DESIGN AND CONSTRUCTION OF SMARTBALL FOR OIL & GAS PIPELINE INSPECTION

Prepared by

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Dissertation submitted in partial fulfilment of the requirements for the

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CERTIFICATION OF APPROVAL

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By

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A project dissertation submitted to the
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Approved by,

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(Dr. Dereje Engida Woldemichael)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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LUQMAN HAKIM BIN ZULKEFLI

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ABSTRACT

After the commissioning of an oil or gas pipeline, it is vital that it is inspected periodically to maintain its integrity**.** Traditional detection equipment which is the pipeline inspection gauges or pigs has a high risk of blocking a pipeline. The objectives of the project are to design a free swimming inspection device which can run freely in a pipeline with minimum risk of blocking a pipeline, and to develop a sensitive leak detection system that can detect small leaks in oil and gas pipelines. The scope of the project will involve mainly on the designing of the Smartball and also the testing of the product. For this project, in order to detect leaks, an acoustic sensor and a pressure sensor are used. Based on previous studies and literature reviews, when pressurized product leaks from a pipe, it creates a distinctive acoustic signal that is transmitted through the product flowing in the pipeline, and this signal can be received by using an acoustic sensor, on board the Smartball. In order to achieve the objectives of the project, the project was conducted starting from literature review, followed by the designing of the Smartball, material and equipment selection, fabrication and testing, and finally result analysis. The sensors need to be programmed to the microprocessor in order to allow the sensors to detect the acoustic wave and pressure difference. The fabrication of the Smartball was divided into two, which are fabrication of the cores, and fabrication of the inner components. However, due to some difficulties, the design of the Smartball needs to be modified. After fabrication, the product needs to be tested in a pipeline in order to test the mobility of the Smartball, and to test the functionality of the sensors. However, due to lack of availability of pipeline facilities, the Smartball was not able to be run in a pipeline. Thus, an indirect test was performed by submerging the product in bucket of water, and heated with a heating coil. This was done in order to proof that the onboard sensors can detect the changes in temperature and pressure of the surrounding, the microprocessor can process the data obtained from the sensors, and the data can be stored in a memory storage. From the indirect tests performed, if the temperature and pressure were able to be detected by the sensors, processed by the microprocessor, and stored in the memory storage, it can be concluded that the acoustic sensor will be able to detect, and be stored in an actual test runs that will be performed in the future.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

After the commissioning of an oil or gas pipeline, it is vital that it is inspected periodically to maintain its integrity. According to Werf (2006), time, deterioration and corrosion of the world‘s ageing pipeline infrastructure increase the overall likelihood of pipeline failures, according to industry trends. It appears that 65% of all pipeline failures are caused by corrosion. World governments are putting pipeline integrity laws into place that regulate the pipeline business. In the USA, the Pipeline Integrity Bill requires regulated pipelines to be inspected for integrity every five years if transporting liquid, and every seven years if transporting natural gas.

Currently, the pipeline is the main medium of oil and gas transportation. Due to the transmission medium, transport conditions, change of geographical climate, and construction influence, weld cracking, corrosion, etc. will appear in the pipeline. This will eventually generate leaks in the pipeline, causing economic loss and environmental pollution.

1.2 PROBLEM STATEMENT

By its very nature, it is difficult to know exactly what is going on inside, or even outside a pipeline. Traditional detection equipment which is the pipeline inspection gauges or pigs, is highly costly and has a high risk of blocking, even damaging the pipeline.

A new device known as the Smartball is invented in order to overcome these limitations. Compared to traditional internal pipeline inspection tools, the Smartball can adapt to different diameter of pipes and easily pass through them. The device has small impact on pipeline transportation, escapes from geographical environment and climate change, and are low cost with less maintenance.

1.3 OBJECTIVES

This project has been identified to have the following objectives:

i. To design a free swimming inspection device which can run freely in a pipeline with minimum risk of blocking a pipeline.
ii. To develop a sensitive leak detection system that can detect small leaks in oil and gas pipelines.

1.4 SCOPE OF STUDY

This project will involve mainly on the designing of the Smartball and also the testing of the product. Based on the objectives of the project, the product will require to be able to flow freely in a pipeline and able detect anomalies that are present in the pipeline. During the tests, it will involve testing the product in a scaled pipeline and testing out the functionality of the on board sensors of the Smartball.

For this project, in order to detect leaks, only an acoustic sensor and a pressure sensor will be used for the product.

1.5 OUTLINE OF THE THESIS

The remainder of this thesis is organized as follows; Chapter 2 discusses about the literature review of the project in the area of oil and gas pipeline inspection. Chapter 3 discusses about the methodology that has been adopted into this research. Chapter 4 elaborates on the results and discussions for the project. Finally Chapter 5 discusses on the conclusion and the recommendations for the project.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

For pipeline inspection tasks, the pipeline inspection gauges or pigs are currently the most reliable and commonly used. Pigs were originally developed to perform cleaning tasks inside the pipeline. Smart or instrumented pigs have been introduced for decades, and have become quite sophisticated and capable to perform various other tasks such as gauging, detect metal loss, leaks and many more (Tiratsoo, 1991). However, pigs also have limitations.

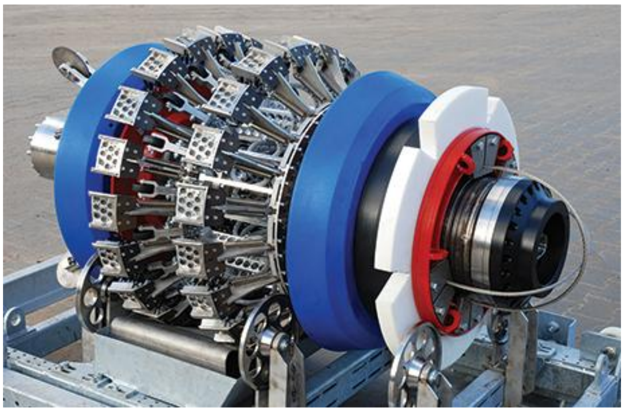

Figure 2.1: An ultrasound pig tool (source: ROSEN Group)

According to Volk (2012), deepwater pipelines have many challenges when it comes to in-line inspection where the pigging of deepwater lines presents particular difficulties. For deepwater pipelines, pigs can be launched from platforms, from surface vessel, or from remote subsea pigging units. Many pipelines are being tied together, like branches on a tree, before being sent to the shore, due to the economics of offshore exploration and production. Therefore, these lines can be hard to pig since flexible pipes are usually sized differently from rigid steel pipe and the may also change diameter from one section to another. Inspecting and maintaining these lines are expensive and technologically challenging since the pipelines lie on the ocean floor, often several thousand feet below the surface.

2.2 SMARTBALL DESIGN

The Smartball device diverges from the traditional cylindrical shape of in-line tools or pigs (Mueller, 2011). According to Mueller (2011), one of the benefits of the spherical design of the Smartball is that it allows much greater flexibility in the methods of deployment and retrieval to a cylindrical tool. Furthermore, it is able to negotiate a much wider range of bore changes, small radius bends and other obstacles that may exist within the pipeline. Besides being able to run in lines without pig traps, Smartball can also run in most unpiggable pipelines due to its flexibility. Moreover, Oliveira et al (2011) also stated that the Smartball can be used in both liquid and gas pipelines.

The Smartball is capable of running through any pipeline with the size of 4" diameter or greater (Oliveira et al., 2011). The device is inserted into an operational pipeline in the same manner as a smart pig and can monitor many miles of pipeline during a single deployment. In order to track the location of the Smartball, it is equipped with an on-board accelerometers and can also be tracked by GPS synchronized surface sensors in the same way as a conventional pig.

Figure 2.2: Spherical design of the Smartball (source: Pure Technologies)

The Smartball is fully sealed in order to ensure that no electronic components are exposed to the pipeline environment. This allows the Smartball to achieve high levels of reliability in a wide range of hostile conditions, and ensure that the device is intrinsically safe for use in flammable products such as oil and gas (Oliveira et al., 2011).

The tool is composed of a pressure tight, aluminum alloy core that contains a power source, electronic components and instrumentation which consists of an acoustic sensor, accelerometer, magnetometer, GPS synchronized ultrasonic transmitter, and temperature sensor. The core is encapsulated inside either a protective outer foam shell or a polyurethane coating. The outer foam shell or polyurethane coating provides additional surface area to propel the device while reducing the ambient noises present in the pipeline (Mueller, 2011)

2.3 PRINCIPLE OF DETECTION

When pressurized product leaks from a pipe, it creates a distinctive acoustic signal that is transmitted through the product flowing in the pipeline (Kurtz, n.d.). Acoustic leak detection equipment identifies the resulting sound or vibration. It has been proven that such systems to be the most effective and reliable means for identifying leaks in pipelines, but fixed sensors have limited range due to the rapid attenuation of sound. This limitation can be rectified by using a free-swimming, un-tethered acoustic leak detection device by passing directly by any leak, regardless of its location along the pipeline. By operating inside the pipe, the device is not affected by ground cover or environmental conditions, and there is less possibility that sections of the line could be missed (Oliveira et al., 2011). Kurtz (n.d.) also agreed that acoustic leak detection systems have been proven to be an effective means for identifying leaks in water pipelines. Acoustic leak detection equipment identifies the sound or vibration induced by the fluid escaping from pipes under pressure.

According to Li et al (2012), the design of the Smartball is to improve and redesign traditional detectors. The Smartball is loaded with accelerometers, magnetometers, and acoustic sensors, and continuously records all the acceleration information, acoustic activities, and changes of the magnetic induction in the pipeline. Chen and Guo (2011) also stated the distance travelled by the Smartball can be measured by fixing a three-axis accelerometer to the spherical center of the Smartball.

According to Mueller (2011), while the Smartball traverses in the pipeline, it acquires high quality acoustic data that is evaluated to identify leaks. Since the acoustic sensor of the Smartball passes no further than a pipe diameter from an acoustic anomaly of interest, three significant advantages are recognized. The first advantage is that the Smartball can be used to detect leaks on medium and large diameter pipe, ranging from 4 inches and greater in diameter. The second advantage is that the Smartball can be used on pipes manufactured of any pipe material including steel, plastic, concrete, etc. The third advantage is that the Smartball has been experimentally proven to be able to detect leaks as low as 0.028 gallons per minute under ideal conditions (Mueller, 2011).

2.4 STRUCTURE OF A SMARTBALL

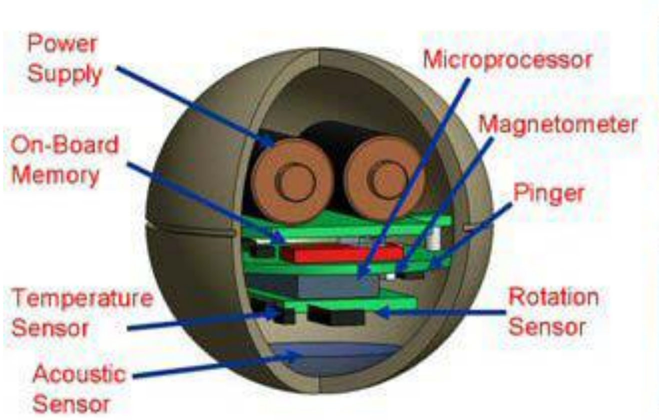

Figure 2.3: Internal structure of a Smartball (source: Pure Technologies)

According to Ariaratnam and Chandrasekaran (2010), the sensors loaded into the Smartball are comprised of five sensors which includes acoustic sensor, accelerometers, magnetometers, pressure sensor and temperature sensor. Acoustic sensor is used to detect leaks in the pipeline. Magnetometers are used to identify pipe weld joints, block valves and in-line valves. Temperature and pressure sensors are used to measure the temperature and pressure in the pipeline. The Smartball is equipped with an on-board memory to record the data obtained from the sensors. The pinger acts as a transmitter to facilitate ball tracking.

2.5 LEAK ACOUSTIC SIGNAL FEATURES

According to Wei et al., (2012), when a leak is present in a pipeline, the high differential pressure between the inner and outer pipeline will cause the release of the elastic energy. This process makes the gas inject into the outer space with a high speed, and produces the sound vibration along the pipeline at the same time. When the gas pipeline leaks, the gas flows under the differential pressure and export condition, and this can be considered as one of the free turbulent injection situation. The jet noise belongs to the category of aero acoustics, and its acoustic source can be considered as quadrupole acoustic source.

According to Yang et al., (2008), in a pipeline leakage, there will be a turbulent jet in the leak. When the jet hits the wall of the pipe, it will carry significant turbulent pressure fluctuations which will impact on the pipe to generate a sound. In addition, as water passes through the leak hole, its velocity increases. If the velocity is high enough, the pressure at the leak point can drop below the vapor pressure of the liquid and form vapor bubbles. The downstream static pressure is normally higher than the vapor pressure of the liquid. Therefore, the bubbles of vapor implode. When a bubble implodes, all the energy is concentrated into a very small area. This creates an enormous pressure in the small area, generating minute shock waves. These shock waves impacting on the solid portions of the pipe wall also causes a sound.

Yang et al., (2008) also stated that in the pipelines with leaks, if the pressure drop is across the leak, the velocity at the exit will be

$$U = \sqrt{2p/\rho}$$

Where ρ is the water density. This gives U = 14m/s for ρ = 1 Bar, 16 m/s for 1.4 Bar, and 32 m/s for ρ = 5.6 Bar. The Reynolds number Re=Ud/v for leak circular hole of diameter d = 1mm and U = 16 m/s is $Re = 1.6 \times 10^4$.

So, there will be a turbulent jet in the leak pipe. When the jet hits the wall of the pipe, it will carry significant turbulent pressure fluctuations which will impact on the pipe to generate a sound.

CHAPTER 3

METHODOLOGY

3.1 RESEARCH METHODOLOGY

In the process of completing this project, various methods and sources will be referred to so as to facilitate this project. The working flow diagram has been identified and will be used in the design and construction of the Smartball.

3.2 WORK FLOW

Figure 3.1 shows the flow chart that has been planned in order to complete the project. Based on the flow chart, the methodology for this project will be conducted as followed:

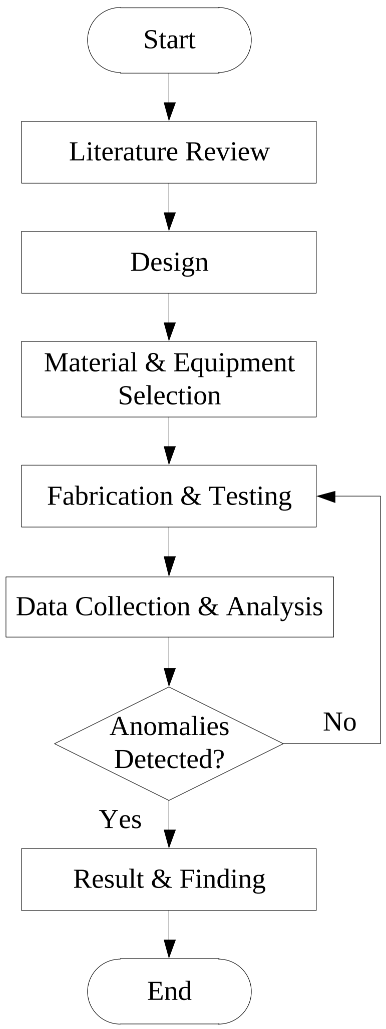

Figure 3.1: Flow Chart

3.2.1 Design

The design process of the project was done in two phases: conceptual design and detailed design. Conceptual design was done by drawing multiple hand sketches and the best design concept will be selected. The best conceptual design was used to create a detailed design using CATIA.

3.2.1.1 Conceptual Design

The conceptual design was done by drawing hand sketches. The conceptual design was done before proceeding with the detailed design. Figure 3.2 shows the conceptual design of the Smartball.

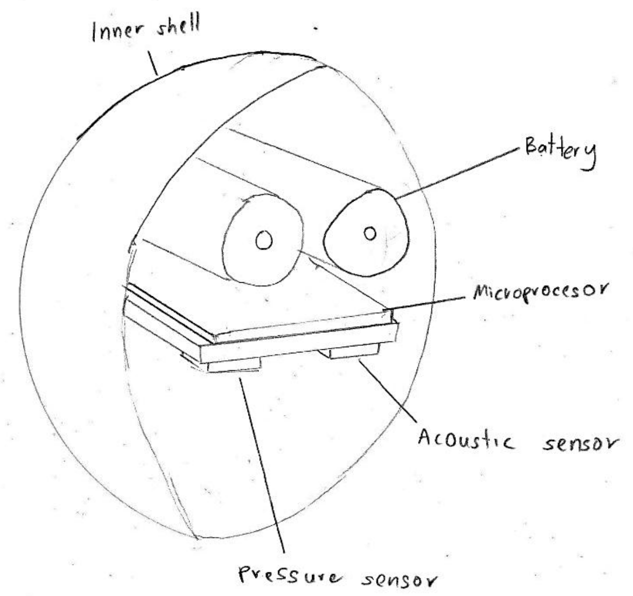

Figure 3.2: Conceptual Design of the Smartball

3.2.1.2 Detailed Design

After completing the conceptual design, the detailed drawing of the Smartball was done by using CATIA. The detailed design of the Smartball will be discussed further in section 4.1.

3.2.2 Materials & Equipment Selection

Experimental planning was be done in order to identify the required materials and also the sensors in order to fabricate the Smartball. Methods such as morphology chart was used to assist the material selection and sensor identification for the Smartball.

3.2.3 Fabrication and Testing

The fabrication of the Smartball commenced during the FYP II. The fabrication was done after obtaining the design and identifying all the necessary materials and sensors. After fabrication, the product will be tested by doing a test run of the Smartball in the laboratory.

The fabrication of the Smartball is divided into two parts: fabrication of the inner and outer core, and fabrication of the inner components.

3.2.3.1 Fabrication of the cores

The required materials for the cores have already been identified and will be discussed further in section 4.2.1, along with their functions and specifications. However, the fabrication of the inner and outer cores need to be modified due to difficulty in obtaining the aluminum sphere in terms of time for manufacturing and also the cost of manufacturing. Because of that, some alterations had been done to the design of the Smartball.

3.2.3.2 Fabrication of the inner components

The fabrication of the inner components is done by installing and configuring all the required components in the interior of the Smartball. The materials and components for the inner structure of the Smartball has already been identified and discussed further in section 4.2.2. The specifications of the sensors required, which are the acoustic and pressure sensors are discussed in section 4.2.3.

Figure 3.3 shows the acoustic sensor configuration and Figure 3.4 shows the pressure sensor circuit configuration.

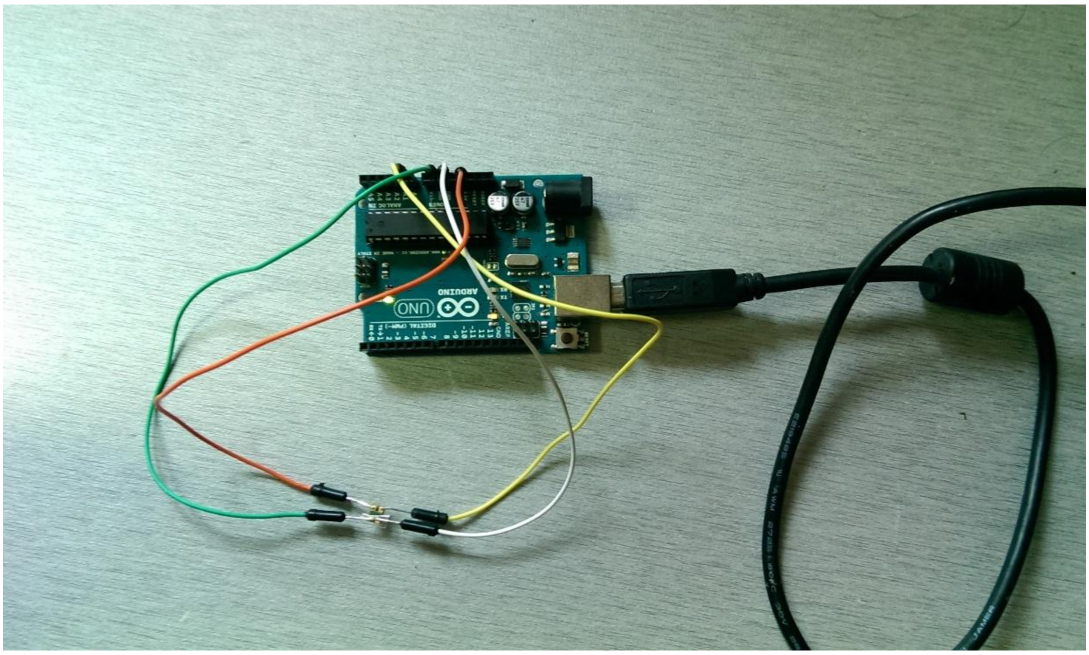

Figure 3.3: Acoustic Sensor Circuit Configuration

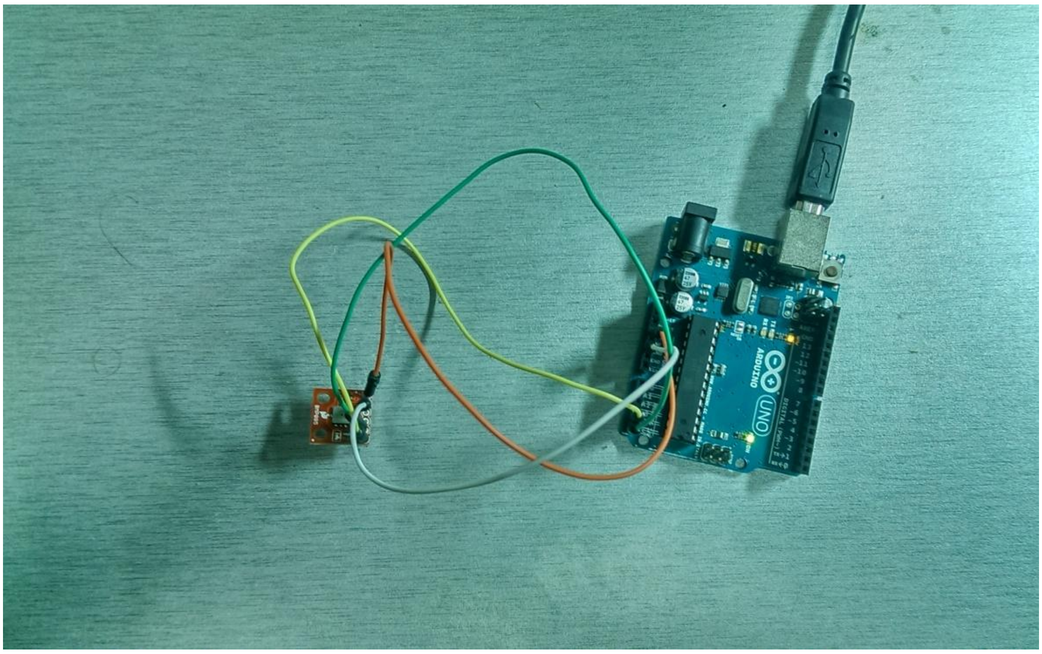

Figure 3.4: Pressure Sensor Circuit Configuration

After fabrication, the sensors need to be programmed to the microprocessor in order to capture the data obtained by the sensors. The programming of the sensors to the microprocessor was done by using the Arduino Integrated Development Environment (IDE). Figure 3.5 shows the coding for the pressure sensor in the Arduino IDE and Figure 3.6 shows the coding for the acoustic sensor in the Arduino IDE.

BMP_memory_log_rev4 §

```
#include <Wire.h>
#include <Adafruit_BMP085.h>
#include <SD.h>

Adafruit_BMP085 bmp;
const int chipSelect = 8;
unsigned long time;

void setup() {
  Serial.begin(9600);
  if (!bmp.begin()) {
        Serial.println("Could not find a valid BMP085 sensor, check wiring!");
        while (1) {}
  }

  Serial.print("Initializing SD card...");
  // make sure that the default chip select pin is set to
  // output, even if you don't use it:
  pinMode(10, OUTPUT);

  // see if the card is present and can be initialized:
  if (!SD.begin(chipSelect)) {
    Serial.println("Card failed, or not present");
    // don't do anything more:
    return;
  }
  Serial.println("card initialized.");

}

void loop()
{
  time = millis();

    Serial.print(time/1000); //print the time in seconds
    Serial.print("  ");

    Serial.print(bmp.readTemperature()); //print the temperature reading
    Serial.print("  ");

    Serial.print(bmp.readPressure()); //print the pressure reading


    File dataFile = SD.open("Pressure.txt", FILE_WRITE); //write the file in SD named "PRESSURE.txt"

    if (dataFile)
    {
      //write the data onto the SD
      dataFile.print(time/1000); //print the time in seconds
      dataFile.print("  ");

      dataFile.print(bmp.readTemperature()); //print the temperature reading
      dataFile.print("  ");

      dataFile.println(bmp.readPressure()); //print the pressure reading


    dataFile.close();
    // print to the serial port too:

    }

    Serial.println();
    delay(1000); //set delay to 1 second
}
```

Figure 3.5: Coding for the pressure sensor in the Arduino IDE

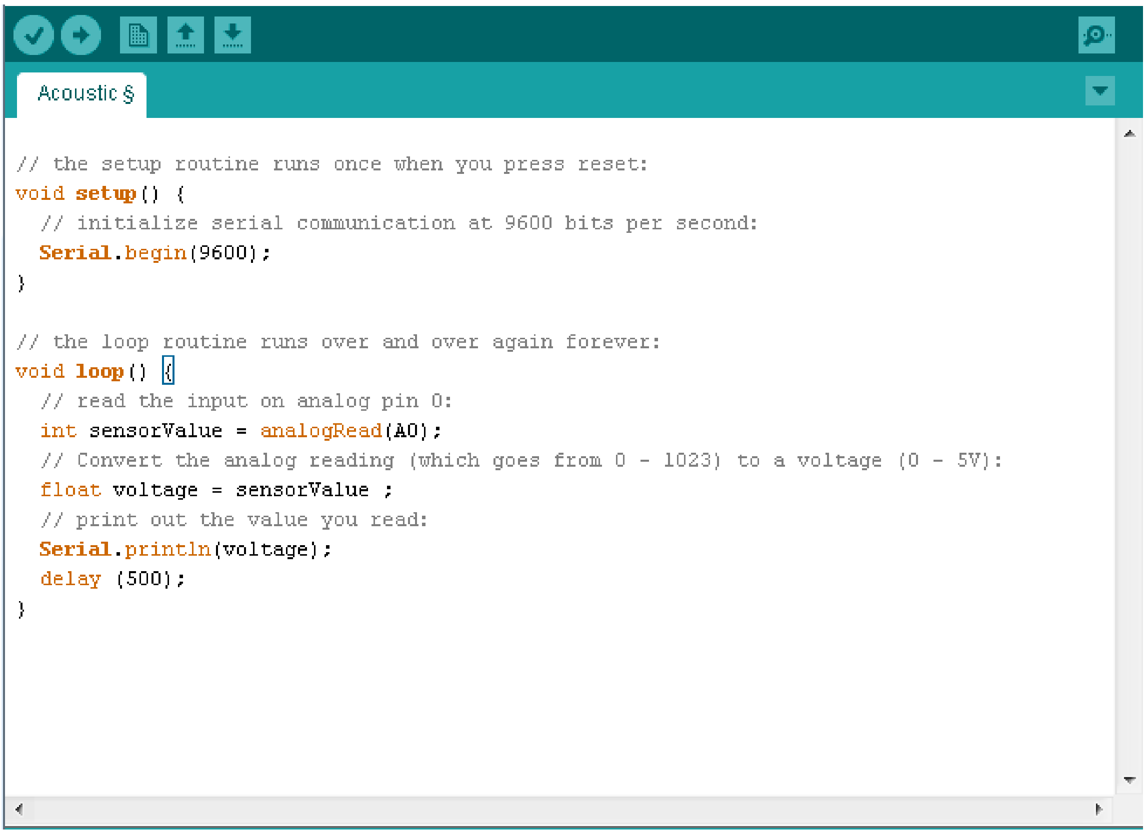

Figure 3.6: Coding for the Acoustic Sensor in the Arduino IDE

3.2.3.3 Testing

After the completion of the fabrication of the Smartball, the product will be tested in a pipeline. A hole will be introduced to the pipeline to simulate leak and to see whether the product is able to capture and record the leak present. If the Smartball fails to obtain the required result, the product will be repaired and the tests will be repeated.

However, due to lack of availability of pipeline facilities to test the product, the product cannot be tested in a pressurized pipeline. Therefore, an indirect test was conducted, which means that the product will be tested without inserting it into a pipeline.

The product was tested by submerging it into a bucket of water, which was then heated up by using a heating coil. This was done in order to test that the sensor can detect the temperature changes of the surrounding, the microprocessor is working, and the data can be stored in the memory card.

3.2.4 Data Collection and Analysis

The data obtained from the sensors are processed by the microprocessor and will be stored in the memory card. The data collected from the tests will be used to verify the results. The data will be evaluated and analyzed in order to identify the type and location of the anomalies present in the pipeline. If the sensors fail to detect the anomalies in the pipeline, the product will be repaired or refurbished and the tests will be rerun.

3.2.5 Results and Findings

The analyzed data will be deduced to justify the results. The findings will be used to conclude the report of the experiment.

3.3 GANTT CHART

Table 3.1 shows the Gantt chart with the key milestone of the project for the FYP I and FYP II period.

Table 3.1: Gantt Chart

		FYP 1														FYP 2													
No	Task Name\Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project Research and Study																												
	Literature Review		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Technical Specification			■	■	■	■	■	■																				
	Milstone: Completion of Extended Proposal								●																				
2	Design																												
	Conceptual Design								■	■	■																		
	Detailed Design										■	■	■																
	Milestone: Final Design of Product												●																
3	Material & Equipment Selection																												
	Material Selection										■	■	■	■	■														
	Sensors Identification										■	■	■	■	■														
	Milestone: Finalize Required Materials & Equipments														●														
4	Fabrication & Testing																												
	Fabrication of Product																■	■	■	■	■	■	■						
	Product Testing																		■	■	■	■	■	■					
	Milestone: Completion of Product Fabrication																							●					
5	Data Analysis																												
	Software Development																				■	■	■						
	Data Collection																		■	■	■	■	■						
	Data Intepretation																				■	■	■	■	■				
	Milestone: Achieve Functional Sensors and Reliable Data																								●				
6	Result & Finding																												
	Report Preparation																								■	■	■	■	■
	Milestone: Report Completion																												●

■ Process ● Proposed Milestone

3.4 KEY MILESTONE

Figure 3.7 shows the key milestone of the project for the period of FYP I and FYP II. During FYP I, the extended proposal was completed during week 8. Then, the final design of the product was completed during week 12, followed by the finalization of the materials and equipment selection on week 14.

During FYP II, the project will continue and the product fabrication is expected to be completed on week 9 with the sensors being functional with reliable data obtained to be achieved on week 10. Finally, report writing on the outcome of the project is to be completed on week 14.

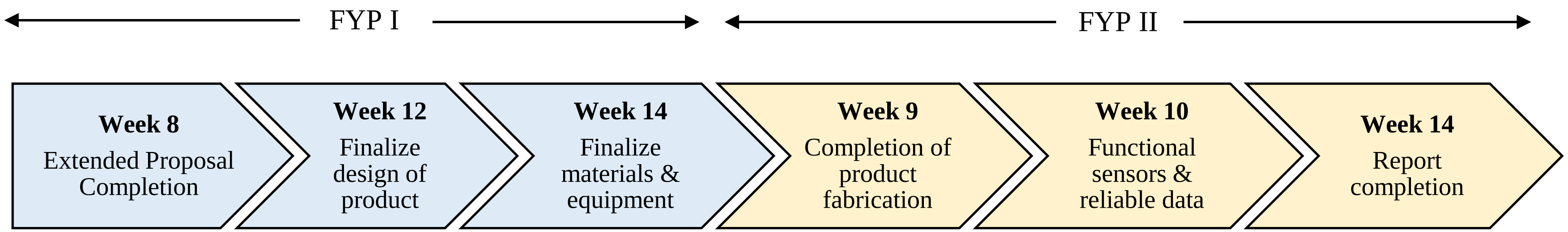

Figure 3.7: Key Milestone

CHAPTER 4

RESULTS AND DISCUSSION

4.1 DESIGN OF THE SMARTBALL

The detailed design of the Smartball was done by using CATIA. Figure 4.1 shows the assembly drawing of the Smartball and Table 4.1 shows the bill of materials for the Smartball.

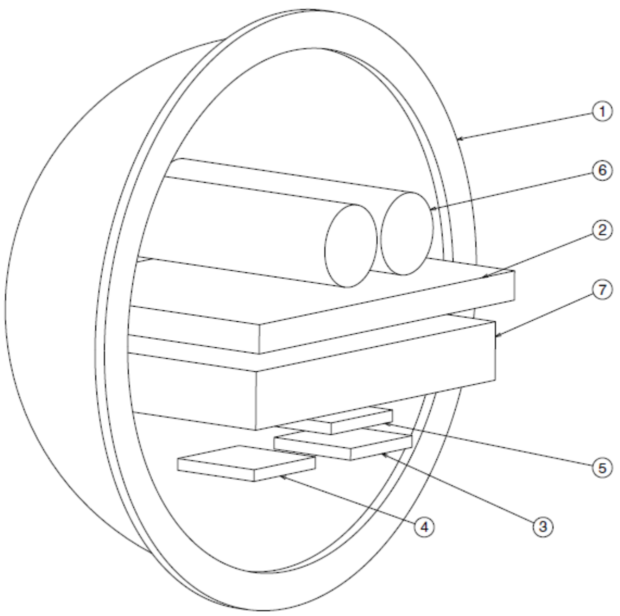

Figure 4.1: Assembly Drawing of the Smartball

Table 4.1: Bill of Material

BILL OF MATERIAL		
NO	DESCRIPTION	QTY
7	BREADBOARD	1
6	BATTERY	2
5	MEMORY CARD	1
4	PRESSURE SENSOR	1
3	ACOUSTIC SENSOR	1
2	MICROPROCESSOR	1
1	INNER CORE	1

4.2 MATERIALS AND EQUIPMENT SELECTION

Materials and equipment selection for the product has been conducted. Based on research studies, the body materials and the interior components were identified based on the requirements of the project.

4.2.1 Body Materials

The body materials of the Smartball are consisted of the outer shell and the inner shell. The inner shell will be the hard casing which encloses all the interior components and to ensure that no electrical components are exposed to the pipeline environment. The outer shell will provide additional surface area to propel the device while reducing the ambient noises present in the pipeline. Table 4.2 shows the body materials that had been identified for the Smartball.

Table 4.2: Body Materials of the Smartball

No	Parts	Materials
1	Outer Shell	Polyurethane
2	Inner Shell	Aluminum

4.2.2 Interior Components

The interior components of the Smartball are enclosed and secured in the inner shell of the Smartball. The interior components are consisted of the acoustic sensor, pressure sensor, microprocessor, memory, and power supply. These components are identified by finding the products with the best specifications that suit the requirement for the project. Table 4.3 shows the interior components of the Smartball required for the product fabrication.

Table 4.3: Interior Components of the Smartball

No	Components	Model/Type	Manufacturer	Remarks
1	Acoustic Sensor 	SPM0404HE5H	Knowles Acoustics	1 unit
2	Pressure Sensor 	BMP085	Bosch Sensortec	1 unit
3	Microprocessor 	Arduino UNO R3	Arduino	1 unit
4	Micro SD Card Shield 	MicroSD Shield	Sparkfun	1 unit

5	Memory 	Micro SD	Kingston	1GB
6	Power Supply 	9V Battery	GP	1 unit

4.2.3 Sensors Specifications

The sensors are determined by the requirements in order to detect leaks in a pipeline. There are two sensors required for this product which are the acoustic sensor and pressure sensor. The specifications has been identified for both acoustic and pressure sensor.

4.2.3.1 Acoustic Sensor

When a leak is present in a pressurized pipeline, a sound vibration or acoustic waves will be produced along the pipeline. The acoustic wave can be detected by using an acoustic sensor installed in the Smartball. The acoustic sensor used for the Smartball is SPM0404HE5H from Knowles Acoustics. Figure 4.2 shows the acoustic sensor used. The acoustic sensor is omni-directional, which means that it can detect the acoustic wave from all direction. The specifications of the acoustic sensor are listed in Table 4.4.

Table 4.4: Acoustic Sensor Specifications

Parameters	**Minimum**	**Typical**	**Maximum**	**Units**
Sensitivity	-51	-47	-43	dB
Frequency range	10k	N/A	65k	Hz
Supply voltage	1.5	N/A	3.6	V
Supply current	0.10	N/A	0.25	mA
Operating temperature	-40	N/A	+100	°C
Signal to noise ratio	55	59	N/A	dB

Figure 4.2: SPM0404HE5H Acoustic Sensor (Source: Knowles Acoustics)

4.2.3.2 Pressure Sensor

A leak in a pipeline will cause a difference in the pressure or pressure loss of the medium. The pressure loss in the pipeline can be detected by using a pressure sensor. The pressure sensor used for the Smartball is the BMP085 Pressure Sensor from Bosch Sensortec. Apart from being able to detect pressure, the BMP085 can also detect the surrounding temperature. Figure 4.3 shows the pressure sensor that is used for the Smartball. The specifications of the pressure sensor are listed in Table 4.5.

Table 4.5: Pressure Sensor Specifications

Parameters	**Minimum**	**Typical**	**Maximum**	**Units**
Pressure range	300	N/A	1100	Pa
Supply Voltage	1.62	2.5	3.6	V
Supply current	N/A	5	N/A	µA
Operating temperature	-40	N/A	+85	°C

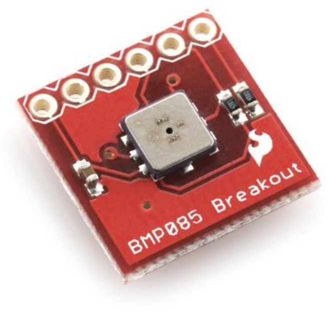

Figure 4.3: BMP085 Pressure Sensor (source: Bosch Sensortec)

4.2.3.3 Microprocessor

The microprocessor used for the Smartball is the Arduino Uno R3. It has 14 digital input/output pins, 6 analog inputs, a USB connection, a power jack, and a reset button. It can be connected to a computer with a USB cable or can be powered with an AC – to – DC adapter or battery. Figure 4.4 shows the Arduino Uno R3 that is used as the microprocessor for the Smartball.

The data obtained from the sensors will be processed by the Arduino, and will be stored to the memory card. Table 4.6 shows the specifications of the Arduino Uno R3.

Table 4.6: Arduino Uno R3 Specifications

Parameters	Description
Operating Voltage	5V
Input Voltage	6-20V
Digital I/O Pins	14
Analog Input Pins	6
Clock Speed	16 MHz

Figure 4.4: Arduino Uno R3 (Source: Arduino)

4.3 PRODUCT FABRICATION

As discussed earlier, the product fabrication of the Smartball is divided into two: fabrication of the core and fabrication of the inner components.

4.3.1 Smartball Shell

As discussed earlier, the body materials of the Smartball need to be changed due to some unavoidable difficulties. The spherical shape of the Smartball needs to be replaced with cylindrical shape as the manufacturing of spherical shape requires precision tools. Moreover, the aluminum body of the design needs to be replaced with PVC as the cost of manufacturing is expensive and requires an ample amount of time to manufacture. Therefore, the final design of the product was done in a cylindrical PVC pipe.

Figure 4.5 shows the final design of the product. The interior components of the Smartball are enclosed inside the cylindrical PVC pipe.

Figure 4.5: Final product design of the Smartball

4.3.2 Interior Components

All the components are wired to the microprocessor and are run by using a 9V battery. The data is processed by the microprocessor and finally it is stored to the memory card by connecting it to the MicroSD Shield.

Figure 4.6 shows the final electrical components that are used for the Smartball. The interior components are place inside the PVC pipe container.

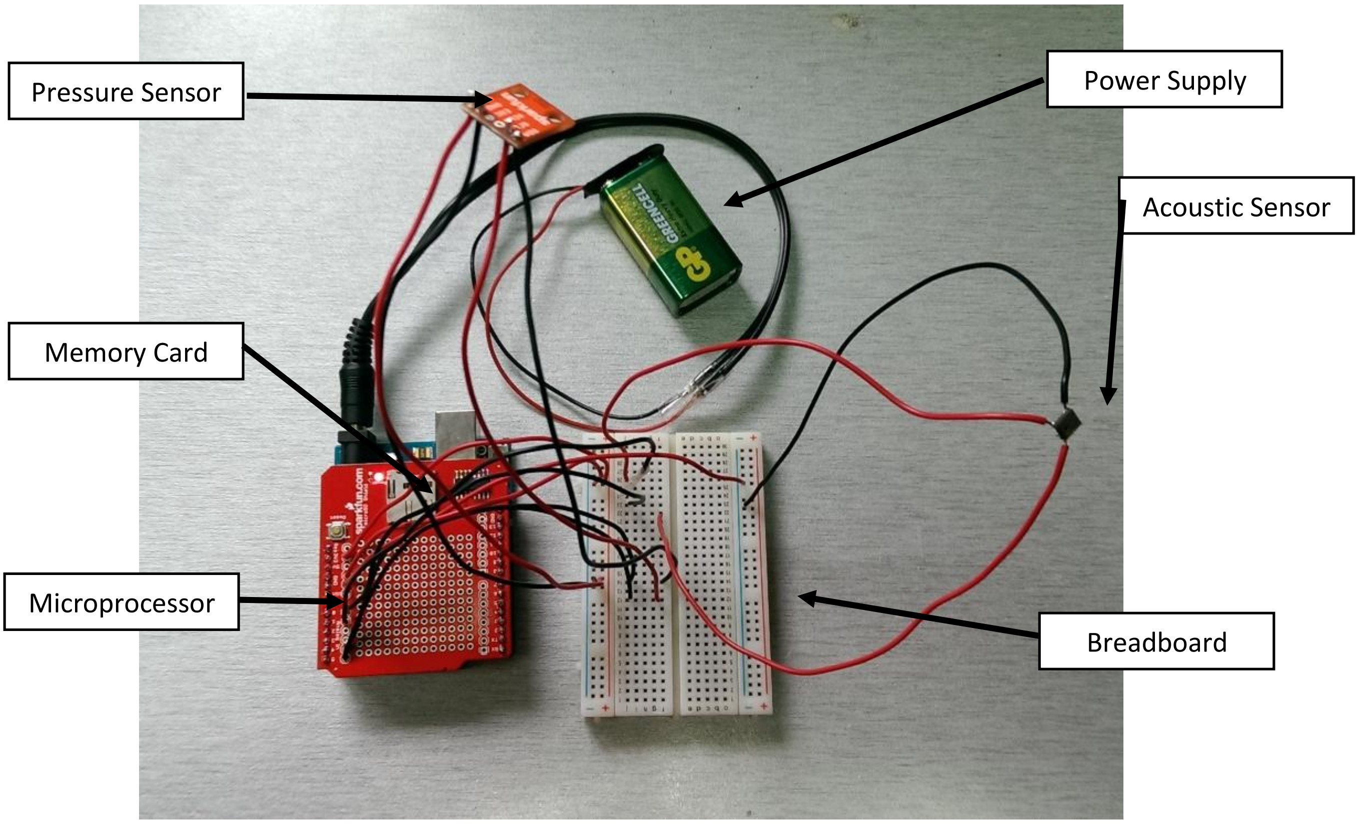

Figure 4.6: Interior components of the Smartball

4.4 TESTING

Due to the lack of availability of pipeline facilities to test the product, an indirect test was performed. The test was conducted by submerging the product in a bucket of water, and heating it by using a heating coil. There are three outputs measured in the test run, which are the time, pressure and temperature. The outputs measured are presented in this section.

Figure 4.7 shows the setup for the test run of the product.

Figure 4.7: Test run setup of the product

After the test run is completed, the data stored in the memory card is extracted and analyzed. The results obtained are plotted in a graph of temperature and pressure against time.

Figure 4.8 shows the graph obtained from the first test run.

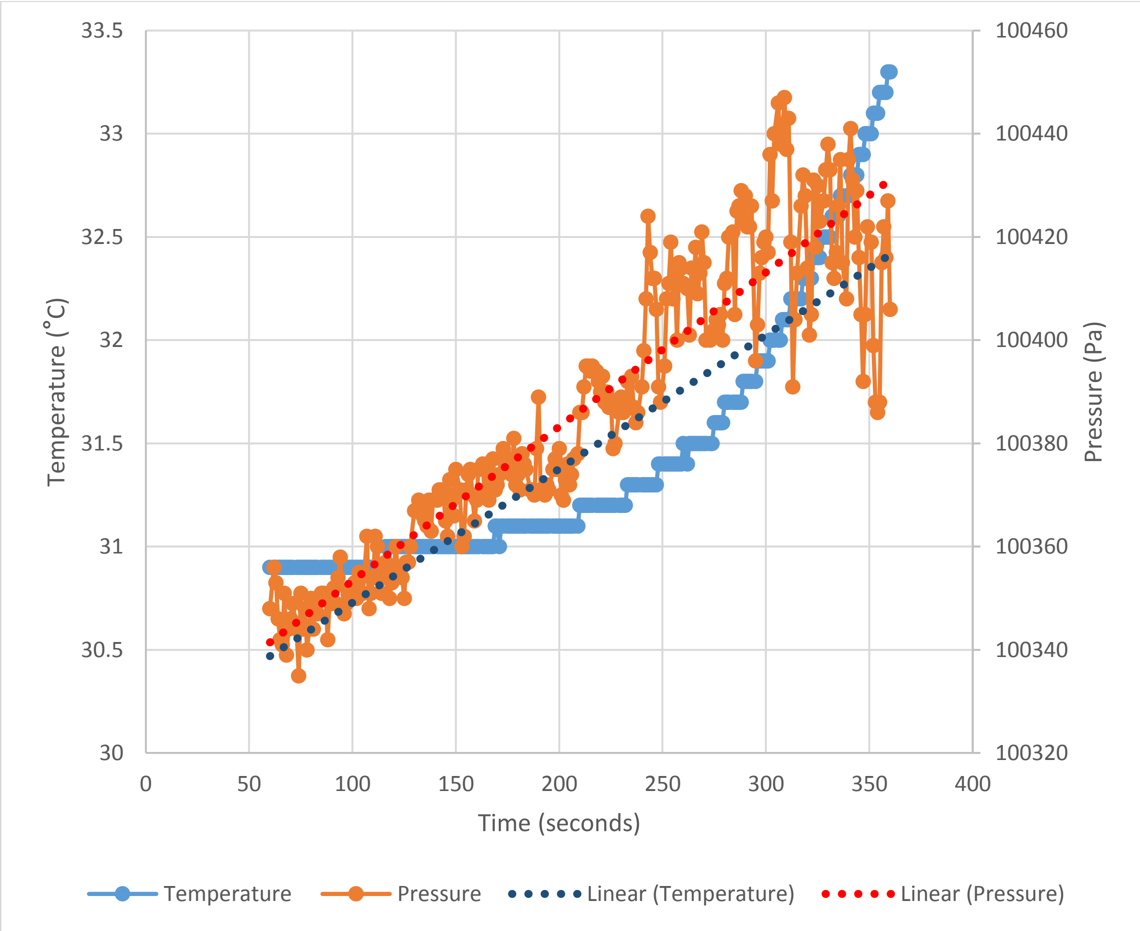

Figure 4.8: Graph of Temperature and Pressure over Time (1st run)

The test was conducted for the second time in order to validate the results of the first run of the test. Figure 4.9 shows the graph obtained from the second test run.

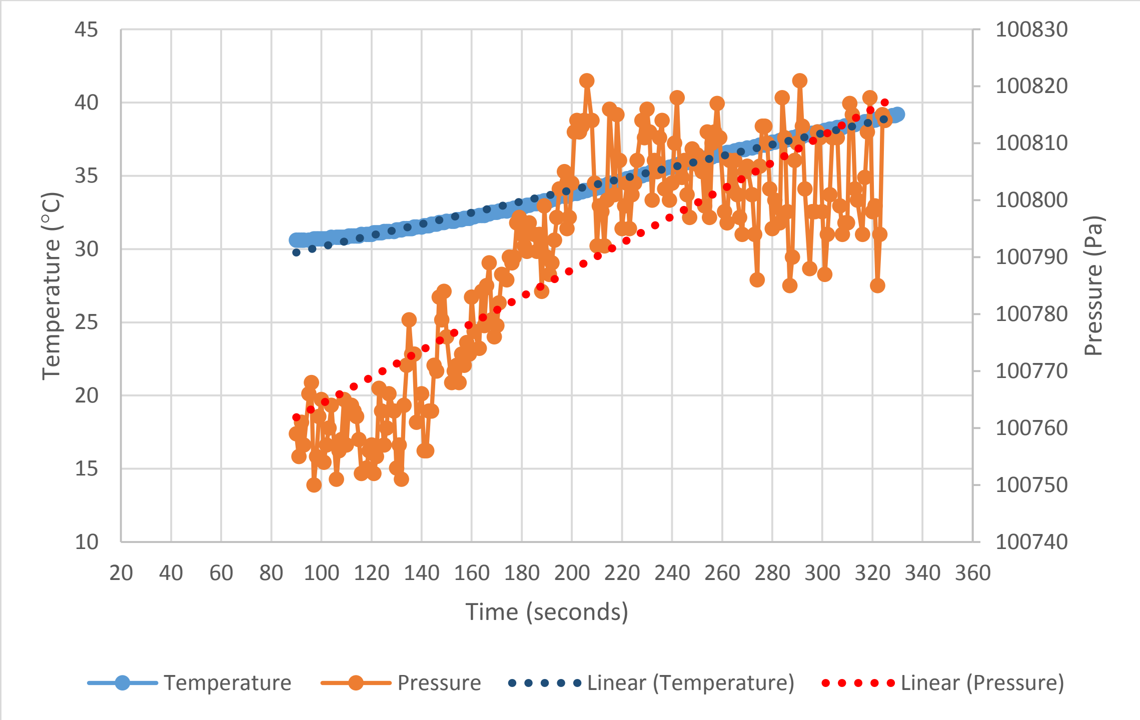

Figure 4.9: Graph of Temperature and Pressure over Time (2^{nd} run)

From the test runs conducted, it can be seen that there is a significant increase in pressure with the increase in temperature in both test runs.

From the theory of Ideal Gas Law:

$$PV = mRT$$

Where,

P = pressure

V = volume

m = mass

R = Gas constant

T = temperature

Therefore,

$$P \propto T$$

The increase in temperature will result in the increase in pressure, as P is directly proportional to T. Thus, the result obtained, is in accordance to the Ideal Gas

Law, and it proves that the pressure sensor is able to detect the temperature and pressure change of the surrounding.

From the indirect tests performed, if the temperature and pressure were able to be detected by the sensors, processed by the microprocessor, and stored in the memory storage, it can be concluded that the acoustic sensor will be able to detect, and be stored in an actual test runs that will be performed in the future.

CHAPTER 5

CONCLUSION

5.1 CONCLUSION

Based on the objectives of this project, the Smartball needs to be able to flow freely in a pipeline with minimum risk of blocking a pipeline, and to develop a sensitive leak detection system which can detect small leaks in a pipeline. However, due to some difficulties faced during the completion of the project, some modifications need to be done on the design of the product. Furthermore, due to the lack of availability of pipeline facilities, indirect tests were performed.

The indirect tests was conducted in order to prove three major things. First, is that the pressure sensor, which is able to detect the surrounding temperature, can detect the change in temperature of the surrounding. Then the change in temperature will cause in the change in pressure. Secondly, the test is conducted to prove that the microprocessor is able to process the data obtained by the sensors and the data can be stored in the memory card. Third, the electronic components, including the sensors and microprocessor are able to run by using a battery, as the Smartball is a closed system which requires it to be deployed in a pipeline, or to put simply as a wireless device.

From the indirect tests performed it shows that the pressure sensor can detect the changes in temperature and pressure of the surroundings, the microprocessor is able to process the data obtained by the sensors, and the product can be run wirelessly by using a battery. In a nutshell, if the temperature and pressure were able to be detected by the sensors, processed by the microprocessor, and stored in the memory storage, it can be concluded that the acoustic sensor will be able to detect, and be stored in an actual test runs that will be performed in the future.

5.2 LIMITATIONS

During the process of completing the projects, various difficulties and obstructions were faced which resulted in the limitations in the design and construction of the Smartball, and also on the testing of the product.

First, the cores of the Smartball were not able to be fabricated in a spherical shape. This is because of the difficulty in manufacturing the spherical shape due to high cost and an ample amount of time required to manufacture the spherical shape. Besides, the inner core was not able to be fabricated by using aluminum as the fabrication of one aluminum shape is highly costly, and also requires a large amount of time for fabrication.

Secondly, the product was not able to be run in an actual pipeline. This is due to the lack of availability of pipeline facilities to test the product. Therefore, indirect tests were performed.

5.3 RECOMMENDATIONS AND FUTURE WORKS

For future works, the fabrication of the Smartball will be done in the spherical shape. This will allow the product to be run easily in a pipeline, and the product can be deployed and retrieved easily during operation.

Secondly, the fabrication of the inner core will be done by using aluminum. This is to ensure that the interior components are safely secured inside the inner core, and the Smartball can have a higher integrity.

Thirdly, the Smartball needs to be tested in an actual pipeline with simulated leaks to test the functionality of the acoustic sensor and the pressure sensor. Besides, it needs to be tested in an actual pipeline in order to test the mobility of the Smartball, in order to proof that a Smartball can move freely in a pipeline with minimum risk of blocking a pipeline.

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