ISSN : 2355-9365 e-Proceeding of Engineering : Vol.2, No.2 Agustus 2015 | Page 4620

ANALYZE THE SOLAIR INCINERATOR'S PROBLEM USING INTERGRATION ANALYSIS OF PRODUCT DECOMPOSITION AND MODULARIZATION WITH CHANNEL MODEL (C&CM) APPROACH AS A REFERENCE FOR DESIGNING THE IMPROVEMENT OF PRODUCT ARCHITECTURE

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Abstract

System engineering of product requires tools and technique for system decomposition and integration to simplify the complex interactions. Otherwise most of the modularization methods focus on the redesign of existing products, in such matrix representation is often used as a tool for integration analysis. This paper focus on component based system architecture and implements effective method for supporting inexperience designer to analyze the problem of product architecture using "Contact & Channel Model" that developed at the University Karlshruhe. Bandung Techno Park, Telkom University developed custom design of incinerator named SOLAIR as an alternative technologies to solve domestic waste problem. From the interview and observation, the authors found some weaknesses that occur such as difficulties way to repair some components because the design is integral and some of components placed adjacent to burner that impact higher risk of failure. This paper lead to conclusions regarding problem analysis of SOLAIR incinerator using Faiure Mode Effect Analysis (FMEA) that resulted RPN value for suggestion in future research and problem analysis of incinerator using integration analysis that resulted six clustered (Fuel, Burning, Waste, Cooling, Waste mixer, and Disposal chunks) based on component interactions. Conduncting with Modularization with C&CM approach that analyze functions involving in each module and detachability of each connecting surface of the modules (WSs of WSP 1, 2, 11,and 12 has to be concerned for product architecture improvement in future research.

Keywords: Product Architecture, Modularization , Integration Analysis , Incinerator

1. Introduction

Main issue of waste in Indonesia is organic waste as the biggest composition about 65% and main source of pollution with less effective handling. Waste management that applied in some areas in Bandung still using conventional operation, named the concept of get-haul waste. This conventional waste management causes high burden on landfill. One of the alternative technologies that have been developed to deal with domestic waste problem in the micro and the macro scale is known as the incinerator. Bandung Techno Park, Telkom University either developed custom design of incinerator named SOLAIR.

From the interview and observation, the authors found some weaknesses and problems that occur such as difficulties way to repair some components when its damaged because the design is integral and other components placed adjacent to burner so higher risk for failure. Based on the problem, researcher take modularization approach using Contact and Channel Model Contact (C & CM) as problem identification approach.

Product architecture emphasizes how the product can be changed. The architecture of the product determines the functional elements of the product will be influenced by a change to a particular component, and which components must be changed to achieve a desired change to a functional element of the product [1].

This paper describes effective method for supporting inexperience designer to analyze the the problem of product architecture using elementary design model "Contact & Channel Model" C&CM developed at the Institute of Product Development at the University Karlshruhe [2]. This paper lead to conclusions regarding problem analysis of SOLAIR incinerator using C&CM model approach as reference for designing the product architecture improvement in future research.

ISSN : 2355-9365 e-Proceeding of Engineering : Vol.2, No.2 Agustus 2015 | Page 4621

2. Research Conceptual Model

2.1 Conceptual Model

Conceptual model for this research is contained in Figure as follow.

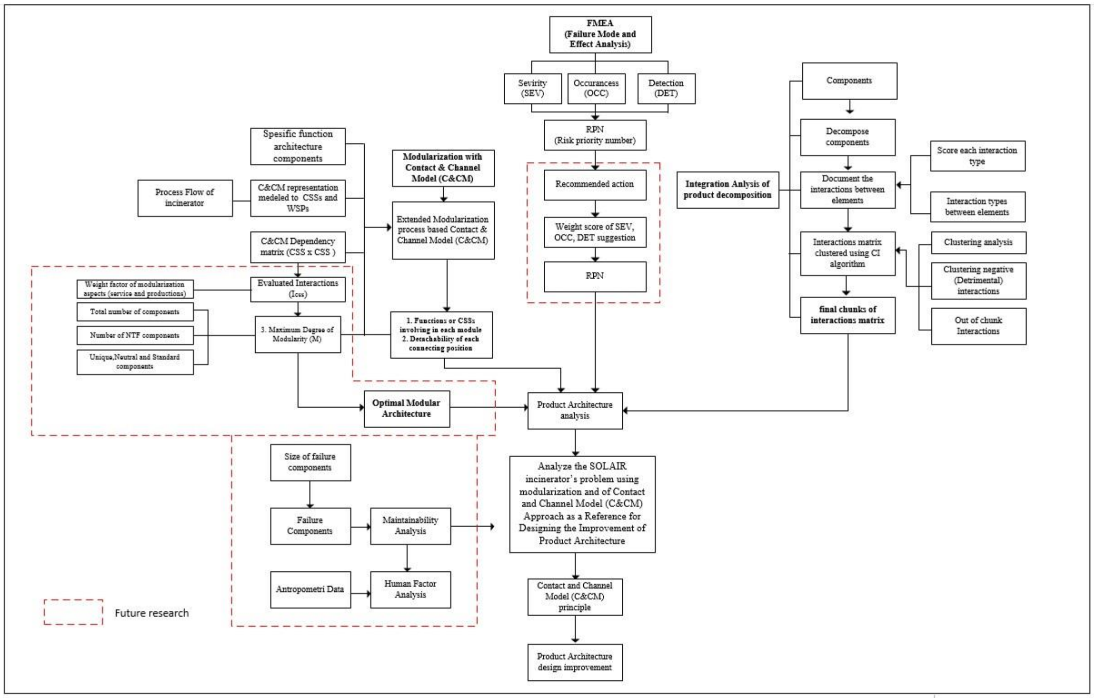


Figure 1 Conceptual Model

This research start from identification of existing incinerator and define the problem using integration analysis of product decompositon.To analyze the interaction between components,it using the weight score interaction that introduce by Pimler and Eppinger [3] [4]. This information is useful to define the product architecture in future research . The method involves three steps [3] [4]

Step 1) Decompose of the system into elements: Describe product concept in terms of functional and/or physical elements which achieve the product functions.

Step 2) Document of the interactions between the elements:
Identify the interactions which may occur between the functional and physical elements.

Step 3) Clustering the elements into architectural chunks : Cluster element into chunks based on criteria set by the overall product design strategy of them , These chunks then define the product architecture.

While Most of the modularization methods using C&CM model focus on the redesign of existing products, in such matrix representation is often used as a tool for integration analysis [3] An integration analysis of modular architecture of a system is considerably related to the functional analysis. The classification in this paper is taken primarily from the modular product schematic according to Pahl [5] that determine sub-function into four types include basic function (BF) , Auxiliary Function (AF) , special function (SF) and adaptive function (ADF) . Based on that extended modularization process VDI2223, there are 3 steps should do in order to know maximum degree of modularity (M_{max}) [6] of incineration system but in this research only deliver first of three step of VDI2223.

2.2 Problem Solving Systematics

1. Problem identification

a. Problem analysis phase of existing product

Problem analysis used in this study is according to Albers [7] .It is about identification of existing product architecture using Failure Mode and Effect Analysis (FMEA),modularization and Contact & Channel Model approach method in which matrix representation is often used as a tool for integration analysis .

ISSN : 2355-9365 e-Proceeding of Engineering : Vol.2, No.2 Agustus 2015 | Page 4622

b. Result analysis

At this stage of the analysis of the results of problem defined. Problem determined as reference for design improvement of product architecture.

c. Stage Conclusions and Recommendations

This stage contains the conclusions based on the problem results of the analysis with reference to the purposes of this study. The resulting conclusions at this stage is suitable for proposed design to make better product architecture. Suggestions for assessment necessary for further analysis of Product Architecture improvement design and related with maintainability analysis in future research

3. Data Collecting and Data Processing

3.1 Data Collecting

There are two types of data collections, primary data consist of interview to operator and list of components. While secondary data is flowchart of SOLAIR incinerator.

4. Result and Analysis

4.1 Integration Analysis of Product Decomposition

To illustrate the integration methodology, Figure 2 shows some typical of components of an incineration system.

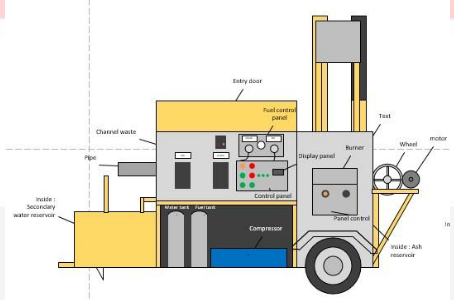


Figure 2: Solair Incineration System Component Schematic From Right View

At step 1, we have a design decompose into unit-level elements as shown in table 1

Table 1 Decomposed Elements For Incineration System

Components	
Fuel tank	Waste channel
Water tank	Waste channel pipe
Fuel hose	Secondary combustion fumes
Water hose	Water sprayer
DC compressor	Blower
Fuel controler	Electric Motor for blower
Display panel	Water reservoir
Burner	Water pipe
Burner panel control	Water pump
Water channel	Secondary Water reservoir
Diesel Channel	Primary flue
Combustion chamber	Screw
Entry door	Electric motor
Waste channel	Ash reservoir
Waste channel pipe	Waste mixer
Secondary combustion fumes	Mixer electric motor
Water sprayer	Mixer wheel

ISSN : 2355-9365 e-Proceeding of Engineering : Vol.2, No.2 Agustus 2015 | Page 4623

Then step 2 is documenting the interactions between elements. Pimmler and Eppinger [7] suggest four types interactions,as shown in table 3 .

Table 2 initial chunks of Solair Incinerator

Initial Chunks
Waste chunks
Burning process
Cooling process

Waste chunks represents the set of components located in the front side of SOLAIR incinerator that are involved in waste chunks to combustion

Burning chunks represent set of components located in the right side of SOLAIR incinerator that are involved with heat transfer.

Cooling chunks represents the set of components located in the left side of SOLAIR incinerator that are involved in heat exchange until disposal.

Table 3 Simple Taxonomy Of System Element Interactions [7]

Spatial	Needs for adjacency or orientation between two elements
Energy	Needs for energy transfer/exchange between two elements
Information	Needs for data or signal exchange between two elements
Material	Needs for material exchange between two elements

A quantification scheme facilitates weighting interactions relative to each other . Off-diagonal square marks in the DSM are replaced by a number (coupling coefficient) e.g., an integer -2,-1,0,1,or 2 . Some interactions between elements are more important than others .Moreover ,some interactions are described as desirable , while other are detrimental .

Table 4 Example Of A Spatial Interaction Quantification Scheme [7]

SPATIAL		
Required	+2	Physical adjacency is necessary for functionallity
Desired	+1	Physical adjacency is beneficial, but not necessary for functionallity
Indifferent	0	Physical adjacency does not affect functionallity
Undesired	-1	Physical adjacency canses negative effects but does not present functionality
Detrimental	-2	Physical adjacency must be prevented to achieve functionality

Table 4 described this interaction quantification scheme. For incineration system presented in this paper, the scoring of the spatial type interaction is modified in the following manner: elements performing the function of a conduit, or flow pathway have a spatial interaction score of (+1). Examples of such elements include fuel and water hose, water and fuel channel in burner, water pipe from to water reservoir, pipe waste to combustion chamber ,secondary combustion fumes from combustion chamber, primary flue to environment. This modification is necessary for the following reason: although hoses required to achieve product functionality, generally they are spatially flexible and can be routed around other elements in the design. Neverthless it is desirable components which conduits connect to be placed close to another in order to minimize conduit length.

Table 5 and 6 shows samples how this rating scheme is applied to an interaction between component in incineration system.

ISSN : 2355-9365 e-Proceeding of Engineering : Vol.2, No.2 Agustus 2015 | Page 4624

Table 5 quantification of the interaction between water reservoir and primary flue in incineration system

Elements	Water reservoir and primary flue	
Function: (water reservoir)	To store water for cooling process	
Function: (Primary flue)	As an conduit path flow for gas emissions into environment after the cooling process.	
Relationship :	Primary flue is used to be exit channel for gas emissions to environment after cooling process . Water reservoir is the component that used to store water for cooling process	
Score	Spatial : +2	Energy : +2
	Information: 0	Material : 0

(a)

Elements	Fuel controller and Fuel tank	
Function: (Fuel controller)	To control the flow pressure of water	
Function: (Fuel tank)	To store the fuel	
Relationship :	Fuel controller is used to control the fuel	
Score	Spatial : +1	Energy : 0
	Information: +2	Material : 0

(b)

Table 6 (a) quantification of the interaction between water reservoit and primary flue, (b) fuel controller and fuel tank

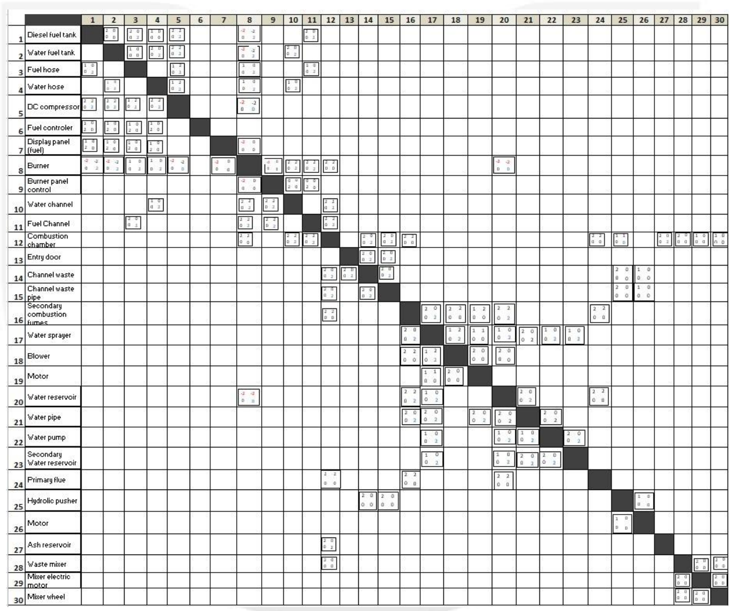
Static DSMs that use in this case is for representing system elements existing simultaneously of product architecture [8]. Static DSMs are usually analyzed with clustering algorithms. For this situation the type of DSM tool can be in the product development process is:

a) Component based or Architecture DSM
it used for modeling system architectures based on components and or sub system and their relationships.

A component-based DSM documents interactions among elements in a system architecture. Pimmler and Eppinger [7] use a component-based DSM to reveal and explore alternative architectures "to improve the quality of resulting product design and to ease the substantial coordination demands that are required when subsystems interact".

Figure 8 shows an interaction matrix displaying the result of quantifying the interactions for 30 elements of incineration system.

Table 7 incineration system interaction matrix



At step 3, clustering elements into architecutral chunks.

Table 8 show clustered interaction matrix for incineration system.

The basic idea of a clustering algorithm is to reorder the row and columns so that all marks are so close to the diagonal as possible or form a tight cluster with other marks. The algorithm used here is Cluster Identifictaion (CI) algorithm. This was chosen because it is easy calculate manually and the algorithm can result in overlapping modules or it may leave a function out of final clustering, in which case it is up to the designer to decide how to deal with them.

ISSN : 2355-9365 e-Proceeding of Engineering : Vol.2, No.2 Agustus 2015 | Page 4625

Table 8 Independenty Clustering Based On Material Interactions

		Fuel hose	DC compressor	Burner	Fuel Channel	Channel waste	Channel waste pipe	Water sprayer	Water reservoir	Combustion chamber
		3	5	8	11	14	15	17	20	12
1	Diesel fuel tank	2	2	2	2					
2	Water fuel tank		2	2						
3	Fuel hose		2	2	2					
4	Water hose			2						
5	DC compressor	2								
8	Burner	2			2					
10	Water channel			2						
11	Fuel Channel	2		2						
12	Combustion chamber				2					
13	Entry door					2	2			
14	Channel waste						2			
15	Channel waste pipe						2			
16	Secondary combustion fumes							2	2	
17	Water sprayer								2	
18	Blower							2		
20	Water reservoir							2		
21	Water pipe							2	2	
22	Water pump							2	2	
23	Secondary Water reservoir							2	2	
27	Ash reservoir									2

Burning · Waste · Cooling · Disposal

Table 8 shows material interaction perspective for an incineration system, where the material exchange is the most crucial architectural design., the incineration system can be clustered into subsystems on the basis of materials interactions using Cluster Identifiacation (CI) algorithm.

The burning cluster represents the set of components involved with heat transfer to the cooling process. Burning chunks consist of burner, fuel tank, combustion chamber. Waste chunks involved entry door, channel waste, and channel waste pipe.
The cooling clustered consist of secondary combustion fumes, blower, motor, water reservoir, water sprayer, water pump, water pipe .Disposal cluster represent the components consist of ash reservoir.

Clustering can significantly impact the coordination complexity of the design process resulting from this analysis. The interactions documented in the previous step describe, at the system level, the design issues which the engineering teams must resolve. Therefore, coordination complexity can be reduced if the elements are clustered such that the interactions predominately occur within chunks, rather than between chunks [7]. Even though the interactions have been quantified for each type, some types of interactions are generally more important than others. For example, in product architecture clustering, spatial adjacency requirements may be given a high priority because it is often difficult to overcome adjacency restrictions that are necessary or detrimental for the product's function. Information signals, on the other hand, may be more easily carried across chunks and can be specified through coordination across chunks. However, relative importance of the interaction types is highly dependent upon the nature of the product being designed [7].

Table 9 Independenty Clustering Based On Spatial Interactions

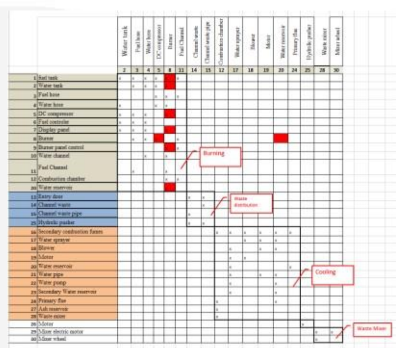


Table 10 final chunks based on clustering

Final cluster
Fuel chunks
Burning chunks
Waste chunks
Cooling chunks
Disposal chunks
Waste mixer chunks

ISSN : 2355-9365 e-Proceeding of Engineering : Vol.2, No.2 Agustus 2015 | Page 4626

CLUSTERING NEGATIVE

(DETRIMENTAL) INTERACTIONS

Clustering for system and team chunks began by closely grouping positive material interactions into chunks, then expanded the clustering to include the perspective of the other interactions types , which resulted in mixing negative interactions within those positive interactions base chunks. This result may be have positive and negative interactions.

Table 11 Detrimental interactions between components of SOLAIR Incinerator

Component interactions	Spatial	Energy
Fuel tank- Burner	-2	-2
Water tank-Burner	-2	-2
Compressor-Burner	-2	-2
Display panel(fuel)-burner	-2	
Panel control-burner	-2	
Water reservoir-burner	-2	

Fuel tank, water tank, compressor, display panel, panel control for burner is placed near to burner, it higher risk for them to explode because the heat of burner is very high (500-1200 degree of celcius) so, its better adjacent them separately. The value -2 means that that component will affect functionality. In incinerations system, the waste reservoir either described as having a detrimental (-2) material/energy/spatial interaction with burner because high pressure from combustion towards water reservoir. Based on the real condition and interview with d eloper, the heat transfer of burner made the water reservoir often leakage. This detrimental interactions is usefull for determining the components that must be adjacent in different chunks to avoid the disfunctionality.

Out-Of-Chunk Interactions

For very dense or complex interaction matrices, it is not possible to cluster all interactions will remain. Rather, several out-of-chunk interactions will remain.

In this case of incineration system, the burner are described as having a detrimental (-2) material/energy/spatial interaction with some components such as compressor, fuel and water tank because of heat transfer that will affect functionality. Since the enviromental separation in this case is obvious, they should not placed in the same chunk for only that reason. (They would, however, be placed in the same chunks due to material exchange interactions.

4.2 Modularization with Contact and Channel Model (C&CM)

A process to make a product more modular can be called “modularization”. Most of modularization methods focus on the redesign of existing product, in which a matrix representation is often used as a tool for an integration analysis. Neverthless, modularization is not a process to turn a non-modular into a “complately modular” product but it can be applied to increase the degree of modularity [9].

Table 12 lists of Basic Function (BF), Auxiliary function (AF), Specific Function (SF) incinerator

BF Components	AF Components	SF Components
Water	Water hose	Control panel
Fuel	Fuel hose	Display panel
Burner	Water channel	Burner panel
Combustion chamber	Fuel channel	
Entry door	Motor pusher	
Channel waste	Pipe channel waste	
Blower	Motor mixer	
Ash reservoir	Wheel	
Water sprayer	Motor blower	
Water reservoir	Secondary combustion fumes	
Water pump	Water pipe	
Secondary water reservoir		
Primary flue		
Compressor		

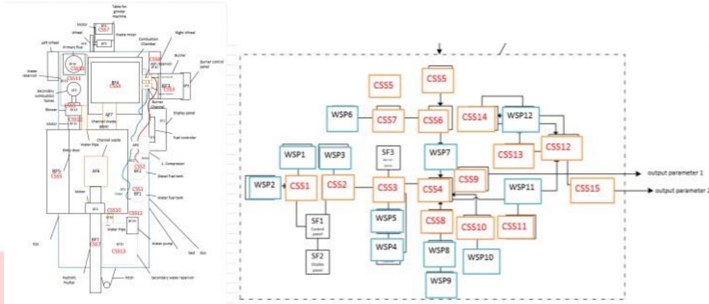
ISSN : 2355-9365 e-Proceeding of Engineering : Vol.2, No.2 Agustus 2015 | Page 4627

Normally the function architecture of the product is a combination of the BF and AF. In C&CM, the functions and their interactions are modeled to CSSs and WSPs (shown in figure 14), in which the hardware perception and understanding of the functional interactions are revealed [2] .

Based on that extended modularization process VDI2223, there are 3 steps should do in order to know maximum degree of modularity of incineration system [2]. But step 4.2.2 and 4.2.3 will be calculated in future research.

STEP 4.2.1

In the C&CM, the function and their interactions are modelled to CSSs and WSPs.



(a) (b)

Figure 14. (a) Rough layout of existing incinerator with C&CM representation, (b) Function structure

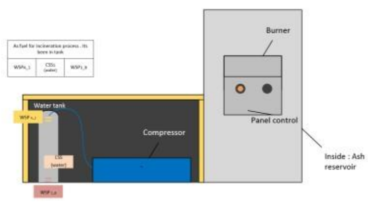


Figure 15 C&C-A description process between compressor and water

The Contact & Channel-Approach (C&C-A) is used for building Contact & Channel-Models (C&CM) of technical system. The C&C-A provides generic elements to deduce specific models.

Figure 14 shows relevant WSP and CSS are depicted in a lower level of detail between water tank and compressor. Compressor pump the water to burner via hose. The function of compressor cannot be fulfilled unless WSPA_1 between tank and compressor. If one of these elements is not build up correctly the function cannot be fulfilled. For further analysis of every elements will be suitable delivered in future research to find new technical solutions.

5.2 FMEA

Based on calculation by multiply weight score severity ,occurences and detection, get the result Risk Priority Number (RPN) value. RPN is decide which the risk that still acceptable and unacceptable. Compressor has has five kind of failure that unacceptable, they are overheating, High voltage surge, refrigant floodback, contamination and corrosion which has score 432, 315, 648, 486, and 405. The parameter of unacceptable is the score of RPN, this is based on team developer.. After getting this score of each problem, the next researcher in future research will consider the problem above by doing some recommended action or additional work to reduce RPNs less than 200. Those information will usefull to define product architecture. For this case, the parameter of RPN score is 200.

For the failure modes where action was taken, there should be a significant reduction in the RPN. If not, that means action did not reduce the severity, likelihood of occurrence, or detectability.

Among all potential failure occurred, the highest RPNs is leakage of water reservoir, it is 630. While the smallest RPNs is 240, it is burner control.

ISSN : 2355-9365 e-Proceeding of Engineering : Vol.2, No.2 Agustus 2015 | Page 4628

5. Conclusion

1) Based on calculation of RPNs in FMEA analysis:
   a. Compressor has has five kind of failure that unacceptable, they are overheating, High voltage surge, refrigant floodback, contamination and corrosion which has RPNs 432, 315, 648, 486, and 405.
   b. Burner has potential failure that unacceptable, it is explosion which has RPNs 280.
   c. Burner control has potential failure control of failure electrical integrity, which has RPNs 240.
   d. And the Water reservoir has kind of failure that unacceptable, it is leakage. It has highest RPNs among other, it is 630.

2) Final chunks obtained from fuel, burning, waste chunks, cooling and disposal chunks. And using interactions analysis (spatial, energy, information, material) as adjustment.

   Fuel chunks (added) represent set of components that are involved with resource /fuel . This chunks is comprises fuel and water tank, hose ,compressor, display panel and control panel.

   Burning chunks (Unchanged and revised) represent set of components located in the right side of SOLAIR incinerator that are involved with heat transfer. This chunks is comprises water and fuel channel, burner, combustion chamber and ash reservoir.

   Waste chunks (Unchanged) represents the set of components located in the front side of SOLAIR incinerator that are involved in waste chunks to combustion. This chunks is comprises entry door, channel waste , channel waste pipe ,motor and Screw.

   Cooling chunks (Unchanged) represents the set of components located in the left side of SOLAIR incinerator that are involved in heat exchange until disposal. This chunks is comprises Secondary combustion fumes, water sprayer, blower, motor, water pipe , water pump ,secondary water reservoir , primary flue.

   Disposal chunks (added) involved ash reservoir**.** This added chunks is based on material clustering result

   Waste mixer chunks (added) represent set of components that are involved waste mixer, motor and wheel.

6. Suggestions for future research

Suggestions for further research are as follow.

1) The future work of the research is to apply this problem resut analysis of modularization of redesign process to consider integration solution and the improvement product architecture that will be designed in CAD system for the depiction of the system’s physical structure.
2) To continue this research, writer suggest for using Design Principle and guidelines from the Element Model C &CM literature according Pahl and Beitz (1997) to help fulfilling the requirement of technical system such as Adding,Removing,Changing the Working Surface Pairs and Channel and support structure.
3) For futher analysis , this research can continue with maintainability analysis approach in order to give deepeer analysis on modularization method to define optimal modular architecture then designing the product architecture improvement.
4) To generate alternative architecture , it is important to consider integration solution based not only on interactions but also on other strategic and product architecture concern.

ISSN : 2355-9365 e-Proceeding of Engineering : Vol.2, No.2 Agustus 2015 | Page 4629

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