

# Kinematic analysis of door closer mechanism using software package SAM 8.1

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**Abstract:** *The topic of this paper is to study and describe kinematic analysis of a door closer. By performing kinematic analysis, the velocity, acceleration and point position values are obtained. These data are important for the optimal sizing of the mechanism and supporting elements. We compare the analysis made by the graphical method with the analysis obtained with computer programs designed for kinematic analysis (SAM 8.1).*

**Keywords:** *kinematic analysis; SAM 8.1; door closer*

## 1. INTRODUCTION

The door closing mechanism (Fig 1) is a mechanical apparatus which absorbs the energy of opening a door (usually by human hand), using it to close the door without excessive force. This yields a practical solution for closing the door completely, without unnecessary physical damage to the door frame.



**Figure 1.** *Door closer mechanism*

One of the first references to a device used for closing doors can be found in the "Hero of Alexandria" scriptures, where automata used for closing temple doors were described. It is supposed that the door closing apparatus was working using weights and levers. A smaller version of the device, used for smaller doors (found on houses, stores, and such), used a rope with a loop, connected to the door frame.

Nowadays, door stopping mechanisms (door stoppers in later text) are commonplace. Modern door stoppers can be adjusted meticulously. They can be set for the door to stay open, the door could

be closed at a certain speed, and the pressure to the frame can be defined. The velocity regulation option is important for those doors which are used by a lot of people throughout the day. A smaller closing velocity allows a small group of people to pass quickly. By increasing the door closing velocity, the movement of a group of people is made more convenient, and the thermal losses and gains are reduced, therefore increasing the energy efficiency of a building.

Door stoppers are also tightly connected with fire safety regulations of an object, especially in those objects where the possibility of a fire hazard is high. By putting a door stopper on a fire door, which needs to be fully closed in the case of fire accident, the spreading of smoke and fire is mitigated. The door stoppers can also be used for security purposes. The electronic locks, for instance, are not completely safe without a stopper. When a person enters the room, the door is closed automatically. There is a possibility that the person who just entered the room does not close the door, leaving it unlocked. In order to prevent this case, a door stopper is installed in order to completely close the door at all times, thereby locking it as well. Door stoppers play an important role in keeping the air conditions in a room constant. As an example, let us assume the case of a mechanical engineering company with fine-grain processing. In the laboratory which contains measuring apparatuses, the exact temperature and air humidity must meet the prescribed values, yet the conditions found in the plant are different. Therefore, it is important to keep all doors open for as minimum as possible, in order to prevent air flow between these rooms. Door stoppers are often used for privacy purposes in bathrooms and changing rooms. Door stoppers are also used in cases where the velocity of opening

a door must be kept constant, in order to mitigate the air flow conditions (e.g., draft, wind).

## 2. SAM 8.1

SAM (Synthesis and Analysis of Mechanisms) is an interactive PC-software package for the design, analysis (motion and force) and optimization of arbitrary planar mechanisms. Mechanisms can either be generated via the design wizards or they can be assembled from basic components, such as: beams, sliders, gears, belts, springs, dampers and friction elements. SAM integrates pre-processing, numerical analysis and post processing, such as animation and xy-plots, in an easy to-use environment offering pull-down menus, mouse support and help facilities.

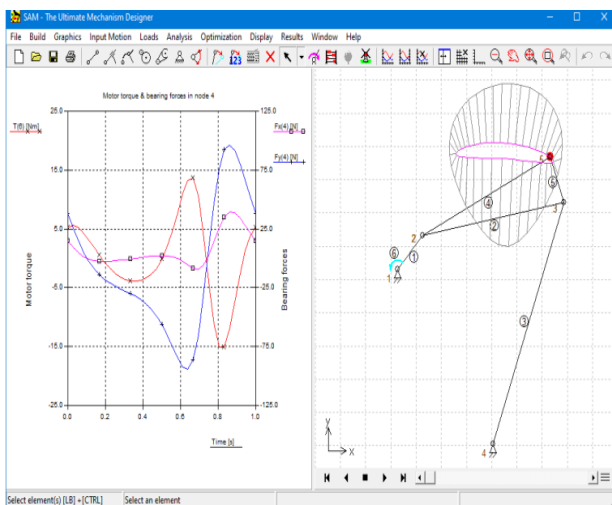


Figure 2. Typical screenshot of SAM 8.1

The mathematical foundation of the analysis kernel, which is inspired by the well-known finite element approach, offers a large number of features and overcomes many of the problems of traditional mechanism programs. Open loop, closed loop, multiple loops and even complex planetary mechanisms can equally well be analyzed due to the finite element formulation. Even the most complex mechanisms, including planetary gear trains, can be modeled within minutes.

The analysis results can be displayed either in tabular or graphical form. The tabular listing can be viewed on the screen, send to a printer or stored in a readable formatted list file. The x/y plot option allows to plot any variable against time or any other variable. An unlimited number of functions can be combined into one x/y plot with optionally two different scalings to allow proper multiple display of variables with different amplitude ranges. It is possible to output selected data to an external file (ASCII format) for customized post-processing.

SAM can also animate the mechanism motion. As a further aid for the designer the path and velocity hodograph of any number of moving points can be plotted. Also, a complete project documentation (ASCII-format) can be automatically generated.

Once the mechanism has been constructed and the inputs have been defined any of the following kinematic quantities can be calculated (all relative or absolute):

- nodal position, displacement, velocity, acceleration
- angles, angular velocity and acceleration

Furthermore, SAM can perform force-analysis, thus enabling the calculation of:

- driving torque (force)
- reaction forces in bearings
- internal forces in elements
- required or transmitted power

External forces, such as process forces, can be applied as function of time or as function of any motion result, that is calculated by SAM. The same holds for external torques. The user can define a force (value & direction) as function of time.

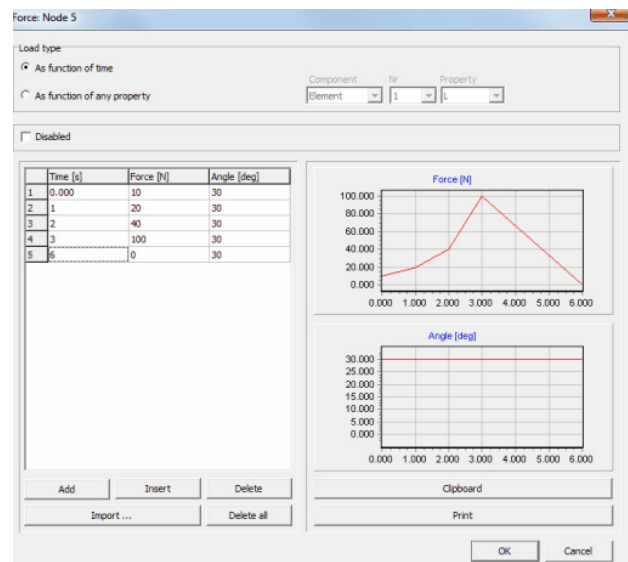


Figure 3. Force profile as function of time

SAM can also optimize the parameters of a mechanism such that a desired trajectory is followed as good as possible. The first screenshot below shows the result of a manual attempt to find a 4-bar mechanism with a coupler point motion that mimics the Bezier curve through 8 specified points. This mechanism is used as a starting point for an optimization in which the RMS-value of the deviation of the actual trajectory from the target curve is chosen as optimization objective function and the positions of the nodes of the mechanism are the design parameters. All moving nodes can be chosen arbitrarily, whereas the support points are limited in their range, as indicated. As can be seen, the mechanism that resulted from the optimization process shows significantly better correspondence with the requested target path.

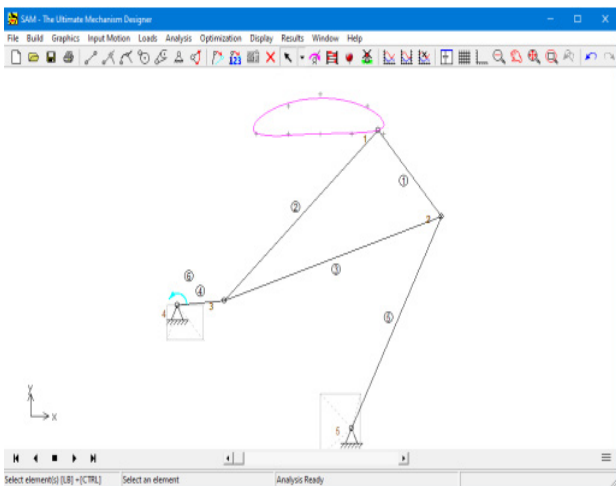


Figure 4. Optimized 4-bar mechanism

### 3. KINEMATIC ANALYSIS USING SAM 8.1

The kinematic analysis will be performed using SAM 8.1 software tool. The first thing that needs to be done is draw a schematic of the door stopper when the door is fully open.

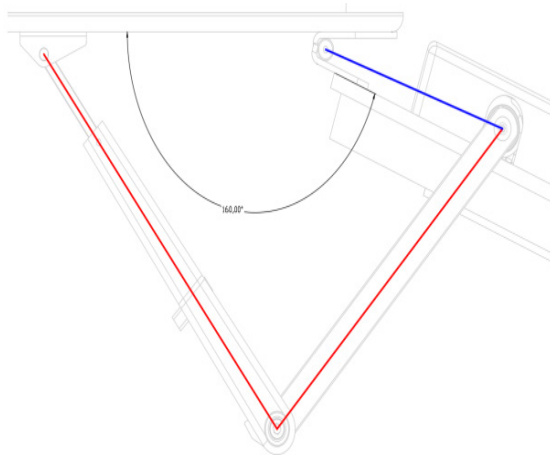


Figure 5. Polygon position in AutoCad

First, draw a beam using SAM. The fixed support is positioned on one end of the beam, where the origin of the coordinate system is to be placed. After that, the coordinates of each point is read from AutoCad (Fig 6).

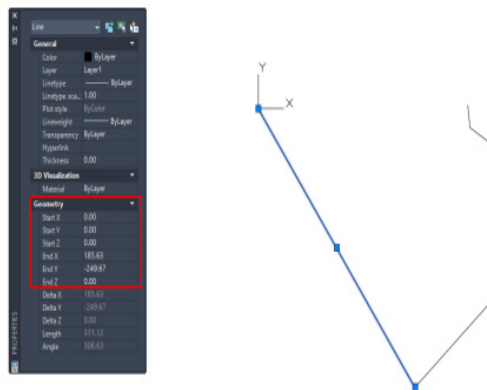


Figure 6. Coordinate display in AutoCad

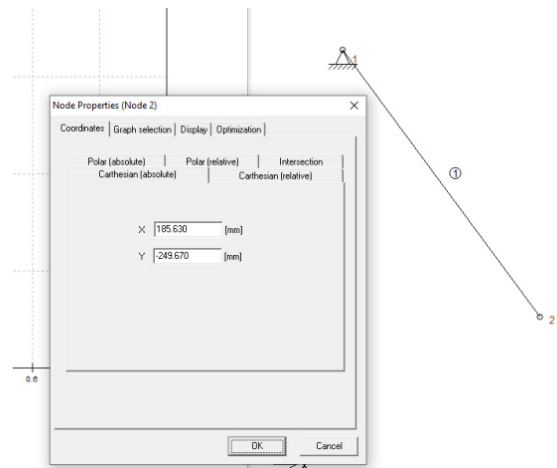


Figure 7. Node properties dialog box

After the coordinates for all the points are noted, the kinematic schematic of the mechanism is obtained.

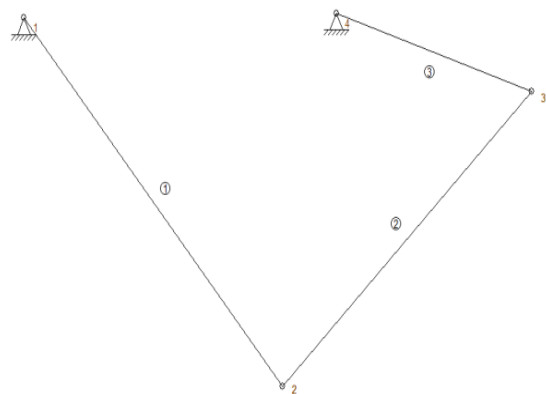


Figure 8. Kinematic scheme of mechanism

For the kinematic analysis, the most important point for velocity and acceleration calculation are points 2 and 3.

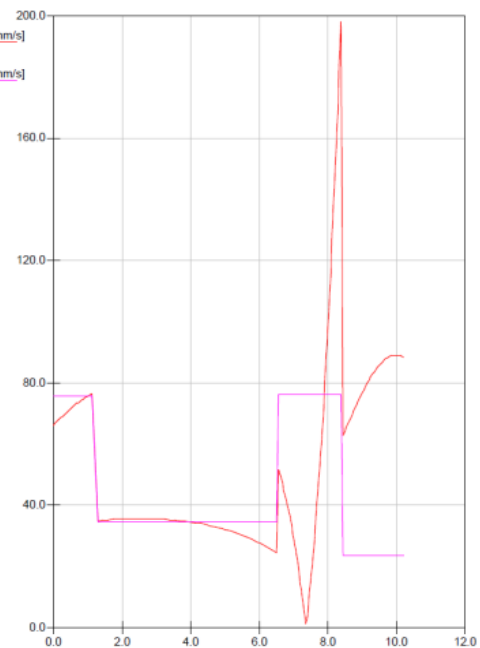
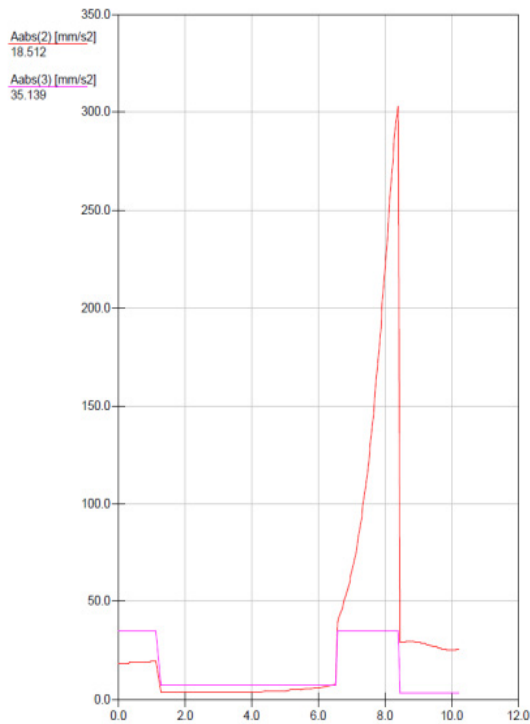
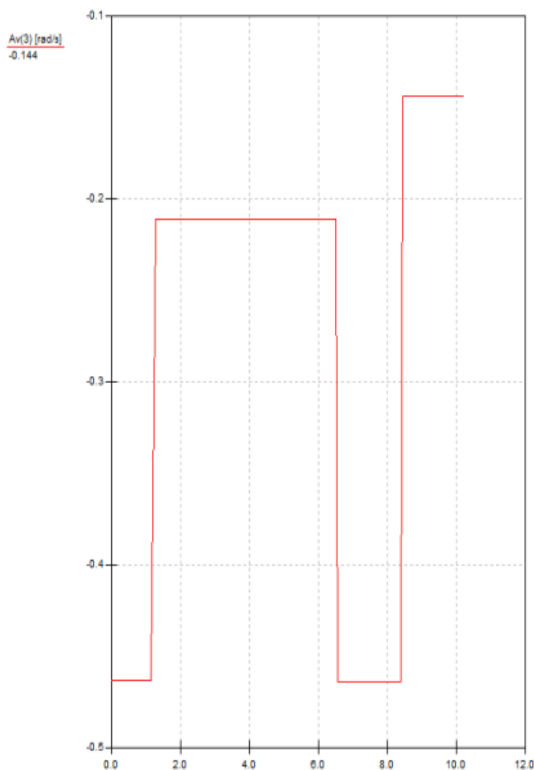


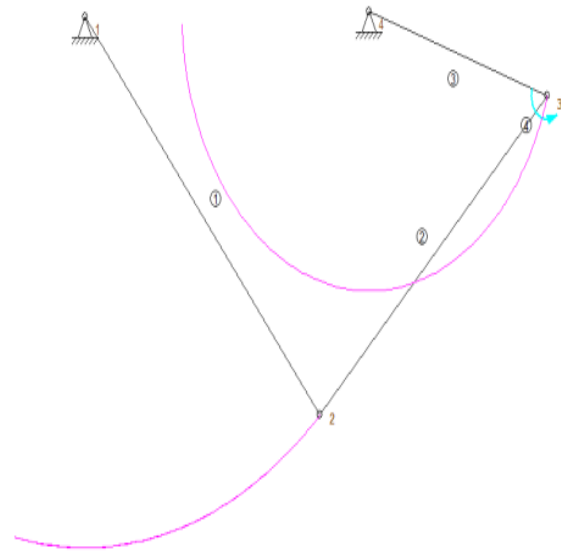
Figure 9. Velocity diagram of point 2 and 3



**Figure 10.** Acceleration diagram of point 2 and 3  
 Also, the angular velocity of point 3 can be of interest. The angular velocity of point B is interesting because the mechanism (located in point B) and the door is considered a single body.



**Figure 11.** Angular velocity of point B  
 Another interesting fact for SAM is that this software plots the graphs for the location of points.



**Figure 12.** Path of point 2 and 3  
 Results can also be displayed in tabular form.

Table 1. Comparison of velocity results

Point	Velocity (m/s) AutoCad	Velocity (m/s) SAM
A-2	0,071	0,07061
B-3	0,076	0,07583

Table 2. Comparison of acceleration results

Point	Acceleration (m/s²) AutoCad	Acceleration (m/s²) SAM
A-2	0,019	0,01897
B-3	0,035	0,03514

Table 3. Results of relative error

Point	Velocity	Acceleration
A-2	0,00039	0,00003
B-3	0,00017	0,00014

The relative errors between the results are insignificant. Therefore, the results of solving this problem graphically are same as solving it by using simulation.

#### 4. CONCLUSION

The door stopper is a very useful apparatus, which has extensive uses, such as in security, social and ecological. For security purposes, it is used mostly for fire doors in order to keep them tightly closed, as well as for automatically closing and locking a door. The goal is to optimize closing time in order to meet social and energetic requirements. The less the door is opened, the less the thermal losses,

thus saving the energy, positively affecting the environment and reducing the financial costs.

The kinematic analysis yields the velocity and acceleration values for all characteristic points of the mechanism. Also, the position values for each point are important in designing the mechanism, in order to avoid collisions with other parts of the mechanism or other bodies. The analysis was conducted in a graphical manner using the CAD software suite, but in a way that can also be performed by hand. Also, a modern way of kinematic analysis, where the calculation of velocity and acceleration for each position was performed by using the given parameters.

By knowing all velocity and acceleration values, a kinematic diagram is generated. The maximum values can easily be read from the diagram. With the help of these diagrams, tension and force inside the beams should be calculated as a next step, in order to optimally determine the dimensions of the mechanism. The flaw of this kind of analysis is the precision of time and angular velocity measurement. For a more precise analysis, the measurements should be made using modern equipment, such as sensors.

#### ACKNOWLEDGEMENTS

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#### REFERENCES

- [1] Rusov, L. (1990). *Mechanics-Kinematic*, Faculty of Mechanical Engineering, University of Belgrade, Belgrade. (in Serbian)
- [2] Pisačić, K., Kondić, V., Višnjić, V., Kinematic analysis mechanism using computer application SAM, Technical Journal 9, 3(2015), p.p. 298-302.
- [3] Krishnaraju, A., Abdul, Z., Design and SAM analysis of reconfigurable four-legged mechanism using single degree of freedom, International Journal of Heavy Vehicle Systems, January, 2018.
- [4] Đ.Jovanović, M.Krstić, B. Milenković: Kinematic analysis of complex mechanism using SAM, Conference on Mechanical Engineering Technologies and Applications COMETA 2020, Faculty of Mechanical Engineering East Sarajevo, November 26-28 2020, ISBN 978-99976-719-8-1; pp.189-196.
- [5] [file:///C:/Users/uSER/Downloads/sam80us\\_manual.pdf](file:///C:/Users/uSER/Downloads/sam80us_manual.pdf)