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Research Paper

STRESS ANALYSIS OF MECHANISMS FOR TROLLY-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 ink is called as crank and third link is called as coupler and follower is the fourth link. By changing the angle between two 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, Trolly-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

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analyse the various stresses induced in the trolley-cum-wheelchair used for patient handling.

The model is drawn on NX-6 software fallowing 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 discritised 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

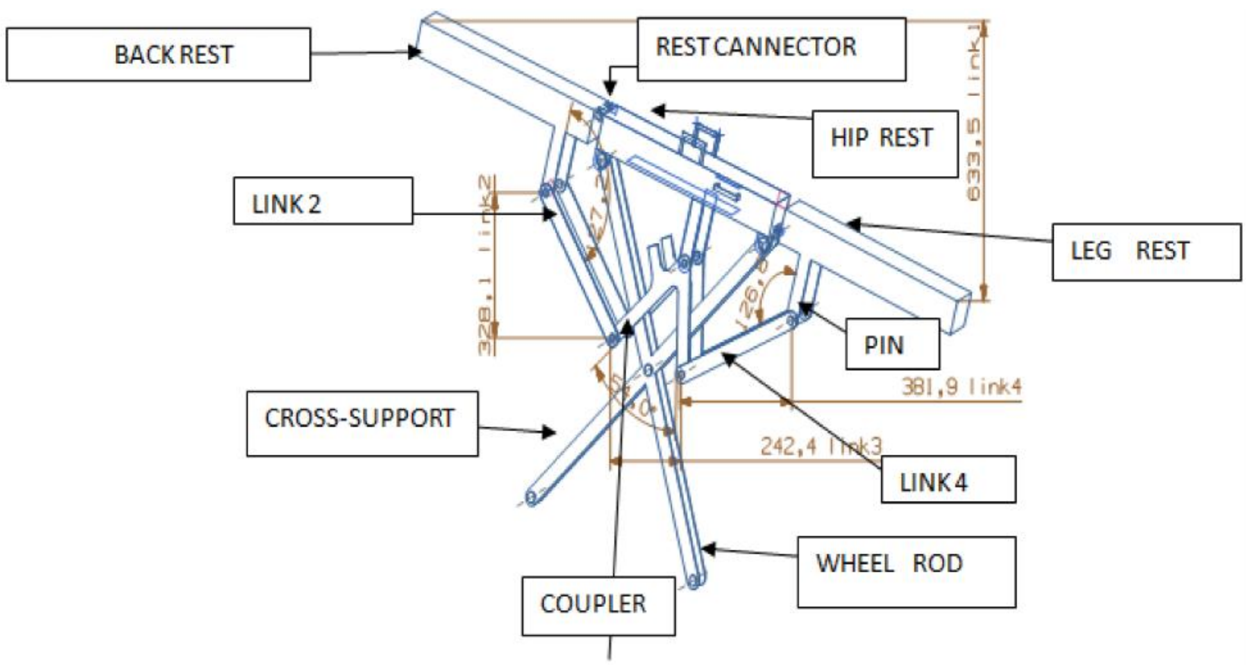
Fine meshing for the trolley-cum-wheelchair is performed in ANSYS which is capable to fill small gap section and geometrically region.

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

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



magnitude of pressure on each rest is determined by the fallowing equation

$$P = \frac{F}{A}$$

where, P is the pressure in N/mm^2

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

A = Surface area (mm^2) of the top rest on which the pressure is applied.

Pressure applied on each of back, hip and leg rest = 6.2285 x 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

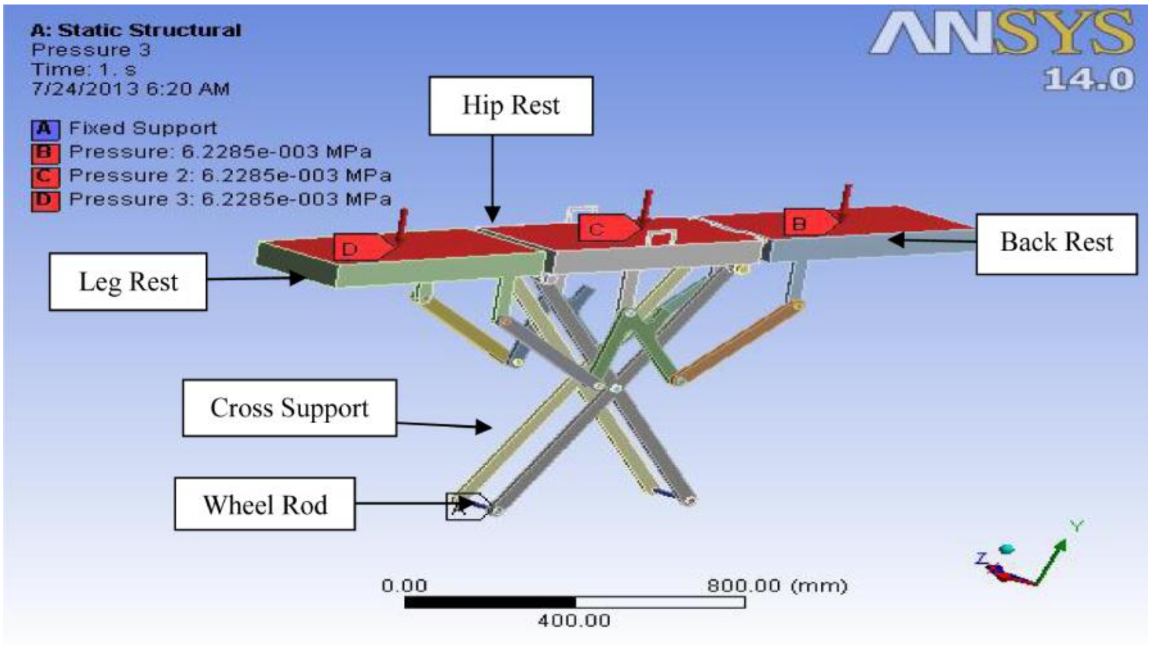
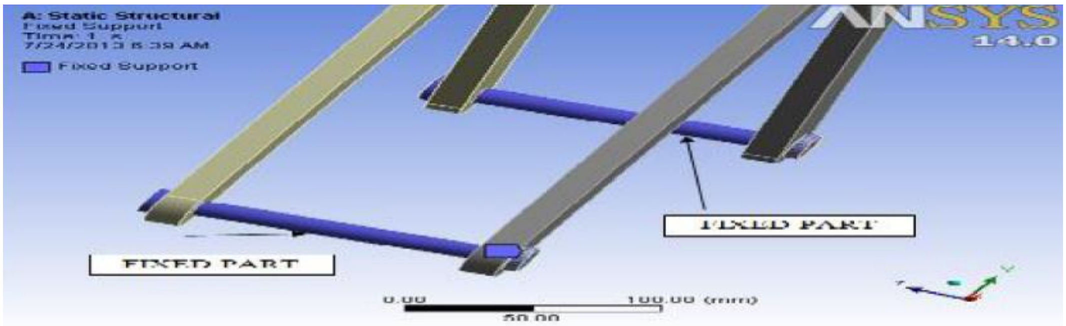


Figure 3: The Fixed Support Boundary Condition



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

$$\sum F_x = 0$$

$$\sum F_y = 0 \text{, and}$$

$$\sum F_M = 0$$

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 fallows:

- Shear stress at link 2

$$^{2}{}_{2} = \frac{F}{A}$$

F = Shear force acts on the link in N

A = Cross-sectional area of link m^2

$^{2}{}_{2}$ = Shear stress at link N/m^2

$$^{2}{}_{2} = \frac{100.387}{0.040 \times 0.015} = 0.167\ Mpa$$

- Shear stress at link 4

F = Shear force acts on the link in N

A = Cross-sectional area of link m^2

$^{2}{}_{4}$ = Shear stress at link N/m^2

$$^{2}{}_{4} = \frac{F}{A}$$

$$^{2}{}_{4} = \frac{98.01}{0.040 \times 0.015} = 0.163\ Mpa$$

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

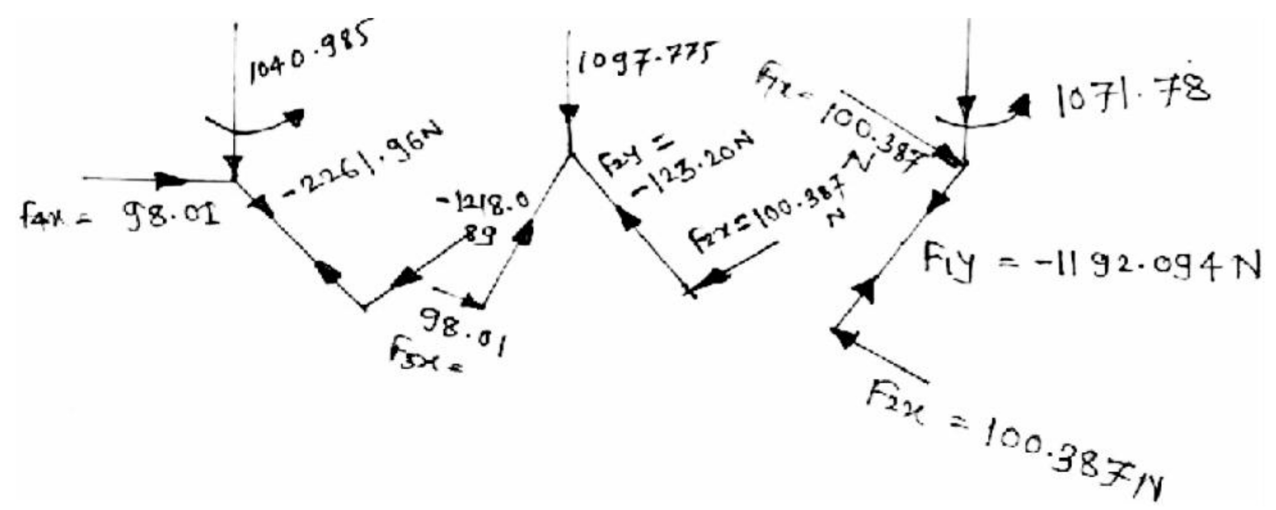
F = Shear force acts on the link in N

A = Cross-sectional area of link m^2

$^{2}{}_{3}$ = Shear stress at link N/m^2

$$^{2}{}_{3} = \frac{F}{A}$$

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



$$^{2}{}_{3} = \frac{98.01}{0.040 \times 0.015} = 0.163\ Mpa$$

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

  F = Shear force acts on the link in N

  A = Cross-sectional area of link m^2

  $^{2}{}_{3}$ = Shear stress at link N/m^2

$$^{2}{}_{3} = \frac{F}{A}$$

$$^{2}{}_{3} = \frac{100.387}{0.040 \times 0.015} = 0.167\ Mpa$$

- Compressive stress at link 4

  F = Compressive force acts on the link

  A = Cross-sectional area of link

  $^{2}{}_{C}$ = Compressive stress (N/m^2)

$$^{2}{}_{C} = \frac{2261.96}{0.040 \times 0.015} = 3.769\ Mpa$$

- Compressive stress at link 2

  F = Compressive force acts on the link

  A= Cross-sectional area of link

  $^{2}{}_{C}$ = Compressive stress (N/m^2)

$$\pm_{C} = \frac{1192.049}{0.040 \times 0.015} = 1.9867\ Mpa$$

- Maximum principal stress at link 4

  $\pm_{C}$ = Compressive stress (N/m^2)

  $^{2}{}_{2}$ = Shear stress (N/m^2)

  $\pm_{C2}$ = Maximum principal stress (Mpa)

$$\pm_{C2} = \frac{\pm_{C}}{2} + \frac{1}{2}\sqrt{(\pm_{C})^2 + 4(^{2}{}_{2})^2}$$

= 3.7760 Mpa

- Maximum principal stress at link 2

$$\pm_{C2} = \frac{\pm_{C}}{2} + \frac{1}{2}\sqrt{(\pm_{C})^2 + 4(^{2}{}_{2})^2}$$

= 2.0006 Mpa

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

$$\pm_{C2} = \frac{\pm_{C}}{2} + \frac{1}{2}\sqrt{(\pm_{C})^2 + 4(^{2}{}_{2})^2}$$

= 2.043 Mpa

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

$$\pm_{C2} = \frac{\pm_{C}}{2} + \frac{1}{2}\sqrt{(\pm_{C})^2 + 4(^{2}{}_{2})^2}$$

= 0.298 Mpa

- Maximum shear stress at link 4

$$^{2}{}_{\max} = \frac{1}{2}\sqrt{(\pm_{C})^2 + 4(^{2}{}_{2})^2}$$

= 1.891 Mpa

- Maximum shear stress at link 2

$$^{2}{}_{\max} = \frac{1}{2}\sqrt{(\pm_{C})^2 + 4(^{2}{}_{2})^2}$$

= 2.023 Mpa

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

$$^{2}{}_{\max} = \frac{1}{2}\sqrt{(\pm_{C})^2 + 4(^{2}{}_{2})^2}$$

= 1.028 Mpa

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

$$^{2}{}_{\max} = \frac{1}{2}\sqrt{(\pm_{C})^2 + 4(^{2}{}_{2})^2}$$

= 0.195 Mpa

- Deformation at link 4

  p = load in N

  L = load in N

  E = Young modulus (N/mm^2)

  A = 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

$$\partial_L = \frac{PL}{EA}$$

= 0.03784 mm

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

$$\partial_L = \frac{PL}{EA}$$

= 0.000293 mm

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

$$\partial_L = \frac{PL}{EA}$$

= 0.0242 mm

- Bending stress at link 4

  M = Force is act at link 4 perpendicular distance in N-mm

  M = 1040.985 × 30 = 31229.5 N-mm

  z = Section of modulus at link 4

$$Z = \frac{1}{6}tb^2 = \frac{1}{6}15 \times 40^2$$

= 4000 mm^4

$$\pm_b = \frac{M}{Z}$$

= 7.8 Mpa

- Bending stress at link 2

$$Z = \frac{1}{6}tb^2 = \frac{1}{6}15 \times 40^2$$

= 4000 mm^4

$$\pm_b = \frac{M}{Z}$$

= 8.08 Mpa

Bending at fulcrum of coupler

Force is act at the link 3 by link 4

2261.96 × 241.0653 = 545.2800 ×10^3 N-mm

Force is act on the link 3 by link 2

Therefore, 1192.094 × 299.661 = 357.22 × 10^3 N-mm

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

Z = 3107.282

$$\pm_b = \frac{M}{Z}$$

= 114.96 Mpa

- To find the reaction

  R_a = Reaction at support at A

  R_b = Reaction at B

  $R_a + R_b$ = 1040.985 + 1097.775 + 1071.78

  $R_a + R_b$ = 3210.54 N

  $\Sigma M_{at} A$

  3210.54 × 295 – 590 R_b = 0

  947.10 × 10^3 = 590 R_b

  R_b = 1605.25 N

R_a = 1605.25 N

Force is act at perpendicular distance

M = 1605.25 × 501.1963 = 804.54 × 10^3 N-mm

Z = 4000 mm^4

$\pm_b$ = 201.135 Mpa

Comparison of Various Stresses

various stresses are calculated analytically are found closer to the FEM result obtained. The bending stress are less than the permissible stress. The comparative result are shown in Table 1 for 180° angle between backrest and hip rest.

Table 1: Comparison of Stress 180° Angle Between Backrest and HIP Rest

Types of Stress	Types of Values	Link			
		L2	L3		L4
			1st End Near Link 4	2nd End Near Link 2	
Maximum Shear Stress (Mpa)	Analytical Value (Mpa)	2.02300	1.0280	0.1950	1.8910
	FE Value (Mpa)	1.15340	1.0092	0.5883	1.8105
	Deviation (Mpa)	0.86960	0.0188	0.3933	0.0805
Deformation (mm)	Analytical Value (mm)	0.03784	0.0242	0.0002	0.0718
	FE Value (mm)	0.13155	0.1313	0.0053	0.1298
	Deviation (mm)	0.09371	0.1071	0.5321	0.0580
Maximum Principle Stresses (Mpa)	Analytical Value (Mpa)	2.00060	2.0430	0.2980	3.7760
	FE Value (Mpa)	2.21690	2.0531	0.6264	3.6451
	Deviation (Mpa)	0.21630	0.0101	0.3284	0.1309
Bending Stresses (Mpa)	Analytical Value (Mpa) (FE result not available)	8.08	At fulcrum pin between l_1 and l_2 is 114.96		7.8000
	Permissible Stress (Mpa)	517.5	517.5	517.5	
	Deviation (Mpa)	509.42	402.54	509.7	

CONCLUSION

The trolley-cum-wheelchair under investigation has been studied for kinematics in the previously reported literature. The obvious reason is the mechanisms for conversion from wheel to stretcher and stretcher to wheel is complex and primarily focus of design. However, The linkages sizes are mostly evolved from the previous design and not much variation in them where made while the mechanism were modification. Hence some studies in this regard are justified.

The conventional mechanical approach are used to find the forces involved through free body diagram. The result obtained were used to find theoretical stresses in each of the element which showed that stresses are much less and hence there is scope for reduction in material.

The theoretical results obtained above were verify through FE analysis. The analysis was performed for different angle of inclination of leg rest with respect to hip rest and hip rest with respect to back rest. For all such combination the stresses both theoretically 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.

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