

The Application of Concurrent Engineering Tools and Design Structure Matrix in Designing Tire

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Abstract: The development of automobile industry in Indonesia is growing rapidly. This phenomenon causes companies related to the automobile industry such as tire industry must develop products based on customers' needs and considering the timeliness of delivering the product to the customer. It could be reached by applying strategic planning in developing an integrated concept of product development. This research was held in PT. XYZ that applied the sequential approach in designing and developing products. The need to improve in one stage of product development could occur re-designing that needs longer time in developing a new product. This research is intended to get an integrated product design concept of tire pertaining to the customer's needs using Concurrent Engineering Tools by implementing the two-phased of product development. The implementation of Concurrent Engineering approach results in applying the stage of project planning, conceptual design, and product modules. The product modules consist of four modules that using Product Architecture – Design Structure Matrix to ease the designing process of new product development.

Keywords: Concurrent Engineering, QFD, Product Architecture-DSM, Product Development

1. Introduction

The transportation in Indonesia, specially the number of private cars has increased every year. Based on database of Badan Pusat Statistik in Indonesia, the number of passenger cars in 2011 and 2012 consecutively were 9.548.866 and 10.432.259 units, and in 2013 was 11.484.514 units [1]. The number has increased by 1.052.255 units between 2012-2013. The data proved that the growth rate is increasing every year in Indonesia. Every industry that related to automotive especially private car consequently needs preparation to face the increasing demand and needs in parts of the cars.

The tire industry is one of industries that need preparation to face the increasing growth rate of private car. PT. XYZ is one of the industry which produces tire for passenger cars. PT. XYZ always keeps improving their products based on customers' needs, but they still got delays in developing product design process. The activity of developing a new product usually needs six to ten years depending on the conformity of product to consumers' specification, because there is only one flow in every department related to the product development activity. PT. XYZ is using sequential method in developing their products.

The new product development activity starts from the product design department by creating the ideation of new product concept, then production process planning department starts their work, and



so on until the product is made in prototype and examined its conformity. If the specification of product does not conform to the technical requirements, production process needed in tire, or the examination of the prototype, it will need the activity of redesign. Redesign is an activity of revising the design of a product because of discrepancy between product design and technical requirement and process needed in production, or because the prototype does not pass the examination. The activity of redesign would result in waste the usage of resources, such as time, cost, and energy, or the examination of prototype, it will need the activity of redesign. The redesign problem could be solved by using the Concurrent Engineering approach. It has some tools that could be used, like Quality Function Deployment (QFD) [2] and additional method that could be integrated – Design Structure Matrix (DSM) [2], [3]. The QFD was also found to be useful in enhancing other DSM capabilities for managing detailed information between the different elements of complex systems [4]. The Concurrent Engineering approach is linking part characteristics from QFD Phase II to DSM in developing product architecture [5].

The problem that will be discussed, is there are no integration between the product design department and process planning department in develop of new product concept of radial tire. The integration is needed to prevent the need to redesign or re-adjusting product design form every department by utilizing Concurrent Engineering Tools and Design Structure Matrix.

2. Literature Review

Concurrent engineering (CE) is an engineering management philosophy and a set of operating principles that guide a product development process through an accelerated successful completion. Concurrent engineering is concerned with the timely availability of critical design information to all development participants. For most complex engineering tasks all relevant information required by a specific development team cannot be completely available at the start of that task. Therefore, CE requires the maximization of such information and the ability to share and communicate useful information on a timely basis [6].

The fundamental difference between Concurrent Engineering (CE) and Sequential Engineering (SE) is the involvement of departments in the organization in product development activity. Concurrent Engineering puts all the problems such as maintenance, manufacturing, etc. In the beginning process, the product development process by using SE takes much time in building concepts compares to CE. Figure 1 shows the difference of time needed between SE and CE. Notice that only 3% of the development process was spent on planning in SE and 27% was spent on design. Compare that with the time used planning in the CE process. The time required was more than 10 times greater, the planning process took about one-third of the entire process time, and design 22%. In SE, only one-third of the development time was spent on planning and design, and the rest of the time was spent fixing problems that arose when the product was transferred to the manufacturing organization. In contrast, over half of the development effort was spent on planning and design in CE, yet there was a 40% savings in time using CE [2].

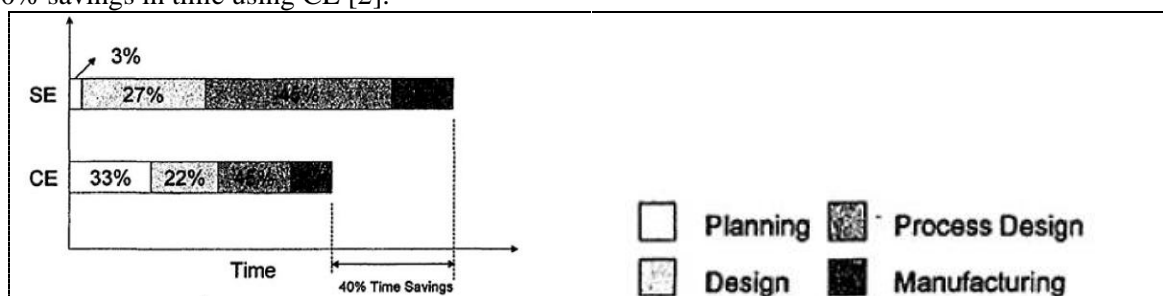
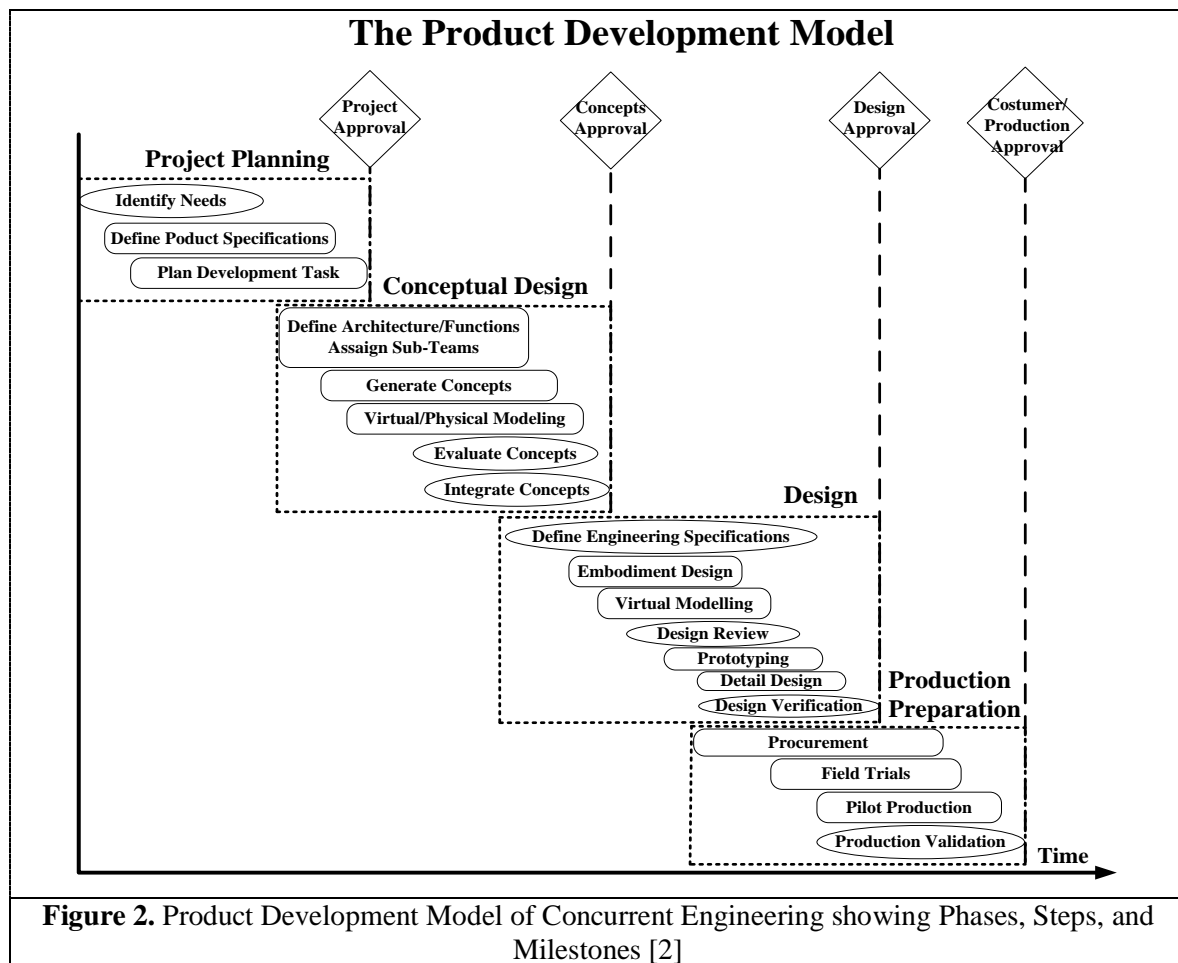


Figure 1. Difference between Sequential Engineering and Concurrent Engineering [2]

The product development model is made up of four phases as can be seen in Figure 2. The four phases are project planning, conceptual design, design, and production preparation.



There are three development steps in project planning phase, i.e. identify needs, define product specification, and plan development tasks. The customer and field service can provide valuable input in this phase. The goal of this phase is to develop a project planning document. The second phase (conceptual design) consists of five steps in which this phase begins with a definition of the product and its function form. Next, different design concepts are developed, modeling is performed, the concepts are evaluated and the best design concepts are selected for further development. The selected concepts are integrated into a set of final concepts [2].

2.1. Quality Function Deployment (QFD)

QFD is a method for structured product planning and development that enables a development team to specify clearly the customer's wants and needs, and then to evaluate each proposed product or service capability systematically in terms of its impact on meeting those needs. QFD is a central tool in support of Concurrent Engineering. It brings the multi-functional team together in the first place, it develop the top-level House of Quality matrix. At each step in the process, it helps keep the team focused on customer satisfaction, the primary ingredient of product success [7].

The QFD method is used frequently because of its ability to incorporate both internal and external customer needs in the process of product design. The overall goal of QFD is the reduction in the length of product development cycle, including packaging, simultaneous improvement of product quality and lower production costs. Some of the acknowledged benefits of QFD include preservation of the newly established and well-known data about the target product and user's satisfaction [8].

The QFD matrix has two major components: one captures the customer information and one contains technical information. The voice of customer is the basic input required to understand the

customers' wants and needs. Once the customers' wants and needs are known, the QFD team can begin developing the technical information portion of the matrix. The customers' voice must be translated into items that are measurable and actionable within the company. Companies use a variety of names to describe these measurable items, such as design requirements, technical requirements, product characteristics, and product criteria. The relationship between the customer information and technical information can be examined so that the team can begin a study to determine the target value that should be established for each technical requirement. The objective is to ensure that the next-generation product will be truly competitive and satisfy its customers' wants and needs [9].

QFD normally has four forms (matrix), i.e. product planning matrix, part deployment matrix, process planning matrix, and process and quality control matrix. Product planning matrix compares the customer's requirement with the product characteristics. Part deployment matrix compares product characteristics with the requirements of the more important components (subsystems) into which the product can be broken down (critical part characteristics). Process planning matrix relates the characteristics of the single subsystems with their respective production processes (critical process steps). Process and quality control matrix defines inspection and quality control parameters and methods to be used in the production process of each process step (quality control process steps) [10].

2.2. Design Structure Matrix (DSM)

DSM or known as a dependency structure matrix is a chart to show the relationship of every activity. DSM is used to solve the related problem of every activity in product design process as well as project planning [3]. DSM is represented as a square $N \times N$ matrix, mapping the interactions among the set of N system elements. Depending on the type of system being modeled, DSM can represent various types of architectures. For instance, the DSM elements in modeling a product's architecture would be the components of the product, and the interaction would be the interface between the components.

DSM models can be partitioned or rearranged using a variety of analytical method, the most common of which are clustering and sequencing, as shown in Figure 3. Clustering analysis applies primarily to the kinds of interaction networks found in product and organization architecture DSM models, where interaction marks are largely symmetric about the diagonal. Sequencing analysis applies primarily to the kinds of directional or temporal interaction networks found in process DSM models [11].

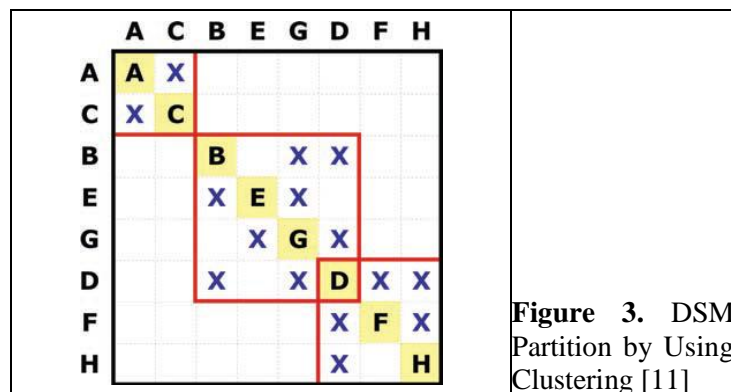


Figure 3. DSM Partition by Using Clustering [11]

3. Research Method

3.1. Data Collection

The primary data were collected by the observation or direct measurement and questionnaire, which includes the consumers' needs, technical requirements, and critical parts. The secondary data were gained through interviewing the production department in PT. XYZ to collect the product types, specification, demand rate, tire initial design, and production process of tire.

The attributes of product that will be asked to the respondent are based on [12] and [13] i.e.

1. Pattern of tread rubber [12]

2. Inner liner thickness [12]
3. Material of ply or carcass [12]
4. Section width [13]
5. Ratio aspect of section width and section height [13]
6. Service life of radial tire in kilometer [13]

The population of this research is all the employee of production department in PT. XYZ. The population size is 86 people who understand the constraints of every product criterion to ease the evaluation of the product. This research is using the total sampling or complete enumeration, therefore the sample size is the same as the population size.

3.2. Data Analysis

This research is focused on product development by using project planning phase and conceptual design phase of concurrent engineering approach. The project planning phase starts from identify needs, then define product specification, and plan development task. The project planning phase use House of Quality [2]. The consumers' needs were analyzed by using statistical method to validate the questionnaire. The primary and secondary data were drawn into House of Quality (HoQ), and then the determination of Multi Component Relationship is using the Product Architecture – Design Structure Matrix. The Product Architecture is used in the conceptual design phase [2].

4. Results and Discussion

The result of identification pertaining to the consumers' needs is shown in Table 1.

Table 1. Identification of Consumers' Needs.

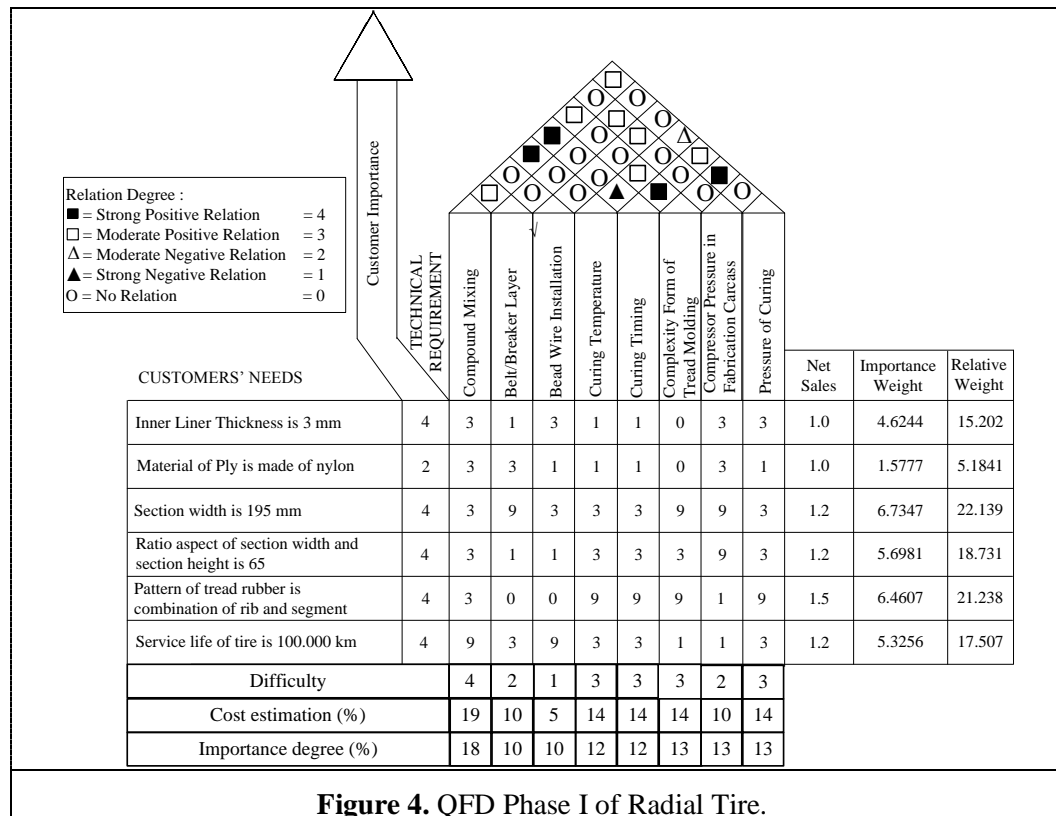
No	Variable
1	Inner Liner Thickness is 3 mm
2	Material of Ply is made of nylon
3	Section width is 195 mm
4	Ratio aspect of section width and section height is 65
5	Pattern of tread rubber is combination of rib and segment
6	Service life of tire is 100.000 km

The Table 2 listed the consumers' needs pertaining to the questionnaire result. It showed the importance weight of the variable.

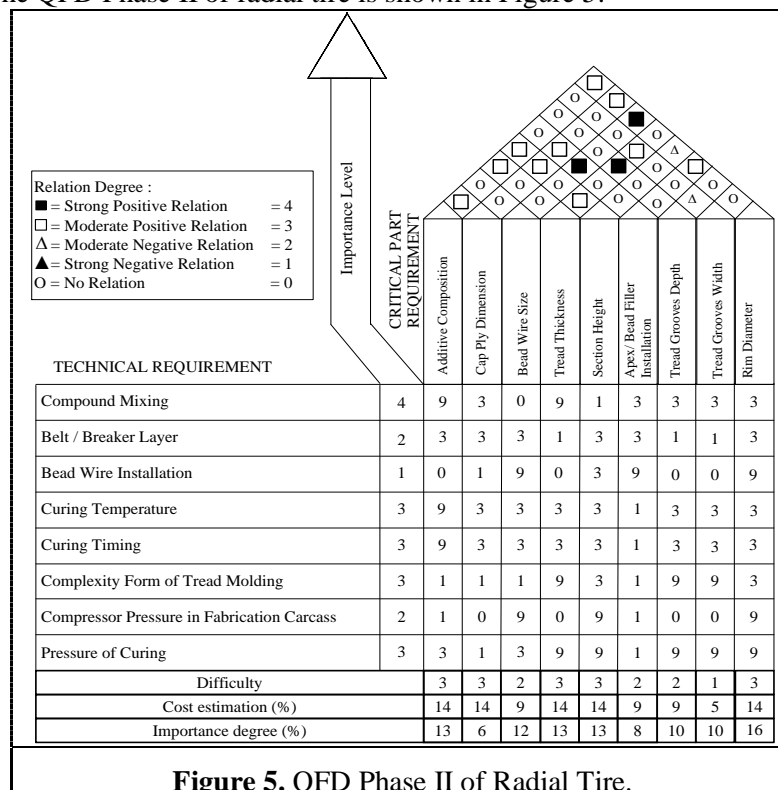
Table 2. Importance Weight of the Variable.

No	Consumers' Needs	Questionnaire Result					Importance Weight
		Measurement Scale					
		1	2	3	4	5	
1	Inner Liner Thickness is 3 mm	1	6	23	32	24	4
2	Material of Ply is made of nylon	7	30	27	18	4	2
3	Section width is 195 mm	6	18	25	30	7	4
4	Ratio aspect of section width and section height is 65	0	4	30	35	17	4
5	Pattern of tread rubber is combination of rib and segment	1	4	10	40	31	4
6	Service life of tire is 100.000 km	1	1	23	33	28	4

QFD phase I of radial tire is shown in Figure 4. Figure 4 explains that the highest difficulty, cost estimation, and importance degree of the technical characteristics is compound mixing.



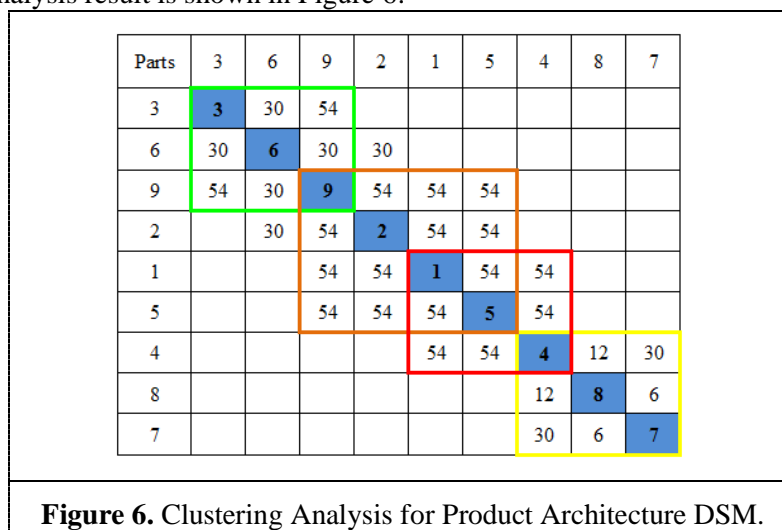
All the technical characteristics from QFD (phase I) will be inserted to the QFD (phase II) as the input of “whats” column [9]. The importance level of the technical characteristics comes from the difficulty level. The QFD Phase II of radial tire is shown in Figure 5.



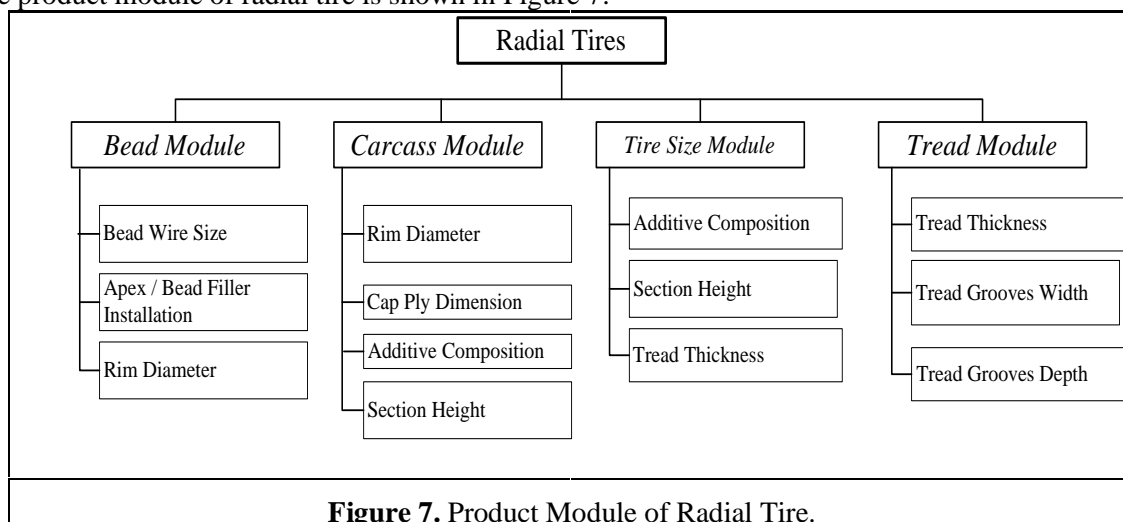
The critical parts of radial tire design are the highest difficulty, cost estimation, and importance degree. Figure 5 shows that the critical parts are additive composition, cap ply dimension, tread thickness, section height, and rim diameter. The critical parts from QFD Phase II is linked to DSM in developing product architecture [5]. The steps in developing product architecture of DSM are as follow [11]:

- Determination of boundary system by transforming data from critical parts.
- Determination of interaction strength and component symmetry.
- Determination of model's granularity.
- Identification the interaction of each component by clustering.
- Clustering analysis of two goals: minimizing (the number or strength) the interaction of outside the cluster and minimizing the size of clusters.

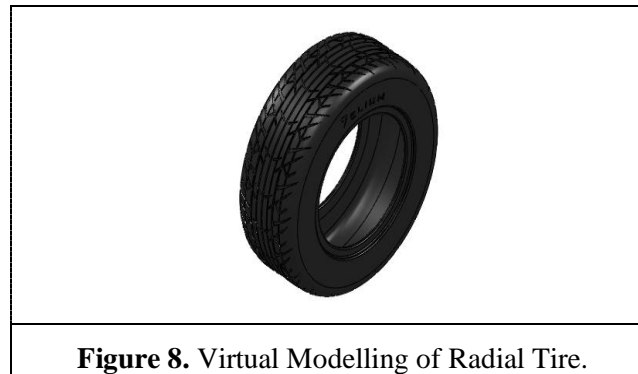
The cluster analysis result is shown in Figure 6.



The product module for radial tire could be made based on clustered product architecture of DSM. The product module of radial tire is shown in Figure 7.



Virtual modelling is made by using software CAD form. The concept resulted from the representation of key characteristics, so that the concept could be evaluated from various considerations. Four modules from the Product Architecture DSM have been the basis of virtual modelling the radial tire. The virtual modelling of a radial tire is shown in Figure 8.



The integrated concept is based on the product architecture that consists of four modules radial tire. The design concept of this research is grouping the critical components from radial tire into four substructures. The explanation of radial tire component design is as follow:

- Module 1 consists of bead wire size, apex/ bead filler installation, and rim diameter. The initial design of each part is found in the production process department for manufacturing bead wire and determination of the rim diameter that will be used. The concept design improvements in bead wire shows that each component has standard that mutually influences in minimizing the assembly design of apex/ bead filler and bead wire. The selection and measurement of rim diameter as an initial component design is the most important process in determining the installation of bead wire that will be assembled to become a radial tire.
- Module 2 consists of rim diameter, cap ply dimension, additive composition, and section height. The initial design of each component is found in process production department for compound mixing, extrusion, and cutting. The concept design improvement shows that these components affect the section height in one department of manufacturing carcass. These components have standard that mutually influences in minimizing the manufacturing design of radial tire carcass.
- Module 3 consists of additive composition, section height, and tread thickness. The additive composition that exists in module 2 is the determinant of quality and endurance of the tire, whereas section height is the determinant of tire size. The tread thickness is the determinant of tire form that is related to module 4.
- Module 4 consists of tread thickness, tread groove width, and tread groove depth. All the components affect in the final pattern of tread that will determine the ability of tire in doing the grip on the road surface. Module 4 is related to curing the process which is the process of stamping the tire tread to the green tire with help of evaporation and pressure to shape green tire in the molding.

5. Conclusion

Attributes of the radial tire design based on the consumers' needs consist of six variables, i.e. inner liner thickness, the material of ply (carcass), the section width, ratio aspect, the pattern of the tread, and its service life. The relationship of radial tire's components using the Product Architecture. DSM is divided into four modules which each module consists of clustering parts characteristics. Module 1 consists of bead wire size, apex/ bead filler installation, and rim diameter. Module 2 consists of rim diameter, cap ply dimension, additive composition, and section height. Module 3 consists of additive composition, tire height, and tread thickness. Module 4 consists of tread thickness, tread groove width, and tread groove depth.

The conceptual design of radial tire was done by using the second phase of QFD to get five critical parts, i.e. additive composition, cap ply dimension, tread thickness, section height, and rim diameter. The activity of alternative product design, planning and radial tire design was done by the approach of

Concurrent Engineering by implementing the two phased of product development. The Project Planning step was done by using the QFD phase I to identify the consumers' needs. The Conceptual Design step was done by using QFD phase II to identify the importance weight of radial tire design and also part characteristics. The final result in implementing the Concurrent Engineering approach is virtual model of radial tire and product modules of Product Architecture Design Structure Matrix to improve the design activity in giving information for the company by integrating the process of each department in the design planning of radial tire.

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