Design, Analysis, Control and Manufacturing of a Head Massaging Machine

1Aman Chaure, 2Rajkumar.E

1Under Graduate student, SMEC, VIT, Vellore, India,
amanchaure@gmail.com,
2Associate professor, Department of Design and Automation, SMEC, VIT,
Vellore, India
rajkumar.e@vit.ac.in

Abstract. Nowadays, a lot of people are suffering from unexpected Headaches at odd hours of the day due to their hectic schedule and busy lifestyle. Many devices for massage therapy have already been introduced in the market for the same but none of them are actually worth the price as they fail to deliver the quick necessary relief. For overcoming this problem, we have come up with a new design for head massaging which mainly works on the ideal concept of massage therapy by pressing the optimum pressure points located at the extremes of the forehead. The novelty of this paper lies in the mechanism involved that will help us to achieve the desired output. We will be presenting the complete design, control and manufacturing for the product by a series of simulations which will includes Linear Static Stress analysis for evaluating the strength of the design which can produce the right amount of force, Vibrational/Modal Frequency response for analysing the stability while functioning, Fatigue Test for evaluating the maximum stress the design can bear for a good life and finally comes the Thermal Analysis for evaluating the heat dissipation from the electronics. The Computer Aided Design will be developed on SOLIDWORKS Software and the Finite Element Simulations will be conducted on ANSYS for optimization. Some post simulations will also be conducted such as drop test for evaluating the chances of sudden failure under the circumstances of impact loading. At last there will be a complete manufacturing planning for the entire design along with its DFMA planning.

Keywords. Optimization, Computer Aided Design, Finite Element Simulations

I. Introduction

Massage therapy the most important part of physiotherapy), is one of the most useful way of relieving ourselves from mental stress. For this a head massaging machining has been designed with actuators in the most promising location for the quick relief operation. A rocker arm mechanism has been modified and designed to serve the purpose. The push rod of the rocker arm along with the cam shaft is replaced with the Linear actuators for serving the same purpose. The effective output of work maintained by the designed control system for optimum functionality.

The point at which the proposed designed machine focuses over.

Figure 1. The point of Action of Force for massage
2. Literature Review

Juvenile Rheumatoid Arthritis: Benefits from Massage Therapy [1], this paper focuses on the effect of head massaging over the children for decrease in the stress levels and the anxiety, Head massage machine, a currently existing Patent in the same field [2]. Hand type electric massage machine, another consisting patent [3], The short-term effects of myofascial trigger point massage therapy on cardiac autonomic tone in healthy subjects [4], this paper contains the study of point massage therapy for stress relieving effects over the body, The effect of massage in patients with chronic tension headache [5].

3. Problem description

A lot of designs are currently existing under the head massaging division or category. But our design mainly focuses over the two points each on either side of the forehead serving only a single action but having the greatest effect of its little functionality. The main problem is that all the currently existing designs are focusing over multiple points of the head and fore head but are not capable of providing quick relief by the same. For this problem I have come up with a very simple solution by focusing all the energy of a small device over the most promising location of the head.

4. Methodology

The methodology for our design is quite simplistic. We have started with rough design for the same product and then by analysing the same with Triz contradiction matrix followed by a 2nd design. Then Simulating the same with Static Analysis in SOLIDWORKS Software for analysing its functionality. The detailed study is giving in the steps followed here.

Step 1: 1st conceptual Design, containing the details just about the basic idea.
Step 2: Triz Contradiction Matrix with results, for improving the design on the basis of Triz concepts.
Step 3: 2nd iterative design with the changes proposed by the Triz matrix, giving us the improves design.
Step 4: Analysing the same design for its functionality in SOLIDWORKS Simulation package.

Step 5: The manufacturing planning for the same using FLASHPRINT Software for printing the structure in a single go.
Step 6: The Control Planning for the same with Arduino UNO and a Linear Motor.

| S No. | Improving Factors/Worsening Factors: | 20 | 21 | 24 | 27 | 40 | 41 |
|-------|-------------------------------------|----|----|----|----|----|----|
|       | weight of Moving Object             | 28, 31, 40, 35 | 35, 1, 30, 39 | 1, 2, 28, 3 | 19, 6, 3, 10 | 5, 24, 27, 21 | 1, 5, 36, 25 |
|       | weight of stationary Object         | 35, 31, 8, 40 | 15, 5, 17, 30 | 35, 31, 7, 3 | 28, 35, 7, 31, 17, 31, 3 | 25, 35, 3, 7 | 35, 8, 9, 1 |
|       | Duration of Action of Moving Object | 35, 3, 17, 14 | 35, 24, 40, 13 | 13, 1, 19, 12 | 23 | 21, 28, 15, 24 | 35, 4, 10, 3 |
Outcomes of the Triz Matrix:

- **Principle 3. Local quality**
  - A. Change an object's structure from uniform to non-uniform, change an external environment
  - B. Make each part of an object function in conditions most suitable for its operation.
  - C. Make each part of an object fulfill a different and useful function.

- **Principle 5. Merging**
  - A. Bring closer together (or merge) identical or similar objects, assemble identical or similar parts to perform parallel operations.
  - B. Make operations contiguous or parallel; bring them together in time.

- **Principle 6. Universality**
  - A. Make a part or object perform multiple functions; eliminate the need for other parts.

**5. Modelling**
The isometric View for the Model is shown from both Front and Back Side in the figures 1 to 2. Then comes the orthographic views from figure 3 to figure 4. In these figures the dimensional views are presented along with all the dimensions in mm.

**Figure 2.** Isometric view of the Head Massaging Machine.
Figure 3. Isometric view of the Head Massaging Machine.

Figure 4. Orthographic view of the top head part.
6. Experimentation

The Finite Element Analysis was done to carry out the Static Simulation to Check the Stress and Deformation and The Strain over the Structure under the Reaction forces over the Structure itself. The Factor of Safety was also Calculated for the same for verifying the overall safety limits for the Functionality.

| Study name       | Static 1         |
|------------------|------------------|
| Analysis type    | Static           |
| Mesh type        | Solid Mesh       |
| Thermal Effect:  | On               |
| Thermal option   | Include temperature loads |
| Zero strain temperature | 298 Kelvin |
| Include fluid pressure effects from SOLIDWORKS Flow Simulation | Off |
| Solver type      | FFEPlus          |
| Inplane Effect:  | Off              |
| Soft Spring:     | Off              |
| Inertial Relief: | Off              |
| Incompatible bonding options | Automatic |
| Large displacement | Off              |
| Compute free body forces | On              |
| Friction         | Off              |
| Use Adaptive Method: | Off             |
7. Results and Discussions

Units

| Unit system: | SI (MKS) |
|-------------|----------|
| Length/Displacement | mm |
| Temperature | Kelvin |
| Angular velocity | Rad/sec |
| Pressure/Stress | N/m² |

Material Properties

| Model Reference | Property | Component |
|-----------------|----------|-----------|
| Name: Nylon 6/10 | Model type: Linear Elastic Isotropic | SolidBody 1(Boss-Extrude1)(13 mm pin-1), SolidBody 1(Boss-Extrude1)(13 mm pin-2), SolidBody 1(Boss-Extrude1)(28 mm pin-1), SolidBody 1(Boss-Extrude1)(28 mm pin-2), SolidBody 1(Scale1)(cylinder-1), SolidBody 1(Cut-Extrude7)(head sub part) |
| Default failure criterion: Max von Mises | Stress | |
| Yield strength: 1.39043e+08 N/m² | Tensile strength: 1.42559e+08 N/m² | |
| Elastic modulus: 8.3e+09 N/m² | Poisson's ratio: 0.28 | |
| Mass density: 1,400 kg/m³ | Shear modulus: 3.2e+09 N/m² | |

Figure 6: Model with Constraints

Resultant Forces

| Selection set | Units | Sum X | Sum Y | Sum Z | Resultant |
|---------------|-------|-------|-------|-------|-----------|
| Entire Model  | N     | 1.04606e-05 | -15.4034 | 3.45294 | 15.7856 |

Reaction Moments

| Selection set | Units | Sum X | Sum Y | Sum Z | Resultant |
|---------------|-------|-------|-------|-------|-----------|
| Entire Model  | N.m   | 0     | 0     | 0     | 0         |
| Name        | Type               | Min                      | Max                      |
|-------------|--------------------|--------------------------|--------------------------|
| Displacement1 | URES: Resultant Displacement | 0.000e+00 mm Node: 3046 | 6.210e-02 mm Node: 3114  |

**Figure 7.** Displacement Contour

| Name | Type       | Min     | Max     |
|------|------------|---------|---------|
| Strain1 | ESTRN: Equivalent Strain | 7.819e-11 Element: 9115 | 2.921e-04 Element: 2417 |

**Figure 8.** Strain Contour

| Name      | Type     |
|-----------|----------|
| Displacement1 {1} | Deformed shape |

**Figure 9.** Deformation
8. Manufacturing Simulation

The recent Trends in the market are the advancements in the additive manufacturing. With the ease of Manufacturing, additive manufacturing plays a very important role in the new Product Development. Thereby we will be using the 3D printing with Flash Forge Guider II printer for Additively Manufacturing the product with Nylon 6 material. The hinges and pins of Standard sizes can be used for assembly purpose if not preferred for printing.
Time required for Printing with Flash Forge Guider Printer is Calculated to be around 27 Hours and its analysis can be seen in the below photograph & The Preferred Configuration for Printing Parameters is given below:

Figure 12. 3d Printing Time Calculations for Flash Forge Guider 2 Printer.

Figure 13. Parameters for Printing Nylon 6/10 With Flash Forge Guider 2 printer.
9. Control System

The Control system has been designed to give pulse load to the rocker arms of the product giving it a too & fro motion along with some delay in the between two cycles. This Control System is powered by an Arduino UNO & Genuino UNO,

![Diagram of control system](image)

**Figure 15.** The image for the control system [8], from an open source document.

10. Prototype Development

The Prototype development will be done in future for this product after filing a design patent. The same manufacturing planning will be done for making a functional prototype for the same.
11. Conclusions

By this project, we can conclude that after this planning the machine is ready for the manufacturing and testing in the authorization of a Physician. After testing in the real time and by the affiliation of a doctor, the machine will be ready for production on a large scale.

References

[1] http://www.goodfellow.com/E/Polyamide-Nylon-6.html
[2] http://www.matweb.com/search/datasheet.aspx?MatGUID=8d78f3ef9b6f49d595896ce6ce6a2ef1&ckck=1
[3] http://www.regner.es/product/ra-47x-high-speed-linear-actuator-with-feedback/
[4] https://electronicsforu.com/electronics-projects/controlling-linear-actuator-arduino
[5] https://www.hackster.io/robotgeek-projects-team/control-a-large-linear-actuator-with-arduino-8a3953
[6] https://help.solidworks.com/2018/english/SolidWorks/cworks/t_Performing_Static_Analysis.htm