Design, Analysis and Optimization of Cost Effective, MCM Wheelchair for Handicaps

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Abstract

The main aim of this paper isto design, analyze and develop a fully comfortableMCM (Multipurpose Commode Motorized) wheelchair for handicapped users. The purpose of the study was to design a cost effective, adjustable, and lightweight wheelchair with lot of good features. A quality function design of the wheelchair is prepared on CATIA V5 software and also there simulations and weight evaluated with their performance. Design model was prepared using anthropometric parameters of tallest user. To assess the wheelchair designs, static strength, and stability, here the researchers carried out the static and crash analysis using 1D,2D and 3D meshing with the help of ANSYS 14.0 and HYPERMESH 12.0, thereby applying loads and various boundary constraints to evaluate the deformation and the von-mises stress on different members to study the high stress concentration points.Wheelchair designed for paralysis were developed that were cost effective, adjustable and had light weight compared to commercially available wheelchairs.

Keywords: CATIAV5, ANSYS 14.0, HYPERMESH 12.0, COMMODE, CAE, VON-MISES, MESHING

I. INTRODUCTION

This study is related to wheelchairs, help persons who paralyzed as a result of disease, age, from birth or injury from an accident has limited options for inexpensive and flexible wheelchairs. As a result many people go without any assistance and will never fully recover or are euthanized.Many of the wheelchairs currently on the market are custom-made for individual, or require extensive manufacturing, or are not adjustable, or are expensive.

The goal of this study was to design, evaluate, and develop wheelchair that are suitable for various size ranges of users and that are easily adjustable and produced at a low cost.Market survey provides us an estimation of cost and various simple mechanisms for compact design.This inexpensive wheelchair is meant to give guardians an alternative to the existing relatively high cost, less adjustable wheelchairs for rehabilitation. The wheelchair dimensions will also be adjustable.

After load approximation and material selection, preparing CAD model of frame was a next step, CATIA V5 software was used for the designing purpose. Manikin was created in same software on the basis of user's data and checked it under different realistic conditions to check the all possible ergonomics for user's safety purpose.

Circular cross-section is employed for the frame development because circular section is always a perfect one to resist the twisting, the rolling effects, and preferred for torsional rigidity. Whole of the frame model was made up of round hollow cross section tubes of AISI 1018 steel throughoutframe. Tubes of 2 mm thickness with 25.4 mm outer diameter were used in the design.

The wheelchair design was also to be evaluated using computer analyses that focus on performance features such as static strength, light weight and stability. We have also done some analytical calculations for effective design, and FEA analysis on the CAE softwaresANSYS14.0 and HYPERMESH 12.0 provides the design validation for the product.

II. DESIGN PURPOSE

Our design purpose is to provide a simple and cost effective construction of a MCM wheelchair for the physically handicapped persons. Keeping in mind those things we done some searching work on market availability and facing the problem of complexity and economy, after that we design this product which is automatic and hand operated according to user's suitability.

The proper material selection for different parts improves product life and cost effectiveness also.The goals of this product design were to design, evaluate, and develop wheelchairs that are easily adjustable and produced at a low cost. After much iteration, CAD model of wheelchair assembly was proposed as shown in Figure 1.

Fig. 1: Wheelchair Assembly in CATIA V5

Whole of the frame model was made up of round hollow cross section tubes of AISI 1018 steel throughout chassis. Tubes of 2mm thickness with 25.4 outer diameters were used in the design. Mass properties showed the mass of product was to be 42 kg (approx.).

III. FRAME MODELING IN CAE SOFTWARES

This frame is developed in Ansys (APDL Menu)shown in figure no.2, by plotting the keypoints, lines and arcs. The element type selected for it is PIPE 16 is a uniaxial element with tension, compression, torsion, and bending capabilities. The element has six degrees of freedoms: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z axes. The real constants involved in the pre-processing of PIPE 16 element are its outer diameter and thickness value.

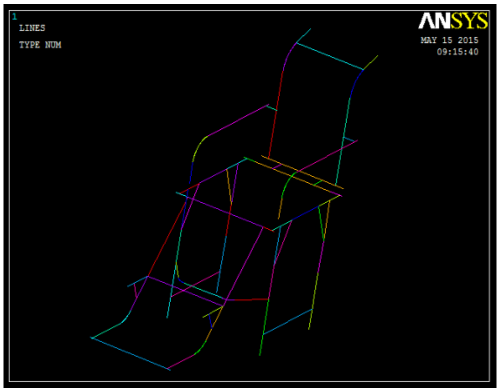


Fig. 2: Frame Modeling in ANSYS 14.0 (APDL)

In Hypermesh12.0 we firstly draw the wireframe with the help of nodes and lines, then extrude all mid surfaces as shown in the figure no.3:-

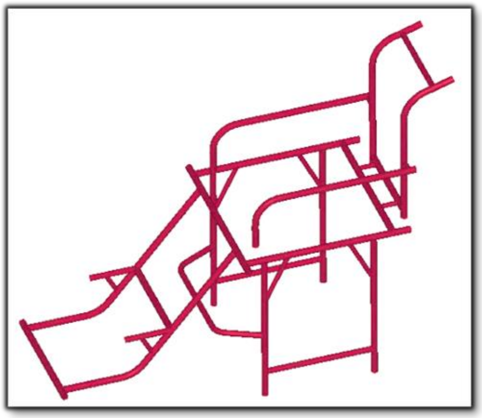


Fig. 3: Frame Modeling in HYPERMESH 12.0

IV. 1-D MESHINGIN IN ANSYS 14.0

The meshing has always been the key of the finite element model and for the exact solution of any object; it should be properly meshed with relevant element shape and size. We introduced the element division in each line for the sufficient meshing, i.e., number of divisions is 5(all lines)[3], as shown in the figure no.4:

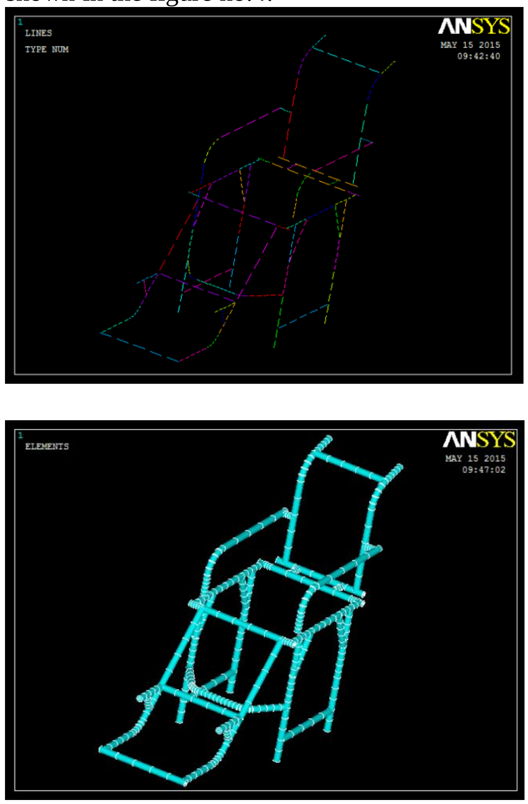
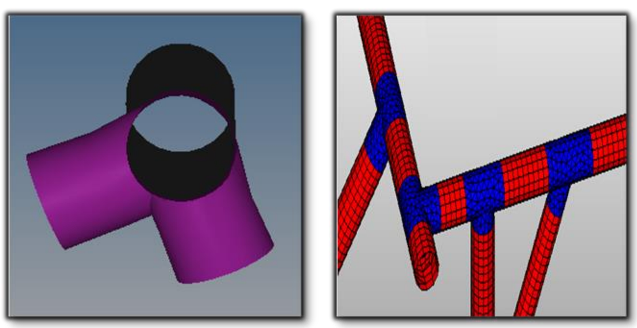


Fig. 4: Meshed frame in ANSYS 14.0 (APDL)

V. 2D MESHING IN HYPERWORKS 12.0

Mathematically element thickness (specified by user) is assigned half in +Z axis, half in –Z axis. Hence, for appropriate representation ofgeometry via 2d mesh its necessary to extract mid surface and generate nodes and elements (Tria/Quad/mixed) on the midsurfaces. Whole frame is meshed in the similar way with separate meshing at various weld joint locations. Finally we remove all mesh errors manually for warpage, aspect ratio, skew, jacobian, length, angle etc. for improving the meshed elements quality [1]. We provide weld joints meshing separately for accurate simulation as shown in figure no.5:-



Mid Surfaces before Meshing　　Meshed Elements (Quad+Tria)

Fig. 5: Frame Meshing (With Weld Joints-Shown By Blue)

VI. IMACT ANALYSIS

We have started from modeling of wheelchair in CATIA V5 then we started CAE procedure in HYPERMESH 12.0 with starting step of body mid surface generation and after this we have erased the internal errors of surfaces and then we completed 2D meshing, on proceeding further we removed meshing errors. After all this we applied boundary conditions (loads and constraints), then we evaluated the solution with help of software, then at last we got the results [4]; stress and displacement contours as shown in the figure no.6:

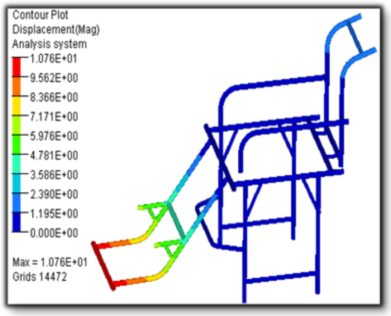


Fig. 6: Result-Nodal Displacement in HYPERMESH 12.0

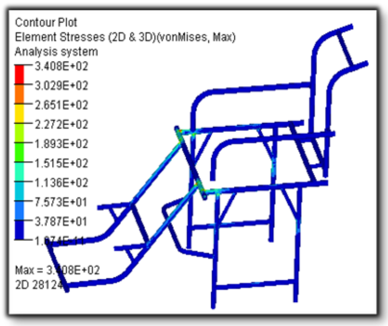


Fig. 7: Result-Element Stresses in HYPERMESH 12.0

VII. DEAD WEIGHT ANALYSIS

We have started from modeling of frame in ANSYS 14.0- MECHANICAL APDL, with starting step of modeling firstly we plot all necessary keypoints with the help of various coordinates, then we plot all required lines and arcs through these keypoints. Then we start with meshing of the all frame's members manually. Then we apply all possible boundary conditions (loads and constraints) on particular members, nodes, and keypoints. Then we evaluated the solution with help of software, and then at last we got the results (von-mises stress and nodal displacement) as shown in the above figures [3].

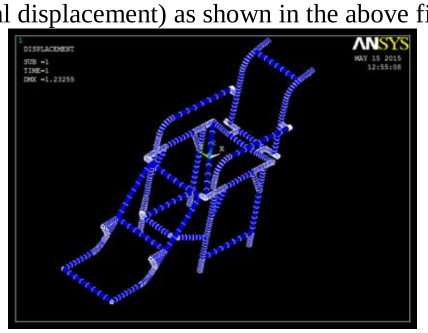


Fig. 8: Result-Nodal Displacement (DMX) In ANSYS 14.0

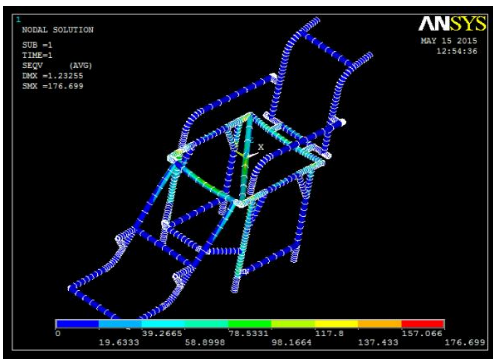


Fig. 9: Result-Element Stresses (SMX) In ANSYS 14.0

VIII. CRASH ANALYSIS

In this section we have done crash test. The role of this test is to ensure the safety of wheelchair user. In this we have imported model (IGES format)in HYPERMESH 12.0 and then we completed surface clean up procedure, then we stepped to tetra mesh, then we removed all meshing errors, finally we apply all possible boundary conditions on various elements and then we run the model file for analysis with the help of RADIOS solver of HYPERMESH, at last we got results[4].

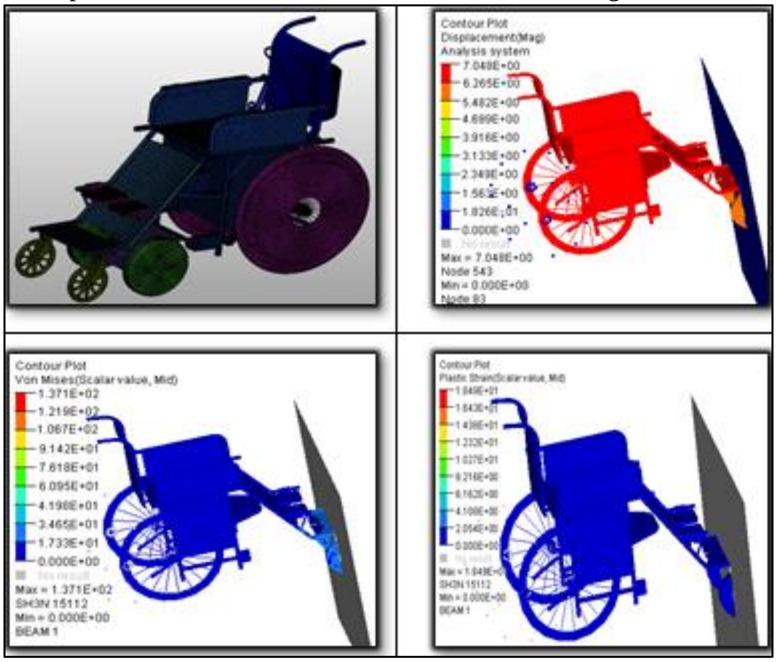


Fig. 10: Crash Analysis Results with Meshed Model

Table – 1

CONFIGURATION	*RESULTS*
TOTAL NO. OF ELEMENTS	*8357*
DMX(mm)	*7.048E+00*
SMX(Mpa)	*1.371E+02*

A. Frame's Material Properties [5]:

Table – 2

STEEL GRADE: AISI 1018 (MILD/LOW CARBON STEEL)		
S.NO.	*PROPERTIES*	*VALUES*
1.	*Young's modulus*	*2e+5 N/mm^2*
2.	*Poisson ratio*	*0.3*
3.	*Density*	*7800 kg/m^3*
4.	*Yield Strength*	*472 N/mm^2*
5.	*Ultimate Tensile Strength*	*491 N/mm^2*

B. Analysis Results:

ANALYSIS TYPE	*FORCE APPLIED*	*ANALYSIS RESULTS*	
		DMX(mm)	*SMX(Mpa)*
IMPACT	*4G*	*1.076E+01*	*3.408E+02*
DEAD WEIGHT	*3G*	*1.232E+00*	*1.766E+02*
CRASH	*Velocity*	*7.048E+00*	*1.371E+02*

Considerable factor of safety was observed for all analysis.

The frame should be able to withstand the impact, dead weights, and crash conditions and provide utmost safety to the driver without undergoing much deformation[1].

C. Formula Used:

1) Force Calculation:

For a 3G force;
Weight of vehicle = 110 kg (weight of wheelchair+ of user)
Then, G = 110 × 10 = 1100 N
3G = 3 × 1100 = 3300 N
If we apply force on "n" no. of nodes;
Then force to be applied on each node = 3300 ÷ n
e.g.; If force applied at 25 nodes, then we apply force of magnitude = 132 N at each 25 nodes in the desired direction.

2) Factor of Safety Calculation:

$$\text{FOS} = \frac{\text{Yield point stress}}{\text{design stress}}$$

IX. CONCLUSION

With the help of above CAE software based analysis, we can check all possible strengths of our model with the help of various applied boundary conditions. In our design we provide a comfortable product for disable user even considering his daily life routine activities. Commode concept of our design is to attract the user because design of our wheelchair is easy to handle and its simple serviceability. Appropriate material selection and cost consideration makes our design valid for Indian local market. In this design we use the simple mechanism for user friendly concept.

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