DEVELOPMENT OF AN ERGONOMICALLY DESIGNED WALKER

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Abstract - Over the year's walker or rollator have helped many elderly people to overcome the barrier of dependency.
Differently able person can enter all type of field in current days. So, we can provide more facility to them, for that reason we can select this project, in this walker by attached the sitting plate in the walker itself it gives more facility to them. The design features a full frame walker that provides secured and stable support while being foldable and compact. By this walker we can sit anywhere at any time easily. 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.

***Key Words*:** Walker, Design, Load Analysis, Mobility, Ergonomics, Anthropometry, Product Evaluation

1. INTRODUCTION

For several years, researchers have been addressing the needs of persons with mobility disabilities through alternative or augmentative devices. These solutions are selected based on the degree of disability of the user. For the purposes of this reviews will present, on the one hand, alternative devices, which are used in case of total incapacity of mobility. These devices are usually wheelchairs or solutions based on autonomous especial vehicles. On the other hand, the augmentative devices are developed to users with residual mobility capacities. They are used to avoid, whenever possible, the inadequate use of alternative devices, thus improving the physical and cognitive capabilities. These elements can be used as mobility-training devices, self-portable devices, such as prostheses or external, such as crutches, canes and walkers. These equipment allow the user to walk on plane surfaces only. These make them dependent on external help during climbing up the elevated surfaces. By using low cost we can made the walker when a person walk for a long distance if they can tried they can sit easily by using the same walker. So, they can be relaxed easily. Technology bridges the gap between able and differently able persons. There should be changes made in the existing design of walker to solve this problem allow the user to be independent. The aim for this project was to develop a rollator adapted for the "next generation", with new norms and demand that still fulfil the main function of a traditional rollator. One goal was to create an age independent solution that meet the demands connected to both function and aesthetics. For example the rollator should have a low weight, seating palace, basket and be accepted product in the society. The solution should increase and inspire to a healthier and longer life as a flexible an independent person.

The process of fabrication is initiated from conceptual design stage by considering the advantages as well simplicity. Basically the entire Design and Fabrication of this project could be divided into 3 stages which are concept review and fabrication, designing and make finishing. The walker with extension for spinal cord injuries patients is equipped by using all items and methods for instance aluminium, screw, bearing, gas springs and also skills in manufacturing process like welding to join all the parts together. Practical fabrication and design involves the measurement, marking, cutting the material into required dimensions, assembly and lastly is making finishing.

Some of the available designs of the walkers are studied.

1.1 Standard Walker

It has use the aluminium crutch with high quality aluminium alloy treated for the surface and sponge for the handle. These walkers have a gear for the height adjustment and also anti-skidding rubber foot-pads with slice inside it, which make it more durable. It has come for the free size.

Material	(a) Aluminium alloy treated on surface (b)Sponge foaming handle.
Advantages	(a)Anti skidding rubber foot pads and metal slice inside which make it durable (b) gears for height adjustment

1.2 Rollite Walker

This type of walkers are totally are made from the lightweight aluminium for the frame. It has come with 27 inches for overall width and 32-36 inch for the height adjustment. It weight are around 300 lb. This Rollite rollator are easier to handle because it has come with a roller to make it easy to move. It also has the ergonomic hand brakes lock the rear wheels for the security.

Material	(a)Lightweight aluminium frame with blue colour
Advantages	(a) Flexible backrest for comfort. (b) Ergonomic hand brakes lock the rear wheels for security (c) Flip-up seat with built-in handle

1.3 Walklite Walker

This walker has been made from light aluminium. The dimension of this walker is 80-90cm for height and 44.2cm for the width and 5.7kg weight. These have only rollers on the back wheel and have no brakes been made from light aluminium.

Materials	(a)Durable aluminium provides strength while remaining light weight (b) Contoured, plastic grips for enhanced comfort and a secure hold.
Advantages	(a)The secondary handles provide stable assistance from a seated to a standing position. (b) Single release folding mechanism is designed to aid users with limited hand dexterity. (c) Can be used as a portable toilet safety frame

1.4 Project Objective

There are two main objectives to achieve in this research which are:

a) To help in rehabilitating injured users and to allow users with permanent disabilities as well as to move without aid

b) To designed and fabricate adjustable and portable 4-legs walker.

2. LITERATURE REVIEW

The following resources helped us getting an insights about the walkers, therefore converting our abstract idea into solid form-

1. 01 Aug 2011, 113(1):229-241 DOI: 10.2466/10.15.26.pms.113.4.229-241 PMID: 21987922

In this paper researches draws our attention toward wrist deviation and vertical force among elderly individuals using a walker for assistance to stand up and sit down.

2. 12 Mar 2012, 6(1):14504-NaN DOI: 10.1115/1.4005786 PMID: 23904904 PMCID: PMC3707190

In this a detailed steps for the design, development and fabrication of walker is given. It suggest how we can use bilateral gas springs so that we can design non-electrically powered walker to provide upward lift.

3. 30 Sep 2017, 81(1):81-86 DOI: 10.1016/j.jcma.2017.04.009 PMID: 28974355

In this paper, design of additional armrest is given. It can be attached to a standard walker for users performing sit-to-stand transaction more easily and evaluate it with clinical assessments and a body worn sensor.

Table-1: Approximate dimension of the purposed Walker

DIMENSION	MEASUREMENT
Length	0.8 meter
Breadth	1 meter
Side Support rod height	1.35 meter
Platform rest height	0.85 meter

4. Nurul Ariff Ah Binti Hamidi gave the design procedure of his 4 different concepts and distinguish between major advantages and disadvantages of four concept designs by switching base as flat, rubber, and changing heights.
5. F. Nickpour and C. O'Sullivano found out that many of the features and components of different walking aids are similar and can be rearranged to form various better walking aids. Their focus was on the design to be more accessible and less costly. Design principles on which the foundation is laid is affordability and evolvability.
6. Ahmad Muammar Bin Md Yasin, Lim Wei Liong, Patrick S. K. Chua*, Zheng Jianxin proposed a new design of walker which is handier, compact and user-friendly. In this paper, first of all, the previous design is considered, and their cons are removed in the new design.
7. Maria Joseph published a journal on Aluminium. A metal of choice. In this they describe the properties of Aluminium. Aluminium is a light, conductive, corrosion-resistant metal with a strong affinity for oxygen.

3. METHODOLOGY

3.1 Design and Fabrication

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 frame is similar to standard walker, which are stable and mobile but provide no lift assistance. To minimize weight & enhance modularity, the base will be constructed from aluminium alloy 6061 piping connected by structural fittings. A novel pneumatic elevator assembly will be design to lift the platform. Commercially available, remote release gas springs with range of motion will be choose as the actuators for the lifting mechanism. Each spring contains a locking valve controlled by a hydraulically actuated pin within the rod end, when the pin is released (the button is pushed) the rod end is free to move. When the pin is engaged the gas springs are locked at their current position.

3.2 Material Selection

The frame is being constructed from Aluminium alloy 6061 because of the following properties:
1. It is a medium to high strength heat-treatable alloy.
2. It is very good to corrosion resistance.
3. It has very good weld ability.
4. It has good machinability.

3.3 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-2: Anthropometric measurements of world

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.

3.4 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.

4. 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/mm2. 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:

$E/R = M/I = \sigma/y$ (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, σb M×Y_{max} /I
III. Moment of Inertia, I = πd 3t/8
IV. Distance from Neutral axis, Y_{max} = d/2
V. Diameter, d = 21.0385 mm.

The nearest standard diameter is 25 mm i.e. 1 inch is selected from the manufacturer's catalogue.

4.1 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:

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

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

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.

$$WTI = \frac{F_x \times walker\ height}{F_y \times r_p} \times 100\ \%$$

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:

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

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

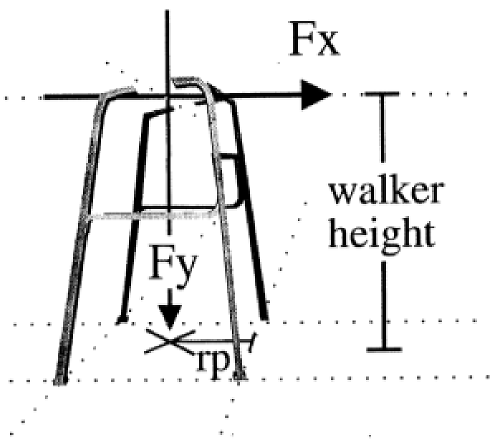


Fig-1: Representation of (F_x) and (F_y)

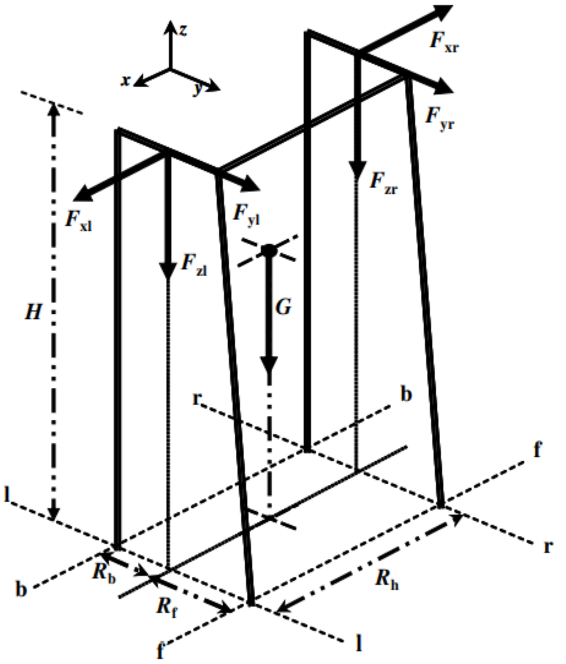


Fig-2: Free Body Diagram of walker

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.

5. WORKING

For user interface it contains widely available platform with manual height adjustment. The platforms allow users with hand grips capabilities to walk & supporting body weight through the shoulders. This platform will move relative to the frame through extension / compression of bilateral gas springs. Materials are proposed for the fabrication of the walker is aluminium 6061 gas springs. Two gas spring actuators will be attach bilaterally to create the pneumatic elevator assembly. Vertical motion of the bilateral springs is coupled through a single hydraulic push button release system, allowing to release of bot springs with the push of one button is not compressed. Once upright, the button is released to lock the springs. To sit, the user simply pushes the button & user body weight to compress the cylinders.

The rollator consist of several different parts, the parts are illustrated in figure4 and listed in the table 1, below.

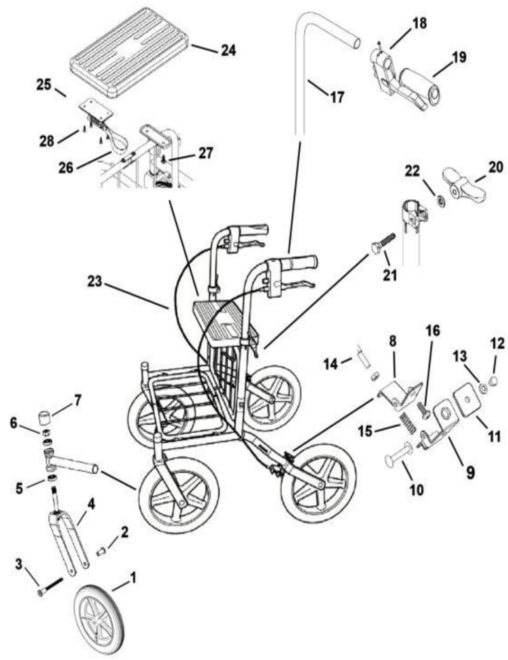


Fig -3: Rollator Parts

Table-3: Rollator Parts

1) Complete wheel	9) Brake outer part	17) Handlebar ERGO
2) Wheel nut	10) Wear plate	18) Wing nut
3) Stud	11) Screw M6*16	19) Screw
4) Front fork	12) Tray	20) Seat cushion
5) Bearings	13) Adjusting Screw with lock nut	21) Gate lock
6) Locking nut	14) spring	22) Towing eye
7) Cover hat	15) Handle tube	23) Screw M6*20
8) Brake inner part	16) Handle Brake	24) Screw gate lock

Possible accessories

- Basket- max load 10 kg
- Tray-max load 2 kg
- Cane holder
- Back support
- Oxygen Holder- max load 5 kg
- Slow down brake
- One-hand brake
- Splash guard.

5.1 Gas Spring Construction

Gas springs can be defined as hydro-pneumatic, energy storage elements. Nitrogen gas and oil are utilized for providing compressible and damping (motion control) mediums. Gas springs can be configured to meet a wide range of requirements. Gas springs equation consist of a precision rod attached to a piston, moving within a sealed cylinder containing pressurized nitrogen gas and oil. Their force (F) is equal to the pressure differential (P) between internal and external (environment) pressures, acting on the cross-sectional area of the rod (A). While for most applications ΔP (pressure differential) can be approximated by the spring's internal pressure (P), ΔP must be taken in consideration for gas springs used in high pressure environments (e.g. Sub-sea applications).

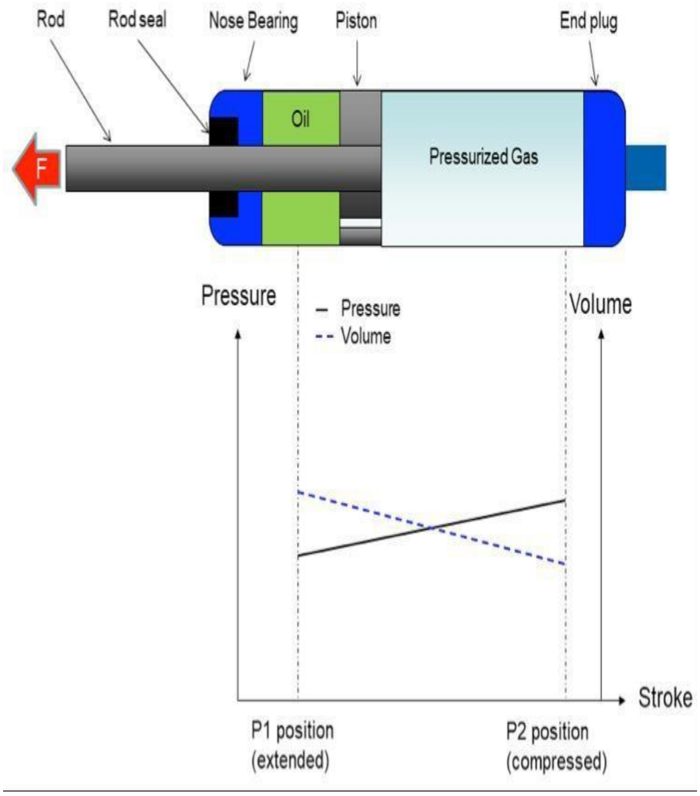


Fig -4: Gas Spring schematic - Pressure/ Volume vs. stroke diagram. As the piston moves from the fully extended position (P1) to the fully compressed position (P2), the pressure (solid line) rises and the volume (dashed line) reduces.

As the Piston rod introduced into the cylinder i.e., compressible stroke, the internal gas volume increases resulting in proportional increase in pressure (Boyle's law). Consequently the force of a gas spring is higher when the rod is compressed (see Fig. 1)
The difference between the forces seen at the two extreme rod positions- named P1-force and P2- force respectively- is an important gas spring characteristic and called K-factor (IGS) or gas spring progression. When compared to mechanical springs, gas springs can achieve very low K-Factors, typically ranging from 1.05 to 1.8 (or %-80% progression). Unlike coil springs, gas springs are pre- loaded (pressurized) at the required P1-force which is available immediately. For this reason, P1 force must be taken in account when calculating the force of a gas spring at a given position: Where F is the force of a gas spring, k is the spring constant expressed in N/mm (force change per unit of compression) and X is the deflection distance in mm.

5.2 Quantification of stability

Stability of rollator users was quantified using the methodology developed by Costamagna et al. [10], which, for the first time, looked at the user and their walking aid as a single combined system and quantified stability by calculating the combined (or system) Stability Margin (SM System) of user and device from wheel-force, insole-pressure, and position data using bespoke Matlab algorithms. SM System is defined as the shortest distance between the Centre of Pressure of the combined system (CoP System) and the nearest edge of the combined Base of Support (BoS System) (Fig 1) and indicates how far the system is from tipping; hence, the higher SM System, the more stable the system is. Fig 1 shows how the size of BoS System can vary, including double support with the rollator grounded, single support with the rollator grounded, and double support with the rollator lifted (e.g. when the user is in the process of stepping onto a ker). It seems reasonable to think that when BoS System is smaller, SM System is also likely to be smaller; but this should not be confused with an unsafe gait as BoS System may well be being sensibly utilised. For this reason, SM System has been normalised by a parameter representative of the size of BoS System (Eq. 1).

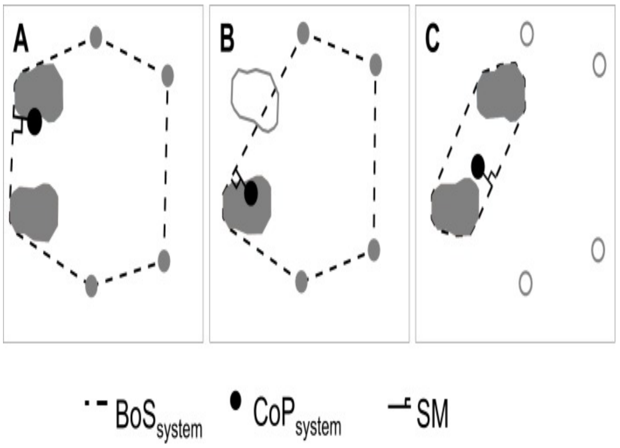


Fig -5: Examples of combined centre of pressure, combined base of support and system Stability Margin.

Examples of combined centre of pressure, combined base of support and system Stability Margin for 3 cases: A) all 6 feet on the ground; B) 4 rollator feet on the ground and user in single support on their right foot; C) user in double support and rollator fully airborne (e.g. being lifted up a step). Grey foot prints indicate feet that are grounded; white foot prints indicate feet that are airborne.

6. RESULT

Static analysis is performed on chassis using Autodesk's Fusion 360 software considering following 3 materials and load is considered of 100 N

1. Aluminium – High Strength Alloy
2. Mild Steel
3. Stainless Steel

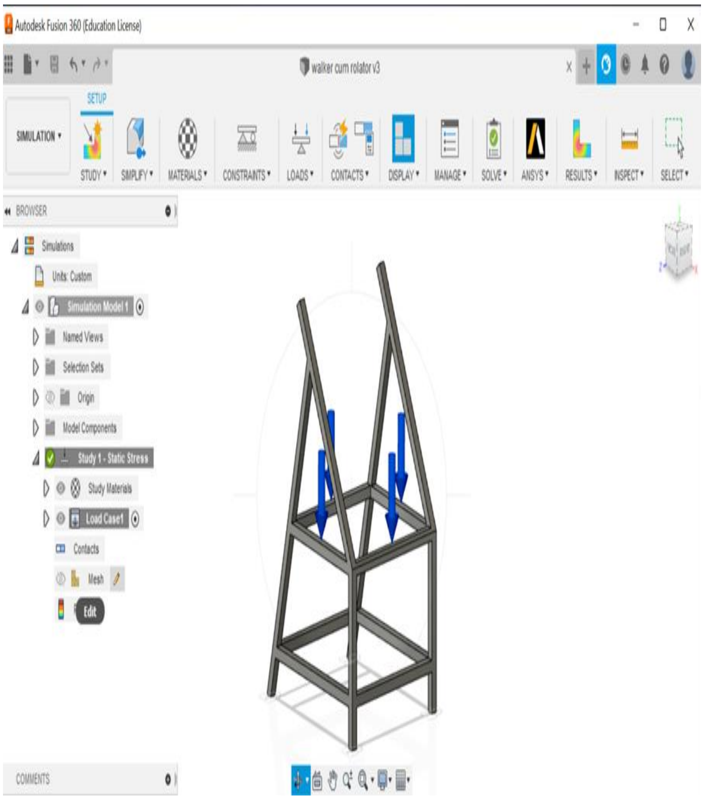


Fig -6.1: Application of Load

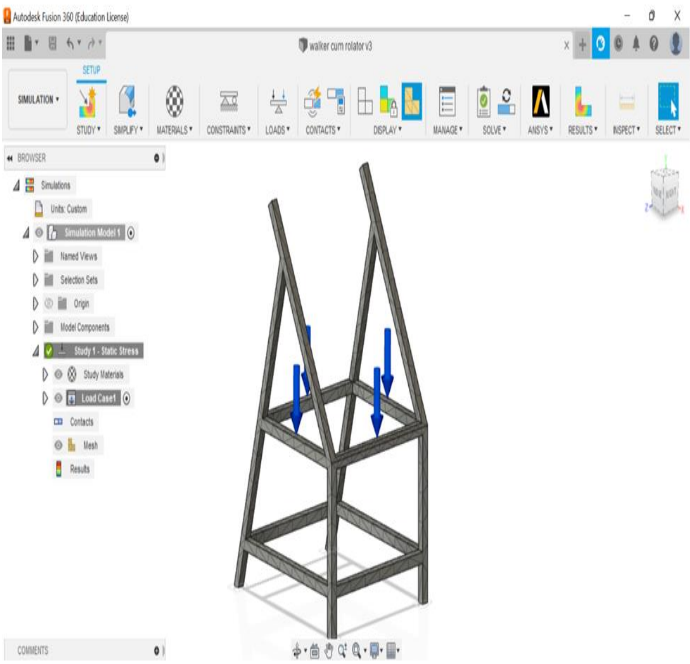


Fig -6.2

6.1 Aluminium – High Strength Alloy

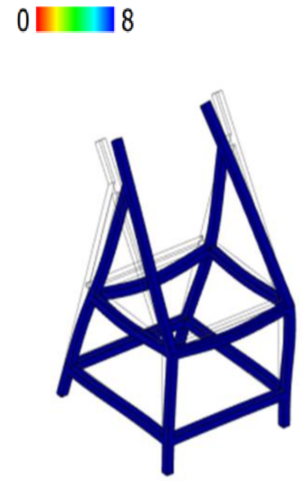
6.1.1 Properties

Aluminum - High-Strength Alloy

Density	2.78E-06 kg / mm^3
Young's Modulus	73080 MPa
Poisson's Ratio	0.33
Yield Strength	324.1 MPa
Ultimate Tensile Strength	468.8 MPa
Thermal Conductivity	0.134 W / (mm C)
Thermal Expansion Coefficient	2.3E-05 / C
Specific Heat	880 J / (kg C)

Safety Factor

Safety Factor (Per Body)

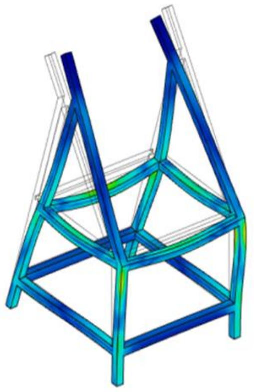


Result Summary

Name	Minimum	Maximum
Safety Factor		
Safety Factor (Per Body)	15	15

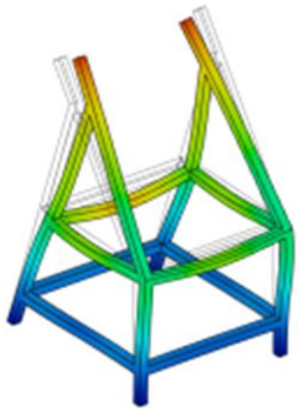
Von Mises

[MPa] 0 – 0.5572



Displacement

Total
[mm] 0 0.0125



6.2 Mild Steel

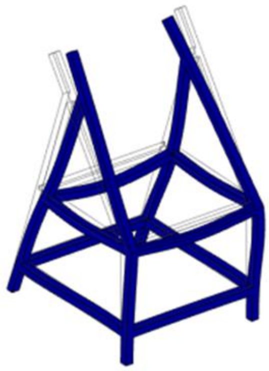
6.2.1 Properties

Steel, Mild

Density	7.85E-06 kg / mm^3
Young's Modulus	220000 MPa
Poisson's Ratio	0.275
Yield Strength	207 MPa
Ultimate Tensile Strength	345 MPa
Thermal Conductivity	0.045 W / (mm C)
Thermal Expansion Coefficient	1.2E-05 / C
Specific Heat	480 J / (kg C)

Safety Factor

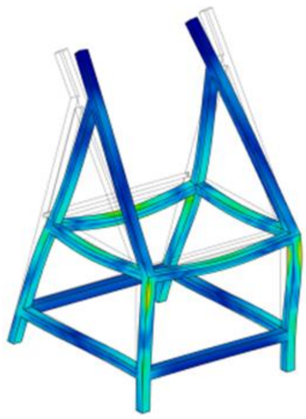
Safety Factor (Per Body)
0 8



Result Summary

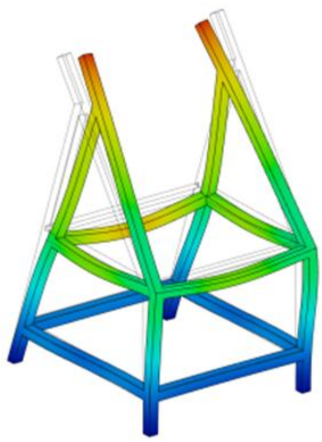
Name	Minimum	Maximum
Safety Factor		
Safety Factor (Per Body)	15	15

Von Mises
[MPa] 0 0.5634



Displacement

Total
[mm] 0 0.00416



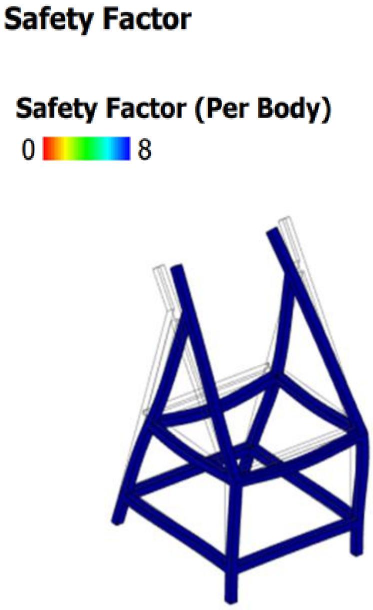
International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 06 Issue: 10 | October - 2022 Impact Factor: 7.185 ISSN: 2582-3930

6.3 Stainless Steel 202

6.3.1 Properties

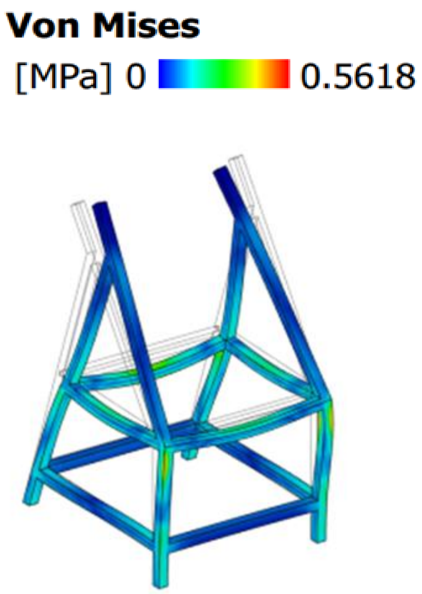
Stainless Steel AISI 202

Density	7.855E-06 kg / mm^3
Young's Modulus	204773 MPa
Poisson's Ratio	0.29
Yield Strength	412.3 MPa
Ultimate Tensile Strength	667.4 MPa
Thermal Conductivity	0.0162 W / (mm C)
Thermal Expansion Coefficient	1.24E-05 / C
Specific Heat	500 J / (kg C)



Result Summary

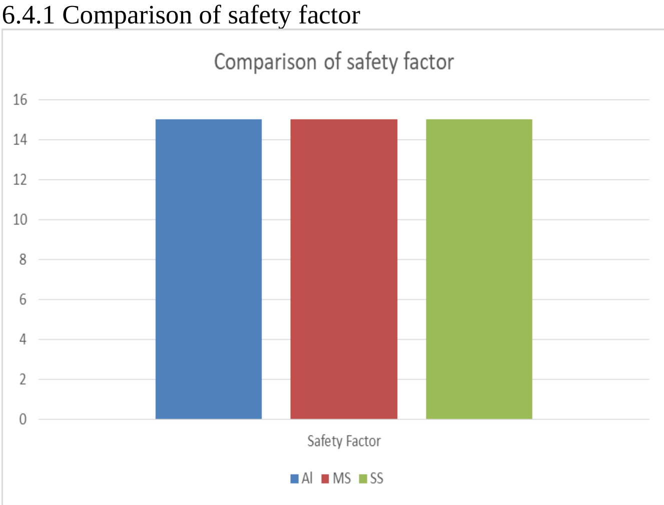
Name	Minimum	Maximum
Safety Factor		
Safety Factor (Per Body)	15	15



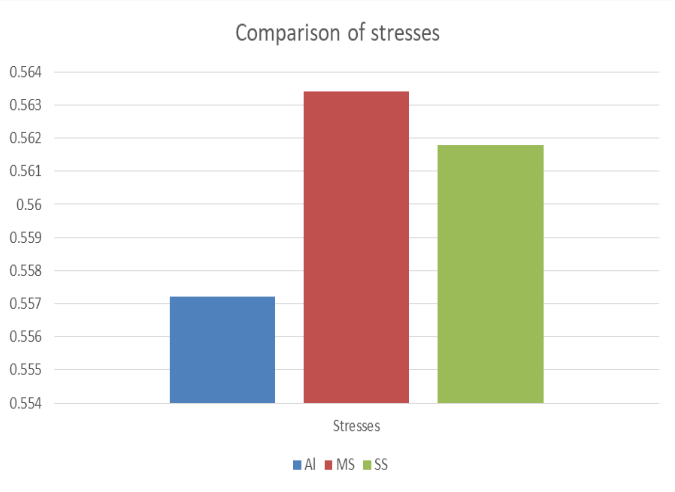
6.4 Result Comparison

Sr. No.	Material	Maximum Safety Factor	Maximum Stress (Mpa)	Maximum Deformation (mm)
1	Aluminium – High Strength Alloy	15	0.5572	0.0125
2	Mild Steel	15	0.5634	0.00416
3	Stainless Steel	15	0.5618	0.004468

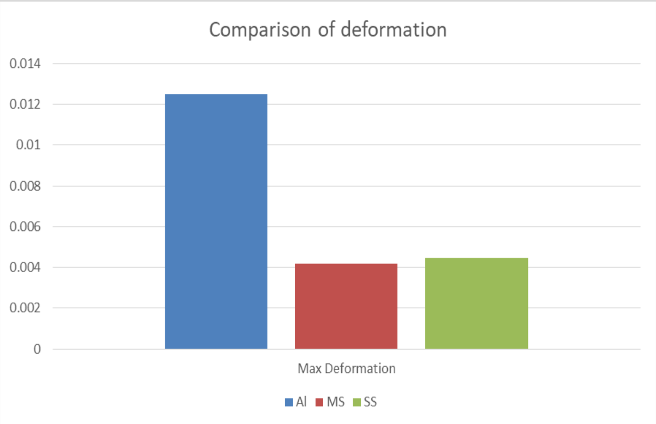
6.4.1 Comparison of safety factor



6.4.2 Comparison of stresses



6.4.3 Comparison of deformation



7. ANALYSIS CONCLUSION

As the result compared we came to know that,

1. Aluminum have higher deformation among others and also it is more expensive than others so that it is not feasible to use for chassis.
2. Mild Steel develops more stress and less deformation against the load application as compare to others. Also its surface is very rough to use and it is not rust proof. Hence mild steel is not feasible.
3. Stainless steel shows nearly same deformation as mild steel and also it develops less stress compare to mild steel. Stainless steel have very smooth surface and it is rustproof also. Hence we selected stainless steel as the material of chassis.

8. CONCLUSIONS

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. The sitting plate was attached in the walker itself so they can walk by using this walker and they can sit in the walker when they tired or when they need that facility definitely this walker bridge the gap between the able and disable people.

ACKNOWLEDGEMENT

I take this opportunity to thanks Prof P.S. Bajaj for his valuable guidance and for providing all the necessary facilities, which were indispensable in completion of this work. First of all I am thankful to Prof A. V. Patil (H.O.D, Mechanical Engineering Department.) and also thankful to Prof. Dr. R. B. Barjibhe (Dean, Academics & Administration) to give us presentation facility.
I am also thankful to all staff member of the Mechanical Engineering Department. I would also like to thank the college for providing required journals, books and access to the internet for collecting information related to the project. Finally I am also thankful to my friends and well wishers for their valuable comments and suggestions.

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