STRESS ANALYSIS OF MECHANISMS FOR TROLLEY-CUM-WHEELCHAIR

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The project deals with the stress analysis of four bar mechanisms of the trolley-cum-wheelchair. The four bar mechanisms has four links of which the first link is called as fixed link and the second link is called as crank and third link is called as coupler and follower is the fourth link. By changing the angle between two first rest of trolley-cum-wheelchair the various stresses such as the maximum shear stress and bending stress and maximum principal stress and deformation on each link of four bar mechanism is determined. The ANSYS results on the each link of four bar mechanisms are compared with the analytical calculation of four bar mechanism and verified. The models of trolley-cum-wheelchair are prepared in NX-6CAD software. These models is exported to opened in the ANSYS14 workbench software and FE analysis is made. FE values are compared with the analytical calculation done using the principle of free body diagram and the forces and stress are verified.

Keywords: Stress analysis, Four bar mechanism, Trolley-cum-wheelchair

INTRODUCTION

Generally a person who is suffering from some kind of deceases and requires continuous monitoring by doctor and may require external aids like oxygen, blood transformation, saline etc. for cure is known as a patient. He is generally admitted in a hospital. The patient is confined to bed in hospital and is required to be moved to other places for taking X-ray or undergoing sonography or CT scan procedure. The handling of the patient is rather difficult and is required to be planned meticulously. In patient handling, a lot of problems are being faced by nursing staffs, the people who handle the patient at home, and the patient himself. These problems consist of pain to patient, in various portions of body like shoulder, back, legs, etc.; while moving him from one place to another place. In the hospitals, the nursing staff is also facing some health problems like pain in their shoulders and backbone, as they have to do the work of patient handling repeatedly. The main objective of this research work is to
analyse the various stresses induced in the trolley-cum-wheelchair used for patient handling.

The model is drawn on NX-6 software following parts are used in the model as shown in Figure 1.

- Backrest
- Hip rest
- Leg rest
- Rest connector pins
- Pins
- Link 2
- Coupler
- Link 4
- Support connector
- Support connector pins
- Cross support

**FE PROCEDURE**

The model created in NX-6 was imported. It was discretised as per following detail Finite Element Meshing of Trolley-Cum-Wheelchair.

Type of Mesh : 1 mm Brick Mesh  
Number of Nodes : 546916  
Number of Elements Size : 224574

Fine meshing for the trolley-cum-wheelchair is performed in ANSYS which is capable to fill small gap section and geometrically region.

**Loading and Boundary Conditions**

**Loading Conditions**

To generate the solution in ANSYS, constraint should be given after generating mesh In case of trolley-cum-wheelchair, load are applied on the each rest. The magnitude of loads is considered to be 120 kg considering the accidental overloading due to drap. The

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**Figure 1: The Various Parts of Trolley-Cum-Wheelchair**

![Diagram](image-url)
The magnitude of pressure on each rest is determined by the following equation

\[ P = \frac{F}{A} \]

where, \( P \) is the pressure in N/mm²

\( F \) = The force of 120 kg is applied to the rest.

\( A \) = Surface area (mm²) of the top rest on which the pressure is applied.

Pressure applied on each of back, hip and leg rest = \( 6.2285 \times 10^3 \) Mpa

Figure 2 shows the Applied Pressure on the FE model.

**Boundary Condition**

For the model of the trolley-cum-wheelchair, all 6 degree of freedom of that constraint region are locked. Pressure is applied vertically on back rest. The boundary condition are defined on the wheel rod. These are the component in

**Figure 2: Pressure is Applied to Rest and Fixed Support is Applied to Wheel Rod to the Trolley-Cum-Wheelchair**

**Figure 3: The Fixed Support Boundary Condition**
contact with the cross support. There are two wheel rod are used as shown in Figure 3.

**Procedure of Calculating the Analytical Force**

**For 180° (Angle Between Back Rest and HIP Rest)**

For any system static equilibrium is necessary condition is

\[ \sum F_x = 0 \]
\[ \sum F_y = 0 \], and
\[ \sum M = 0 \]

Negative value indicates compression of link

After finding the forces involved in each of the links, the FBD with calculated values of forces as shown in Figure 4.

Various stresses are calculated from the forces on Figure 4 as follows:

- Shear stress at link 2
  \[ \tau_2 = \frac{F}{A} \]

  \[ F = \text{Shear force acts on the link in N} \]
  \[ A = \text{Cross-sectional area of link m}^2 \]
  \[ \tau_2 = \frac{100.387}{0.040 \times 0.015} = 0.167 \text{ Mpa} \]

- Shear stress at link 4
  \[ \tau_4 = \frac{F}{A} \]

  \[ F = \text{Shear force acts on the link in N} \]
  \[ A = \text{Cross-sectional area of link m}^2 \]
  \[ \tau_4 = \frac{98.01}{0.040 \times 0.015} = 0.163 \text{ Mpa} \]

- Shear stress at link 3 (one end of coupler near link 4)
  \[ \tau_3 = \frac{F}{A} \]

\[ F = \text{Shear force acts on the link in N} \]
\[ A = \text{Cross-sectional area of link m}^2 \]
\[ \tau_3 = \frac{98.01}{0.040 \times 0.015} = 0.163 \text{ Mpa} \]

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**Figure 4: The Free Body Diagram for 180° Angle Between Back Rest Angle and HIP Rest Angle**

![Free Body Diagram](image-url)
\[ \tau_3 = \frac{98.01}{0.040 \times 0.015} = 0.163 \text{ Mpa} \]

- Shear stress at link 3 (one end of coupler near link 2)

\[ \tau_3 = \frac{F}{A} \]

\[ \tau_3 = \frac{100.387}{0.040 \times 0.015} = 0.167 \text{ Mpa} \]

- Compressive stress at link 4

\[ \sigma_c = \frac{\tau_c}{2} \sqrt{\left(\sigma_c\right)^2 + 4\left(\tau_z\right)^2} \]

\[ \sigma_c = 1.9867 \text{ Mpa} \]

- Maximum principal stress at link 4

\[ \sigma_{cz} = \frac{\sigma_c}{2} + \frac{1}{2} \sqrt{\left(\sigma_c\right)^2 + 4\left(\tau_z\right)^2} \]

\[ = 2.0006 \text{ Mpa} \]

- Maximum principal stress at link 3 (one end of coupler near link 4)

\[ \sigma_{cz} = \frac{\sigma_c}{2} + \frac{1}{2} \sqrt{\left(\sigma_c\right)^2 + 4\left(\tau_z\right)^2} \]

\[ = 2.043 \text{ Mpa} \]

- Maximum principal stress at link 3 (one end of coupler near link 2)

\[ \sigma_{cz} = \frac{\sigma_c}{2} + \frac{1}{2} \sqrt{\left(\sigma_c\right)^2 + 4\left(\tau_z\right)^2} \]

\[ = 0.298 \text{ Mpa} \]

- Maximum shear stress at link 4

\[ \tau_{\text{max}} = \frac{1}{2} \sqrt{\left(\sigma_c\right)^2 + 4\left(\tau_z\right)^2} \]

\[ = 1.891 \text{ Mpa} \]

- Maximum shear stress at link 2

\[ \tau_{\text{max}} = \frac{1}{2} \sqrt{\left(\sigma_c\right)^2 + 4\left(\tau_z\right)^2} \]

\[ = 2.023 \text{ Mpa} \]

- Maximum principal stress at link 3 (one end of coupler near link 4)

\[ \tau_{\text{max}} = \frac{1}{2} \sqrt{\left(\sigma_c\right)^2 + 4\left(\tau_z\right)^2} \]

\[ = 1.028 \text{ Mpa} \]

- Maximum shear stress at link 3 (one end of coupler near link 2)

\[ \tau_{\text{max}} = \frac{1}{2} \sqrt{\left(\sigma_c\right)^2 + 4\left(\tau_z\right)^2} \]

\[ = 0.195 \text{ Mpa} \]
• Deformation at link 4

\[ p = \text{load in N} \]
\[ L = \text{load in N} \]
\[ E = \text{Young modulus (N/mm}^2) \]
\[ A = \text{Area of Cross-Section (mm}^2) \]

\[ \frac{PL}{EA} = \frac{2261.96 \times 400}{210 \times 10^2 \times 40 \times 15} \]

= 0.0718 mm

• Deformation at link 2

\[ \frac{PL}{EA} = 0.03784 \text{ mm} \]

• Deformation at link 3 (one end of coupler near link 2)

\[ \frac{PL}{EA} = 0.000293 \text{ mm} \]

• Deformation at link 3 (one end of coupler near link 4)

\[ \frac{PL}{EA} = 0.0242 \text{ mm} \]

• Bending stress at link 4

\[ M = \text{Force is act at link 4 perpendicular distance in N-mm} \]
\[ M = 1040.985 \times 30 = 31229.5 \text{ N-mm} \]
\[ Z = \text{Section of modulus at link 4} \]
\[ Z = \frac{1}{6}tb^2 = \frac{1}{6}15 \times 40^2 \]

= 4000 mm^4

\[ \sigma_b = \frac{M}{Z} \]

= 7.8 Mpa

• Bending stress at link 2

\[ \sigma_b = \frac{M}{Z} \]

= 8.08 Mpa

Bending at fulcrum of coupler

Force is act at the link 3 by link 4

\[ 2261.96 \times 241.0653 = 545.2800 \times 10^3 \text{ N-mm} \]

Force is act on the link 3 by link 2

Therefore, \( 1192.094 \times 299.661 = 357.22 \times 10^3 \text{ N-mm} \)

\[ Z = \frac{15 \times 2\left[(36.5415)^2 - 15^2\right]}{12 \times 36.5412} \]

= 3107.282

\[ \sigma_b = \frac{M}{Z} \]

= 114.96 Mpa

• To find the reaction

\[ R_a = \text{Reaction at support at A} \]
\[ R_b = \text{Reaction at B} \]
\[ R_a + R_b = 1040.985 + 1097.775 + 1071.78 \]
\[ R_a + R_b = 3210.54 \text{ N} \]
\[ \sum M_{ar} A \]
\[ 3210.54 \times 295 - 590 R_b = 0 \]
\[ 947.10 \times 10^3 = 590 R_b \]
\[ R_b = 1605.25 \text{ N} \]
Note: The image contains text from a scientific paper discussing the mechanics of a trolley-cum-wheelchair. The text is presented in a logical sequence, with mathematical calculations and conclusions drawn from the analysis. The primary focus is on the comparison of various stresses and stresses are calculated analytically to be compared with the Finite Element Method (FEM) results. The stresses are found to be less than the permissible stress, and thus there is scope for reduction in material. The conventional mechanical approach is used to find the forces involved through free body diagrams, and the theoretical results are verified through FE analysis. The analysis was performed for different angles of inclination of the leg rest with respect to the hip rest and hip rest with respect to the backrest. For all such combinations, the stresses both theoretically and analytically are found to be less than the permissible stress.
and through FE showed a close match. The maximum stress is induced at 150° inclination is in link 3 and it is of the order 6.9746 Mpa which is significantly less then permissible stress. Hence it can be concluded that trolley-cum-wheelchair under consideration could have different cross-section for its linkages preferably the hallow cross-section shall contribute to the decrease in weight significantly hence it can be concluded that the current design under consideration is unnecessary heavy and hence have wide scope.

REFERENCES


