SUSTAINABLE TECHNOLOGY FOR SUSTAINABLE PRODUCT DEVELOPMENT IN MECHANICAL DESIGN
CASE STUDY: SUSTAINABLE PRODUCT DEVELOPMENT OF NEW DESIGN FLEXIBLE SHIELD USING FINITE ELEMENT METHOD

Willyanto Anggono¹, Hariyanto Gunawan²
Product Innovation and Development Centre Petra Christian University¹,²
Mechanical Engineering Petra Christian University¹,²
Jalan Siwalankerto 121-131, Surabaya 60236
E-mail: willy@petra.ac.id¹, hariyanto@petra.ac.id²

Abstract
Sustainable technology is a part of the broader concept of sustainable product development and virtual reality means existing or resulting in essence or effect though not in actual fact, form, or name. Understanding the mechanical design is very hard to do because it is very hard to visualize the mechanical design product and the performance of the mechanical product during design phase. To predict the performance of the mechanical product during design phase is possible to do using Finite Element Method technology (ANSYS Software). Virtual reality technology using ANSYS software can perform the performance of the mechanical product during the design phase.

Product design is always interesting to most of the people. It is also becoming more and more popular now a days. Flexible shield design is a part of mechanical design. Designing a product such as a flexible shield as a part of a pump system that dispenses soap-products is a very interesting case because of its nonlinear geometry and nonlinear material behaviour problem. The function of the flexible shield is to protect the soap pump from intruding water. Investigation on performance of the current design flexible shield found that the current design of the flexible shield has not succeeded yet because there are no enough vertical reaction force in the upper part of the flexible shield after the deformation 9 mm to return to its rest position by itself (the requirement is 10 mm deformation).

In the real experiment, the product must contain enough vertical reaction force on the upper part area of the flexible shield to return to its rest position independently. At that situation, there is no minimum turning point in the force against displacement graph. In the ANSYS simulation, this condition is illustrated by the same graph force against displacement as the real experiment. To eliminate the locking mechanism during the deformation, the discontinuity should not exist, which means there should be no minimum turning point in the force against displacement graph.

The full scale tests (real experiment test) are expensive and require a lot of time, material and money. The full scale tests is not the Sustainable Product Development way of Flexible Shield design. Using Finite Element Method Technology changing material and shape are very easy to do and many other designs can be made easily. Reducing cost, material and time of the design is the most important aspect. Reducing cost, material and time of the mechanical design using virtual reality is a sustainable product development in the mechanical design.

The combination of material and geometry are two very influencing factors to the performance of new design flexible shield. From the analysis using Finite Element Method technology, it is discovered that the displacement position of the minimum turning point in the force against displacement graph of the new design concept is bigger than the current design, which matches the requirement of the flexible shield.

Designing the mechanical product using ANSYS software can reduce material, cost and time of the product development. Finally, virtual reality using Finite Element Method is a sustainable technology for Sustainable Product Development in the flexible shield design because Finite Element Method technology using ANSYS software can perform the performance of the product during the design phase.

Keywords: Sustainable Product Development, Sustainable Technology, Flexible Shield.

1. INTRODUCTION

Sustainable technology is a part of the broader concept of sustainable product development (Weenen, 2002) and virtual reality means existing or resulting in essence or effect though not in actual fact, form, or name (Anggono, 2006). Understanding the mechanical design is very hard to do because it is very hard to visualize the mechanical design product and the performance of the mechanical product during design phase. To predict the performance of the mechanical product during design phase is possible to
do using Finite Element Method technology (ANSYS Software). Virtual reality technology using ANSYS software can perform the performance of the mechanical product during the design phase (Anggono, 2004).

Product Design is always interesting to most of the people. It is also becoming more and more popular now a days. Flexible shield design is a part of mechanical design. Designing a product such as a flexible shield as a part of a pump system that dispenses soap-products is a very interesting case because of its nonlinear geometry and nonlinear material behaviour problem. The problem is that the Flexible Shield does not return to its rest position completely by itself. The function of the flexible shield is to protect the soap pump from intruding water. The flexible shield has to return to its rest position completely by itself after 10 mm deformation as the technical requirement of the flexible shield. Investigation on performance of the current design flexible shield found that the current design of the flexible shield has not succeeded yet because there are no enough vertical reaction force in the upper part of the flexible shield after the deformation 9 mm to return to its rest position by itself (Anggono, 2004).

In the past, to try to achieve the desired result, the flexible shield have been made with the combination of several geometries and several materials and yet the success has not been gained. The geometry and material above were changed, based on experiment trial and error. The problem will be very big and very complicated if the experiment trial and error would be used, so the software program (ANSYS) will be used to help to solve the problem. The full scale tests are expensive and require a lot of time. Finally, reducing cost and time of the design is the most important aspect.

2. REVIEW OF THEORITICAL BACKGROUND, MATERIALS AND RESEARCH METODOLOGY

2.1. Review of Non Linear Geometry Structural Analysis

The Finite Element Method (FEM), also called FEA (Finite Element Analysis), is actually an approximate mathematical method for solving problems which can be determined by differential equations. The main idea of FEM is to break a complicated problem with irregular edge conditions into small pieces (elements) of a finite size. Each piece is considered to be part of the main problem, thus connected to the other pieces via the global state information (i.e. deformation) of the element nodes, which are common nodes with the neighborhood elements. For the small element itself, the internal physical laws (i.e. Hooks law for elastic deformation problems) can be calculated. The global problem can be transformed into a matrix of simple element equations which are connected by the condition, that common nodes undergo the same change of global state. Forces which act on the edge of the global thing can be simplified as acting at discreet nodes. This all together gives a big system of mostly linear equations which can be easily solved by computer. The result is the change of global state for each node (i.e. the new node coordinates after the deforming of structures. Having this, further information for the small elements itself can be obtained, i.e. the element stresses in each direction (Budynas, 1999). The Newton-Raphson approach is a famous method to solve nonlinear problems. In
this approach, the load is subdivided into a series of load increments. The load increments can be applied over several load steps. Before each solution, the Newton-Raphson method evaluates the out-of-balance load vector, which is the difference between the restoring forces (the loads corresponding to the element stresses) and the applied loads. The program then performs a linear solution, using the out-of-balance loads, and checks for convergence. If convergence criteria are not satisfied, the out-of-balance load vector is re-evaluated, the stiffness matrix is updated, and a new solution is obtained. This iterative procedure continues until the problem converges. In non-linear problems, we have to consider that the change of geometry and material property during the load application, it has to be solved in more than one step, mostly iterative, using the results of the last run as start value for the next run, until certain exit conditions are fulfilled. Such problems include large deformation.

2.2. Materials

There are too many combinations of experiments in respect of the types of materials to be tested; the experiment’s range should be narrowed. After studying the material properties, it was decided to perform the experiments using 3 materials that are Evoprene 931, Desmopan 385 and Exact 0210. The material properties of the flexible shield can be described from the stress against strain graph (Budinski, 2002).

2.3. Element Type

To be familiar with some element types and potential element types to fulfil the needs in this problem that can be used in Ansys are needed before using the Ansys program to solve the problem. The possible element types that can be used to solve the problem are SHELL51 Axisymmetric Structural Shell, SHELL43 Plastic Large Strain Shell, SHELL93 8-Node Structural Shell, SOLID95 3-D 20-Node Structural Solid (ANSYS Inc., 2002).

The simulation is very important to solve the problem. After knowing the possibilities using element type and the material behaviour from the explanation above, we perform a simulation in Ansys using SOLID95 element type because of the irregular shape and thickness change of the designed flexible shield.

2.4. Milestones Flow Chart For The Research

![Milestones Flow Chart For The Research](image)

Figure 3. Milestones Flow Chart For The Research

3. RESULTS AND DISCUSSION

3.1. Material Selection

Basically, a lot of types of material can be used for this flexible shield product. The consideration to choose the best material for the flexible shield depends on a lot of requirements, beside material property, price and produce ability must also be considered.
Table 1. Material Properties for Evoperne 931, Desmopan 385 and Exact 0210

<table>
<thead>
<tr>
<th>Material</th>
<th>E (at 30%)</th>
<th>Tensile strength</th>
<th>Price/Unit Volume</th>
<th>$\sigma^2/E$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evoperne 931 (Alpha Cary)</td>
<td>6.45 MPa</td>
<td>10.3 MPa</td>
<td>Euro 5.07</td>
<td>16.42</td>
</tr>
<tr>
<td>Desmopan 385 (Evozyn)</td>
<td>14.7 MPa</td>
<td>40 MPa</td>
<td>Euro 4.97</td>
<td>108.24</td>
</tr>
<tr>
<td>Exact 0210 (Des Plastics)</td>
<td>75 MPa</td>
<td>21 MPa</td>
<td>Euro 4.33</td>
<td>5.88</td>
</tr>
</tbody>
</table>

Table 2. Material Comparison Table And Selection

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Evoperne 931</th>
<th>Desmopan 385</th>
<th>Exact 0210</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pricing</td>
<td>3</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>$\sigma^2/E$</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Produce ability</td>
<td>4</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Total weighing value</td>
<td>33</td>
<td>35</td>
<td>26</td>
</tr>
</tbody>
</table>

Desmopan 385 is the best material regarding the material property. It can be concluded from the Merith parameter ($\sigma^2/E$) is the biggest value compare with the other material. Regarding price per unit volume (economical side), Exact 0210 is the lowest price. From the three materials above, the best material has to be selected by applying the quality function deployment method (QFD). In this method each material is valued in several criteria, which are price, material property, and produce ability. Each criteria is also valued based on its importance rank, which is named weighing value. The individual values and weighing factor range from 0 (very bad) to 5 (very good), with 0 for very bad material, and 5 for very good material. Then the value for each criterion is multiplied by its weighing factor to obtain its weighing value. Eventually, the material that will be chosen is the material with the highest total weighing value among other materials. The total weighing value for Desmopan 385 is the highest value, finally Desmopan 385 have been chosen as the material for the flexible shield.

3.2 Implementing The New Design of Flexible Shield Using Sustainable Technology For Sustainable Product Development In Mechanical Design

After defining the elements of the Product Design Specification (PDS) or requirements for The Flexible Shield, then the concept generation process starts. PDS is used as a guideline to generate the concepts (Pugh, 1996). As many concept as possible is needed to be generated for the design of the flexible shield, because single concepts are usually a disaster. During the concept generation, a lot of sketches were made as the visualization of the ideas for each concept that came out. Beside the sketches, another way to visualize the concepts is by simulation modeling using software. As the result, the models for the new design are made based on quality function deployment method.

![Figure 4. The New Design Flexible Shield](image-url)

The simulation is very important to solve the problem. The simulation is performed using half model of the product because the new flexible shield is a symmetry product as well and the symmetry feature in Ansys software can perform the symmetry product using half model. This problem must be performed by nonlinear geometry analysis and non linear material behavior analysis. Boundary condition at the lower part area of the new flexible shield is the displacement in any direction equal to zero ($u_x$, $u_y$, and...
u, are equal to zero). Boundary condition on the upper part area of the flexible shield is zero displacement in x and z direction. While in y direction the displacement varies from 0 mm (no deformation situation) to 18 mm (full stroke displacement).

Figure 5. The Simulation Of The New Design Flexible Shield During Deformation (2mm until 18 mm).

Figure 5 illustrates the condition of the flexible shield during deformation. To obtain the force against deformation graph, all the nodal force on the upper part area are summed. All of the nodes are picked up at every deformation shape from 2 mm until 18 mm with 2 mm steps. The result can be seen as follow.

Figure 6. Nodal Force Against Displacement Of The New Design Flexible Shield

From Figure 6, it can be seen where the critical displacement, which is the minimum turning point. In that situation, the flexible shield will not return to the rest position. In the critical displacement, the vertical reaction force on the upper part of the flexible shield is not sufficient to return the flexible shield to its rest position. From the above graph, it can be seen that the position of the minimum turning point of the new concept is has moved to 13 mm, which is bigger than minimum turning point of the current design.

4. CONCLUSION

The full scale tests (real experiment test) are expensive and require a lot of time, material and money. The full scale tests is not the Sustainable Product Development way of Flexible Shield design. Using Finite Element Method Technology changing material and shape are very easy to do and many other designs can be made easily. Reducing cost, material and time of the design is the most important aspect. Reducing cost, material and time of the mechanical design using virtual reality is a sustainable product development in the mechanical design.

The combination of material and geometry are two very influencing factors to the performance of new design flexible shield. The Quality Function Deployment method is a very important tool to choose the best material and geometry for the new flexible shield. From the analysis using Finite Element Method technology, it is discovered that the displacement position of the minimum turning point in the force against displacement graph of the new design concept is bigger (the minimum turning point position at 13 mm displacement) than the current design (the minimum turning point position at 9 mm displacement), which matches the requirement of the flexible shield (10 mm displacement).
Designing the mechanical product using ANSYS software can reduce material, cost and time of the product development. Finally, virtual reality using Finite Element Method is a sustainable technology for Sustainable Product Development in the flexible shield design because Finite Element Method technology using ANSYS software can perform the performance of the product during the design phase.

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