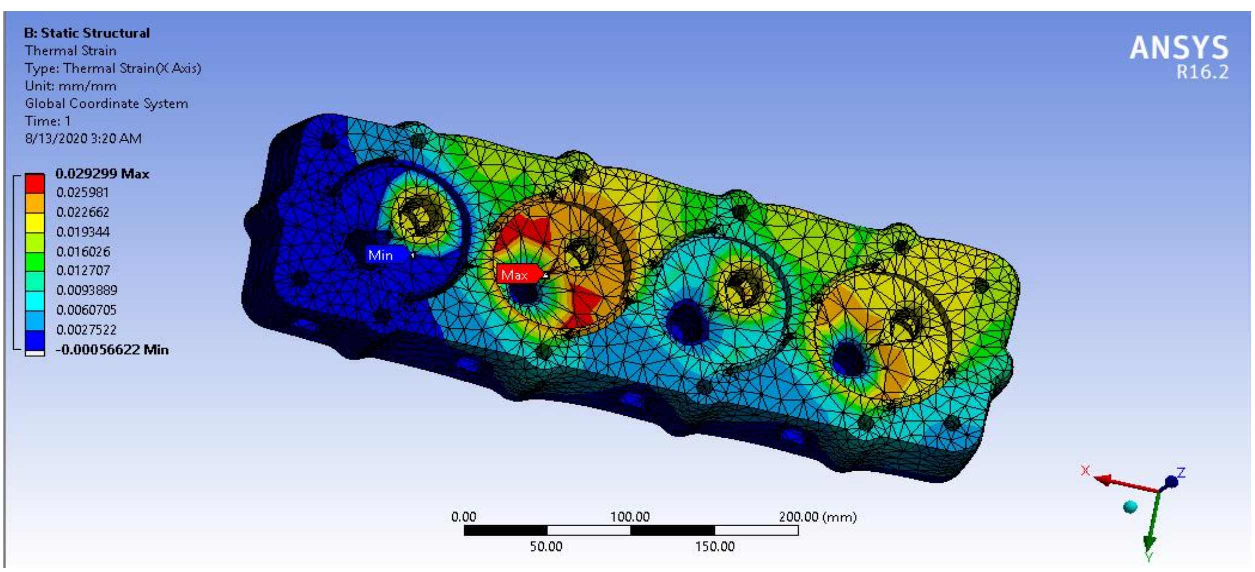


Fig 69:Thermal deformation

Maximum value: 0.029299 mm / mm =2.9 %

2.4.Total equivalent deformation:

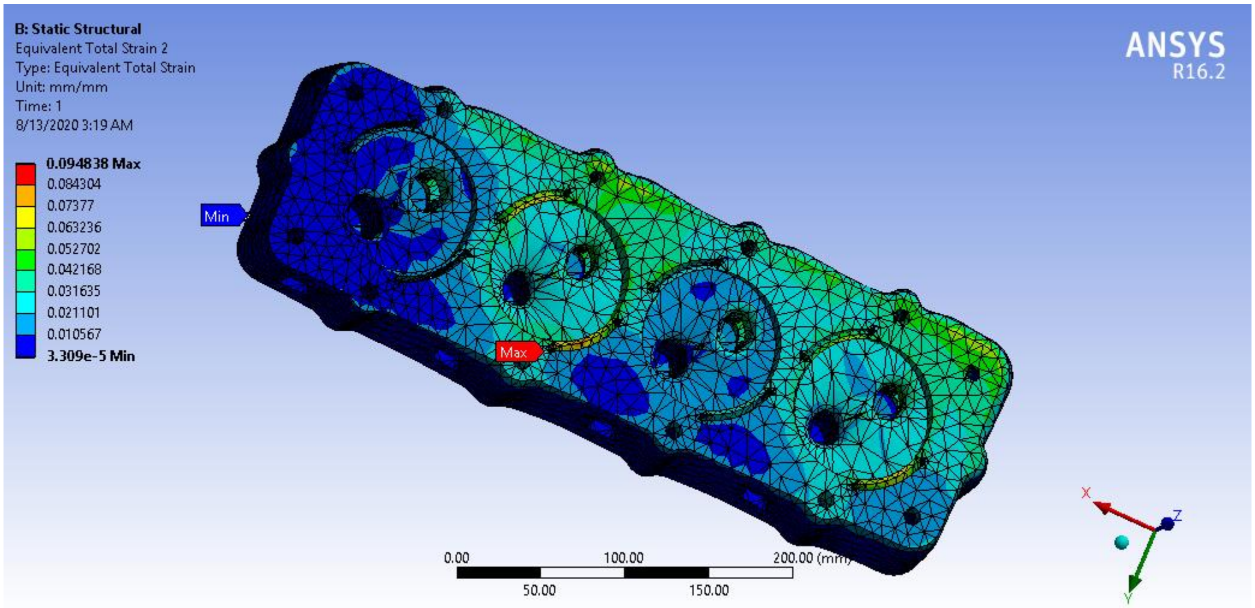


Fig 70: Total equivalent deformation

2.5. Equivalent stress (Von-Mises):

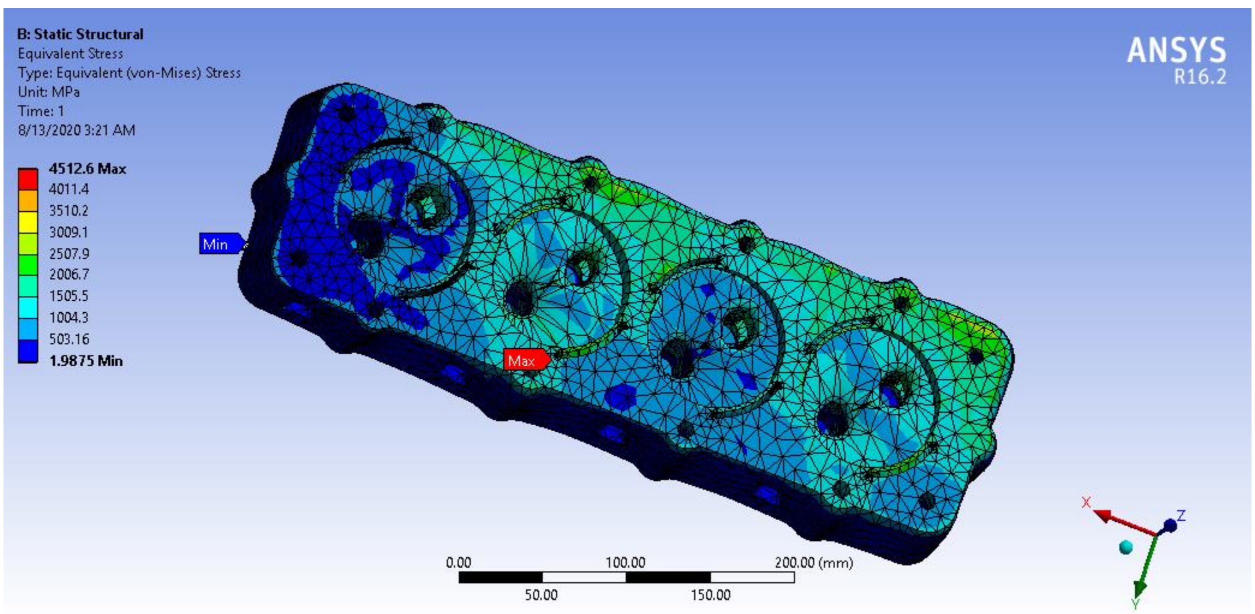


Fig 71: Equivalent stress (Von-Mises)

The maximum stress reaches 4512.6 MPa, it is bigger than the stress obtained in the normal case

2.6.Total displacement:

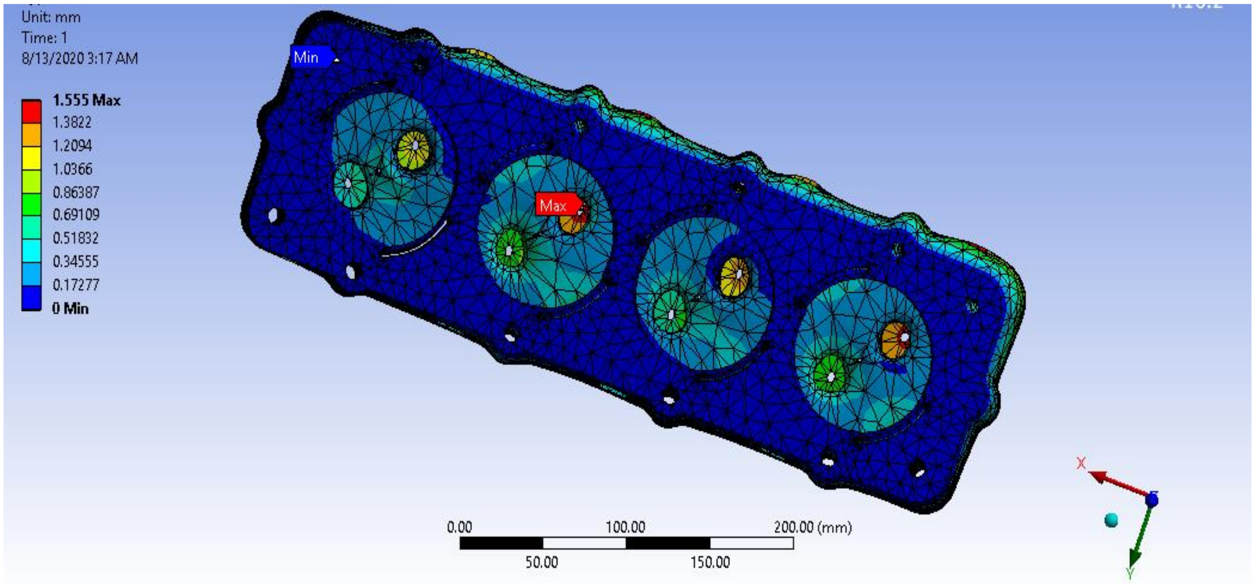


Fig 72: Total displacement

The maximum displacement is in the combustion zone with a value of 1.555 mm, because of the maximum temperature which deforms the zone (this high temperature expands the combustion zone if for that we obtained a maximum displacement value).

The minimum displacement is in the fixed support area.

The figure represents the evolution of the temperature (° C) as a function of the length (mm) of the cylinder head :

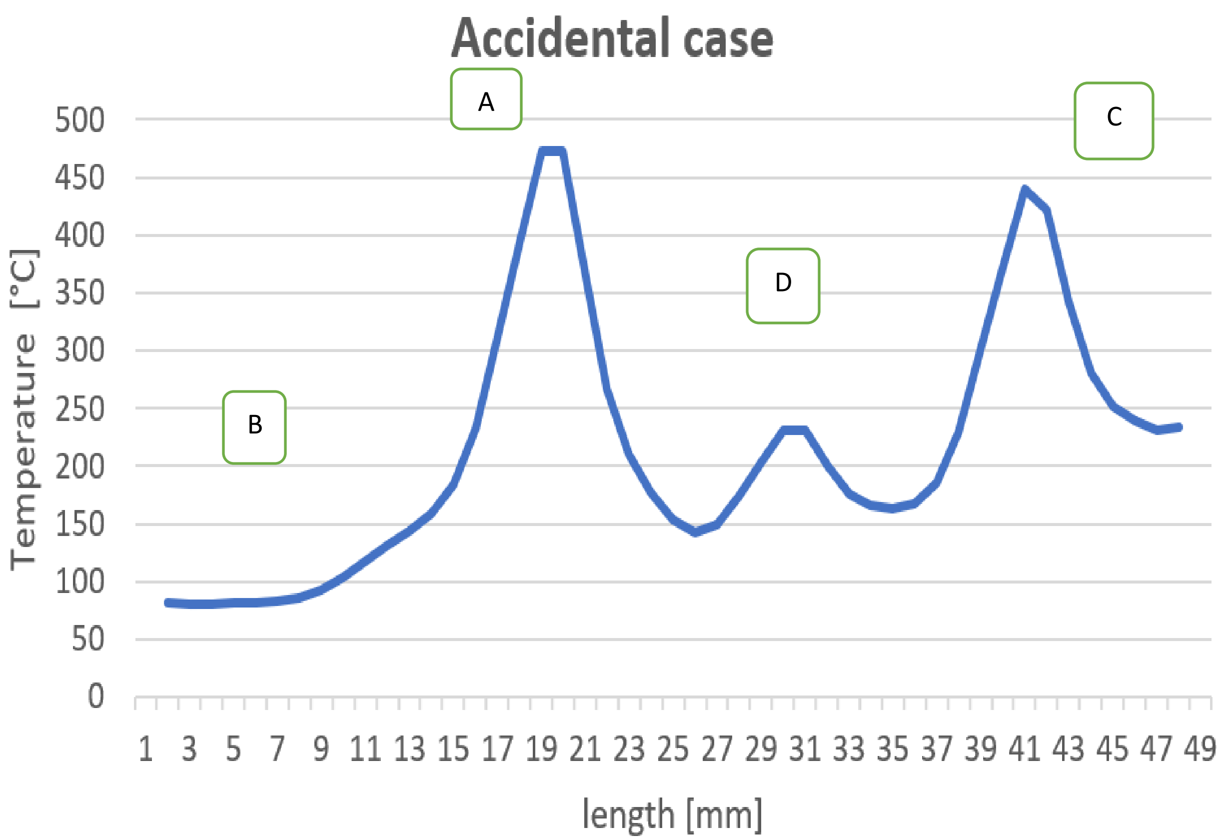


Fig 73:Temperature as a function of the length of the path

The maximum temperature = 480 ° C

Minimum temperature = 89 ° C

We notice that :

The curve goes up from point B(intake zone) to point A (work zone), and goes down to point D (compression temperature), then we see another increase towards point C (temperature = 448 ° C),

The reason for the increased temperatures is the lack of coolant.

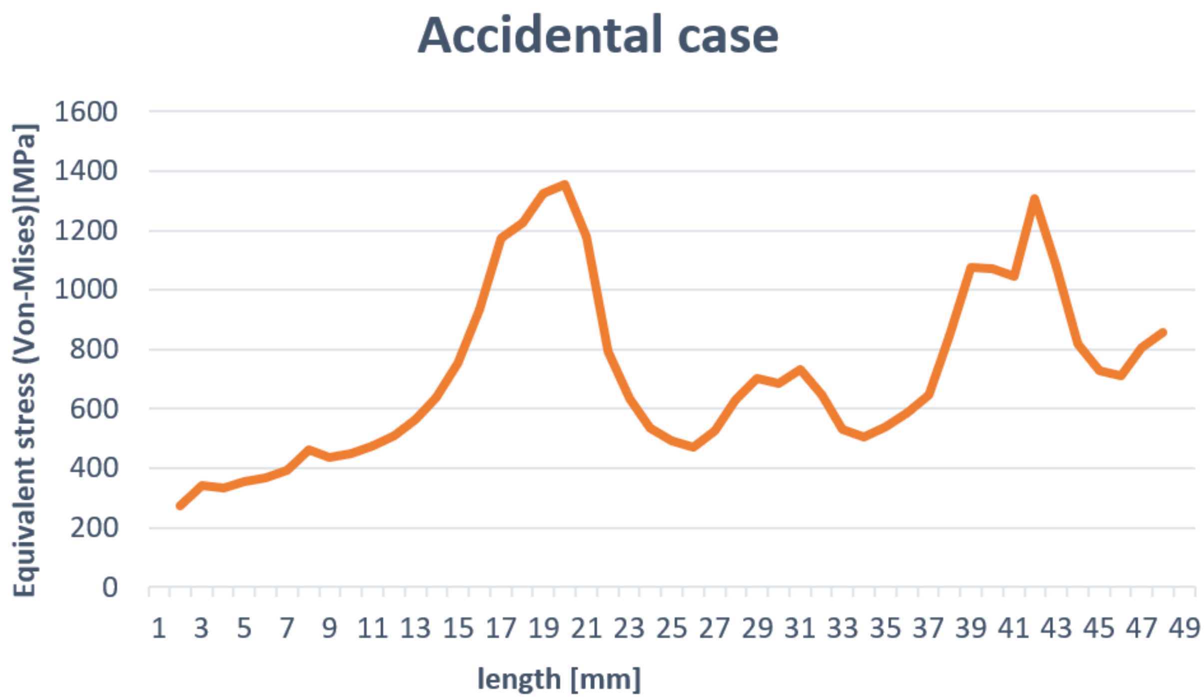


Fig 74:The equivalent stress (Von-Mises) as a function of the length

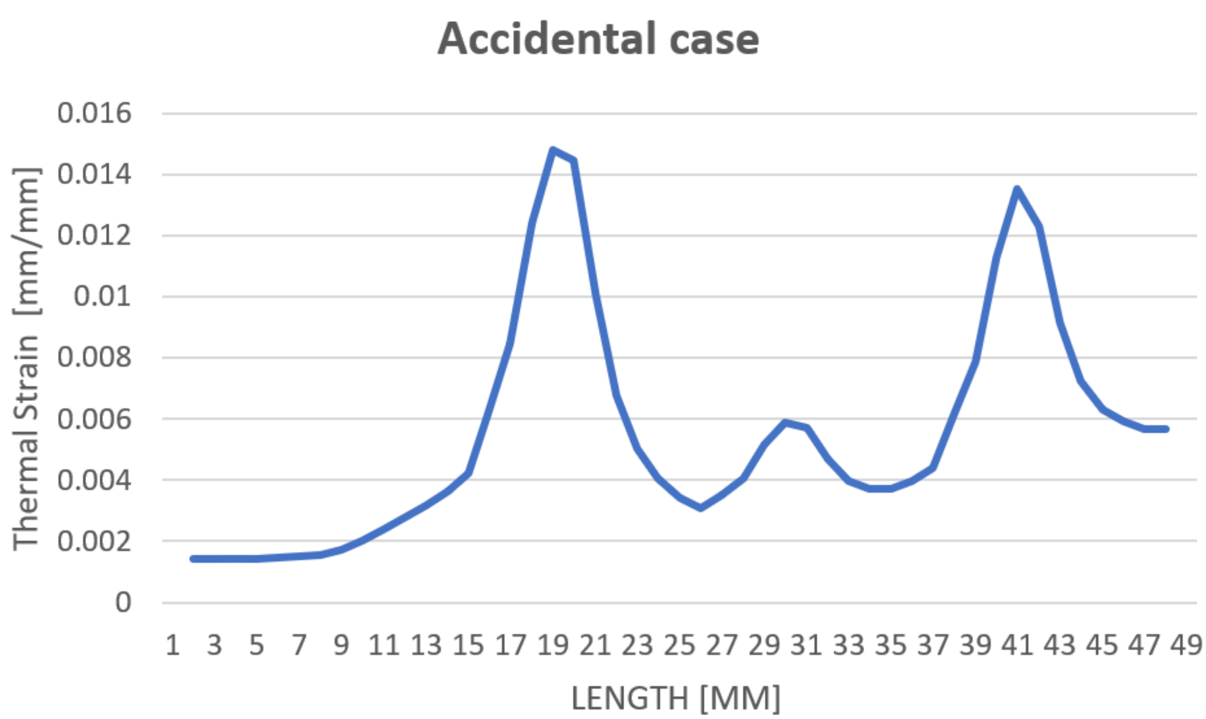


Fig 75:Thermal deformation as a function of length

Thermal deformation has a relationship with temperature (heat), this means that thermal deformation increases proportionally with increasing temperature.

It is noted that the distribution of the thermal deformation along the trajectory (path) chosen for the accidental case is different from that obtained in the normal case.

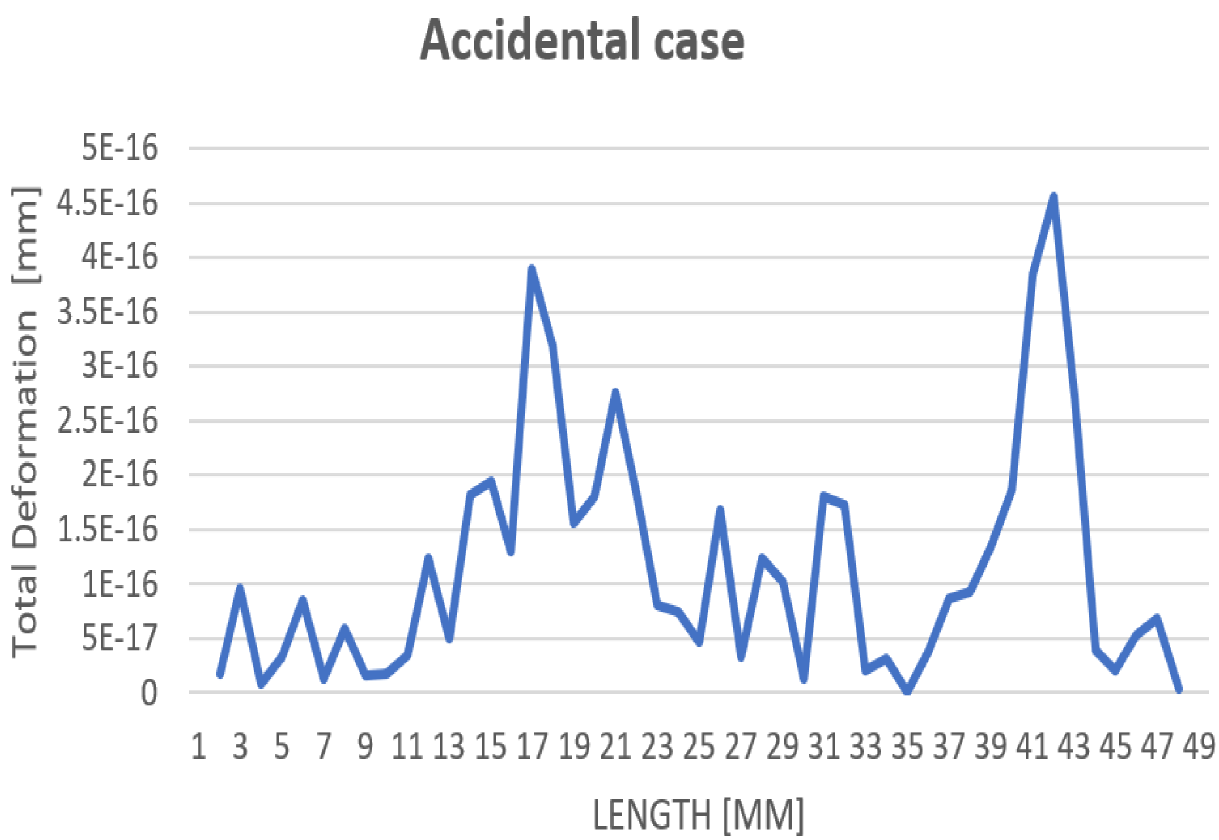


Fig 76: Total deformation as a function of length

3.Comparison between the normal case and the accidental case:

3.1 Temperature Comparison:

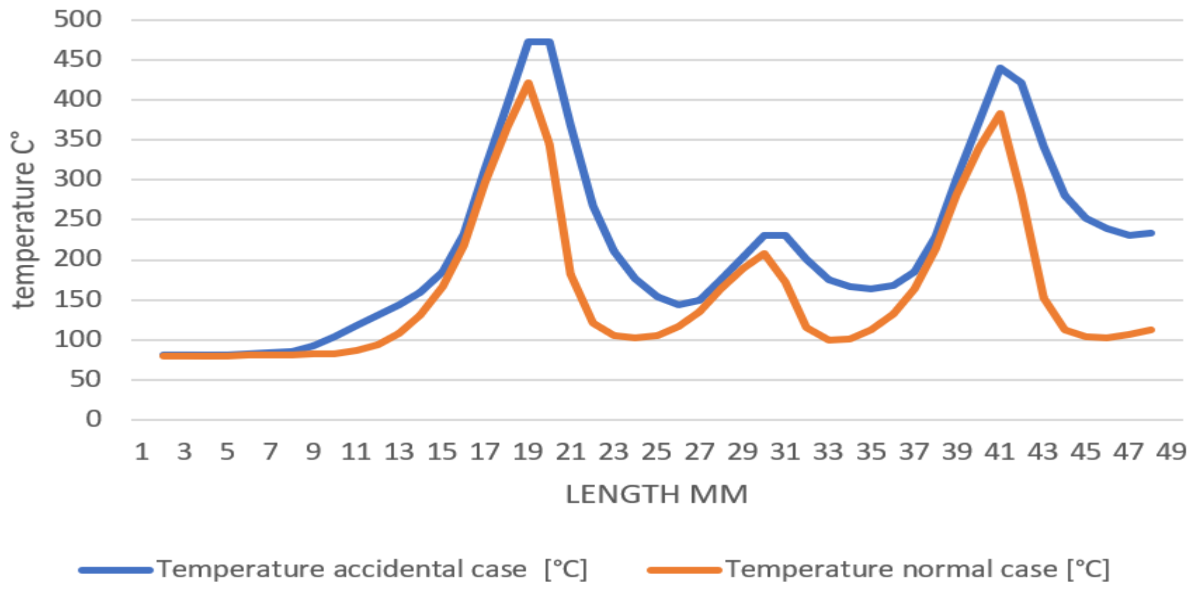


Fig 77: Temperature Comparison between the normal case and the accidental case

3.2 The equivalent stress (Von-Mises) Comparison

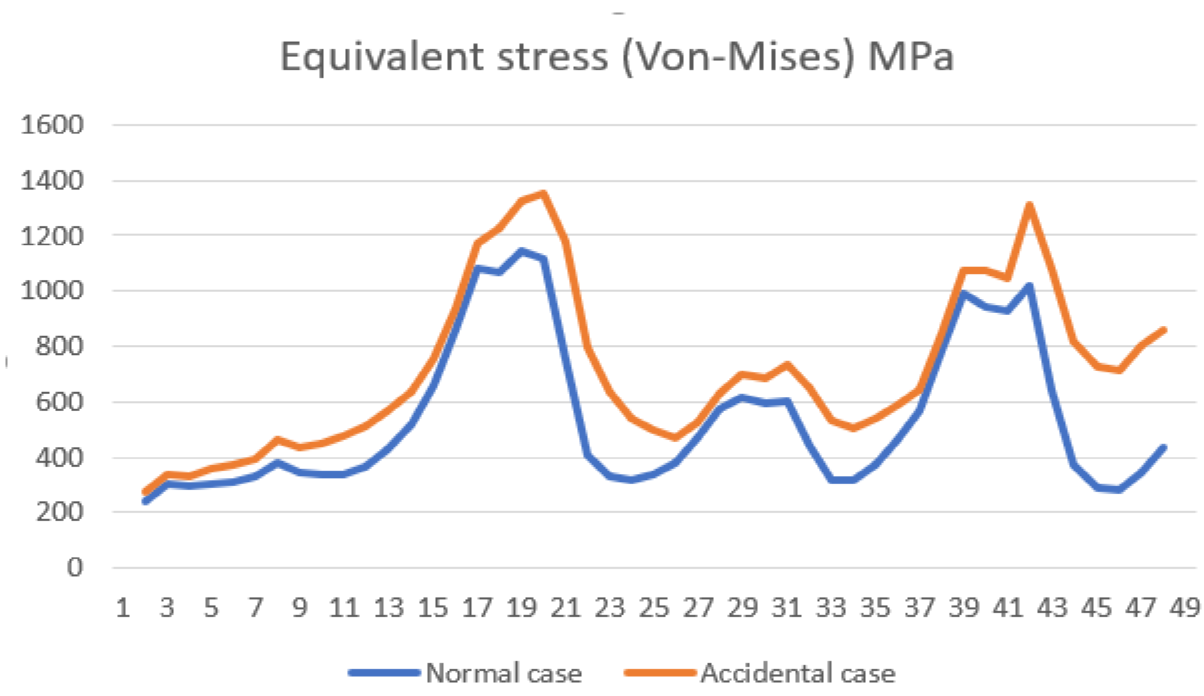


Fig 78: The equivalent stress Comparison between the normal case and the accidental case

We note that in cylinder head that

As we see in the graphs, there is not much difference between the two cases. This is due to the inefficiency of the cooling zone in our design.

The following table presents the maximum values (Ϭ Von-Mises, thermal deformation, the total displacement) of **Aluminum alloy**:

	value
Ϭ Von-Mises	3895.2 MPa
thermal deformation	2.9 %
total displacement	1.375 mm

Table 9: table presents the maximum

GENERAL CONCLUSION

GENERAL CONCLUSION

The work presented in this thesis tackled a thermomechanical study and modeling of a cylinder head for the purpose of ensuring proper operation of the engine cylinder head in automotive, avoid the increase and spread of temperatures, constraints thermomechanical and deformations and displacements.

We used an "aluminum alloy" cylinder head as the type of material used in the simulation, this choice is especially for its thermomechanical properties.

This end of study project allowed us to make a thermomechanical calculation on a model normal in aluminum alloy and an accidental calculation with an absence of coolant in the cylinder head, this shows that the combustion temperature has a direct impact like damage in the accidental case which gives a spread and an increase in the temperature throughout the cylinder head, the maximum equivalent stress (Von-Mises) is greater in this case that the constraint in the normal case, then the coolant has a principle to cool the engine temperature and thus avoid the risk of overheating which could cause irreparable damage.

In the future, we recommend testing with other materials that have elastic limits even higher than the material tested such as (gray cast iron, steel ...) and we recommend performing a test using other designs that have a larger cooling area with respecting cylinder head dimensions

the future student must design another reliable cooling circuit this for reduce the maximum Von Mises stress, he will also have to choose another more resistant aluminum alloy