CHAPTER 6
CONCLUSION

6.1 Conclusion

The aims of this thesis are to design and develop an algorithm of an inferential coriolis for CNG refueling with SYSID methodology that would provide a minimum percentage error.

It discusses fundamental issues in the development of simulation model for a coriolis flowmeter when subjected to various flow and pressure differences i.e., in circumstances similar to natural gas refueling system. The approaches of identifying the SYSID model is elaborated into three main issues: how to mathematically develop the parametric and state-space which includes the GL, ARX, ARMAX, OE, BJ, and N4SID models; what testing facility is needed to conduct the series of experiments; and how to extract useful information for comparisons and verification of the estimated model.

In particular, it has been organized to answer questions such as,

- what mathematical algorithm is required to produce an optimal model order for inferential coriolis.
- how to implement algorithm and build a simulation model for identification purpose using the LabVIEW system identification module.
- how to specify problems and scenarios to be analyzed (the relevant experimental design), and
- how to extract useful information for comparisons.

Results have shown that algorithm developed from this work (discrete mathematical function to estimate current mass and mass flowrate of CNG) is capable of providing zero percentage error when measures in single pressure flow, continuous pressure flow and multi pressure flow conditions including random disturbances. Therefore, by implementing this inferential coriolis technique in the actual natural gas refueling application, it would provide cost savings in term of operational and expenditure cost.

The main contributions of this work are:

- The detailed comparisons of percentage error in multi pressure flow experiments (the amount of natural gas measured by inferential coriolis, Micro Motion coriolis and load cell in higher, medium and lower pressure differences) were given. The inferential coriolis algorithm, which has not been reported elsewhere to be used in natural gas metering application has been shown to have several advantages compares to current technology of coriolis i.e., based on vibrational pipes concept.

- As existing method applied in metering system is not able to reduce cost of natural gas operational cost, this work demonstrated steps taken in reducing current flowmeter price by embedding inferential coriolis algorithm in a typical dispenser controller using the well established technique of system identification theory and validating the results on actual multi pressure of natural gas test rig. One of the promising results is less than 1% percentage error of natural gas measurement.

6.2 Recommendation

It is important to point out that inferential coriolis is totally a new concept of coriolis flowmeter which would bring major impacts especially in oil and gas industries. At this point, there is no other way to develop a mathematical model or function of a coriolis force, especially when pressure is applied from 0 to 3600 psig, compares to SYSID method used in this thesis. For that reason, a patent is required for the disclosure of this invention.

Advance Natural Gas Dispenser (AND) is one of significant applications that could make inferential coriolis as a major impact to the flowmeter developers. It is a prototype of natural gas dispenser recognized as meterless dispenser that uses intelligent controller to measure flow of gas without coriolis flowmeter as illustrated by Figure 6.1. Notably, the controller contains executable program of inferential coriolis formula.

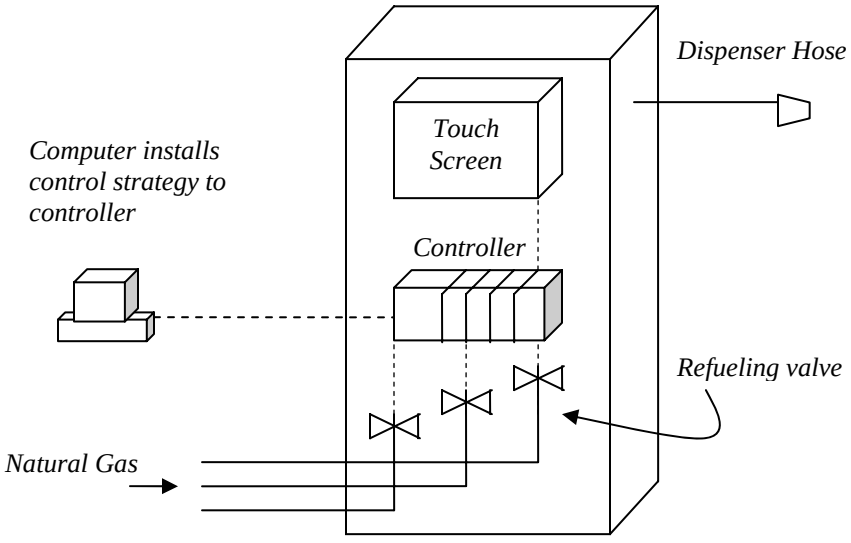

Figure 6.1: Advanced NGV Dispenser (AND)

Apart of that, the coriolis force analyzed in this thesis which includes mathematical derivation of coriolis and principle of motion mechanic, could also be applied to explain other following relevant areas, and may be up to some extend, could be implemented in other extreme conditions such as,

- Hydrogen metering – Hydrogen is the smallest chemical element with atomic number 1 or 1.00794 atomic mass unit. To get a similar mass like NGV vehicle, pressure of H_2 need to be stored at 50,000 to 100,000 psig, 10 times higher than current CNG refueling, which is difficult to measure accurately by current coriolis.
- Wet gas metering – There has been considerable effort by flowmeter manufacturers to research and develop wet gas flow meters over the last decade. The aim of these state of the art wet gas flow meters is to meter the gas and liquid phases simultaneously. Wet gas flow metering is a major challenge to the natural gas production industry and potential applications for wet natural gas flow meters have been growing rapidly since the early 1990's. Many natural gas reservoirs that initially produce dry gas flows are becoming wet natural gas flows as the conditions in the reservoirs change as they age. Also, the desire to maximize the financial return of the existing off-shore infrastructure has led to increased use of wet gas production flow tie-backs so marginal assets that would not be financially viable if they required dedicated platforms of their own can be tapped by utilizing existing platforms.
- Multiphase metering – is a flowmeter that could measure the flow rates of oil, gas and water in oil wells without separation, mixing or moving parts. These are probably the most advanced type of flowmeters in the market and require much expertise in their application and usage. For the case of "multiphase" meters used with wet gas flow (where the industry generally uses the term "multiphase" to mean two-phase gas and liquid flow where there is more than one liquid component – which usually means natural gas, liquid hydrocarbon liquid and water) the aim of the designs are to meter the gas and each liquid component. However, although there are such meters on the market they tend to be expensive (relative to standard gas meters) and due to their relatively recent arrival on the market and the lack of independent data their performance is keenly debated at many conferences.

The work presented in this thesis has contributed to a new coriolis metering concept, and may be up to some extend the measurement of natural gas. Even though the approach presented here offers some promising results, much work remains to be done to produce a generalized inferential coriolis flowmeter, or even for multi-phase flow metering.