Design and Development of Spring Loaded Chair Using FEA

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Abstract – The present work covers the generation of concepts and design based on customer requirement. The product design engages few methods such as Quality Function Deployment (QFD), Morphological Analysis, Functional Decomposition, Go, No-Go technique, etc. We have studied and implemented QFD and as it is a very crucial technique in identifying the customer requirements, upon which our project work is based.

Keywords: Product Design; QFD; Technique; Morphological; Customer requirements

1. INTRODUCTION

In an environment of increasing globalization, the needs of the population are on a constant rise. This pushes developers to improve their designs constantly in command to uphold their market position. Aside from product quality, price and lead-time are key factors disturbing the acceptability of a product [1]. Many companies identified for their creativity and innovation in product design (PD) fails to get the novel products into the markets [2]. Effort associated with converting information into finished products can be because of poor manufacturing practices and poor design. Design decisions influence sales strategies, efficiency of manufacturing, production cost, speed of maintenance etc [3]. Absolute reorganization of decision-making progression and the participants in the decision process is essential for improvement in the design process. The over the wall concept of design i.e. series of walls between various functional areas must be broken down and replaced with new co-operative interaction amongst the people from various functional areas [4].

The improvement of the design process can be achieved through [5]:

- Multifunctional Design Teams:
- Marking Design Decisions Concurrently Instead of Sequential Decisions:
- Design for Manufacturing and Assembly (DFMA):
- Design Review:
- Design for Environment:
- Quality Function Deployment (QFD):

The chairs existing in today’s markets have received certain negative customer responses regarding various characteristics of the chair. The purpose of the thesis is to identify the problems with a certain product, in this case, a chair and to study the techniques of product design as to address the problem and provide a solution to it, which may make happy the customer base [6]. Through this hypothesis, we intend to identify the customer grievances connected to the chairs used in the college, and offer a solution, which could eliminate the complaint of the customer. An attempted carried out to eliminate the grievances of the faculty by providing them with a spring-loaded chair [7].

2. METHODOLOGY

2.1 QFD Formulae

- Customer Requirements =x₁, x₂, x₃, x₄, x₅, x₆, x₇
- Engineering Requirements = y₁, y₂, y₃, y₄, y₅, y₆, y₇
- Customer Importance = (From Survey)
- % Customer Importance = \( \frac{y}{x} \times 100 \)
- Engineering Importance = \( \frac{\sum x \cdot y}{\sum x} \times 100 = EI \)
- Rank = [EI max , EI min]

2.2 Design Formulae

The formulas for the calculation of the stiffness of the designed spring are shown below:

\[ k = \frac{P}{\delta} = \frac{Gd^4}{8Nd^3} \]

- Where,
  - K = stiffness of the spring
  - G = modulus of rigidity = 78e3 N/mm²
  - D = diameter of material = 5mm
  - Nₐ = number of active windings = 10
  - D = coil mean diameter = ((35+25)/2) = 30 mm
  - Thus, k = (78* 10³+5³)/(8*10*30³) = 22.569 N/mm

We have been witnessing a constant rise in the competition to produce better goods on a daily basis with the increase in the demand for increased comfort levels. Under such situations, the people have started
to disown the old products and move towards smarter and more appealing products. With the advancement in science and technology, there has been an increased emphasis on the seating posture and hence to design a chair that meets the increasing comfort levels becomes a necessity. To achieve the required customer needs, we must first identify the grievances of the customers and hence a structured approach must be adopted. This can be done using techniques such as Quality Function Deployment (Fig. 1) [8].

![Flow chart of Quality Function](Fig. 1 Flow chart of Quality Function)

### 3. RESULTS AND DISCUSSION

To generate concepts and design for our chair, we have conducted a customer survey regarding the existing chairs among the faculty and the response we received is Table 1:

**Table 1 Customer Survey**

<table>
<thead>
<tr>
<th>Customer Requirements</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comfortable</td>
<td>3</td>
</tr>
<tr>
<td>Reliable</td>
<td>3.5</td>
</tr>
<tr>
<td>Cheap</td>
<td>4.5</td>
</tr>
<tr>
<td>Safe</td>
<td>4</td>
</tr>
<tr>
<td>Weight</td>
<td>3</td>
</tr>
<tr>
<td>easy to operate</td>
<td>4.5</td>
</tr>
<tr>
<td>Aesthetically pleasing</td>
<td>3</td>
</tr>
<tr>
<td>Total out of 35</td>
<td>25.5</td>
</tr>
</tbody>
</table>

A further survey regarding the optimum requirements was conducted among the faculty and the response is as Table 2:

**Table 2 Importance of Customer Survey**

<table>
<thead>
<tr>
<th>Customer Requirement</th>
<th>Importance (x/5)</th>
<th>% of Customer Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comfortable</td>
<td>4.9</td>
<td>16.72354949</td>
</tr>
<tr>
<td>Reliable</td>
<td>4.5</td>
<td>15.35836177</td>
</tr>
<tr>
<td>Cheap</td>
<td>4.1</td>
<td>13.99317406</td>
</tr>
<tr>
<td>Safe</td>
<td>4.7</td>
<td>16.04095563</td>
</tr>
<tr>
<td>Weight</td>
<td>3.6</td>
<td>12.28668942</td>
</tr>
<tr>
<td>easy to operate</td>
<td>3.7</td>
<td>12.62798635</td>
</tr>
<tr>
<td>Aesthetically pleasing</td>
<td>3.8</td>
<td>12.96928328</td>
</tr>
<tr>
<td>Total out of 35</td>
<td>29.3</td>
<td>100</td>
</tr>
</tbody>
</table>

The above values indicate the average ratings of 50 customers among the population surveyed. Once we had gathered the survey from the customers, we identified that the most important characteristic, which the people need is comfort. We then used this information in the house of quality, which is a part of the Quality Function Deployment.

Under the QFD technique, we used the house of quality to determine the following:

1. Inter-relationship between the engineering characteristics
2. Relationship between engineering characteristics and customer requirements
3. Establishing the priority between customer requirement and engineering characteristics.

To carry out an efficient and easy procedure for design, we have derived the Interrelationship between various Engineering characteristics. This has been done by adopting the house of quality approach. In this approach (Table 3), we have plotted one engineering characteristic against other engineering characteristics required for the production of the chair. This has been done in order to identify what effect one engineering characteristic has on the other engineering characteristics is shown in Fig. 2 and 3.

**Table 3 Arranging in the level of Importance**

<table>
<thead>
<tr>
<th>Rank of Importance</th>
<th>Engineering Requirement</th>
<th>Importance in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Material quality</td>
<td>23</td>
</tr>
<tr>
<td>2</td>
<td>Expected Life</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>Shape</td>
<td>14</td>
</tr>
<tr>
<td>4</td>
<td>Cost of production</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>Strength</td>
<td>11</td>
</tr>
<tr>
<td>6</td>
<td>Manufacturing time</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>Weight</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>dimensions</td>
<td>7</td>
</tr>
</tbody>
</table>
3.1 Solid modelling of the spring loaded Chair

![Design of Chair in Solidworks](image)

![Spring designed for the assembly](image)

3.2 Stiffness calculation for the designed spring

In order to perform the static analysis of the assembly to plot deflections and stresses, the stiffness of the spring has to be calculated. The model of the spring designed is shown in below Fig. 4. The formulas for the calculation of the stiffness of the designed spring are shown below:

\[
K = \frac{P}{\delta} = \frac{Gd^4}{32Nd^3},
\]

where,

- \( K \) = stiffness of the spring
- \( G \) = modulus of rigidity = 78e3 N/mm²
- \( D \) = diameter of material = 5mm
- \( N_a \) = number of active windings = 10
- \( D \) = coil mean diameter = ((35+25)/2) = 30 mm

Thus, \( k = \frac{(78*10^3*5^4)}{(8*10*30^3)} = 22.569 \) N/mm

The material of the assembly and spring is steel with the following properties:

- Young’s modulus: 200GPa
- Rigidity modulus: 0.078MPa
- Poisson ratio: 0.3
- Density: 7850 Kg/m³

3.3 Static analysis of assembly with 150 kgs

Static analysis is performed to find the deflections and the stresses due to a load of 150 Kgs. The boundary conditions applied for the static analysis of the assembly are shown from Fig. 5 to Fig. 19.
Fig. 8 Deflections in y direction
Fig. 9 Total deflections
Fig. 10 Stress in x direction
Fig. 11 Stress in y direction
Fig. 12 Stress in z direction
Fig. 13 1st principal stress
Fig. 14 2nd principal stress
Fig. 15 Von Mises stress
Fig. 16 Total deflections
Fig. 17 1st principal stress
4. CONCLUSION

For application of QFD on the problem, the customer requirements were plotted against the engineering requirements in the Interrelation Matrix. The design was made with respect to the obtained rank of engineering requirement. A static Analysis was done on the spring assembly and the stiffness of the designed spring is found to calculate the deflections and the stress in the assembly for the different loads i.e., 90 kgs, 120 kgs and 150 kgs. From the above discussions, if we consider the deflections and stress for maximum load of 150 kgs, the deflection obtained is 0.251 mm which is negligible and the Von-Mises stress developed is 200.3 MPa which is in the permissible limit. Thus it is said that the design is safe for the maxim load.

REFERENCES