Design and Analysis of Prosthetic Hydraulic Hand

Shabana Khanam[1], K. Nageswar Rao[2]
[1]Dept of Mechanical Engineering
[2]Assistant Professor, Dept of Mechanical Engineering
[1, 2] Akula Sreeramulu College Of Engineering , Prathipadu , Tadepalligudem ,Westgodavari

Abstract- *This project shows an alternative for prosthetic terminal devices. It´s objective is be able to grasp cylindrical objects up to 70 mm of diameter. During the design of this terminal device, different variables were consider, such as be modular, anthropomorphic, ecofriendly (less material and energy use for production) and the ability to be 3D printed in different plastic materials like PLA (Polylactic acid), ABS (Acrylonitrile butadiene styrene) and PET (Polyethylene terephthalate). The scope of this project explores the usage of hydraulics and solid structures capable of move without changing its original shape. As a result it's presented a design of a terminal device that base itself on the idea of an affordable prosthetic with applicable functionality. Furthermore the audience for this prosthetic device are people form United States, who are left handed.*

Keywords- Alternative, Modular, Hydraulics.

I. INTRODUCTION

In medicine, a **prosthesis** (plural: prostheses; from Ancient Greek *prósthesis*, "addition, application, attachment"[1]) is an artificial device that replaces a missing body part, which may be lost through trauma, disease, or congenital conditions. Prosthetic amputee rehabilitation is primarily coordinated by a prosthetist and an inter-disciplinary team of health care professionals including psychiatrists, surgeons, physical therapists, and occupational therapists.

Types

A person esprostéticos should be designed and assembled according to the patient's appearance and functional needs. For instance, a patient may need a transradialpros thesis, but need to choose between an aesthetic functional device, a myoelectric device, a body-powered device, or an activity specific device. The patient's future goals and economical capabilities may help them choose between one or more devices.

Cranio facial pros theses include intra-oral and extra-oral prostheses. Extra-oral prostheses are further divided in to hemi facial, auricular (ear), nasal, orbital and ocular. Intra-oral prostheses include dental prostheses such as dentures, obturators, and dental implants.Prostheses of theneck include larynx substitutes, trachea and upper esophageal replacements,Somatopros theses of the torso include breast prostheses which may be either single or bilateral, full breast devices or nipple prostheses.

II. LITERATURE

There are 35 muscles involved in movement of the forearm and hand, with many of these involved in gripping activities. During gripping activities, "the muscles of the flexor mechanism in the hand and forearm create grip strength while the extensors of the forearm stabilize the wrist (27)". There are four major joints of the hand, Carpometacarpal, Intermetacarpal, Metacarpophalangeal, and interphalangeal joint, with "9 extrinsic muscles that cross the wrist and 10 intrinsic muscles with both of their attachments distal to the wrist (10)." These muscles include the pronator radii teres, flexor carpi radialis, flexor carpi ulanris, flexor sublimisdigitorum, and Palmaris longus on the extrinsic layer and the flexor profundusdigitorum, flexor

III. METHODOLOGY

For better understanding, this methodology was divided in two parts. The first one being the calculations and the second being the design.

3.1 Calculations.

In accordance with the main functionality of the terminal device, calculations become a must. With that said, in order to grasp a cylindrical object (in this case a soda can of 0.34 Kg.) was needed an equation (1) to determine the amount of force needed [3] & [4] from the prosthetic device.

$$F > \frac{m*(g+a)}{\mu} * (safety\ factor) \quad (1)$$

Where "F" is the amount of force needed to grasp and lift; measured in Newton (N), "m" is the mass required to lift; measure in kilograms (Kg.), "g" is gravitational acceleration consider as 9.8 m/s^2, "a" is the acceleration of the gripper, in this case the terminal device, measure in meters per second square(m/s^2), "μ" is the coefficient of static friction and finally the “safety factor” which is the allowable stress of working stress [5].

Considering these information it was conclude that the minimum force needed to grasp and lift a soda can of 0.34 Kg. is $\frac{2754}{125} \approx 22.03$ (N) this result was calculated using the next data:

licus longus, pronator quadratus, flexor pollicus brevis, and abductor pollicus brevis on the intrinsic layer. Each of these muscles is active during gripping activities.

According to German Sports Scientist Jurgen Weinick, “the characteristic structure of the hand is related to its function as a grasping tool. Grasping ability is made possible by the fact that the thumb can be opposed to the fingers. The fingers and the thumb act as a versatile pair of pliers. They need the palm of the hand as a flat base, on which the object grasped can be held (28).” From this statement, it can be concluded that the anatomy of the hand is more geared toward flexion than extension. Further proof lies in the research of Li, Zatsiorsky, and Latash on the strength of finger flexor vs. finger extensor musculature during isometric tasks. Their findings revealed the flexor mechanism of the fingers to be 62% stronger than the extensor mechanism (18).”

Methods of Assessment for Handgrip Strength

The most common method of assessment for grip strength is the use of a handheld dynamometer. This is a form of what is referred to by Dal Monte and Dragan as a biomechanical measurement. “Biomechanical measurements allow sports coaches to appreciate the bioenergetics and efficiency of sports movements; training can then aim to achieve a maximal energetic output with minimal expenditure of energy, avoiding at the same time possible fatigue and stress lesions in the locomotory system (5).”

Handheld grip strength dynamometry is used to measure the muscular force generated by flexor mechanism of the hand and forearm. There are three main categories of handgrip dynamometers. These include spring-loaded compression, air compression, and hydraulic compression devices. According to Waldo, “since grip is a force, not a pressure, it should be measured in pounds or kilograms. A hydraulic dynamometer is the most accurate choice (27).”

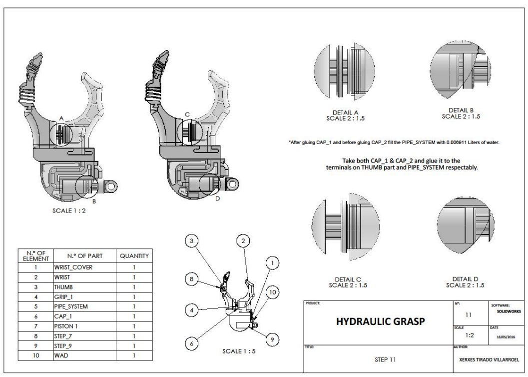
When testing grip strength there are many variables that need to be normalized before testing. The testing protocols need to be consistent with regards to time of day, posture, anthropometric measures and dynamometer adjustments. Goh et al (2001) performed a study on the effects of one night of sleep deprivation and its effects on hormonal profile and performance. Their baseline performance measurement was handgrip strength. During the study, the researchers performed grip strength and hormonal profile testing at different times throughout the day. Their findings revealed “changes in grip strength occurred as a function of time of day. Grip performance increased progressively during the day, but declined during the night (8).” Cappaert (1999) had similar findings, concluding “grip strength also showed time of day differences with the peak in the afternoon (3).” He further concluded, “time of day differences in endocrine function, as measured by plasma cortisol and B-endorphin as well as levels of catecholamines in the urine, mirrored the differences in muscular strength (3).”

Posture and elbow positioning during handgrip testing has also been found to play an important role in the strength results. Various studies have shown grip strength to be greater with less flexion at the elbow (17, 20, 25). The normalization of anthropometric measures such as body height, mass, finger length and perimeter can also have an effect on the outcome of grip strength testing. One such study revealed “there were highly significant relationships between maximal handgrip strength of the dominant hand and general anthropometric variables in all age-groups (26).” Without normalization of testing protocols, the results may be influenced by the aforementioned variables.

Handgrip Strength as a Predictor of Physical Functioning

Grip strength has long been thought of as a possible predictor of overall body strength, but little if any research that correlated the two was found. Smith et al (2006) found a direct correlation in grip strength and overall body strength in very old and oldest females. The study revealed that, “grip strength was moderately correlated with overall body strength in the very old and oldest populations (23).” Fry et al (7) also found a correlation between grip strength and performance in American Men Junior Weightlifting. Though in theory, one would believe the two are correlated and more studies may be necessary for other populations. Many of the research studies correlated grip strength to various other physical variables including nutritional status, rotator cuff weakness, fatigue, and overall physical function.

In his book Science of Sports Training, sport scientist Thomas Kurz recommended the measurement of handgrip strength using a hydraulic dynamometer to reveal the physical readiness of an athlete. This information provides valuable data to the coach with regards to an athlete’s potential training status. If the athletes grip strength is percentage kilograms below baseline or previous workout, the athlete may be fatigued. If the opposite is true, the athlete will have recovered optimally and performance may increase. This theory draws parallel to the findings of studies performed by Michiko et al (1999), Hunt et al (1985), and Frederiksen et al (2002). Each of these studies used handgrip dynamometric testing to evaluate physical functioning in surgical, lifestyle disease, and mid to late life subjects. The findings of each of these studies correlated less than optimal physical functioning or fatigue with lower strength scores in handgrip dynamometric testing. In a recent report by the ACSM, it was concluded that, "handgrip muscular endurance has been shown to suffer a delayed decline on the second morning following intoxication (1)." This research provides further evidence toward the correlation between immune functioning and handgrip strength.Final Design



IV. STUDY RESULTS

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+000mm Node: 1	2.829e+003mm Node: 52539

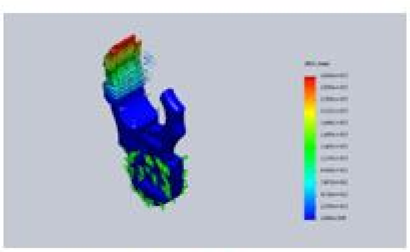
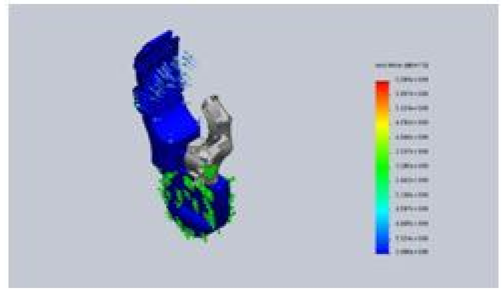


Figure 6.4(a) Displacement

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.000e+000N/m^2 Node: 1	6.389e+009N/m^2 Node: 224421



Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	0.000e+000 Node: 1	2.969e+000 Node: 224421

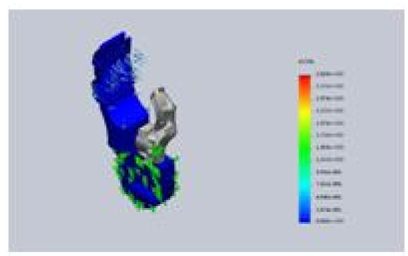


Figure 6.4(c) Strain

V. CONCLUSION

- The Designed model is actually measured from left hand and designed using mechanical priciples the hydraulic mechanism is used and therefore it works intensively upto 16.5kg weight.
- The structural analysis is done to predict the stress strain fatigue life and damage of the product.
- From the observations at 10kg i.e.,98.1N the product fail in 83000 cycles at knuckle are and the stress strain location Is also given .
- It can possiblelift up to 72.6 mm diaobjectswithease.

REFERENCE

[1] American College of Sports Medicine. *The ACSM Report.* April 2000

[2] Budoff, Je. The Prevalence of Rotator Cuff Weakness in Patients with Injured Hands.*J Hand Surg* (2004 Nov;29(6):1154-9).

[3] Cappaert, T. Review: Time of Day Effect on Athletic Performance: an Update. *Journal of Strength andConditioning Research* (1999, 13(4), 412-421).

[4] Coldiron, B. Grip Strength and Subjective Fatigue in Patients with Primary Biliary Cirrhosis.*American MedicalAssociation* (2001).

[5] Dal Monte A., Dragan I.; *The Olympic Book of Sports Medicine.* Pp 109. Cambridge, Ma 1988

[6] Frederiksen, H, D Gaist, Hc Petersen, J Hjelmborg, M McGue, JwVaupel, and K Christensen. Hand Grip Strength: aPhenotype Suitable for Identifying ic Variants Affecting Mid- and Late-Life Physical Functioning.*GenetEpidemiol*(2002 Aug;23(2):110-22).

[7] Fry, Ac, D Ciroslan, Md Fry, Cd Leroux, Bk Schilling, and Lz Chiu. Anthropometric and Performance VariablesDiscriminating Elite American Junior Men Weightlifters.*Journal of Strength and Conditioning Research*(2006Nov;20(4):861-6).

[8] Goh, V, T Tong, Cl Lim, E Low, and L Lee. Effects of One Night of Sleep Deprivation on Hormone Profiles andPerformance Efficiency.*Military Medicine*(2001:166,5:427).

[9] Guo, Cb, W Zhang, Dq Ma, Kh Zhang, and Jq Huang. Hand Grip Strength: an Indicator of Nutritional State andthe Mix of Postoperative Complications in Patients with Oral and Maxillofacial Cancers.*British Journal of OralMaxillofacSurgury*.(1996 Aug;34(4):325-7).

[10] Hall S. *Basic Biomechanics.* Pp 217-219. New York, NY 2007

[11] Hughes, S, B Lyons, and J Mayo. Effect of Grip Strength and Grip Strengthening Exercises on Instantaneous BatVelocity of Collegiate Baseball Players.*Journal of Strength and Conditioning Research*(2004, 18(2), 298-301).

[12] Hunt, Dr, Bj Rowlands, and D Johnston. Hand Grip Strength--a Simple Prognostic Indicator in Surgical Patients."
JPEN J Parenter Enteral Nutr(1985 Nov-Dec;9(6):701-4).

[13] Incel, N, E Ceceli, P Durukan, HrErdem, and ZrYorgancioglu. Grip Strength: Effect of Hand Dominance.
Singapore Med Journal (2002 43(5): 234-237).

[14] Kenjle, K, S Limaye, Ps Ghurge, and Sa Udipi. Grip Strength as an Index for Assessment of Nutritional Status ofChildren Aged 6-10 Years. *Journal of Nutrition and Science Vitaminol (Tokyo)*(2005 Apr;51(2):87-92).

[15] Kozirs, L. Current Comments: Report on Alcohol and Athletic Performance. *American College of Sports Medicine*
(2000).

[16] Kurz T. *Science of Sports Training.* Stadion Publishing Co. 2001

[17] Kuzala, Ea, and Mc Vargo. The Relationship Between Elbow Position and Grip Strength. *American Journal ofOccupational Therapy* (1992 Jun;46(6):509-12).

[18] Li Z., Zatsiorsky V., Latash M; The Effect of Finger Extensor Mechanism on the flexor force during ismetrictasks. *Journal of Biomechanics.* 34. pp1097, 2001

[19] Michiko, S, M Yoko, K Naoko, F Akinobu, and F Toshio. The Correlation Between Grip Strength and LifestyleDisease.*SangyoEiseigakuZasshi*(1999 :41:391).

[20] Momiyama, H, M Kawatani, K Yoshizaki, and H Ishihami. Dynamic Movement of Center of Gravity with HandGrip.*Biomedical Research*(2006 Apr;27(2):55-60).

[21] Poliquin C. *The Poliquin International Certification Program Theory II Manual.* Pp 2-42. East Greenwich, RI 2006

[22] Ratamess, N, A Faigenbaum, G Mangine, J Hoffman, and J Kang. Acute Muscular Strength Assessment Using FreeWeight Bars of Different Thickness.*Journal of Strength and Conditioning Research*(2007, 21(1), 240-244).

[23] Smith, T, S Smith, M Martin, R Henry, S Weeks, and A Bryant. Grip Strength in Relation to Overall Strength andFunctional Capacity in Very Old and Oldest Old Females.*The Haworth Press Inc.*(2006) pp 63-78.

[24] Stumbo, T, S Merriam, K Nies, A Smith, D Spurgeon, and J Weir. The Effect of Hand-Grip Stabilization onIsokinetic Torque At the Knee.*Journal of Strength and Conditioning Research*(2001, 15(3),372-377).

[25] Su, Cy, Jh Lin, Th Chien, Kf Cheng, and Yt Sung. Grip Strength in Different Positions of Elbow and Shoulder.
Arch Phys Med Rehabil(1994 Jul;75(7):812-5).

[26] Visnapuu, M, and T Jurimae. Handgrip Strength and Hand Dimensions in Young Handball and BasketballPlayers.*Journal of Strength and Conditioning Research*(2007, 21(3), 923-929).