CHAPTER I

INTRODUCTION

1.1 Background

In response to high petroleum price and environmental concerns, natural gas becomes an alternative fuel in the market today, as well as solving out of environmental issues on the higher emission of gasoline uses. Compressed Natural Gas (CNG) offers the fuel cost-savings to the vehicle owners, due to better efficiency of energy resource utilisation, provides cleaner burning fuel. Therefore, research in utilising the gas as another alternative fuel should be given a special priority.

The total energy use by Natural Gas Vehicles (NGV) includes not only direct vehicle consumption but also the whole processes of extraction, processing, transportation, distribution and compression of the gaseous fuel. If more natural gas refueling stations are built, will create more convenience for public to use this new fuel. In line with this, there are many natural gas vehicle-refueling stations being built by PETRONAS. Sdn. Bhd (Malaysian national petroleum company). From year 2000 to 2007, there are 39 NGV refueling stations being built nationwide (http//:www.petronas.com.my). However, this development is not fast enough since the government is targeting for 94 refueling stations by the year 2009 to serve a total of 57,000 NGV demands.

Since NGV relates to the either distribution or public use of refueling station, therefore for storage purposes the gas must be compressed to a higher pressure generally ranging between 200 bars to 250 bars in the refueling storage tanks. The high compression system is necessary for the natural gas refueling appliances, and therefore a reliable compressor would be among the main and important equipment in the refueling facilities.

A new high-pressure multistage wobble-plate gas compressor design for Home Refueling Appliance (HRA) as equipment of the slow fill of the NGV usage has been developed. The design is based on a type of the reciprocating wobble-plate compressor. Basically, this compressor has two compression sides with four stages in each side of the compression and the overall pressure to be achieved is 250 bars. Currently, the available wobble plate compressors are only single-sided and single stage compression, having discharge pressure around 20 to 30 bar and much more popular in automotive air-conditioning system application. Whereas for this new design, two sets of wobble plates-piston assemblies were being installed on a rotating shaft and in a mirror-image arrangement. Further, the multi-stage compression system has been configured in order to enable the compressor to compress gas to a very high pressure.

In this new symmetrical multistage wobble plate compressor, an oil-free lubrication system is one of the specific requirements so that no contamination will occurs. Since the performance and emission level of natural gas-fueled vehicles are sensitive to the oil carried-over in the compressor, thus the prevention of contamination during compression process is very important.

Oil-free or non-lubricated piston rings as a part of assembly compression system were selected for the compressor in order to achieve a minimum contamination. However, until now, no literature has been found discussing specific issue on how to design such an oil-free lubrication system for the wobble plate compressors. Therefore, in this research the focus is on the process of designing the oil-free piston rings assembly.

1.2 Statements of Problem

Currently, NGV refueling stations nationwide are installed with imported models of reciprocating gas compressor. This compressor usually uses oil as lubricant inside the crankcase and cylinder wall, where all friction parts are lubricated with oil. In another gas compressor model, oil mist is used to lubricate the piston rings controlled with a timer. In this type of compressor, the final discharge is freed from traces of oil by using separators and filters.

Nevertheless, the oil is normally not fully removed. In addition, the effect of “trapped-oil” could contaminate the gas inside the tank, it could affect compression process and dropped the combustion performance of the engine. To overcome this problem, the solution is to use such compressors that operate without any lubrication oil (oil-free) especially on the inside wall of the cylinders.

Conceptually, a criteria of success for the compression process in oil-free compressing gas depends on the piston ring assembly design. Several factors such geometry, material selection, friction, wear and tribological influences are important parameters to design and to make the analysis ensuring the “good sealing” compression process for this new compressor. The good sealing means low leakage, low friction, low power consumption, low wear, low temperature rise, long life operation and high efficiency of compressor.

Piston rings for current reciprocating compressor have to meet all the requirements of a dynamic seal for linear motion that operates under demanding tribological conditions. During sliding process between piston ring and cylinder liner cause the friction and wear. Piston rings assembly wear would occur on the contact surface between ring, piston and cylinder wall after a certain amount of time of operation. Due to the operation within, the contact surface usually experiences much higher pressure than other parts and gets much force, which would cause deformation on the geometry and degradation of quality of the surface material. Then eventually the distorted surface affects the functionality of the piston rings, and results significant energy losses. Because of that wear, the piston rings also lose their sealing function. To overcome these problems, the piston ring material should be selected particularly one that has small thermal coefficient of expansion, good creep resistance, good resistance to chemical attack to prevent any gas leakage.

Examination of performance on the new compressor was conducted to have a very high gas pressure exerted in the final stages rise up 250 bar. During the operation of compressor with high pressure difference across piston rings contributed significantly to the ring extraction between the piston and cylinder liner clearances. On other hand, lowering clearances reduced the ring extraction, but increased the possibility of piston contact with cylinder liner, while the piston rider rings also being worn out. Further, high pressure also generated higher surface contact temperatures. This temperature it higher than the measured gas discharge result in the piston ring creep and extrusion.

At the other challenge, small final stages piston diameter (10 mm) and piston ring geometry at very high pressure also needed a consideration to assemble more pieces of ring in order to prevent gas leakage. Eventually, by placing more rings the friction force will increase, temperature, power consumption and wear rate will also increase. Therefore, to reduce all these affects a careful selection of material, design and analysis of piston ring assembly are very critical in this new developed of high pressure symmetrical wobble-plate compressor.

1.3 Objective of Research

To develop an oil-free piston ring assembly for a new multistage symmetrical wobble plate compressor.

1.4 Scope of Research

The development work of the new symmetrical wobble-plate compressor was carried out by a team of researchers and each member has a scope to focus upon. For the author’s scope, this research was focused on the overall development of Piston Ring Assembly.

1.5 Contribution of Research

The contributions of this research were developing a new piston shape, cylinder liner shape for a new symmetrical wobble-plate compressor.

1.6 Thesis Outline

The thesis outline is divided into five stages. The first stage is concept development for the oil-free piston ring assembly based on literature review. This includes a through understanding of the problem by going through the literature review, and reserve engineering work. In the development of the existing oil-free piston ring assembly, it is found that basically a reciprocating compressor using a vertical, horizontal (in opposed design) and scotch yoke mechanism are using a crankshaft with crosshead mechanism to transfer the movement of the piston which slides in and out of the cylinder. For specific comparison, of an oil-free compressor the Balance Scotch Yoke mechanism was studied and reverse engineered.

In the second stage of the project, theory of piston ring assembly was carried out. It was done by taking various references from the existing oil-free compressor, and comparison from such an established manufacture of the sealing materials. Some technique selections of material were conducted in this research such as imitative and comparative procedures. Considering the material characteristic in high temperature, a selection of the oil-free material of piston ring assembly based on polymer resin such as polytetrapolyethelyne (PTFE) and polyetheretheleneketone (PEEK) were adopted in this research.

In the fourth stage of the work a laboratory scale tribotest was also conducted to establish the characteristic of the material selected. A reciprocating wear method was used to measure the friction and wear rate to predict the life span of the contacting piston rings-cylinder liner. The results in the experiment give the real value of the coefficient of friction of sliding parts, wear coefficient, and figures out the film transfer phenomena between piston ring-cylinder liner as well as to know the type of wear that happens during sliding. At the same time, the surface roughness affect and other tribological aspects were also studied. This stage also describes the modeling and simulation method of the piston ring assembly were using Computational Aided Design (CAD) software and Finite Element Method (FEM) approach. The computational static analysis was used to check the sizing geometry and material performance, to ensure that the part would not fail. Von Misses (stress) and deformation value for each part were calculated and compared with yield strength of material to obtain the part safety factor. To do all these, using a commercial Solid-Work integrated with COSMOS Finite Element software. From these analyses, the piston ring assembly design parameters and its relationship are revealed.

The final stage was the development of the prototype and the rig followed up by discussion of the experimental results. The focus of this experiment was to monitor the performance of actual designed piston rings. The main objective in this test was to verify the performance of piston ring at the specified pressure of up to 250 bar. The test was also equipped with Data Acquisition System (DAS).

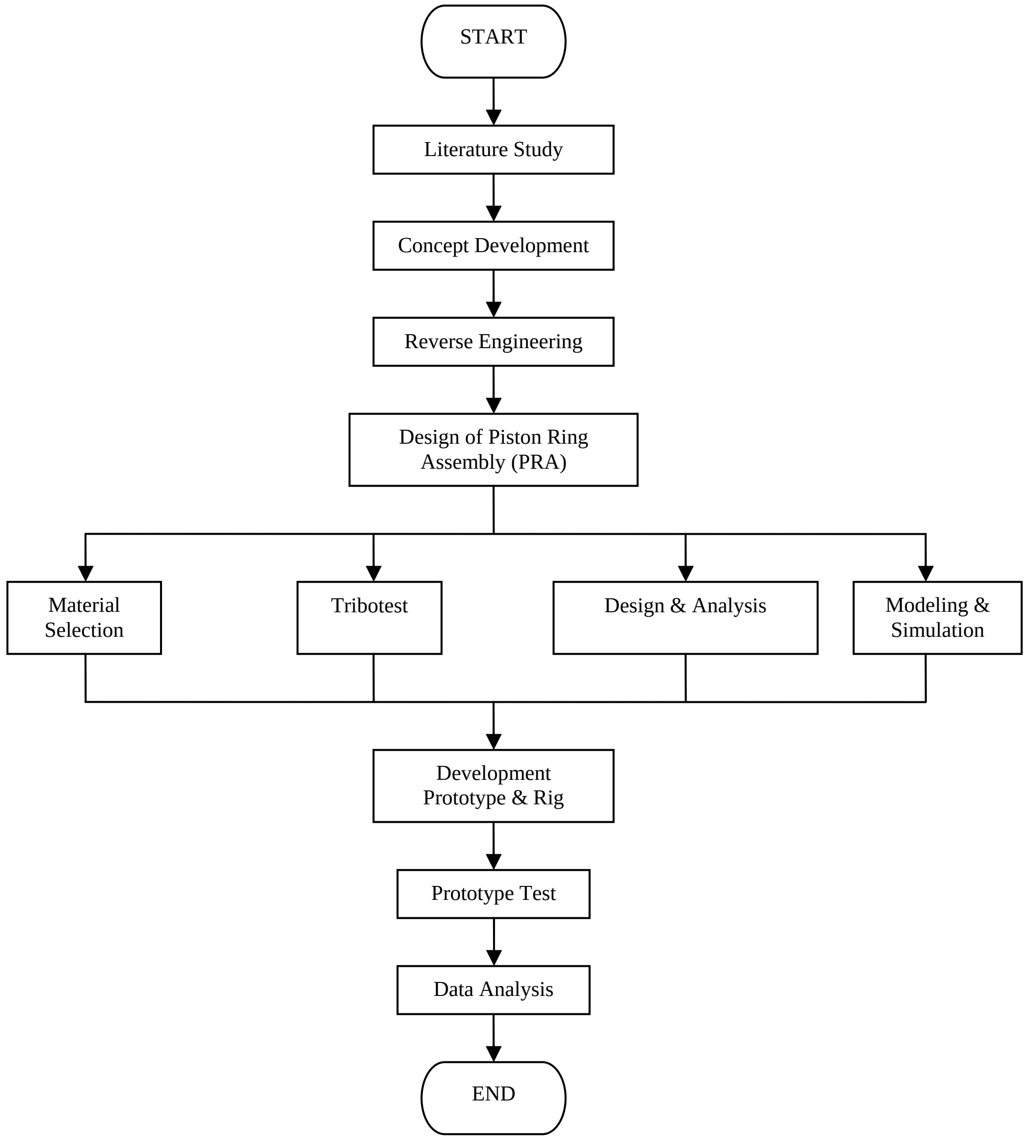

Figure 2.1 Flowchart of Research Phases