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Research Paper

DESIGN, SYNTHESIS AND SIMULATION OF FOUR BAR MECHANISM FOR GUIDING WHEELS FOR CLIMBING

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In field of providing mobility for elderly and disabled, the aspect of dealing with stairs continues largely unresolved. This thesis focuses on presenting the development of stair climbing wheel chair mechanism with high single step capability. The mechanism is based on four wheeled cluster connected to base via. Powered linkages so as to permit forward direction and high single step functionality. Primary considerations were inherent stability, restriction of size, aesthetics and low cost. This research work presents a design of a mechanism that aims a wheel to climb steps of 220 mm high. The proposed four bar mechanism installed on each wheel of assembly. Which can be capable to climb stair height suitable comfortable motion. The compactness of the mechanism design makes it suitable for staircase climbing assembly for aiding people with disability.

Keywords: Synthesis, Simulation, Four bar mechanism, Guiding wheels

INTRODUCTION

This chapter discusses the necessity, history of wheel chair and the developments taken place to facilitate the transport of patients, old persons or specially abled persons.

Necessity

In field of providing mobility for elderly and disabled, the aspect of dealing with stairs continues largely unresolved. The most possible solution to make transportation of peoples from one floor to another can be done by lifts, but for those buildings which are generally less than three storied, the option of lifts is not feasible financially. The normal peoples can move for different heights but for disabled persons the wheelchair is one of best option for moving.

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History

Figure 1 shows the earliest records of wheeled furniture was an inscription found on a stone slate in China and a child's bed depicted in a frieze on a Greek vase, both dating back to the 6th century B.C.E. The first records of wheeled seats being used for transporting the disabled date to three centuries later in China; the Chinese used their invented wheelbarrow to move people as well as heavy objects. A distinction between the two functions was not made for another several hundred years, around 525 C.E., when images of wheeled chairs made specifically to carry people begin to occur in Chinese art. Later dates relate to Europeans using this technology during the German Renaissance. The invalid carriage or Bath Chair seems to date from around 1760. Harry Jennings and his disabled friend Herbert Everest, both mechanical engineers, invented the first lightweight, steel, collapsible wheelchair in 1933. Mr. Everest had broken his back in a mining accident. The two saw the business potential of the invention and went on to become the first mass-manufacturers of wheelchairs: Everest and Jennings. Their "x-brace" design is still in common use, albeit with updated materials and other improvements.

Figure 1: Ancient Wheel Chair

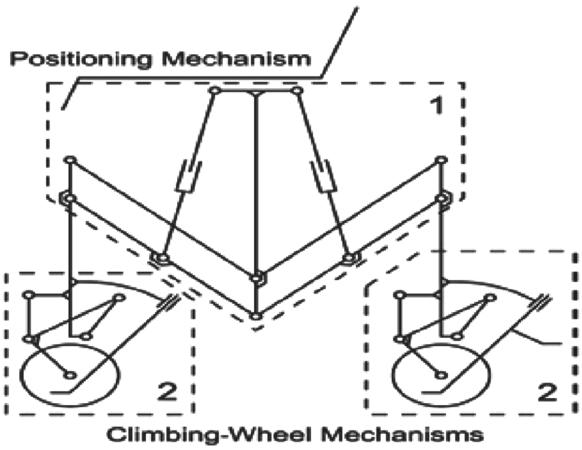
Wheel Chair with Four Bar Mechanism to Guide Four Wheels Independently

The following Figures 2a and 2b shows CALMOS wheelchair prototype (CAstilla-La Mancha Obstacle Surpassing Wheelchair) is a new prototype that belongs to the category of hybrid locomotion vehicles. It has been designed and built at the School of Engineering of Castilla-La Mancha University. Main features of CALMOS Wheelchair are large load capacity and relevant adaptability

Figure 2: CALMOS Wheelchair Position Mechanism

(a) CALMOS Wheel Chair

(b) Positioning Mechanism



to a wide variety of obstacle geometries. Figure 2a shows the prototype and Figure 2b shows its kinematic scheme. In CALMOS Wheelchair operation, the problem of climbing a staircase is split into two sub-problems, namely positioning the front and rear axles, and then operating the step climbing mechanism. Each sub-problem has been solved by using two independent mechanisms. These mechanisms are named positioning mechanism and climbing wheel mechanism, respectively, as shown in Figures 2a and 2b. This design approach can give different mechanical solutions for each problem. In this way each mechanism can be developed to fulfill its own requirement. The positioning mechanism needs four stable support points at each instant in order to maintain horizontal the seat and to perform the accommodation of the wheelchair to the staircase. These points are supplied by the four climbing mechanisms, one for each wheel. The positioning mechanism operation is independent by the wheel while climbing an obstacle. Furthermore, the frame of the Climbing Mechanism needs to be maintained vertical in order to perform the climb operation, which is a task for the positioning mechanism yet.

FORMULATION OF PROBLEM

Necessity

In field of providing mobility for elderly and disabled, the aspect of dealing with stairs continues largely unresolved. The most possible solution to make transportation of peoples from one floor to another can be done by lifts, but for those buildings which are generally less than three storied, the option of lifts is not feasible financially. The normal peoples can move for different heights but for disabled persons the wheelchair is one of best option for moving.

Literature Review

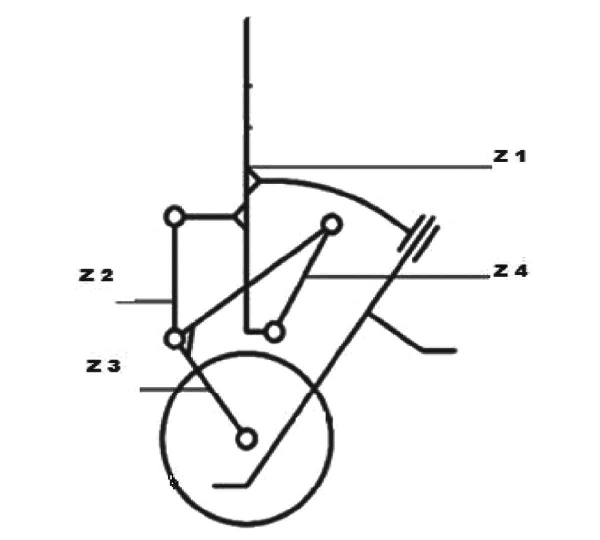
Gonzalez *et al.* (2008) explained the A mechanism that aims a wheel to climb obstacles, steps, or slopes with a suitable smooth path. The all our bar linkage can be installed on each wheel of vehicle, which therefore can capable to climb stairs with suitable comfortable motion. A straight line trajectory for centre of wheel is ensured through an easily controlled motion, and compactness of mechanism design makes it suitable for staircase climbing wheelchair for aiding people with disabilities.

Morales and Feliu (2007) explained a new advance in mobility assistance came with development of wheelchair of negotiation architectural barrier. The first commercial models were based on a single-section track mechanism. He also mentioned about a complete mechanical and kinematic design methodology of a new wheelchair with additional properties like, a capability of adapting to the new environment overcoming special profile characterized by obstacle with vertical slopes, a capability to move system, in a comfortable way for passenger, over continuous smooth profile and a capability to ascent and descent staircase. It is very important to remark these new qualities are obtained without necessary of personal assistance. All mechanical design methodology is described .Also sections involve description of different mechanical devices, the performance of these mechanisms in real situation and mechanical synthesis design used to obtained a compact solution. Also a kinematic design methodology which performs the forward and inverse kinematic over smooth profile. Moreover, this methodology can be easily particularized to a special profile characterized by obstacles with vertical slopes. Also gives a short description of experimental prototype designed.

Development of Calmos Wheelchair

It is proposed to develop Calmos wheelchair in the present reaserch work. The Figure 3 shows calmos wheelchair with position mechanism and its basic four bar mechanism. It is proposed to synthesis and simulate the mechanism.

Figure 3: Basic Four Links in Mechanism

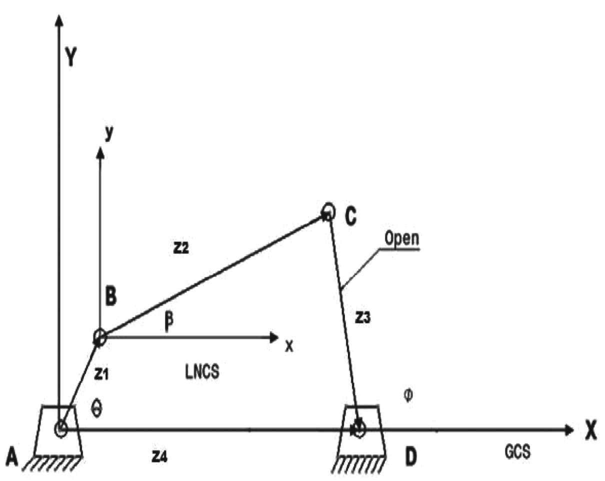


FORMULATION OF PROBLEM

The proposed research work attempt, to synthesis a four bar mechanism of CALMOS wheel chair with the mechanism installed on each wheel of climbing chair and simulates its operation (Figure 4).

Synthesis of Mechanism by Freudenstein's Method

Figure 4: Basic Four Bar Mechanism



The Basic Freudenstein's Equation for Four Bar Chain is as Under

$K_1\cos\Phi - K_2\cos\theta + K_3 = \cos(\theta\text{-}\Phi)$

where, $K_1 = Z_1/Z_2$

$K_2 = Z_1/Z_4$

$K_3 = Z_1^2 + Zl_2^2 - Z_3^2 + Z_4^2/2Z_2Z_4$

Z_1 – Length of input link.

Z_2 – Length of couplar link.

Z_3 – Length of output link.

Z_4 – Length of fixed link.

Θ – Input angle.

Φ – Output angle

K_1, K_2, K_3 are constant.

To synthesis the four bar mechanism three constants K_1, K_2, K_3 are to be established. These values can be established by assuming three exact positions of mechanism. These three positions are defined by three values of Θ and Φ. Three accurate postions are evaluated by Chebechevs spacing.

METHODOLOGY

This chapter discuses the methodology to syntsise of four bar mechanism by Freudenstein's equation and its simulation.

Methodology of Synthesis and Simulation of Mechanism

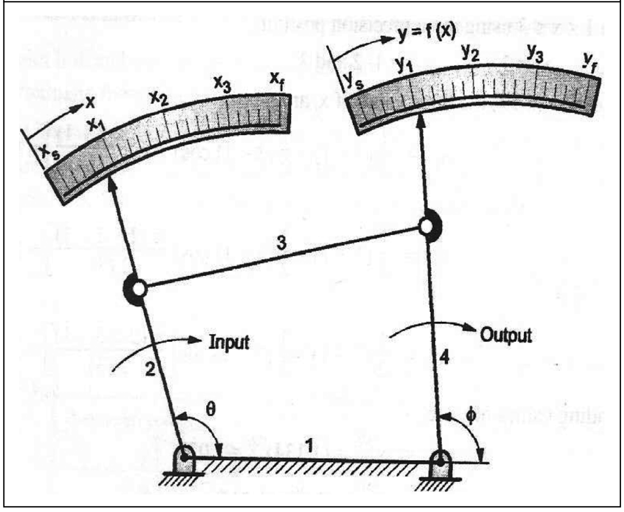
The steps in synthesis and simulation of four bar chain are:

- Assume the range of input angle and output angel for satisfactory performance of the Mechanism.
- Assume three precision position of the mechanism by assuming different input output relationship like $\theta = \Phi^2$.
- For each input output relationship assume three precision positions and evaluate the link lengths by Freudenstein's equation.
- For each input output relationship establish the link lengths by Freudenstein's equation.
- simulate each mechanism and ascertain its satisfactory performance.
- Select the mechanism which leads is satisfactory performances.
- Out of mechanism giving satisfactory performance, a mechanism is selected which follows Skeleton diagram in PRO-E.

Establishing Three Precision Positions by Assuming Relationship, i.e., *Y* = *X*⁵ by Chebyshev Spacing Method

Figure 5 shows four bar mechanism with X and Y as inputs and outputs in place of θ and Φ. X and Y are the functions of theta and phi respectively.

Figure 5: Functional Relationship for Input and Output



For Function $Y = X^5$

By chebyshev spacing formula

$\Delta Xj = \Delta X/2*(1–\cos(\Pi(2j–1)/2n))$

$\Delta X = (Xn+1)–(X0) = 360–0 = 360$

For j = 3.5, 4.5, 5.5

$\Delta X_1 = 360/2*(1–\cos(\Pi(2*3.5–1)/2*3)) = 35$

$\Delta X_2 = 360/2*(1–\cos(\Pi(2*4.5–1)/2*3)) = 45$

$\Delta X_1 = 360/2*(1–\cos(\Pi(2*5.5–1)/2*3)) = 55$

Now,

$X_0 = 0$	$Y_0 = \infty$
$X_1 = 226$	$Y_1 = 5.89*10^{11}$
$X_2 = 261$	$Y_2 = 1.21*10^{12}$
$X_3 = 306$	$Y_3 = 2.68*10^{12}$
$X_4 = 360$	$Y_4 = 6.04*10^{12}$

We have,

$\theta_j = \Delta\theta/\Delta X(Xj–X1)$ $\quad \Phi_j = \Delta\Phi/\Delta Y(Yj–Y1)$

Therefore,

$\theta 1 = 360/360*(0–0) = 0$

$\Phi 1 = 120/6.04*10^{12}(\infty – \infty) = 0$

$\theta 2 = 360/360*(261–226) = 35$

$\Phi 2 = 120/6.04*10^{12}*(1.21*10^{12}–5.89*10^{11}) = 50$

$\theta 3 = 360/360*(261–206) = 45$

$\Phi 3 = 120/6.04*10^{12}*(2.68*10^{12}–1.21*10^{12}) = 55$

$\theta 4 = 360/360*(360–306) = 55$

$\Phi 4 = 120/6.04*10^{12}*(6.04*10^{12}–2.68*10^{12}) = 65$

Now by Freudenstein's equations

$K_1 Cos\theta 1 + K_2 Cos\Phi 1 + K_3 = –Cos(\theta 1–\Phi 1)$

We have,

$0.81K_1 – 0.5K_2 + K_3 = –0.81$

$0.707K_1 + 0.034K_2 + K_3 = –0.37$

$0.57K_1 + 0.98K_2 + K_3 = –0.96$

Therefore

$K_1 = 0.33, K_2 = –0.37, K_3 = 1.08$

We have

$K_1 = Z_1/Z_4$

$K_2 = –Z_1/Z_2$

$K_3 = Z_3^2 – Z_2^2 – Z_1^2 – Z_4^2/2*Z_2*Z_4$

Assuming

$Z_1 = 220$ mm,

$Z_4 = 72.29$ mm, $Z_2 = 29$ mm, $Z_3 = 195$ mm

Using several different functions the synthesis can be carried out as follows (Table 1):

Table 1: Basic Link Dimensions on Comparision

Function	Z_1	Z_2	Z_3	Z_4	Result
$Y = X^5$	220 mm	29 mm	195 mm	72.29 mm	Simulated
$Y = X^3$	220 mm	129 mm	340 mm	536 mm	Can be Simulated
$Y = X^2$	220 mm	35 mm	205 mm	80.29 mm	Can be Simulated
$Y = 1/X$	220 mm	73.82 mm	319 mm	151.72 mm	Can be Simulated

SIMULATION OF CLIMBING WHEELCHAIR

A simulation of a system is the operation of a model of the system. The model can be reconfigured and experimented with; usually, this is impossible, too expensive or impractical to do in the system it represents. The operation of the model can be studied, and hence, properties concerning the behavior of the actual system or its subsystem can be inferred. In its broadest sense, simulation is a tool to evaluate the performance of a system, existing or proposed, under different configurations of interest and over long periods of real time. Simulation is used before an existing system is altered or a new system built, to reduce the chances of failure to meet specifications, to eliminate unforeseen bottlenecks, to prevent under or over-utilization of resources, and to optimize system performance. For instance, simulation can be used to answer questions like: What is the best design for a new telecommunications network? What are the associated resource requirements? How will a telecommunication network perform when the traffic load increases by 50%? How will a new routing algorithm affect its performance? Which network protocol optimizes network performance? What will be the impact of a link failure?

The steps involved in developing a simulation model, designing a simulation experiment, and performing simulation analysis are:

Step 1: Identify the problem.

Step 2: Formulate the problem.

Step 3: Collect and process real system data.

Step 4: Formulate and develop a model.

Step 5: Validate the model.

Step 6: Document model for future use.

Step 7: Select appropriate experimental design.

Step 8: Establish experimental conditions for runs.

Step 9: Perform simulation runs.

Step 10: Interpret and present results.

Step 11: Recommend further course of action. Although this is a logical ordering of

Figure 6: Skeleton Digram

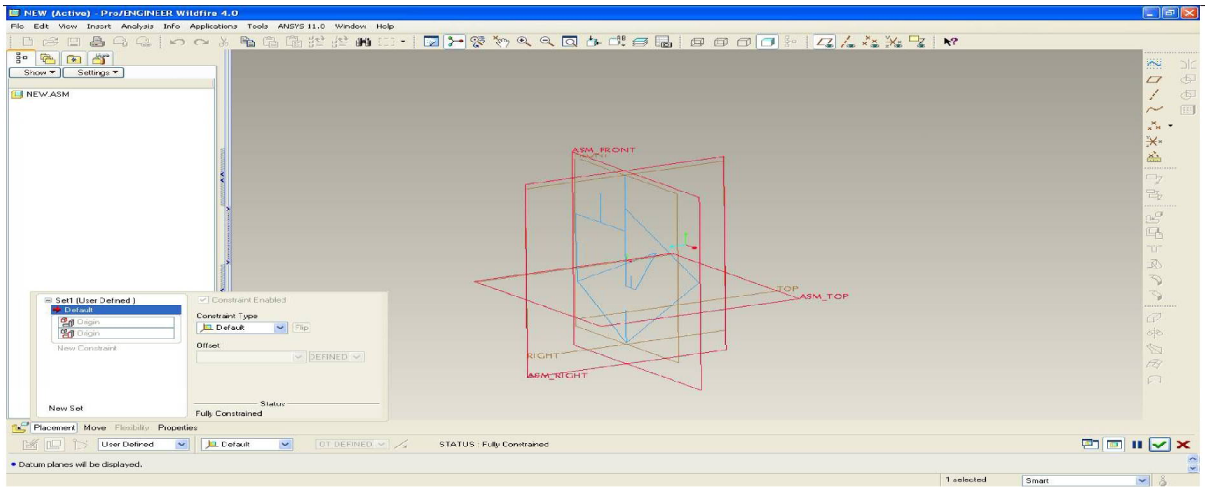


Figure 7: Simulation of Four Bar Mechanism

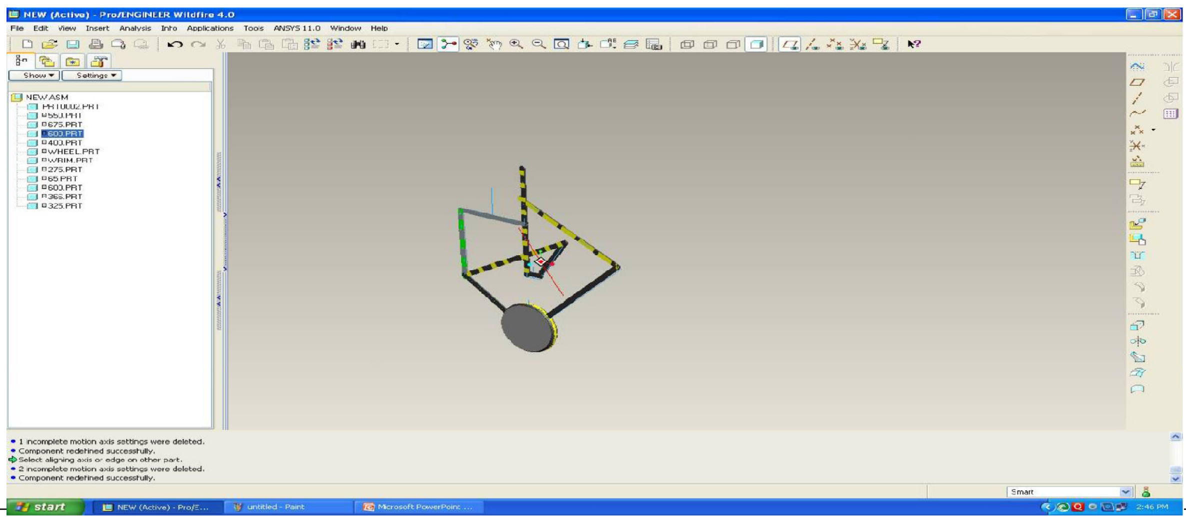


Figure 8: Simulated Mechanism

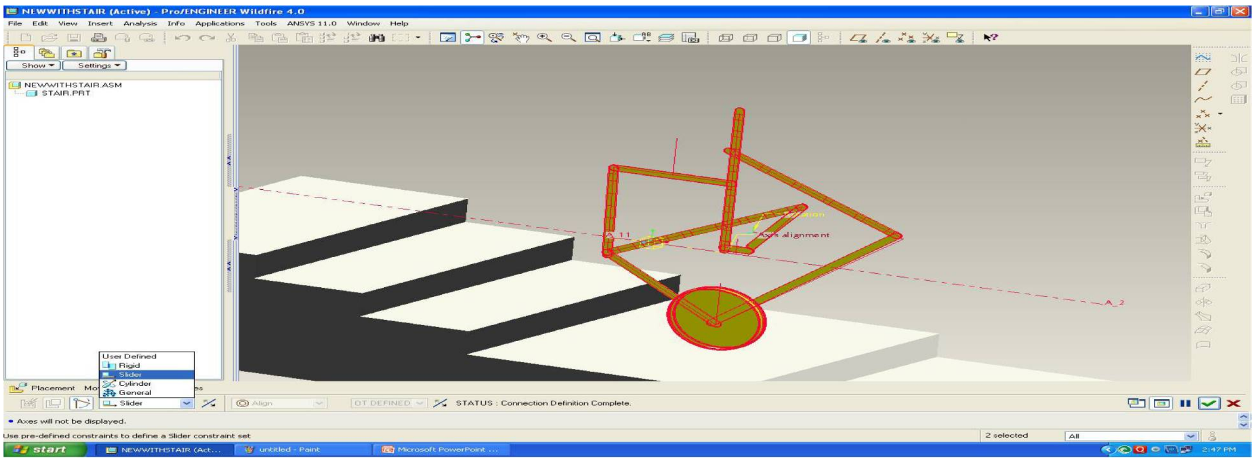
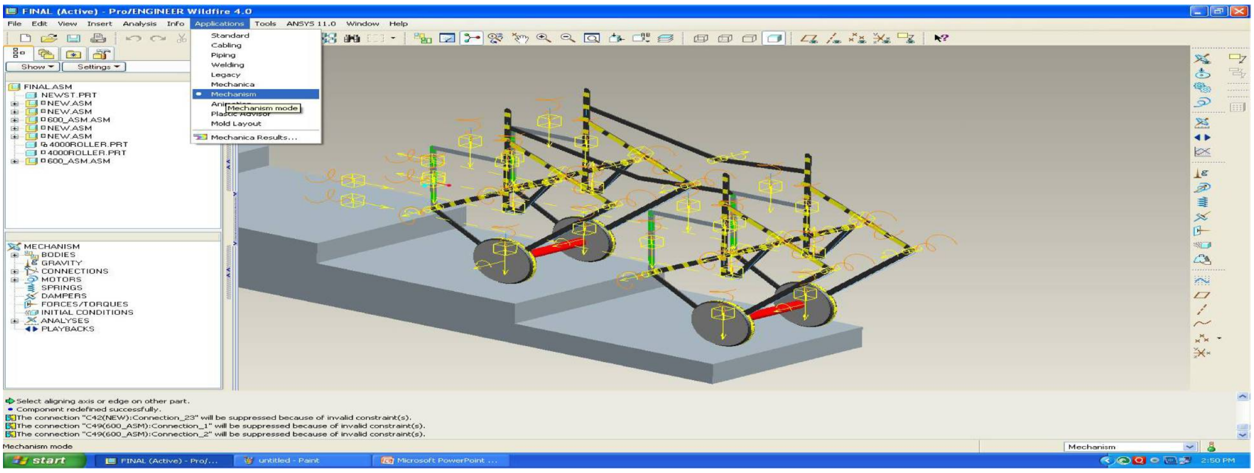


Figure 9: Simulate Four Wheeled Assembly



steps in a simulation study, many iterations at various sub-stages may be required before the objectives of a simulation study are achieved. Not all the steps may be possible and/or required. On the other hand, additional steps may have to be performed.The simulation for mechanism is as shown in Figures 6 to 9.

BIBILOGRAPHY

1. Antonio Gonzalez-Rodriguez, Angel G Gonzalez-Rodriguez and Rafael Morales (2010), "Mechanical Synthesis for Easy and Fast Operation in Climbing and Walking Robot".
2. Anu Maria (1997), "Introduction to Modelling and Simulation", Proceedings of the 29th Conference on Winter Simulation, pp. 7-13, ACM Press.
3. Erdman and Sendor (2001), *Mechanism Design: Analysis and Synthesis*, 4th Edition.
4. Gonzalez A, Ottaviano E and Ceccarelli M (2008), "A Generalized Performance on

the Kinematic Functionality of a Four-Bar Based Mechanism for Guiding Wheels in Climbing Step and Obstacles", *Journal Mechanism and Machine Theory*.

5. Morales R, Feliu V, Gonzalez A and Pintado P (2006a), "Kinematic Model of New Staircase Climbing Wheelchair and its Experimental Validation", *The International Journal of Robotics Reaserch*, Vol. 9.

6. Morales R, Feliu V, González A and Pintado P (2006b), "Coordinated Motion of a New Staircase Climbing Wheelchair with Increased Passenger Comfort".

7. Morales R and Feliu V (2007), "Kinematic Model of a New Staircase Climbing Mechanical and Kinematic Design Methodology of a New Wheelchair with Additional Capabilities", *Journal Robotic Research*, Book Aided by Maki K Habib.

8. Suwarna B Torgal, Tripathi K and Nagar N K (2003), "Simulation of Software for Four Bar Function Genrator Mechanism".