



# Computer-Aided Kinematic Analysis of Two-Movement Follower Mechanism

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**Abstract.** Cams and followers are parts of many mechanical systems, including those that assure rotation and translation intermittent movement of an element, example for conveyor belts or rotating stages. The paper deals with the analysis of the influence of geometrical parameters on the kinematics of two-movement follower mechanism using Computer-Aided Engineering. The profile of the cam was analytically determined. The geometric model and the kinematic analysis of the mechanism were made with several software packages (AutoCAD, Autodesk Inventor, Adams and Altair Inspire).

**Keywords:** cam-follower mechanism · kinematic analysis · CAE

## 1 Introduction

Cam-follower mechanisms for intermittent  $90^\circ/120^\circ/180^\circ/360^\circ$  rotation [2–5] find application in different devices and machines, such as system with conveyor belts on various levels, or rotating stages - terrestrial or aquatic - which can move also vertically. For the analysis and geometric modelling of these types of mechanisms, classical and modern methods can be used, as well as high-performance software (e.g. Altair Inspire - module Inspire Motion [8], Autodesk Inventor [7], Msc Adams [6], Pro-Engineering - module Pro-Mechanica).

In [1] was presented the structural and kinematic analysis of a cam-follower mechanism with a rotating cam and a translating flat-faced follower with continuous rotation; the cam has a circular profile connected to a rectilinear one; at the points of changing the radius of curvature of the cam, oscillations of velocity and acceleration occur.

The present work is an extension of paper [1], and has the aim to investigate the effect of cam profile connection radius on the kinematics of the mechanism, in order to reduce acceleration shocks.

The cam with the same geometrical dimensions like in the previous work is considered, except the connection radius between the linear and circular profile, which has higher value. In the first stage, it will be considered the mechanism with axial follower, then with eccentricity and continuous rotation.

For comparative purposes, kinematic analysis was performed using the software Msc Adams and Altair Inspire.

## 2 Analysis of the Mechanism

Figure 1 shows the kinematic scheme of the rotating cam-translating plate follower mechanism which is used in the first stage of this study.

The known geometric data are:  $R = 35$  mm,  $r = 15$  mm,  $a = 15$  mm (Fig. 2). The coordinates of the points on the cam profile are established - the points on the fillet arc (including the ends A and B), the points on the linear profile and those on the circular profile, using the equations established in [1] (1-7).

$$x_A = |DO_2| = \sqrt{|O_1O_2|^2 - |DO_1|^2} = \sqrt{2a(R-r) - a^2} \quad (1)$$

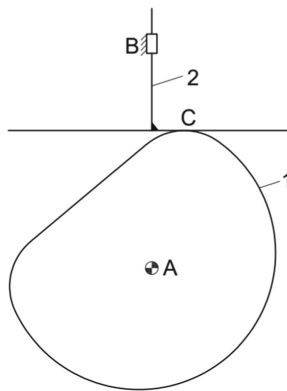


Fig. 1. The kinematic scheme of the mechanism.

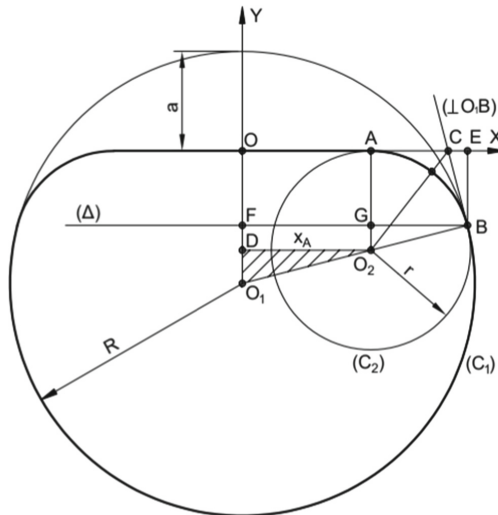
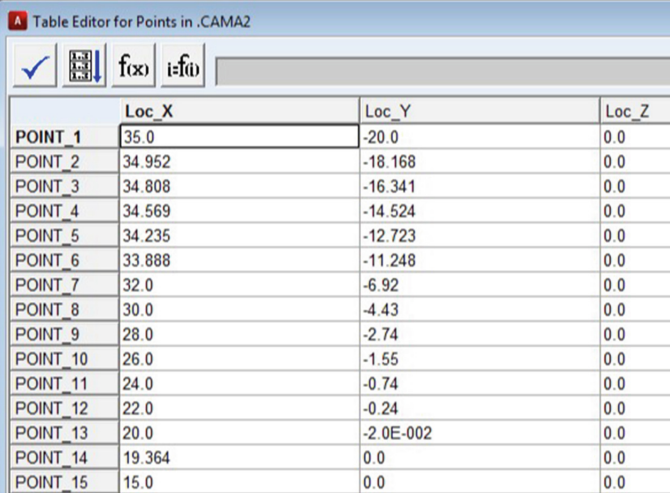


Fig. 2. The scheme for determining the coordinates of cam profile points.



	Loc_X	Loc_Y	Loc_Z
POINT_1	35.0	-20.0	0.0
POINT_2	34.952	-18.168	0.0
POINT_3	34.808	-16.341	0.0
POINT_4	34.569	-14.524	0.0
POINT_5	34.235	-12.723	0.0
POINT_6	33.888	-11.248	0.0
POINT_7	32.0	-6.92	0.0
POINT_8	30.0	-4.43	0.0
POINT_9	28.0	-2.74	0.0
POINT_10	26.0	-1.55	0.0
POINT_11	24.0	-0.74	0.0
POINT_12	22.0	-0.24	0.0
POINT_13	20.0	-2.0E-002	0.0
POINT_14	19.364	0.0	0.0
POINT_15	15.0	0.0	0.0

**Fig. 3.** Table Editor for the points of the mechanism.

$$y_A = 0 \quad (2)$$

$$x_B = |\overline{OE}| = |\overline{FB}| = \frac{R}{R-r} \cdot \sqrt{2a(R-r) - a^2} \quad (3)$$

$$y_B = -|\overline{EB}| = -[(R-a) - \sqrt{R^2 - x_B^2}] \quad (4)$$

The arc  $\widehat{AB}$  from the circle  $C_2$  is determined with (5).

$$(x - x_{O_2})^2 + (y - y_{O_2})^2 = r^2 \Rightarrow$$

$$y = y_{O_2} + \sqrt{r^2 - (x - x_{O_2})^2} \quad (5)$$

$$x_{O_2} = x_A; y_{O_2} = -r \quad (6)$$

For the chosen profile of the cam ( $R = 35$  mm,  $r = 15$  mm,  $a = 15$  mm) the Cartesian coordinates of the points were calculated.

Coordinates of both cam and flat-faced follower are entered in the Table Editor (Fig. 3, Fig. 4), and then the profiles are generated (Fig. 5, Fig. 6 and Fig. 7).

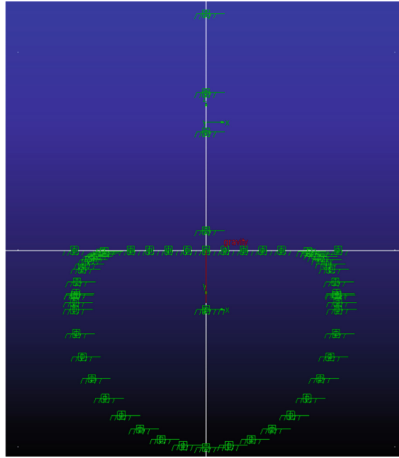
The joints of mechanism are built: the rotation joint between the cam and the base, the translation joint between the follower and the base, and the open joint between the cam and the follower by the sequence of instructions Connectors-Curve-Curve.

The engine is placed in the rotation joint of the cam and has an angular velocity of  $\omega = 30^\circ/\text{s}$  (Fig. 8).

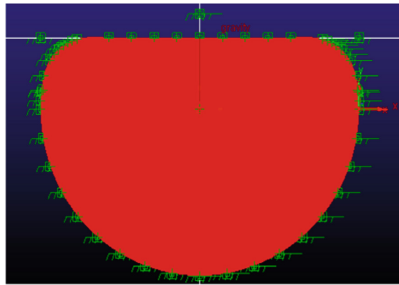
After simulation, the results for the positions, velocities and accelerations of the follower are shown in Fig. 9 and Fig. 10. It is observed that at the moment of starting, the acceleration has a great variation (Fig. 10).

	Loc_X	Loc_Y	Loc_Z
POINT_16	10.0	0.0	0.0
POINT_17	5.0	0.0	0.0
POINT_18	0.0	0.0	0.0
POINT_19	-5.0	0.0	0.0
POINT_20	-10.0	0.0	0.0
POINT_21	-15.0	0.0	0.0
POINT_22	-19.364	0.0	0.0
POINT_23	-20.0	-2.0E-002	0.0
POINT_24	-22.0	-0.24	0.0
POINT_25	-24.0	-0.74	0.0
POINT_26	-26.0	-1.55	0.0
POINT_27	-28.0	-2.74	0.0
POINT_28	-30.0	-4.43	0.0
POINT_29	-32.0	-6.92	0.0
POINT_30	-33.888	-11.248	0.0
POINT_31	-34.235	-12.723	0.0
POINT_32	-34.569	-14.524	0.0
POINT_33	-34.808	-16.341	0.0
POINT_34	-34.952	-18.168	0.0
POINT_35	-35.0	-20.0	0.0
POINT_36	-34.468	-26.077	0.0
POINT_37	-32.889	-31.97	0.0
POINT_38	-30.31	-37.5	0.0
POINT_39	-26.811	-42.497	0.0
POINT_40	-22.497	-46.811	0.0
POINT_41	-17.5	-50.31	0.0
POINT_42	-11.97	-52.889	0.0
POINT_43	-6.077	-54.468	0.0
POINT_44	0.0	-55.0	0.0
POINT_45	6.077	-54.468	0.0
POINT_46	11.97	-52.889	0.0
POINT_47	17.5	-50.31	0.0
POINT_48	22.497	-46.811	0.0
POINT_49	26.811	-42.497	0.0
POINT_50	30.31	-37.5	0.0
POINT_51	32.889	-31.97	0.0
POINT_52	34.468	-26.077	0.0
POINT_53	35.0	-20.0	0.0
POINT_55	0.0	-20.0	0.0
POINT_55_2	-35.0	0.0	0.0
POINT_56	-20.0	0.0	0.0
POINT_57	-10.0	0.0	0.0
POINT_58	0.0	0.0	0.0
POINT_59	10.0	0.0	0.0
POINT_60	20.0	0.0	0.0
POINT_61	35.0	0.0	0.0
POINT_62	0.0	5.0	0.0
POINT_63	0.0	30.0	0.0
POINT_64	0.0	40.0	0.0
POINT_65	0.0	60.0	0.0

Fig. 4. Table editor for the points of the mechanism.



**Fig. 5.** The generation of points on the cam profile and of the flat follower.



**Fig. 6.** The generation of the cam profile.

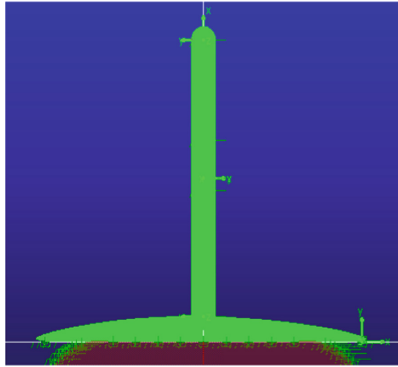
At the points of changing the radius of curvature of the cam, oscillations of velocity and acceleration occur.

For the mechanism in the current study there were lower shocks of the follower acceleration to the impact of the follower with the linear profile of the cam than to the variant in the paper [1], where the radius of curvature was 5 mm.

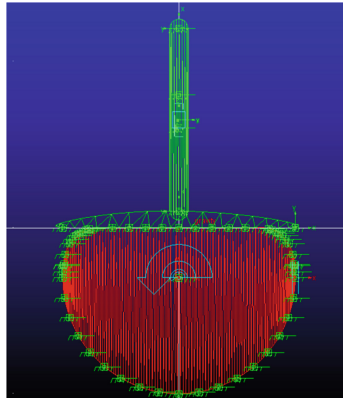
The values of the maximum and minimum velocity of the follower are 9.7 mm/s, respectively - 9.59 mm/s (the velocity values from [1]: the maximum is 12.64 mm/s and the minimum is -12.71 mm/s).

The maximum acceleration of the follower is 4.6 mm/s<sup>2</sup> and the minimum - 5.39 mm/s<sup>2</sup>, significantly lower than that in [1] (maximum acceleration in [1] is 44.69 mm/s<sup>2</sup> and minimum acceleration is -7.9 mm/s<sup>2</sup>).

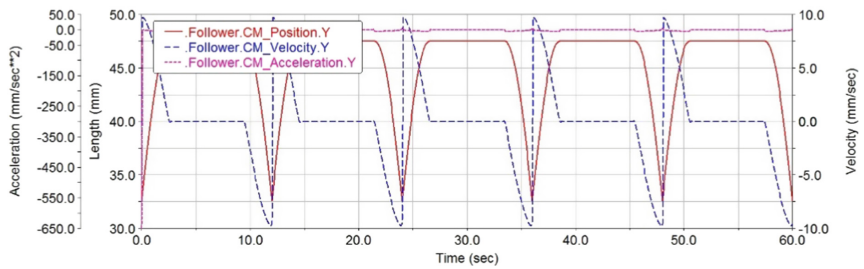
For a comparative study of the results, the geometric model of the mechanism with 20 mm eccentricity between the plane of the cam and the shaft of the follower is also made in the Autodesk Inventor program. After this, it was exported in \*.stl format and imported in Altair Inspire 2021.2.3 and the kinematic animation/analysis was performed for motor speed  $n = 5$  rpm (Fig. 11).



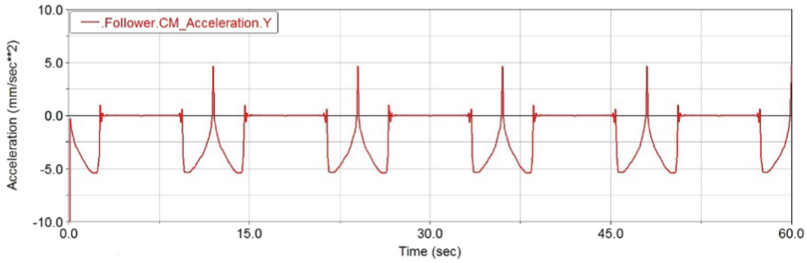
**Fig. 7.** The generation of the follower profile.



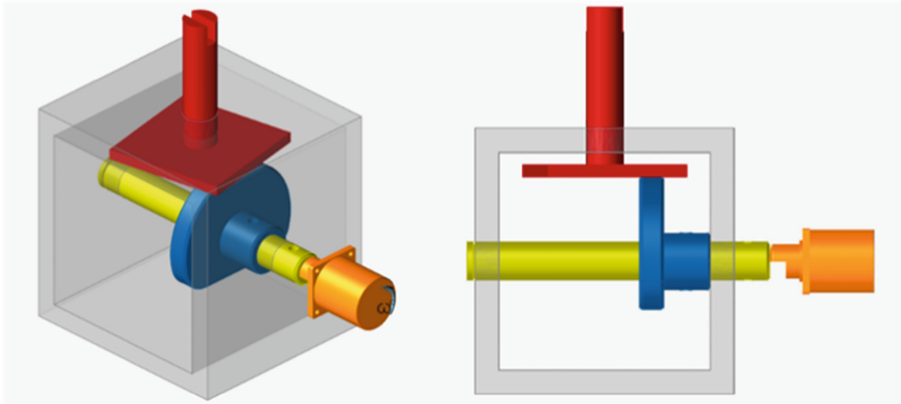
**Fig. 8.** The placing of the engine in the camshaft.



**Fig. 9.** The diagrams of position, velocity and acceleration of the follower.



**Fig. 10.** The diagram for acceleration of the follower at bigger scale.

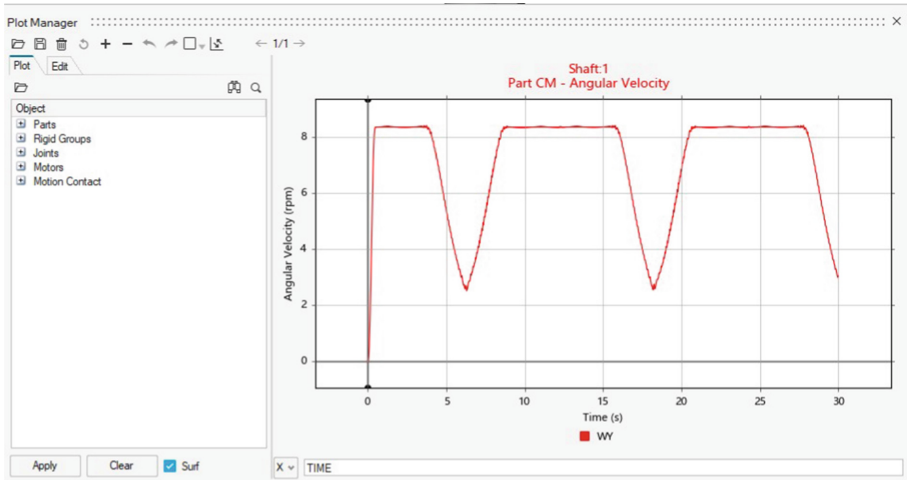


**Fig. 11.** Geometry and Motion for mechanism applied in Altair Inspire program.

The same kinematic diagrams were obtained with both programs Msc Adams and Altair Inspire.

If there is no slip between the cam and the follower, the cam velocity is equal to that of the follower at the point of contact and depends on the current radius and the angular speed of the cam.

In Fig. 12 it is shown the diagram for the angular velocity of the follower with 20 mm eccentricity between the plane of the cam and the shaft of the follower.



**Fig. 12.** The diagram of angular velocity of the follower.

The angular velocity of the follower around its own axis, due to the eccentricity and the frictional force between the cam and the follower, is variable and continuous, because in this phase the stopper was not mounted to block the rotational movement of the follower.

The maximum value of the angular velocity of the follower is on the circular profile of the cam, 8.7 rpm, and the lower is on the linear profile of the cam, 2.6 rpm.

### 3 Conclusions

In conclusion, for cam-flat follower mechanism which has linear and circular profile with fillet, at the points of changing the radius of curvature, oscillations of velocities and accelerations occur. The acceleration has maximum finite value (soft shock) when the follower comes into contact with the linear profile of the cam. Increasing the connection radius and keeping the other geometric parameters identical determines the decrease of acceleration shocks. The angular velocity of the follower around its own axis, for the mechanism with eccentricity, is variable and continuous. Programming with high-performance programs such as Msc Adams and Altair Inspire reduces design time and ensures accurate results.

### References

1. Cretu, S.M., Corzanu, A., Corzanu, V.: Mecanisme cu came. Sitech, Craiova (2021).
2. <https://www.youtube.com/watch?v=iX5KuIO8fFo>, last accessed 2022/03/26.
3. [https://www.youtube.com/watch?v=5IEGc\\_GlwvA](https://www.youtube.com/watch?v=5IEGc_GlwvA), last accessed 2022/03/26.
4. <https://www.youtube.com/watch?v=RoNH0YXpW2c>, last accessed 2022/03/26.
5. <https://www.youtube.com/shorts/Hikxwq8-I>, last accessed 2022/03/26.



6. [http://www.kts.tul.cz/content/files/podklady/Book\\_Adams-Tutorial-w.pdf](http://www.kts.tul.cz/content/files/podklady/Book_Adams-Tutorial-w.pdf), last accessed 2022/03/26.
7. <https://help.autodesk.com/view/INVNTOR/2021/ENU/>, last accessed 2022/03/26.
8. [https://2021.help.altair.com/2021.2/inspire/en\\_us/index.htm](https://2021.help.altair.com/2021.2/inspire/en_us/index.htm), last accessed 2022/03/26.

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