DESIGN AND ANALYSIS OF ADVANCED WALKER CUM ROLLATOR

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ABSTRACT

Over the year's walker or rollator have helped many elderly people to overcome the barrier of dependency. As the age grows, the muscles and bones suffer weakening due to lack of calcium because of which person has to depend on others for their movement. This unwanted condition creates a bad physiological and psychological impact on the victim and slowly pulls them out of all possible types of interactions with society. Thus, to make the walker more users friendly, safe, and reliable, a new design or solution is proposed. This not only addresses the problem which is prevalent in the elderly section of society but also will be helpful to people with other disabilities. The proposed design of the walker is to increase the safety and movability of the user. The design of this walker is advanced as it consists of various sensors like an Obstacle sensor, GPS, and Load Sensor. In this paper, the design and analysis of an advanced walker cum rollator is elaborated, which significantly reduces the challenges faced by the elderly and specially challenged in day-to-day life.

Keywords: Design; Load Analysis; Mobility; Rollator; Stability; Walker

INTRODUCTION

Living normally is more difficult for those unfortunate individuals who lose the ability to stand on their own feet due to lower back or limb problems. This miserable condition, fortunately, has a solution as walkers or rollers which support the system to transfer the weight of the body to the ground through a mechanical structure instead of their legs. This reduces the pressure coming on the legs to a significant value. Furthermore, wheels are used in the design to enhance mobility. The Designers have proposed designs over time to improve Walker's performance and enhance the comfort of the victim. But no walker or roller contains brakes to stop it if necessary, instead feed on the motor itself is provided in opposite direction or it is done manually. But in the proposed design drum brakes are added to improve the safety of the user and controlling is also increased significantly. Sensors like GPS, Obstacle sensors, Load Sensors are also implied in this walker design to ease the comfort for the user.

The study by Didymose Poovathumkal (Poovathumkal.,2019) describes the three major material choices are aluminium, mild steel & cast iron. The study by M. Le and E.C. Jung (Le & Jung.,2018); Nurul Ariffah Binti Hamidi (2012) suggested a three-wheeled design that can be used for climbing stairs. The study by E. Costamagnaa, et.al (2017) proposed an accurate method of calculating the combined stability of the patient and the walker frame by using the concept of combined Centre of Pressure (COP_{sysem}). The study by Merlet, J. P.(2011) provides a design for a walker cum rollator that uses a clutch system. The study by P. Médéric, et.al.(2017) describes the Kinematic design-analysis of the complex mechanical functions, geometrical parameter-optimization, and the actuator's capacity, dynamical simulation-evaluation of the mechanical design. The effective length of links of actuators for the device was determined through experimental measurements of interaction forces and hand movements were recorded during assisted sit to stand transfers of elderly patients. R Anslow and J Spicer (2001) Barry Deathe; et.al.(1996) experimented to find out the stability of the walker, none of the walking aid was found to be perfect. Gerard Lacey and Shane MacNamara (2000) described the design of advanced mobility aid and evaluation for people suffering from walking issues. Different types of sensors were used to gather data for navigational uses.

Based on this research, the existing solutions for walking aid significantly lack in fields like comfort, technology, and safety provided to the user. Thus, a better and more reliable design is hereby proposed to address the problems faced by the user. Comfort is improved by distributing equal weights on all the wheels (standing and sitting position) to enhance the combined stability of the walker. The technological advantage is offered by the addition of weight & proximity sensors to provide real-time information mainly to specially challenged users. The brakes are inducted into the design to improve the safety of the user. Also, there is a scope for the addition of a clutch mechanism in the automated version of the hybrid walker cum rollator. The design that is presented is more ergonomic because of its multi-purpose serving capability. It is also convenient to use due to its less weight which provides better mobility and lesser strain to the body of the user.

A. Anthropometric Measurements

Anthropometry is the science of measurement and the art of application that establishes the physical geometry, mass properties, and strength capabilities of the human body. These Anthropometric measurements will help to design the proper walker as they will provide dimensions of different body sizes. Anthropometric measurements are used in many fields. For example, athletes understand that body size and composition are important factors in sports performance. Anthropometric data had been taken from the table mentioned below which enables designers to perceive exact measurement and material conditions for designing. Hence, the data considered in the design is corresponding to India.

TABLE I

ANTHROPOMETRIC MEASUREMENTS OF WORLD [13]

Population	Sitting Height		Height		Foot Length	
	Female	Male	Female	Male	Female	Male
Japan	760	813	1476	1585	204	224
France	797	853	1481	1607	209	237
North Africa	770	807	1454	1527	217	237
West Africa	720	734	1402	1507	206	234
South America	783	846	1478	1608	205	227
North America	803	860	1494	1627	217	239
Spain and Portugal	780	804	1465	1533	198	228
North India	750	800	1412	1535	199	222
India	780	814	1469	1506	199	218
Eastern Europe	814	840	1502	1615	217	237
Northern Europe	823	880	1541	1668	217	232
Australia	810	860	1521	1607	212	244
Southeast Europe	790	830	1485	1595	212	237
Central Europe	803	870	1518	1575	212	232
Africa	750	790	1442	1545	202	232
Middle East	780	813	1496	1582	214	232
South India	723	743	1351	1485	194	217
China	720	770	1406	1590	204	224
Southeast Asia	730	763	1402	1495	201	214

Based on height and weight, the different candidates are chosen and give an idea about the anthropometric measurements of people and will help further in the design of the Walker. Based on the input measurements the material suitable for the walker is selected. Further, it may help to give an idea of the market the walker is concerned about.

TABLE II

DETAILS OF SELECTED CANDIDATE

Person	**Weight of the Person**	**Height of the Person**
Candidate 1	80	5’5’’
Candidate 2	84	5’10’’
Candidate 3	52	4’11’’

Based on weight and height three different candidates were studied. This data helped with the design of the walker as it shows the various measurement requirements of different persons.

METHODOLOGY

The key insights had been taken from the existing problems by identifying every aspect of the walker and ensuring the possibility of improving the current model and its function. The basic problems with existing walkers have been addressed in the design to increase the convenience of the users. The material is selected based on the design and load conditions on the walker. The CAD Modeling is done by using SOLIDWORKS software and lastly, the model is analyzed with different load conditions using ANSYS software. The design of this walker is modified by the addition of various sensors mainly the Obstacle sensor, GPS, and Load Sensor, which will increase the safety of and reduces the challenges faced by the elderly.

DESIGN AND ANALYSIS OF WALKER

The design calculations and analysis of the walker can be done by considering different load conditions on the walker and fulfilling the requirement of the user. The different materials can be used for the walker. But, making a lightweight walker and satisfy the loading condition is an essential part of the design. Table III shows the different materials and their properties which can be used for the walker.

TABLE III

MATERIALS AND ITS PROPERTIES USED FOR WALKER

Material	Tensile Strength (Mpa)	Yield Strength (Mpa)	Density (G/Cc)
Magnesium Alloy	230	160	1.81
Aluminum Alloy	300	241	2.7
Steel	400-550	250	7.8

A. Design calculations for Walker cum Rollator

The material for the walker is an Aluminium 6061-T6 pipe of thickness 1.5 mm is considered. The Allowable tensile strength of the selected material is 227 N/mm^2. The reactions on each wheel are3% of axial load which is negligible. The product is designed for a 120 kg person. According to research most of the load is transmitted to the frontal region of the walker. The load transmitted through the body is 90% of 120 kg (1177.2 N) i.e. approximately 1060 N. The front part walker bears the maximum load up to around 65 to 70% and the rear wheel bears 30 to 35% while walking. But there is a chance of getting more load on the backside while standing hence it is calculated according to full load condition as the product works as a wheelchair also.

To find out the diameter of the pipe front section is selected as it bears the maximum load. The assumption is made that the load transmits equally from both the vertical components of the frame. The maximum bending moment is calculated by shear force diagrams and bending moment diagrams. And with the help of bending Moment Equation we can calculate further the diameter of the shaft:

$$\frac{E}{R} = \frac{M}{I} = \frac{\sigma}{y} \qquad (1)$$

Where, σ is bending stress, y is the distance from the neutral axis, M is bending moment, I is the second moment, E is Young's modulus of elasticity and R is the radius of curvature.

i. Maximum bending moment, M =78175 N-mm

ii. Allowable Stress, $\sigma_b \frac{M \times Y_{max}}{I}$ (2)

iii. Moment of Inertia, $I = \frac{\pi d^3 t}{8}$ (3)

iv. Distance from Neutral axis, $Y_{max} = \frac{d}{2}$ (4)

v. Diameter, $d = 21.0385\ mm$, The nearest standard diameter is 25 mm i.e. 1 inch is selected from the manufacturer's catalogue.

B. Stability and mobility of the Walker

The stability and mobility of the walker can be defined by using the force diagram to understand the different forces acting on the walker. As per medical norms, the walker is required to be adjustable in height, such that the elbow flexion is 30 degrees. Else the gait and standing stability is assumed to be impaired. [10]. Walker Tipping Index (WTI) indicates how likely the model is to tip over due to vertical and horizontal forces that are acting on the body of the walker. Further, normalizing the tipping index with respect to the bodyweight that is being transferred on the device.

i. Centre of force for walker

The centre of force is the force that is radially pointing and the magnitude is dependent on the distance from the source. Examples of central forces are gravitational force, electrostatic forces, and spring force. It is used to define the stability of the body. The centre of the force is calculated by considering the load which is transmitted to the frontal and rear part of the walker. It is assumed that F_1 and F_2 are the loads is transmitted towards the front end of the walker and, F_3 and F_4 are the loads transmitted to the rear part of the walker. It can be determined that about 65% of the load is transmitted towards the front end and the remaining 35% of the load is transmitted to the rear part of the walker.

F_1=F_2= 689.0 N (65% of the load transmitted)

F_3= F_4= 371.0 N (35% of the load transmitted)

The centre of force in the horizontal direction COF_X and vertical direction COF_Y is calculated by:

$$COF_X = \frac{W_{12}(F_1 - F_2) + W_{43}(F_4 - F_3)}{2(F_1 + F_2 + F_3 + F_4)} \quad (5)$$

$$COF_y = \frac{L\,(F_1 - F_4) + L\,(F_4 - F_3)}{2(F_1 + F_2 + F_3 + F_4)} \quad (6)$$

Where, Depth of walkers, L=1030.5 mm; Distance between the front wheel and rear wheels, W_{12}= W_{43}=600 mm. Solving the above equations, COF_X= 0 mm and COF_Y=77.287 mm. Based on calculations the design of the walker can be interpreted and thus the walker can be further analyzed.

ii. Walker Tipping Index (WTI)

The tipping force (F_t) and the force applied in the vertical direction (F_v) on the handle of the walker by the user also considering the perpendicular distance are used to determine Walker's Tipping index. Vertical (F_y) and anterior (F_x) forces that are acting on the walker frame is illustrated in Fig.1. Anterior force (F_x) creates a moment of force when it is applied to the handles of the walker. This force will incite the walker to tip forward.

To avoid the walker from tipping forward, this forward force (F_x) that creates a moment should be less than the moment created by vertical force (F_y). F_y is applied at a distance of (r_p) (perpendicular distance from the front end of the walker). By using data obtained from the centre of pressure and forces acting upon the walker frame, a WTI curve can be generated which can give an idea of the stability of the walker in all four directions.

The four directions of the walker are represented as,

$WTI_{forward}$: Over front arms

$WTI_{backward}$: Over the rear arms

$WTI_{prosthetic\ sidex}$: Ipsilateral position (beside the prosthetic leg)

$WTI_{intact\ sidex}$: Contralateral position (Beside the intact leg).

The stability of the walker will be relatively lower if the WTI curve is high.

$$WTI = \frac{F_x \times walker\ height}{F_y \times r_p} \times 100\ \% \quad (7)$$

Where F_y is a vertical force, F_x is the horizontal force acting perpendicular to the axis, r_p is the perpendicular distance of the walker (centre of pressure) to the axis. The walker height is the distance between the handles of the walker to the floor.

The WTI is defined as follows:

$$WTI = \frac{(\sum F_t \times R_t)}{(\sum F_v \times R_v)} \quad (8)$$

Where, the distances of (F_v) and (F_t) from the tipping axis are (R_v) and (R_t), respectively.

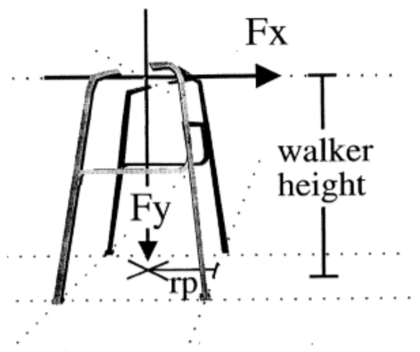


Fig.1. Representation of (F_x) and (F_y) [10]

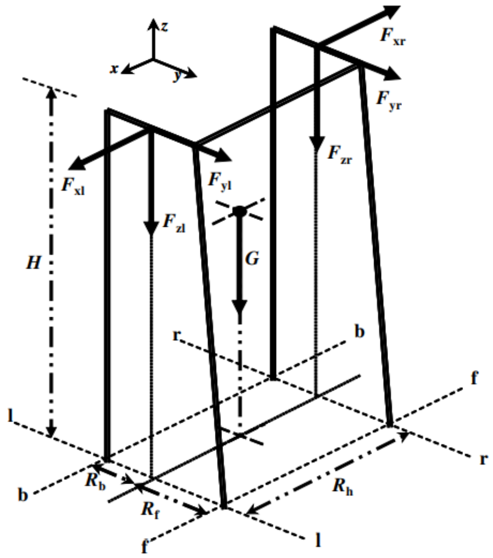


Fig.2. Free Body Diagram of walker [19]

iii. Height of walker

The stability is dependent on Walker Tipping Index and the height of the walker is decided based on WTI [10]. The user body weight is also a deciding factor in the adjustment of the height of the walker. This walker is designed for height suitable for the user and also to not affect the stability of the walker.

C. Computer-Aided Design Model for Walker cum Rollator

The CAD Model gives the idea about the prototype and due to its loading conditions can be analyzed. CAD Model of this walker is prepared on SOLID WORKS modelling software. The material properties became critical for testing how the design will behave under different loading conditions, before investing time and money into the construction of a real prototype. The CAD model is designed to suit the safety of the user and to ease the problem of the elderly section of society. This design has been done so that no toppling takes place during the usage of this walker.

Fig.3. CAD Model of Walker

Fig.4. Sitting Position in Walker cum Rollator

D. Analysis of Walker cum Rollator

The analysis was performed on ANSYS software considering the material that was used for the manufacturing of the product and applied 1177.2 N loads on it, to get the results for maximum deformation and stress at critical point. The analysis was purely based on the safety conditions of the user and the sustainability of the product. TABLE IV shows the properties of Aluminium 6061-T6.

TABLE IV

MATERIAL PROPERTIES

Properties	**Unit**	**Magnitude**
Density	g/cc	2.7
Poisson’s Ratio	-	0.33
Tensile Yield Strength	MPa	276
Ultimate Tensile Strength	MPa	310
Modulus of Elasticity	GPa	68.9

a) Analysis of Walker cum Rollator for Seated Position

The seat of the walker cum rollator is designed for an individual weighing a maximum of 120 kg and who is at an average height of between 5.5 ft and 6 ft tall. The seat has been positioned in such a way that when an individual would sit upon it, the load will be equally distributed amongst all four of its wheels, maintaining a suitable centre of gravity so that the chances of rollover is minor and wear of all the parts of the walker cum rollator occurs uniformly and gradually. In fig. 5, A (Blue highlight) are two fixed supports, and point B (red highlight) is the region where the load is to be applied. The respective deformation and maximum principal stress are noted from the result.

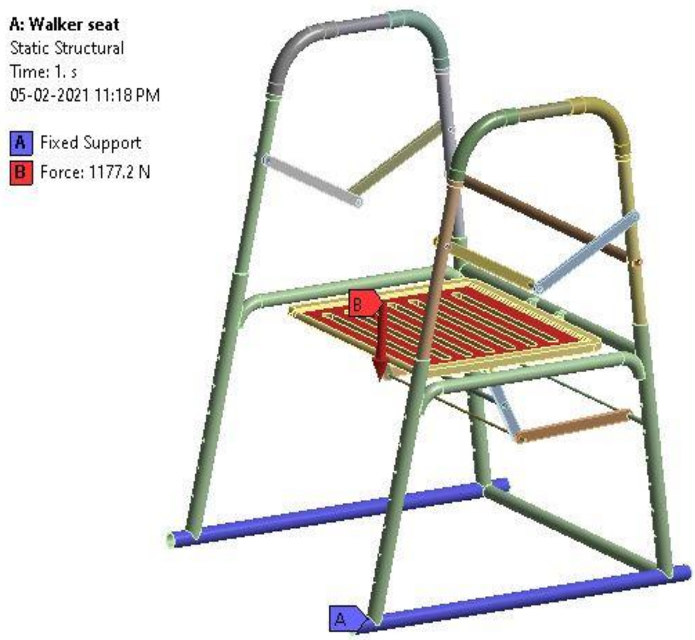
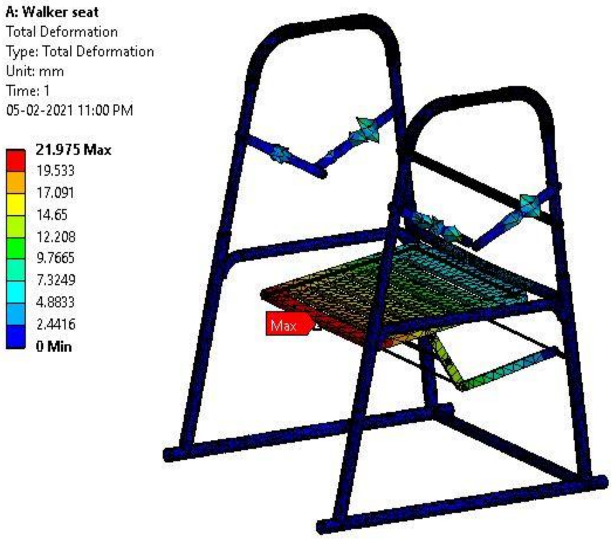


Fig.5. Force Analysis of Walker cum Rollator for Seated Position

A load of 1177.2 N is applied to the seat. The maximum deformation is observed at the front end of the seat. The maximum deformation after the analysis is 21.975 mm. This level of deformation does not occur instantly though the time in which the load is applied over the seat is swift. The deformation in the design can be reduced by adding a bar across the seat without much increase in the weight or by adding appropriate supports to the front end of the seat.



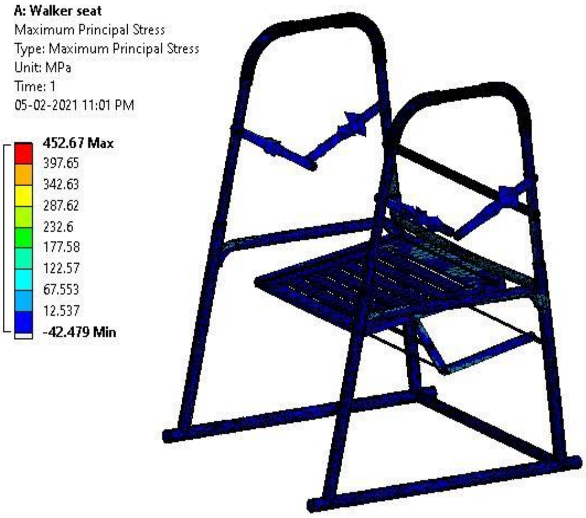


Fig.6. Total Deformation in walker seat

Fig.7. Maximum Principal Stress in the walker for Seated Position

From Fig. 6 and Fig. 7, it is concluding that the maximum principal stress undergone when an individual would take a seat. From fig. 6, the total deformation in the walker is 21.975 MPa and from fig.7, the maximum principal stress was turned out to be 452.67 MPa.

b) Analysis of Walker cum Rollator for Standing Position

In the case when the model will have to be used as a walker, the seat is made such that it can be folded downwards, allowing the individual to stand in between like any other normal walker and use it comfortably. While performing this analysis, the factor being such that the load will be applied on the handles gradually rather than instantly is considered. In fig. 8, A (Blue highlight) are two fixed supports and, point B and C (red highlight) are the regions where the load is to be applied. Again, the respective deformation and maximum principal stress are noted from the result.

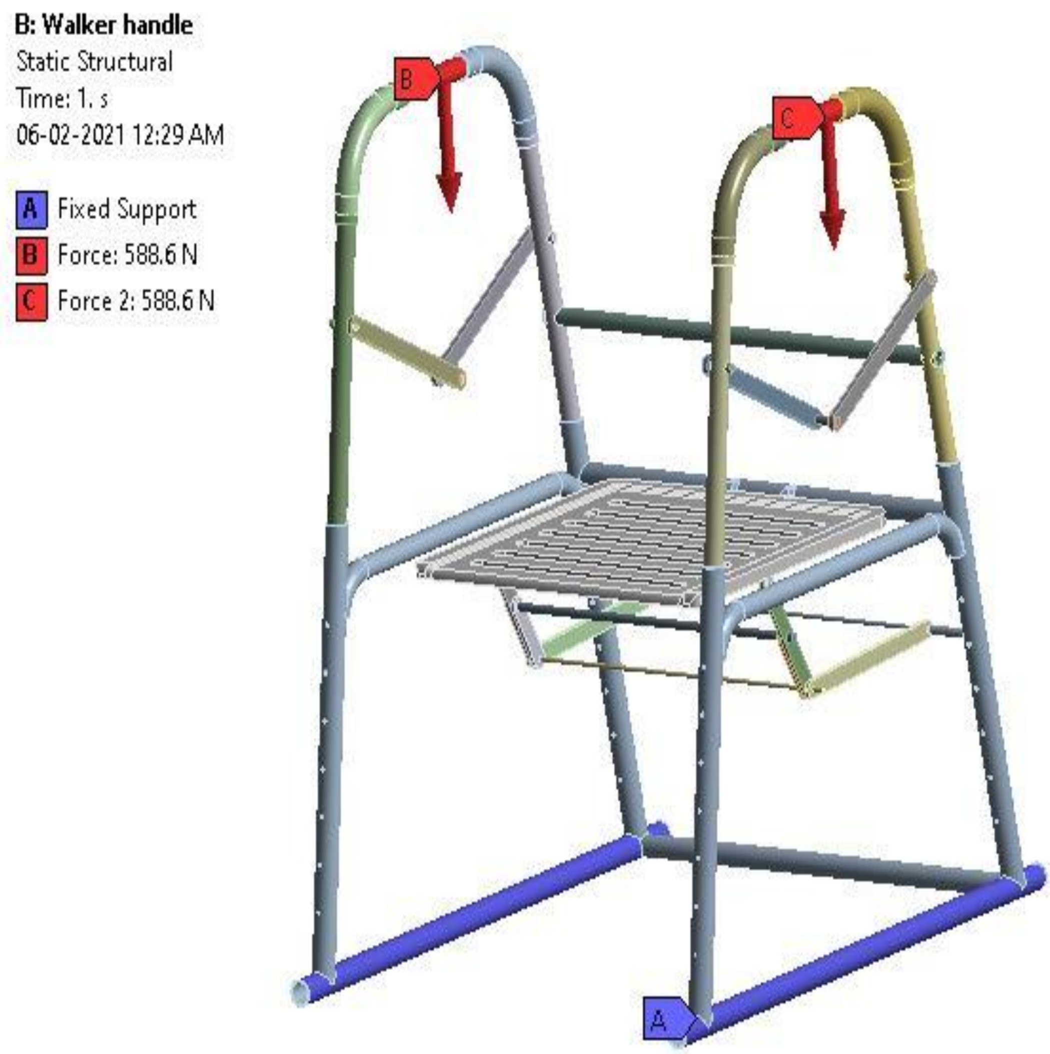


Fig.8. Force Analysis of Walker cum Rollator for Standing Position

From fig. 8 and fig. 9, the total deformation occurring on the handle is 41.495 mm and the maximum principal stress on the handle is 486.7 MPa. It can conclude that, from the above results design of the walker cum rollator is reliable.

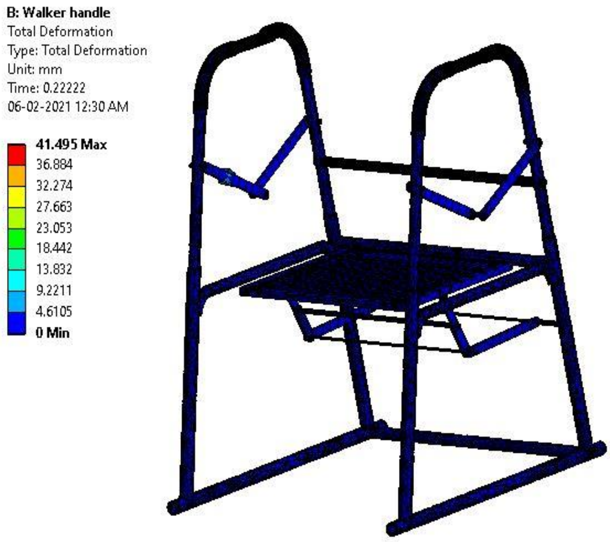


Fig.9. Total Deformation in the handle section

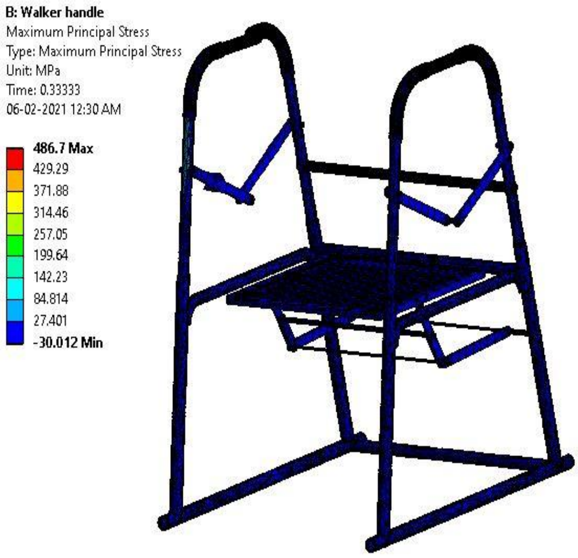


Fig.10. Maximum Principal Stress in the walker for Standing Position

E. Advancement in Design of Walker

The various sensors are added to this walker so that the blind or visually impaired can travel safely. For instance, the obstacle sensor may protect the user from any accident, and with the help of GPS sensors the user's locations can be easily accessible to family members which increases the safety of the user.

a) Obstacle Sensor (Proximity Sensor)

The built-in IR transmitter and receiver in the Infrared Obstacle Sensor Module send out IR energy and search for reflected IR energy to detect the presence of any obstacle in front of the sensor module. The detection range can be adjusted using an onboard potentiometer. When it comes into contact with an obstacle, the sensor will finally stop working.

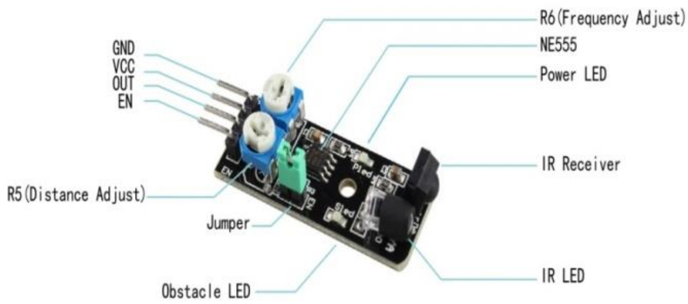


Fig 11 Obstacle Sensor [14]

b) Global Positioning System (GPS)

These sensors are receivers with antennas that use a satellite mode of communication to provide information of velocity, timing and precise location via a network of orbiting satellites in lower earth orbit. GPS does not only help to track the location of the device also it may transmit the location of the user to any other devices with data service according to the situation.

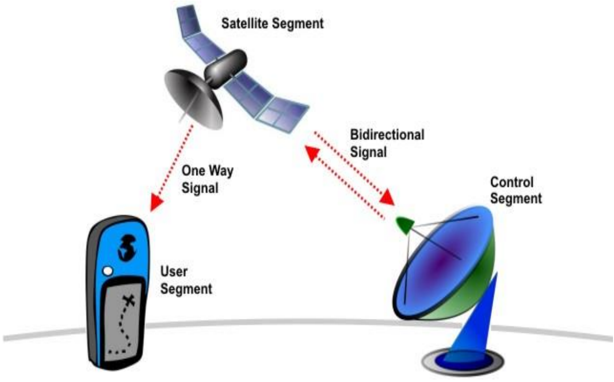


Fig 12 Global Positioning System (GPS) [15]

Fig 13 Load Sensor [16]

c) Load Sensor

Load sensors can be used in the walker with the help of the input of load cells, load sensors can be used in the walker. A force transducer is a load cell. It turns a force such as tension, compression, strain, or torque into a tangible and structured electrical signal. The electrical signal changes proportionally to the force applied to the load cell. Eventually, the alarm can also be compiled with this setup. Whenever the given weight on the walker is exceeded the alarm will start and warned the user about weight being exceeded beyond operational limits.

CONCLUSION

Through this research paper, the aim is to reach out to the elderly section with a walking disability and provide them with a better lifestyle and independence. The design is done with the aim of it being as ergonomic, light, and user friendly as possible. The main advantage of making this design of walkers is that most of the products available in the market are just for walking and thus the people have to invest in other products along with the wheelchairs, rollator, etc. This design is made such that it serves two purposes of it being a walker and rollator with adjustable height by considering anthropometric measurements of the user. If these types of walkers roll out in the market of today's times it will have a huge impact on the society of elderly people, who will not only be helped by these convenient walkers but also be able to lead easy and comforting lives. Lastly, this will also help other developers to improve the existing models further in other to provide our elder generation with the respect and comfort they deserve.

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