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A Kinematic Design and Analysis of a Robotic Multi Motion Drive Machine

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ABSTRACT

Mechanism design is just one of the many challenges that you as a designer/engineer have to face and if it's not your daily routine it is important that the tools you are using are easy and intuitive. This study investigates on the kinematic analysis of a Multi Motion Drive Machine (MMD), in general, of a planar parallel 3-RRR robot with three synchronously driven cranks. For this aim, it is used a special software SAM (Synthesis and Analysis of Mechanisms) for kinematical methods on velocity, acceleration, force and torque analysis, which allows engineers to simulate and optimize 2D mechanisms and drives.

Keywords: 2D geometric design, kinematic analysis of motions, planar mechanism, simulation of movement.

1 Introduction

Number examples of walking equipment integrated with heavy vehicle systems and robots have been conceived, measured and built in the last 25 years to realize a modern field of applications [1]. In recent years, the increase in computerized software for visual design and analysis of kinematic problems has also brought convenience to researchers. Therefore, one of these software programs SAM is presented [2-4], was used in this study and the mechanism discussed in [5] was examined.

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 including 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.

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 loop and even complex planetary mechanisms can equally well be analyzed due to the finite element formulation [2-4].

Kinematics is a science discipline that developed in mechanics, in which describes the motion of points,

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bodies, and systems of bodies. So, kinematics is often denoted to as the "geometry of motion". Therefore, to solve a kinematics problem starts out by characterizing the geometry knowledge. Then, with integrating geometry arguments, the position, velocity and acceleration of any unknown parts of the system can be resulted.

A high-speed planar mechanism with modifiable compulsory courses was introduced and analyzed in [5-7]. It was with Software Packages Maple [8] demonstrated and shown that the question whether the cranks of a given mechanism are completely revolvable cannot be answered. After geometrically perception, it was proved that the problem can only be resolved from case to case by a numerical analysis [9].

The rest of the paper is constructed as follows: In the following, it is given the definition, geometric construction and kinematical methods for the design and simulation of a Robotic Multi Motion Drive Machine with SAM. In section 3 is in generally the design of the MMD and as an another example with a curvilinear translation with SAM demonstrated. Finally, the concluding remarks are presented.

2 Definition of the Mechanism

A robotic multi motion drive machine that in this study geometrical and kinematical investigated was in the Dr. E. Fehrer Company as a needle punching machine in Linz/Austria produced (Figure 1).

Figure 1: Needle punching machine as a MMD.

This multi motion drive machine consists of a synchronized vertical and horizontal movement, which results in a virtually elliptical needle tip path. It allows the infinite movement of horizontal progress even while needling is in progress, and also permits the infinite adjustment of horizontal advance. A multi motion drive machine defined above is displayed as geometrical in Figure 2a.

The motion is a curvilinear translation. In Figure 2b could be seen how the variation of the phase shift $\delta_b = \pi + \varphi$ acts on the trajectories. For $\varphi = 0$ all trajectories are aligned. In Figure 2c is demonstrated relative path at 3000 rpm and belt speed v in m/min. The underlying sizes of geometrical depiction for needle punching machine in Figure 1 are

$$\overline{A_0B_0} = 140\ mm$$

$$\overline{A_0A_1} = \overline{B_0B_1} = \overline{C_0C_1} = 22.5\ mm$$

$$\overline{A_1A_2} = \overline{B_1B_2} = \overline{C_1C_2} = 110\ mm$$

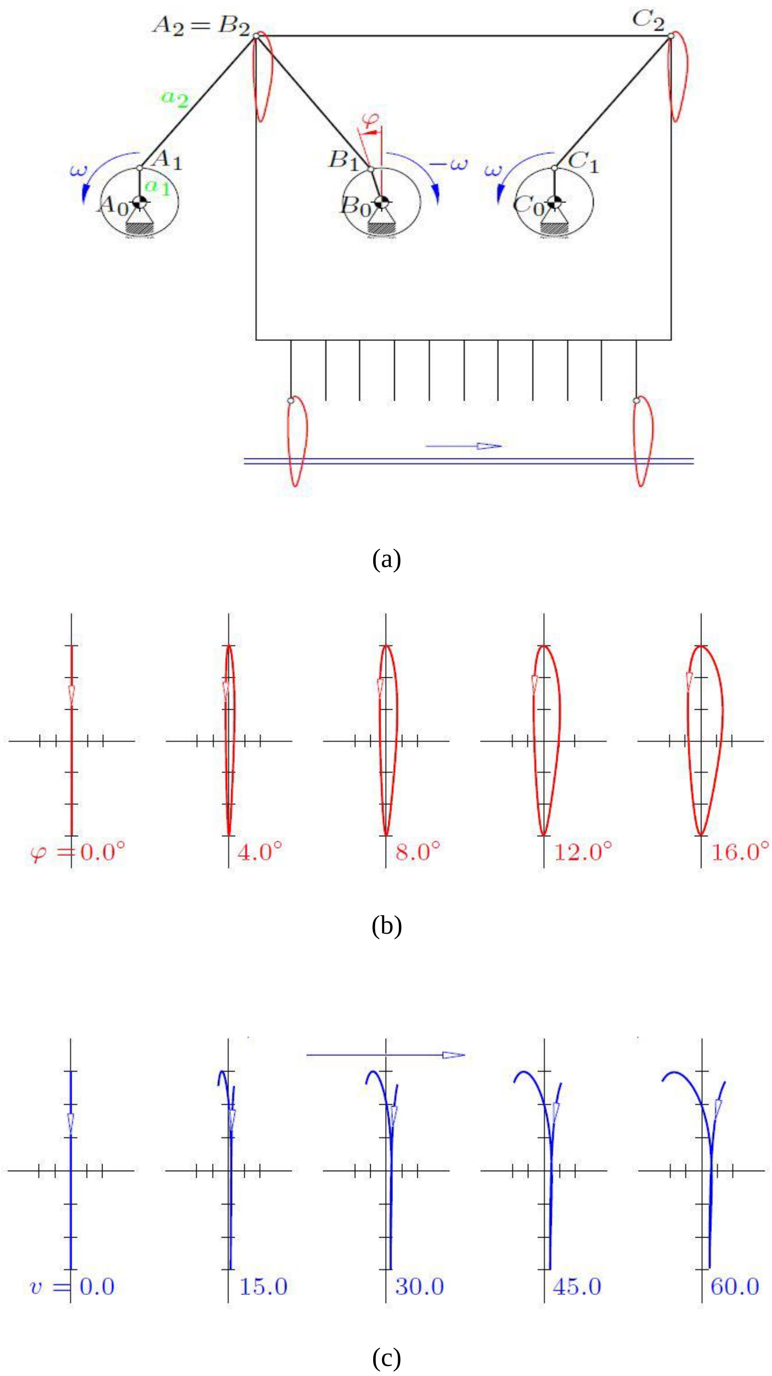

Figure 2: a) A geometrical design of MMD, b) Changing on the trajectories, c) Relative path at 3000 rpm and belt speed *v* in *m/min*.

3 Design of the MMD with SAM

In general form such planar mechanisms (see Figure 3) were precisely investigated in [1] and [2].

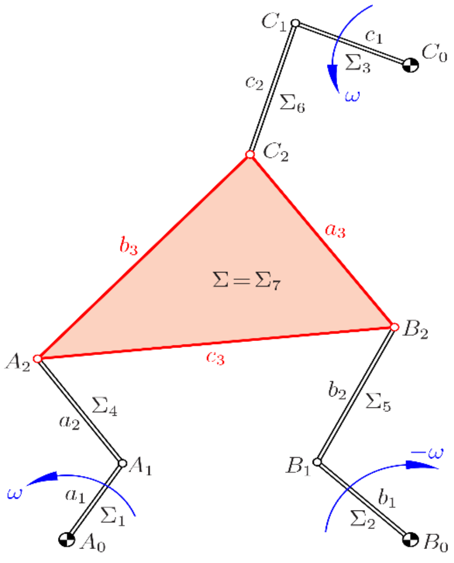

Figure 3: A planar parallel mechanism

SAM is a software to design, analysis and allows automatically optimize mechanisms and drives [6]. It allows kinematical methods on velocity, acceleration, force and torque analysis, in which engineers to simulate and optimize 2D mechanisms and drives. In Figure 4 is displayed a MMD with SAM in general form.

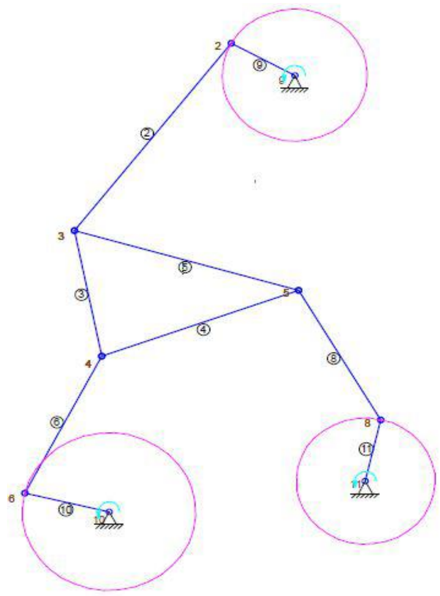

Figure 4: A demonstrated example with SAM such as Figure 3 with 360^0 turnability of A_0, B_0 and C_0.

The simulation with SAM in Figure 5, shows all path curves by the motion for all triangle edges, especially on join points 3, 4 and 5.

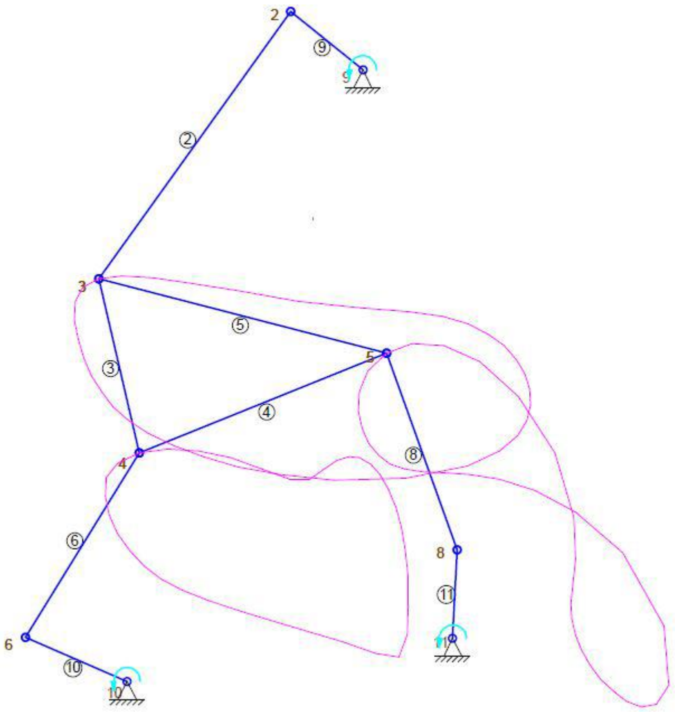

Figure 5: All path curves of triangle edges with 360^0 turnability A_0, B_0 and C_0.

In Figure 6 is displayed all velocity and acceleration charts of the join points 3, 4 and 5, in which red line shows velocity and pink line shows acceleration of 3., blue line shows velocity and black line shows acceleration of 4., light blue line shows velocity and green line shows acceleration of 5. join point.

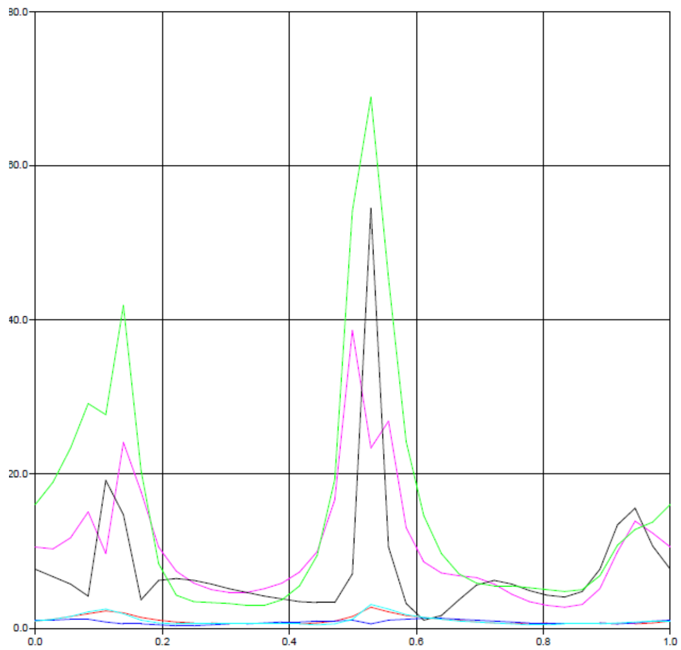

Figure 6: All velocity and acceleration chart of the join points 3, 4 and 5.

As an example analysis, the data are also given in Table 1 that the maximum and minimum speeds and accelerations of the points during movement.

Table 1: *Minimum and maximum velocity and acceleration values of the designed simulation in 1 second.*

Join point number	***Min Velocity mm/s***	***Max Velocity mm/s***	***Min Acceleration mm/s²***	***Max Acceleration mm/s²***
3	554171 (red line)	2282416 (red line)	2792687 (pink line)	38502438 (pink line)
4	407788 (blue line)	1289225 (blue line)	1095002 (black line)	53827562 (black line)
5	535557 (light blue line)	2544359 (light blue line)	2946404 (green line)	68715196 (green line)

As an another example a curvilinear translation in Figure 7 is demonstrated and in Figure 8 velocity, acceleration charts of the join points 4 is displayed, in which blue line shows velocity, and green line shows acceleration. Here, minimum- and maximum velocity values are 280 mm/s and 1667 mm/s and minimum- and maximum acceleration values are 2073 mm/s^2 and 12871 mm/s^2 respectively.

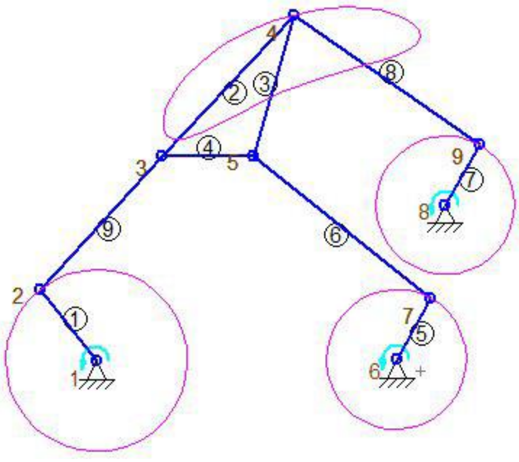

Figure 7: Path curves of join point 4 as a curvilinear translation.

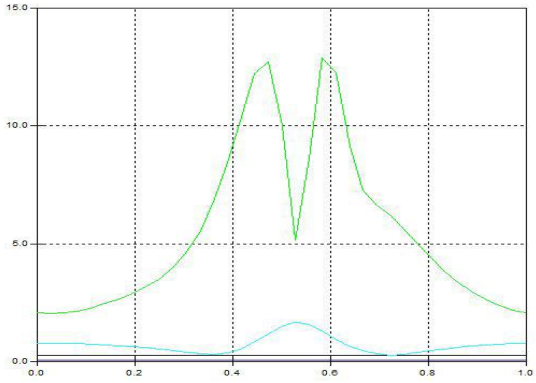

Figure 8: Velocity and acceleration chart of the join point 4 as a curvilinear translation.

4 Results and Conclusions

In this study it was found that the numerical solutions of the mechanism described above obtained with Maple can also be obtained with SAM.

SAM gives to researcher's possibilities not only to design of 2D planar mechanisms but also all construction data, which may be needed, such as the coordinates all join points, the length of the cranks, velocity and acceleration values of every moment of the movement as well as force and torque analysis. Below displayed text could be printed out with "Project Documentation" option under data bookmark of MMD as follows

```
    JOIN POINTS

        Join points number: 2

        x-coordinate:  461615.8 mm

        y-coordinate:  701720.6 mm


        Join points number: 3

        x-coordinate:  285692.2 mm

        y-coordinate:  431238.1 mm


        Join points number: 4

        x-coordinate:  329673.1 mm

        y-coordinate:  261911.6 mm

etc.

    ELEMENTS

        Element Number: 2

        Type:  Crank

        Join points:  2, 3

        Coordinates: (461615.8, 701720.6); (285692.2, 431238.1) mm

        Length:  322660.6 mm

        Angle:  236.96 deg


        Element Number: 3

        Type:  Crank

        Join points:  3, 4

        Coordinates: (285692.2, 431238.1); (329673.1, 261911.6) mm

        Length:  174945 mm
```

Angle: 284.56 deg

Element Number: 4

Type: Crank

Join points: 4, 5

Coordinates: (329673.1, 261911.6) ; (569369, 365266.7) mm

Length: 261029.5 mm

Angle: 23.32 deg

etc.

FIXINGS

Fixation number: 1

Type: Shift

Join point: 9

Direction: *x*, *y*

Fixation number: 2

Type: Shift

Join point: 10

Direction: *x*, *y*

Fixation number: 3

Type: Shift

Join point: 11

Direction: *x*, *y*

DRIVE MOVEMENT

Drive Number: 1

Type: Rotation

Element (Point): 9 (9)

Profile: Linear -360 deg, 1s, 36 steps

Drive Number: 2

Type: Rotation

```
Element (Point):  10 (10)

Profile:  Linear    -360 deg, 1s, 36 steps


Drive Number:  3

Type:  Rotation

Element (Point):  11 (11)

Profile:  Linear    -360 deg, 1s, 36 steps
```

Finally, SAM is a software that can be recommended for use in engineering because it is possible to design 2D kinematic chains, whether the created design is motion limited or not, and it is possible to report every moment of motion.

5 Declarations

5.1 Study Limitations

The author(s) declared none of limitation faced in this study which might significantly affect research outcome.

5.2 Acknowledgements

The author(s) present his/their thanks to the anonymous reviewers for constructive suggestions, which improve the quality of the paper.

5.3 Funding source

The author(s) declared no funding source.

5.4 Competing Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

6 Human and Animal Related Study

For this type of study, formal consent is not required.

6.1 Ethical Approval

Since this study involved a desk review, the author(s) assert that all procedures contributing to this study comply with the ethical standards of the relevant institutional committees. For this type of study, formal consent is not required.

6.2 Informed Consent

Informed consent was obtained from all individual participants included in the study.

References

[1] A. Krishnaraju &H. Abdul Zubar, "Design and SAM analysis of reconfigurable four-legged mechanism using single degree of freedom", *International Journal of Heavy Vehicle Systems*, vol. 28/2, 2021, DOI: 10.1504/IJHVS.2021.115577

[2] SAM 8.1, *ARTAS Engineering Software*, Netherlands. https://www.artas.nl/en/

[3] AM Rankers & HW Schrama, "SAM: Simulation and Analysis of Mechanisms", *Proceedings of the ASME 2002 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*. Vol. 5, pp. 1383-1387, 2002. https://doi.org/10.1115/DETC2002/MECH-34370

[4] O. Bologa, "Simulation and Analysis of Mechanisms (SAM)", *The Annals of "DUNĂREA DE JOS" University of Galati*, Fascicle X, Applied Mechanics, ISSN 1221-4612, 2010.

[5] E. Can, "Analyse und Synthese eines schnelllaufenden ebenen Mechanismus mit modifizierbaren Zwangläufen", *PhD Thesis*, Vienna University of Technology, 2012.

[6] E. Can & H. Stachel, (2014). "A planar parallel 3-RRR robot with synchronously driven cranks," *Mechanism and Machine Theory*, vol. 79, pp. 29-45, 2014. https://www.sciencedirect.com/science/article/pii/S0094114X14001086

[7] E. Can, "The geometric design of currently polplan and velocity vectors of a planar parallel robot", *Sakarya University Journal of Science*, vol. 19, pp. 151-156, 2015. http://www.saujs.sakarya.edu.tr/tr/pub/issue/20704/221134

[8] Maple, Mathematics software Waterloo, Canada. https://www.maplesoft.com/

[9] E. Can & Ö. Canay, "A planar robot design and construction with Maple", *The Online Journal of Science and Technology*, vol. 6/2 pp. 1-5, 2016. https://dergipark.org.tr/en/download/article-file/210190