THE EFFECT OF BILLET-BARREL TYPE THROTTLE ON AN INTAKE FLOW OF A THROTTLE BODY UNIT

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A report submitted
in fulfillment of the requirements for the Degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I declare that this project report entitle “The Effect of Billet-Barrel Type Throttle on An Intake Flow of A Throttle Body Unit” is the result of my own work except as cited in the references.

Signature	:	…………………………………...
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Date	:	

APPROVAL

I hereby declare that I have checked this report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature	:	……………………………………
Name of Supervisor	:	Dr. Faizul Akmar bin Abdul Kadir
Date	:	

DEDICATION

To my beloved family

ABSTRACT

Throttle body unit is a main component of air intake system in vehicle's engine, which is functioned to control quantity of air entering engine's combustion chamber. Common throttle body utilize the concept of butterfly valve. This concept however has a notable problem which is the plate and spindle that obstruct the air flow. This problem persist even at full throttle, causes flow restriction, which then leads to reduction of engine performance, induction of pressure drops and high pumping losses at high engine speed. In order to improve the engine performance, the newly billet-barrel throttle is designed to replace the current design of butterfly throttle as this design can eliminate flow restriction, which then reflects a high engine performance and high engine speed. The air flow pattern through billet-barrel throttle at idle throttle, partial throttle and full throttle are studied in order to know whether the newly billet-barrel throttle can improve the current butterfly throttle or not. Two concept design of billet-barrel throttle was designed using SolidWorks drawing software, then one of the best designs was choose through design selection method and imported to Ansys-Fluent to proceed the Computational Fluid Dynamic analysis. At the end of case study, the result of the case study was compared with conventional throttle body, which is butterfly throttle and the best design of throttle body was chosen at the end of research work. Four methods had been used in this research study, which are literature review by reviewing, analyzing and synthesizing information from previous study, designing newly billet-barrel type throttle using SolidWorks software, flow simulation analysis using Ansys-Fluent and lastly, comparison method in order to know whether newly billet-barrel type throttle can improve the current butterfly throttle or not especially at full throttle. Referring to major finding of this research study, billet-barrel throttle shows low performance at idle throttle due to high pumping losses at this throttle opening. At partial throttle, both throttle types have shown almost identical performance. However, at throttle opening beyond than 75°, billet-barrel throttle shows a significant performance enhancement with an increase of 39% in mass flow rate, which then reflects a better engine performance at this throttle opening. According to these findings, newly billet-barrel throttle can improve the current butterfly throttle as its resulting in high engine performance and high engine speed at full throttle.

ABSTRAK

Pendikit merupakan komponen utama dalam sistem pengambilan udara sesebuah enjin kenderaan, yang mana berfungsi untuk mengawal kuantiti udara yang masuk ke dalam injab pembakaran enjin. Pendikit kebiasaannya menggunakan konsep injab rama-rama. Namun begitu, konsep ini mempunyai sedikit kelemahan, yang mana plat dan gelendong menganggu aliran udara. Masalah ini sentiasa berlaku walaupon pada bukaan penuh pendikit, menyebabkan gangguan pada aliran udara, yang kemudiannya membawa kepada pengurangan prestasi enjin, aruhan penurunan tekanan dan peningkatan kehilangan kuasa mengepam pada kelajuan enjin yang tinggi. Untuk menambah baik prestasi enjin, pendikit tong bilet baru direka bentuk untuk menggantikan pendikit rama-rama yang digunakan sekarang memandangkan reka bentuk ini boleh menghapuskan gangguan pada aliran udara, yang kemudiannya membawa kepada peningkatan prestasi enjin dan kelajuan enjin. Corak aliran udara melalui pendikit tong bilet pada bukaan kecil pendikit, bukaan separuh pendikit dan bukaan penuh pendikit dikaji untuk mengetahui samada pendikit tong bilet baru mampu meningkatkan prestasi enjin mahupon tidak. Dua konsep reka bentuk pendikit tong bilet telah direka bentuk menggunakan perisian lukisan iaitu SolidWorks, kemudian satu konsep reka bentuk terbaik dipilih melalui kaedah pemilihan reka bentuk untuk dimasukkan ke Ansys-Fluent software untuk meneruskan analisis Pengiraan Dinamik Bendalir. Pada bahagian akhir kajian kes ini, hasil kajian kes kemudiannya dibandingkan dengan pendikit konvensional, iaitu pendikit rama-rama. Reka bentuk terbaik untuk unit pendikit dipilih di akhir kajian. Empat kaedah telah digunakan dalam kajian ini, iaitu tinjauan literatur dengan mengulangkaji, menganalisis dan mensintesis maklumat daripada kajian lepas, mereka bentuk pendikit tong bilet baru menggunakan perisian SolidWorks, analisis simulasi aliran menggunakan Ansys-Fluent dan akhir sekali, kaedah perbandingan untuk mengetahui samada pendikit tong bilet baru mampu menambahbaik pendikit rama-rama sekarang mahupon tidak, terutama pada bukaan penuh pendikit. Merujuk kepada penemuan utama daripada kajian ini, pendikit tong bilet menunjukkan prestasi yang rendah pada bukaan kecil disebabkan oleh kehilangan kuasa mengepam yang tinggi pada bukaan ini. Pada bukaan separuh pendikit, kedua-dua jenis pendikit menunjukkan prestasi yang hampir sama. Namun begitu, pada bukaan pedikit melebihi 75°, pendikit tong bilet menunjukkan peningkatan prestasi yang ketara dengan peningkatan kadar aliran jisim sebanyak 39%, yang kemudiannya menunjukkan prestasi enjin yang lebih baik pada bukaan ini. Menurut penemuaan ini, pendikit tong bilet baru mampu menambahbaik pendikit rama-rama sekarang memandangkan pendikit ini menghasilkan prestasi enjin dan kelajuan yang tinggi pada bukaan penuh pendikit.

ACKNOWLEDGEMENTS

First of all, I would like to express my deepest thank you to my supervisor, Dr. Faizul Akmar bin Abdul Kadir for giving me an opportunity to do my final year project under him. He never hesitated to guide and advise me whenever I confronted problems during completing this project. I am deeply thankful for his patience and advice while leading me in this project.

Secondly, I would like to express my special thanks to my course mates for giving me their support patience and encouragement, especially Nur Nazartul Ainna binti Nazarudin, who always share her knowledge about CFD analysis and guide me to use Ansys Workbench to simulate the air flow pattern.

Finally, I would like to thanks my family for their everlasting support and inspiration. Without them, I believe that I cannot end my final year project successfully.

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2D	Two-dimensional
3D	Three-dimensional
CFD	Computational Fluid Dynamic
CNC	Computer Numerical Control
DC	Direct Current
ETB	Electric Throttle Body
ETC	Electric Throttle Control
FEM	Finite Element Method
HOQ	House of Quality
PCM	Powertrain Control Module
PDEs	Partial Differential Equations
TPS	Throttle Position Sensor
WOT	Wide Open Throttle

LIST OF SYMBOLS

θ – Throttle opening angle

v_x – Velocity vector in x-direction

v_y – Velocity vector in y-direction

v_z – Velocity vector in z-direction

μ_e – Effective viscosity

ρ – Density

t – Time

g – Acceleration due to gravity

G_k – Turbulence kinetic energy due to mean velocity gradients

G_b – Turbulence kinetic energy due to buoyancy

Y_M – Fluctuating dilatation in compressible turbulence to the overall dissipation rate

$C_{1\varepsilon}$ – Constants

$C_{2\varepsilon}$ – Constants

$C_{3\varepsilon}$ – Constants

C_μ – Constants

σ_k – Turbulent Prandtl numbers for k

σ_ε – Turbulent Prandtl numbers for ε

S_k – User-defined source terms

S_ε – User-defined source terms

μ_t – Turbulent viscosity

CHAPTER 1

INTRODUCTION

In this chapter, an overview of the study is carried out to achieve the objective of the study. This chapter will briefly explain about the background of study, problem statement, objective of study and scope of study.

1.1 Background of Study

The throttle body unit is a part of the main components of air intake system in a traditional spark ignition gasoline engine, which is functioned to control the amount of air that flow into the engine's combustion chamber. The throttle body is located between the air filter and the intake manifold. This device contains the delicate throttle system that controls a key component of spark ignition, which is air flow to regulate the air-fuel mixture ratio required to ignite the combustion engine. An intake combustion engine categorized as an air pump; more air entering and exiting the engine, more power is generated to the engine.

Throttle body unit consists of housing unit that contains a throttle plate; usually butterfly valve type, which is rotate on the shaft when the driver pushes down the accelerator pedal. As noted by Arai et al. (2006), throttle valve is assembled in a bore wall part of the throttle body unit and rotate by a predetermined rotation angle, θ with respect to a rotation angle, 0° depending on its full close position. Usually, the throttle body unit made from alloy under CNC process to enhance it durability as it is one of high-performance component in automotive technology.

Older throttle body mechanism is design using mechanical moving parts and throttle plate is connected to the accelerator pedal via a cable. When the driver wants to drive the car faster, the driver presses the pedal, which is in turn pulls the cable and opens the throttle plate to allow the air enters the car's engine. Due to new technologies and the need for reduced emissions and increase efficiencies, most of the car nowadays use ETB, which is connected to the accelerator pedal without using any cables. This system takes the direct throttle control away from the driver and gives it to PCM. The PCM then analyses the inputs and the sensors on the vehicle (engine load, engine temperature, transmission, etc.), sends a command to the electric motor in the throttle body and placing throttle valve at the desired opening to allows the air flow into the engine. The desired opening of the throttle plate is determined by TPS that built in air intake system unit.

The butterfly throttle valve is a common throttle plate that used in automotive industry in order to regulate the flow due to its simplest design, lower in cost and lighter in weight (Balaji, et al., 2016). The butterfly valve has a disc, which is positioned in the center of the pipe with rod passing through it; this rod is connected to an actuator on the outside of the valve. Due to this design, the induction of pressure drop always occurs in the flow, regardless of valve position as the disc is always present within the flow. This type of throttle plate also may affect the engine performance as the pumping losses occur at high engine speeds even with the plate at full throttle position.

The current design of throttle body unit already fulfils the automotive technology requirements, but this design can be replacing with another type of throttle in order to improve the engine performance and fuel efficiency. Another design of throttle body that can be used to replace the butterfly type throttle are slide type throttle, IRIS concept throttle and billet-barrel type throttle. In this study, a research work is conducted to investigate the effect of the billet-barrel type throttle on an intake flow of a throttle body unit.

At the end of the research work, some comparison between the billet-barrel type throttle and butterfly type throttle had been done in order to decide the best throttle body type for car's engine.

1.2 Problem Statement

The butterfly throttle valve commonly used as a throttle plate for the throttle body unit due to its simplicity. The butterfly type throttle has spindle at the center of the valve which connected to an actuator on the outside of the valve. This design of throttle plate can restrict the airflow which leads to reduction of performance of the engine (Ashraf, et al., 2017) and induction of pressure drop due to disc always present within the flow even though at full throttle position (Balaji, et al., 2016). This design also affected the performance of the car's engine as some pumping losses occur at high engine speeds.

Due to these issues, the butterfly throttle valve still can be improving in order to achieve the best performance of the engine. One of the alternatives to improve the performance of the engine is by replacing the current throttle type with new design of throttle type. A research work is conducted to replace butterfly throttle type to a newly billet-barrel throttle type as the barrel-shaped throttle valve can eliminate the flow restriction at full throttle and high engine speeds (Ashraf, et al., 2017). In this research, the effect of the new type throttle on an intake flow of a throttle body will be investigate.

1.3 Objective of Study

There are few objectives that need to be achieved through this research work. Those objectives are:

i. To design a throttle body unit using billet-barrel type of throttle replacing butterfly type of throttle.

ii. To study about air flow pattern through the valve for idle, partial throttle and full throttle of the throttle body unit.

iii. To compare the result of the case study with conventional throttle body which is butterfly type of throttle.

1.4 Scope of Study

In order to achieve the objectives of the research work, few designs of throttle body unit, which is billet-barrel type of throttle has been designed and the air flow pattern through the valve for idle, partial throttle and full throttle of throttle body unit has been studied. A simple 3D model of billet-barrel type of throttle has been designed using SolidWorks and these designs will be used for this research only, without considering design packaging. Then, 2D steady state computational model is developed in ANSYS-FLUENT to investigate the flow pattern of the air through the valve. The throttle body unit of Proton Persona 1.6 has been used as benchmarks for the size of throttle body. The scope of research work only designing new type of throttle body and analyzing air flow pattern through the valve without considering material used, manufacturing process, temperature effect and manufacturing cost. At the end of the research work, the result of the best design of billet-barrel type throttle will be compared with conventional throttle body.

CHAPTER 2

LITERATURE REVIEW

This chapter will discuss the literature review, which done by reviewing, analyzing and synthesizing the information about throttle body and it flow characteristics from previous article, textbooks or journal. In completing this chapter, student have done some research about history of automobile, throttle body, computational fluid dynamic and the proposed design of billet-barrel type throttle design in order to understand this study deeply.

2.1 History of Automobile

Nyamwange (2014) describe an automobile as a wheeled vehicle that carries its own engine or motor that use as passenger transportation. Automobiles also called as motorcar or car, which designed to run primarily on road, have seating at least for one people; typically have four wheels and propelled by an internal combustion engine using volatile fuel. This definition had been supported by Dowlen (2013) which claims automobiles as vehicles powered by steam or electricity and those vehicles with different number of wheels.

The original idea of automobile invention cannot be attributed to a single individual as the idea certainly occurred long before it was recorded. According to Nyamwange (2014), an idea of the automobile innovation originates in Europe, not America and those who accept steam-powered road vehicles as automobile agree that Nicolas Cugnot was the first inventor of automobile. Nicolas Cugnot designs the military tractor with only three wheels and powered by a steam engine. This tractor became a first car invented as early as 1769 in France and it was functioned as haul artillery.

The idea of a self-propelled vehicle had been considered by Leonardo da Vincci in the 15th century and in 17th century, Otto von Guericke has invented an air engine, air pump and the basic components of the reciprocating engine, which are metal piston, cylinders and connecting rods. In the same century, Christiaan Huygens which is a Dutch inventor, produced an engine that worked by air pressure, which developed by explosion of powder charge. Denis Papin built a model engine using vacuum principle, which is use condensation of steam to produce the vacuum. In 1832, an air-powered vehicle has been produced.

2.2 Development of Internal Combustion Engine

According to Heitmann (2009), in 1860, Etienne Lenoir had invented an internal combustion engine that used illuminating gas (gas derived from heating coal in large retorts), which ignited by spark that generated from battery and coil. This type of engine called as two-stroke engine. Etienne Lenoir succeed in inventing a car powered by internal combustion engine and he proved that this car can work properly by drove it from Paris to Joinville in 1862. This internal combustion engine was noisy, inefficient and tend to overheat, but it performs better than a steam-powered engine.

Nicholas Otto interested to improve the performance of two-stroke engine as he observed this engine produce lack of punch and found that more power could be obtained by compressing the charge before feeding it into the cylinder. In order to improve the engine, Otto develops four-stroke cycle (intake, compression, power and exhaust), which called as Otto cycle. In four-stroke engine, fuel was drawn into the cylinder on intake stroke and ignited by spark, halfway on the next reciprocal stroke.

In 1885, Daimler used Otto cycle in a gas vapor engine, and he applied petrol engine to a motor car after following year. Karl Benz was said as a first inventor in gasoline engine car development for automotive industry. This car was built and running by water-cooled and single cylinder engine that developed about 0.8hp at 400 rpm, which categorized as fast for an engine performance during that time. According to Heitmann (2009), Emile Levassor was the key French inventor-engineer of the late nineteenth century as he uses Daimler's engine in designing vehicle which set the basic mechanical pattern for modern automobiles and placed this engine in front of vehicle body. Before he dies, Emile Levassor proved the merits on his design – that a vehicle of his design could be practical to use – in the 1895 Paris-Bordeaux-Paris race.

Internal combustion engine is used until now to power the vehicle and it's use petrol or diesel as fuel. This type of engine is widely used in automobile manufacturing as it provides high efficiency compare to steam-powered engine and electric-powered engine. In internal combustion engine, combustion process of air and fuel take place inside the cylinder engine (Ganesan, 2007) and heat is generated within the cylinder. Georgiev (2011) define an internal combustion engine as an engine, which chemical energy of the fuel is released inside the engine and used directly for mechanical work to rotate the wheels of car. When the fuel inside the engine cylinder is ignite, it generates high pressure and temperature, which then transferred the pressure force to the piston to rotate the wheels of car.

There are three major types of internal combustion engines. First type of internal combustion engine is a spark ignition engine, which is generally used in automobiles industries as it has overall high efficiency over external combustion engine. This engine also more compact than external combustion engine and required less space to place it in car's body. Second type of internal combustion engine is diesel engine, which is used in large vehicles and industrial systems. Another type of internal combustion engine is gas turbine, which is used in aircraft and stationary power generation.

According to Ganesan (2007), there are few types of internal combustion engine and its can be classified in few classes, such as number of strokes, design of engine, method of ignition, cylinder arrangement etc. The first classification of the internal combustion engine is number of strokes. Sridhar et al. (2013) defines stroke as a distance travelled by the piston inside the cylinder in one direction. Internal combustion engine has two types of stroke, which are two-stroke engine and four-stroke engine. In two-stroke engines, a piston moves one time up and down inside cylinder and complete one crankshaft revolution during single time of fuel ignite. The injected fuel is ignited for every two strokes of piston and produces power for every one rotation cycle of crankshaft (Sridhar, et al., 2013). This type of engine has high torque compare to four-stroke engines and generally, this type of engine used in scooter and pumping sets. Ganesan (2007) said four-stroke engine complete its cycle in four strokes of pistons or two revolutions of crankshaft during single time of fuel ignite. In simple word, the injected fuel is ignited for every four strokes of piston inside the cylinder and produce power for every two rotations crankshaft (Sridhar, et al., 2013). This type of engine generally used in bikes, cars and truck.

Next, the classification of internal combustion engine is design of engine which is reciprocating engine or rotary engine. Reciprocating engine also named as piston engine, which generate the pressure force by combustion of fuel to exert on the piston to starts reciprocating motion. The crankshaft converts reciprocating motion into rotary motion and finally rotate the wheels of the car. Besides that, rotary engine or Wankel engine is another design of internal combustion engine which has rotor and can rotate freely. Dhaval (2012) defines rotary engine as a type of internal combustion engine that use a rotor to convert pressure into rotating motion. The basic concept of this engine is to avoid reciprocating motion of piston with its inherent vibration and rotational-speed-related mechanical stress. In rotary engine, a combination of air and fuel is burned to generate pressure to force the pistons to move forth and back. Then, the connecting rods and crankshaft convert the reciprocating motion of pistons into rotational motion to power the car. According to Dhaval (2012), this type of engine widely used in variety of vehicles such as automobiles, racing cars, aircraft and go-carts as its design more compact and lightweight compare to reciprocating engine. Nowadays, it is no longer used in automobile industries.

Besides that, the internal combustion engine also can be classified by method of ignition, which are compression ignition engine and spark ignition engine. Both types of engine are quite similar but compression ignition engine operates at a much higher compression ratio, which is 16 to 20 to ignite fuel as this engine needs a high-compression ratio to self-ignite the fuel, while spark ignition engine only need 6 and 10 to ignite fuel (Ganesan, 2007). In compression ignition engine, air is inducted during suction stroke and the temperature at the end of compression stroke is rising to self-ignite the fuel. In spark ignition engine, combustion happens when a spark, which is generates by spark plug ignites the air-fuel mixture (Sridhar, et al., 2013) that injected into combustion chamber through intake manifolds and due to this fact, this engine called as spark ignition engine (Sridhar, et al., 2013). This engine also called as petrol or gasoline engine due to fuel that use in this engine. Kaminski et al. (2004) said combustion in spark ignition engine is a complex cyclic process which consist seven phases; air intake, fuel injection, compression, spark ignition, combustion, expansion and exhaust process. In the beginning of spark ignition engine development, this engine was observed as instable combustion which led to fluctuations of power output, making it difficult to control and this problem become the main issues in spark ignition engine technologies until 2003 (Kaminski, et al., 2004).