Conceptual Design Support Tool for Subsea Equipment

by

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Universiti Teknologi PETRONAS

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CERTIFICATION OF APPROVAL

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Approved by,

____

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2013

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.

MOHD ROZAIRIE BIN JAHIR

ABSTRACT

Conceptual design is the most critical phase of product design and development process. It is the stage where major decisions are made by which will have an impact on the latter stage of design and related manufacturing processes. A tool called Conceptual Design Support Tool (CDST) had been developed to assist designers during conceptual design process. The overall goal of this project is to enhance the current CDST knowledge base. The enhancement will focus on product design in oil and gas domain particularly subsea equipment. In order to achieve this goal, the project will involves familiarization of CDST, study on subsea equipment, expanding CDST knowledge base and demonstration of the enhanced CDST. The enhancements of the CDST are important because the conceptual design can be perform more efficiently as the knowledge base expanded. The knowledge base expansion can also preserve expert's knowledge and train novice designer with the available design concept inside the knowledge base. Towards this goal, design concept for subsea separation system have been collected and stored inside the CDST knowledge base. These design concepts are generated based on the functional decomposition of the subsea separation system.

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious, the Most Merciful. Praise to Him the Almighty that in his given courage and strength, the project is successfully completed in given time. First and foremost, I would like to give my special thanks to my supervisor, Assoc. Prof. Dr. Fakhruldin Bin Mohd Hashim for the guidance and advice given. This truly helped the smoothness and progression of this project. Last but not least, I would like to thank my family for their great encouragement throughout my years of study and the completion of this project.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Conceptual design is a process of generating alternative design intellectually during early stage of product design and development process. This process will generates alternative design or also known as design concept and the supporting analysis that will determine the feasibility of each design concept. During this early stage, the designer can explore and generate variance of design concept without the constraints exist during later stage of product design and development. Through conceptual design a good product can more likely be achieve as result of great options provided by the design concept generated.

However, the conceptual design stage is the most critical phase in product design and development process. The decisions made during this stage have a large impact on the cost, performance, reliability, safety and environment. Is has been estimated that 75% of final product cost are based on the design decision during this stage [1]. As a result, the concept decision selected during this stage is extremely important. Hence, it is crucial to provide designer with access to the right tool to support such design activities.

1.2 PROBLEM STATEMENT

Conceptual Design Support Tool (CDST) is a tool developed to support the process of generating design concept in any engineering system and it is mainly focus on application of morphology chart. This tool can be further enhanced from the current version. The current version of CDST based on past project only focus on subsea processing system. Thus, the CDST Concept Library content will be enhanced to support subsea separation system.

1.3 OBJECTIVES

The main objectives of this project are:

i. To expand and enhanced the current CDST by enlarging the morphology chart knowledge base for subsea separation.
ii. To demonstrate the capability of the enhanced version of CDST.

1.4 SCOPE OF STUDY

These will be the scope of study that will be covered during the project timeline:

i. Explore all subsea separation system to be integrated inside CDST.
ii. Expand the design concepts inside of CDST based on the propose subsea system.

CHAPTER 2

LITERATURE REVIEW

2.1 CONCEPTUAL DESIGN SUPPORT TOOL

Conceptual Design Support Tool (CDST) is a new conceptual design process model in which the systematic design approach is integrated with knowledge-based system [2]. The nature of conceptual design process is iterative and time consuming. CDST is developed to assist designer during the conceptual design process by handling some of the monotonous activities giving the designer more time to concentrate on the creative part [3]. This support tool will assist in generating alternative concept for given functions, provide design knowledge from the design knowledge base, creating morphology chart, combining compatible alternative concept, and evaluate the concept variants.

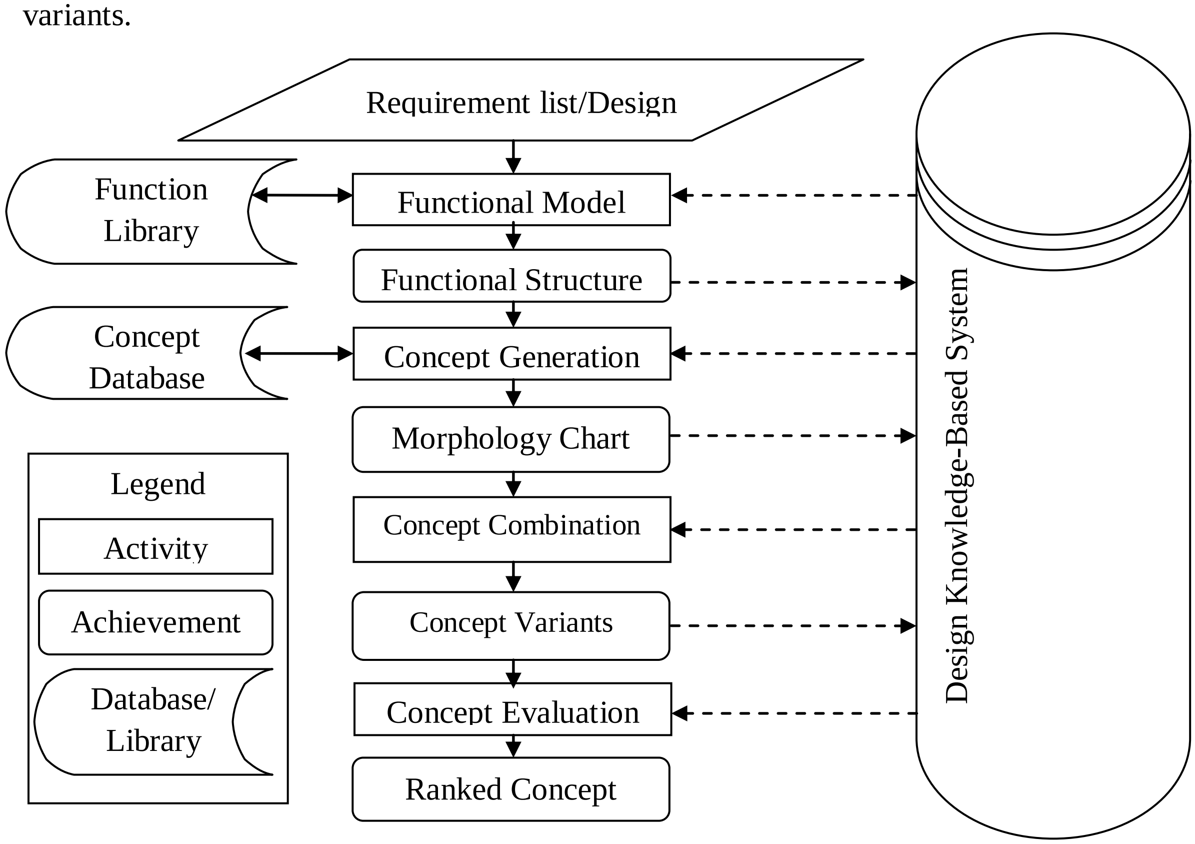

Figure 1: The proposed conceptual design process model [3]

In the first phase of design process, conceptual design is a process to achieve design requirement or specification in which different concept are generated [4]. Through research on how human perform conceptual design based on a systematic design approach, a conceptual design process model shown below in Figure 1 is proposed [3]. The activities are done by using the designer's knowledge and/or the design knowledge-based system while the achievements from a given activity are displayed to the user. The achievements are also given as an input to the design knowledge-based system to perform the next activity. The dotted line in Figure 1, indicate the integration of systematic design approach with the knowledge-based system.

CDST was developed by using the proposed conceptual design model in Figure 1. The knowledge-based system is generic to be used with any of mechanical conceptual design process. However, there is no known conceptual design support tool to address oil and gas industry domain [3]. Past research focused on developing the subsea separation system in order to support this domain. This support tool will be used in this project to further develop the concept library.

2.2 MORPHOLOGY CHART

Morphology analysis was first suggested and applied by Fritz Zwicky in 1943 for the design of aerospace system [5]. Morphology chart is normally applied at the beginning of idea generation with function analysis as a starting point [6]. It is use to ensure the required function works. The functions are expressed as verb-noun action pairs while the means are specific ways or devices for using or converting energy and for processing information and/or materials [4]. It is a method to generate ideas in an analytical and systematic manner.

Creating morphological charts consist of three step process which is functional decomposition, generation of multiple means, and combining means of accomplishing each function to form a potential solution [7]. A table is constructed by listing all the function based on functional decomposition. The means for each function are listed in row next to each function row as shown in Figure 2. The variance of potential solutions can be generated by combining one means for each function.

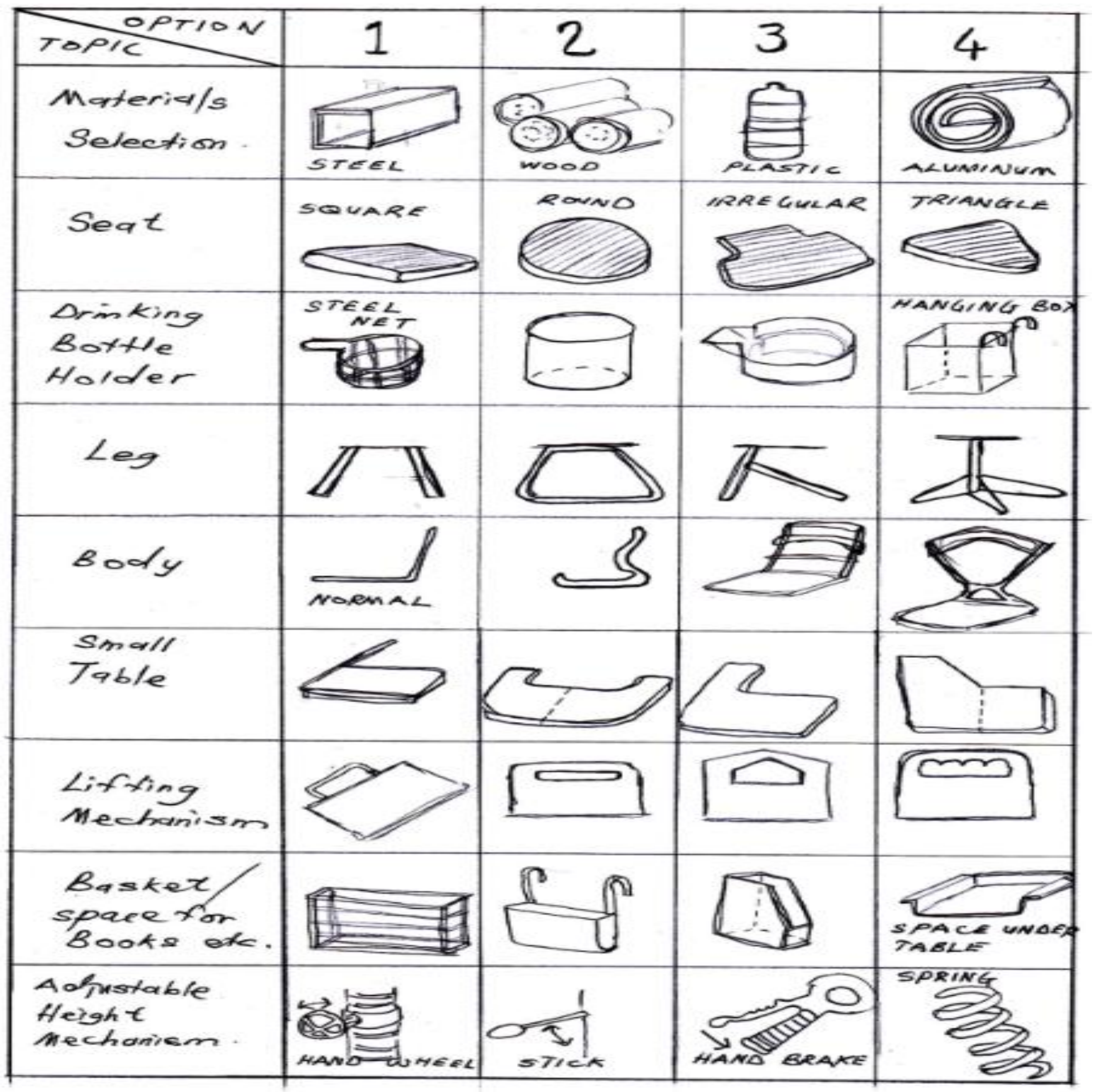

Figure 2: Example of Morphology Chart

In reference to Conceptual Design Support Tool (CDST), the means can be generated from the available concepts inside the concept database. New ideas that are not included in the concept database can be added to enhance the CDST. As a result, the enhancement of CDST concept library will give various possibilities that suit the needs of the product.

2.3 SUBSEA EQUIPMENT

Subsea equipment is normally referred to underwater oil and gas facilities. The development oil and gas are usually split into two categories which are shallow water and deep water in order to distinguish the different facilities and approaches that are needed [8]. The first subsea well was completed in the Gulf of Mexico in 1961 and the evolution in the use of subsea technology has been in uptrend since then [9].

The complexity of subsea production system can range from a single well with a flowline linked to a fixed platform, floating production storage and offloading (FPSO) or an onshore installation, to several wells [8]. The major basic components in the subsea system are normally consisting of subsea trees, subsea manifold, jumper system, flowlines, control system and umbilical [10]. The development of subsea equipment requires specialized equipment which must be reliable and economically feasible operating cost. Development of these field required strict requirement for the various system function.

The adoption of a design philosophy at the initial design stage is critical to meeting the goal of reliability and cost-effective subsea equipment. As a result the, the conceptual design phase can be support by using Conceptual Design Support Tool (CDST) to support this domain in generating new design concept to challenges the problem faced by subsea equipment designer.

CHAPTER 3

METHODOLOGY

3.1 PLANNED PROJECT ACTIVITIES FLOW

This section will explain on the planned project activities flow to complete the project on Conceptual design Support Tool for Subsea Equipment.

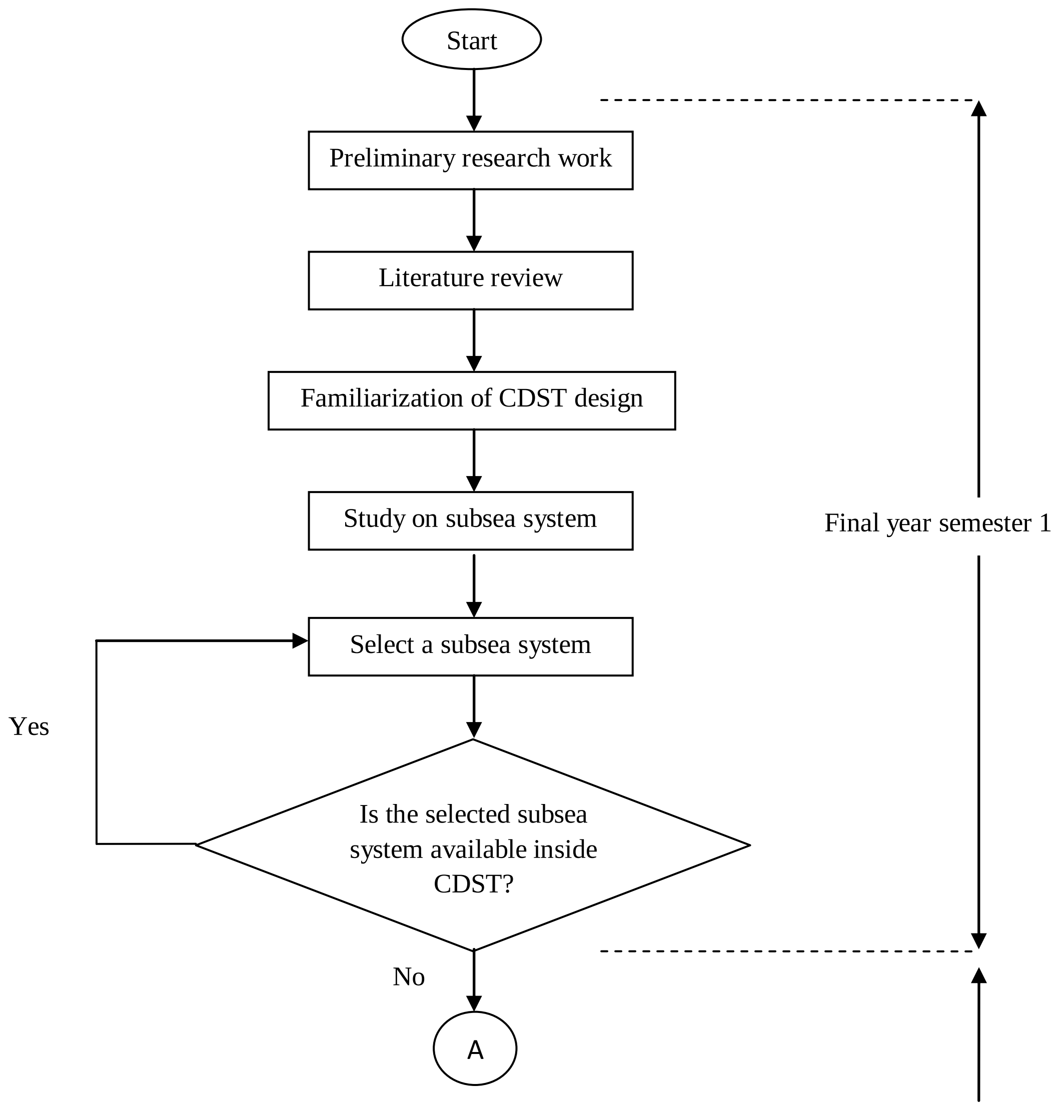

Figure 3: Project Flow Chart

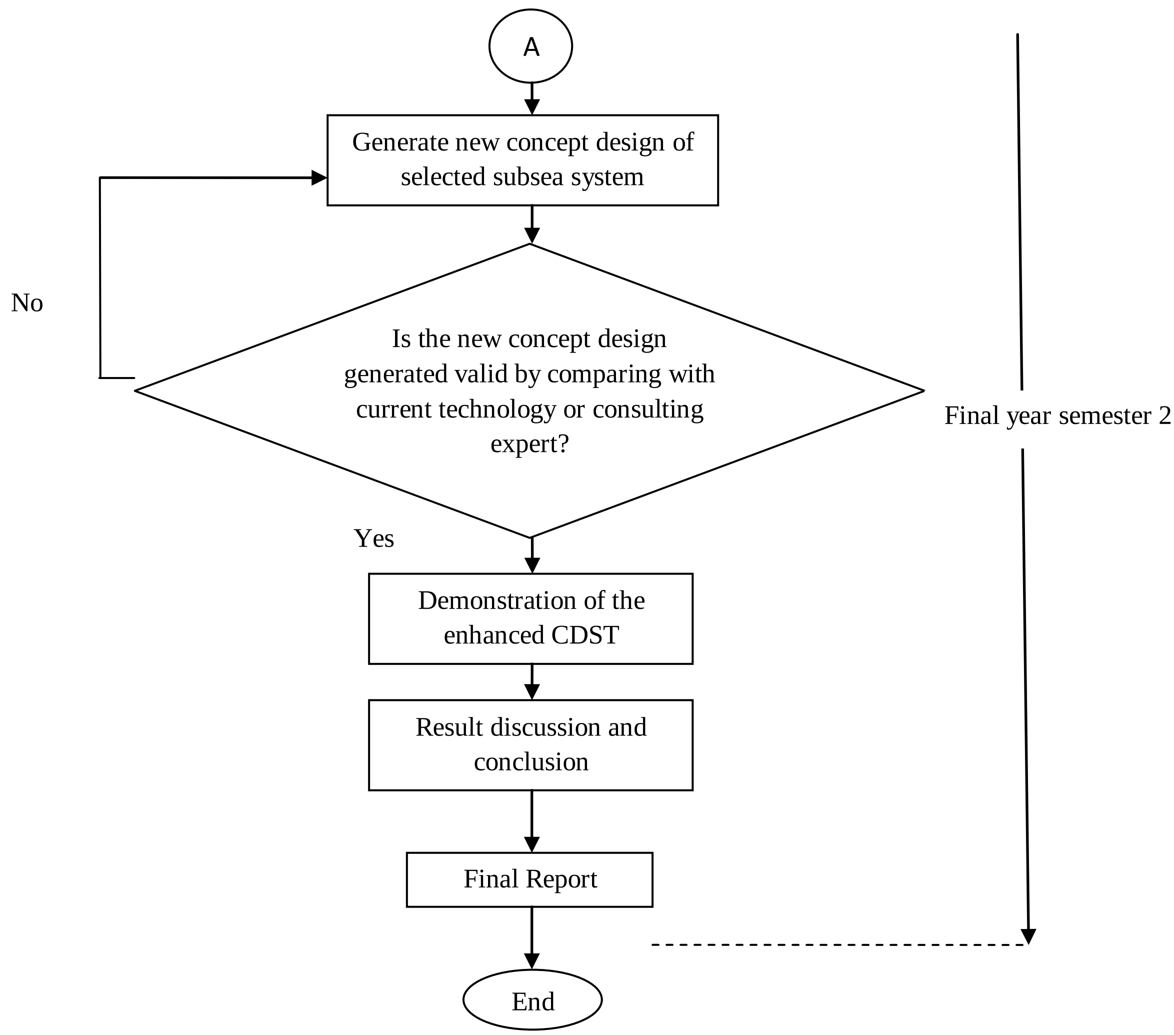

Figure 4: Continuation of Project flow chart

The project starts with preliminary research work. In this stage, the basic overview and information of the title are gathered by conducting first meeting with supervisor. The information and past research about the topic given by the supervisor is carefully studied to gain insight on the project requirement. After all the requirements are fully understand, the project proceeds with literature review. All the necessary material and information are retrieved as much as possible to get more knowledge on the topics related to this project. Commencement of the second stage of the project begins when all the research works on the literature are complete. The next stage would be to completely understand and familiarized with the Conceptual Design Support Tool

(CDST) working system. This includes study on the working principle of CDST and how to add new design concept inside the CDST concept library. Further studies on CDST programming will also be consider or pursue if the addition of new subsea system required program interface modification.

In order to expand the concept library of CDST, a study on subsea system must be done. This is important in order to understand the working principle of specific subsea equipments. A datum or reference point will be selected from the commercially available equipment. Then functional analysis of the equipment to decompose it physical and functional attribute will proceed. This will lead to creation of morphology chart to identify the concepts that the equipment has adopted. After the study, a specific subsea system will be selected to be work on and this selection will be cross check with the current CDST. If the subsea system selected is already available inside the CDST another subsea system will be selected and if the subsea system selected are not available the project proceeds to the main stage of this project.

The progress continues to the main stage of the project which is to expand the concept database. During this phase, a study will be conducted first to know the concepts that are already been embedded into the database. If the design concept is not available inside the system database, the new design concept will be embedded into the system database. However, before the new design concept is embedded into the CDST database, a validation is required to ensure the design concept are generally accepted and technically proven in the industry. This validation is performed by referring to the handbooks, patents, and research paper and consult will expert in the industry.

After completing the stage of expanding the database with new design concept, a demonstration will be conducted in order to test the new capability of the enhanced CDST. The early version of CDST which available for subsea processing system will be compare with enhanced CDST that support new selected subsea system. This project finally ends with the production of final report which discusses the result acquired from this project development. The timeline of the planned progress flow are shown in gantt chart section.

3.2 GANTT CHART

Task Key Milestone	Final Year Semester 1													
	Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Selection of project title														
2. Preliminary research work • Literature review														
3. Familiarization of CDST														
4. Research on subsea system • Study on subsea system • Subsea system selection														
5. Submission of interim report														

Figure 5: Gantt chart for final year semester 1 project schedule

Task Key Milestone	Final Year Semester 2													
	Week													
	15	16	17	18	19	20	21	22	23	24	25	26	27	28
6. Expanding CDST database concept • Generate new concept • Validate new concept • Embed new concept														
7. Submission of progress report														
8. CDST Demonstration • Model simulation • CDST version comparison														
9. Submission of dissertation														
10. Oral presentation														
11. Submission of final report														

Figure 6: Gantt chart for final year semester 2 project schedule

CHAPTER 4

RESULT AND DISCUSSION

4.1 FAMILIARIZATION OF CDST

The familiarization of CDST includes the study on the working principle of CDST .One of the subject areas are on the functional modeling. Functional modeling is a process of analyzing the requirement list or design specification and described it in terms of the overall function. The overall function is then decomposed based on its complexity into sub-functions and the functional structure constructed guided by the function library. This function library is based on functional basis proposed by Hirtz et al, which is adopted in the CDST development. Table 1 and Table 2 below show the functional basis reconciled function set used to assist designers in functional modeling.

Table 1: Functional basis reconciled function set [10]

Class (Primary)	Secondary	Tertiary	Correspondent
Branch	Separate		Isolate, Sever, Disjoin
		Divide	Detach, Isolate, Release, Sort, Split, Disconnect, Subtract
		Extract	Refine, Filter, Purify, Percolate, Strain, Clear
		Remove	Cut, Drill, Lathe, Polish, Sand
	Distribute		Diffuse, Dispel, Disperse, Dissipate, Diverge, Scatter
Channel	Import		Form entrance, Allow, Input, Capture
	Export		Dispose, Eject, Emit, Empty, Remove, Destroy, Eliminate
	Transfer		Carry, Deliver
		Transport	Advance, Lift, Move
		Transmit	Conduct, Convey
	Guide		Direct, Shift, Steer, Straighten, Switch
		Translate	Move, Relocate
		Rotate	Spin, Turn
		Allow DOF	Constrain, Unfasten, Unlock

Table 2: Continuation of functional basis reconciled function set [10]

Connect	Couple		Associate, Connect
		Join	Assemble, Fasten
		Link	Attach
	Mix		Add, Blend, Coalesce, Combine, Pack
Control Magnitude	Actuate		Enable, Initiate, Start, Turn on
	Regulate		Control, Equalize, Limit, Maintain
		Increase	Allow, Open
		Decrease	Close, Delay, Interrupt
	Change		Adjust, Modulate, Clear, Demodulate, Invert, Normalize, Rectify, Reset
		Increment	Amplify, Enhance, Magnify, Multiply
		Decrement	Attenuate, Dampen, Reduce
		Shape	Compact, Compress, Crush, Pierce, Deform, Form
		Condition	Prepare, Adapt, Treat
	Stop		End, Halt, Pause, Interrupt, Restrain
		Prevent	Disable, Turn off
		Inhibit	Shield, Insulate, Protect, Resist
Convert	Convert		Condense, Create, Decode, Differentiate, Digitize, Encode, Evaporate, Generate, Integrate, Liquefy, Process, Solidify, Transform
Provision	Store		Accumulate
		Contain	Capture, Enclose
		Collect	Absorb, Consume, Fill, Reserve
	Supply		Provide, Replenish, Retrieve
Signal	Sense		Feel, Determine
		Detect	Discern, Perceive, Recognize
		Measure	Identify, Locate
	Indicate		Announce, Show, Denote, Record, Register
		Track	Mark, Time
		Display	Emit, Expose, Select
	Process		Compare, Calculate, Check
Support	Stabilize		Steady
	Secure		Constrain, Hold, Place, Fix
	Position		Align, Locate, Orient

Table 3: Functional basis reconciled flow set [10]

Class (Primary)	Secondary	Tertiary	Correspondent
Material	Human		Hand, Foot, Head
	Gas		Homogenous
	Liquid		Incompressible, Compressible, Homogeneous
	Solid	Object	Rigid-body, Elastic-body, Widget
		Particulate	
		Composite	
	Plasma		
	Mixture	Gas-gas	
		Liquid-liquid	Aggregate
		Solid-solid	
		Solid-liquid	
		Liquid-gas	
		Solid-gas	
		Solid-liquid-gas	
		Colloidal;	Aerosol
Signal	Status	Auditory	Tone, Word
		Olfactory	
		Tactile	Temperature, Pressure, Roughness
		Taste	
		Visual	Position, Displacement
	Control	Analog	Oscillatory
		Discrete	Binary
Energy	Human		
	Acoustic		
	Biological		
	Chemical		
	Electrical		
	Electromagnetic	Optical	
		Solar	
	Hydraulic		
	Magnetic		
	Mechanical	Rotational	
		Translational	
	Pneumatic		
	Radioactive/Nuclear		
	Thermal		

After the functional decomposition is done based on the functional basis, the next step is to generate a range of alternative solutions that can satisfy each sub-function in the functional structure.

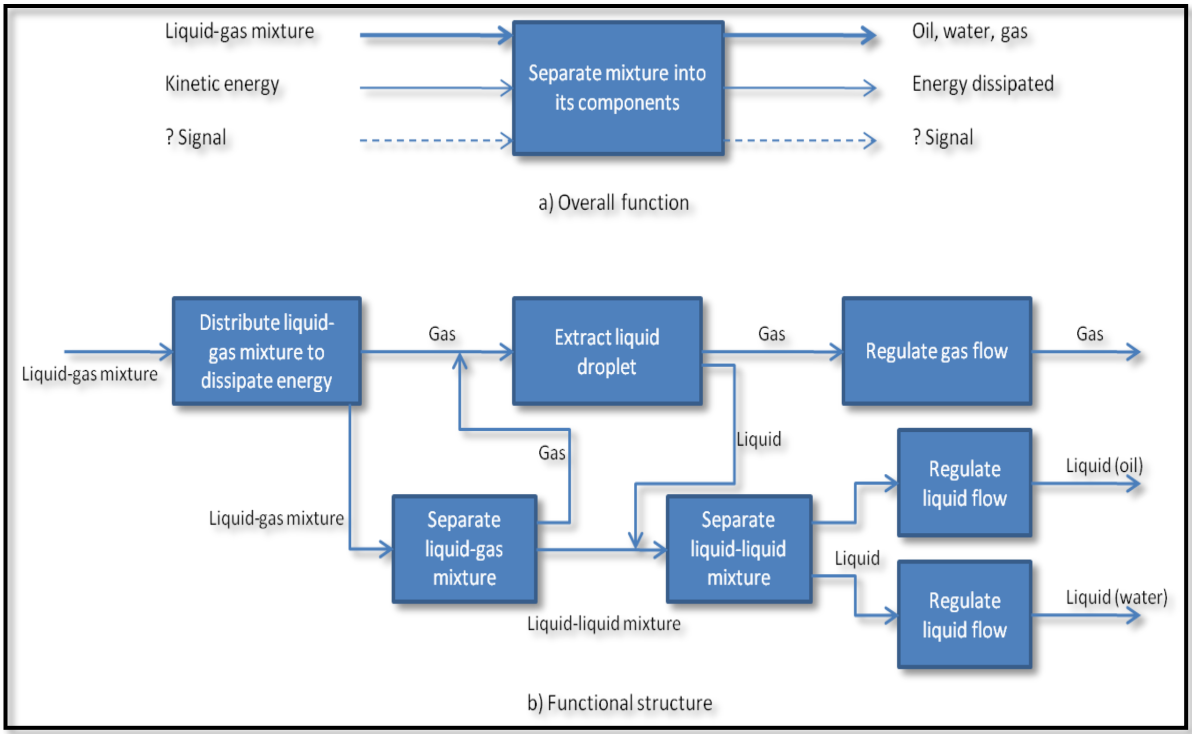

Figure 7: Example of functional decomposition for three-phase oil and gas separator [2]

Figure 8: CDST welcoming page

Opening the CDST application will bring the user to the CDST welcoming page shown in Figure 8. The "Next" button on this window will brings the function library window as shown in Figure 9 below. In the function library window, the user can enter the overall function on the space provided, and then each sub-function in the provided input system based on the user manually generated functional decomposition.

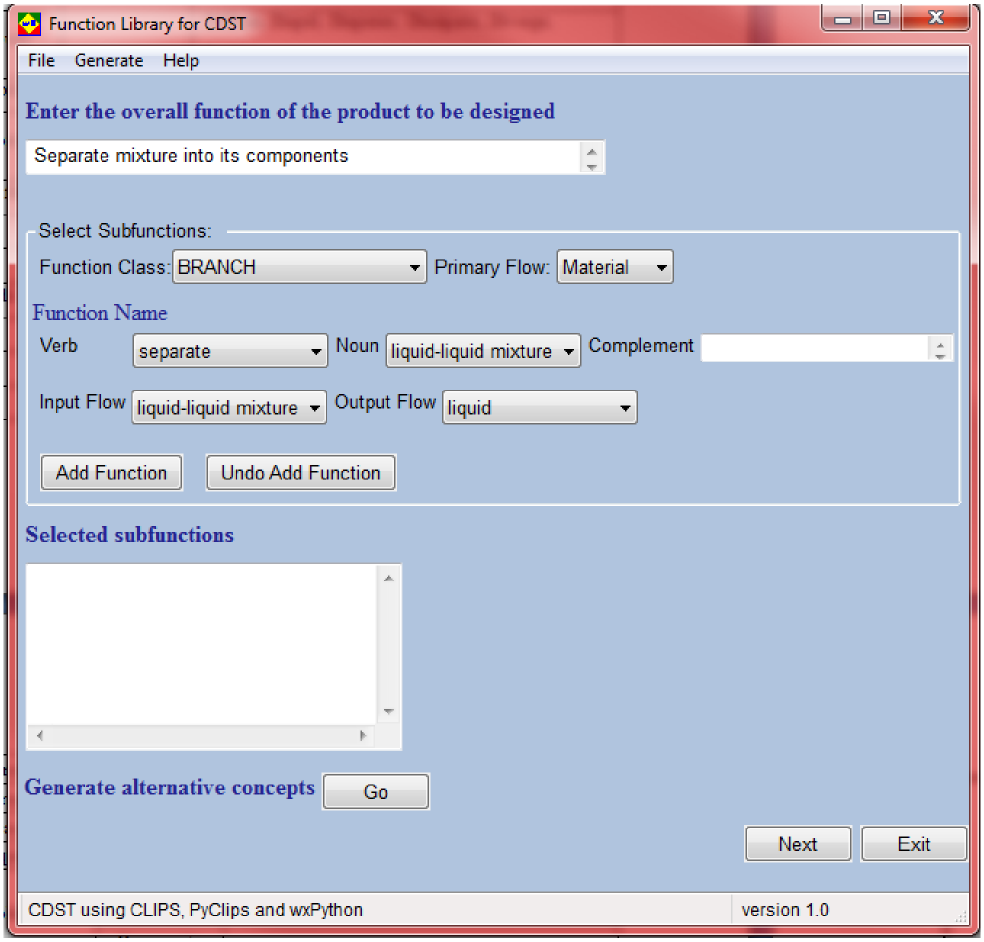

Figure 9: Function library window

The function library windows works by accepting input form user textually about the overall function. Then each subfunction is define by selecting the the "Function Class", which refer to the primary class in the functional basis reconciled function set. The primary class consist of eight choices which will relate to corresponding secondary and tertiary catergories. This relation will determine the choices of the "Verb" field fo the function. Similarly, the user selects one option from the "Primary Flow" which has three choices as in the functional basis reconciled flow set and this selection will automatically determine the "Noun" field and the "Input Flow" and "Output Flow" choices. The users can enter additional information about the function definition in the "Complement" text field if required. When all the of the choices are selected, the subfunction can be add to the system by using the "Add Function" button. This will display the subfunction in the "Selected Subfuntions" windows.

Based on the functional decomposition example shown in Figure 7, the user can enter the overall function of "Separate mixture into its components" into the space provided. Then the user can enter the subfunctions accordingly. For example, the subfunction separate liquid-liquid mixture can be enter as shown in Figure 10. Once the required information are entered in the input box, press the "Add Function" button to add the subfunction into the working memory of the knowledge-based system.The added subfunction will be displayed in the "Selected subfunction" test field. The sub-function addition are repeated untill all the subfunction under the overall function in the functional decomposition are included.

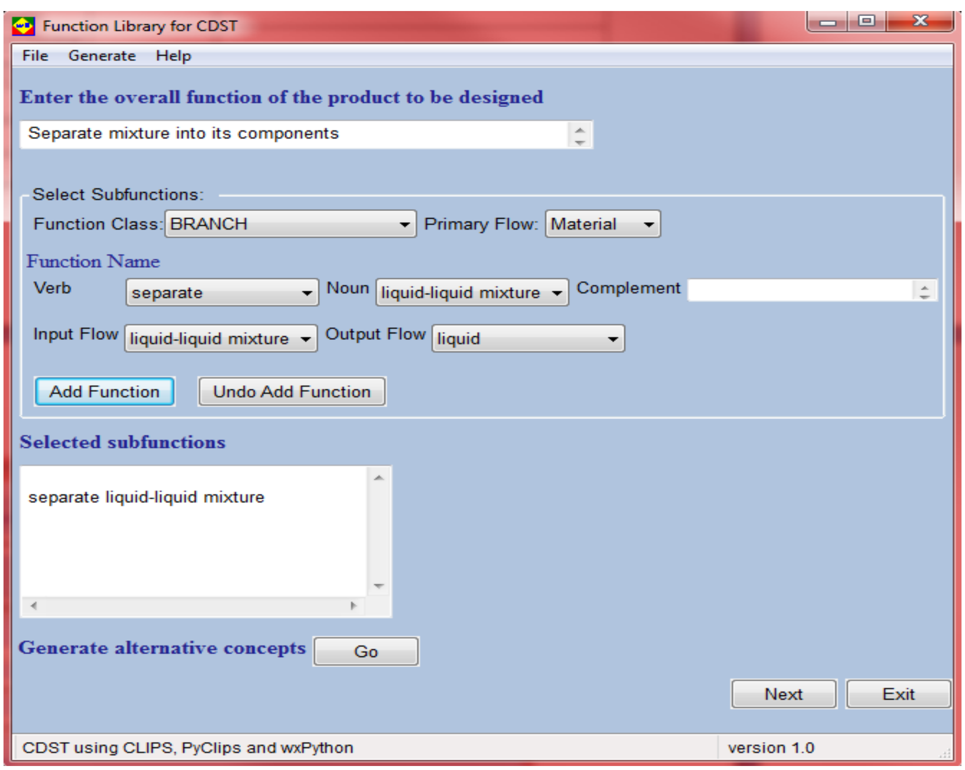

Figure 10: Example to add subfunction into the function library

The concept generation process is initiated by using "GO" button in the function library window. A pop up window in Figure 11 will ask user to select the type of function to be considered for concept generation. If the user selects the "Both Primary and Secondary Functions" option, the system will search for concepts whose primary and secondary function match with the subfunctions in the function structure. On the other hand, if "Only Primary Functions" is selected, CDST will only considered primary functions in searching for the alternative concepts.

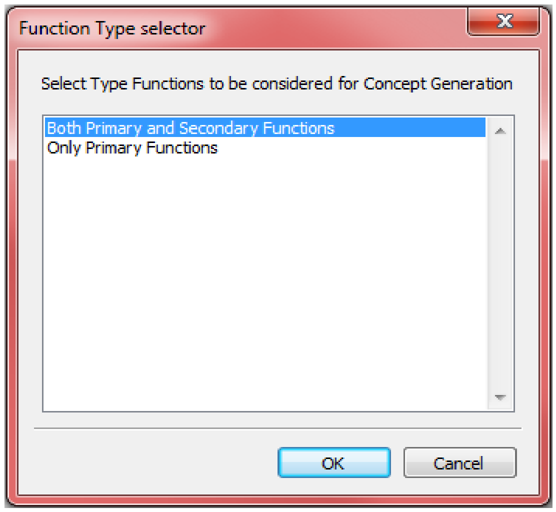

Figure 11: Function type selector

If there are alternative concepts in the database for each subfunction, a text message will state that "Concepts are generated for all subfunctions successfully" however if one or more subfunctions have no alternative concept, then a message windows will pop up to generate concepts manually. Figure below show the generate concepts manually window.

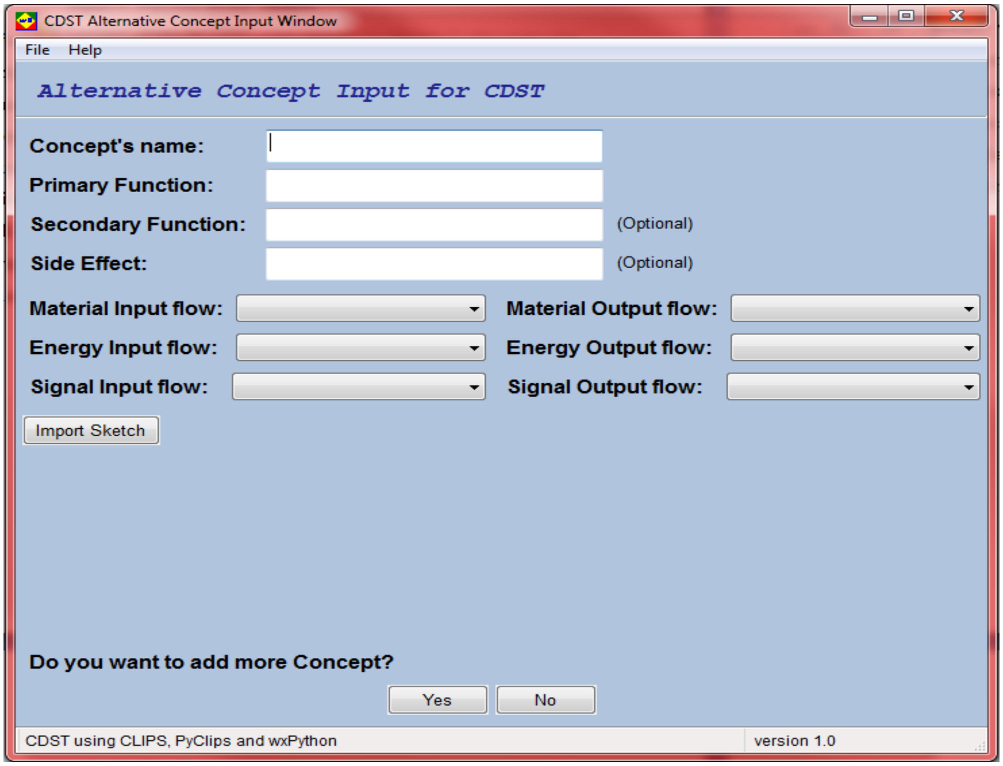

Figure 12: Window to generate concept manually

From this window, the entire alternative concept for each subfunction can be generated manually based on the user idea or if the design concept are still not available inside the CDST's working memory of the knowledge based system. The final output of the concept generation process is the morphology chart consisting of the subfunctions in the functional structure together with all the available alternative concepts both generated from the database and by the user. Figure 13 below show the flowchart of CDST from the start until morphology chart generation.

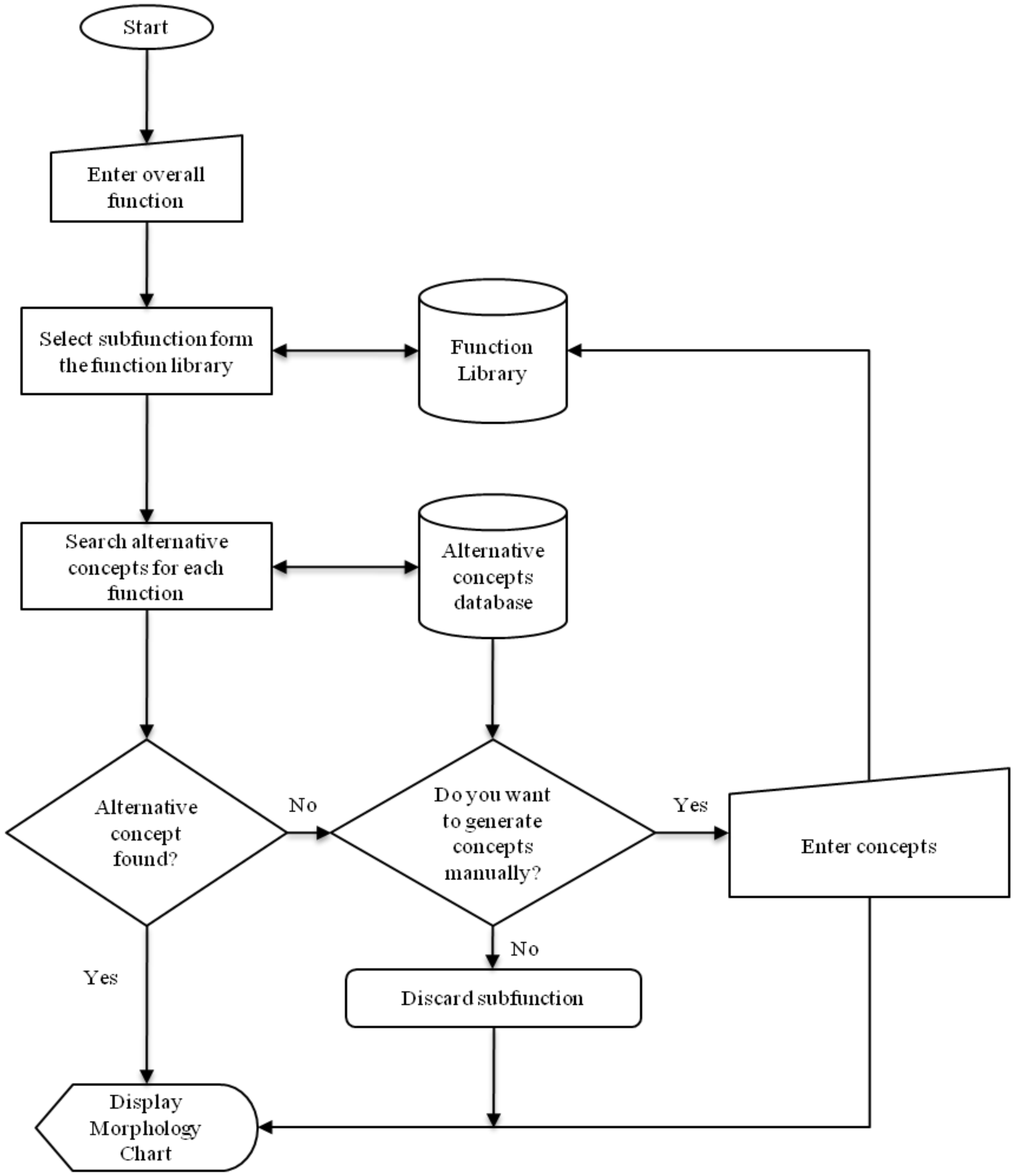

Figure 13: CDST flow chart until morphology chart generation adaptation [11]

4.2 RESEARCH ON SUBSEA SEPARATION SYSTEM

The next step after the familiarization of CDST is to study and select a subsea system that will be used to be use inside the CDST. After studying the available subsea system, it is decided that this project will proceed with subsea separation system.

Subsea separator can be classified into two types which is two-phase separator and three-phase separator. In the two-phase separator, gas is separated from the liquid with the gas and liquid being discharged separately while in the three-phase separator, well fluid is separated into gas, oil, and water with the three fluids being discharged separately. From the classification, a functional decomposition is done based on functional structure for both two-phase separator and three-phase separator.

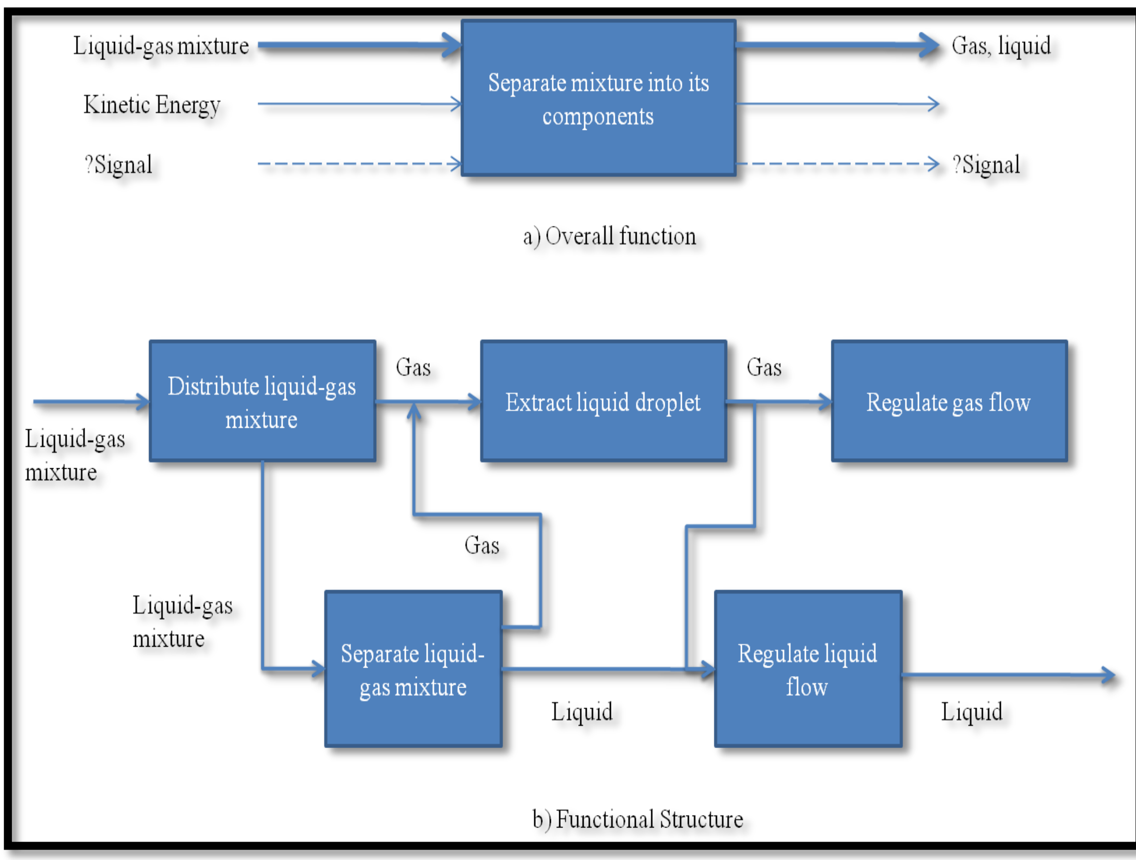

Figure 14: Two-phase separator functional decomposition

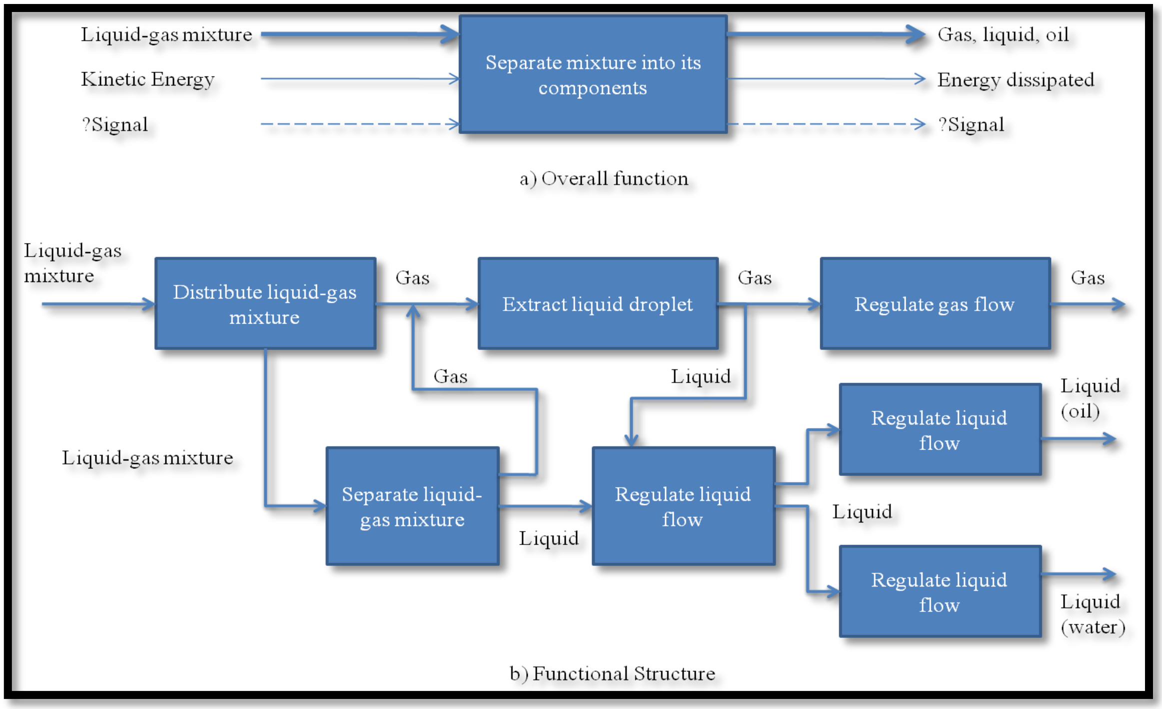

Figure 15: Three-phase separator functional decomposition

Based on this functional decomposition, the function of both two-phase separator and three-phase separator can be clearly defined in the morphology chart. The functions for two-phase separator are:

i. Distribute liquid-gas mixture
ii. Separate liquid-gas mixture
iii. Extract liquid droplet
iv. Regulate gas flow
v. Regulate liquid flow
vi. Transport liquid

The functions for three-phase separator are:

i. Distribute liquid-gas mixture
ii. Separate liquid-gas mixture
iii. Extract liquid droplet
iv. Separate liquid-liquid mixture
v. Regulate gas flow

vi. Regulate liquid flow

vii. Transport liquid

4.3 EXPANDING CDST DATABASE CONCEPT

The project continued to the next stage which is the main part of the project. In this stage, the project will proceed by expanding the CDST database concept particularly on the function generated for the separator. This stage started by generating a new concept that is not available inside the CDST. Once a new concept is generated, the concept is validated to make sure it is functioning and proven to be working in real environment. Lastly, the validated concept is embedded inside the CDST to expand its current database

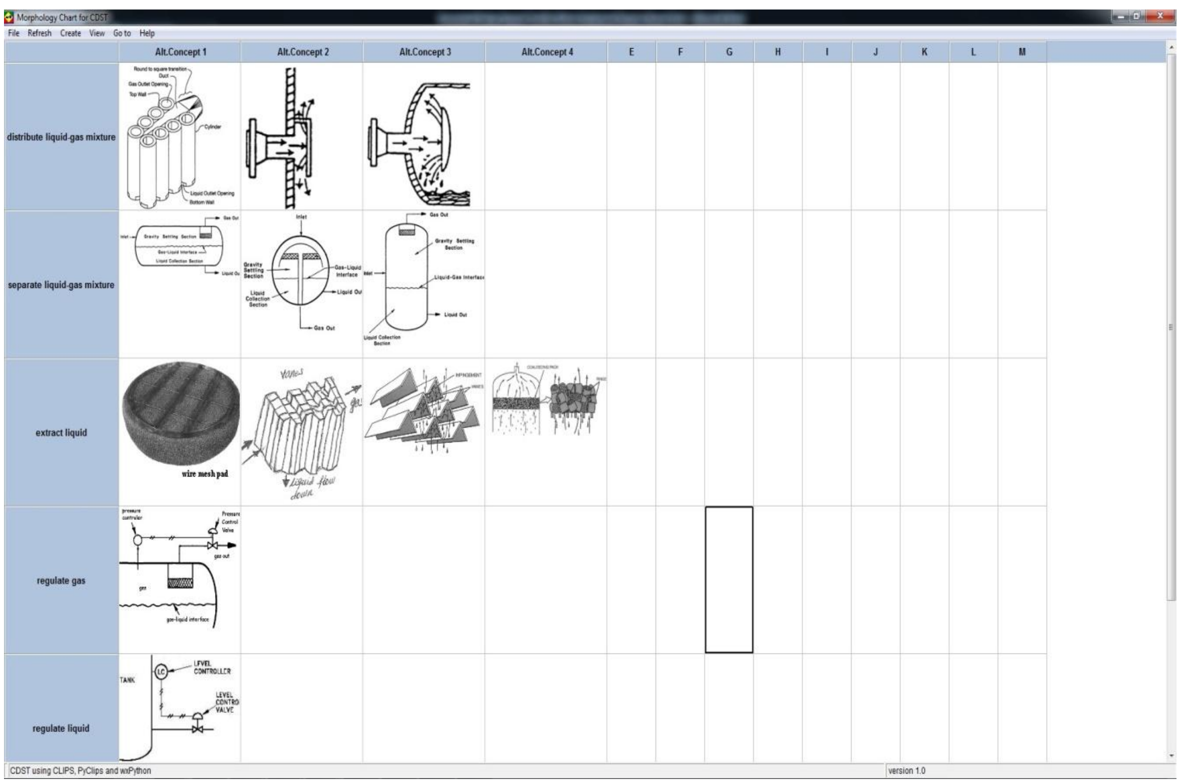

Figure 16: Snapshot 1 of two-phase separator morphology chart before database expansion

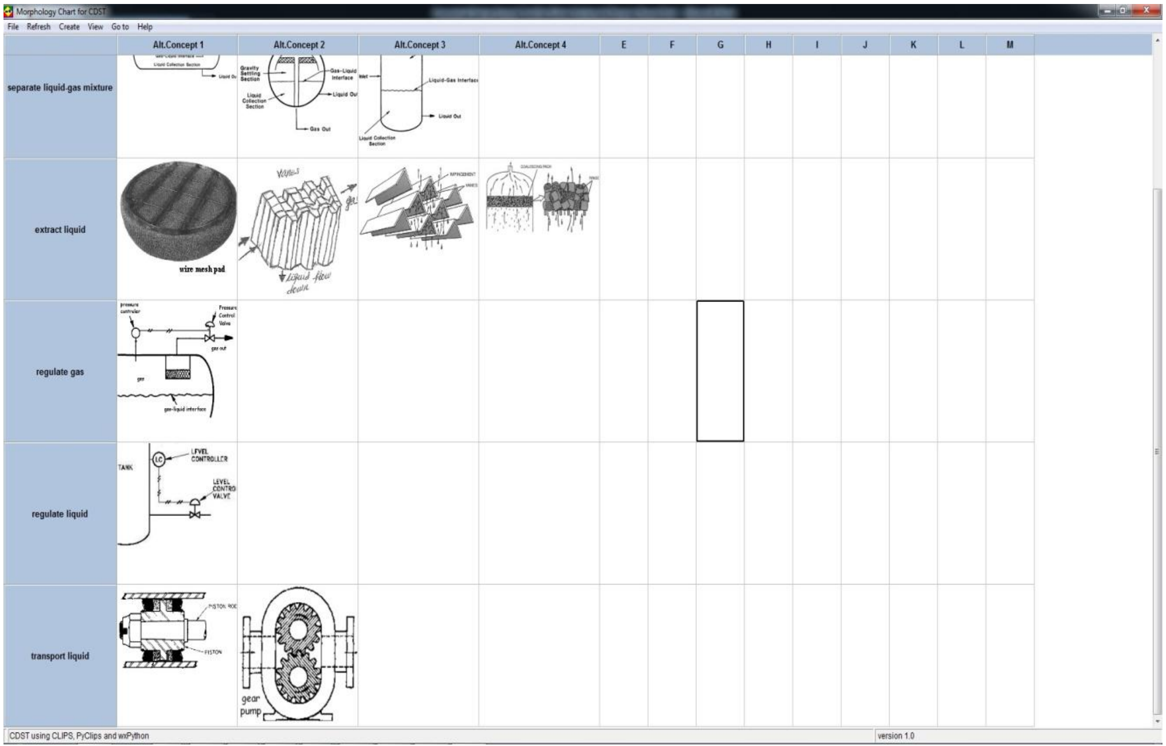

Figure 17: Snapshot 2 of two-phase separator morphology chart before database expansion

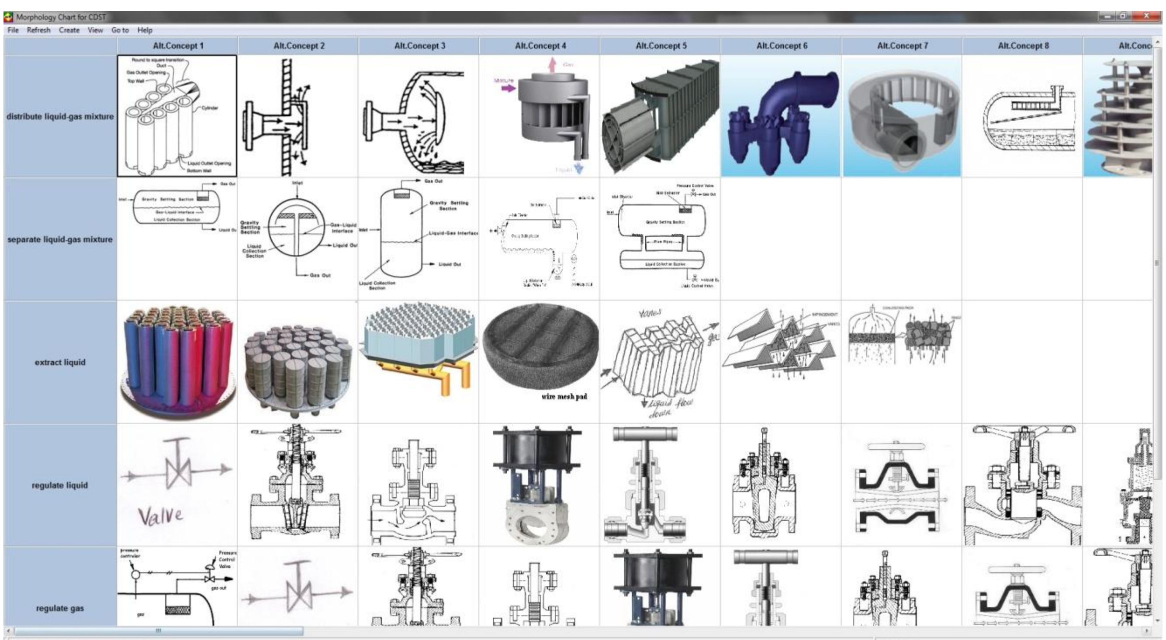

Figure 18: Snapshot 1 of two-phase separator morphology chart with enhance database expansion progress [13], [14], [15], [16], [17], [18], [19]

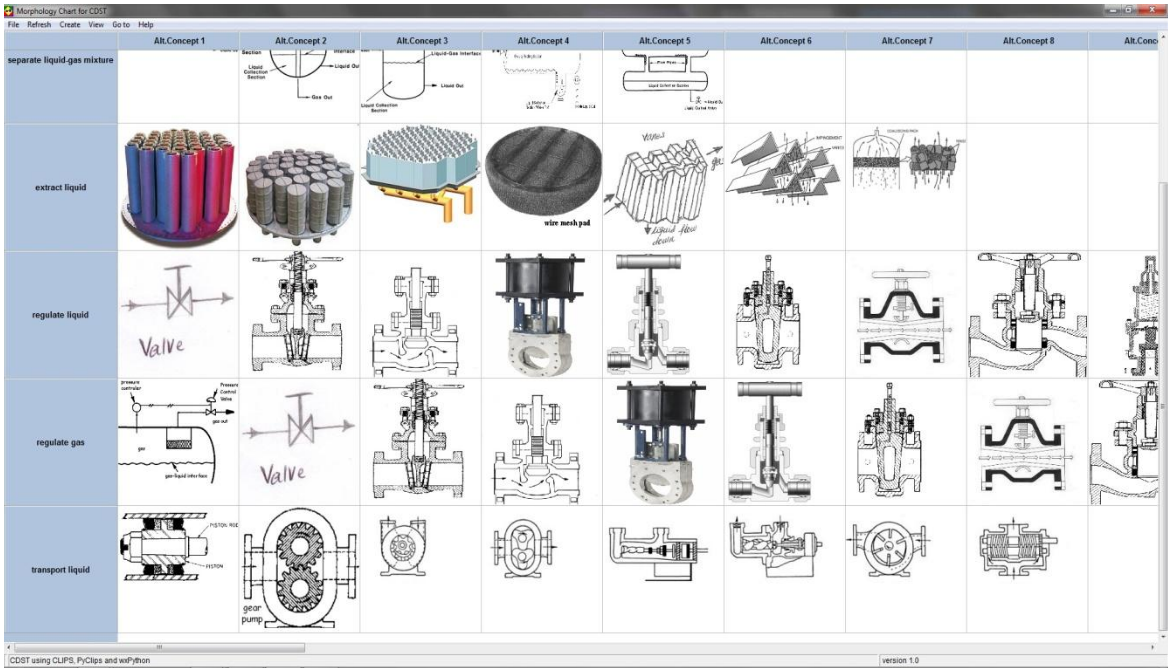

Figure 19: Snapshot 2 of two-phase separator morphology chart with enhance database expansion progress [13], [14], [15], [16], [17], [18], [19]

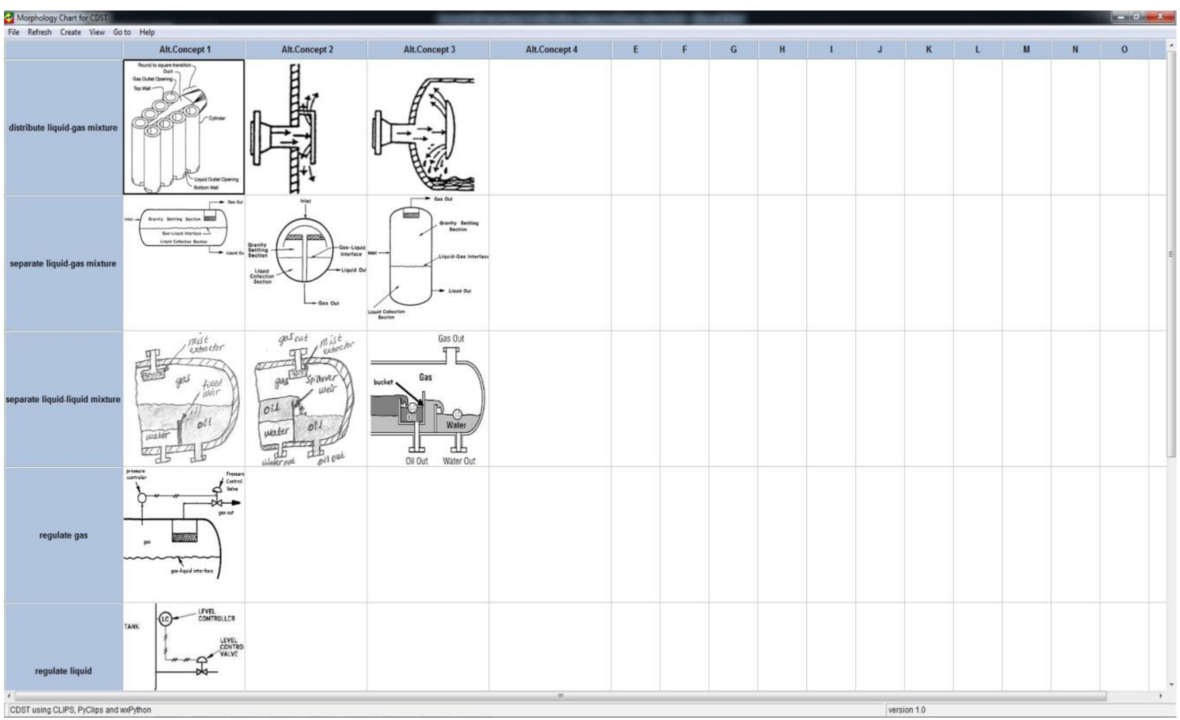

Figure 20: Snapshot 1 of three-phase separator morphology chart before database expansion

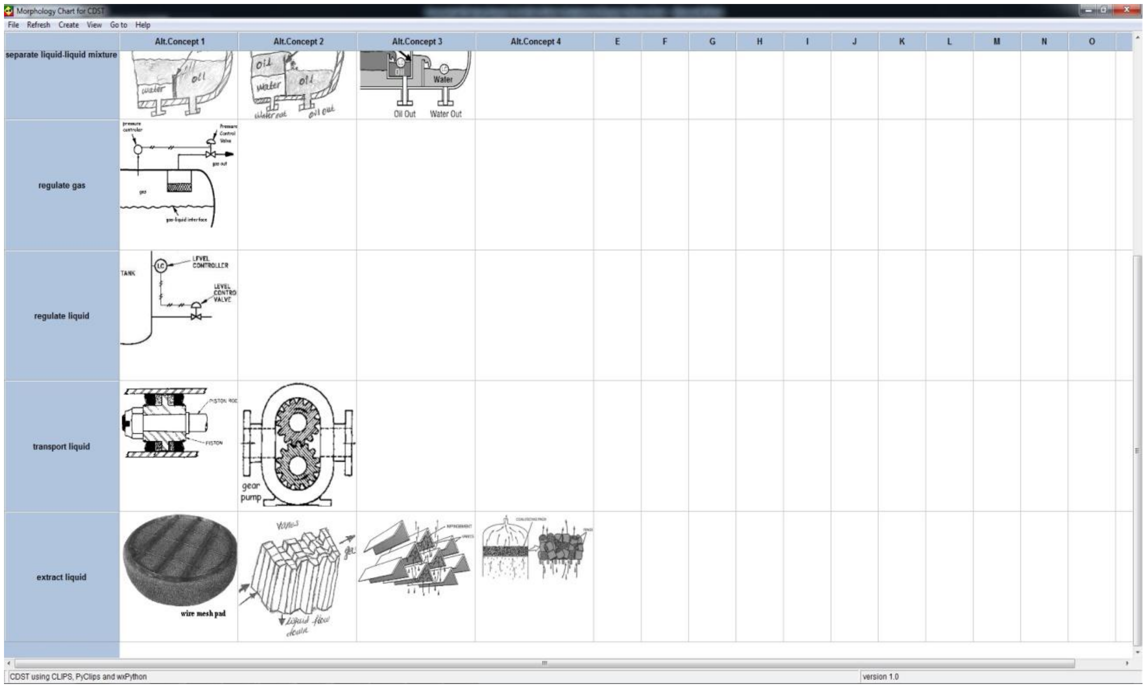

Figure 21: Snapshot 2 of three-phase separator morphology chart before database expansion

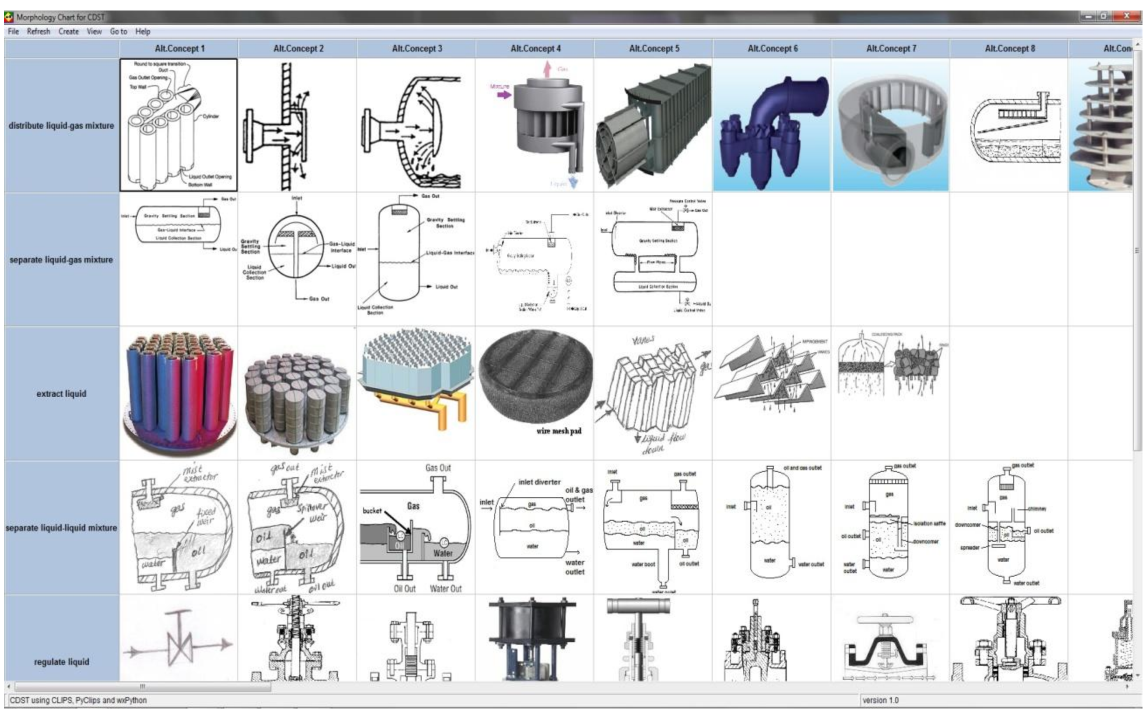

Figure 22: Snapshot 1 of three-phase separator morphology chart with current database expansion progress [13], [14], [15], [16], [17], [18], [19]

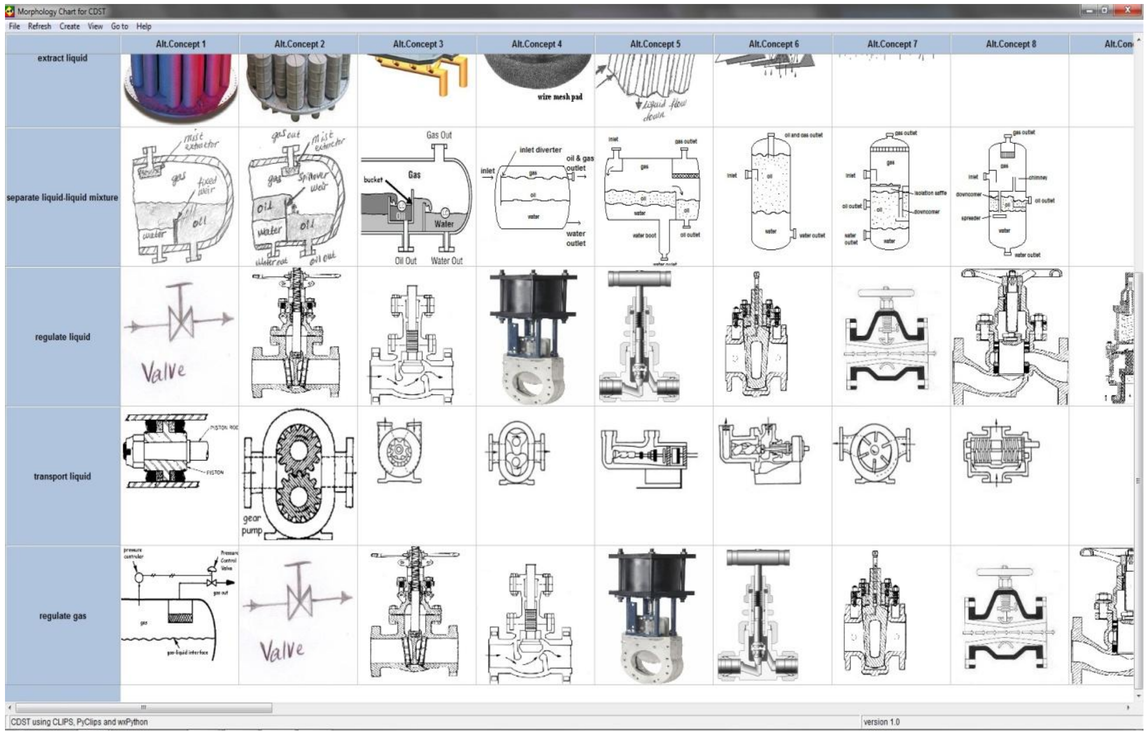

Figure 23: Snapshot 2 of two-phase separator morphology chart with current database expansion progress [13], [14], [15], [16], [17], [18], [19]

4.4 NEW DESIGN CONCEPTS

The new design concepts embedded in CDST can be divided into two parts which for two-phase separator and three-phase separator. Table below show the data on the number of enhancement made to the CDST and its database.

Table 4: Comparison table before and after enhancement based on number of concept variant possible

	Two-phase separator	Three-phase separator
New design concept added	28	33
Number of concept variant possible before enhancement	720	2160
Number of concept variant possible after enhancement	524160	4193280

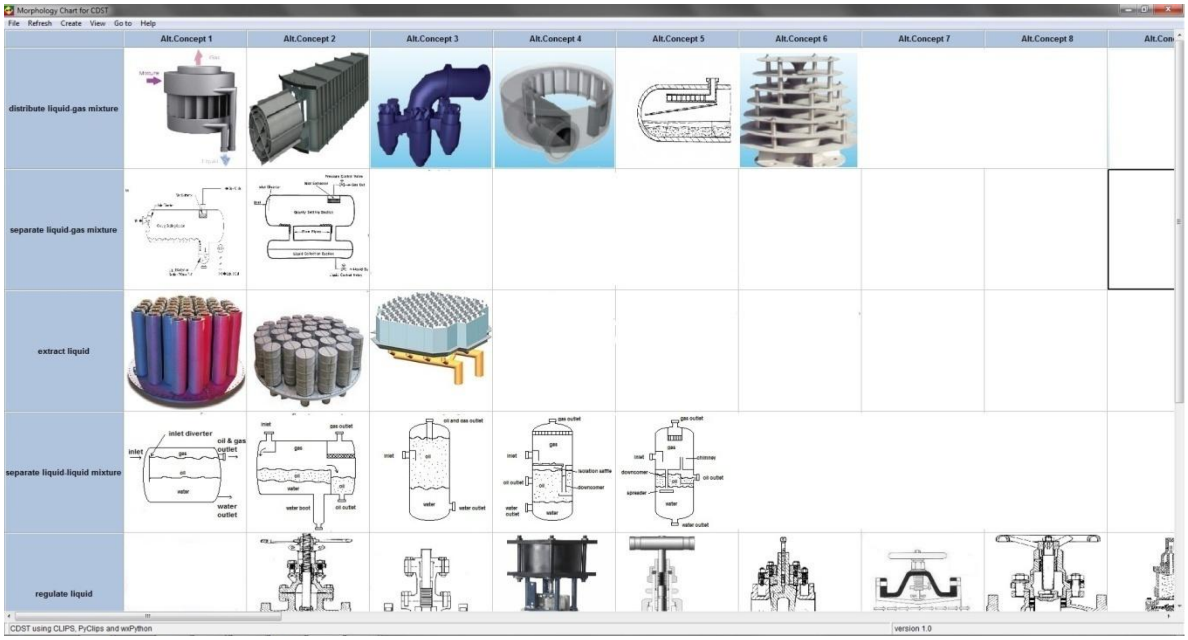

Figure 24: Snapshot of new design concepts embedded into CDST database [13], [14], [15], [16], [17], [18], [19]

From the table 4 shown, by adding the new design concepts into the CDST will enhance the database and thus the morphology chart. The new design concepts added result in the increase of possible concept variant which allows variety in design to be explored.

CHAPTER 5

CONCLUSION

In this project, the project is successful as the objectives of the project are partially achieved. The CDST morphology chart knowledge base for subsea separation system is enhanced by embedding new design concept. The knowledge base is enhanced by embedding 28 new design concepts for two-phase separator and 33 new design concepts for three-phase separator. The enhancements made to CDST improve the number of possible concept variant from 720 to 524160 for two-phase separator and 2160 to 4193280 for three-phase separator. However, this only partially achieved the second objective of the project which is to demonstrate the capability of the enhanced version of CDST. This is due to the enhancement are only done on subsea separation system which is not fully reflect the capability of the enhanced CDST which can be use for the design of other system. The enhanced version of CDST supposes to open a new opportunity to explore new design of other subsea equipment which is not demonstrated in this project.

Although the project is successful, there is still big room for improvement and enhancement especially for the CDST. This tool can be further expand to encompass other mechanical engineering domain to support the conceptual design stage. Apart of that, the tool itself can be improved by revising and revamping the tool programming code to make it more users friendly.

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