

DESIGN AND MAKING OF MECHANICAL IRIS GEAR USING 3D PRINTING

R. Syam Sudhakar Rao

Associate Professor

Department of Mechanical Engineering

Guru Nanak Institutions Technical Campus, Ibrahimpatnam, Telangana, India

Abstract: Rehabilitation therapy is the process to reduce the impairments and disabilities of upper or lower limb that are caused by accidents or stroke. This paper presents the design and development of a new hand rehabilitation device based on iris mechanism with basic Arduino coding to train the flexion and extension of the hand. The iris mechanism is designed using CATIA VR20. The steps to design the iris mechanism is shown in this paper, starting with the first layer (lower body), then the blade, second layer with gear, and third layer (for holding all layers together). The measurement of inside diameter is decided by considering the average size of object can hold by the patient for basic daily life. The inside diameter of the iris mechanism varies from 15 mm to 110 mm to enable the patients to adapt to various object sizes. The device can be used for the right-handed or left-handed person. The preliminary output shows that the designed mechanism is able to perform the opening and closing motion for the rehabilitation of hand function. The holding rod of the mechanism opens to the maximum 110 mm as the second layer with gear is rotated 77°.

Index terms - Rehabilitation, CATIA VR20, Arduino, Iris mechanism.

1. INTRODUCTION

Mechanical iris (Iris diaphragm) is a type of intricately designed mechanism. The center can gradually open and close. There are several ways to design and construct an iris mechanism. In this article, some design files are shared. With the help of a laser cutter, 3d printers, and some other tools, the files can be downloaded and built.

This paper is based on prediction of bounds on stiffness of the iris system and a methodology to make design decisions. Compliant iris has found use in gripping and holding the objects. It can be used as an end effectors gripper of a robotic arm. A closed form expression of stiffness is required to relate design the compliant iris. The novelty of the paper lies in providing a methodology to design based on formulating stiffness equations. Although, a closed form expression is not delivered but stiffness bounds are conveyed for a particular set of design parameters.

2. DESIGN AND IDEALOGY

For making a cardboard mechanical iris, the following materials with given specifications are used. Paper, Card or heavy weight paper, drinking straw, X-acto knife, Cardboard, Glue stick, Glue gun (or just make do with the glue stick), Small cross-head screwdriver, Large cross-head screwdriver, Rubber bands. And specifications are: Aperture ~5-50 mm, Outside diameter ~100 mm, number of blades ~8, Rotational movement ~80 degrees, Pin size ~6 mm, Blade thickness ~0.25 mm (0.01").

To create the iris design template, iris-calculator.com is used, which generates the plans to help. For making exact one, the following steps are followed. 1) Actuator Ring, 2) Base Lid, 3) Blades, 4) Slots, and 5) Wall.



Fig. 2.1 Making initial pilot holes



Fig. 2.2 Checking the pin holes



Fig. 2.3 Cutting the blade

The housing for the cardboard mechanical iris is created using 4 parts (2 of which are identical). Using few layers of cardboard are needed, depending on how thick it is. 1) Base and lid layers & cut out, 2) Slots template pasted onto cardboard & Slot layers, 3) Wall template glued on 2 layers of cardboard, 4) Taping the inside of the wall & Repeat cuts on both sides and 5) final assembly.



Fig. 2.4 Slots template pasted


Fig. 2.5
Taping the inside of the wall


Fig. 2.6 Blade stacking



Fig. 2.7 Installing the blades

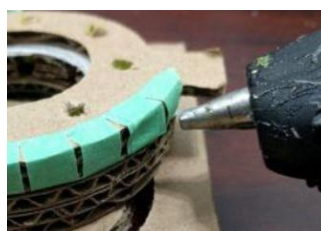


Fig. 2.8 Wall gluing



Fig. 2.9 Completed IRIS

3. GEOMETRIC MODELING PROCEDURE BY CATIA V5 R20

After selecting the sketch tool, by going to profile in the sketcher module and select pre-defined profiles and create a profile as show in fig. 3.1 then select existing workbench. After the sketch design, go to insert and select sketch-based tools. In sketch-based tools select shaft tool. After that a shaft tool definition will pop up on the screen. In shaft tool definition, select selections as sketch and specify first angle as 360° (Fig. 3.2).

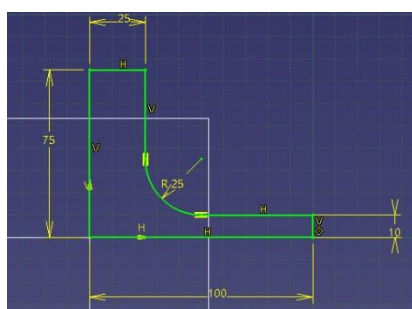


Fig. 3.1 Sketch tool

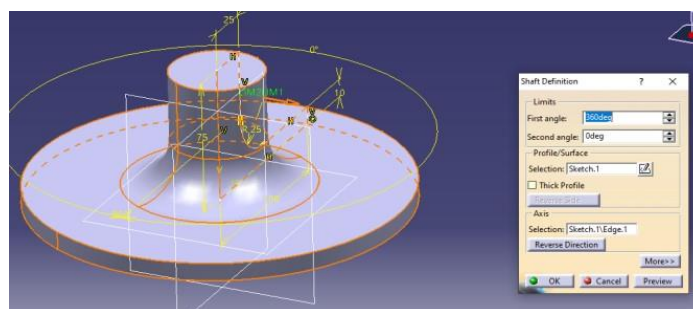


Fig. 3.2 Shaft tool

In part design goes to sketcher tool and select sketch, then select plane, then it will enter to sketcher module. In sketcher module, go to profile and select pre-defined profiles and create a profile as show in fig. 3.3 then select existing workbench. After the sketch design, go to insert and select sketch-based tools. In sketch-based tools select pad tool. After that a pad tool definition will pop up on the screen. In shaft tool definition, select selections as sketch and specify first length as 120.

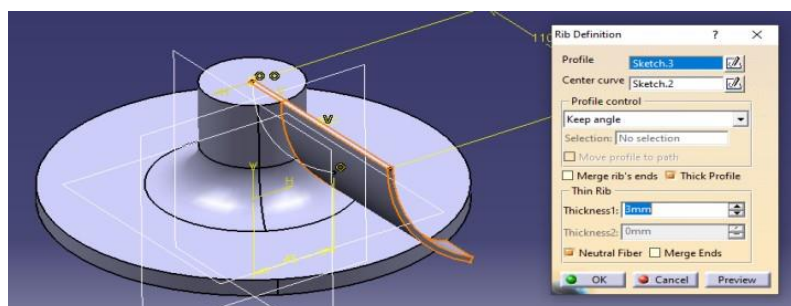


Fig. 3.3 Pad tool

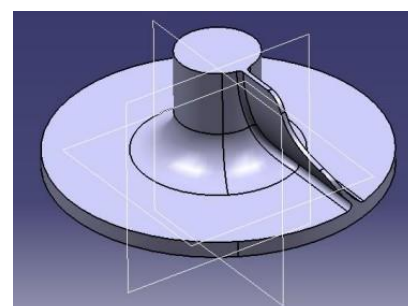


Fig. 3.4 Groove tool

In part design goes to sketcher tool and select sketch, then select plane, then it will enter to sketcher module. In sketcher module, go to profile and select pre-defined profiles and create a profile as show in fig. 3.4 then select existing workbench. After the sketch design, go to insert and select sketch-based tools. In sketch-based tools select groove tool. After that a groove tool definition will

pop up on the screen. In shaft tool definition, select selections as sketch and specify first angle as 360° . After the groove design, go to insert and select transformation-based tools. In transformation-based tools select circular pattern tool. After that a circular pattern tool definition will pop up on the screen. In circular pattern tool definition, specify first instances as 18.

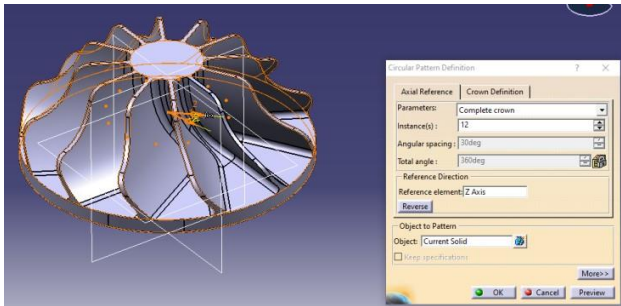


Fig. 3.5 Circular pattern tool

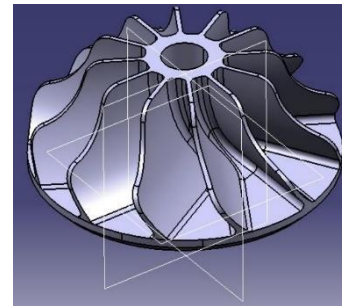


Fig. 3.6 Impeller

In part design goes to sketcher tool and select sketch, then select plane, then it will enter to sketcher module. In sketcher module, go to profile and select pre-defined profiles and create a profile as show in fig. 3.6 then select existing workbench. After the sketch design, go to insert and select sketch-based tools. In sketch-based tools select pocket tool. After that a pocket tool definition will pop up on the screen. In pocket tool definition, select selections as sketch and specify first angle as 360° .

4. 3D PRINTING

To generate 3d print, go to Creality slicer software. On the top we can see folder option, the click on it a browser will pop up. Select the model “impeller”. Once the model is placed on Creality slicer, then select download option at the top. Show that model can be sliced by using layer method.

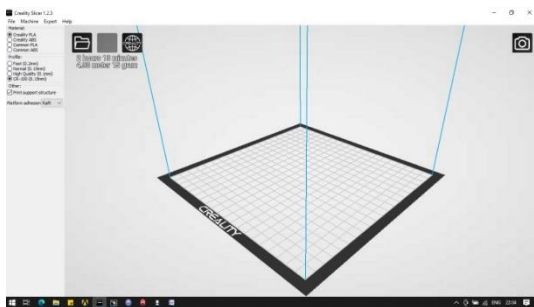


Fig. 4.1 Creality slicer

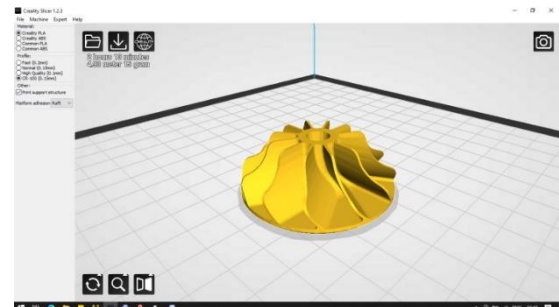


Fig. 4.2 Model in Creality slicer



Fig. 4.3 3D printed layer to layer in Creality slicer

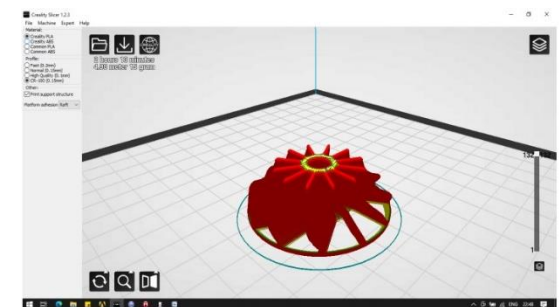


Fig. 4.4 3D printed layer to layer in Creality slicer

5. CALCULATION

5.1 Stiffness Analysis: In order to analyse the stiffness of the compliant iris arrangement in the compliant direction, stiffness expression of curved beam has been derived in terms of geometric dimensions and material properties and stiffness of multiple beams have been added to obtain overall stiffness. For a general beam, stiffness is derived using Castigliano Theorem. Castigliano's Theorem is one of the energy methods (based on strain energy) that can be used to solve a wide range of deflection problems. It relates the deflection in an elastic body in any direction

(a) to the partial derivative of the strain energy with respect to the input loads F_i in the direction a. (equation 1)

$$\delta_i = \frac{\partial U}{\partial F_i} \text{ ----- (1)}$$

5.2 Derivation of Stiffness Expression: With reference to the symbols presented in figure 5.1. Consider, instantaneously, each of the curved beam has a radius of curvature R and makes an angle θ with the longitudinal axis. The whole of the iris is composed of 6 such curved beams. From figure 5.1, we get $F_n = F \cos(\theta)$, $F_\theta = F \sin(\theta)$ and $M = F R \sin(\theta)$. Let 't' be the thickness of the beam and as $R \gg 1$, so the strain energy terms take the form as presented in equations 2 – 7.

$$dU_1 = \frac{M^2 R}{2 EI} d\theta \text{ ----- (2)} \quad dU_2 = \frac{F_\theta^2 R}{2 AE} d\theta \text{ ----- (3)}$$

$$dU_3 = -\frac{M F_\theta}{AE} d\theta \text{ ----- (4)} \quad dU_4 = 1.2 \frac{F_n^2 R}{2 AG} d\theta \text{ ----- (5)}$$

where 'A' is the cross-sectional area of the beam, 'G' is the shear modulus of the material of the iris, 'E' is the Elastic modulus of the material and 'I' is the area moment of inertia for the curved beam.

$$U = \int_0^\theta dU_1 + dU_2 + dU_3 + dU_4 \text{ ----- (6)}$$

$$\delta = \frac{\delta U}{\delta F} = \int_0^\theta FR \left(\frac{R^2 \sin^2 \theta}{EI} + \frac{\sin^2 \theta}{AE} - \frac{2 \sin^2 \theta}{AE} + \frac{1.2 \cos^2 \theta}{AG} \right) d\theta \text{ ----- (7)}$$

$$\text{the net deflection } \delta \text{ is given by, } \delta = FR \left(\theta - \frac{\sin 2\theta}{2} \right) \left(\frac{R^2}{2EI} - \frac{1}{2AE} + \frac{1.2}{2AG} \right) \text{ ----- (8)}$$

So, the stiffness of one beam of rectangular cross section $A = b t$ and $I = \frac{b t^3}{12}$ becomes 9.

For a compliant iris with six beams, we have overall torsional stiffness as 11 utilising the net deflection angle (α) and the net moment (M_t). The net torsional stiffness is given by equation 9.

$$\text{Overall torsional stiffness (K)} = 36 k (r)^2 \text{ ----- (9)}$$

where r_{iris} is the net radius of the whole iris (the bigger) structure, The net analytical expression of torsional stiffness of the iris 'K' is presented in equation 9. However, the terms 'R' and θ are variables as the radius of curvature of the iris and the angle spanned by the flexure keeps on changing. So, we need to express both in terms of α which is the net rotation of the iris. The iris opens proportional to the rotation angle α . We assume that the net change in the length of each of the flexure is negligible. So, we have the geometric relation (equation 10).

$$R \theta = L \text{ ----- (10)}$$

Let α_0 be the initial rotation for the net iris output structure. The equation 10 is reduced to equation 11.

$$\sin \left(\frac{\alpha + \alpha_0}{2} \right) = \frac{2 r_{iris}}{L} \sin \frac{\theta}{2} \text{ ----- (11)}$$

Graphically, for non-zero solution, $\frac{L}{r_{iris}} > 2$.

6. DISCUSSION

Although, a closed form expression for the net stiffness is not known but the bounds in the stiffness can be used for design purposes. It should be known that the net stiffness of the iris changes with change in the output angle. The upper bound and lower bound for the expression of stiffness are expressed in Figures 6.1 & 6.2. The expression of stiffness is increasing in θ for all values of L. So, the maximum stiffness occurs when each of the flexure is at extreme values of θ . Let the value of θ is limited by θ_0 . The minimum stiffness occurs when $\theta = L$ and $R = r_{iris}$. So, in case we have a required stiffness during a complete operation of the opening of the aperture, then the various parameters in maximum stiffness and minimum stiffness expressions can be varied.

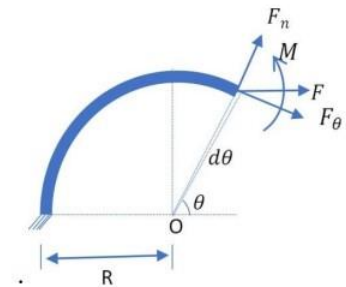


Fig. 5.1 Curved beam

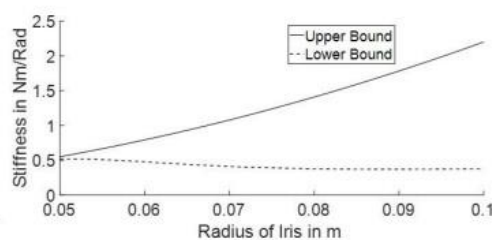


Fig. 6.1 Upper and Lower Bounds of Stiffness variation with iris radius

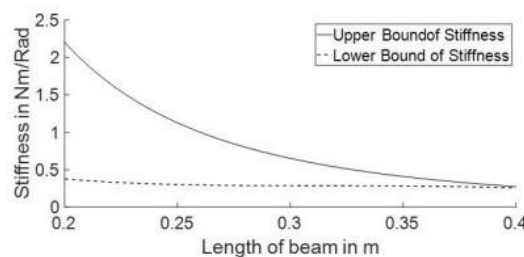


Fig. 6.2 Upper and Lower Bounds of Stiffness variation with flexure length

7. CONCLUSION

From this critical review of research and design and making of Mechanical iris gear, the following points are concluded.

- 1.The design parameters like number of widths, teeth, number of planets, face width, tooth profile modification, material are designed in Catia and are very important in deciding the load capacity in bending and wear, life and cost of gears.
- 2.Finite element design, load distribution program are important methods used for load analysis of iris gear.
- 3.Deformation of tooth slank due to load can be reduced or compensated by tooth plants.
- 4.The designed mechanical iris gear with given specification is manufactured using 3D printing.

8. ACKNOWLEDGEMENT

I would like to express my very great appreciation to Mr. M. Sujjan Kumar for his valuable and constructive suggestions during the planning and development of this research work. His willingness to give time so generously has been very much appreciated. I would also like to extend my thanks to the faculty Mechanical Engineering of Guru Nanak Institutions Technical Campus, Hyderabad for their help in offering me the resources in running the program. Finally, I wish to thank my family members for their support and encouragement throughout my study.

REFERENCES

- [1] Kaufui V. Wong and Aldo Hernandez, A Review of Additive Manufacturing, ISRN Mechanical Engineering, vol. 2012, Article ID 208760, (2012) 10 pages.
- [2] 3D printing Encyclopaedia Britannica, (2014), <http://3dprinting.com/what-is3d-printing/> accessed on 27.04.2015
- [3] Richard D'Aveni, Harvard Business Review, May 2015, 42-48
- [4] L Adendorff, '3D technology: 3D printing the next frontier?' Aroq - JustStyle.Com (Global News), (2014) p. 12, Entrepreneurial Studies Source, EBSCOhost, viewed 1 June 2015.)
- [5] Kovacs, M. TECHNOLOGY: 3D printing gears up for fashion industry change. Aroq - JustStyle.Com (Global News), 1 (2015)
- [6] <http://www.tamicare.com/> accessed on June 1, 2015
- [7] http://en.wikipedia.org/wiki/Selective_laser_sintering accessed on June 2, 2015