SIMULATION TEST OF AUTOMOTIVE INTAKE VALVE USING COMPUTER AIDED ENGINEERING SOFTWARE

HAFIERUL HAFIZ MD RAZI

UNIVERSITI MALAYSIA PAHANG

UNIVERSITI MALAYSIA.PAHANG

BORANG PENGESAHAN STATUS TESIS

JUDUL: **SIMULATION TEST OF AUTOMOTIVE INTAKE VALVE USING COMPUTER AIDED ENGINEERING SOFTWARE**

SESI PENGAJIAN: 2008/2009

Saya **HAFIERUL HAFIZ BIN MD RAZI**
(HURUF BESAR)

mengaku membenarkan tesis (PSM/Sarjana/Doktor Falsafah)* ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hakmilik Universiti Malaysia Pahang.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

☐ SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)

☐ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh Organisasi/badan dimana penyelidikan dijalankan)

☑ TIDAK TERHAD

Disahkan oleh

______________________________	______________________________
(TANDATANGAN PENULIS)	(TANDATANGAN PENYELIA)
Alamat Tetap:	Nama Penyelia:
NO 2429 LRG JGT 4/2	**MOHD RASHIDI BIN MAAROF**
TAMAN RIA JAYA, 08000 SUNGAI PETANI	
KEDAH DARUL AMAN	
Tarikh: ____________________________	Tarikh: ____________________________

CATATAN: * Potong yang tidak berkenaan
** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT atau TERHAD
υ Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah dan Sarjana secara penyelidikan, atau disertasi bagi pengajian secara kerja kursus dan penyelidikan, atau Laporan Projek Sarjana Muda (PSM)

SUPERVISOR DECLARATION

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

Signature :...
Supervisor : MOHD RASHIDI BIN MAAROF
Date :...

SIMULATION TEST OF AUTOMOTIVE INTAKE VALVE USING COMPUTER AIDED ENGINEERING SOFTWARE

HAFIERUL HAFIZ BIN MD RAZI

A report submitted in partial
requirements for the award of the degree of
Bachelor of Mechanical Engineering with Automotive Engineering

Faculty of Mechanical Engineering
Universiti Malaysia Pahang

NOVEMBER 2008

I declare that this thesis entitled *Simulation test of automotive intake valve using computer aided engineering software* is the result of my own research except as cited in references. The thesis has not been accepted for any degree is not concurrently submitted in candidature for any other degree.

Signature :………………………….
Name : HAFIERUL HAFIZ BIN MD RAZI
Date : 14 NOVEMBER 2008

To my beloved mother and father,

Mr. Md Razi Bin Abd Hamid

Mrs. Jamaliah Binti Abd Razak

ACKNOWLEDGEMENT

In preparing this thesis, I was in contact with many people and academicians. They have contributed toward my understanding, thought, and also guidance. In particular, I wish to express my sincere appreciation to my main thesis supervisor, Mr Mohd Rashidi Bin Maarof for his valuable guidance, advice and continuous encouragement, constructive criticism and suggestion throughout this project. Without his continued support and interest, this thesis would not have been the same as presented here.

My sincere also extends to all my beloved family especially my mother Jamaliah Binti Abd Razak because if not of his prayer and support I would not be here and done this thesis. Moreover, I would like to thanks for all my colleagues and other who has provides assistance at various occasions. Their view tips are useful indeed in helping me to achieve doing this thesis. Without all of you this thesis will not be an accomplishment.

ABSTRACT

Analysis of stress with different material in intake valve is the main purpose of this project. This research was carried about the stress impact in intake valve head where the most wear would occur at particular different RPM. The study of this thesis is based on previous research in intake valve stress and fatigue by experiment. Without actual experiment, intake valve stress can be analyzing by simulation using ALGOR software and specific RPM with specific maximum cylinder pressure can be calculated via GT-POWER software. Three most common intake valve materials was tested to be compared between stress which are common steel intake valve material, ceramic intake valve material and titanium alloy intake valve material. The best material for intake valve within the three material tested would be titanium alloy intake valve. Titanium alloy material properties shown a very low impact of Von Mises Stress 173.6537 Mpa compared to ceramic intake valve 184.1683 Mpa and steel intake valve 179.0992 Mpa at the constant given load 16614.9411 N in 2000 RPM and temperature 300^{o}C. The stress effect at intake valve seat showed the highest stress impact of Von Mises Stress at all intake valve material. It also shown a possible of wear happened in a form of ring around intake valve seat.

ABSTRAK

Analisa mengenai tekanan pada injap masuk injin adalah tujuan utama projek ini. Kajian ini dibuat mengenai tekanan terhadap kepala injap masuk dimana kehausan dijangkakan berlaku pada putaran injin yang berbeza. Informasi mengenai tesis ini adalah berpandukan kajian terdahulu mengenai tekanan injap masuk dan kejerihan injap masuk. Tanpa experimen, tekanan di injap masuk boleh dianalisa menggunakan perisian ALGOR FEMPRO dan puncak tekanan didalam silinder dapat dicari menggunakan perisian GT-POWER. Tiga bahan injap masuk yang lazim digunakan telah diuji dan dibandingkan tekanannya iaitu injap masuk yang terdiri daripada injap masuk keluli tahan cacat, injap masuk seramik, dan injap masuk campuran titanium. Bahan injap masuk yang terbaik ialah dari campuran titanium. Bahan dari campuran titanium menunjukkan kesan terendah terhadap tekanan Von Mises Stress iaitu cuma 173.6537 Mpa jika dibandingkan dengan injap masuk seramik 184.1683 Mpa dan injap masuk keluli tahan cacat 179.0992 Mpa berdasarkan beban 16614.9411 N dan suhu 300^{o}C. Kesan tekanan terhadap bahagian *seat* injap masuk menunjukkan kesan tekanan Von Mises yang tertinggi kepada semua jenis bahan. Ia juga menunjukkan kemungkinan kehausan berlaku dalam bentuk cincin sekeliling *seat* injap masuk.

TABLE OF CONTENT

CHAPTER	TITLE	PAGE
	DECLARATION	**ii**
	DEDICATION	**iii**
	ACKNOWLEDGMENT	**iv**
	ABSTRACT	**v**
	ABSTRAK	**vi**
	LIST OF TABLE	**x**
	LIST OF FIGURE	**xi**
	LIST OF SYMBOL	**xiii**
	LIST OF ABBREVIATION	**xiv**
	LIST OF APPENDIX	**xv**
1	**INTRODUCTION**	
	1.1. General Overview	1
	1.2. Problem Statement	2
	1.3. Project Objective	3
	1.4. Scope of Project	3
	1.5. Flow Chart of this Project	4
2	**LITERATURE REVIEW**	
	2.1 Combustion Fundamental in Four stroke engine	5
	2.1.1 Intake stroke	5
	2.1.2 Compression Stroke	6
	2.1.3 Power Stroke	6
	2.1.4 Exhaust Stroke	7

	2.2	Gas Exchange Process	8
	2.3	Exhaust Process	9
	2.4	Intake process	10
	2.5	Volumetric Efficiency	10
	2.6	Type of Valve	11
	2.7	Poppet Valve	13
		2.7.1 Intake Valve	14
		2.7.2 Exhaust Valve	15
	2.8	Valve Seat	16
	2.9	Valve material	16
	2.10	Combustion Process	19
3	**METHODOLOGY**		
	3.1	Project Methodology	21
	3.2	First stages: Literature Study	23
	3.3	Second Stage: Make 3D modeling of Intake Valve	24
		3.3.1 Measurement of Intake Valve	24
		3.3.2 Drawing and Design in Solid work	25
	3.4	Third Stage: Analyzing using GT-POWER simulation	26
	3.5	Forth Stage: Analysis using ALGOR FEMPRO	28
		3.5.1 Simulation Boundary Setting	29
		3.5.2 Creating the Computational Mesh	29
4	**RESULT AND DISCUSSION**		
	4.1	Result	32
	4.2	Comparison Result of Experiment and Simulation	33
	4.3	Intake Valve Material AISI 405 Stainless Steel Stress And Displacement	35
		4.3.1 Material properties effect of AISI 405 stainless steel	35
		4.3.2 The Affect of Von Mises Stress AISI 405 Stainless Steel	36
	4.4	Intake valve material Sapco Silicon Nitride (Si3N4) stress and displacement	38

4.4.1 Material properties effect of ceramic Sapco Silicon Nitride (Si3N4) 38
4.5 Intake Valve Material Titanium Alloy (6A1-4V) Stress And Displacement 41
4.5.1 Properties of Titanium Alloy 41
4.6 Summary of the result and comparing between three material stress and displacement 44

5 CONCLUSION AND RECOMMENDATION
5.1 Conclusion 47
5.2 Recommendation 48

REFFERENCES 49

Appendix A-B2 51-53

LIST OF TABLE

TABLE NO.	TITLE	PAGE
2.1	Valve head diameter in term of cylinder bore	14
4.1	Von Mises Stress and Nodal displacement magnitude for Stainless Steel AISI 405	38
4.2	Von Mises Stress and Nodal displacement for Sapco Silicon Nitride (Si3N4)	41
4.3	Von Mises Stress and Nodal displacement magnitude for Titanium Alloy 6A1-4V	44

LIST OF FIGURE

FIGURE NO.	TITLE	PAGES
2.1	Intake stroke	6
2.2	Compression stroke	6
2.3	Power stroke	7
2.4	Exhaust stroke	7
2.5	Geometry of poppet valve	13
2.6	Intake valve design geometry	15
2.7	Exhaust valve design geometry	16
2.8	Intake valve head and intake valve seat area	20
2.9	Intake valve stress impact and location	20
3.1	Flow Chart of Methodology	22
3.2	Step to develop Intake Valve 3D drawing	24
3.3	SolidWorks drawing of intake valve	26
3.4	GT-POWER diagrams of Daihatsu 660 engine	27
3.5	Simulation in ALGOR FEMPRO software	28
3.6	Selection of mesh percentage	30
3.7	Boundary condition and loading	31
4.1	Selecting the mesh percentage and verified the result	34
4.2	Result of Von Mises Stress for 2000 RPM stainless steel AISI 405	36
4.3	Result of nodal displacement magnitude for 2000 RPM Stainless Steel AISI 405	37
4.4	Result of Von Mises Stress for 2000 RPM of Silicon Nitride (Si3N4)	39
4.5	Result of nodal displacement magnitude for 2000 RPM of Silicon Nitride (Si3N4)	40
4.6	Result of Von Mises Stress for 2000 RPM of Titanium Alloy 6A1-4V V	42

4.7	Result of nodal displacement magnitude for 2000 RPM of Titanium Alloy 6A1-4V	43
4.8	Graph of Maximum Von Mises Stress of the three material Vs rpm	46

LIST OF SYMBOLS

%	percentages
B	bore
D	diameter
L	lift
R	fillet radius
Ø	cone angle
Ψ	seat angle

LIST OF ABBREVIATION

BDC	Bottom Dead Center
CAD	Computational Aided Design
CAE	Computer Aided Engineering
TDC	Top Dead Center
3D	Three Dimensional
kPa	Kilo Pascal
mm	millimeter
RPM	Revolution per minute
FEA	Finite element analysis

LIST OF APPENDIX

APPENDIX	TITLE	PAGE
A	Daihatsu 660 engine specification	51
B1	Gantt chart for FYP 1	52
B2	Gantt chart for FYP 2	53

CHAPTER 1

INTRODUCTION

1.0 General Overview

On 3cylinder 4-stroke engine like the Daihatsu 660 used in Perodua Kancil there is a process of combustion process. This occur during the power stoke where air-fuel mixture been ignite by sparks plug and combust pushing the piston down to bottom depth center.

The combustion process in the engine producing high pressure and load affect the combustion chamber which include intake valve head and exhaust valve head in certain range of maximum pressure and temperature. At maximum combustion load in the intake valve seat and intake valve head would damage the valve if the valve material is not chosen properly. High stress impact on the valve head could course valve wear and the valve might be not tightly close.

So to improve the stress impact different material can be choose as different material have their specific ultimate tensile strength that can stand again stress at different loading impact. The material chosen for intake valve must also withstand temperature about 300^{o}C. In order to investigate the combustion chamber stress impact on intake valve head some variable must be put constant. The temperature and design of the intake valve is been set constant as the loading impact is increase according to specific RPM and specific maximum combustion chamber pressure for the Daihatsu 3 cylinder 4-stroke engine.

The best way to investigate and test the stress impact on intake valve head is by using simulation via computer aided engineering software. ALGOR Fempro is the best software available to investigate stress analysis. Three different intake valve materials can also be selected using ALGOR software. The GT-POWER software can provide the information of maximum combustion chamber at different RPM.

1.2 Problem Statement

Nowadays the performance of engine is depends on the valve train instability which limits the engine speed. Component breakage and excessive wear will occur in the valve train if it is operated in an unstable mode. The major component of valve train instability is the valve weight itself. Different material would course different valve weight, stress impact and life cycle of an intake valve.

However, to analyze the stress impact on intake valve there are several parameter that need to be considered. The parameter is the material for intake valve must have high ultimate tensile strength as intake valve experienced high cylinder pressure and high temperature during combustion process. Three material selected are tested in ALGOR software and compared between Von Mises Stress. The best material out of three selected material is to be choose.

1.3 Project Objective

Basically the main purpose in accomplishing this task are stated below

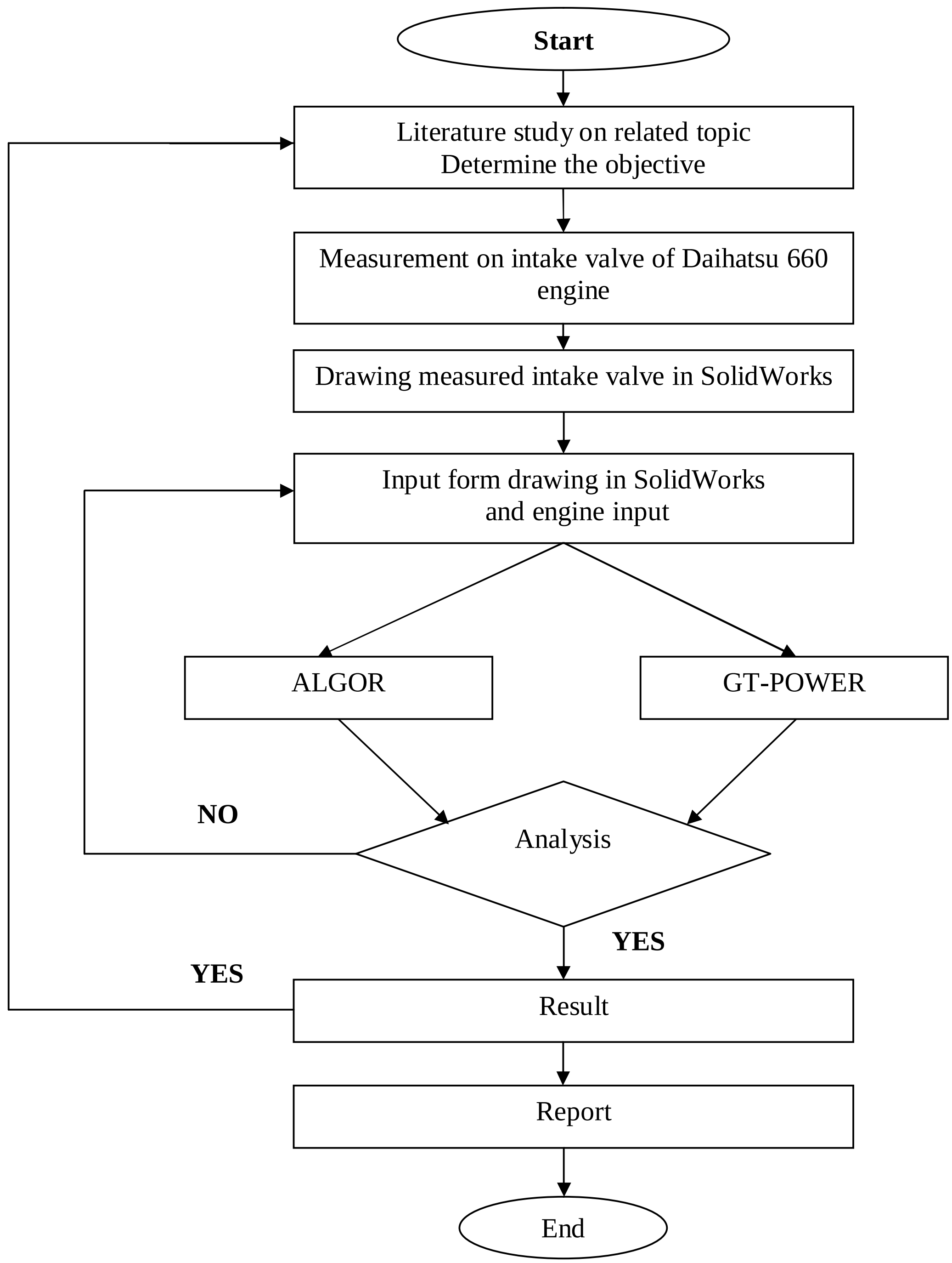
i. To investigate the stress in intake valve using CAE software.
ii. To compare the maximum stress between 3 different material of intake valve.

1.4 Scope of Project

The scope of this project is focusing on the criteria that stated below

i. The most common intake valve for engine below 1.6cc is chosen
ii. Combustion chamber effect in intake valve head was considered
iii. 3 most common intake valve materials were chosen.
iv. Only static stress analysis with different material model using CAE software was considered.

1.5 Flow Chart of This Project



CHAPTER 2

LITERATURE REVIEW

2.1 Combustion Fundamental in Four stroke engine

Four stroke engine also known as Otto Cycle because The German engineer Dr. Nikolaus August Otto (b. June 10, 1832 - d. January 26, 1891) developed the four-stroke internal-combustion engine, which offered the first practical alternative to the steam engine as a power source [1]. On four stroke engines there are four phases of operation per cycle, each corresponding to an upward or downward stroke of a piston [3]. The detail of each phase within the four stroke engine is as follows:

2.1.1. Intake stroke ; on this stoke it will begin with the piston in Top Dead Center (TDC) position during the piston goes downward the fresh air- fuel mixture was drawn into the cylinder and finished at Bottom Dead Center (BDC) [2].During this phase the intake was start open 12 degree before TDC and its still remain for 56 degree past BDC after this stroke ends this to give more air fuel mixture to flow into the cylinder [3].

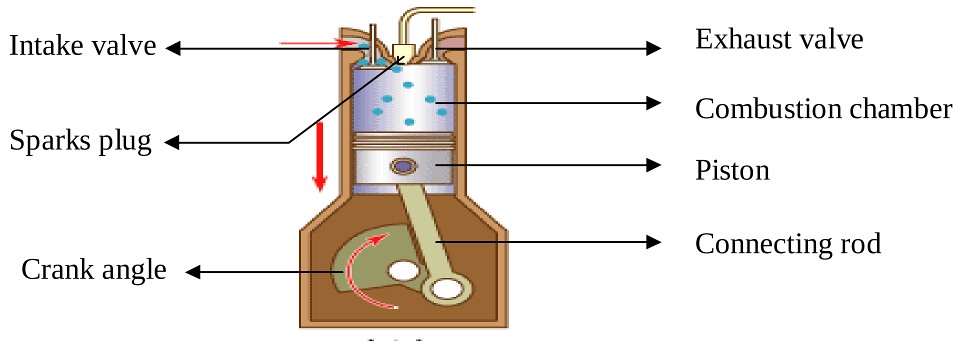


Figure 2.1 Intake stroke [6]

2.1.2. Compression Stroke; for this stroke the both valve was close and the piston moves back to TDC. During the moves of piston upward the fresh air-fuel mixture was compress until the TDC then the spark is induce which is to initiate combustion and the pressure in cylinder rises during this combustion process [3].

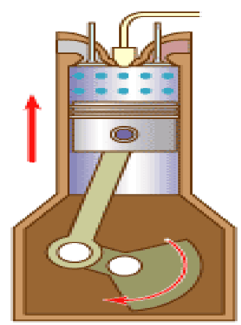


Figure 2.2 Compression stroke [6]

2.1.3. Power Stroke ; it is also known as expansion stroke, in this stroke the piston goes downward to BDC and drives the cranks of the engine to give power to the drive train. The fact that it happen because during the combustion process the pressure rapidly increase that push the piston to goes downward [3].

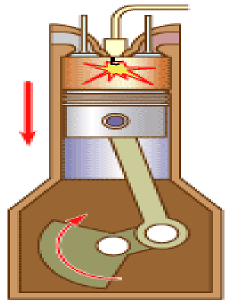


Figure 2.3 Power strokes [6]

2.1.4. Exhaust stroke ; This is when the gas burn from the power stroke was bring out from cylinder trough the exhaust valve because the cylinder pressure is higher than exhaust port pressure. At this stroke the valve start open at 47 degree before BDC on the power stroke this is for give more time for the exhaust gases to leave the cylinder [3].

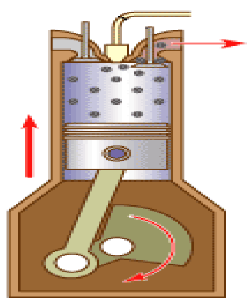


Figure 2.4 Exhaust strokes [6]

During this four stroke engine phase there is occur gas exchange in the intake and exhaust stroke. The gas exchange process will be discussed in the new sub topic.

2.2 Gas Exchange Process

The gas exchange process occurs on intake and exhaust stroke. The purpose of intake is to admit the fresh charge for the next cycle and for the exhaust is to remove the burned gases at the end of the power stroke [1]. The indicate power of an internal combustion engine at given speed is proportional to the mass flow rate.

During this process there is subsystem that should be consider like intake and exhaust manifold, intake and exhaust port and valve lift and geometric design. All of this system could give an effect to this process. Because, if the process not work sufficiently the performance of engine will decrease because of the charging and expelling the fuel and gases not flow properly. So it will influence the volumetric efficiency when charging the fresh fuel.

During the exhaust process, the gas exchange process is to retaining the mass of the fuel to flow into the cylinder so the pressures on the cylinder not reduce. This higher pressure in exhaust process is needed to fully expel the burn gases to prevent it from producing the emission.

The primary goal of the gas exchange process are the inducting maximum air mass at the wide-open throttle or full load and retaining that mass within the cylinder [1].

2.3 Exhaust Process

Exhaust process is to expel the burned gases from the cylinder to the exhaust manifold. This process consist two steps blow down and exhaust stroke .During the exhaust valve open near the end of the expansion stroke the high temperature gases suddenly subjected to a pressure decrease as the resulting blow down occur [5].

A large percentage of gases leave the combustion chamber during the blow down process that was driven by the differential across the open exhaust valve. But there is still had exhaust gases at the cylinder.

The gases then pushed out from the cylinder trough the valve when the valve exhaust still open by the piston that travels from Bottom Dead Center (BDC) to Top Dead Center (TDC) during the exhaust stroke.

During the blow down process the gas leaving the combustion chamber by it kinetic energy due to high velocity flow trough the exhaust valve. But at the end of the process there is still a residual gas trapped in the clearance volume on the cylinder [5].

Therefore, there is losing power during through back pressure. The exhaust valve opens at the beginning of the exhaust stroke, and then the piston pushes the exhaust gases out of the cylinder. If there is any amount of resistance that the piston has to push against to force the exhaust gases out, power is wasted. Using two exhaust valves rather than one improves the flow by making the hole that the exhaust gases travel through larger.

The residual gas will mixed with the new incoming charge of air and fuel is carried out during the intake process [5].

2.4 Intake Process

Intake process is the system that to deliver the proper amount of air and fuel into the cylinder with right accuracy and equally to all cylinders at the proper time in engine cycle [5].

On this process consist intake manifold, throttle, intake valve and either fuel injector or carburetor to add fuel [5] and during the induction process it will flow trough to this component system.

During this process the pressure drop in the intake system is depends on engine speed the flow resistance of the element in the system and the cross sectional area for charge the fresh air fuel mixture through the valve. In usually practice to improve the charging for intake and emptying for exhaust stroke in cylinder and make the best inertia of gases in both stroke by extend the valve open phase beyond the intake and exhaust stroke [1].

In intake manifold, inside the diameter of the runner must be large enough to reduce high flow resistance through inlet valve and increase the volumetric efficiency.

2.5 Volumetric Efficiency

Volumetric efficiency is a ratio (or percentage) of what volume of fuel and air actually enters the cylinder during induction to the actual capacity of the cylinder under static conditions. Besides that volumetric efficiency is used as an overall measure of the effectiveness of four stroke cycle engines and its intake and exhaust system as an air pumping device [1]. It is desirable to have maximum volumetric efficiency in the intake of any engine [5].

There are many physical and operating variables that could affect the volumetric efficiency. One of it is closing intake valve after BDC .It was the timing of closure the intake valve that could affect the amount of air enter the cylinder.

When intake valve is open and the piston is moving from TDC to BDC. The air was pushed into the cylinder trough the open valve due to create vacuum by the additional volume being displaced by the piston [5].

There is a pressure drop in the air when it passes through the intake valve and the pressure in the cylinder is less than the manifold pressure. This different pressure is to allow the air to enter the cylinder by flow through the valve.

2.6 Types of Valves

A valve is a mechanical device that is used to control the volume of flow and pressure of fluids. Closing, opening, or partially opening a passage through which the fluid passes regulates this flow. Valves are used in areas of commercial applications, domestic and process applications, automobiles, hydraulic presses, medical equipment and many more.

There is a lot of type valve design. Many of these valves serve to control the pressure of fluids and are known as pressure-control valves. There is a lot of type of valve and it can identified by it names and use. Below is the type of valve and the usage.

i. Butterfly Valves have circular plates attached to a shaft resembling wings of butterfly, hence the name. The shaft has a handle that can be turned so that the wings obstruct the water passage. The wings are immersed in the water and this causes a pressure drop. These valves are used in water supply systems for flow control.

ii. Gate Valves are used in process industries for full open or full close systems. It has a rectangular or round gate fitted to a stem, which is enclosed in a threaded housing. The gate allows the flow when stem is raised and stops when it is lowered. It was use in high-pressure lines like steam turbines.

iii. Globe Valves have a spherical body shape with two mating halves. A baffle with a central disc separating the two halves is placed in housing. A screw handle controls the rate of flow. They are used in high frequency throttling applications. The whole assembly was mounted in a bonnet to make it leak proof.

iv. Check Valves allow flow in only one direction. These are used in chemical process plants, water purification plants, petrochemical industries where the processed fluid is made to flow into a low-pressure area. These valves prevent reverse flow of the fluid and hence avoid contamination.

v. Solenoid Valves are used in machine tool hydraulics and heavy earthmoving equipment. It has a loop of wire, wrapped around a metallic core and when current is passed, it creates a magnetic field. The magnetic field is used to open or close plungers in flow lines to quickly open or close the flow.

vi. Flow Control Valves are used to automatically maintain a constant flow rate. They can be controlled by a calibrated flow meter or temperature and pressure gages. The gages can be preset to the desired flow rate. When the actual flow rate varies from the present value, the gages will adjust the flow. These devices are used in complex chemical and petrochemical plants where manual adjustment of flow is not feasible since there may be thousands of such valves.

vii. Poppet Valves are used to control the flow of exhaust and intake gases in automobiles. These valves are controlled by the camshaft and other devices and need to be very accurate and durable over extended use at high temperatures.

2.7 Poppet Valve

Most internal combustion engine use poppet valve. The position of this valve is the top of the cylinder head. This valve was use because of their ability on reduce the power loses and flow through the valve compare to ring type valve and plate valve. The result can be seeing at the table below.

.

Besides that, the poppet valve is inexpensive and has a good sealing so that why it become the famous choice. Figure 2.5 shown the geometric of poppet valve

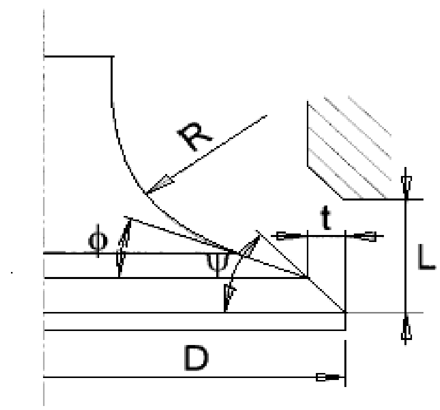


Figure 2.5 Geometry of poppet valve

Valve seat is the surface against which an intake or an exhaust valve rests during the portion of the engine operating cycle when that valve is closed. Valve stem is the long rod at above of the valve head diameter. This valve stem is used to push down on the valve and open it that push by camshaft. There is two type of the poppet valve on the combustion engine.

2.7.1 Intake Valve

For valve head diameter for intake and exhaust is different, intake is larger than exhaust because to increase the volumetric efficiency to the combustion chamber. This valve head design should consider the type of the combustion chamber. Table 2.2 below shown valve head diameter design in term of cylinder bore.

Table 2.1: Valve head diameter in term of cylinder bore

Combustion Chamber Shape	Inlet	Exhaust	Approximate mean piston speed,max power m/s
Wedge or Bathtub	0.43-0.46B	0.35-0.37B	15
Bowl-in-piston	0.42-0.44B	0.34-0.37B	14
Hemispherical	0.48-0.5B	0.41-0.43B	18
Four-valve pent-roof	0.35-0.37B	0.28-0.32B	20

The angle of valve surface at the interface with the valve seat is generally design to give minimum flow restriction as the airflow around the corner the stream lines separate from the surface and the cross section area of flow is less than the passage area. Usually valve angle of intake is 30 degree for give flow restriction and give more flow to the cylinder. The actual flow area to the flow passage area is called valve discharge coefficient.

Shape and angle of valve surface are sometimes design to give special mass flow patter to improve overall engine efficiency. Besides that the design of two or three valve is to give more flow area and less flow resistance. The intake valve design geometry shown in Figure 2.6 in the next page.

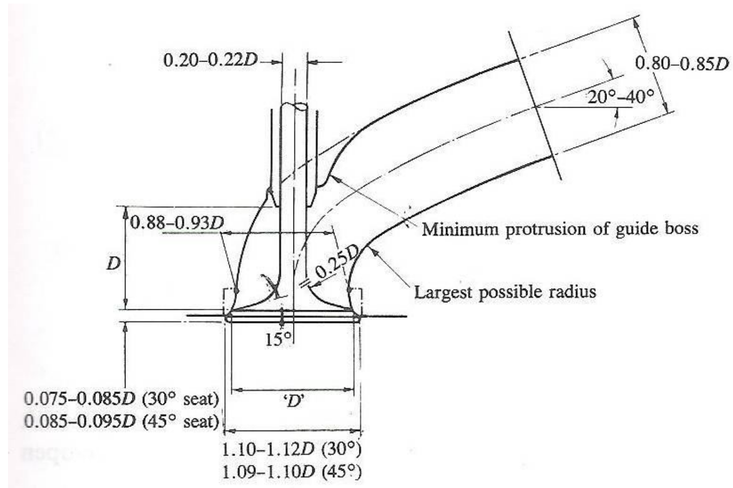


Figure 2.6 Intake valve design geometry

2.7.2 Exhaust Valve

Exhaust valve is smaller than intake valve. The valve is smaller because the small head diameter is enough to expel the burn gas from the chamber. The valve face angle of valve usually 45 degree it is to close tightly with valve seat than could transfer heat to the valve seat.

By change, the geometry of the poppet valve will affect the flow through the valve that affect on discharge coefficient. Discharge coefficient is defined as the linear relationship between an actual flow rate and ideal flow rate of a compressible flow. The exhaust valve design geometry shown in the Figure 2.7**.** However, flow through the intake valve is the main purpose in design valve because it will influence the volumetric efficiency during intake stroke.

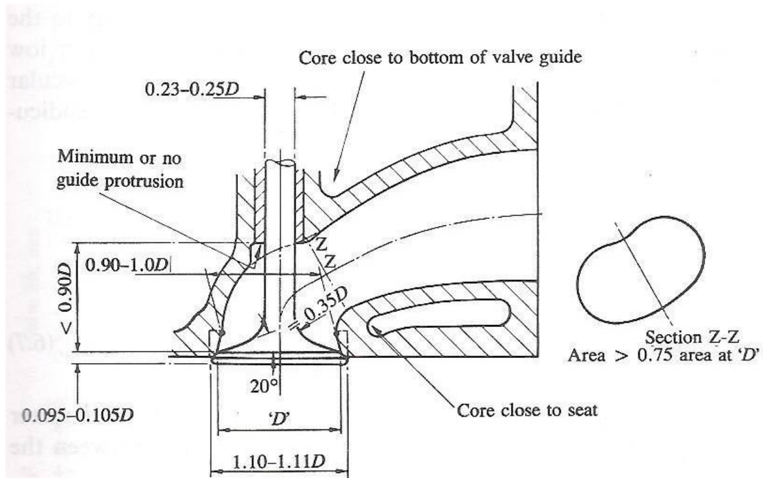


Figure 2.7 Exhaust valve design geometry

2.8 Valve Seat

The intake valve seat place is where the valve is tightly close connecting the valve head to the seating. The valve and seat insert must allow the inner side of the cylinder to be tightly sealed and the working fluid to be exchanged smoothly. While the engine is in operation, the valve seating face makes direct contact with the seat insert seating face. The contact between the two seating faces causes wear and the wear of both faces reduces the sealing ability of the valve and seat insert [2].

2.9 Valve Material

There are essentially two basic type of steel used to make valves. One is martensitic steel and the other is austenitic steel. The difference is in the microstructure of the steel and how the various ingredients in alloy interact when the molten steel is cast and cooled. This effect not only the hardness and strength of the steel, but also its corrosion resistance and magnetic propertied. Different material properties of intake valve also would have different stress impact and different ultimate tensile strength. Martensitic steels are magnetic while austenitic steels are non-magnetic [15].

In martensitic steel, the steel is “quenched”(cooled) very quickly from a molten state to freeze the grain structure in a particular configuration. Under microscope, the grain structure has a needle-like (acicular) appearance. This makes the steel very hard but also brittle. Reheating and cooling the steel (a process called tempering) allow some of the martensite crystals to rearrange themselves into other grain structures which are not as hard or brittle. The hardness and tensile strength of steel can be fine tuned by carefully controlling the heat treatment and quenching process to achieve the desired properties.

Steel alloy with martensitic grain structure typically have a high hardness at room temperature after tempering, which improves strength and wear resistance. These characteristic make this type of steel a good choice for application such as engine valve. As the temperature goes up, martensitic steel loses hardness and strength. Above 1000^{o}F or so, low carbon alloy martensitic steel loses too much hardness and strength to hold up very well. For this reason, low carbon alloy martensitic steel is only used for intake valves, not exhaust valve. Intake valve are cooled by the incoming air/fuel mixture and typically run around 800oF to 1000oF, while exhaust valve are constantly blasted by hot exhaust gases and usually operate at 1200^{o}F to 1450^{o}F or higher [15].

To increase high temperature strength and corrosion resistance various element may be added to the steel. On some passanger car and light truck engines, the original equipment intake valves are 405 stainless steel intake valve with manganese added to improve corrosion resistance. For higher heat application, a 8440 alloy may be used that contain chromium to add high temperature strength. For many late model intake valve are made of an alloy called Silchrome 1 (Sil 1) that contain 8.5% chromium.

Exhaust valve may be made from martensitic steel with chrome and silicon alloys or a two piece valve with stainless steel head and martensitic steel stem. On application of higher heat requirements, a stainless martensitic alloy may be used. Stainless steel alloys as a rule contain 10% or more chromium.

However the most popular exhaust valve material comes from austenitic stainless steel alloys such as 21-2N and 21-4N. Austenite forms when steel is heated above a certain temperature which varies depending on the alloy. The austenitizing temperature ranges from 1600^{o}F to 1675^{o}F which is above the temperature where hot steel goes from red to nearly white. Chromium is added to increase corrosion resistance. The end product is an alloy that may not be as hard at room temperature as a martensitic steel but is much stronger at the high temperatures at which exhaust valve commonly operate.

The same alloy can be used for both intake valve and exhaust valve but the best result are usually obtained when different alloys are selected for the intake and exhaust valve. It is because that and exhaust alloy that has good high temperature strength and corrosion resistance are not needed on the intake side. It may not have the hardness and wear resistance of an intake alloy at lower temperature. Intake valve run cooler and washed with fuel vapors which tend to rinse away lubrication on the valve stem. So for intake valve wear resistance may be more importance than high temperature strength or corrosion resistance if the engine will be involved in any kind of endurance racing. Exhaust valve on the other hand run much hotter than the intake valves and must withstand the corrosive effect of hot exhaust gases and the weakening effect of high temperatures. Consequently a premium valve material is an absolute must on the exhaust side especially in turbocharged and supercharged engines and those that inject oxide to boost power.

As combustion chamber temperature goes up, valve alloy that work fine in a stock engine may not have the strength, wear or corrosion resistance to hold up in a performance application. Intake valve material must be upgraded into performance valve material for performance application. Materials that may be used for performance application include carbon steel alloys, stainless steels, high strength nickel-chromium-iron alloys, ceramic, and titanium. The alloy that most common used for performance in intake valve is titanium alloy and ceramic.

Titanium is often viewed as the ultimate valve alloy material because of its lightness. Titanium is about 40% lighter than steel, making it a good alternative for high revving engine. Lighter valve also allow more radical cam profiles that open and close the valves more quickly for better off the line performance and low end torque. The durability of titanium is similar to that of stainless steel. But from a cost standpoint, titanium is way beyond any steel alloy as a single titanium valve may cost RM231-RM297 or more. Thus titanium alloy are usually used in performance car racing and some motorcycle engine only [15].

Ceramic thermal barrier coatings may also be applied to the combustion side of the head to reflect heat back into the combustion chamber. The theory here is that a heat reflective coating helps the valve run cooler. This helps the exhaust valves run cooler and last longer, and reduces heat transfer from the intake valves to the incoming air/fuel mixture for a denser, more powerful mixture. Heat reflected back into the combustion chamber also improves burning efficiency and power. Ceramic material also developed for turbo-charger turbine wheel and combustion engine valve. Ceramic have magnificent light weight properties in intake valve where ceramic is 60% lighter than steel intake valvel [4].

2.10 Combustion Process.

In the power stage of engine cycle it happened to be the combustion process where sparks ignite around 10^{o}ATDC. The cylinder pressure is at peak due to the burning of chemical reaction of the fuel-air mixture. High pressure in the cylinder then pushing the piston to bottom depth center. The pressure does not push the cylinder but also push the entire component in the combustion chamber wall including the head of intake valve surface.

The maximum pressure in cylinder for 4 stroke cycle is about 45 bar to 50 bar. This high pressure push the valve surface creating a high stress plus with temperature around 300°C to 500 °C creating a possible break down or wear mechanism in the intake valve surface [1]

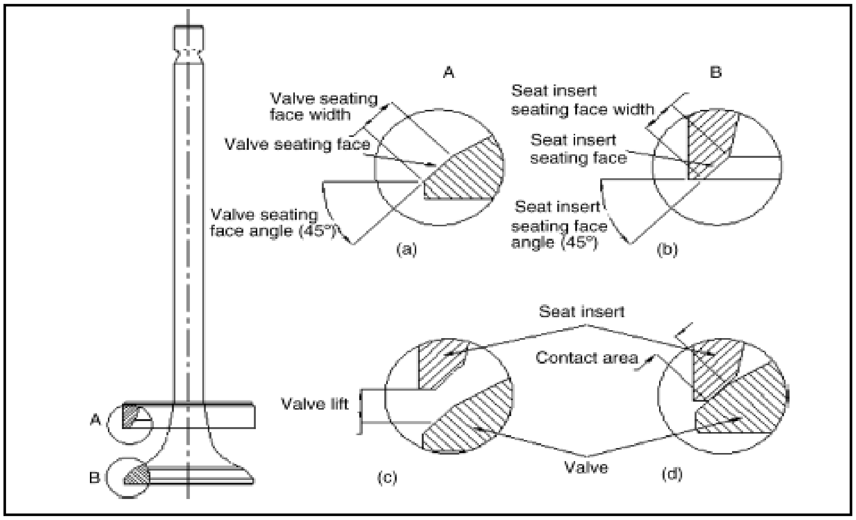


Figure 2.8 Intake valve head and intake valve seat area [4].

In the figure 2.8 the valve seat is the section where the intake valve touches the cylinder case and seal the air-fuel mixture enter the combustion chamber and the mixture out to intake manifold [4].

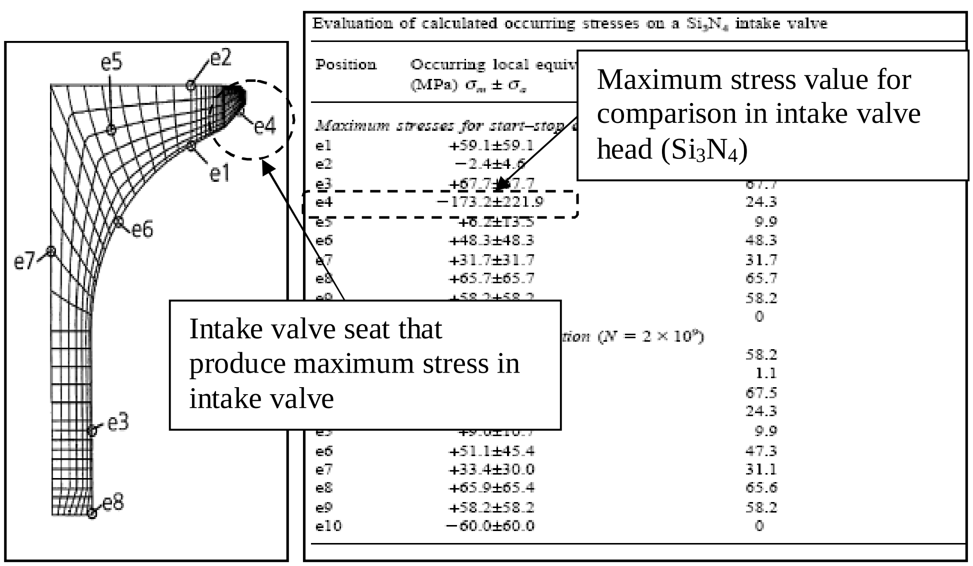


Figure 2.9 Intake valve stress impact and location [4].

CHAPTER 3

METHODOLOGY

3.1 Project Methodology

In fulfillment of the project objective, there are five important stages in simulation analysis in computational fluid dynamic on intake system process on four-stroke engine single cylinder. These include

i. Stage 1: Literature study
ii. Stage 2: Make 3D modeling of Intake Valve
iii. Stage 3: Analyzing using GT-POWER simulation
iv. Stage 4: Analysis using ALGOR simulation

All of this stage should be followed to ensure that simulation analysis will perform successfully and without any error would occur.

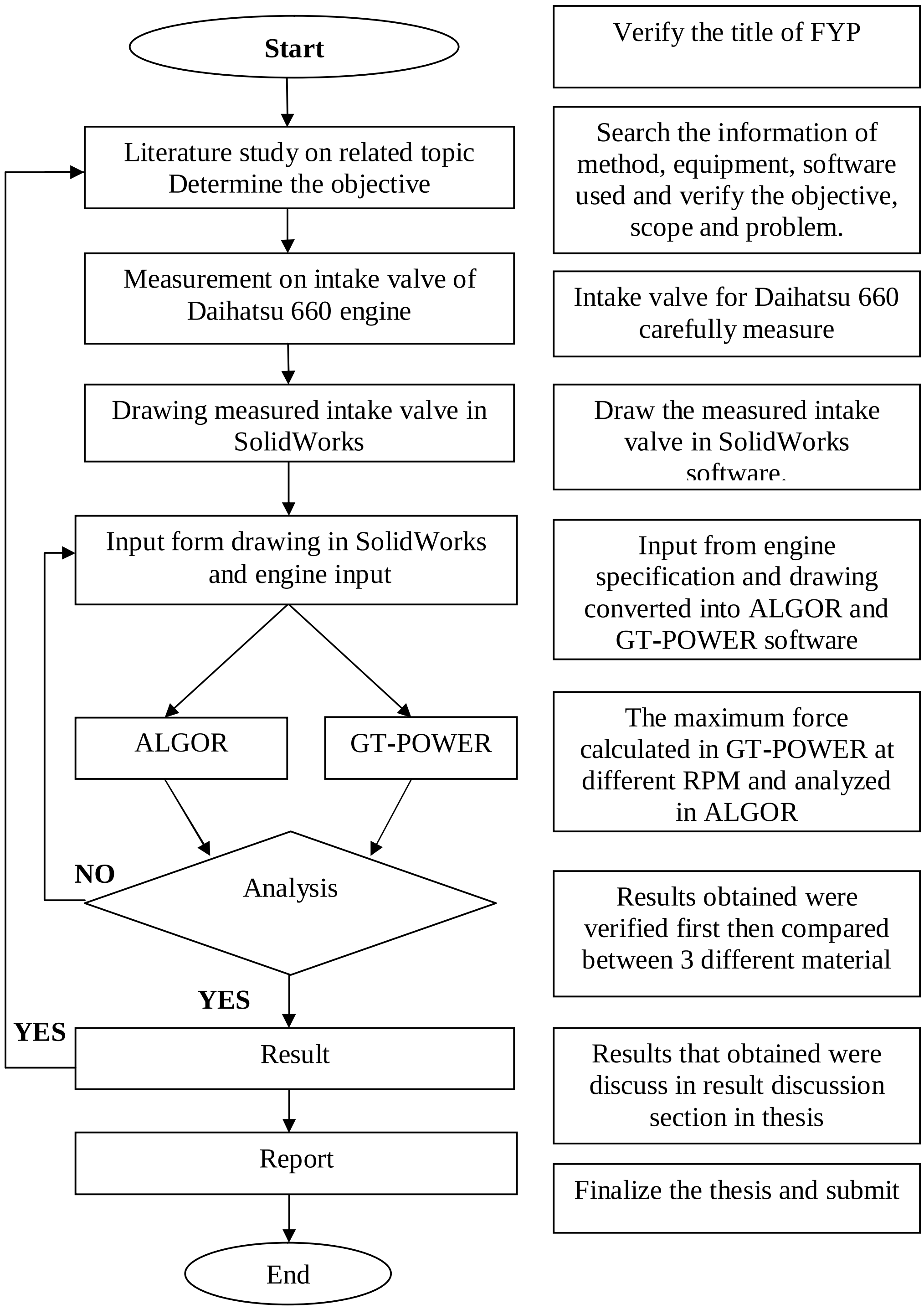


Figure 3.1 Flow Chart of Methodology

3.2 First Stage: Literature Study

Based on this literature study of this project it will focus on combustion stress in intake valve. This is to define which components that involved on this process, so the objective of this project will succeed.

The focusing is to know the material involve in the intake valve, the maximum combustion pressure in the cylinder, proper selection of simulation analysis software and other parameter involve as temperature.

i. Define the intake valve
ii. Define the principle of gas exchange process
iii. Define the purpose of intake valve
iv. Type of valve
v. Effect of different valve lift and design parameter
vi. Poppet valve geometry for intake

This is the most important part and most elegant way to know and study about the intake valve stress in four-stroke engine. All of this information is needed to study and define the affect of different material on the intake valve stress study.

Besides that ,from this basic understanding and information, it is able to choose the suitable intake valve material, so that the objective of this project will be achieved After get, all related information the next step is make a 3D modeling of intake valve using suitable software.

3.2 Second Stage: Make 3D modeling of Intake Valve

At this stage intake valve 3D modeling will be made by using computational software that could convert the actual model into computer model. Because in simulation analysis, the 3D model is the important part to make sure the result that get is reasonable and approximately same with the actual situation or near to literature review value.

However, to generate the 3D modeling there are several steps that should be followed. The step that will be use in this stage can be divided into two, which are:

i. Measure of intake valve of Daihatsu 660 four-stroke engine.
ii. 3D drawing using SOLIDWORKS.

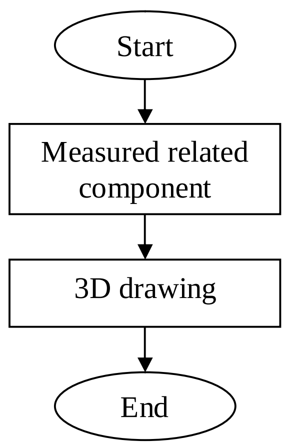


Figure 3.2 Step to develop Intake Valve 3D drawing

3.2.1 Measurement of Intake Valve

On this measurement stage the engine intake valve that will be use to generate 3D modeling is Daihatsu 660 for Perodua Kancil. Then the disassemble intake valve will be measured using vernier caliper and ruler.

However, to get an accurate and precise value, do the measurements continuously about three reading, so that any error from human during do the measurement will be prevent. While all the measurement is done, the next step is to generate 3D modeling of the engine by using all of that measurement value.

3.3.2 Drawing And Design in SolidWorks

After finished with the measurement of the related component, the next step is generating the entire related component in computer by using solid work. This is important step before performing simulation.

In this project, the software that will use to design is SolidWorks. This SOLIDWORKS is mechanical design as a computer aided design software CAD. This software is being choose because of its capability for designer to sketch idea of the design in three-dimensional models and can produce detail drawing. Besides that, by using this software it enables user to design much faster and precise.

Solid Work designs are in 3D design that based on component. To make the design of the intake valve it must have steps that should be following. It include

i. Sketch : Create the sketch by know where to put the dimension that was get from the measurement process for the intake valve.

ii. Features: Select the appropriate features for intake valve and determine the best features that could be apply.

After the intake valve has been drawn, the next step is setting the simulation boundary condition. However, before do simulations make sure the intake valve is complete and transfer in IGES format if not it should be doing some modification.

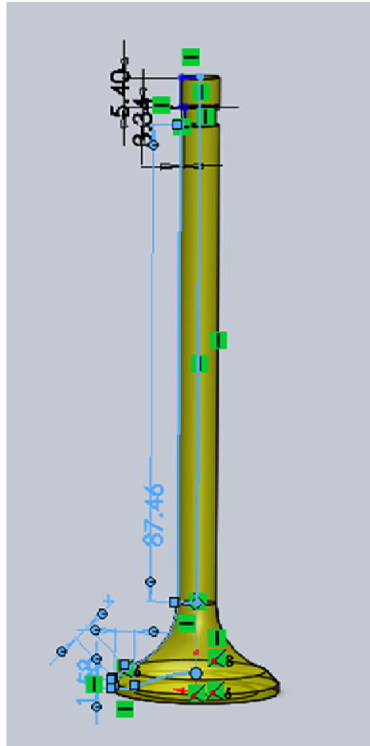


Figure 3.3 SolidWorks drawing of intake valve (all dimension in mm)

3.4 Third Stage: Analyzing Using GT-POWER Simulation

The first part that should be consider was the combustion pressure of burning air-fuel mixture in the combustion chamber equally distributed in the intake valve head. The pressure values of the combustion are depending on the RPM of the Daihatsu engine. Maximum combustion pressure is the reading that suit to analyze forming the stress loading in the intake valve head.

However, to get the loading is not by using mere experiment and sensor. The loading of the combustion chamber is been analyze by GT-POWER software. The software of GT-POWER simulates the engine (figure 3.4) and produces the output of combustion chamber maximum pressure according to specific RPM value. Thus the maximum pressure value (Bar) then converted to loading in Newton for easy analyze value. GT-POWER software is widely used to analyze the engine performance and testing without wasting money manufacture the engine. The combustion pressure for Daihatsu 660 three cylinders is being simulated via GT-POWER software. The diagram of GT-POWER software can be seen in figure 3.4 below.

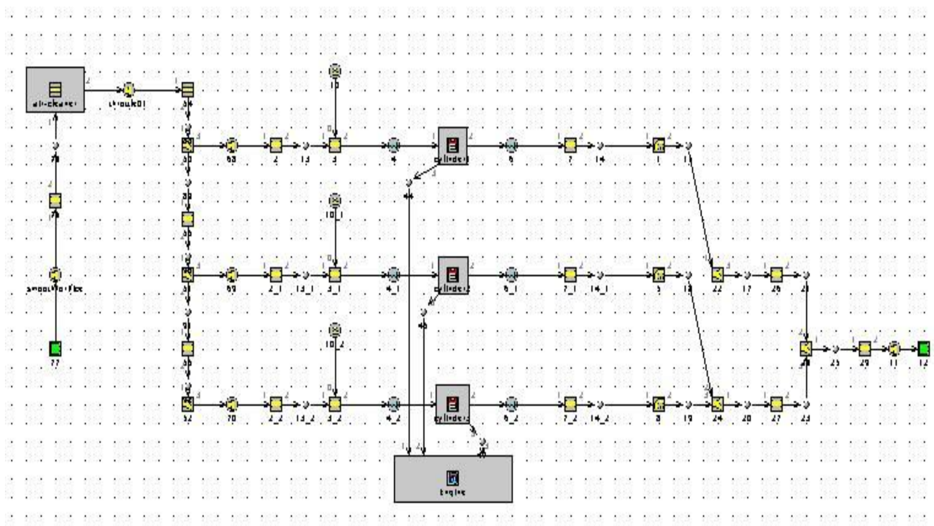


Figure 3.4 GT-POWER diagrams of Daihatsu 660 engine

3.5 Forth Stage: Analysis Using ALGOR FEMPRO Simulation

In this stage, the simulation result data from SOLIDWORKS in IGES file and simulation result combustion pressure data form GT-POWER are transferred in ALGOR FEMPRO software. The analysis of stress in term of Von Mises Stress is simulated by ALGOR software. The result then varies with three different material test in which are the Stainless Steel AISI 405,the Sapco Silicon Nitride (Si_3N_4), and the Titanium Alloy 6A1-4V.

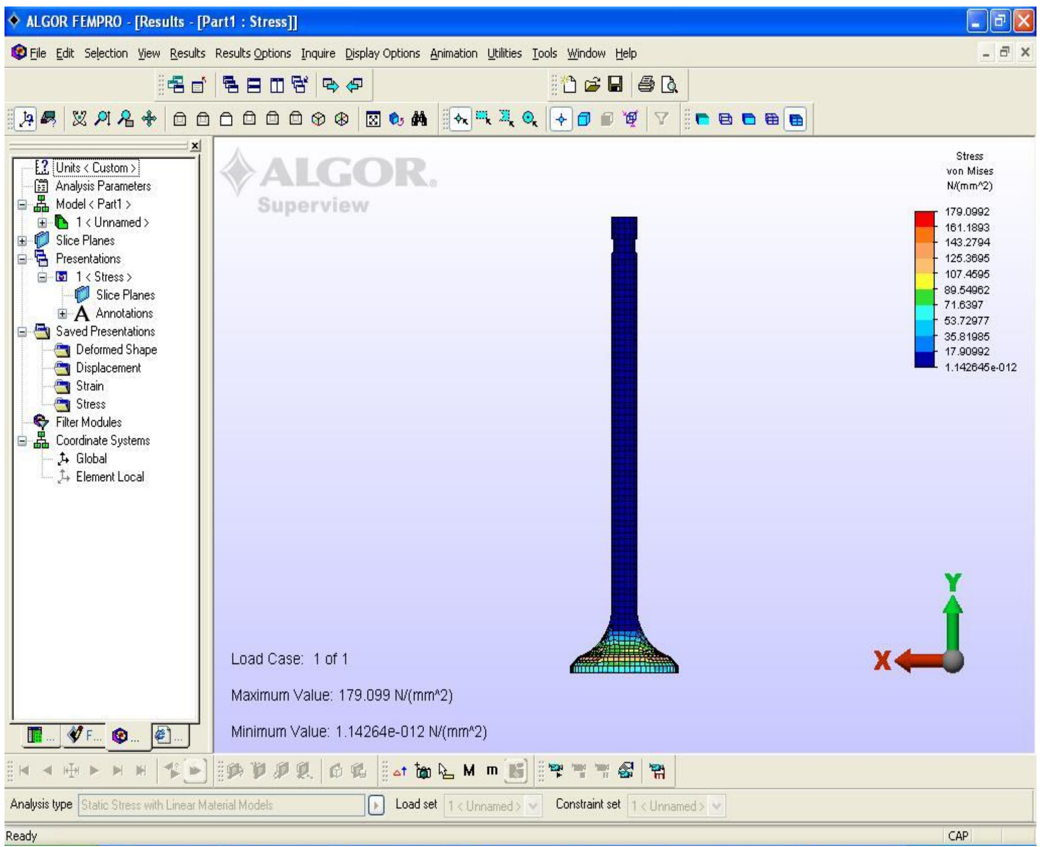


Figure 3.5 Simulation in ALGOR FEMPRO software

3.5.1 Simulation Boundary Setting

It is important to make sure that simulation could give the accurate and precise result. In the boundary condition setting, it will focus in several steps to get the best result for the simulation and nearer to the literature review result. Firstly is defining the pressure for the combustion chamber and the loading effect of the pressure. Second is finding the best meshing for the model.

3.5.2 Creating the Computational Mesh

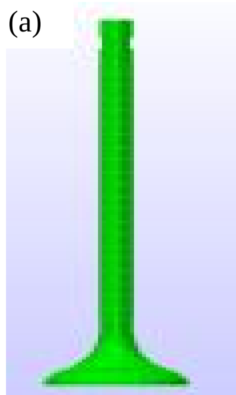
Before run the simulation, creating mesh is important because it will influence the result, verified the result and time for the simulation to end it process. Therefore, for creating meshing there is several steps that should followed.

i. At the beginning, the meshing automatically set to 50% (figure 3.9 a) mesh percentage (figure 3.6) which a bit rough meshing selected and the result of Maximum Von Mises Stress, Si_3N_4 silicon nitride intake valve material for a given loading 16614.9411 N is 84.28169 Mpa.

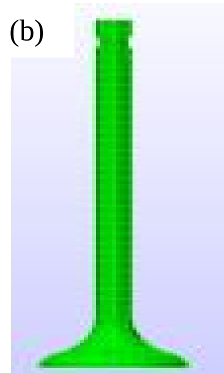
ii. Then run the simulation again with percent of meshing lowered for finer mesh in intake valve and satisfied the result in literature review. Time of the simulation of the loading also been taken.

iii. The best meshing would be 20% mesh percentage (figure 3.9 d). Even though 20% mesh percentage is quite fine meshing but the result of Von Mises Stress is nearer in the literature study but it is needed to verify the simulation result. The result difference between the simulation and literature review only 6.33%.

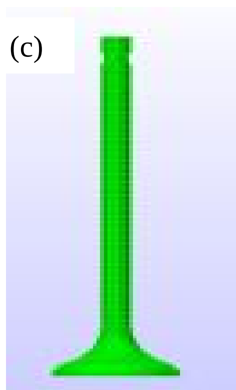
This entire step is to make sure the result is approximately same with the previous data. However, the time of this project is important too, because if the simulation takes too much time it will influence the progress of this project. Therefore, it is important to define the suitable meshing due to the time.



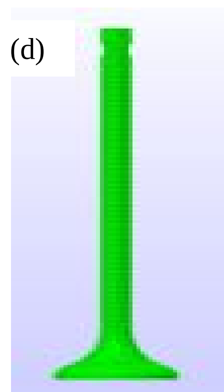
50% mesh percentage



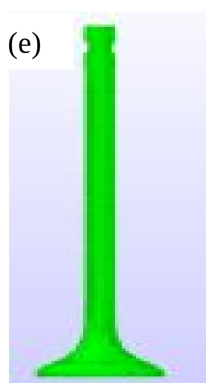
40% mesh percentage



30 % mesh percentage



20% mesh percentage



10% mesh percentage

Figure 3.6 Selection of mesh percentage

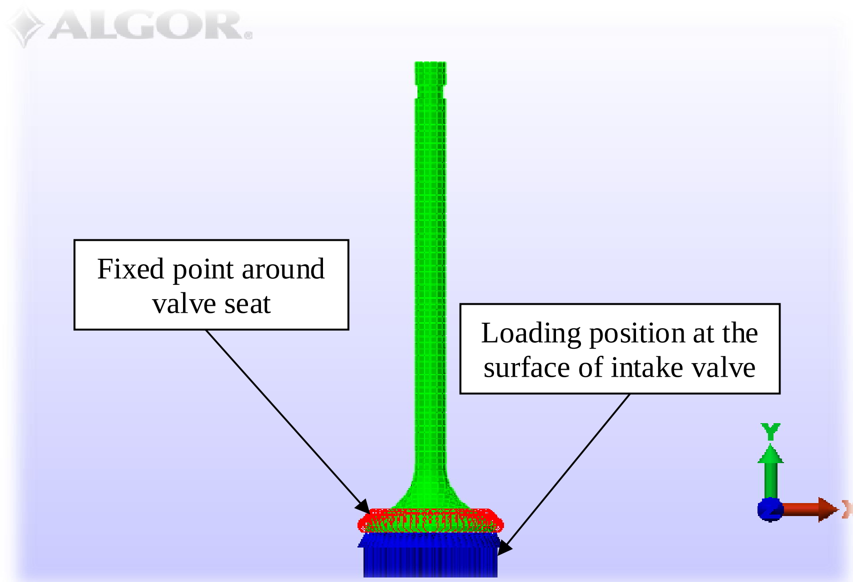


Figure 3.7 Boundary condition and loading

In the figure 3.7 above the intake valve is considered in power process where intake valve close and valve seat seal the air-fuel mixture entering and out of the combustion chamber. The combustion effect of pressure then converted into Newton for easy calculation in the software.

The fixed point or boundary condition is determined by the place where the loading from the combustion chamber being stopped. It happened to be around the valve seat. This also already discuss in the literature review section.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Result

The result in analysis of intake valve stress can be divided into several stages. This stage helps to determine the parameter in order to simulate the stresses and nodal displacement magnitude effect from the loading. Then choose the best material between the simulated materials for the intake valve.

To determine the overall result, the stages in the simulation of the result are:

i. Comparison Result of Experiment and Simulation
ii. Intake valve material AISI 405 Stainless Steel stress and displacement
iii. Intake valve material Sapco Silicon Nitride (Si_3N_4) stress and displacement
iv. Intake valve material Titanium Alloy (6A1-4V) stress and displacement
v. Summary of the result and comparing between three material stress and displacement.

All these stages of result will come by the overall result in order to have a validation of chosen material as the best material for the intake valve between materials simulated.

4.2 Comparison Result of Experiment and Simulation

On this stage, the comparison was needed to validate the simulation result. It is made to ensure that the result is in correlation with the actual experimented result or nearly the same as previous study. The result can be verified by meshing the intake valve material and test the loading impact. The closer value of Von Mises Stress for the ceramic material in the literature study is considered the best meshing. The result for chosen the correct meshing can be seen in Figure 4.1**.**

From the Figure 4.1, it shown that the result from 20% mesh with maximum loading of 16614.9411 N at 300^{o}C temperature would give 184.1683 Mpa of Von Mises Stress. From the literature study the same material of ceramic Sapco Silicon Nitride, Si_3N_4, same design and same loading would give maximum stress impact of 173.2 Mpa. The different between the literature review experimented and ALGOR simulation is 6.33% only.

The factor that could be influenced the simulation result than the experiment from literature review is the effect of continuous loading or dynamic stress impact in the intake valve. Some other factor may be temperature difference as in the previous research the temperature is stated unclear about 300^{o}C-900^{o}C.

However, from that result shows only ceramic material Si_3N_4 silicon nitride is used to verify the result as same material used in the literature study to verify it. The other two materials are to compare the result between each other in contact of stress and displacement magnitude. By looking at the material UTS the stress is expected not to reach more than UTS value as it would change the structure of the intake valve by mere cylinder pressure.

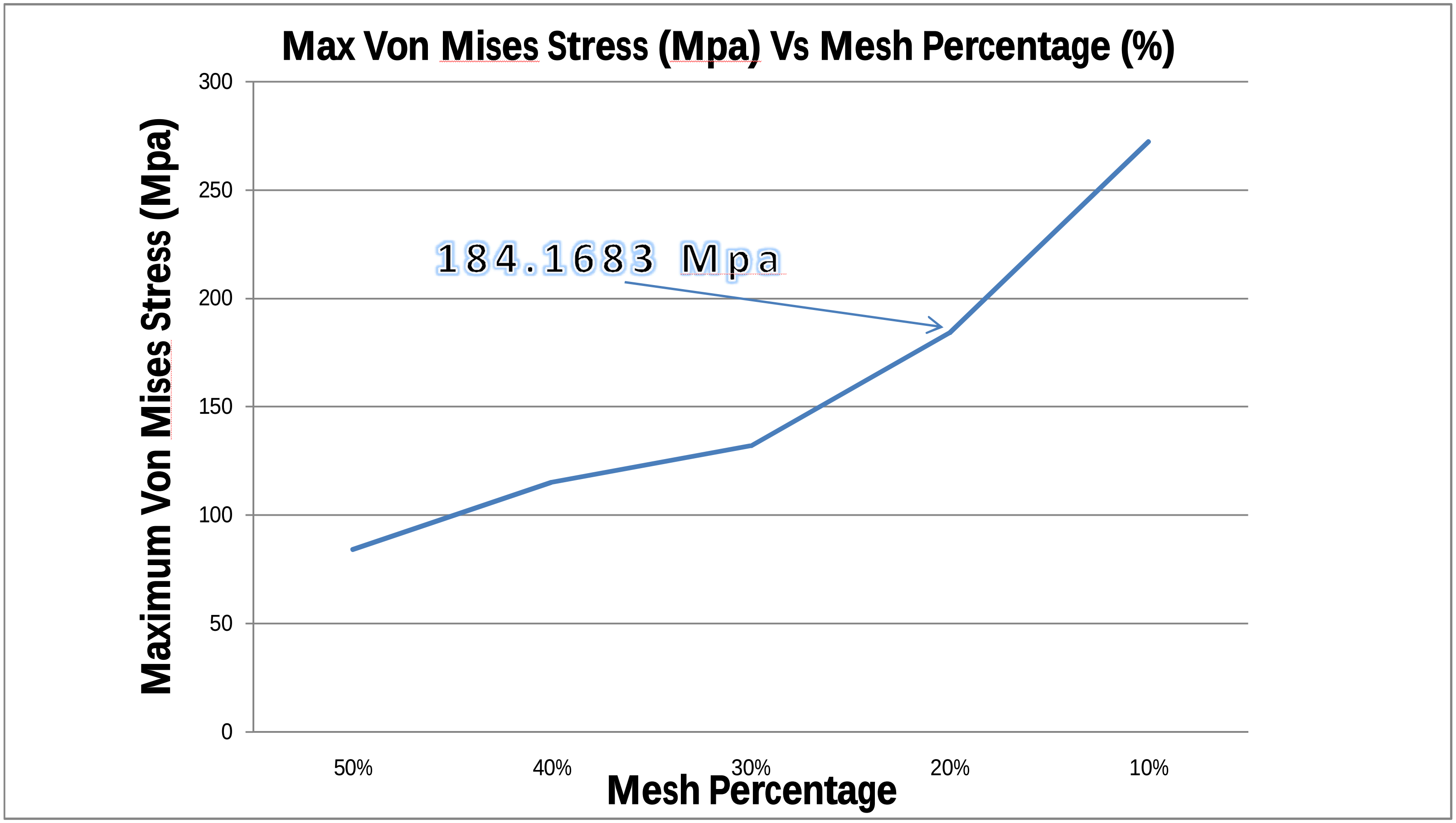


Figure 4.1 Selecting the mesh percentage and verified the result

4.3 Intake Valve Material AISI 405 Stainless Steel Stress And Displacement

Stainless steel AISI 405 is chosen to be intake valve material as it was originally common intake valve material for many common vehicles as such Daihatsu three cylinder four stroke engine 660 cc. First objective is to investigate stress analysis in intake valve thus the previous software, GT-POWER that determine the maximum cylinder pressure for certain RPM is used for the loading in intake valve. The stress distribution can be seen when the loading run in ALGOR. Stainless Steel AISI 405 is expected to have high strength towards stress impact

4.3.1 Material Properties Effect of AISI 405 Stainless Steel

Stainless Steel AISI 405 has a high strength property of steel, having properties of 276 Mpa of yield strength. AISI 405 stainless steel also in categorize of steel with common name Chromium Steel. Even though stainless steel 405 has the highest weight comparing between ceramic and titanium but stainless steel is the cheapest material. Raw material for steel cost RM 5 per kilogram. AISI 405 stainless steel also have high melting point thus the temperature effect in intake valve does not really affect the stress on this material. It is stated that the melting point of AISI 405 is in between 1480^{o}C-1530^{o}C. AISI 405 is the most common valve material as it has the strength endurance to wear, high melting point and cheap price.

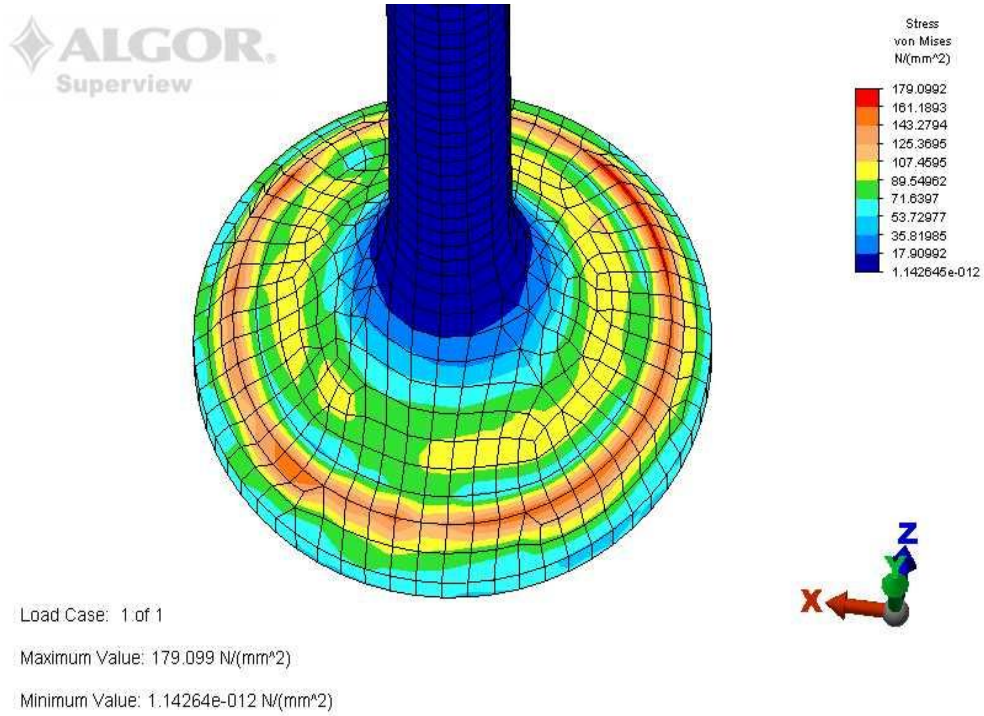


Figure 4.2 Result of Von Mises Stress for 2000 RPM Stainless Steel AISI 405

4.3.2 The effect of Von Mises Stress AISI 405 Stainless Steel

The figure 4.2 above shown the affect of von mises stress impact when the intake valve undergo combustion chamber pressure loading of 16614.9411 N. This maximum pressure happened during RPM of 2000. The maximum Von Mises Stress can clearly been seen in the reddish area value of 179.0992 N/mm^2. The red area in the ALGOR result of intake valve specifically shown happened to be in the valve seat.

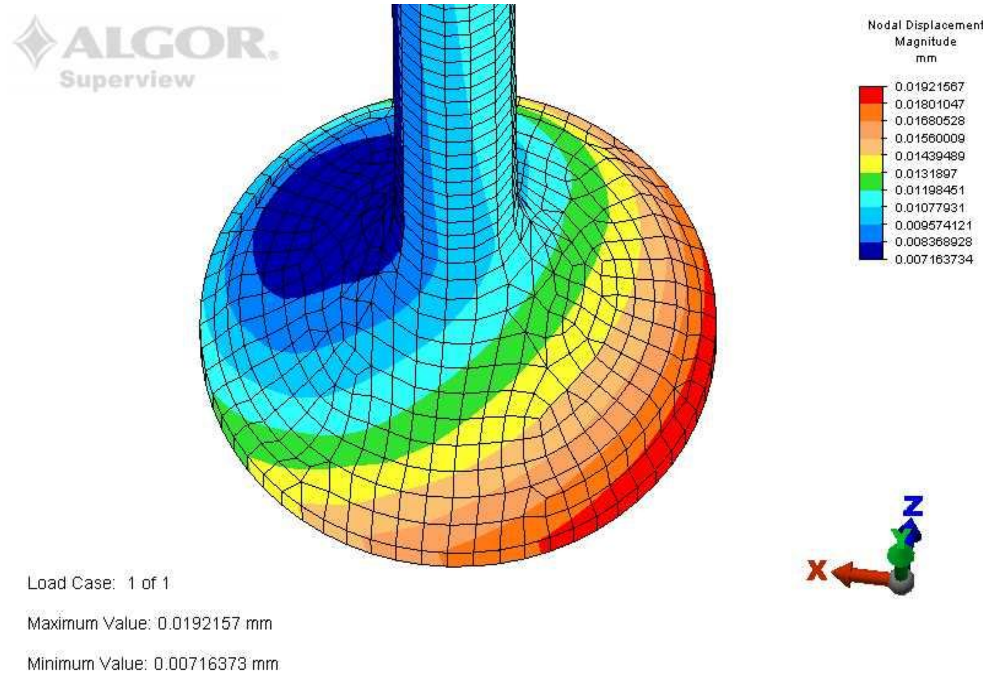


Figure 4.3: Result of nodal displacement magnitude for 2000 RPM
Stainless Steel AISI 405

The valve seat area is where the valve seat close tightly in order to prevent any air-fuel mixture enter combustion chamber during other phase rather than intake stroke. The valve seat also will develop wear if being under loading of combustion chamber repeatedly. The data from the simulation identified critical location of wear or failure most probably occur. The simulation also proved by experiment and real time wear. After a few years of vehicle engine the valve seat is corrupted with wear.

Table 4.1: Table of Von Mises Stress (N/mm^2) and Nodal displacement magnitude (mm) for Stainless Steel AISI 405

Test No	RPM	Force (N)	Von Mises Stress (N/mm^2)	Nodal Displacement Magnitude (mm)
1	500	13215.6876	142.4573	0.01541015
2	1000	15089.6350	162.6573	0.01761044
3	1500	16219.0878	174.8322	0.01892534
4	2000	16614.9411	179.0992	0.01921567
5	2500	16495.0956	177.8074	0.01898701
6	3000	15565.3852	167.7857	0.01816306
7	4000	12696.3572	136.8580	0.01468758
8	5000	11381.6886	122.6879	0.01319067

4.4 Intake valve material Sapco Silicon Nitride (Si_3N_4) stress and displacement

On this material the same method for the previous material is installed to the silicon nitride Si_3N_4 ceramic intake valve. The ceramic then been simulated with different loading from different RPM same with the previous material. This ceramic Silicon Nitride (Si_3N_4) is chosen to be tested as intake valve material because ceramic are currently used as important component such as turbine wheels, gudgeon pins or motor valves. Defect of many metallic compound have been existing for many year but only little temperature or corrosion wear because of stress and environment about ceramic recorded.

4.4.1 Material properties effect of ceramic Sapco Silicon Nitride (Si_3N_4)

Stress impact of the ceramic valve shown the highest impact of von mises stress compare to the AISI 405 stainless steel and titanium intake valve. It is somehow expected form ceramic intake valve as ceramic intake valve have the lowest ultimate tensile strength 350 Mpa. However ceramic intake valve have highest thermal resistance as superior thermal resistance is one of ceramic properties.

It is said that ceramic also have excellence wear and corrosion resistance. Ceramic also have another importance property for intake valve which is light material. Ceramic is the lightest material compare to AISI 405 Stainless Steel and Titanium Alloy intake valve. Approximately 60 % lighter than steel intake valve.

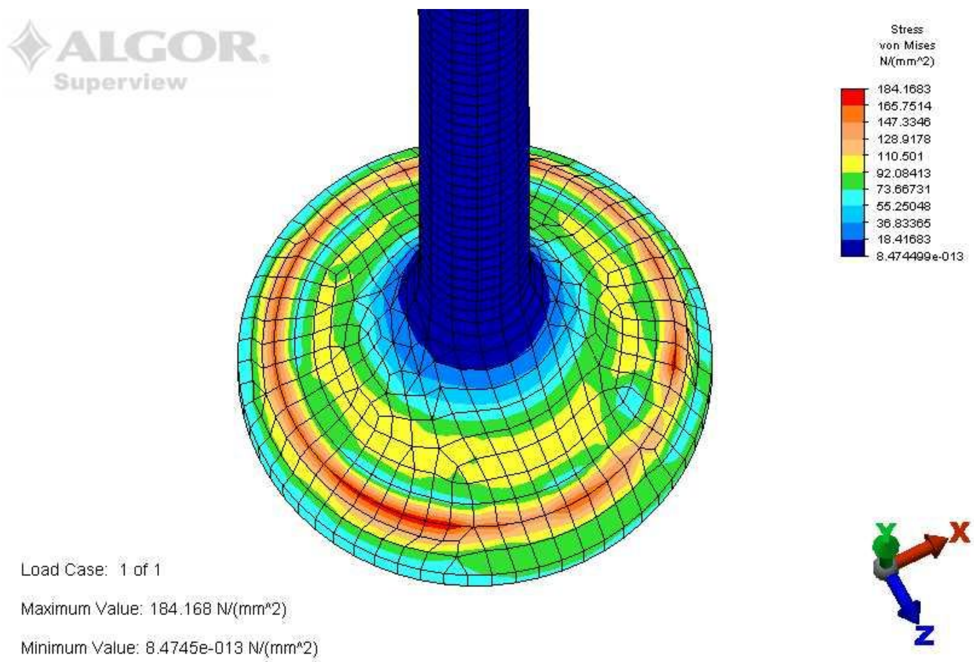


Figure 4.4 Result of Von Mises Stress for 2000 RPM of Silicon Nitride (Si_3N_4)

The figure 4.4 shown the effect of Von Mises Stress impact when the intake valve with material of Sapco Silicon Nitride (Si_3N_4) undergo combustion chamber pressure loading of 16614.9411 N. This maximum pressure happened during RPM of 2000. Same with the intake valve using Stainless Steel AISI 405 material, the maximum Von Mises Stress can also been seen in the reddish area value of 184.1683 N/mm^2.

The result shown that Von Mises Stress of intake valve under material of Sapco Silicon Nitride (Si_3N_4) have highest impact on Von Mises Stress compared with Stainless Steel AISI 405 at a given same loading and same temperature.

This due to the poor strength property of ceramic material which have lowest UTS compare to the steel and titanium. This low strength compared with AISI 405 stainless steel and Titanium Alloy 6A1-4V (figure 4.6) would effect of early wear and several damage of valve seat compare to the other two materials.

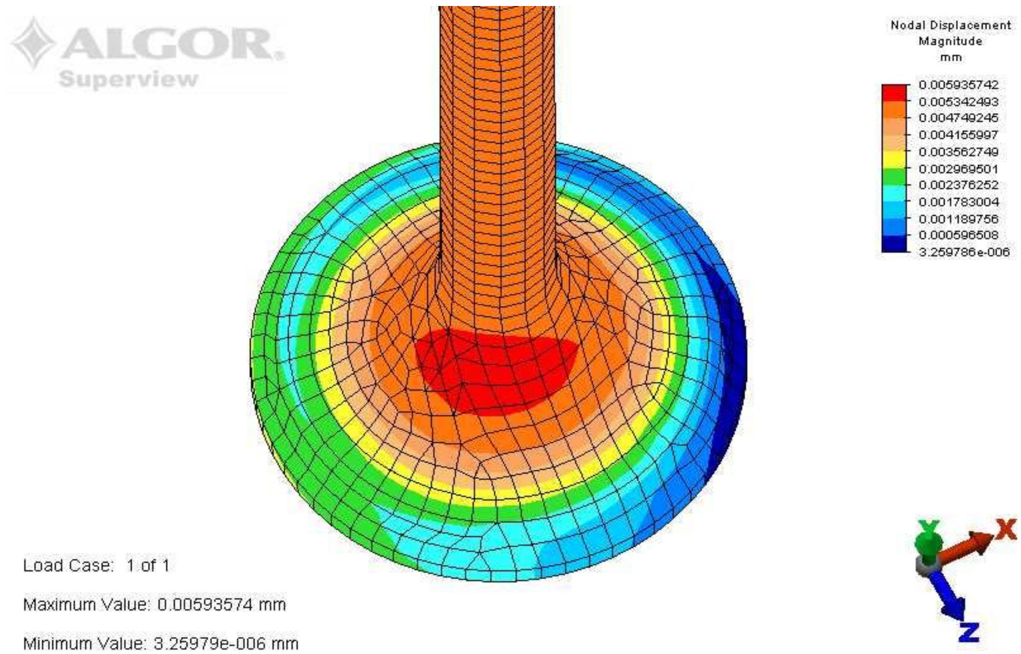


Figure 4.5 Result of nodal displacement magnitude for 2000 RPM
of Silicon Nitride (Si_3N_4)

Table 4.2: Von Mises Stress (N/mm^2) and nodal displacement magnitude (mm) for Sapco Silicon Nitride (Si_3N_4)

Test No	RPM	Force (N)	Von Mises Stress (N/mm2)	Nodal Displacement Magnitude (mm)
1	500	13215.6876	146.4892	0.004824507
2	1000	15089.6350	167.2610	0.005499453
3	1500	16219.0878	179.7804	0.005858387
4	2000	16614.9411	184.1683	0.006033563
5	2500	16495.0956	182.8398	0.005956468
6	3000	15565.3852	172.5345	0.005669366
7	4000	12696.3572	140.7327	0.004603384
8	5000	11381.6886	126.1603	0.004166499

4. 5 Intake Valve Material Titanium Alloy (6A1-4V) Stress and Displacement

The titanium alloy is considered a magnificent alloy with very high strength. Titanium alloy is grouped in metallic material which contains mixture of titanium and other chemical element. Such alloy has a high tensile strength and toughness even extreme temperature. However, the high cost of both raw materials and processing limit their use to military applications, aircraft, spacecraft, medical devices, connecting rods on expensive sports cars and some premium sports equipment and consumer electronics. Auto manufacturers Porsche and Ferrari also use titanium alloys in engine components including intake valve due to its durable properties in these high stress engine environments.

4.5.1 Properties of Titanium Alloy

Titanium alloy (6A1-4V) has an ultimate tensile strength as high as 828 Mpa. Titanium alloy have melting temperature about 1649^{o}C. The combination of high strength-to-weight ratio, excellent mechanical properties, and corrosion resistance makes titanium the best material choice for many critical applications.

Titanium is a strong, light metal. It is as strong as steel and twice as strong as aluminum, but is 45% lighter than steel. Thus lighter material with excellence strength is needed in performing high revolution intake valve to run better engine efficiency.

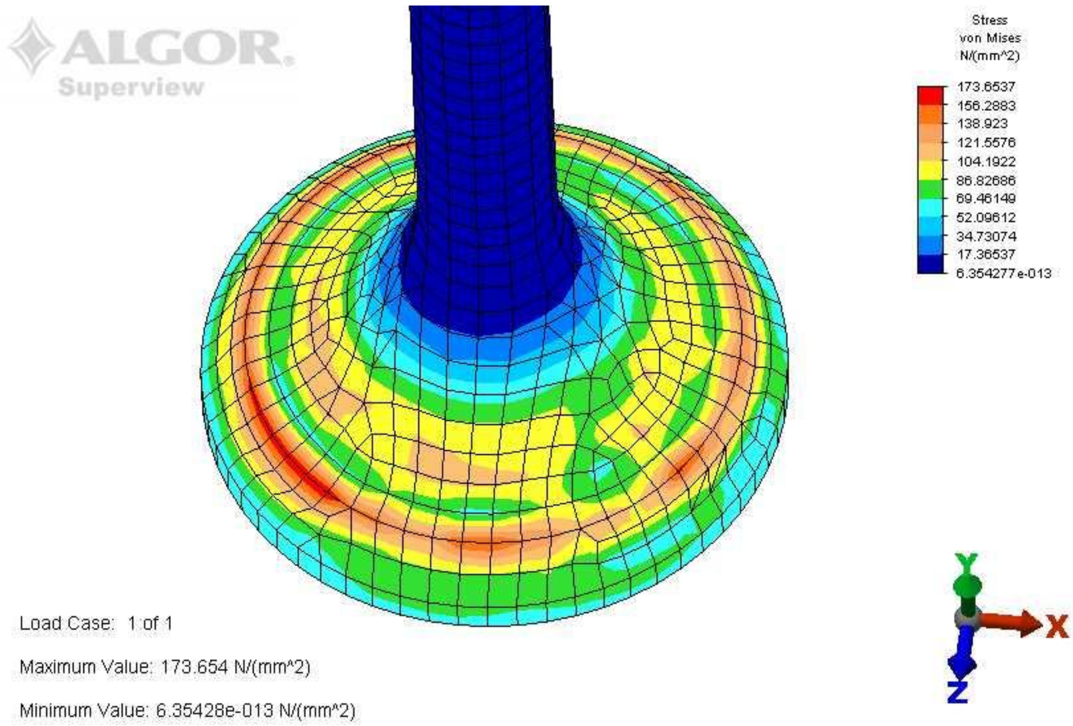


Figure 4.6 Result of Von Mises Stress for 2000 RPM
of Titanium Alloy 6A1-4V V

The figure 4.6 above showed the analysis of Titanium Alloy 6A1-4V Von Mises Stress on ALGOR software. As Sapco Silicon Nitride (Si_3N_4) and Stainless Steel AISI 405 the titanium also showed the same Von Mises Stress impact pattern. However the Von Mises Stress on Titanium Alloy 6A1-4V has the lowest value of Von Mises Stress 173.6537 N/mm^2 which means that with the same loading and same temperature titanium impact of stress is lesser than the other two materials. This makes the titanium alloy stand longer as the material strength in impact stress and temperature. With high resistance towards stress and temperature Titanium Alloy 6A1-4V is expected to have high resistance towards abrasive wear also.

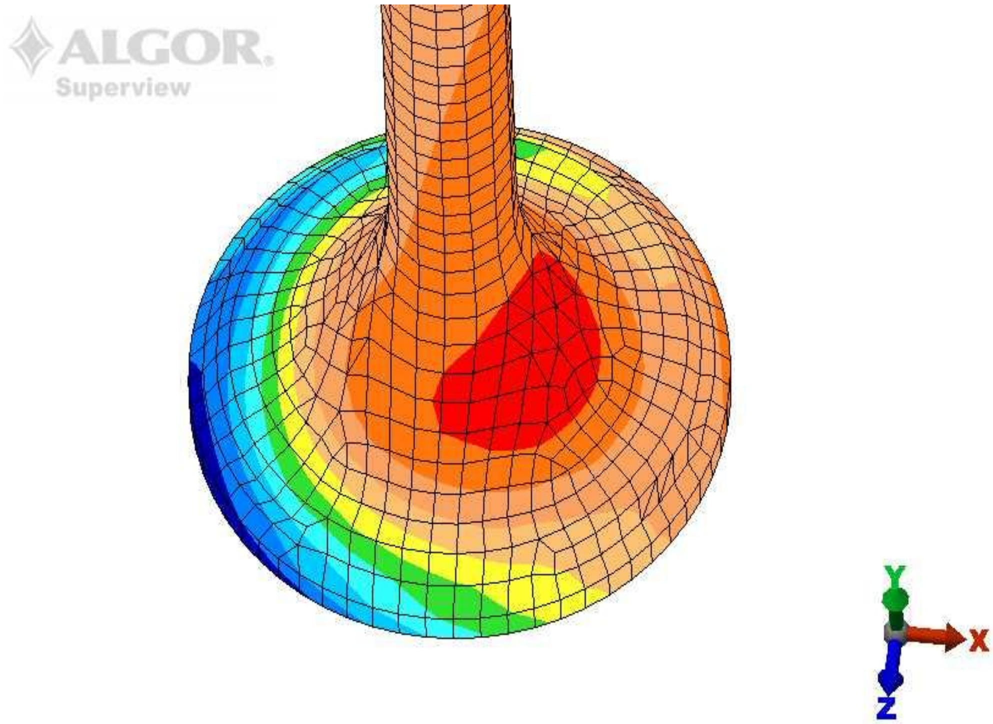


Figure 4.7 Result of nodal displacement magnitude for 2000 RPM of Titanium Alloy 6A1-4V

The figure 4.7 showed the Nodal Displacement Magnitude of Titanium Alloy 6A1-4V. This material showed even magnificent resistance in displacement with highest maximum pressure. With loading of 16614.9411 N at RPM 2000 the intake valve with this material only stretch for 7.338226e-7 mm which is incredibly small value. With engine running in the full load (RPM 2000) the stress impact at this material not even exceed the yield strength of this material (759 Mpa). Titanium Alloy 6A1-4V considered has magnificent strength and resistance with stress and displacement of Daihatsu 660 engine compared with the other two common intake valve materials.

Table 4.3: Von Mises Stress (N/mm^2) and Nodal displacement magnitude (mm) for Titanium Alloy 6A1-4V

Test No	RPM	Force (N)	Von Mises Stress (N/mm^2)	Nodal Displacement Magnitude (mm)
1	500	13215.6876	138.1259	5.762203e-7
2	1000	15089.6350	157.7117	6.619269e-7
3	1500	16219.0878	169.5164	7.267098e-7
4	2000	16614.9411	173.6537	7.338226e-7
5	2500	16495.0956	172.4011	7.298041e-7
6	3000	15565.3852	162.6841	6.969462e-7
7	4000	12696.3572	132.6980	5.600613e-7
8	5000	11381.6886	118.9575	5.066902e-7

4.6 Summary of the result and comparing between three material stress and displacement

From the result of simulated stresses and displacement magnitude of AISI 405 stainless steel, Sapco Silicon Nitride (Si_3N_4) and Titanium Alloy (6A1-4V) the highest resistance towards stress is the intake valve with Titanium Alloy for its material. As predicted Titanium Alloy originally have highest UTS compared between the three materials.

Displacement of Titanium Alloy (6A1-4V) also showed the lowest displacement magnitude changes between the three materials. As the stress impact of combustion pressure in the combustion chamber does not affect much on intake valve with Titanium Alloy by its material.

The Sapco Silicon Nitride (Si_3N_4) ceramic intake valve is consider have highest thermal resistance between the three material but the stress impact due to combustion pressure shown highest impact of Von Mises Stress. This probably due to ceramic material properties which ceramic have the lowest UTS compared between the three materials tested. However the ceramic high thermal resistance property is good in high thermal application jobs such as intake valve in engine.

Nevertheless ceramic have weight reduction by about 60% compare to steel valve. This would make ceramic valve improve valve dynamic and valve train efficiency about 20%. Logically intake valve by ceramic would produce more engine efficiency rather than the other two materials.

Stainless Steel AISI 405 showed an average impact stress of Von Mises stress between the three materials and the highest displacement magnitude. This make Stainless Steel intake valve deform and easier to have wear than the other two material.

Titanium Alloy has weight reduction by 45% compare to steel valve. But a titanium valve price is much higher than steel valve. (estimated RM231-RM297 for a single titanium valve). With greatest resistance towards stress and displacement magnitude between three materials tested, it is considered the best material for the intake valve even its current price is the most expensive.

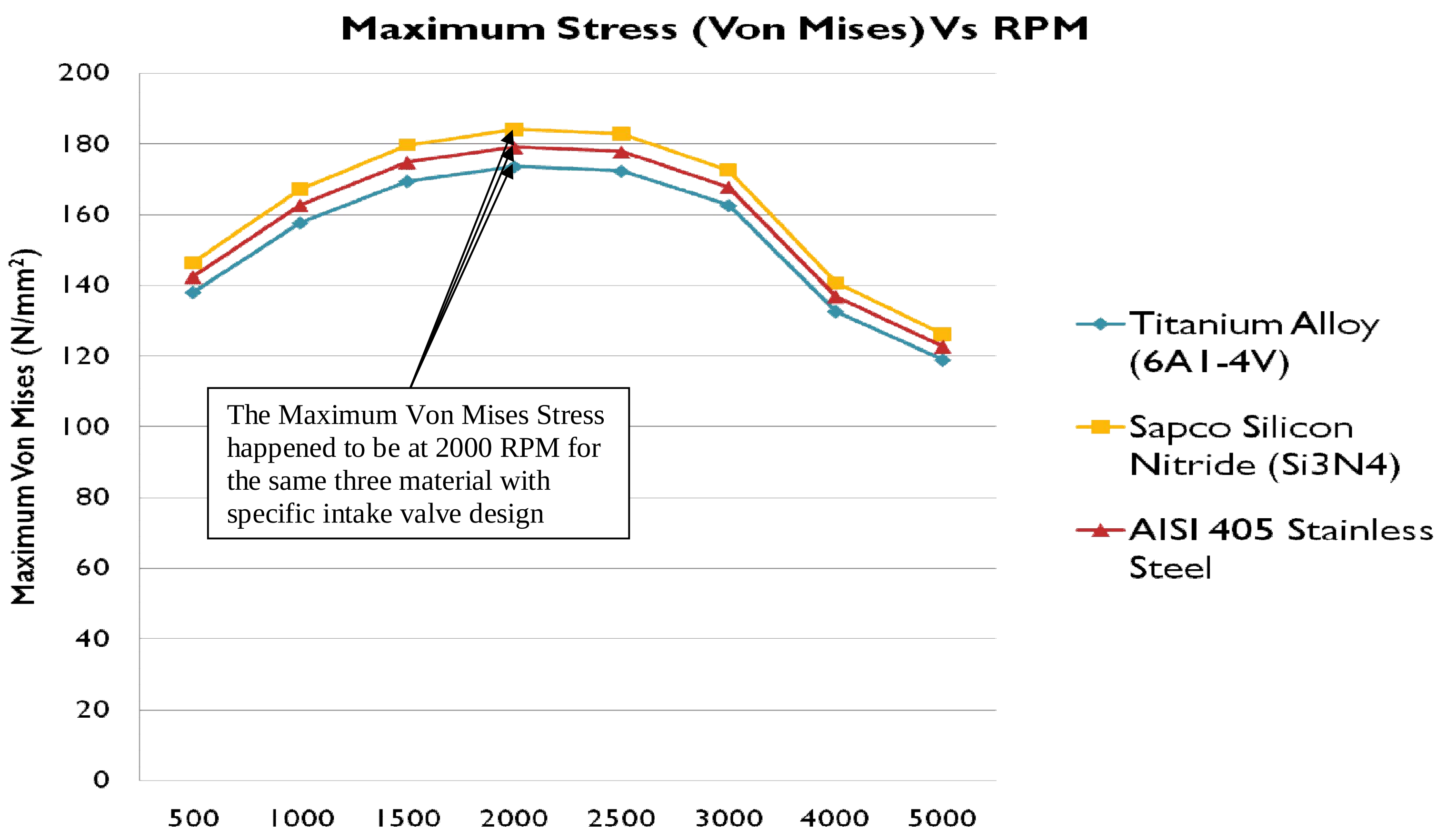


Figure 4.8 Graph of Maximum Von Mises Stress of the three material vs RPM

CHAPTER 5

CONCLUSION AND RECOMMENDATION

There are three type of software been used to finish this project which were SolidWorks for drawing, GT-POWER to find the combustion pressure and ALGOR FEMPRO to analyze the stress, intake valve stress can be analyze using this software and it forming a ring shape of wear. The wear most probably would happen at the valve seat as that particular area have the highest Von Mises Stress in all loading and material simulated.

As conclusion from the simulation, in range of 500-5000 RPM with intake valve temperature 300^{o}C, with loading 16614.9411 N between the three selected material simulated the lowest Von Mises Stress is 138.1259 (N/mm^2) which is the Titanium Alloy 6A1-4V.

In range of 500-5000 RPM with intake valve temperature 300^{o}C with loading 16614.9411 N between the three selected material simulated the lowest displacement is 7.338226X10^{-7}mm which was also the Titanium Alloy 6A1-4V intake valve material.

With this explanation between three material compared Titanium Alloy (6A1-4V) is considered the best material for the intake valve between the three material selected. Titanium Alloy also shown the intermediate material weight thus makes the engine efficiency higher compare to common steel intake valve material.

5.1 Recommendation

From the scope of research the intake valve only consider static impact. In real cases the dynamic impact also gives some extra stresses in intake valve. In order to investigate the dynamic effect proper software needed to calculate the fatigue effect when the intake valve experience cyclic loading.

Other material in intake valve can also be tested rather than depending with common material for the intake valve. As automotive vast development in near future some new material might be more suitable to tackle the wear problem and valve floating because of valve weight during high revolution of the engine.

REFFERENCES

1 John B. Heywood (1988), Internal Combustion Engine Fundamental McGraw Hill

2 The effect of operating conditions on heavy duty engine valve seat wear (Y.S, Wang) Wear201 (1996) 15-25 ELSEVIER.

3 Crouse,W.H and Anglin,D.L.(1993).Automotive Mechanics. 10th ed : MGraw Hill

4 Fatigue design of structural ceramic parts by the example of automotive intake and exhaust valves (C.M. Sonsino) International Journal of Fatigue 25 (2003) 107–116 ELSEVIER

5 Willard W.Pulkrabek (1997), Engineering of the Internal Combustion Engine. Int ed:Prentice-Hall

6 http://www.desmodromics.co.nz/tips.html.

7 NGK Insulator Ltd. R&D activities on sintered silicon nitride materials. Japan : Corporation R&D Group; Oct 1991.

8 Structural stress analysis of an engine cylinder head (Ing. Radek Tichánek) Department of Automotive and Aerospace Engineering Josef Božek Research Center Czech Technical University in Prague

9 A study of exhaust valve and seat insert wear depending on cycle numbers (Keyoung Jin Chun) Wear 263 (2007) 1147–1157 [science direct]

10 The dual spin valve head for high density recording (Hua-Ching Tong) Journal of Magnetism and Magnetic Materials 239 (2002) 106–11 [ELSEVIER

11 Characterisation of wear on a cam follower system in a diesel engine (Per Lindholm) Wear 254 (2003) 1199–1207 science direct

12 The Effect Of HVOF Thermal Spray On The Elevated Temperature High Cycle Fatigue Behavior Of A Martensitic Stainless Steel Anthony Tipton Dresser-Rand, Wellsville, N.Y., USA

15 Analysis of in-cylinder fuel-air mixture distribution in a heavy duty cng engine (Seok Y. Lee) KSAE

16 Development of a valve train simulation process using adams/engine and lotus concept valve train (cott p. Smith) MDI North American User Conference – (2002) .pdf

17 Using co-simulation methods to establish variable valve actuation hardware specifications and control strategies (frederic jacquelin) .pdf

15 http://tomorrowstechnician.com/Article/807/natural_selection_picking_the_perfect_performance_valve.aspx

16 An experimental study of diesel engine cam and follower wear with particular reference to the properties of the materials (J. Michalski) Wear 240 (2000).168–179 ELSEVIER

Appendix

Appendix A1:

Daihatsu 660 (Kancil engine)

Specifications	
Engine type	SOHC 6-valve 4 stroke
Displacement	659 cc
Compression	9.5:1
Bore x stroke	68.0 x 60.5 mm
Max power	22.8KW(31PS) / 6400 rpm
Max torque	49.0 N/m / 3200rpm
Transmission	5 speed
Ignition	SI

Appendix C1

Gantt chart for FYP 1

	project activities	**weeks**													
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	Discuss title and objectives														
2	Discuss scope and problem statement														
3	Chapter 1														
4	Discuss the format of project														
5	Literature - journals and ref. books														
6	Discuss literature on the intake valve														
7	Discuss literature on CAD and CAE														
8	Discuss literature on types of analysis														
9	Chapter 2 - literature review														
10	Discuss the analysis and methodology														
11	Chapter 3 methodology														
12	Preparation for presentation 1														

	project activities	weeks												
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	Literature review													
2	Measure the dimension of intake valve													
3	Design using SOLIDWORKS													
4	Assemble the parts in SOLIDWORKS													
5	Discuss on analysis, constraints and loads													
6	Analyze intake valve design using ALGOR, GT POWER													
7	Analyze and discuss the simulation results													
8	Conclude the project													
9	Complete chapter 4 and 5													
10	Prepare final report													
11	Preparation for presentation 2													