DESIGN SUPPORT SYSTEM FOR PRESSURE VESSEL DESIGN

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MECHANICAL ENGINEERING

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Design Support System for Pressure Vessel Design

by

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Dissertation submitted in partial fulfillment of

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CERTIFICATION OF APPROVAL

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Approved by,

____

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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.

HISYAM JUWAIDI BIN AZIZ

ABSTRACT

The objective of this project is to develop a simple, time saving, user-friendly and in-house software to support design system for pressure vessel design. Pressure vessels are used in a wide number of industries, such as the power generation industry, chemical industry and petrochemical industry. Pressure vessel is a container which carry, store or receive fluids with a pressure difference between outside and inside. Pressure vessels often have a combination of high pressure and high temperature or in some cases flammable fluids and highly radioactive materials. Because of such hazards, it is crucial that the design be such that no leakage can occur. A good design of pressure vessels need to be done before manufacturing or purchasing so that the selected pressure vessels can deliver the task for any industry. The scope of study was to do literature review of the mechanical design of pressure vessel based on the ASME Boiler and Pressure Vessel Code, Section VIII Division 1. Literature reviews of the equations involved in designing the pressure vessels and finally develop the support system for the pressure vessel design using MatLab r2009a. The methods used to achieve the objective of this project are, a) Conducting literature review of the type of pressure vessels, equations for the design of pressure vessel; b) Develop the support system for pressure vessel design using MatLab r2009a. This project concluded that the objective of this project is achieved but it is recommended that the project should be developed further in the future as the possibilities to create the support system for pressure vessel design are high.

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Thanks to GOD, for everything I have achieved so far in my life, because none of them would have been possible without His plan for my life.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background of study

Pressure vessels are used in a wide number of industries, which are first the power generation industry for fossil and nuclear power. Secondly, they are used in the petrochemical industry for storing and processing crude petroleum oil in tank farms as well as storing gasoline in service stations. Besides that, they are used in the chemical industry, specifically in the chemical reactors. In other word, pressurized equipment is essential for industrial plant for storage and manufacturing purposes (Wiencke, 2010).

Pressure vessels came out in various shapes and sizes. The designation and geometry of pressure vessels vary according to standards in the industries. Therefore, this project uses the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII Division 1 as the standard.

It is crucial for the engineers to have engineering software application to ease their work in designing the pressure vessels these days. Therefore, this project is very important as the project is to design a support system for the pressure vessel design. This project will use MatLab as a programming language tool to develop the support system to design the pressure vessel model according to the desired specifications.

1.2 Problem statement

In the market, there are available engineering software applications for modeling of pressure vessel components and features. Unfortunately, they are hard to find and the genuine license is expensive which is about USD 3465 for industrial users. However, for the beginner users, such as the university students or fresh graduated engineers, they will take time to fully understand the tools and manuals for the advanced software applications. Before they can start to design the pressure vessel models, they must first have the access for the software and a long period of time to complete their tasks. A good design of the pressure vessels could give good results for the pressure vessels to be manufactured and purchased. Therefore, a simple design tool to support the pressure vessels design would be suffice to help the beginners especially engineering student.

1.3 Objectives

The objective of this project is to develop a simple, time saving, user-friendly and in-house software to support design system for pressure vessel design based on the international standard.

1.4 Scope of study

a) Using the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII, Division 1 for the design standard of pressure vessels.
b) Unfired Pressure Vessels

CHAPTER 2

LITERATURE REVIEW

2.1 Pressure Vessels

A pressure vessel is one of the most important components in industrial and petrochemical process plants. Pressure vessel encompasses a wide range of unit heat exchangers, reactors, storage vessels and many more. Pressure vessel is defined as a container with a difference between inside pressure and outside pressure. It is further explained that vessels, tanks and pipelines which carry, store, or receive fluids are considered as pressure vessels (Chattopadhyay, 2004). On top of that, pressure vessel is a type of storage tank which is used to store fluid at higher pressure than ambient conditions ("Types of Pressure Vessels,").

For the purposes of design and construction, the pressure vessel is generally defined as the pressure vessel proper including welded attachments up to, and including, the nozzle flanges, screwed or welded connectors, or the edge to be welded at the first circumferential weld to connecting piping. Figure 2.1 shows a typical pressure vessel envelope.

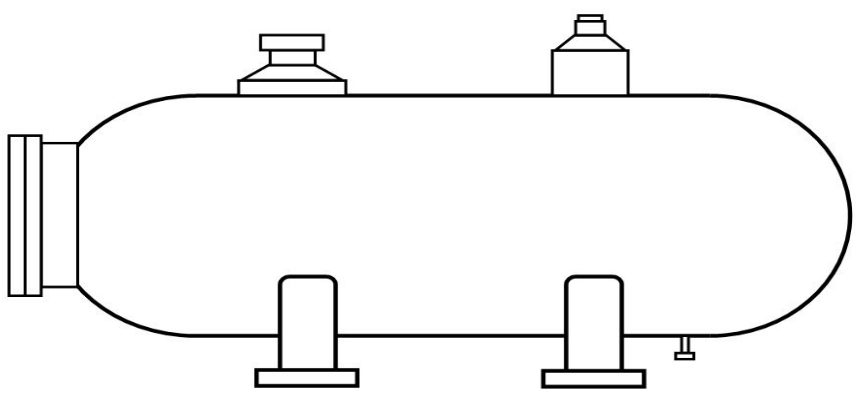
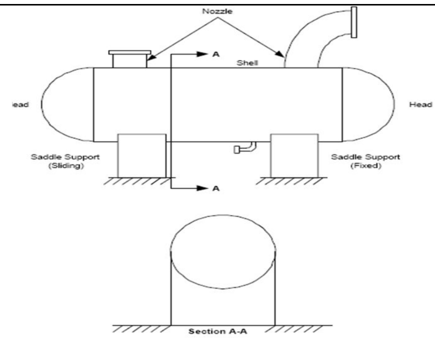


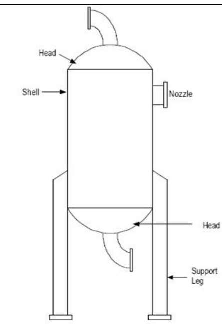
Figure 2.1 Typical pressure vessel

2.2 Type of Pressure Vessels

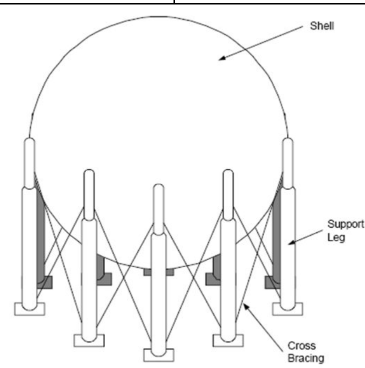
For this, there are three types of pressure vessels, which are: horizontal pressure vessel; vertical pressure vessel; and spherical pressure vessel ("Types of Pressure Vessels,").



Horizontal Pressure Vessel



Vertical Pressure Vessel



Spherical Pressure Vessel

Figure 2.2 Type of Pressure Vessel

2.3 Standards and Codes for Pressure Vessels

Pressure vessels usually have a combination of high pressures together with high temperatures, and sometimes it involves flammable fluids or highly radioactive materials. It is crucial that the design of the pressure vessels results in no leakage can occur because of the hazards. Moreover, the pressure vessels have to be designed carefully to cope with the operating temperature and pressure (Chattopadhyay, 2004).

As the pressure vessels are made in various shapes and sizes, there are certain standards and codes that the engineer or designer need to follow in the design of the vessels. (Chattopadhyay, 2004) mentioned pressure equipment, such as the American Petroleum Institute (API) storage tanks are designed to forbid internal pressure to no more than that generated by the static head of the fluid contained in the tank. Below are the design and construction codes for pressures vessels:

Table 2.1 Design and Construction Codes for Pressure Vessels

Country	Code	Issuing authority
U.S	ASME Boiler & Pressure Vessel Code	ASME
U.K	BS 1515 Fusion Welded Pressure Vessels BS 5500 Unfired Fusin Welded Pressure Vessels	British Standard Institute
Germany	AD Merblatter	Arbeitsgemeinschaft Druckbehalter
Italy	ANCC	Associanize Nationale Per II Controllo Peula Combustione
Netherlands	Regeis Voor Toestellen	Dienst voor het Stoomvezen
Sweden	Tryckkarls kommissionen	Swedish Pressure Vessel Commision
Australia	AS 1200:SAA Boiler Code AS 1210 Unfired Pressure Vessels	Standards Association of Australia
Belgium	IBN Construction Code for Pressure Vessels	Belgian Standards Institute
Japan	MITI Code	Ministry of International Trade and Industry
Country	Code	Issuing authority
France	SNCT Construction Code for Unfired Pressure Vessels	Syndicat National de la Chaudronnerie et de la Tuyauterie Industrille

2.4 ASME Boiler and Pressure Vessel Code

The organization of the ASME Boiler and Pressure Vessel Code is as follows:

1. Section I: Power Boilers
2. Section II: Material Specification:
   i. Ferrous Material Specifications – Part A
   ii. Non-ferrous Material Specifications – Part B
   iii. Specifications for Welding Rods, Electrodes, and Filter Metals – Part C
   iv. Properties – Part D
3. Section III Subsection NCA: General Requirements for Division 1 and Division 2
   i. Section III, Division 1:
      a. Subsection NA: General Requirements
      b. Subsection NB: Class 1 Components
      c. Subsection NC: Class 2 Components
      d. Subsection ND: Class 3 Components
      e. Subsection NE: Class MC Components
      f. Subsection NF: Component Supports
      g. Subsection NG: Core Support Structures
      h. Appendices: Code Case N-47 Class 1: Components in Elevated Temperature Service
   ii. Section III, Division 2: Codes for Concrete Reactor Vessel and Containment
4. Section IV: Rules for Construction of Heating Boilers
5. Section V: Nondestructive Examinations
6. Section VI: Recommended Rules for the Care and Operation of Heating Boilers
7. Section VII: Recommended Guidelines for Care of Power Boilers
8. Section VIII
   i. Division 1: Pressure Vessels – Rules for Construction
   ii. Division 2: Pressure Vessels – Alternative Rules
9. Section IX: Welding and Brazing Qualifications

10. Section X: Fiberglass-Reinforced Plastic Pressure Vessels
11. Section XI: Rules for In-Service Inspection of Nuclear Power Plant Components

The design of pressure vessels is an important and practical topic which has been explored for tens of years (Carbonari et al., 2011). The American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII, is a live and progressive documents in which it strives to contains the latest, safe, economical rules for the design and construction of pressure vessels, pressure vessel components, and heat exchangers (Farr & Jawad, 2006). The code was sought to standardise the design, manufacturing, and inspection of boiler and pressure vessels in 1914. According to (Carbonari et al., 2011), the Section VIII comprises of 2 divisions, which are the Division 1: Pressure Vessels – Rules for Construction and Division 2: Pressure Vessels – Alternative Rules.

2.5 ASME Boiler and Pressure Vessel Code, Section VIII, Division 1

According to the history, as pressure vessels store energy and have inherent safety risks, many states began to enact rule and regulations regarding the construction of steam boilers and pressure vessels following several catastrophic accidents that happened at the turn of the twentieth century that resulted in loss of many lives (Code, 1994). Almost all pressure vessels in the United States are designed and constructed in accordance with Section VIII, Division 1 (Thakkar & Thakkar, 2012).

Table 2.2 Limitations of articles by several authors

Author (s)	Title	Descriptions/Limitation
(Walker & Tabakov, 2013)	Design optimization of anisotropic pressure vessels with manufacturing uncertainties accounted for	• Using the technique of genetic algorithm to determine the optimum solution
(Carbonari et al., 2011)	Design of Pressure Vessels Using Pressure Approach	• No pressure limit
(Diamantoudis & Kermanidis, 2005)	Design by analysis versus design by formula of high strength steel pressure vessels: a comparative study	• Design by analysis is better in term of limit load capability • Finite Element Analysis is used
(Spence & Nash, 2004)	Milestones in pressure vessel technology	• Focusing on the analysis of the pressure vessel design • Does not cover the advancement of material

Table 2.3 ASME Section VIII Division 1 – "Unfired" Pressure Vessel Rules

Pressure limits	Usually up to 3000 psig
Organization	General, Construction Type & Material U, UG, UW, UF, UB, UCS, UNF, UCI, UCL, UCD, UHT, ULT
Design Factor	Design Factor of 3.5
Design Rules	Membrane - Maximum Stress Generally Elastic analysis Very Detailed design rules with Quality (joint efficiency) Factors. Little stress analysis required; pure membrane without consideration of discontinuities controlling stress concentration to a safety factor of 3.5 or higher
Material and Impact testing	Few restrictions on materials

("A Brief Discussion on ASME Section VIII Division 1 and 2 and The New Division 3," 2000)

2.6 Design Procedure for Pressure Vessels

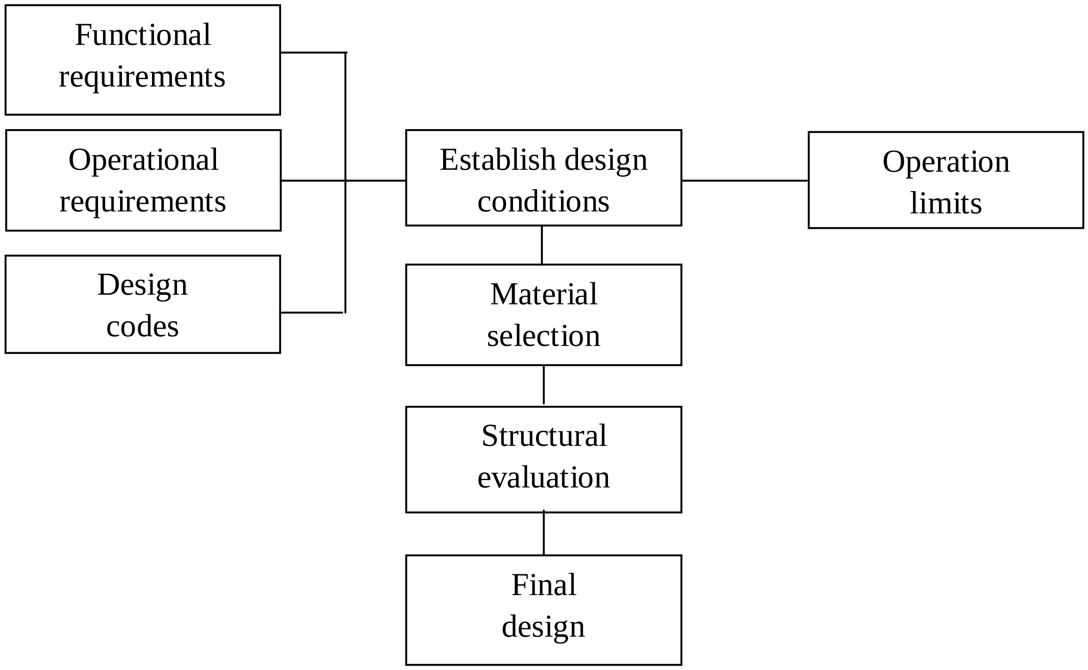


Figure 2.3 Design Procedure for Pressure Vessels

Pressure vessels are designed to meet requirements specified by a team, which includes process engineers, thermodynamic experts and mechanical engineers. The functional requirements cover the geometrical parameters, which are size and shape of the vessel; method of vessel support; and location and size of attachments and nozzles.

The operational requirements are imposed on the vessel as part of the overall plants which include the operating pressure, fluid conditions, external loads and transient conditions. Then, the materials are selected with acceptable temperature ranges and design stresses.

2.7 MatLab as a Programming Language Tools

In order to generate the support system for pressure vessel design, MatLab is one of the many programming language tools to be considered in this project. There are another power tools such as Microsoft Excel, Microsoft Visual Basic and C++. Nevertheless, MatLab is one of the widely used and user-friendly programming languages for scientific and engineering computations (Sen & Shaykhian, 2009).

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

This project is conducted accordingly till the completion of the project in which desired results are obtained as shown in figure below.

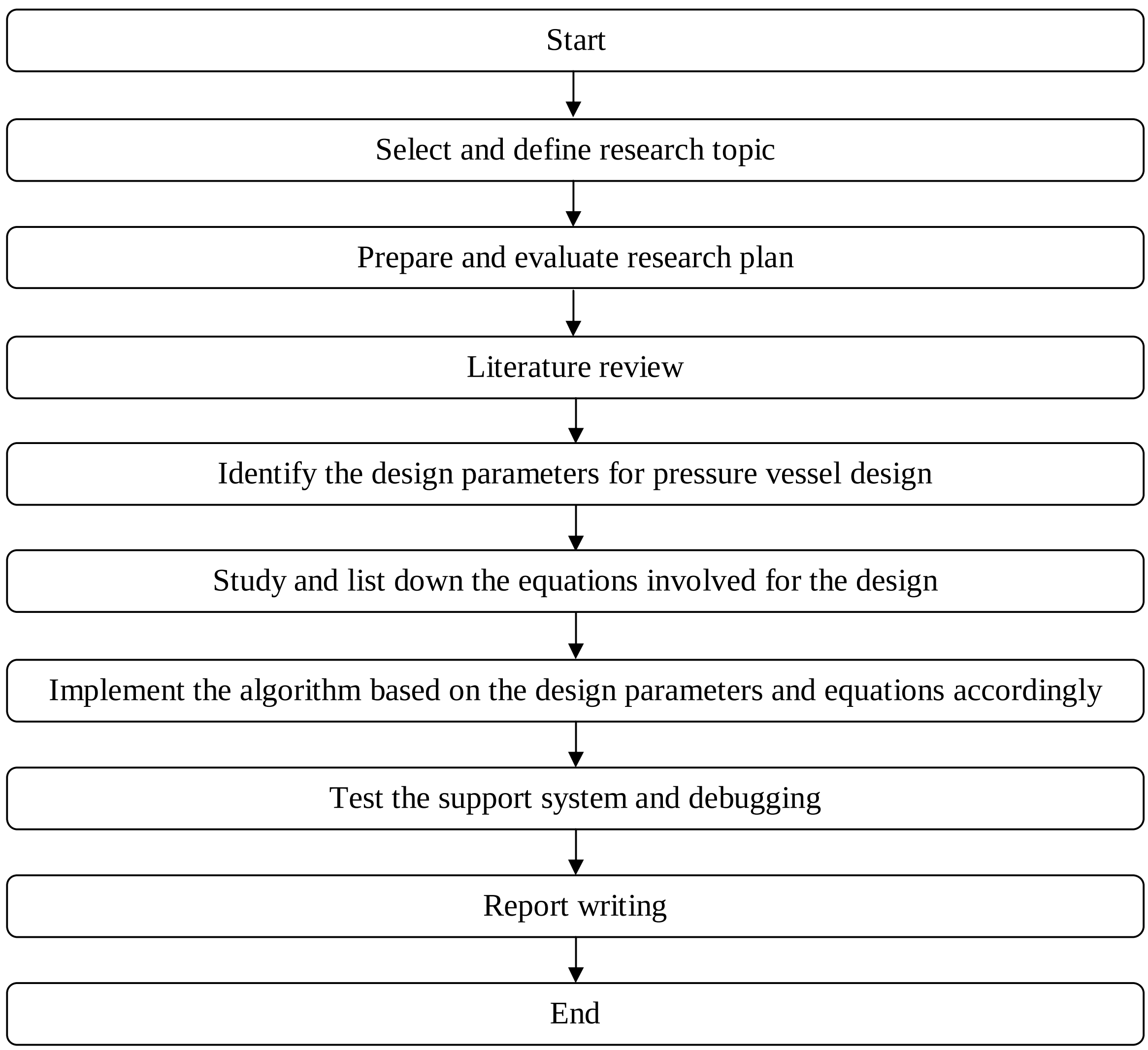


Figure 3.1 Flow chart of the project methodology

3.2 Tools

The tool required to carry out this project is determined to be:

- Matlab r2009a programming software

Matlab software is used specifically to design support system for the pressure vessel design based on the suitable algorithm along with equations for pressure vessel design.

3.3 Key Milestone

Table 3.1 Key Milestone for FYP I

Key Milestone	Proposed Week
Submission of Extended Proposal	Week 6
Proposal Defense	Week 9
Submission of Interim Draft Report	Week 13
Submission of Interim Report	Week 14

Table 3.2 Key Milestone for FYP II

Key Milestone	Proposed Week
Submission of Progress Report	Week 7
Pre SEDEX	Week 10
Submission of Draft Dissertation	Week 12
Submission of Dissertation (soft bound)	Week 13
Submission of Technical Paper	Week 13
Oral Presentation	Week 14
Submission of Project Dissertation (hard bound)	Week 15

3.4 Gantt Chart

Table 3.3 Gantt chart representing the process flows for FYP I

Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Selection of Project Topic														
Preliminary Research Work • Identify the standards and codes of • Identify the available programming language tools														
Submission of Extended Proposal						●								
Preparation for Proposal Defense														
Proposal Defense									●					
Analysis of data • Information gathering (research on specification of pressure vessel and suitable algorithm) • Start-off activities • Preliminary design of software														
Submission of Interim Draft Report													●	
Submission of Interim Report														●

Table 3.4 Gantt chart representing the process flows for FYP II

Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Designing • Working on the algorithm using MATLAB	■	■	■	■	■	■	■	■	■	■					
Testing • Analyze the software based on the result of the input and output data									■	■	■				
Submission of Progress Report							●								
Pre SEDEX										●					
Validate the software									■	■	■				
Submission of draft dissertation												●			
Submission of dissertation (soft bound)													●		
Submission of technical paper													●		
Oral Presentation														●	
Submission of dissertation (hard bound)															●

■	Process
●	Milestone

CHAPTER 4

RESULT AND DISCUSSIONS

4.1 Result

The support system for pressure vessel design created by using the Matlab software can be used to design for three different type of pressure vessels which are horizontal pressure vessel, vertical pressure vessel and spherical pressure vessel.

For each type of pressure vessel, the program will provide only the design of shell, design of head and design cover. The user will be asked to give input for the program to calculate the parameter required for the design of selected type of pressure vessel.

At first the user has to give the volume of the pressure vessel according to the space which the pressure vessel will be placed and volume of the liquid or gas that it will fill. The user also needs to give the length if known based on the ratio of length to the diameter of the pressure vessel must be between 2 to 4. If the length is not given, then the program will choose the default value which is 3.

The user will be asked to give the input value based on the user's specification in the following input data:

- Volume of pressure vessel (m^3)
- Length (m)
- Design pressure (Pa)
- The allowable stress for the materials (Pa)
- Joint Efficiency Factor
- Corrosion factor (m)
- Temperature (^oC)

The flowchart of the program can be illustrated as figure shown below.

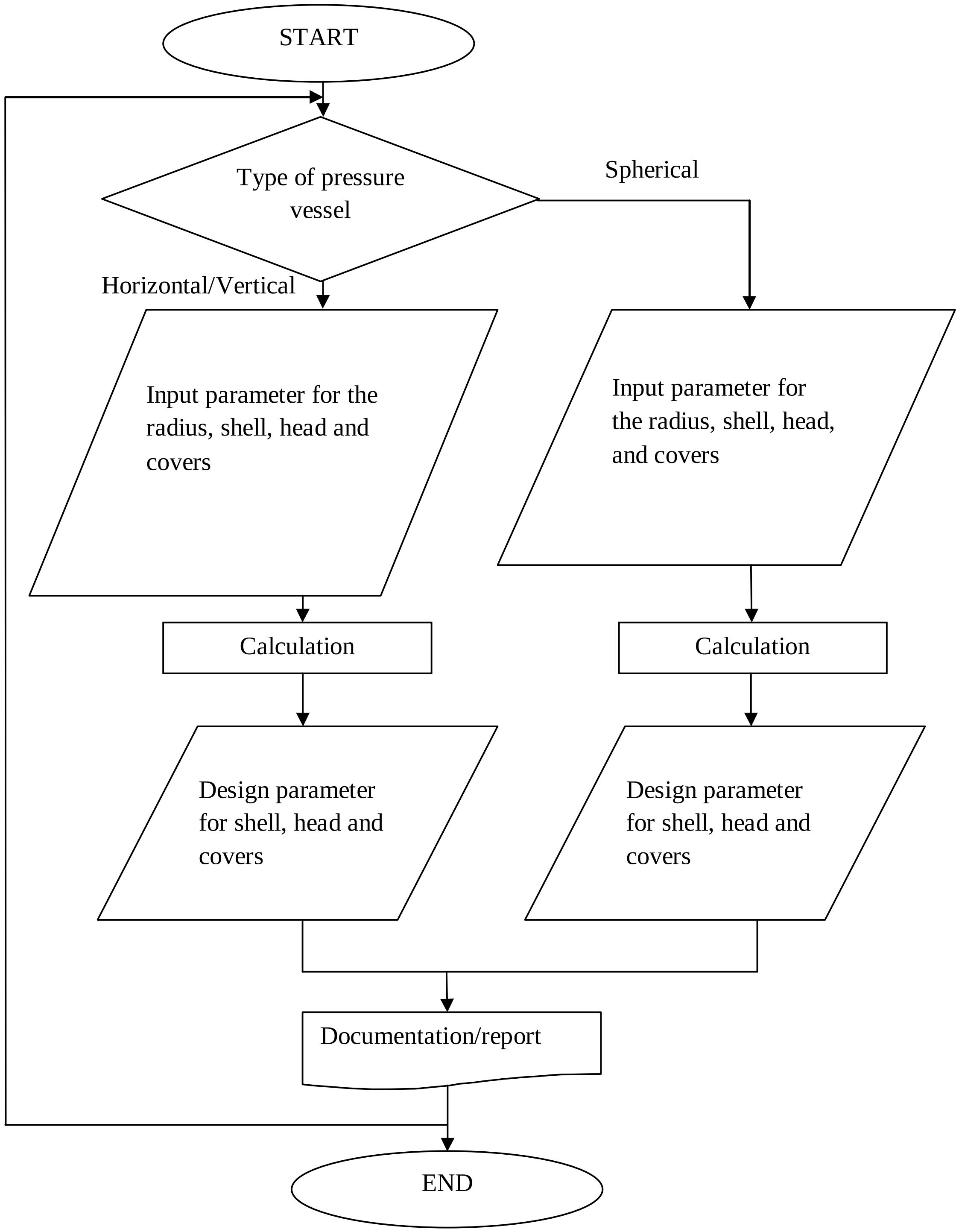


Figure 4.1 Flowchart of the pressure vessel support system

The program starts by asking the user the type of pressure vessel that the user wants to design such as follows:

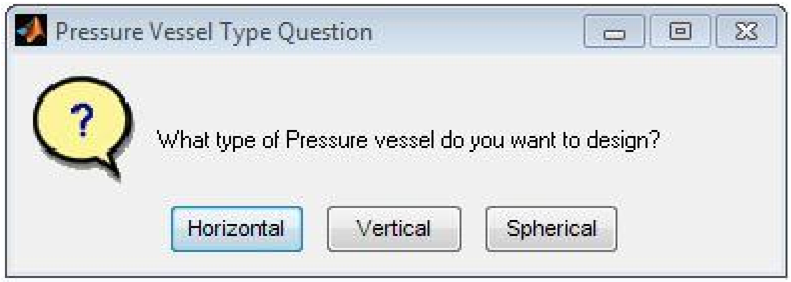


Figure 4.2 Type of pressure vessel the user has to select

There are three options in order to select the type of pressure vessel namely, horizontal, vertical and spherical. For example, when the user chooses to create a horizontal pressure vessel, the following windows will appear.

As the user choose the desired type of pressure vessel, the volume and length will be asked for horizontal and vertical pressure vessel but only the volume will be asked for spherical pressure vessel.

As the inputs are given by the user, the programme will calculate the input through equations in the algorithm to give output such the thickness of the shell.

For the design of shell of horizontal and vertical pressure vessel, the thickness of cylindrical shell will be calculated first given there are two type of cylindrical shell, namely thin and thick given in certain condition. The same programme also works for the spherical pressure vessel.

Then, the user will be given the design of head by choosing three types of head, which are hemispherical head, ellipsoidal head and torispherical head. Should the user choose the different type of head for three different type of pressure vessel.

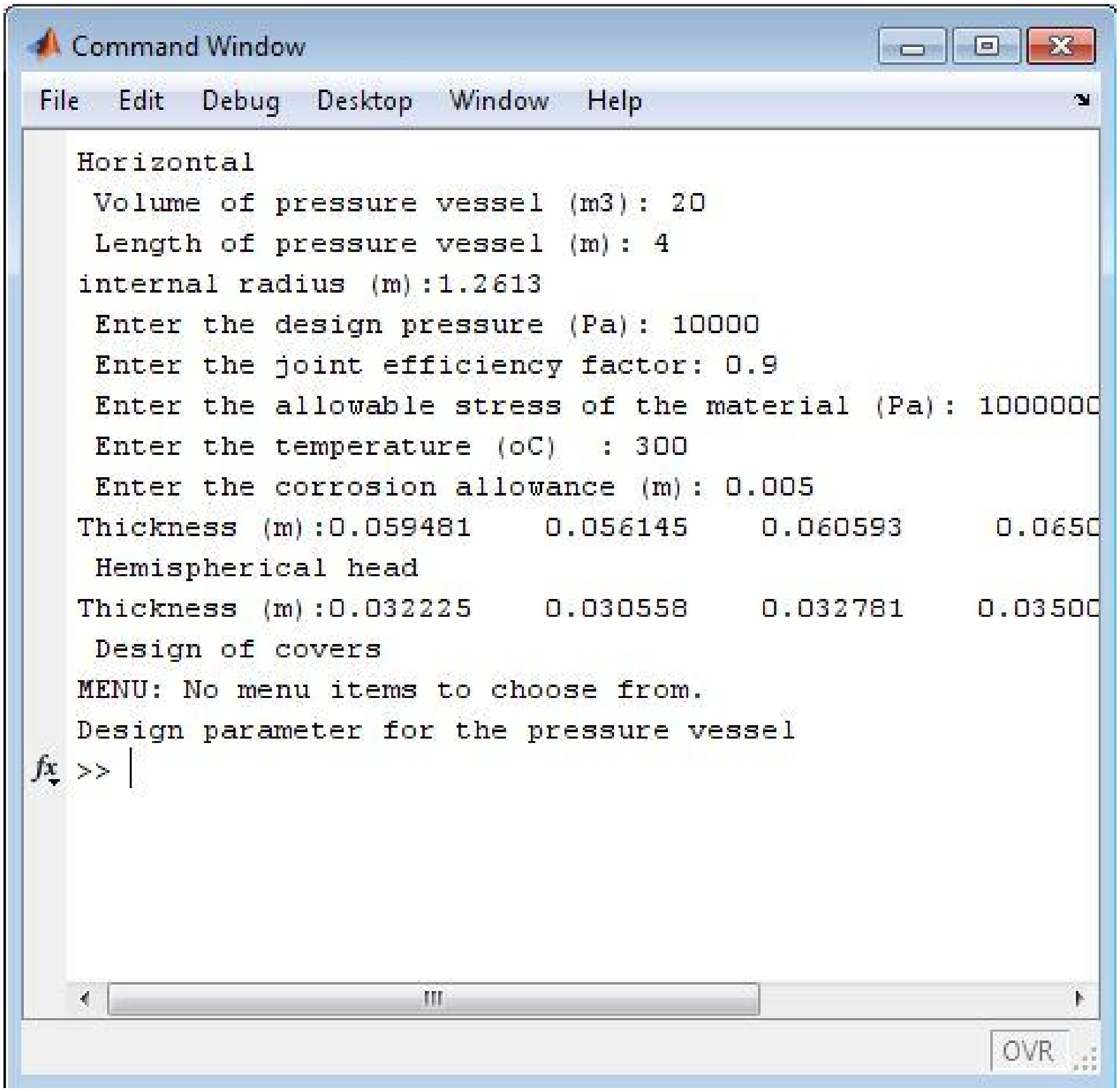


Figure 4.3 Windows showing the input and output parameters of the horizontal pressure vessel

Figure 4.3 shows that design parameter for the horizontal pressure vessel. The input should be given in the SI unit. However, the user need to give the value of allowable stress of the material as it is not provided.

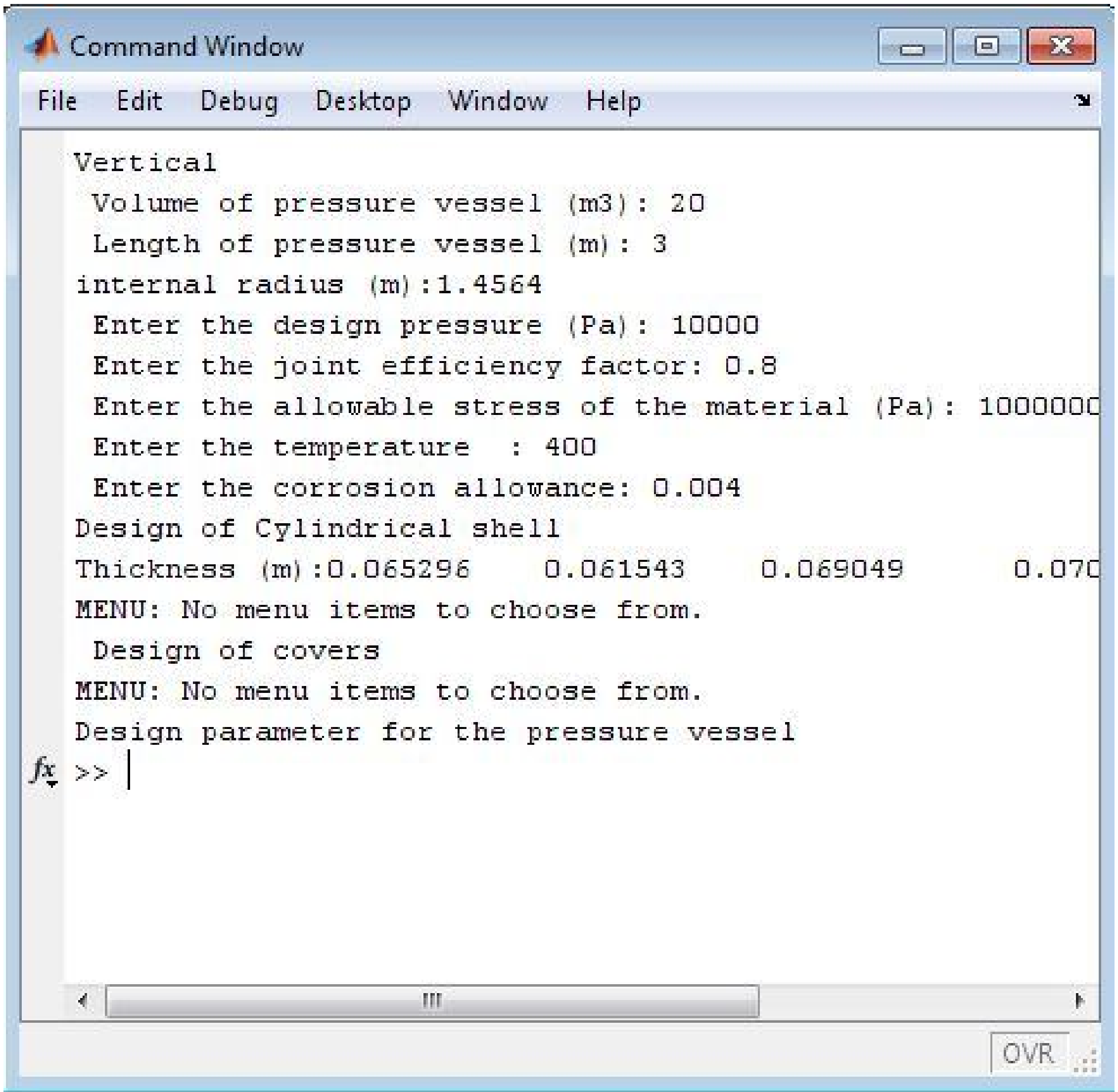


Figure 4.4 Windows showing the input and output parameters of the vertical pressure vessel

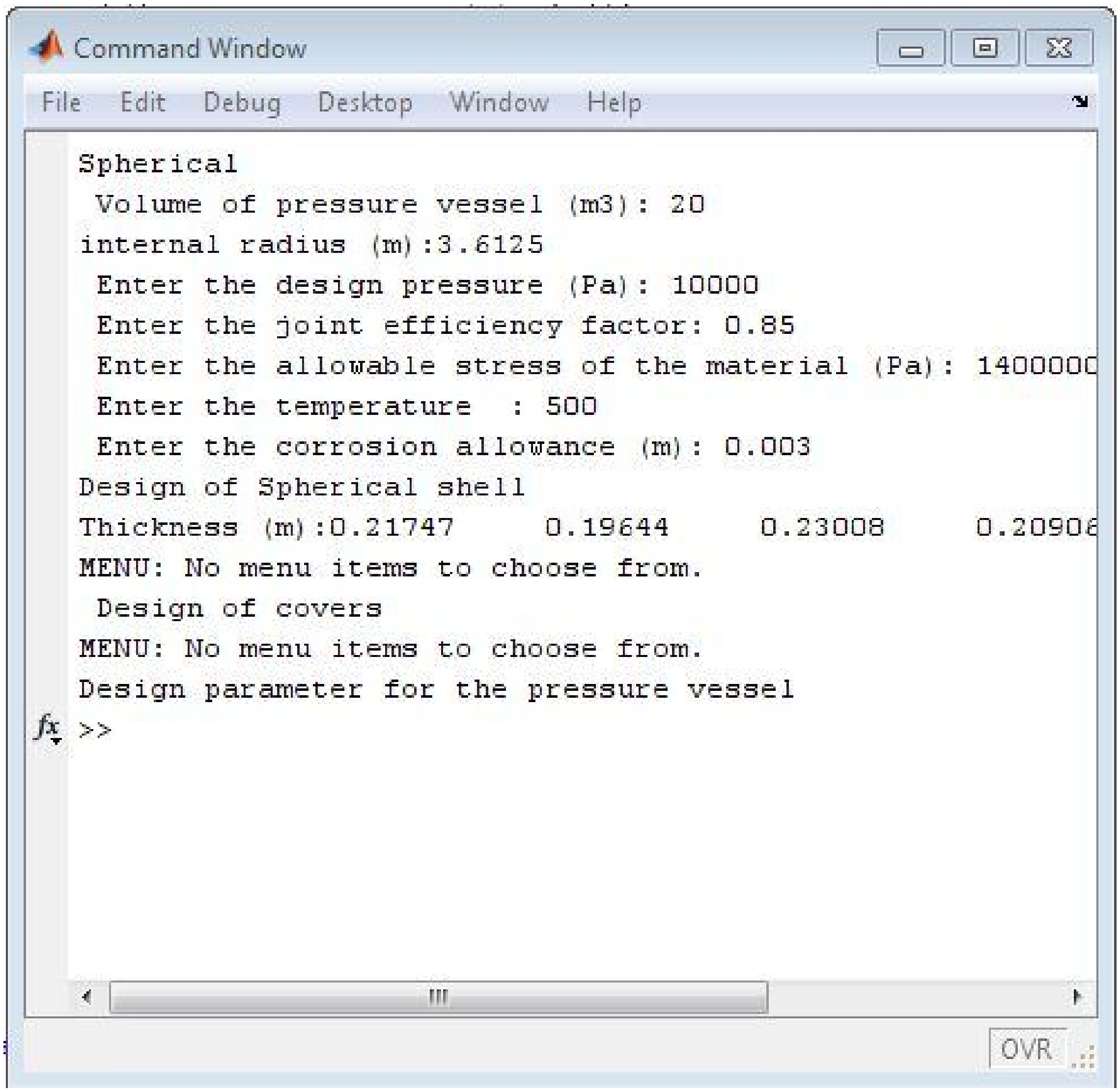


Figure 4.5 Windows showing the input and output parameters of the spherical pressure vessel

4.2 Discussion

The support system for pressure vessel design that has been created in the Matlab is too simple as it does not give full design parameter of the standard pressure vessel. However, the system can deliver the input and output for the calculation of several mechanical design of pressure vessel according to ASME B&PV Section VIII Division 1. The support system done can only do the design of cylindrical and spherical shell, the design of head and the design of covers.

The target was to design for the shell, head, openings, flanges, covers and the support for the pressure vessel. Unfortunately, due to certain problem and difficulties, the project can be done accordingly. The performance of the support system is poor and it still needs debugging process to complete the system.

The design of pressure vessel should be as follows:

Design of Pressure Vessel

1. Select type of pressure vessel:
   - Horizontal
   - Vertical
   - Spherical
2. User's input parameters
   - Volume of pressure vessel
   - Length of pressure vessel
   - Design working pressure
   - Materials
   - Joint efficiency factor
   - Corrosion allowance
   - Temperature
   - Type of fluid

3. Output
    - Volume
    - Length
    - Radius
    - Design of shell
    - Design of head
    - Design of flanges and covers
    - Design of opening
    - Design of supports

The materials should be chosen by the user and the user does not need to give the value of the allowable stress of the material. There should be list of materials for the user to select for the pressure vessel design.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The objective of this project is to develop the simple, time-saving and user friendly support system for pressure vessel design. The support system developed meets the objective of this project, however, due to some difficulties and limitations the support system cannot be done according to the expected result. The support system could have been better as a tool to help engineer and designer to design the pressure vessel with simple steps to save time.

5.2 Recommendation

It is recommended that the support system for pressure vessel design to be further developed and modified in the future. For example, the list of materials should be provided to the user to be chose from the system so that the user will have more choices in creating the design of pressure vessel. As the material is listed, the allowable stress, yield strength and tensile strength should given to the user to be selected. It is easier and time-saving in that way.

Besides that, the mechanical design of pressure vessel should includes the design of head, design of shell, design nozzle, design of flanges and covers and as well as the design of support. Then, the design of pressure vessel will be completed.

Furthermore, the support system for the pressure vessel design is more preferable to be created in Matlab GUI as it gives more user-friendly conditions to the user. The programme can be saved as the executable programme and it can be used in any computer without any Matlab software.

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APPENDICES

APPENDIX A : Mechanical Design for Pressure Vessel

1. Design of Shells

Horizontal and Vertical Pressure Vessels

Cylindrical shells

Thin cylindrical shells

$t = PR(SE - 0.6P), \text{ when } t < 0.5R \text{ or } P < 0.385SE$

where

E = joint efficiency factor

P = internal pressure

R = internal radius

S = allowable stress in the material

t = thickness of the cylinder

Thick cylindrical shells

$t = R(Z^{1/2} - 1)$

where

$Z = (SE + P)/(SE - P)$

where

E = joint efficiency factor

P = internal pressure

R = internal radius

S = allowable stress in the material

t = thickness of the cylinder

Spherical Pressure Vessels

Spherical shells

Thin spherical shells

$t = PR/(2SE - 0.2P)$, *when* $t < 0.356R$ *or* $P < 0.665SE$

where

E = joint efficiency factor

P = internal pressure

R = internal radius

S = allowable stress in the material

t = thickness of the shell

Thick spherical shells

$t = R(Y^{1/3} - 1)$

where

$Y = 2(SE + P)/(2SE - P)$

where

E = joint efficiency factor

P = internal pressure

R = internal radius

S = allowable stress in the material

t = thickness of the shell

2. Design of heads

2.1 Hemispherical heads

<u>Thin hemispherical heads</u>

$t = PR/(2SE - 0.2P)$, *when* $t < 0.356R$ *or* $P < 0.665SE$

where

E = joint efficiency factor

P = internal pressure

R = internal radius

S = allowable stress in the material

t = thickness of the head

<u>Thick hemispherical heads</u>

$t = R(Y^{1/3} - 1)$

where

$Y = 2(SE + P)/(2SE - P)$

where

E = joint efficiency factor

P = internal pressure

R = internal radius

S = stress in the material

t = thickness of the head

2.2 Ellipsoidal heads

$t = PD/(2SE – 0.2P)$, radius-to-depth ratio is 2:1

where

D = inside base diameter

E = joint efficiency factor

P = pressure on the concave side of the head

t = thickness of the head

$t = PDK/(2SE – 0.2P)$, radius-to-depth ratio is other than 2:1

where

$K = (1/6)[2 + (D/2h)^2]$

where

D = inside base diameter

E = joint efficiency factor

P = pressure on the concave side of the head

t = thickness of the head

2.3 Torispherical heads

$t = 0.885PL/(SE – 0.1)$, when L = D and r = 0.06D

where

E = joint efficiency factor

L = inside spherical radius

P = pressure on the concave side of the head

S = allowable stress for the material

t = thickness of the head

$t = PLM/(2SE - 0.2P)$, when 1.0 < L/r < 16.67

where

$M = (1/4)[3 + (L/r)^{1/2}]$

where

E = joint efficiency factor

L = inside spherical radius

P = pressure on the concave side of the head

S = allowable stress for the material

t = thickness of the head

3.0 Design of Conical Sections

$t = PD/[2 \cos a \, (SE - 0.6P)]$, where $a < 30^{o}$

where

t = required thickness

P = internal pressure

D = inside diameter of conical section under consideration

S = allowable tensile stress

E = joint efficiency factor

4.0 Design of flat plates, covers and flanges

Circular flat plates and covers

$t = d(CP/SE)^{1/2}$

where

d = effective diameter of the flat plate

C = coefficient between 0.10 and 0.33

P = design pressure

S = allowable stress at design temperature

E = butt-welded joint efficiency of the joint within the flat plate

t = minimum required thickness of the flat plate

Noncircular flat plates and covers

$Z = 3.4 – (2.4d/D)$

$t = d(ZCP/SE)^{1/2}$

where

d = effective diameter of the flat plate

C = coefficient between 0.10 and 0.33

P = design pressure

S = allowable stress at design temperature

E = butt-welded joint efficiency of the joint within the flat plate

t = minimum required thickness of the flat plate

APPENDIX B: Algorithm in Matlab for Pressure Vessel Support System

```
clear;
ButtonName = questdlg('What type of Pressure vessel do you want
to design?', ...
                         'Pressure Vessel Type Question', ...
                         'Horizontal', 'Vertical', 'Spherical',
'Horizontal');
   switch ButtonName,
     case 'Horizontal',
         disp('Horizontal');

            V = input(' Volume of pressure vessel (m3): ');
         L = input(' Length of pressure vessel (m): ');

         if(L==0);
             r = (V/6/(22/7))^(1/3);
         else
             r = (V/(22/7)/L)^(1/2);
         end
             r = num2str(r);

         disp(['internal radius (m):',r]);

         P = input(' Enter the design pressure (Pa): ');
         E = input(' Enter the joint efficiency factor: ');
         S = input(' Enter the allowable stress of the material
(Pa): ');
         T = input(' Enter the temperature (oC)  : ');
         CA = input(' Enter the corrosion allowance (m): ');

         if (P < 0.385*S*E);

             t = P*r/(S*E - 0.6*P)+ CA; %thin shell

         else

             t = r*((((S*E + P)/(S*E - P))^0.5)-1)+ CA; %thick
shell

         end

         t = num2str(t);
         disp(['Thickness (m):',t]);

% menu(' Select type of head for the pressure vessel ',
'Hemispherical head', 'Ellipsoidal head', 'Torispherical head');
%
% switch menu,
%     case 'Hemipherical head',
         disp(' Hemispherical head ');
```

```
%           if (P < 0.665*S*E);

         th = P*r/(2*S*E - 0.2*P) + CA; %thin hemispherical head

%           else
%
%           t = R*(((2*(S*E + P)/(2*S*E - P))^(1/3))-1) +
CA;%thick hemi head
%
%           end

         th = num2str(th);
         disp(['Thickness (m):',th]);

%      case 'Ellipsoidal head',
%           disp(' Ellipsoidal head ');
%
%           t = P*2*r/(2*S*E - 0.2*P) + CA;
%
%           t = num2str(t);
%           disp(['Thickness (m):',t]);
%
%      case 'Torispherical head',
%           disp(' Torispherical head ');
%
%           t = 0.885*P*2*r/(S*E - 0.1*P) + CA;
%
%           t = num2str(t);
%           disp(['Thickness (m):',t]);
%
% end

    disp(' Design of covers ');

    menu(' Select the type of covers ', 'Circular' ,
'Noncircular');

    switch menu,

        case 'Circular',

            disp(' Circular cover ');

            d = input(' Enter the Effective diameter of flat
plate (m): ');
            C = input(' Enter the coefficient of corner details
(0.1 - 0.33): ');

            t = d*(C*P/(S*E))^0.5 + CA;
            t = num2str(t);
            disp(['Thickness (m):',t]);
```

```
        case 'Noncircular',

           disp(' Noncircular cover ');

            d = input(' Enter the length of short dimension (m):
');
            D = input(' Enter the length of long dimension (m):
');
            C = input(' Enter the coefficient of corner details
(0.1 - 0.33): ');

            t = d*((3.4 - (2.4*d/D))*C*P/(S*E))^0.5 + CA;
    end

    case 'Vertical',
         disp('Vertical');

         V = input(' Volume of pressure vessel (m3): ');
         L = input(' Length of pressure vessel (m): ');

         if(L==0);
             r = (V/6/(22/7))^(1/3);
         else
             r = (V/(22/7)/L)^(1/2);
         end
             r = num2str(r);

         disp(['internal radius (m):',r]);

         P = input(' Enter the design pressure (Pa): ');
         E = input(' Enter the joint efficiency factor: ');
         S = input(' Enter the allowable stress of the material
(Pa): ');
         T = input(' Enter the temperature  : ');
         CA = input(' Enter the corrosion allowance: ');

         disp('Design of Cylindrical shell');

         if (P < 0.385*S*E);

             t = P*r/(S*E - 0.6*P)+ CA; %thin shell

         else

             t = r*((((S*E + P)/(S*E - P))^0.5)-1)+ CA; %thick
shell

         end

         t = num2str(t);
         disp(['Thickness (m):',t]);
```

```
menu(' Select type of head for the pressure vessel ',
'Hemispherical head', 'Ellipsoidal head', 'Torispherical head');

switch menu,
    case 'Hemipherical head',
         disp(' Hemispherical head ');

         if (P < 0.665*S*E);

         t = P*R/(2*S*E - 0.2*P) + CA; %thin hemispherical head

         else

         t = R*(((2*(S*E + P)/(2*S*E - P))^(1/3))-1) + CA;%thick
hemi head

         end

         t = num2str(t);
         disp(['Thickness (m):',t]);

    case 'Ellipsoidal head',
         disp(' Ellipsoidal head ');

         t = P*2*r/(2*S*E - 0.2*P) + CA;

         t = num2str(t);
         disp(['Thickness (m):',t]);

    case 'Torispherical head',
         disp(' Torispherical head ');

         t = 0.885*P*2*r/(S*E - 0.1*P) + CA;

         t = num2str(t);
         disp(['Thickness (m):',t]);

end

    disp(' Design of covers ');

    menu(' Select the type of covers ', 'Circular' ,
'Noncircular');

    switch menu,

        case 'Circular',

            disp(' Circular cover ');
```

```
            d = input(' Enter the Effective diameter of flat
plate (m): ');
            C = input(' Enter the coefficient of corner details
(0.1 - 0.33): ');

            t = d*(C*P/(S*E))^0.5;
            t = num2str(t);
            disp(['Thickness (m):',t]);

        case 'Noncircular',

           disp(' Noncircular cover ');

            d = input(' Enter the length of short dimension (m):
');
            D = input(' Enter the length of long dimension (m):
');
            C = input(' Enter the coefficient of corner details
(0.1 - 0.33): ');

            t = d*((3.4 - (2.4*d/D))*C*P/(S*E))^0.5;
    end

    case 'Spherical',
         disp('Spherical');

         V = input(' Volume of pressure vessel (m3): ');

         r = ((3*V)/(4*7/22))^(1/3);

         r = num2str(r);

         disp(['internal radius (m):',r]);

         P = input(' Enter the design pressure (Pa): ');
         E = input(' Enter the joint efficiency factor: ');
         S = input(' Enter the allowable stress of the material
(Pa): ');
         T = input(' Enter the temperature  : ');
         CA = input(' Enter the corrosion allowance (m): ');

         disp('Design of Spherical shell');

         if (P < 0.665*S*E);

             t = P*r/(2*S*E - 0.2*P)+ CA; %thin shell

         else

              t = R*(((2*(S*E + P)/(2*S*E - P))^(1/3))-1)+
CA; %thick shell
```

```
         end

         t = num2str(t);
         disp(['Thickness (m):',t]);

menu(' Select type of head for the pressure vessel ',
'Hemispherical head', 'Ellipsoidal head', 'Torispherical head');

switch menu,
    case 'Hemipherical head',
         disp(' Hemispherical head ');

         if (P < 0.665*S*E);

         t = P*R/(2*S*E - 0.2*P) + CA; %thin hemispherical head

         else

         t = R*(((2*(S*E + P)/(2*S*E - P))^(1/3))-1)+ CA;%thick
hemi head

         end

         t = num2str(t);
         disp(['Thickness (m):',t]);

    case 'Ellipsoidal head',
         disp(' Ellipsoidal head ');

         t = P*2*r/(2*S*E - 0.2*P) + CA;

         t = num2str(t);
         disp(['Thickness (m):',t]);

    case 'Torispherical head',
         disp(' Torispherical head ');

         t = 0.885*P*2*r/(S*E - 0.1*P) + CA;

         t = num2str(t);
         disp(['Thickness (m):',t]);

end

    disp(' Design of covers ');

    menu(' Select the type of covers ', 'Circular' ,
'Noncircular');

    switch menu,

        case 'Circular',
```

```
            disp(' Circular cover ');

            d = input(' Enter the Effective diameter of flat
plate (m): ');
            C = input(' Enter the coefficient of corner details
(0.1 - 0.33): ');

            t = d*(C*P/(S*E))^0.5 + CA;
            t = num2str(t);
            disp(['Thickness (m):',t]);

        case 'Noncircular',

           disp(' Noncircular cover ');

            d = input(' Enter the length of short dimension (m):
');
            D = input(' Enter the length of long dimension (m):
');
            C = input(' Enter the coefficient of corner details
(0.1 - 0.33): ');

            t = d*((3.4 - (2.4*d/D))*C*P/(S*E))^0.5 + CA;
     end
    end

    disp('Design parameter for the pressure vessel');
```