DESIGN, DEVELOPMENT AND TESTING OF A MULTIFUNCTIONAL JAR AND BOTTLE OPENER

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Abstract. Many fields in Engineering Technology today are focused on encouraging and motivating students to implement their educational concepts in the real world to fight with the increasing demands of new technology in the global market. This paper explores how a project interwoven through the Engineering Technology curriculum can be used to create a product to be sold in today’s market to do basic household jobs and make them easier. The main focus of the bottle opener product existing in the market is that they are used on specific type of bottles and if to be used for different needs different product and will reduce the feasibility and portability as a greater number of products will be used to carry out these operations. Therefore, to eliminate this problem the objective of the project is to develop a multifunction bottle opener which can be used to deal with all the types of bottles available in the market. This product will work on the basic principles of mechanism like rack and pinion mechanism, cork plug and stress bending. Many researchers compared the shapes and mechanism in their work. Though there are similar work, but in the present work casts a unique design and has a functionality difference which makes this project exclusive from other projects. The optimized form of a common product that is a multi-functional bottle and jar opener is obtained from this project which can be used to open different styles of cap of different bottles. Keywords. multi-functional, rack and pinion, stress bending,

1. INTRODUCTION
The product is a solution to the needs of the customer. Anything that can satisfy a customer’s requirement and complete the demand in the market is called a successful product. A typical product development has various phases. The first phase is understanding the opportunity which deals with the identification of customer needs which define the problem to be addressed various tools like customer survey interviews and interviews are used to understand the customer needs. The next stage requires to develop different rough concept (schematic diagram) based on the requirement of the customer known as the concept development process. A concept is then selected out of the of those designed earlier which has the best characteristics and which has the most optimal features required by the customer. Various process like Pugh matrix, panel selection etc. can be used to select the best concept by rating the criteria’s selected for the product and scoring them on the basis of their performance. TRIZ Matrix is applied to the product to provide them with the solutions to the process problems that they face. The features of the product can be improved which are required and some features can be downgraded which doesn’t contribute much to the product’s performance. The final stage implementing a thought deals with the embodiment designing, design for x etc. It is the phase where the material selection, dimensions & tolerances for the product is finalized. In this research study, the general product development process has been kept in mind while designing of the product according to the market needs. A multi-functional jar and bottle opener has been designed based on the process of new product development.
2. PROBLEM DESCRIPTION

The need for a multifunctional jar and bottle opener arises from the market and customer analysis which reveals that the normal bottle openers that are available in market doesn’t serve the purpose of multi-functionality i.e. they don’t have the ability to open the jars. This leads to the commuter to heavily rely on different classes of bottle openers or the usage of hand which can cause injury while opening bottles with hard fixed caps. Hence it is understood that the multifunctional jar and bottle opener is an alternative to the conventional bottle opener existing in the market. From the field survey it has been found that even though there are multifunctional bottle openers in the market, they are found to be less feasible as they don’t serve the purpose of opening jars, even though they are multi-functional. The multi-functional configuration is also found to be not simple which leads to difficulty in manufacturing it. This leads to the requirement of designing and developing a new jar and bottle opener made out of material with high strength that can be operated easily and also very portable. Therefore, the main focus of the bottle opener product existing in the market is that they are used on specific type of bottles and if to be used for different needs, different product and will reduce the feasibility and portability as a greater number of products will be used to carry out these operations. Therefore, to eliminate this problem the objective of the project is to develop a multifunction bottle opener which can be used to deal with all the types of bottles available in the market.

3. FUNCTIONAL MODELLING

The purposeful modelling is nothing however establishing purposeful structure of the merchandise of interest. Solution principles or designs based on conventional methods do not provide required design when latest technologies and inventions are to be used. The solution of the problem should be expressed as a list of the required functions and essential constraints. The created purposeful tree has been developed supported the necessity statement. The need statement has been obtained by the small field survey and literature survey. Fig. 2 and 3 show a simple black box diagram and functional tree of a multifunctional jar and bottle opener respectively. The functional tree has been generated based on the conceptual analysis of the product requirement. The need statement has been obtained by the small field survey and literature survey.
4. CONCEPTUAL DESIGN

Conceptual design is one of the important stages of a product design. After functional modelling, various concepts will be removed based on the various concept generation methods like Pugh matrix, conceptual brainstorming etc.

4.1 CONCEPT GENERATION

Concept generation or getting the ideas, is the most critical step in the engineering design process. Starting with a group of client desires and target specifications, the process concludes with an array of product alternatives from which a final design is selected. There are multiple steps concerned within the generic thought generation method, as well as various approaches. This research paper reviews associated critiques these totally different views among the context of with success developing an electronic medical product that's innovative in style and client attractiveness. The concept generation process required the following steps

- Understanding the problem and the customer needs
- Searching externally through the internet and the markets to find out whether a product like this exists or not
- Searching internally by generating ideas which can be used to compensate the needs of the customer.
- Reflecting the results by getting the feedback of people and making changes in the concept design according the survey reviews.
Figure 4. Flowchart showing the concept generation process

Based on the above-mentioned steps, various concepts have been generated as shown in the Fig.5-7

4.2 CONCEPT EVALUATION AND SELECTION

Concept Generation may provide a lot of concepts to the designer that are related to the problem statement, but not all of them are feasible and can be achieved effectively. In this process the designer tries to limit the concepts generated earlier according to the criteria that are relevant for the production of our concept such as Manufacturing Cost, Weight of the product, Ease of Operation etc. In a typical development process, once the various product ideas are generated, the generated ideas need to be evaluated to pick the most effective conception among the varied-out ideas. Pugh matrix is one of the most effective and appropriate method to select the most feasible concept out of other ideas. The first step in the concept evaluation process is to select a list of criteria which have to be kept in mind while designing of the product and these much be beneficiary for the customers. These criteria mainly depend on the type of product and therefore can be unique for each product.
4.2.1 PUGH MATRIX

The table 1 shows Pugh chart that has been developed for a Multifunctional Jar and Bottle opener product. The criteria chosen for this is based on Multifunctional characteristics of the product (i.e. variety of the products it can be used upon), Portability of the product, Ease of Operation, Manufacturing cost, Safety to the customer and strength of the Product. All these criteria are provided some weightage according to the requirement of the customer as each of them cannot be considered to be equally required in the product. Giving weightage to each criteria can provide extra layer to distinguish among the concepts. It can also provide a form of “robustness” assessment. The weightage of each criteria depends on the customisation of the product and hence varies for each product uniquely. All these concepts are evaluated taking the product which is existing in the market as the baseline or the datum value. The concepts are evaluated for each of the above-mentioned criteria. The scoring and weightage are as shown in Table1.

Table 1. Pugh Matrix

| Criteria          | Weightage | Concept 1 | Concept 2 | Concept 3 |
|-------------------|-----------|-----------|-----------|-----------|
|                   | Score     | Total     | Score     | Total     | Score     | Total     |
| Multifunctionalis | 30.00     | 2         | 0.6       | -1        | -         | 0         |
| Portabi           | 10.00     | 0         | 0         | 2         | 0.2       | 2         |
| Ease Of           | 15.00     | 1         | 0.15      | 1         | 0.15      | 1         |
| Manufacturing     | 10.00     | 0         | 0         | 0         | 0         | 1         |
| Safety to the     | 20.00     | 1         | 0.2       | 1         | 0.2       | 1         |
| Strength          | 15.00     | 2         | 0.3       | 1         | 0.15      | 0         |
| Sum of all        | 1.25      | 0.7       | 0.65      |           |           |           |
| Total Score       | 1.25      | 0.4       | 0.65      |           |           |           |
| Continue?         | Yes       | N         | N         |           |           |           |

The net score is obtained for each design concept based on the weightage and the scoring of each criteria. The concept that has the highest score as compared to other concepts is selected as the best concept by the process of Pugh Matrix Methodology.

5. TRIZ MATRIX

Triz Matrix is a procedure to formalize the process of innovating a product. The TRIZ matrix is applied to get different solutions. The TRIZ is a systematic way to think about issues and get a hint about the most plausible solutions. These solutions are highly plausible because many of these solutions have been successfully implemented in the past and are therefore tried and tested with time. With the assistance of the TRIZ Matrix, one will initial develop multiple solutions. This will help with the rational process of evaluating all the possible solutions and then coming up with the most feasible one. The TRIZ method believes that all technological innovations that have occurred in different industries have been based on a set of “inventive principles”. TRIZ method states that every specific problem that an organization faces can be reduced to a general problem that has been faced before. This general problem then has a general solution based on one of the 40 inventive principles that the matrix contains. Thus, the use of the matrix suggests the general solution. This general solution can then be used to come up with a solution to the problem that the organization is facing.
Table 2. Triz Matrix

| Improving Features | Worsening Features | Shap   | Ease of Repair | Duration of action of the |
|--------------------|--------------------|--------|----------------|--------------------------|
| Weight of the stationary object | 13, 10, 29, 14 | 2, 27, 28, 11 | - |
| Volume of the stationary object | 7, 2, 35 | 1 | - |
| Strength | 10, 30, 35, 40 | 27, 11, 3 | 27, 3, 26 |
| Ease of operation | 15, 34, 29, 28 | 12, 26, 1, 32 | 29, 3, 8, 25 |

Table 3. Inference Matrix

| Improving Features | Worsening Features | Triz Principles |
|--------------------|--------------------|-----------------|
| Weight of the stationary object | Shape | Preliminary Action |
| Volume of the stationary object | Shape | Pre arrange objects such that they come into action from the most convenient place. |
| Strength | Ease of repair | Segmentation |
| Ease of operation | Duration of action of the moving object | Local Quality |

From the results of the inference matrix we can find out the solutions for the product to make it even better as per the demands of the customer.

6. EMBODIMENT DESIGN

Embodiment design is one of the most important part in the process of the modern product development. In this process the main product design is been made with all the specific dimensions and economic criteria as per the requirement of the product to the stage where the detailed design can be sent directly for production purpose. There are various stages carried out as a part of the Embodiment Design. CAD model, Ultimaker modeling and FEA analysis have been carried out for our product.

6.1 FEA ANALYSIS

FEA is used to evaluate the different types of fatigue failure of the proposed in the product design. The location points of the failure and the intensity of different stresses and displacements can be found out through this analysis. The slider of the product is modelled and simulated in the Solidoworks environment. The product is made in a meshed model to make it possible to do the mesh analysis on the product. For the failure analysis of the product the shape of the rim of the bottle opener is kept to be constant as it should not deform under any condition of the loading conditions and the force of 100N and 200N is applied normal to the face of the slider as the average force exerted on the slider by the palm of an average person for opening a bottle. The material selected to manufacture the slider was AISI 316 Annealed Stainless-Steel Bar. Two types of failure test have been conducted on the product i.e. failure under static loading and Fatigue simulation.
6.1.1 STATIC LOADING SIMULATION

The load has been taken as 100N and 200N normal to the face of the slider and the results obtained have been shown in the Fig 8-13 and Table 4.

**Figure 8.** Von Mises Stress under static load 100N  **Figure 9.** Von Mises stress under static load of 200N

**Figure 10.** Displacement under static load of 100N  **Figure 11.** Displacement under static load of 200N

**Figure 12.** Factor of Safety under static load of 100N  **Figure 13.** Factor of safety static load of 200N
Table 4. FEA Solution under Static Loading

| Load  | Type of Load          | Von-Mises Stress | Total Deflection | Yield Strength | Factor of |
|-------|-----------------------|------------------|------------------|----------------|-----------|
| 100 N | Normal to the plane   | 37.15            | 0.156            | 137            | 3.71      |
| 200 N | Normal to the plane   | 74.15            | 0.31             | 137            | 1.86      |

As the proposed design satisfies the criteria for safety, the product is considered safe to use under normal loading conditions.

6.1.2 STATIC LOADING SIMULATION
The cycle frequency has been taken as 20,000 cycles as an average lifetime use of the product. The product is been analysed under the same loading conditions as done previously. The results obtained from the test has been shown in the Fig and table 5.

![Figure 14. Damage Percentage in Fatigue Simulation under a load of 100N](image1)

![Figure 15. Damage Percentage in Fatigue Simulation under a load of 200N](image2)
As the proposed design satisfies the criteria for safety, the product is considered safe to use under normal loading conditions.

7. CAD MODEL
This is the stage where the concept generated after all the tests gets converted into actual 3D object with all the appropriate dimensions and tolerances. It contains various parts like handle, slider, nut and screw, rack with gripper and piercing tool. The product has been joined in such a manner that it achieves the maximum feasibility in all the requirements of the product.
Fig 22 shows the disassembled view of the multifunctional jar and bottle opener. This view shows the multifunctional character of the proposed design, which aids in the ease for operation and portability of the product. Fig 23 shows assembled view of the product which aids to the final representation of the product when ready to use.

8. ULTIMAKER CURA SIMULATION

The recent trends in manufacturing is single component manufacturing by avoiding the joints and fixations leading to better material properties, also by decreasing the chances for failures and defects to take place and serves the function better than ever before. This can be achieved by only known technology “Additive Manufacturing”. In additive manufacturing initially, the part is sliced into different layers with lesser the layer thickness for better the surface finish. Then, other constrains shell thickness or wall thickness is specified for higher the value better the surface strength. Then, the fill density of the part model to be manufactured is specified to give the optimal internal strength. These constrains are inputted to the slicing software CURA where it generates the g-codes and m-codes for the part and constrains given designing the tool path to be followed and the amount of material to be used. This data is then forwarded to the machine which is driven by the code to manufacture the component developing layer by layer.

9. CONCLUSION

In this study, a novel multifunctional jar and bottle design has been developed. The proposed design has good portability and multifunctional characteristics when it is compared with the existing bottle openers available in the market. The design has been evaluated with existing designs using Pugh chart methods and has been made better with the help of solutions using TRIZ Matrix. The CAD model of the product was made based on the previous results and the CURA simulation of the product was processed. The FEA analysis has been carried out for the product to check the strength and possible failures of the product under dynamic loading conditions.
10. FUTURE WORK

The Current study, deals with a conceptual and embodiment design of a multifunctional jar and bottle opener. The downstream activities within the development method like cost of the material used for the manufacturing of the product, proof of conception needs to be developed.

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