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# MSC Adams based kinematic analysis of Klann´s linkage mechanism

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**Abstract** The paper presents the kinematic analysis of Klann´s linkage mechanism using MSC Adams simulation software. The paper states the use cases of the linkage and methods of analyzing its kinematic properties. The linkage creation process is presented along with adding the required constraints and joints. Simulations are focused on evaluating the behavior of the mechanism along with the trajectory, velocity, and acceleration of significant points. Significant points analyzed are the driving crank and the end of the link touching the ground. The results of the analysis are displayed graphically thus representing the mechanism motion.

**Keywords** simulation, mechanism, analysis, trajectory, angular rotation, angular velocity, angular acceleration

## 1. INTRODUCTION

Robot walking mechanisms, a fascinating blend of engineering and biology, have captivated researchers and enthusiasts alike. These mechanisms enable robots to traverse diverse terrains, from flat surfaces to rugged landscapes, mimicking the natural gait of animals. There are 5 methods of robotic movement widely utilized in the industry namely wheeled, tracked, bipedal, aerial, and crawling. Over the millennia animal locomotion adapted to all sorts of terrains and environments making it the most dynamic way of movement. Dynamic movement and adaptability are complicated to recreate using mechanical components. This interdisciplinary approach, drawn from fields like biology, mechanics, and control engineering, has led to the creation of innovative walking robots that push the boundaries of robotic capabilities. The major advantage of mimicking animal-like movement is its agility and adaptability to the terrain thus making it more versatile than wheeled or tracked vehicles. Stability and efficiency are the main problems and focus points when designing the animal-like movement system. Every movement or motion mechanism consists of 2 components called links and joints. These components create linkage. Linkage can be described as a mechanical assembly of rigid bodies connected with joints that allow relative motion between the bodies. Relative motion can be either translational or rotational. When talking about the robotic arm motion system, the endpoint of the last link has an end effector connected to it. This end effector can be either a tool, such as a welder, or a gripper. Grippers can be created to mimic human hands utilizing linkage design. Robotic movements with linkage-based mechanisms can be created by creating rotational joints between the rigid bodies. The endpoint of a link touching the ground will create the desired motion. All movement linkages are different in the trajectory of the endpoint. Many mechanisms have been designed over the years such as the Jansen linkage, Ghassaei linkage, and many more. These mechanisms are best suited for simple yet energy-efficient walking mechanisms. The big advantage of linkages is the ease of control because they are controlled by a single actuator turning the "crank". The crank is the only link connected to the motor via a gear wheel to ensure the smooth circular motion of the mechanism. The linkage-based movement has only 1 degree of freedom (DOF) due to its use of only one actuator. On the other hand, the more complex mechanisms such as robotic arms have more DOF because of more complex control systems utilizing large numbers of actuators. In most cases, the actuators are electric, servo motors, and stepper motors to be precise. In the case of this paper, the mechanism that will be analyzed is the Klann walking mechanism also known as Klann linkage. This walking mechanism was designed by Joe Klann in 1994. Due to its design, its trajectory offers both the high step and long horizontal movement. The design can be further modified by adjusting the length of links. Sheba et al. proposed 5 different configurations that drastically change the gait of the linkage. Proposed configurations are for step climbing, to avoid jamming while walking, and for digitigrade, hammering, and digging motion. Horizontal and vertical movement is adjusted this way thus making the movement more versatile. The Klann mechanism is best used as a movement mechanism for a robotic spider or crab movement and can be used for an amphibious robot movement too. Based on the curvature of the step Klann mechanism is best used for overcoming obstacles and for movement in gravel, sand, and soil ground [1-7, 11-12].

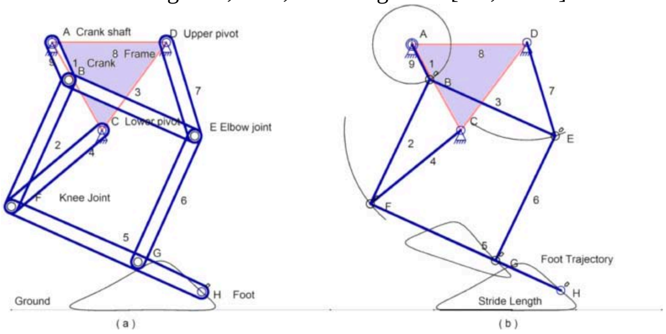


Fig. 1 Linkage-based mechanism for robotic movement [6]

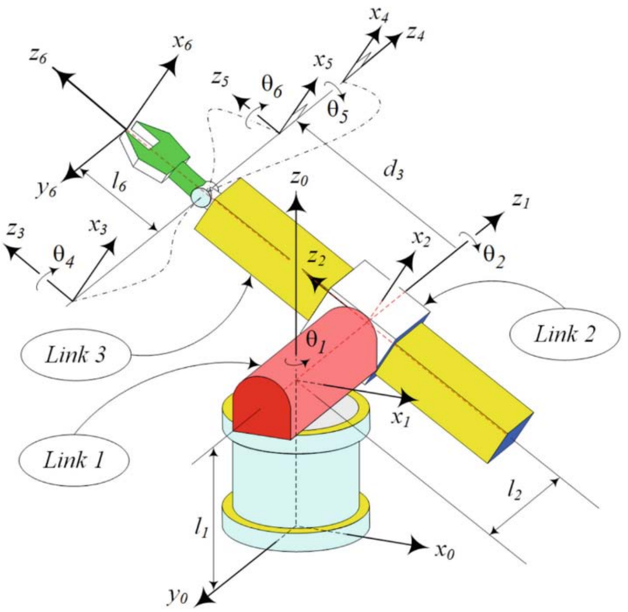


Fig. 2 Linkage-based mechanism of cylindrical manipulator [7]

## 2. KINEMATIC ANALYSIS METHODS

Two methods are used to solve kinematic analyses: kinematic vector analysis and computer-aided kinematic analysis. Kinematic vector analysis is a graphical method of calculating the motion parameters of every point of the mechanism. The mechanism is divided into smaller sub-mechanisms and calculated gradually. Based on the length of the crank the angular velocity of the endpoint of the crank is calculated. This velocity is used for further calculations of all points of the mechanism. It is important to remember that the points represent links, and some links do not move relative to each other because they have a fixed angle between them. More attention was given to graphical methods in the authors' previous work [8-9].

Nowadays computer simulations are most used in industry due to their robustness, ease of use, and many simulation options. Mechanisms are modeled and forces, constraints, and other functions are applied. There are 2 types of computer modeling: mathematical and multibody modeling. Mathematical modeling is a form of modeling the mechanism by defining the properties of elements with mathematical equations. Motion and kinematical dependencies are also derived from equations. This approach is very time-consuming and requires a complex understanding of the physics and mathematics behind the mechanism created. Because of these reasons, mathematical modeling is most suited for solving simple models with low DOF. Software used for this type of simulation is Mathematica, Matlab, or Maple. Multibody modeling is much simpler because the mechanism is modeled by defining the geometry of bodies with various shapes. This kind of modeling is simple and intuitive. Joint connections and their movement are also determined by the functions applied to the joints. Forces are also applied to either the joints or the links themselves. Software suited for this method is Matlab, Simulink, and MSC Adams [8].

In this paper, the multibody analysis will be performed, and the motion parameters of significant points will be analyzed. The biggest advantage of computer-aided analysis is that users can efficiently create and modify the mechanism. Initial conditions, forces, constraints, and other functions can easily be added and modified for optimization purposes. Robust simulations and analysis are performed. The results of the analysis are in the form of graphs, tables, and motion trajectories. Based on these outputs the mechanism and parameters of the simulation can be modified for further testing. In this paper, the software MSC Adams was chosen as best for this analysis [9].

## 3. KLANN MECHANISM ANALYSIS

As previously mentioned, the dimensions of the linkage can be modified to better suit the specific application. For this case, the standard dimensions given by the author Joe Klann were used [10].

| Link | Length [mm] | Joint | Angle [°] |
|---|---|---|---|
| 1 | 110 | α | 13 |
| 2 | 288 | β | 26 |
| 3 | 130 | γ | 45 |
| 4 | 182 | δ | 170 |
| 5 | 265 | ε | 160 |
| 6 | 222 | | |
| 7 | 490 | | |
| 1* | 206.57 | | |
| 2* | 130 | | |
| 3* | 61.45 | | |
| 4* | 266.16 | | |

Table 1. Dimensions of the Klann mechanism

The Klann mechanism was modeled using simple bodies called links with a fixed width and depth of 20 mm. The triangular body was created as the Plate. The plate was placed first and all the other links were added sequentially to ensure proper mechanism dimensions. After modeling the mechanism, the constraints were added namely revolute and fixed joints. Revolute joints were added between each link and fixed joints were added as shown in Fig. 3. Joint D was set as fixed between the triangular plate and the environment. The rotational joint motion was placed on joint A. Since joint A is a rotational joint between the triangular plate and link 1, point B of link 1 is free to move. Adding this motion made link 1 a crank which will move the entire mechanism.

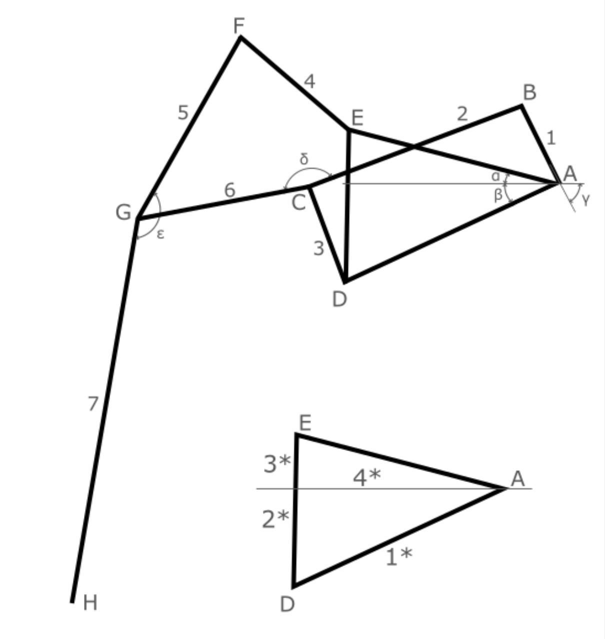

Fig. 3 Diagram of Klann mechanism

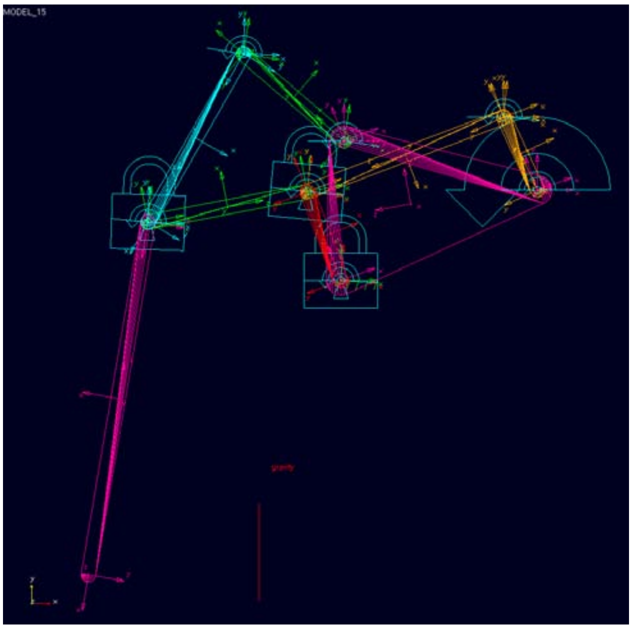
Fig. 5 Finalized Klann mechanism in MSC Adams

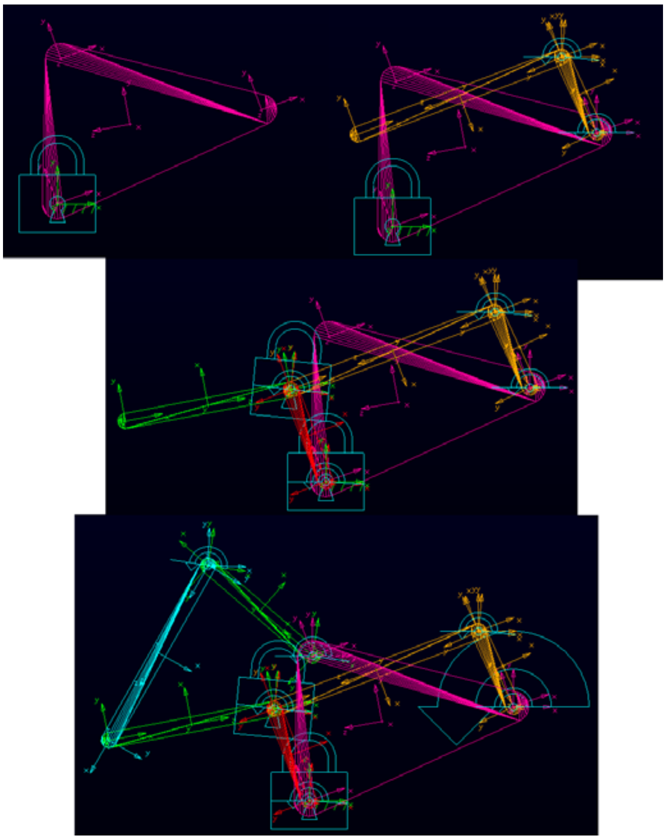
Fig. 4 Modeling of the Klann linkage

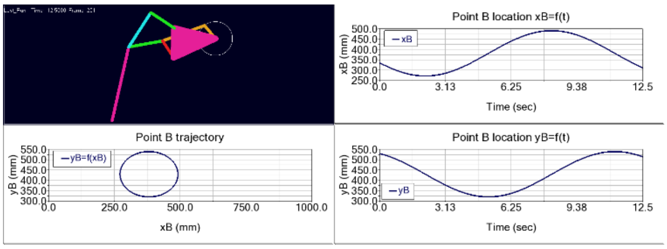

Fig. 6 Trajectory of point B at time t

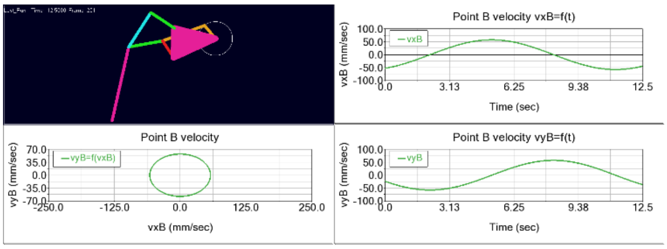

Fig. 7 Angular velocity of point B at time t

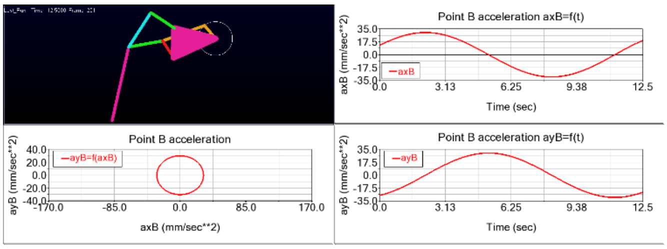

Fig. 8 Angular acceleration of point B at time t

Using the Animation control module the motion trajectories of all significant points were drawn and subsequently, the trajectories of the centers of gravity of all links were drawn. The two most significant points to analyze and compare with each other are point B representing the crank and point H representing the foot of the mechanism. The Postprocessor module was used to generate graphs of the positions, angular velocity, and angular acceleration of the most significant points. Lastly, the position of end point H compared to the angle of the crank B was added to display the change of endpoint location in different angles of the crank.

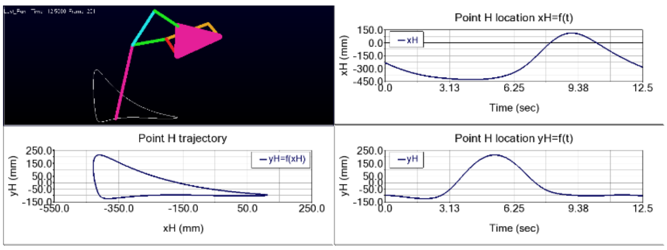

Fig. 9 Trajectory of point H at time t

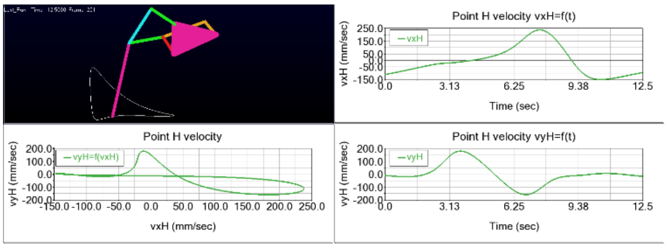

Fig. 10 Angular velocity of point H at time t

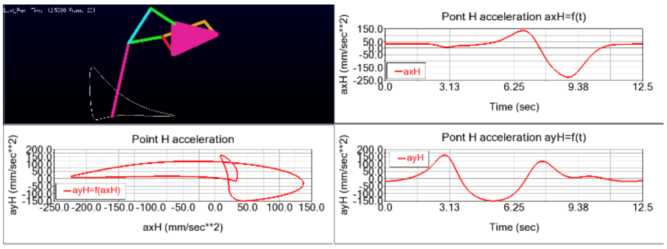

Fig. 11 Angular acceleration of point H at time t

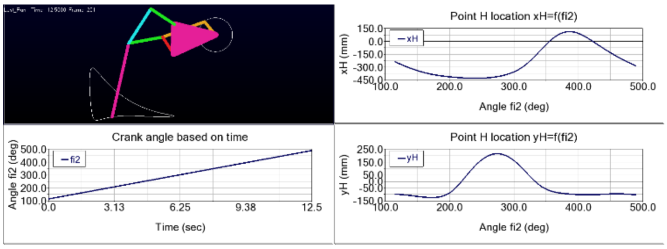

Fig. 12 Position of point H based on the angle of the crank

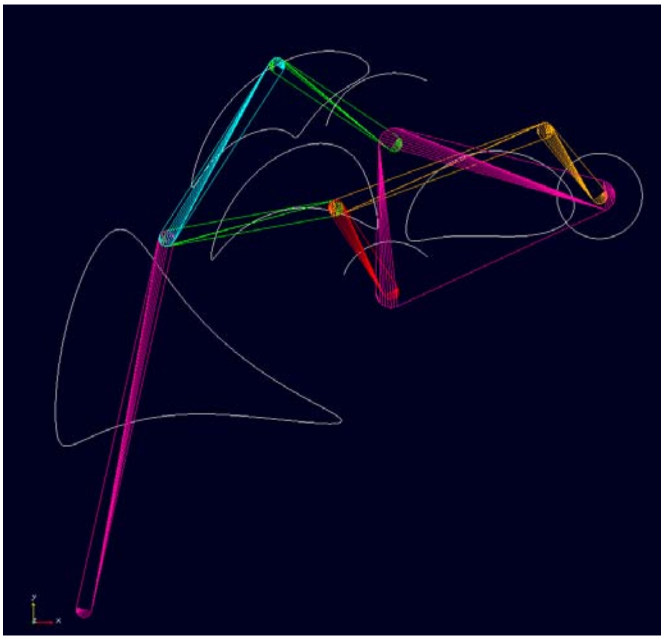
Fig. 13 Motion trajectory of significant points of Klann mechanism

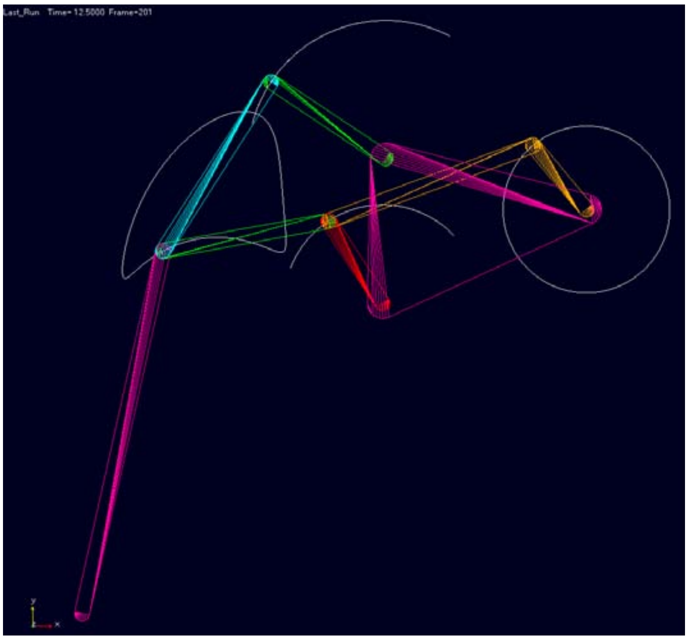
Fig. 14 Motion trajectory of centers of gravity of links of Klann mechanism

## 4. CONCLUSION

Kinematic analysis is a powerful tool for evaluating robotic mechanisms. The Klann linkage mechanism was investigated, and its use as a spider movement was discussed. Modularity of the mechanism was also discussed. Computer-aided simulation software MSC Adams was utilized to perform the kinematic analysis of the linkage. The simulation generated graphs of position, angular velocity, and angular acceleration of significant points. Output graphs provide valuable insights into the mechanism's motion. Motion trajectories were also drawn displaying the movement of all significant points and centers of gravity of all links.

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