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# Design of Gear Driven Cable Operated Mechanical Prosthetic Hand

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***Abstract*: The project is based on the new conceptual design of gear driven cable operate mechanical prosthetic hand. The main objective for this design is increasing the strength, higher level of freedom in movement, reducing the manufacturing cost and force required to operate the prostatic hand. In this paper there will be design and calculation related to prosthetic hand architecture by which it will be very helpful for the future work regarding to prosthetic. In order to support that calculation and design of gear and rotational movement, an analytical analysis done in which the basic parameter which has been choose on the base of the past experience and work related to it.**

***Keywords*: Prosthetic hand, Gear Mechanism, Bio-Powered Mechanism, Fabrication, Design Process, Manufacturing gear based prosthetic.**

## 1. Introduction

In medicine, a prosthetic hand is an artificial device that substitutes a missing body part, which may be lost due to any major medical conditions like blunt trauma, major amputees, surgery, or natural contingencies. There are lots of available Prosthetic amputee rehabilitation devices which primarily available by an inter-disciplinary team of medical rehabilitation professionals including physical therapists and researchers. Prosthetic hands generally consist complex mechanism, custom silicon arm covers and actuation components which require a relatively large activation force due to robust design [1]. A study by the Delft University of Technology, The Netherlands, showed that the development of mechanical prosthetic hands had been neglected during the past decades. The study showed that the pinch force level of most current mechanical hands is too low for practical use.

## 2. Product development

As it is stated above the problems and the thread to solve the issue, comparing the previous experience with the patients we found out that in all different types of hand, they all have a system which is used to operate the hand but there is no or less effort is been made for the increase in the force which it is been produce, such that we define the system to the one which have the higher level of strength due to which the person can be use the hand in the maximum load and mean while it also increase the force, and it all should done by reducing the weight and the effort to be made, in another word the system should be that which can be used in the practical world, after have a full research on the different system for the hand operation we opted for the gear system. The main reason for the gear system is that it has a greater force to be made by less effort and the increase in the pinch force value compare to the current systems and technology related to mechanical hand. Furthermore, to reduce the effort and force to make the movement in the gear the introduction of conventional rope is made but instead of the conventional rope the design opted is the helical rope which will further increase the durability of the product. But the introduction of the gear system and the rope system will be increasing the effort and the force require to make the adjustment of the position of the hand, to solve this problem the introduction of revolving base with the locking system which helps to significantly reduce the effort and the force which is described above. To produce the closing movement in the hand we have used tensile helical spring between thumb and finger in a way that it will not disturb the total hand opening space.

## 3. Objectives

- The main objective is to introduce a gear-spring system by which the outcome capacity to lift total weight by prosthetic hand and strength will be increase.
- Another main objective is to reducing manufacturing cost of various parts of prosthetic hand.
- Making effortless locking system for the design so that the usability if the product can increase.
- Reducing operating force by inserting gear-spring mechanism which can actuate by body-powered rope mechanism
- To increase intuitive control which can easily adopt by natural arm movement of human body.
- To increase optimization of design of prosthetic hand closer to original dimensions of human hand.
- To initiate further research in medical rehabilitation technology.

## 4. Design

### A. Design parameters

From the previous experience, the studies show these parameters for individual part are more suitable for prosthetic hand, which included mainly thumb, fingers and palm.

### B. Main Parts

#### 1) Thumb

| | Length | Width | Thickness | Joint angle |
|---|---|---|---|---|
| Natural | 69.596 | 25 | 24 | 90°(Approx.) |
| Prototype | 79 | 16 | 4.3 | 140° |
| Final design | 76.03 | 18 | 3 | 143° |

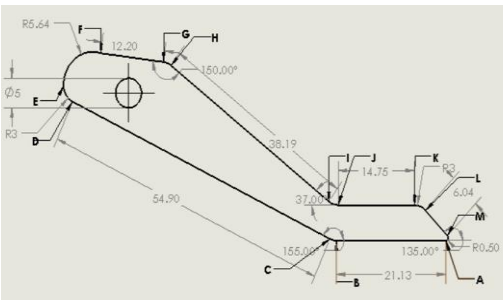

Fig. 1. Parameters

### C. Finger

| | Length | Width | Thickness | Joint angle |
|---|---|---|---|---|
| Natural | 79 | 23 | 21 | 110°(Approx.) |
| Prototype | 94.30 | 16.10 | 3.5 | 43° |
| Final design | 86.86 | 14.28 | 3 | 29.32° |

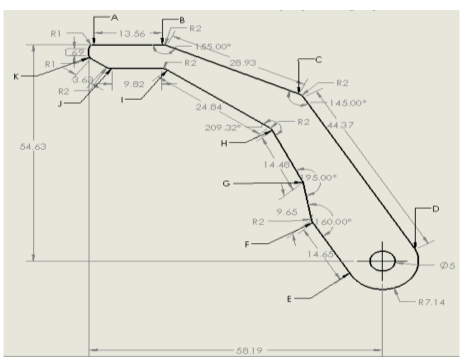
Fig. 2. Finger

### D. Support Plate

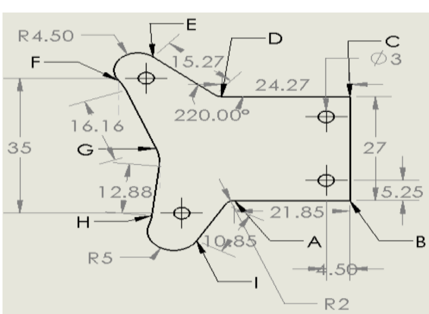

Fig. 3. Support plate

Support plates are welded on base plate at distance. Both thumbs and fingers with gears are fitted on support plates by two pins [2], [3].

### E. Gear

As per dimensions decided by study and ISPO medical standards maximum distance between centers of two gears are 35 mm[4]-[6].

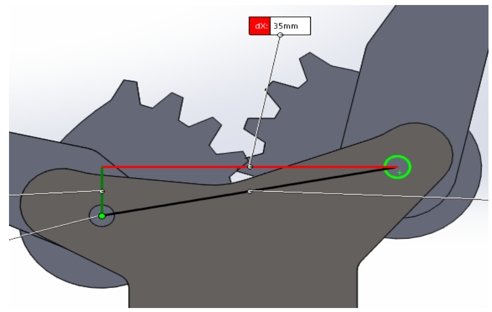

Fig. 4. Gear

### F. Parameters of gear design

In CAD assembly both the gears are simulated as concentric mechanical mates between support plate on two different rotating pins with thumb and fingers respectively as shown. Following parameters are define as per below as per require standard:

| | |
|---|---|
| Dedendum diameter | 32 mm |
| Tangential force, $F_t$ | 117.6 N (12kg) |
| Pressure angle, ϴ | 18.26° |
| No. of teeth | 20 |
| Fatigue strength, $\sigma_b$ (304-Cast stainless steel) | 310.5 N/mm$^2$ |

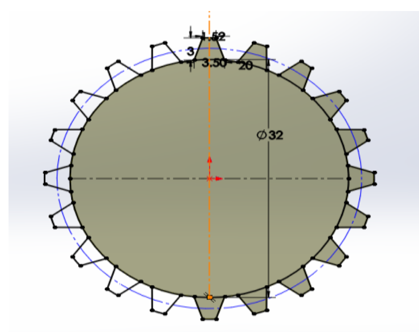

Fig. 5. Design gear

Assume dedendum diameter $d_m$ = 32 mm, as per $d_p$ condition of distance between two gear centers.

Maximum teeth height, $t = 35 - 32 = 3\ mm$

Pitch circle diameter

$$dp = dm + t$$

$$dp = 32 + 3 = 35\ mm$$

Torque, $T = {}^{Ft}/_{\cos \Theta} \times {}^{dp}/_{2}$

$$= {}^{117.6}\!/_{\cos(18.26°)} \times {}^{35}\!/_{2}$$

$$= 2167.12\,\frac{N}{mm}$$

Assume width of teeth, b = 10 mm

Lewis Factor, Y = 0.603(From design data book)

Module, m = ${}^{dp}\!/_{z} = {}^{35}\!/_{20} = 1.75$ Bending stress on gear,

$$\sigma = {}^{Ft}\!/_{b} \times Y \times \Pi \times m$$

$$\sigma = {}^{120}\!/_{10} \times 0.603 \times \Pi \times 1.75$$

$$\sigma = 38.98\,\frac{N}{mm^2}$$

$$\sigma < \boldsymbol{\sigma_b}$$

So, design of gear is safe.

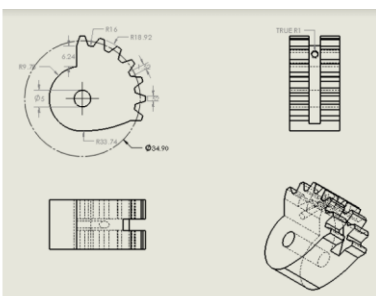

Fig. 6. Parts

After considered design parameters of gear train, modified design into as shown above. Required no. of teeth are only 7 and slot made on gears to fit break wire through it to operate the hand.

## 5. Base plate and rotating cylindrical wrist

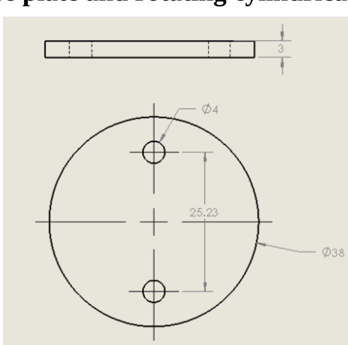


Fig. 7. Cylindrical wrist

Base plate is for support the support plates which are welded on base plate. Base plate contains two holes for nut and bolts for locking rotational position.

### A. *Dimensions for base plate*

| Base plate | |
|---|---|
| Diameter | 38 mm |
| Thickness | 3 mm |
| Distance between two holes (4 mm) | 25.23 mm |

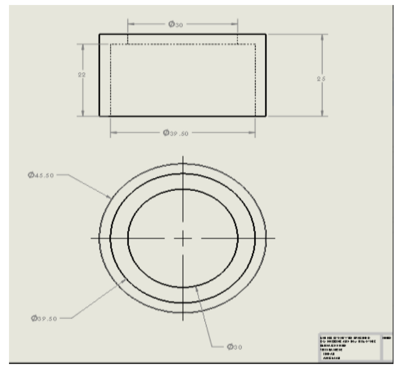

Fig. 8. Parts

Rotating cylindrical wrist on which base plate is fitted by two nut and bolts and also contain hole of 30 mm diameter through cylinder.

| Rotating cylindrical wrist | |
|---|---|
| Inner Diameter | 45.50 mm |
| Outer Diameter | 29.50 mm |
| Height | 25 mm |

## 6. Rotating Pin

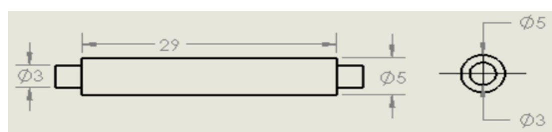


Fig. 8. Rotating pin

Pin is used to fit gears on support plate

## 7. Product development

### A. *Helical spring*

Helical spring not included in CAD model which can define on practical basis as per requirement different prosthetic hand**.**

### B. *Analysis Report*

#### 1) *Thumb*

In analysis, thumb consider as a simple cantilever beam with rotating support at concentric mate of thumb and rotating pin. Following analysis obtained as optimum meshing as per scale as shown in diagram. Static load applied and displacement and stress analysis generated respectively as shown below.

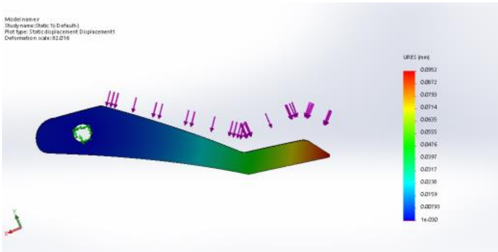

Fig. 9. Thumb

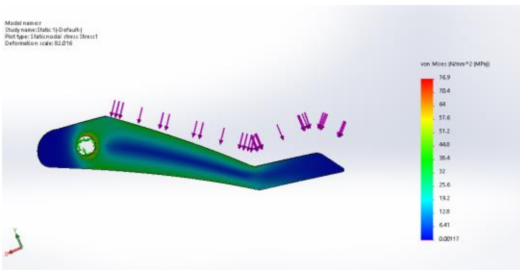

Fig. 10. Scale: 82.016 (Auto generated)

### C. *Fingers*

In analysis, fingers consider as a simple cantilever beam with rotating support at concentric mate of thumb and rotating pin.

Following analysis obtained as optimum meshing as per scale as shown in diagram. Static load applied and displacement and stress analysis generated respectively as shown below.

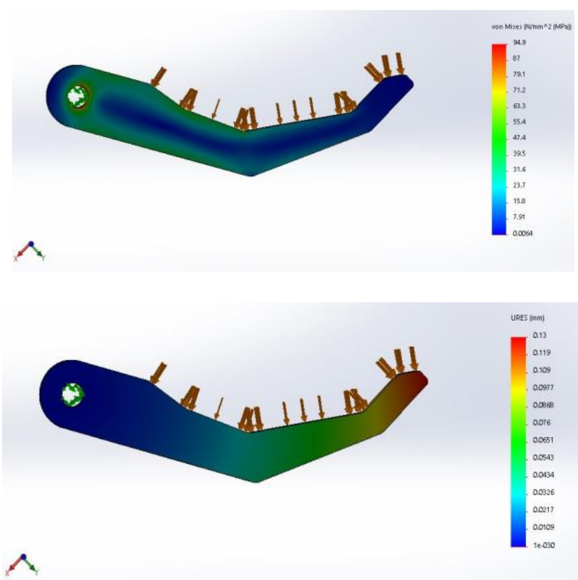

Fig. 11. [Scale: 1(Original)]

### D. *Analysis of assembled parts*

In analysis of whole assembly, both the support plates considered as a simple cantilever beams with fix support with parallel plane in coordination system of assembly. Following analysis obtained as optimum meshing as per scale as shown in diagram. Static load applied and displacement and stress analysis generated respectively as shown below. [Fig. 12 and 13]. Both the rotating pins stressed as shown in figure. [Fig. 14].

Fig. 12. Static load applied and displacement and stress analysis generated

Fig. 13. Static load applied and displacement and stress analysis generated

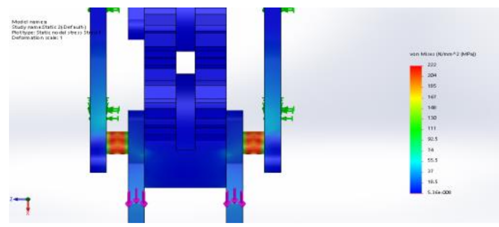

Fig. 14. Rotating pins stress

## 8. Conclusion

Thumb and fingers loaded with 12 kg weight (117.6 N). Analysis shows it's safe in stress and also deformation. Analysis made as considered that maximum capacity of hand to pick up any object is 12 kg (117.6 N). At fully opening position of hand at this max. Load not any remarkable deformation and stress were generated. Maximum stress generates on pin on which gears are fitted, but it is in safe design criteria and tensile spring used which also helps in to decrease generated stress.

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