DESIGN AND MANUFACTURE OF AN ANGLE ADJUSTABLE CRUTCH WITH KENNEDY KEY MECHANISM

P.Sriharsha[1], Shyam Somani[2]

[1]*Department of Mechanical Engineering, National Institute of Technology Karnataka Surathkal, Karnataka, India*
[2]*Department of Mechanical Engineering, National Institute of Technology Karnataka Surathkal, Karnataka, India*

Abstract

A crutch is a mobility aid that transfers weight from the legs to the upper body. It has been observed that users of walking aids require double the energy than the normal gait. Users experience a lot of stress at underarm and wrist while using standard underarm or forearm crutches which is the primary reason for pain and various medical complications. Therefore, a new design of crutch has been developed which allows the user to apply his/her weight over a larger area along the forearm instead of wrist and underarm. The primary objective of the study is provide more comfort to the end user of the crutch. The modeling of the new crutch design has been done using CAD modeling package (Catia). Finite Element Analysis (FEA) of the design has been conducted using ANSYS to understand the stress behavior in the new model. The new crutch has been fabricated using aluminum alloy because of its properties like high strength to weight ratio and low density. The fabrication of the new crutch has been performed in such a way that it ensured the entire crutch can be disassembled easily thus making it easily transportable. The testing of the new crutch has been carried out using energy expenditure method to assess the comfort level of the user.

Keywords: *Finite element analysis, crutch, gait, energy expenditure method, CAD*

---***---

1. INTRODUCTION

A crutch is a mobility aid which is used by the people who cannot use their legs to support their weight, for reasons ranging from short-term injuries to lifelong disabilities. The crutch has not seen any substantial modification since past 5000 years [1].

However, the energy expensed in walking with the crutch walking is two times the energy of normal gait [2,3] and exerts a great stress on the upper body. The prolonged use of crutch is responsible for extreme pain at wrist and forearm [4,5]. Moreover, there are many reasons—physiological and psychological – why it is good to stand and walk rather than sit and use wheeled mobility [6,7].

So looking at the problems involved in the current conventional crutches, the new design tries to increase user comfort, quantification of which is done using the energy expenditure method of testing.

1.1 Objective

The main purpose of this project is to design a crutch which will mitigate the problems faced by the crutch users. Both the users – permanent and temporary are kept in mind while designing the crutch but the main emphasis is given on the permanent users. So the factors like durability and ease of transportation are given a huge importance both while designing and manufacturing the new crutch. Therefore conditions targeted were Indian conditions, where ease of transportability becomes a determining factor.

1.2 Method

Four main steps namely, design, analysis, fabrication and experimentation, are used to converge and analyze the utility of the crutch on day to day basis. Various designs have been deliberated upon and FEM Analysis has been performed for all the designs that are considered. The analysis helped to optimize the design and estimate the stress and deformation at various locations. This further helped to reduce the extra material. After attaining the satisfactory results, the fabrication has been undertaken and the final product was tested on a group of five healthy adults. The test has been performed using Energy Expenditure Index (EEI) to gauge the comfort level of the users [8].

$$EEI = \frac{HR_{walk} - HR_{rest}}{V_{avg}}$$

HR_{walk} = heart rate after walk (beats/min)
HR_{rest} = heart rate at rest (beats/min)
V_{avg} = average velocity (m/min)

2. DESIGN

Various designed and mechanisms were studied and compared to arrive at the best alternative. The main objective of designing the new crutch is to tap the advantage of distributed stress over the forearm. Following the same ideology, new model is developed. The new design consists of adjustable platform which has provision of four angles ranging from 0 to 90 degree at equal intervals. The user has the liberty to adjust the platform angle according to his/her comfort. The Kennedy key and shaft arrangement has been chosen because it provides durability and ease of fabrication. Kennedy Key was designed based on shear mode of failure. This locking arrangement requires the user to remove the key and change the platform angle to the desired position by placing the key back in the arrangement. After the key calculations were done, the components are modeled and integrated into an assembly using Catia (Fig.1).

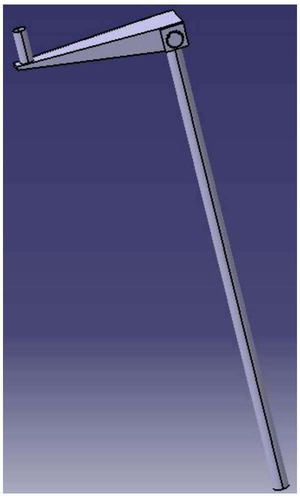

Fig -1: CAD model of the new design

3. ANALYSIS

The analysis was carried out using commercial FEM package (ANSYS). The type of analysis performed was static structural. The contacts specified were frictional for key and the keyway on the rod on which the key rests. The rest of the regions were bonded contacts. The analysis was performed to quantify the equivalent stress (Von Mises) and total deformation.

3.1 Geometry Acquisition and Material Properties

The geometry features were imported from Catia and mesh was generated using the triangular elements on the surface. All the components except key were assigned with the aluminum alloy material from ANSYS library of materials and keys with steel $50C_4$ material. Since the geometry features of CATIA are integrated in the ANSYS software, there was no loss of features and all the features are imported in the correct manner. The linear elastic properties of aluminum alloy were: Young's modulus E = 71 GPa; Poisson's ratio υ = 0.33. The linear elastic properties of steel 50C4 were: Young's modulus E = 210 GPa; Poisson's ratio υ = 0.3.

3.2 Boundary Conditions and Load

The displacement was fully constrained at the tip to simulate the contact at the ground (Fig.2). The displacement constraint at the crutch tip provides the case in which the person is just standing with his feet above the ground in a balanced condition. The loading applied was chosen such that it satisfies the weight criteria of a healthy adult individual in BMI range of 20 to 22. Therefore the chosen value of the load is 400N.

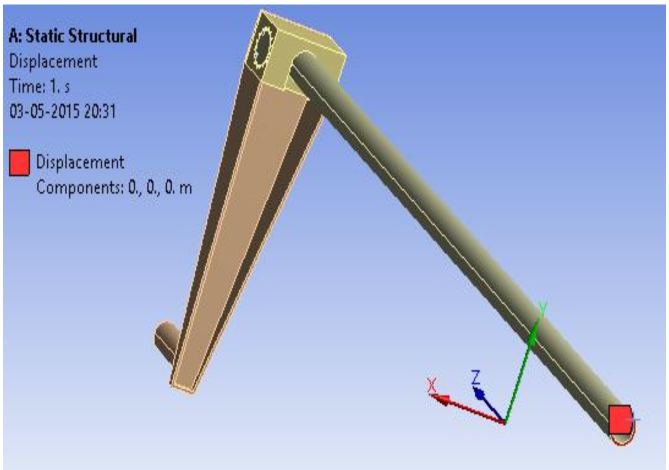

Fig -2: Displacement constraint

A distributed load of 400N was applied in the perpendicular direction on the platform (Fig. 3). The stress and total deformation has been recorded at all the angles.

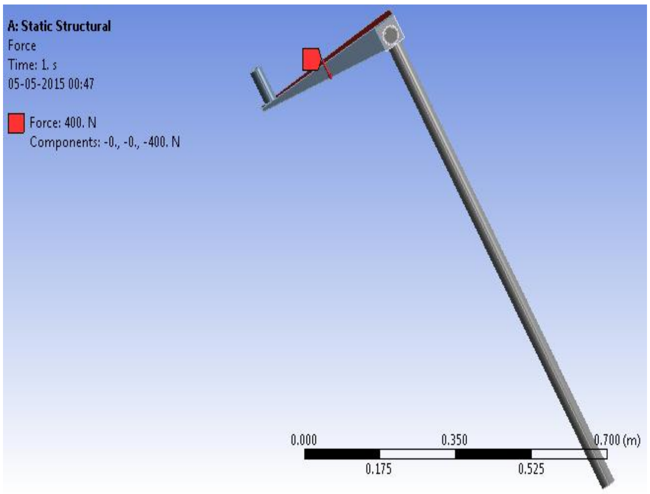

Fig -3: Load applied normal to platform

3.3 Results

A convergence of stress at all the angles was obtained. The maximum Von Mises stress for all the angles were less than the maximum yield strength of Aluminium (280 MPa). Out of all the angles the maximum stress of 86.5 MPa was observed at 22.5 degree angle (Fig.4). Therefore an approximate factor of safety of 3.22 is present in the design. This ensures that any sudden fluctuation in the lading pattern may not cause the crutch to deform immediately.

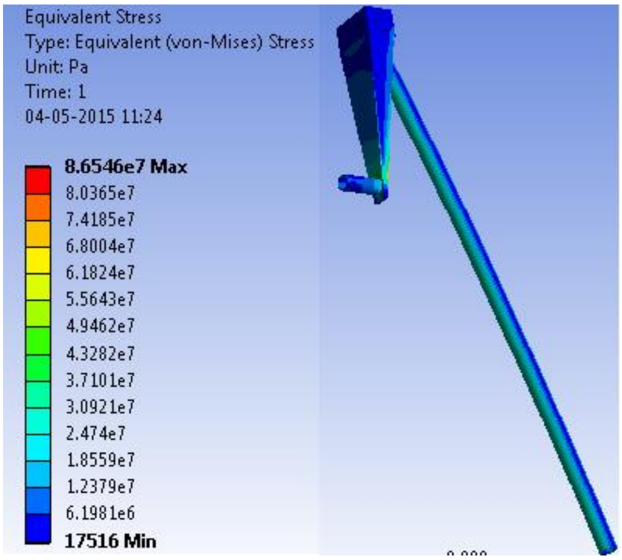

Fig -4: Stress distribution on crutch

The maximum deformation was also observed in the case of 22.5 degree (Fig.5). The value obtained was 9.7 mm which was very small.

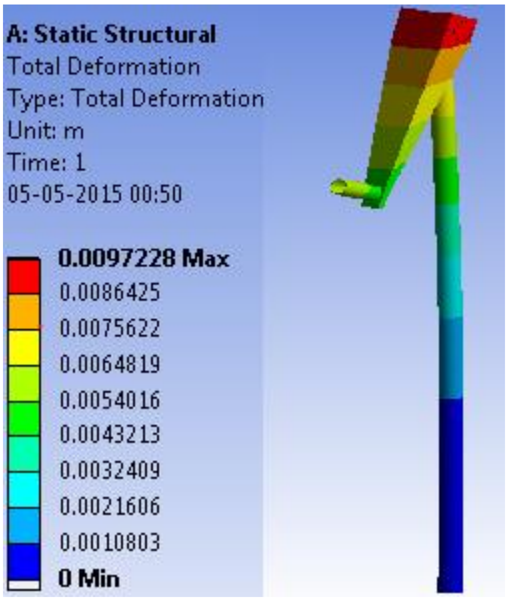

Fig -5: Deformation on crutch

4. FABRICATION AND EXPERIMENTATION

The new crutch model (Fig. 6) was built using Aluminum alloy (HG-30) and steel $^{50}C_4$ materials. Various Processes like Milling, Slotting, threading and other machining operations were performed in order to arrive at the final model of the crutch. To provide the ease of disassembling the model the joining of components was done only by mechanical fasteners like screws, bolts etc.

Fig -6: Fabricated model

4.1 Experiment Methodology

The Energy Expenditure index test was conducted on five volunteers of age group 21 to 23 and BMI of 20 to 22. The experiment was performed first on traditional axillary crutch and then on the new design at all the angles with five minutes gap between each trial. Heart rates after walking and at the rest were recorded using the commercial product (Geonaute). The experiment essentially involved four steps. Firstly the test patient's heart rate was noted at rest. Second step involved the volunteer to walk for fifty feet continuously. The third step involved measuring person's heart rate immediately after the walk. The above mentioned steps were repeated for all angles. The final step was to ask the person to rate (on a scale of 5) the angle as per comfort. This quantitative as well as qualitative way of evaluating the crutch performance provided a better way to gauge the crutch's performance.

4.2 Experiment Results

The results have shown that out of all the possible angles, 22.5 degree angle is the best with mean EEI of 1.14 and comfort rating of 4.2 (Table. 1). The users have also rated 67.5 degree angle at 4.2 for comfort. The mean EEI for the standard crutch is 1.15. From the table it was observed that at 22.5 degree angle mean EEI is less than that of standard crutch. Thus the experiment proved that 22.5 degree was the most suited crutch angle as rated by the users.

Table -1: EEI at Different Platform Angles

S No	Platform angle (in degrees)	Average EEI(beats / min)	Average comfort Rating
1.	90	1.23	3.4
2.	67.5	1.28	4.2
3.	45	1.19	3.3
4.	22.5	1.14	4.2

5. CONCLUSION

Finite Element Analysis was used to find out the stress distribution pattern in the crutch. This analysis gave an estimate of stress values in the new crutch design. The fabrication of the crutch was done by standard Aluminum alloy except the keys which were made of steel 50C4. Energy expenditure method gave a valuable input i.e. which angle is the most comfortable of all. It was found that 22.5 degree is the most suited of all crutch angles. The feedback from volunteers was in synchrony with the energy expenditure method. Therefore the work done showed a coherence in quantitative and qualitative aspect of the test preformed on the group of individuals.

ACKNOWLEDGEMENTS

We would like to thank Department of Mechanical Engineering, NITK surathkal for all the assistance provided during the research work. We also would like to thank Tamu Sutterwala, Vishal Dash and Souvik Halder for their constant support and help during the course of this research project. We thank Ashuthosh Engineering Works for its help with the inputs in manufacturing.

REFERENCES

[1]. Epstein S. Art, history, and the crutch. Ann Med Hist 1937; 9:304–13.
[2]. Thys H, Willems PA, Saels P. Energy cost, mechanical work and muscular efficiency in wing-through gait with elbow crutches. J Biomech 1996, 29(11):1473–1482.
[3]. Fisher SV, Patterson RP. Energy cost of ambulation with crutches. Arch Phys Med Rehabil1981, 62(6):250–256.
[4]. Ginanneschi F, Filippou G, Milani P, Biasella A, Rossi A. Ulnar nerve compression neuropathy at Guyon's canal caused by crutch walking: case report with ultrasonographic nerve imaging. Arch Phys Med Rehabil 2009, 90(3):522–524.
[5]. Malkan DH. Bilateral ulnar neuropraxia. a complication of elbow crutches. Injury 1992, 23(6):426.
[6]. Bruno J. Energy cost of paraplegic locomotion. Clinical Podiatry 1984; 1:291-294.
[7]. Axelson PW, Gurski D, Lasko-Harvill A. Standing and its importance in spinal cord injury management. Proceedings of the RESNA 10th annual conference, San Jose, California. California: RBSNA, 1987; 477-479.
[8]. KTD Kahaduwa, CDA Weerasiriwardane, SM Wijeyaratne. A modified axillary crutch for the lower limb amputees. 2004

BIOGRAPHIES

P.Sriharsha, B.Tech, Department of Mechanical Engineering of National Institute of Technology Karnataka Surathkal
E-mail: harsh933@gmail.com

Shyam Somani, B.Tech , Department of Mechanical Engineering of National Institute of Technology Karnataka Surathkal
E-mail: somanishy@gmail.com