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Design of Innovative Motorized Tricycle for the Disabled Person

[#1] Tatyaso A. Garande, [#2]P.D. Sonawane, [#3]S.T.Chavan, [#4]G.S.Barpande

[1]tatyagarande@gmail.com

[2]pushkaraj.sonawane@mitpune.edu.in

[3]sandip.chavan@mitpune.edu.in

[4]girish.barpande@mitpune.edu.in

[#1]ME Mechanical Design Scholar, Mechanical Engineering Department,Maharashtra Institute of Technology, Kothrud, Pune

[#2]Assistant Professor, Mechanical Engineering Department, Maharashtra Institute of Technology, Kothrud, Pune, India

[#3]Professor,Mechanical Engineering Department, Maharashtra Institute of Technology, Kothrud, Pune, India

[# 4]Associate Professor,Mechanical Engineering Department, Maharashtra Institute of Technology, Kothrud, Pune, India.

ABSTRACT

Nowadays, transportation is inseparable part of human life. Normal person can travel easily by utilizing the facilities such as bicycles, bikes, cars, public transports, etc., but for disabled persons travelling is not so easy. Depending upon the disability (i.e. which part of body is not in function), disabled person can avail travelling facilities such as tricycles, wheelchairs, customized vehicles like bikes, cars, buses etc. But these facilities are not easily accessible for disabled persons due to some difficulties like limitation on distance travelled in case of automated wheelchairs, more physical work for user in case of manual wheelchair and tricycles. Then Retrofitted bikes are much easy and suitable option for those who can easily get into the riders place but persons with severe leg disability are unable to come out from wheelchair and get into the riders position. This problem is solved in case of modified cars and buses as there is provision to get in and out of the vehicle by siting on the wheelchair as it is but this option is more costly. So there is need of solution, which will be less costly and allows the disabled person to take the drivers position without coming out from the wheelchair. In this project we have tried to give most suitable and less costly solution for persons with severe leg disabilities.

*Keywords***—** **Analysis, Disability, Innovative, Meshing, Mode Shape, Retrofit, Wheelchair**

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I. INTRODUCTION

In human life transportation is playing very important role from ancient time, due to transportation and communication facilities we say that, world is coming closer and closer. Day by day new vehicles with variety of models are coming into market. Normal person i.e. person without any disability can avail this vehicles easily. But in our society the number of disabled persons is also considerable, some of them born with disability, some get disabled due to accidents (road, workplace, natural calamities, etc.), large number of persons get disabled due to war activities and due to many other factors. Depending upon the severity of disability, the disabled persons can use the transportation facilities; persons with lesser disability can use the facilities as it is for normal persons, some persons are able to use the vehicles with little bit modifications like retrofitted bikes and cars. There are some utilities like wheelchairs, tricycles which are used by the disabled persons. In some cases the disability is so severe that person can't move from one place to other place without help. The persons with hand and leg disability are able to travel but they are unable to use the vehicles for normal persons as it is. So the vehicles are modified (customized vehicles) to make them accessible to the disabled persons. Nowadays more research work is going on for increasing mobility of disabled persons. Depending upon disabled part of body, different provisions are available like crutches, wheelchairs, tricycles, customized vehicles (retrofitted bikes, cars etc.). Crutches are most commonly used for walking for shorter distances and then manual wheelchairs [1] and hand-cranked tricycles [2] are useful for the persons with leg disability and automatic wheelchairs are designed such that persons with hands & legs disability can be benefited. In automatic wheelchairs many approaches are taken into consideration and depending upon that the control system of wheelchairs is designed, for example smart wheelchair with control through deictic approach [3], intelligent robotic wheelchair [4], path following, stair climbing wheelchairs [5] etc. Another option ofpowered tricycles i.e. battery powered or solar powered tricycles [6], [7] is available for persons with leg disability. Currently many disabled persons are using modified vehicles like retrofitted bikes and customized cars which are having all the controls in hand [9]. In this way, there are various solutions available for travelling of the disabled persons like wheelchairs (manual, automatic), tricycles (manual, powered), modified bikes and cars.But in case of severe leg disabilities, the disabled person needs to use the wheelchair and many times he/she unable touse above available options due to the reasons mentioned in further lines. The wheelchairs (both manual and automatic) are useful only for short distance travel and the manual wheelchairs needphysical work from user or care taker. Then tricycles can be used for some more distance than wheelchairs but are not useful for long distance travel and also gives more physical strain to user. The retrofitted bikes can be used for longer distance travel. But to use these bikes, the wheelchair user should be capable to come out and in from the wheelchair to take the position on bike and it is difficult in most of the cases. So the bike is not useful for most of the wheelchair users. In case of modified cars also, the user needs to come out from the wheelchair. But nowadays the ramp provision is there for some of the cars, so by climbing the ramp the wheelchair user can drive his wheelchair inside the car and take the position of driver. Also buses with ramp provision are available, but the option of cars and bus is not economical for most of the population.

So there is need of solution to the problems faced by disabled persons discussed above, which will be less costly and allows the disabled person to take the drivers position without coming out from the wheelchair. In this project we have tried to give the solution to some of the problems. We have tried to design and manufacture the vehicle structure in such a way that, the vehicle can be driven by the user without coming out from the wheelchair. First we have prepared rough sketch of the projected model then visited some of disabled people in city, discussed about the proposed model, asked them about their expectations from such vehicle also taken important inputs from them. Then cad model of proposed vehicle frame is prepared in Solidworks and meshing of frame is done in Hypermesh then Static Analysis is done in RADIOSS solver by applying loads and boundary conditions. Also Modal Analysis is done and found out different mode shapes of the frame. As results of analysis showing the design is safe, fabrication of the actual frame is started and work is on the verge of completion.

II. Finalising the Frame Design

A. Field and Literature Survey

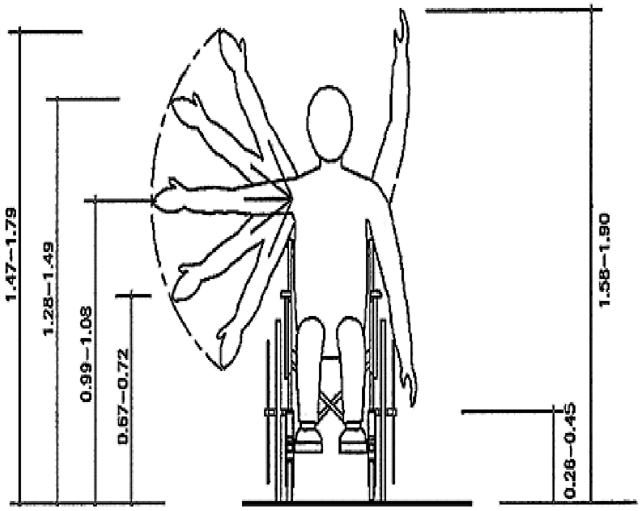


Fig.1 Vertical reaching zones of a wheelchair user[11]

Before start of the actual work, field survey of the disabled persons in Pune city and disabled army soldiers at Paraplegic RehabilitationCenter, Khadki, Pune has been conducted. Discussions were held on current facilities available, problems faced with them. Also expectations and suggestions for new model were discussed. The important points from the suggestions are considered during the designing and manufacturing of the vehicle. Literature available for guidelines and space standards for disabled persons, like ADA standards for Accessible Design [10],Accessibility for the Disabled-Design manual for barrier free environment [11], etc., were taken into consideration while designing the vehicle.

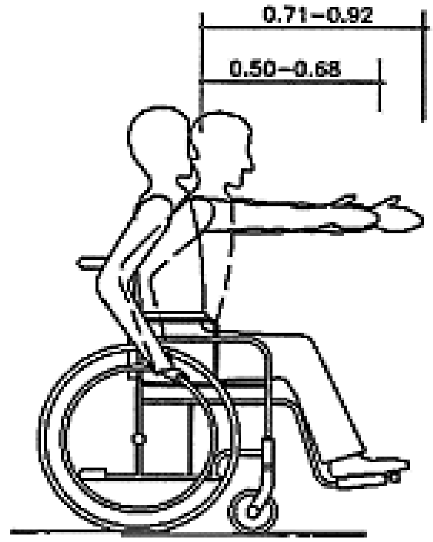


Fig.Horizontal forward reach of a wheelchair user[11]

B. Initial Frame Design (2D)

The initial design (2D-Line diagram) was drawn in Catia by considering the suggestions given by the disabled people and standards provided for the disabled person. Standard size of wheelchair has been taken as 1050mm x 750mm (as per ISI). The space provided for wheelchair is 1200mm x 900mm by ADA Standard 2010.

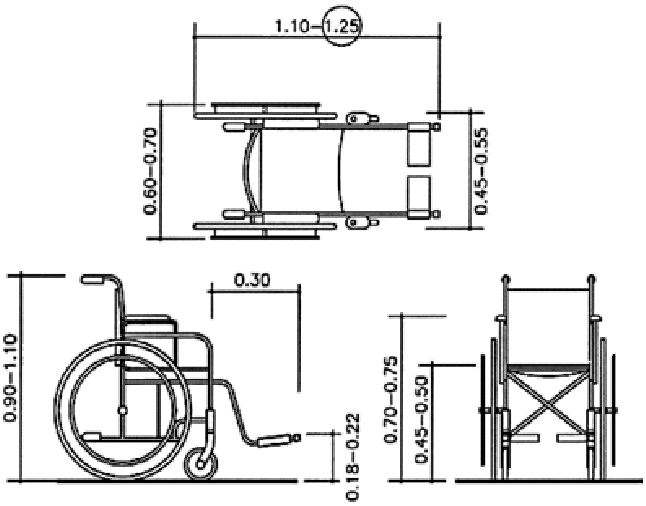


Fig.3 Wheelchair Dimensions[11]

Then the length and slope of the ramp is also taken from the guidelines. The handrails with extension of 305mm should be provided at the ramps as per ADA Standards 2010. The wheelchair user's movements pivot around his or her shoulders. The range of reach is limited, approximately 630 mm for an adult male. While sitting in a wheelchair, the height of the eyes from the floor is about 1190 mm for an adult male. A wheelchair has a footplate and leg rest attached in front of the seat. (The footplate extends about 350 mm in front of the knee). The footplate may prevent a wheelchair user from getting close enough to an object. Like this all the guidelines and standards are taken into considerations while designing the frame of the vehicle.

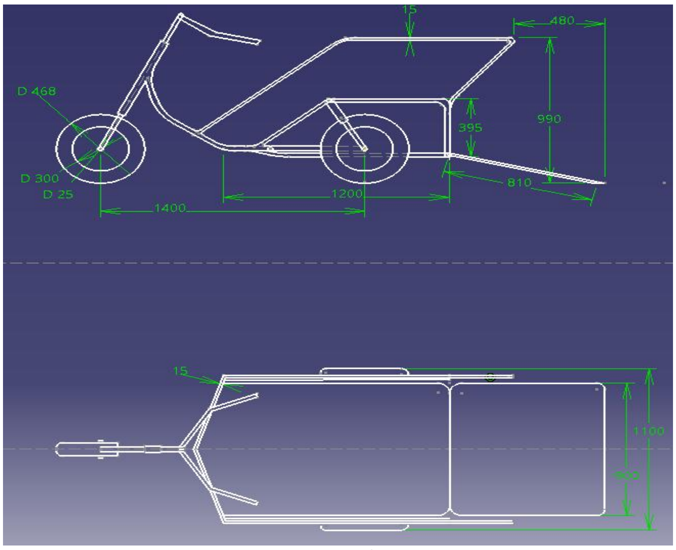


Fig.4 Initial sketch frame(2D)

C. Final Structural Frame

Before design of final structural frame, selection of engine was main task. As the approximate total weight of vehicle without occupant is around 250kg and required speed is around 40-50km/hr. The decision was taken to go for 125cc moped bike engine and the engine of Mahindra Duro-125 was selected as per the resources available. Then the final frame was modeled in Solidworks by using the weldment function. The modelled frame is as shown below.

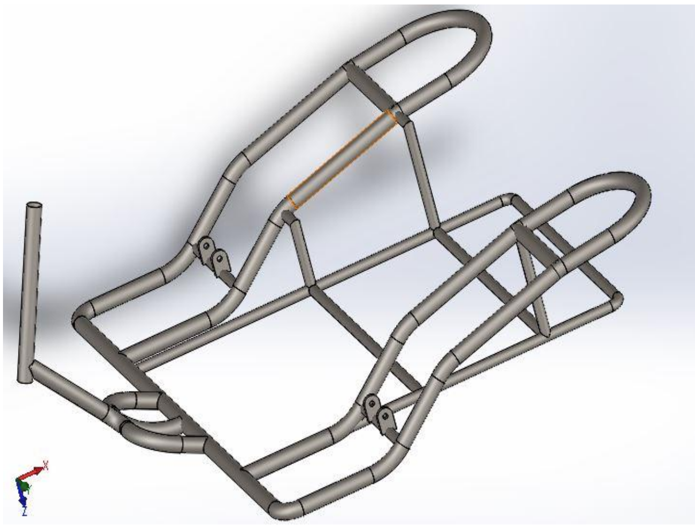


Fig.6 Designed Frame

D. Assembly of the proposed model

The assembly of the final model is being done by using the Solidworks software. The assembly shows overall picture of the targeted model. In actual model the right side trailing arm is replaced by engine assembly. After observing the assembled model visualization of the targeted model can be done easily. The assembled model with wheelchair cad model is also shown in fig.At the time of working the wheelchair can be taken in and out of the vehicle by using ramp arrangement shown in figures. The slope of the ramp is decided by following the guidelines as well as by taking trials actually on field.

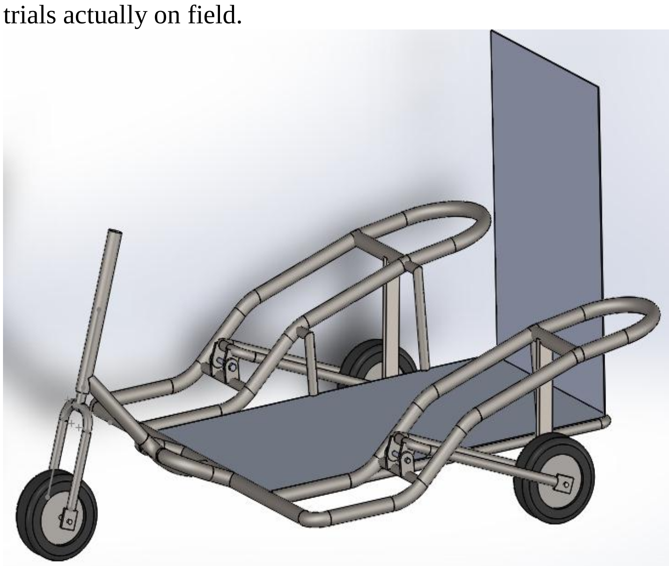


Fig.5 Assembly of the vehicle

The length of ramp will be around 800-850mm and height of the floor from ground 160-180 mm.

III.LOAD CALCULATIONS AND MESHING

A. Loading

After assembly frame is applied upon by different forces due to different components like engine, weight of occupant and wheelchair, weight of frame and floor sheet, weight of ramp, weight of handle assembly etc.F_1= Weight of handle assembly= 250N,F_2= Weight on caster wheels of wheelchair= 270N,F_3= Weight on rear wheels of wheelchair= 730N,F_4= Weight of frame + sheet = 262N,F_5= Weight of ramp = 50N, F_6= Engine weight shared by frame =250N. Let R_A-Reaction at front wheel, R_B-Reaction at left rear wheel (from front view), R_C-Reaction of right rear wheel (from front view).

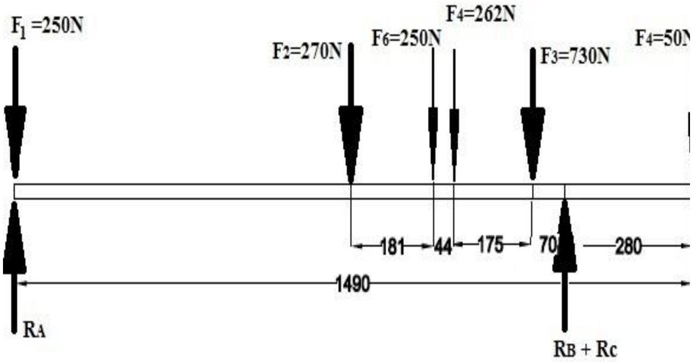


Fig.7 longitudinal beam (side view)

The weights each component is applied at specific point where it is actually acting on the frame.The calculations has been carried out by considering the frame as longitudinal beam and transverse beam, which gives the reactions of these loads at the supports i.e. at the axle of the three wheels of the vehicle.

For finding out the reactions, taking summation of all the vertical forces and equating it to zero for longitudinal beam.

Let R_B+R_C=R

R_A+R - (F_1+ F_2 + F_3 + F_4 + F_5 + F_6) = 0

R_A+R - (250N + 270N + 730N + 262N + 50N + 250N) = 0

R_A+R=1812N,

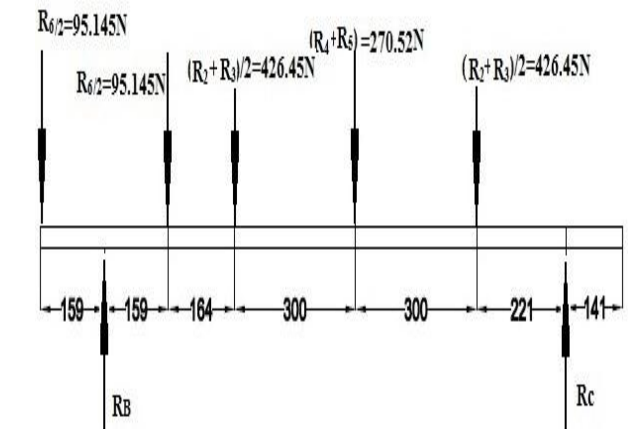
Then, as there is no any inclined or horizontal force acting on the frame, summation of horizontal forces is zero. So, taking moment of all the forces and reactions about point A and equate it to zero.

ΣM_A= 270*740 + 730*1140 + 50*1490 + 262*965 + 250*921 – R*1210 = 0

Therefore, ***R= R_B+R_C=1313.70N, and R_A= 498.30N***

For calculating the reactions R_B and R_C, the transverse beam is considered at the plane of supports B and C, transferring all the forces at transverse plane by mathematical calculations. For transferring the forces on transverse beam, it needs to consider only single force is acting at a time on the longitudinal beam. Refer the figure of longitudinal beam (side view) for the calculations below.

For F_1=0, the component of force F_1 on transverse beam is zero, as it is acting point A.



a Then above loads are distributed over the transverse beam as shown in figure below. The assumption is made such that, the loads on each caster wheel of wheelchair is half of the total load taken by the caster wheels as well as load on each rear wheel of wheelchair is half of the total load shared by the rear wheels of wheelchair. Then the engine weight is shared equally by the two points where the trailing arm is connected to the frame as shown in figure above.

Then for calculating reactions R_B and R_C, taking summation of all vertical forces and equating it to zero.

For F_2=270N, assuming only F_2 is acting on the longitudinal beam then calculating the reaction R_2=R_B+R_C= component of F_2 on transverse beam.

Taking summation of vertical forces and moment of all the forces and reactions about the point A then equating it to zero.

R_A + R_2= 270 N,

ΣM_A=0=270*740-R*1210,

Therefore, R_2=165.12N, R_A=104.88N

In same way, the reactions (R_3, R_4, R_5, R_6) due to forces (F_3, F_4, F_5, F_6) is calculated and listed as below,

R_3=687.77N, R_A=42.23N,

R_4=208.95N, R_A=53.05N,

R_5=61.57N, R_A= -11.57N,

R_6=190.29N, R_A=59.71N,

In above calculations R_A is component of respective force at point A. R_B + R_C – (R_2 + R_3 + R_5 + R_6) = 0,

R_B + R_C – (165.12N + 687.77N + 208.95N + 61.57N + 190.29N) = 0,

R_B + R_C = 1313.70N,Taking moment of all the forces about point B and equating it to zero.

ΣM_B= -95.145*159 + 95.145*159 + 426.45*323.125 + 270.52*623.125 + 426.45*923.125 - R_C*1143.8 =0

Therefore, Reactions ***Rc =612.022N and R_B =701.677N.***

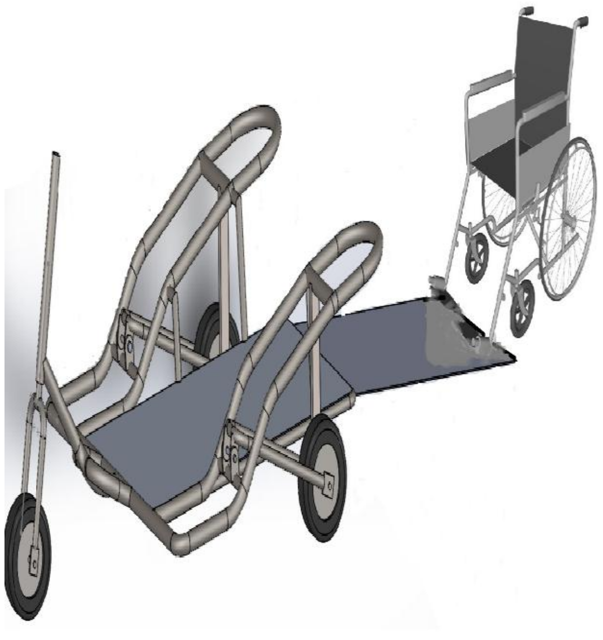


Fig.9 Assembled vehicle arrangement with wheelchair cad model

The loading details of the assumed longitudinal and transverse beams are as shown in the figure and the reactions R_A = 498.70 N, R_B = 701.677 N and R_C = 612.022N are calculated as above.

B. Pipe diameter selection

As mild steel is easily available, economical and purpose serving material, this material is finalized for the fabrication of the frame. In proposed frame, the material is shaped as shown in figure below to support the applied loads. Suppose the pipe is loaded by the reaction force R_B=701.677N and this reaction is transferred to the horizontal member at distance 700mm as shown in figure below,

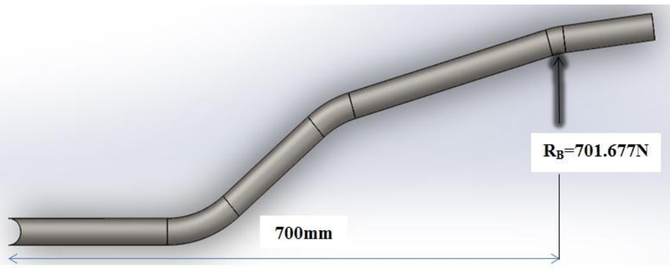


Fig.10 Pipe section loaded under bending

Bending moment at the center of horizontal member can be calculated as-

Bending moment = force * moment arm

$M_b = R_B$ * moment arm

M_b = 701.677* 700 N-mm

M_b= 491173.9 N-mm.

Then the stresses due to bending can be calculated by,

$$\frac{M}{I} = \frac{\sigma}{y}$$

Where, σ- Bending stress in N/mm^2,

M- Bending moment,

I- Moment of Inertia,

y- Distance of extreme fiber from neutral axis of the pipe.

Here, $\sigma = \sigma_b$ and M=M_b= 491173.9 N-mm.

The calculations of successful trial are as below,

By taking the outer diameter of pipe= 38.1mm and thickness of the pipe =2mm,

S_{yt}= 400N/mm^2 (yield strength of mild steel material),

$$I = \frac{\pi}{4}(D^4 - d^4)$$

D-Outer diameter of pipe

d- Inner diameter of pipe

$$I = \frac{\pi}{4}(38.1^4 - 34.1^4)$$

I = 37063.16 mm^4,

$\sigma_b = \frac{M}{I} y$

$$\sigma_b = \frac{491173.9}{37063.10} * 19.05$$

σ_b= 252.46 N/mm^2< 400N/mm^2

Therefore,

Factor of safety = S_{yt}/σ_b,

Factor of safety = $\frac{400}{252.46}$ = 1.5844

In same way the calculations for other dimensions are done results of which are not satisfactory, are listed in table below,

Table.1. Pipe diameter selection

Sr. No.	D [mm]	d [mm]	σ_b [N/mm^2]	FOS
1	25.4	23.4	1091.64 >S_{yt}	0.3664
2	25.4	21.4	615.370 >S_{yt}	0.65
3	38.1	36.1	466.26 >S_{yt}	0.8579
4	***38.1***	***34.1***	***252.46 <S_{yt}***	***1.5844***

C. Meshing

The model shown in above figure is then meshed by using the software Hypermesh. The meshed model is as shown in figure below. In meshing mid-surface mesh (2D mesh) is selected and after completing meshing the thickness of 2mm is defined to it, so that the meshed model will be as same as the actual model.

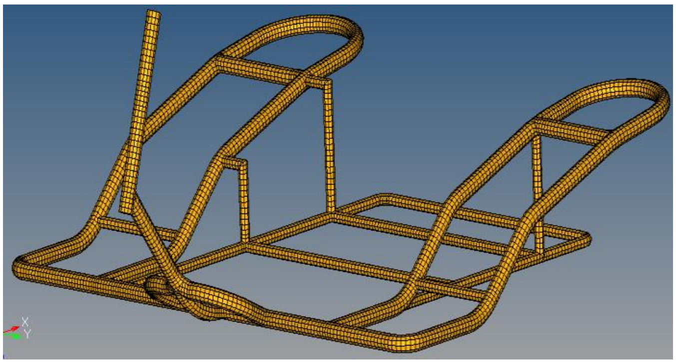


Fig.11 Meshed model

D. Static and Modal Analysis:

The next stage of work will be the static analysis by using the RADIOSS software. After static analysis modal analysis of the model will be done to find out different mode shapes and frequencies of model. After analysis the fabrication of the frame will be completed and assembly of vehicle will be done.

IV. CONCLUSION

Designing work of the targeted vehicle is successfully done. The frame is designed such that user with disability can able to use the vehicle with minimum effort. As the height and length of ramp is decided after getting live experience, so it will be easy to go in and out of the vehicle with wheelchair. After completion of the work, there will be one of the economical, most suitable options available for the disabled persons in the society.

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