ANALELE UNIVERSITĂȚII
"EFTIMIE MURGU" REȘIȚA
ANUL XXVI, NR.1, 2019, ISSN 1453 - 7397

The study of the punching cards mechanism with SolidWorks Motion

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The objective of the paper is to calculate the velocities and accelerations for some points of the punching cards mechanism and to compare the results calculated through grapho-analytical method with the SolidWorks Motion results.

***Keywords**: Mechanism, punching cards, SolidWorks Motion*

1. Introduction

A punched card is a simple piece of paper stock which was widely used in the last century in computers or machines organized as semiautomatic data processing systems [1], [2]. They contain digital information represented by the presence or absence of holes in predefined positions.

The punching cards mechanism transforms the circular movement of the leading element OA into a translation of the driven element point M. The kinematic parameters of the mechanism are the linear velocities and accelerations.

The aim of the present paper was to assess the grapho-analytical method and the facilities of the *Motion* module from *SolidWord (SW)* software for the kinematic calculus of the main points of a punching card mechanism.

2. The geometry and main parameters of the punching cards mechanism

The geometry of the punching cards mechanism presented in Fig. 1 is composed from three beams OA=0.2 m, AB=0.5 m, DM=0.4 m and one triangle BCD with BC=CD=0.35 m and BD=0.55 m. The length of OC distance is OC=0.45 m. The punching cards mechanism is driven by a Rotary Motor applied to the OA beam with constant rotational velocity n_1=191 rot/min equivalent with the angular velocity ω_1=20 rad/s which corresponds to 1145.9 degree/second. The number of rotations during 1 sec is 3.18 and the time of one rotation is 0.314 sec. The rigid angle $\alpha=150^o$ between X direction and OC beam is constant. The start position of the mechanism is defined by 210^o angle between X direction and OA beam. The analysis time of the study was imposed 1 sec. The point M move only along Y direction and point C is fixed. The point O of the OA beam is connected to Fixed part 1 and the point C of the CD beam is connected to Fixed part 2. This study aims to compare the velocities and accelerations of A, B, D and M points, calculated by grapho-analytical method and SolidWorks Motion module.

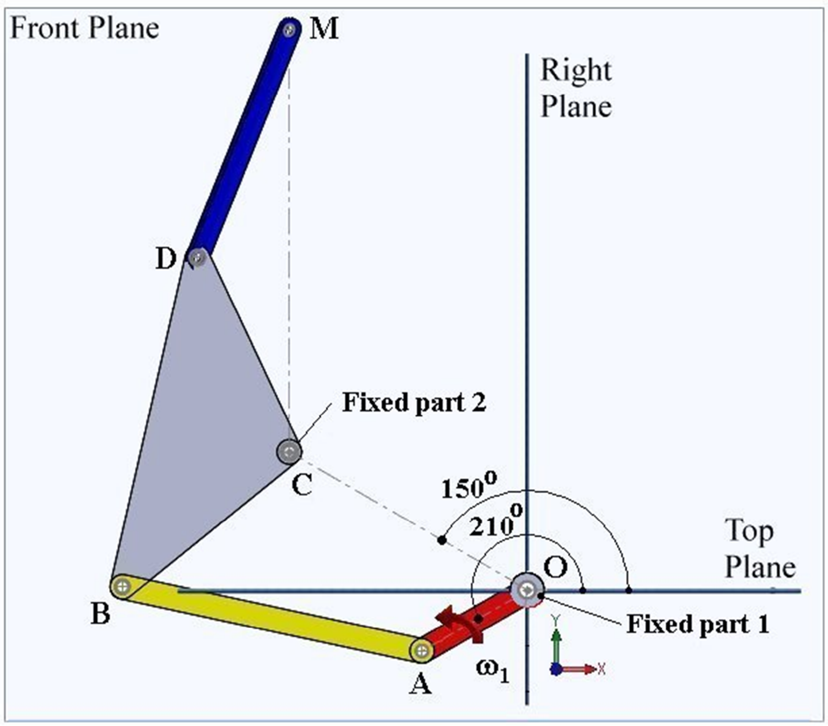

Figure 1. The punching cards geometry

3. Theoretical background and numerical results

The kinematic schema of the starting position mechanism was represented on the k_l=1/100 [——] scale, Fig. 2 [3]. For the calculation of the velocities the $k_v = \omega_1 \ k_l$ = 1/5 = 0.2 [——] coefficient was used [3]. For the calculation of the accelerations the $k_A = \omega_1 \ k_v$ = 4 [——] coefficient was used [3]. The velocities and accelerations are calculated only for the start position of the mechanism by grapho-analytical method through equations (1) ÷ (8) [3].

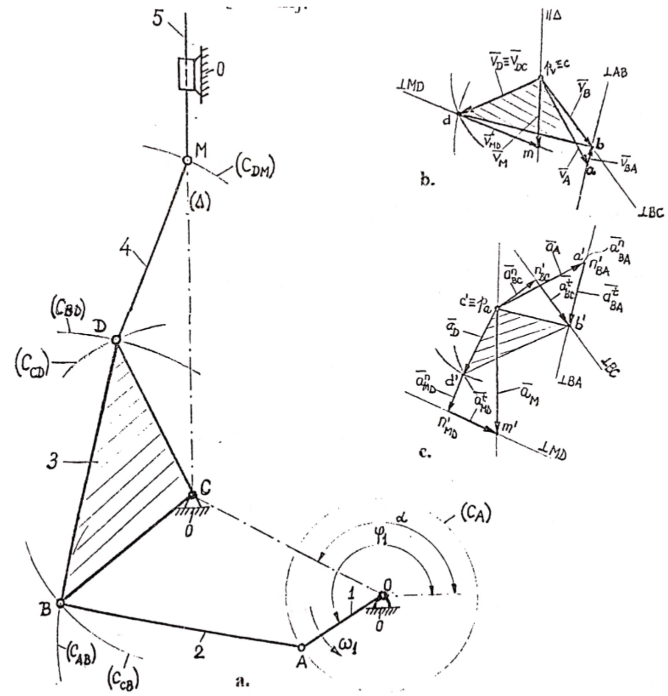

Figure 2. The kinematic schema of the starting position mechanism

$$V_A = \omega_1 \cdot L_{OA}; \quad V_A = 20 \cdot 0.20 = 4 \text{ m/s} \tag{1}$$

$$V_B = K_v \cdot (p_v b) = \frac{1}{5} \cdot 18 = 3.6\, m/s \tag{2}$$

$$V_D = k_v \cdot (p_v d)\, \frac{1}{5} \cdot 18 = 3.6\, m/s \tag{3}$$

$$V_M = k_v \cdot (p_v m)\, \frac{1}{5} \cdot 14 = 2.8\, m/s \tag{4}$$

$$a_A = \omega_1^2 \cdot L_{OA} = 20^2 \cdot 0{,}2 = 80\, m/s^2 \tag{5}$$

$$a_B = k_a \cdot (p_a b) = 4 \cdot 15{,}2 = 60.8\, m/s^2 \tag{6}$$

$$a_D = k_a \cdot (p_a d) = 4 \cdot 15{,}5 = 62\, m/s^2 \tag{7}$$

$$a_M = k_a \cdot (p_a m);\, a_M = 4 \cdot 26 = 104\, m/s^2 \tag{8}$$

4. The stages of Motion Study

The stages of the study are as follows [4] and [5]:

- Activation of the SolidWorks Motion module;
- Creation and specification of the study's options;
- Specify *Rotary Motor*;
- Specify *Motion Mates*;
- Running the design study.

To specify *Rotary Motor* click *Motor* to create a new rotary motor; select the face of the OA beam select *Constant speed* from *Motor Type list* and set 191 rpm value in the speed motor field; click ✓ and the *Rotary Motor1* branch will be created in the MotionManager design tree (Figure 4).

The mates indicated in Table 1 will be applied in *Motion Study* between the assembly components. The mate *Mate7* was only necessary to specify the initial position of the mechanism, but before the motion analysis calculation this mate must be suppresses.

Table 1. The mates applied to the punching cards mechanism

Mate name	Mate type	Component 1	Component 2
Mate1	Coincident	Point O - Fixed part 1	Point O - beam OA
Mate2	Coincident	Point A - beam OA	Point A - beam AB
Mate3	Coincident	Point C - Fixed part 2	Point C - beam CD
Mate4	Coincident	Point B - beam AB	Point B - beam DB
Mate5	Coincident	Point D - beam DM	Point D - beam CD
Mate6	Coincident	Point M - beam DM	Y direction
Mate7	Angle=210^{o}	X direction	OA beam

5. Simulation and theoretical results comparison

For grapho-analytical method the velocities and accelerations were calculated only for the start position of the mechanism, while in SolidWorks Motion the results are calculated for the whole time of the study. The results are presented as charts in Fig. 3 ÷ Fig. 10 and numeric in Table 2 and 3.

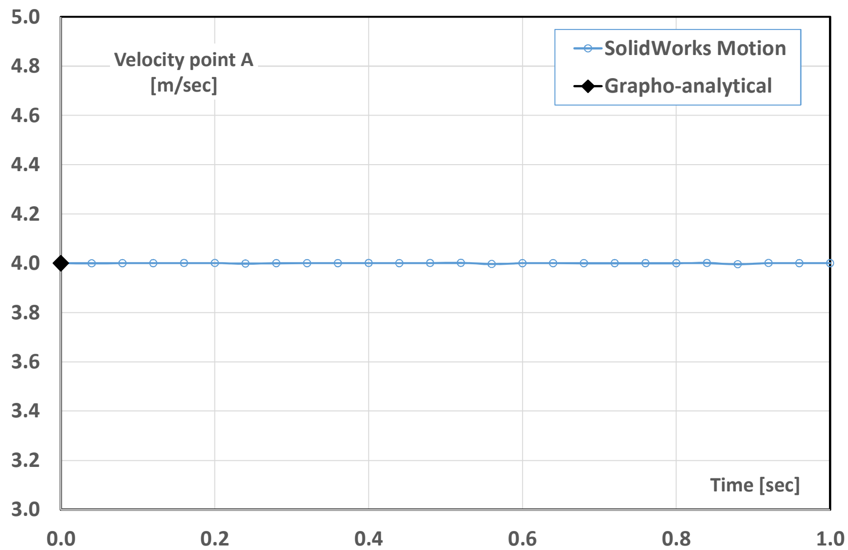

Figure 3. The velocity of point A

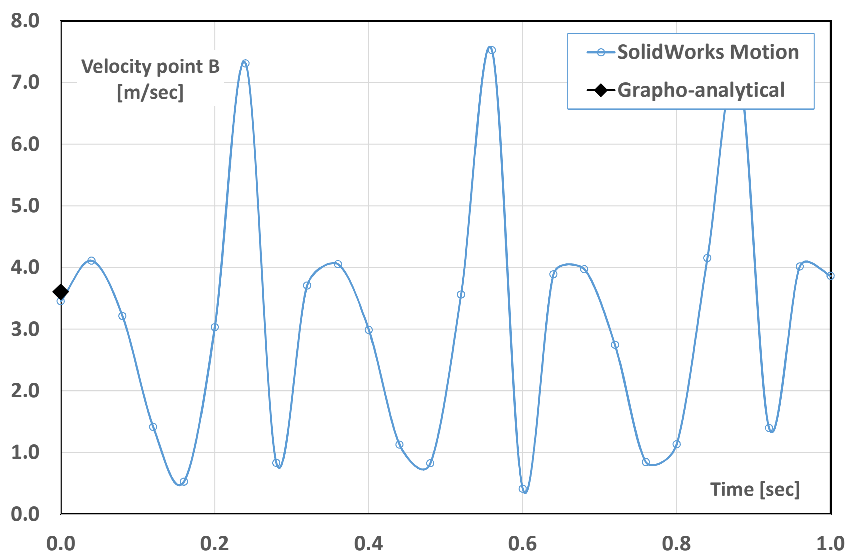

Figure 4. The velocity of point B

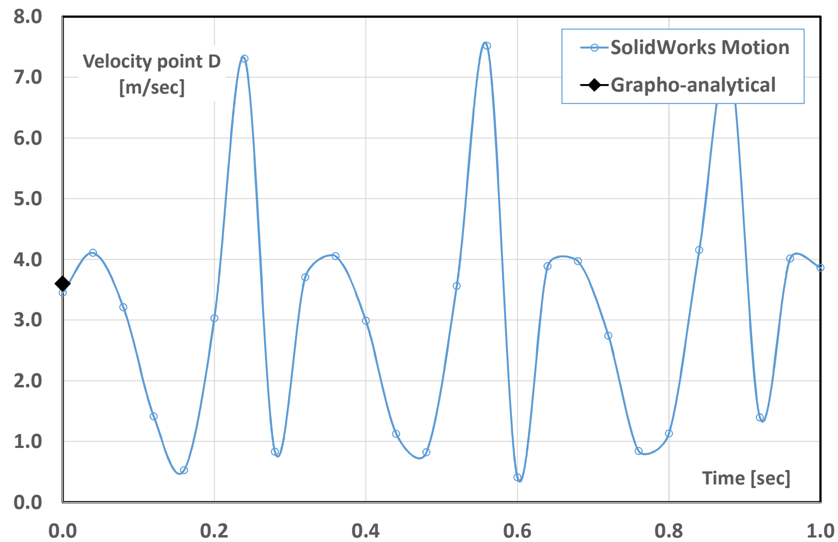

Figure 5. The velocity of point D

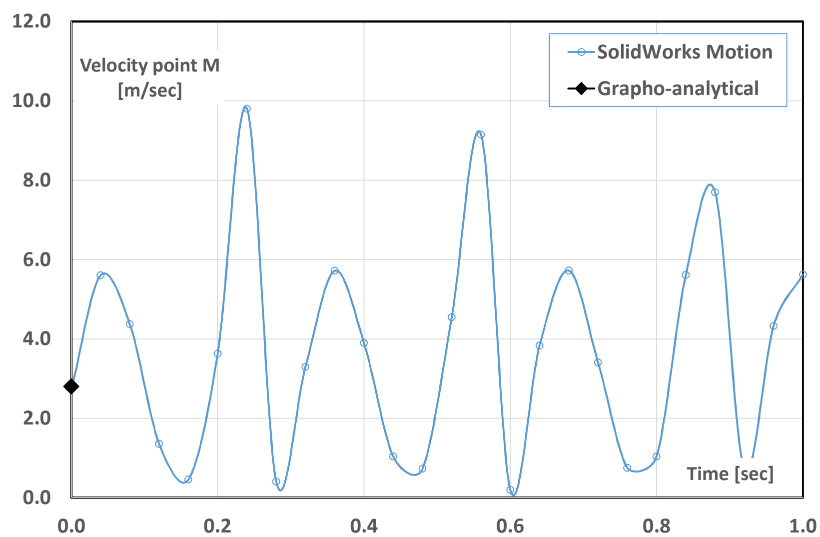

Figure 6. The velocity of point M

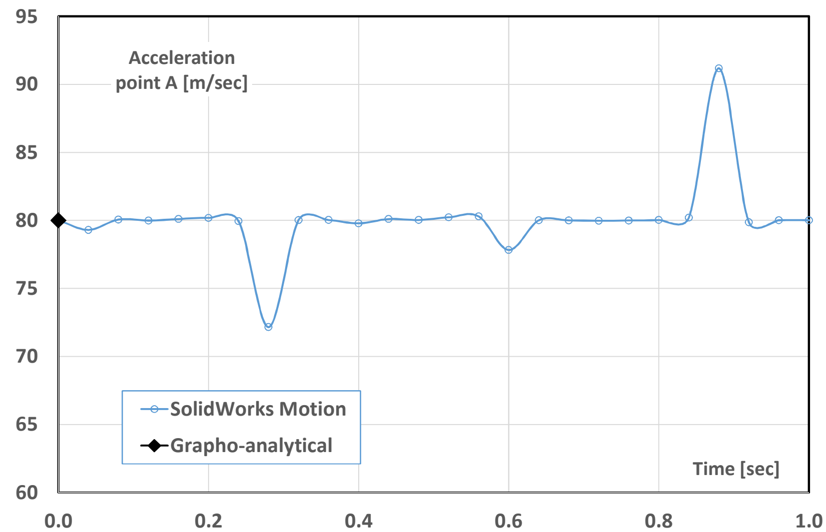

Figure 7. The acceleration of point A

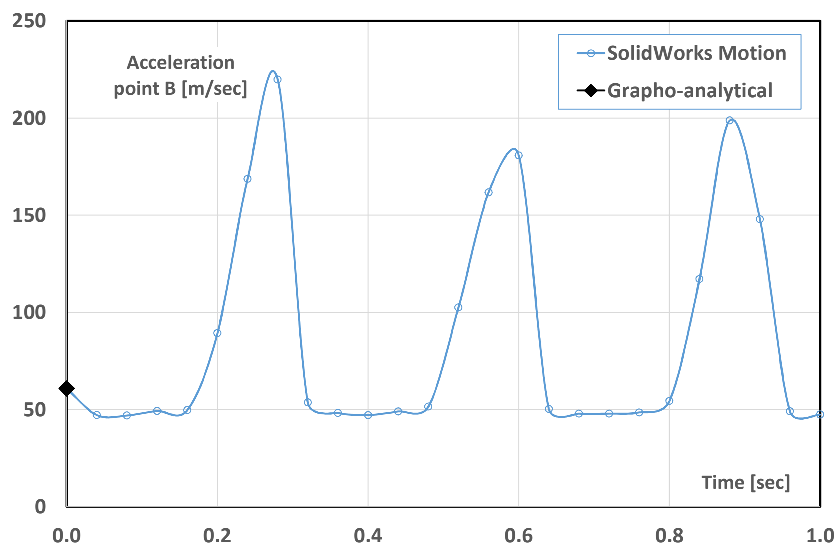

Figure 8. The acceleration of point B

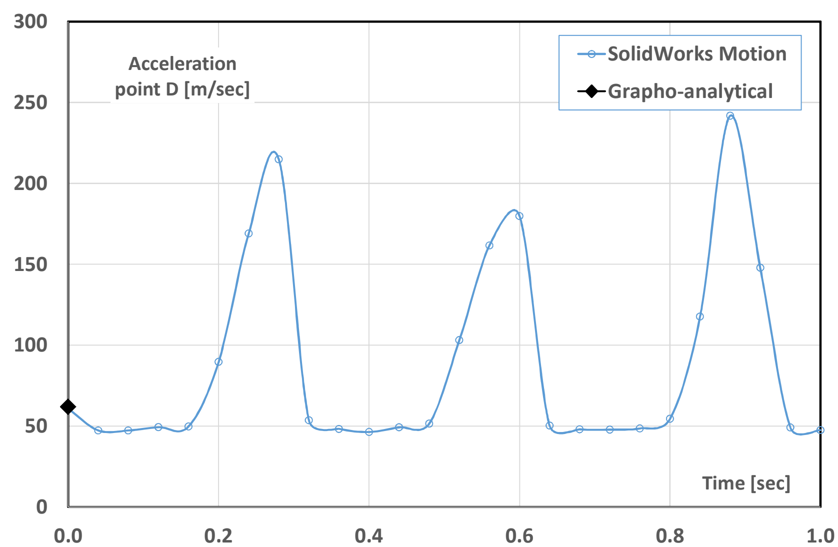

Figure 9. The acceleration of point D

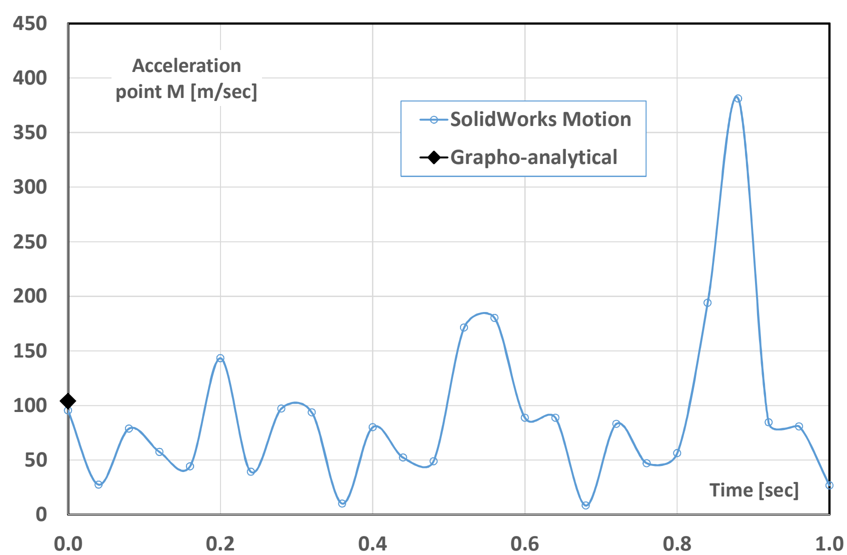

Figure 10. The acceleration of point M

Table 2. Numerical results from SolidWorks Motion

Time	V_A	V_B	V_D	V_M	a_A	a_B	a_D	a_M
sec	m/s	m/s	m/s	m/s	m/s^2	m/s^2	m/s^2	m/s^2
0.00	4.00	3.45	3.45	2.74	80.01	60.83	60.83	95.36
0.04	4.00	4.11	3.45	5.60	79.30	60.83	60.83	27.50
0.08	4.00	3.21	3.45	4.37	80.06	60.83	60.83	78.85
0.12	4.00	1.41	3.45	1.35	79.99	60.83	60.83	57.47
0.16	4.00	0.53	3.45	0.46	80.10	60.83	60.83	44.23
0.20	4.00	3.03	3.45	3.63	80.18	60.83	60.83	143.27
0.24	4.00	7.31	3.45	9.80	79.95	60.83	60.83	39.21
0.28	4.00	0.83	3.45	0.41	72.16	60.83	60.83	97.07
0.32	4.00	3.71	3.45	3.29	80.02	60.83	60.83	93.67
0.36	4.00	4.05	3.45	5.72	80.03	60.83	60.83	10.09
0.40	4.00	2.99	3.45	3.90	79.78	60.83	60.83	80.02
0.44	4.00	1.13	3.45	1.03	80.10	60.83	60.83	52.26
0.48	4.00	0.82	3.45	0.73	80.03	60.83	60.83	48.96
0.52	4.00	3.56	3.45	4.55	80.22	60.83	60.83	171.32
0.56	4.00	7.52	3.45	9.15	80.29	60.83	60.83	180.23
0.60	4.00	0.41	3.45	0.20	77.82	60.83	60.83	88.71
0.64	4.00	3.89	3.45	3.83	80.01	60.83	60.83	88.73
0.68	4.00	3.97	3.45	5.72	80.00	60.83	60.83	8.37
0.72	4.00	2.74	3.45	3.40	79.98	60.83	60.83	83.10
0.76	4.00	0.84	3.45	0.75	79.99	60.83	60.83	47.09
0.80	4.00	1.13	3.45	1.04	80.03	60.83	60.83	56.32
0.84	4.00	4.15	3.45	5.61	80.20	60.83	60.83	194.01
0.88	4.00	7.28	3.45	7.70	91.17	60.83	60.83	381.19
0.92	4.00	1.40	3.45	0.71	79.86	60.83	60.83	84.53
0.96	4.00	4.01	3.45	4.33	80.01	60.83	60.83	80.89
1.00	4.00	3.86	3.45	5.62	80.01	60.83	60.83	26.67

Table 3. Numerical results comparison

Parameter	Time	V_A	V_B	V_D	V_M	a_A	a_B	a_D	a_M
Units	sec	m/s^2				m/s^2			
Grapho-analytical	0.00	4.00	3.6	3.6	2.8	80	60.8	62	104
SW Motion	0.00	4.00	3.45	3.45	2.74	80.01	60.83	60.83	95.36

4. Conclusion

We have presented the required steps to analyze the punching cards mechanism and obtain the kinematic parameters through grapho-analytical method and SolidWorks Motion software. The numerical values calculated by grapho-analytical method were compared in Table 3 with the SolidWorks Motion results. The magnitudes of all results indicated a very good agreement with the values obtained by analysis in SolidWorks Motion software.

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