SIMULATION TESTING ON IMPROVED DESIGN OF COLLEGE CHAIR USING FINITE ELEMENT METHOD (FEM)

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Abstract
In the university life, study activity is a main part of the learning that aims to make students get more knowledge in the focused area of students' interest. College chair is one kind of furniture that is designed for university student and in this research college chair that will be researched is improved from the existing college chair. In the product development process phase, there are testing and refinement stage. This stage is done after the product design have been generated. The sample also needed to facilitate the work and referred as prototype. Prototype is product approximation along one or more dimensions of interest. In a study entitled "Implementation of Quality Function Deployment Method in Design Improvement for College Chair", the design has been done considering the desired needs of the users. The design has not been through the feasibility test includes strength and ability to withstand the load. To solve the problem, this study will use simulations that is performed using Finite Element Method (FEM) in SolidWorks. Having a researched and conducted a series of simulated observations using SolidWorks software, resulting that material used is good material and safe to be used for some part of the college chair.

Keywords: Finite Element Method (FEM), simulation, chair

1. Introduction

In the product development phase, there is one of the step that is testing and refinement. After establishing the design such as shape, dimension and other product characteristics has been done, this testing process need the sample product to facilitate the research that is called prototype. Prototype is an approximation of the product along one or more dimensions of interest [1].

College chair development design has been done considering on the customer need that it has been studied from the previous research. College chair is one kind of furniture that is designed for university student and the design has been improved and used as analytical prototype using CAD software. The previous research, the study problem is solved focusing on the design without considering the material and its feasibility.

In testing process, analytical prototype will be used in the research by simulation. Simulation approach is easier and cheaper than doing model experiment. Modification and variation can be done in the simulation to avoid producing a lot of physical prototype. College chair design simulation will be analyzed using Finite Element Method (FEM). Finite Element Method is the approach method by splitting the geometry model into small elements, then translated into a mathematical model to predict the behavior and strength of the material with particular limit [2].

The expectation of the college chair design simulation is having the stress strength and displacement using the Factor of Safety as a benchmark whether the chair is safe and ready to produce the physical prototype.

2. Literature Review and Research Methodology

2.1. Product Development

Product development process is a series of stages or activity that is done by an organization to arrange, design and commercialize the product. Process starts from the planning phase, concept development phase, system level design phase, detail design, testing and refinement and production ramp-up phase.

Figure 2.1 Product Development Process

2.2. Material Selection

Material is a substance or an object in which new goods can be made from it, or to build something so that it becomes more efficient. The process of increasing the value of material use evolves through a more logical process and through scientific research and also high in developing processing technology. Material selection in product design is required according to the study objective that will test the product feasibility. It has four steps such as translating the design requirements, screening using constraints, ranking using objective and seeking supporting information. Material selection to be discussed is focusing on the table part, cushion part and seat back only.

2.3. Testing and Refinement

In testing and refinement phase involves the construction and evaluation of various versions of initial product manufacturing. A product sample is needed to make the testing and refinement process easier. This product sample is referred as prototype. Prototype is an approximation of the product along one or more dimensions of interest. The definition includes such diverse forms of prototypes as concept sketches, mathematical models, simulation, test components, and fully functional preproduction versions of the product. Prototyping is the process of developing such an approximation of the product.

Prototype is divided into two types that are physical prototype and analytical prototype. Physical prototypes are tangible artifacts created to approximate the product. It represented by a real model of a product and can show the attributes or characteristics that can't be clearly defined. Some of the properties can be shown on the product from the approximation result. On the other hand, analytical prototypes are intangible product, usually mathematical or visual. It can only show the obvious characteristics of the model. Some of the properties can be shown on the product from the analysis result. In this research, type of prototyping will be used is analytical prototype.

2.4. Research Methodology

As the second researcher, this research aims to simulate and identify the feasibility of concept of improved college chair design.

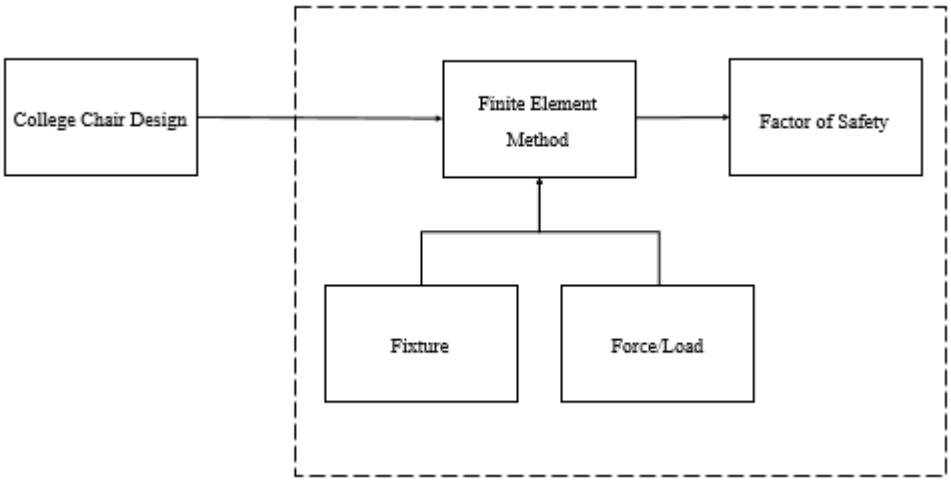


Figure 2.2 Conceptual Model

After the previous research has been done, the design of college chair will be used and the technical feasibility of the design will be known, whether the design is said to be able to withstand the exposed load on the design.

3. Discussion

Data collection in the research is using 3D model data from the previous study entitled "Implementation of Quality Function Deployment Method in Design Improvement for College Chair". Then, the testing of college chair conducted using Finite Element Method. The result of this research is the value for the stress and displacement testing related to the Factor of Safety. If the product testing value is in the range of the value, then the product is appropriate to use.

3. 1. Material Selection

Translating design requirements express as function, constraints, objectives and free variables for each components. The function and objectives of each part is different but the constraints are the same which are the chair have to have wide table, have appropriate height, has long durability, safe and easy to manufacture.

Then, the material is screened using constraints by eliminating material options that cannot do the job. Material options for cushion, table and seat back part are Polyethylene Low Density, Polyethylene High Density, PVC Rigid, and Polyethylene Cross Linked. The advantages and disadvantages is described in the following table:

Table 3.1 Screening Material using Constraints

Material Option	Advantage	Disadvantage
Polyethylene Low Density (PE Low Density)	• Strong and durable • Easy to proceed • Develops character over time • Surface is softer than PE High Density	• Difficult to degradation by earth, but still can be recycled become PE again but the quality will be decreased
Polyethylene High Density (PE High Density)	• Strong and durable • Develops character over time • Higher density than PE Low Density	• Surface of the product will be rough • Material is difficult to process
PVC Rigid	• Strong and durable • Cheap	• Contains additional chemicals to change the chemical consistency of the product • Chemical additives can be out of PVC when used
Polyethylene Cross Linked	• Strong and durable • Has interesting color • Develops character over time • Density and surface can be adjusted but still in the range of density of PE Low density and High Density • Easy to manufacture	• Difficult to degradation by earth • More expensive than other polyethylene for manufacturing process

The objective of the product is using solid material that is strong to be assembled with other parts, can be used longer and easily manufactured. By studying the advantages and disadvantages, the next step for material selection is part material options need to be ranked to find the material that do the job best by its objectives. Looking from the information of material on the table, the material ranking by objectives are Polyethylene Cross Linked, PVC Grid, Polyethylene Low Density, Polyethylene High Density. Polyethylene Cross Linked is chosen to be first rank because it is one kind of material that is closest to the specified constraints. It also supported by the advantages and disadvantages of PE Cross Link correspond to the objective.

After ranking each part or component material options, more researched need to be done, such as study of temperature rate, density, pre drying process and properties. The result of the study is shown on the following table:

Table 3.2 Characteristic Information

Characteristic	PE Cross Linked	PVC	PE Low Density	PE High Density
Temperature Rate	190-200 ℃	160-180 ℃	160-240 ℃	200-280 ℃
Density	950 kg/m^3	1,300 kg/m^3	918 kg/m^3	950 kg/m^3
Pre Drying Process	No need	Need	No need	No need
Properties	Thermoplastic	Thermoplastic	Thermoplastic	Thermoplastic

Temperature rate indicates the melting point of material when the material will be processed. Higher temperature can make the material difficult to be manufactured. Then, density is the important thing to measure the hardness of the material. The higher value of density, the higher the hardness of material since the material need to consider the durability of the product. Some materials requires pre-drying process before it will be processed. The consequences of this process make the process become longer in term of time. Last the properties indicates what kind of material researched. From the property characteristic, the material can be known whether the material can be recycled or not. There are two kinds of plastics that called Thermostatic and Thermoplastic. Thermoplastic type is the plastic that can be recycled.

Therefore, the chosen material is Polyethylene Cross Linked because it is one kind of material that is closest to the specified constraints and also supported by the advantages, and detail information including temperature rate, density, pre drying process and its properties. This Polyethylene Cross Linked material will be used in the SolidWorks simulation and analyzed using Finite Element Method.

3.2. Testing and Refinement Phase

1) Von Mises Stress

Stress can be defined as a magnitude of force acting on a unit area. Stress is the quantity to describe the intensity of strength in model (either solid or liquid). Unit of stress is force per unit area. From the simulation can be found that the biggest impedance in von Mises simulation results that the value of the critical point does not exceed the value of yield strength can be said that the design is feasible to be applied and used in real product.

2) Factor of Safety (FOS)

Factor of safety or commonly abbreviated as FOS is a measurement of the level of object security (components) when receiving an external force. The level of security used is the strength of objects when receiving maximum stress. The value of the factor of safety required for the component to be assumed as safe from the force load simulation is greater than one, or in other words, the maximum receiving value is not greater than the yield strength value of the product material. It will be said fail condition when the material begins to have plastic deformation [3].

3) URES

By looking at the URES results, the displacement will be obtained to know how far the displacement is. The area that experiences the most shifting particles of material is in the red color. The shift is so small that it can be said that the design is good to prevent disposition.

4. Conclusion

Based on the results of data processing and analysis, to be concluded that refers to the purpose of the research, the goal is reached because the design has been technically feasible using finite element analysis.

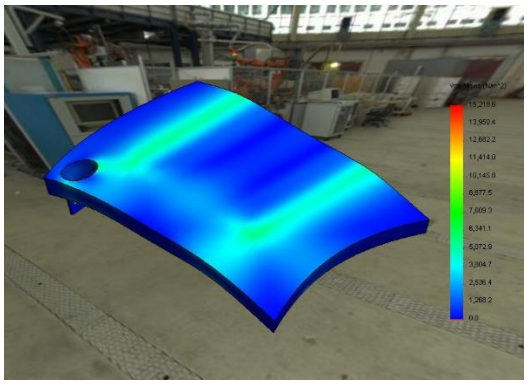
Recommendation for the future research is the research need to be conducted about rapid upper limb assessment and usability testing that is not yet done in this research. In addition, it is necessary to study more so that the design can be more efficient to be applied.

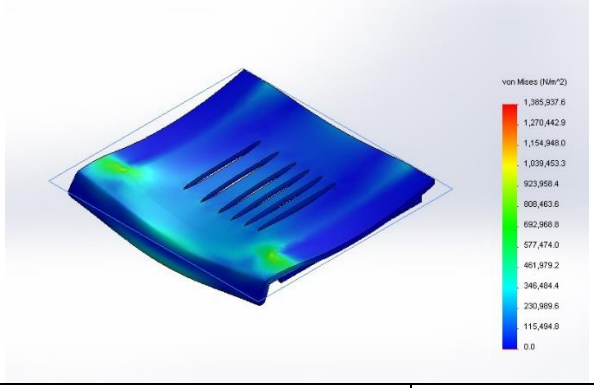
References:

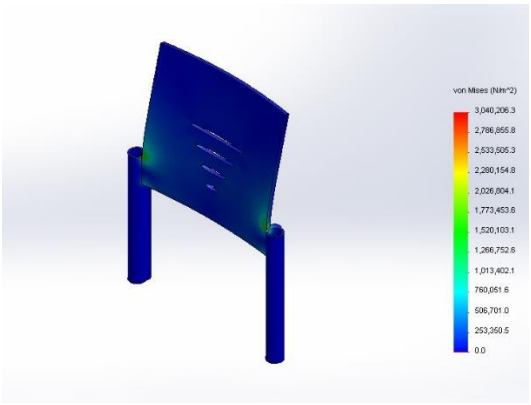
[1] Ulrich, K. T., & Eppinger, S. D. (2012). Product Design and Development, Fifth Edition. New York: McGraw-Hill Education.
[2] Hutton, D. V. (2004). Fundamental Finite Element Analysis. McGraw-Hill.
[3] Alkin, J. Ed. 2009. *Finite Element Analysis Concepts via SolidWorks.* Texas: World Scientific.

Appendix A
[Finite Element Analysis]

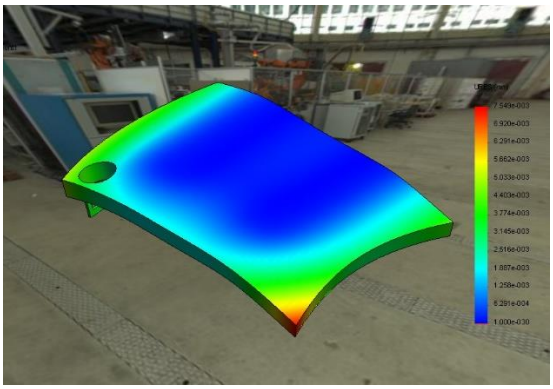
1) Von Mises

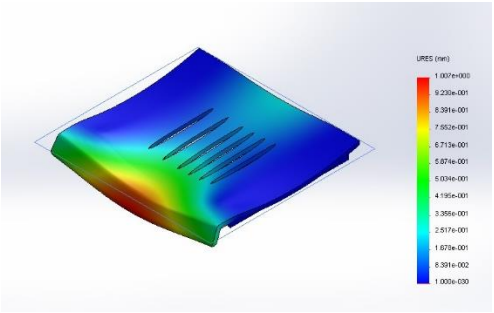
Table Part	
	
Maximum	15218.6 N/m^2
Yield Strength	1.8e+007 N/m^2

Cushion Part	
	
Maximum	1.38594e+006 N/m^2
Yield Strength	1.8e+007 N/m^2

Seat Back Part	
	
Maximum	3.04021e+006 N/m^2
Yield Strength	1.8e+007 N/m^2

2) URES

Table Part


Cushion Part


Seat Back Part