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ANALYTICAL ANALYSIS OF EXTREME POSITION MECHANISMS FOR CONVEYOR LIFITNG SEGMENTS USING KINEMATIC SYSTEM

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Abstract. The process of moving an item in the industrial world has an influence on productivity produced by the company. The company's productivity can be supported by using a conveyor when the transfer process takes place. This study aims to determine the extreme position of the conveyor lift segment mechanism using the kinematic system. The method used is an analytical analysis method with a kinematic system using SAM 6.0 software. The stages of the research process are measuring conveyor segments, drawing kinematic diagrams, depicting movement mechanisms, calculating degrees of freedom (DoF), calculating geometry, and ending the stroke link follower measurements. The results of the study resulted in a degree of freedom that is 1 which shows the movement of the conveyor freedom only 1 direction, and the calculation result of follower link stroke is 22.6o which shows the maximum range that can be done from the movement of the conveyor lifting segment.

Keywords :Productivity, Mechanism, Conveyor, SAM.

1. INTRODUCTION

Technology and science that are increasingly advanced have an impact on the number of companies that develop equipment to support productivity. The process of moving an item in the industrial world has an influence on productivity produced by the company. The company's productivity can be supported by using a conveyor when the transfer process takes place.

Conveyor is a common part of mechanical material handling equipment that moves from one location to another location [1]. The productivity of conveyor use can be known through faster distribution times and minimal expenditure costs [2]. The productivity of conveyor use can be determined by analyzing the distribution process when the conveyor is working.

Valid analysis results are obtained using analytical methods with kinematic systems. An analytical analysis is used to describe the process of knowing each stage to obtain results. The kinematic system description is carried out to describe the process of moving a moving conveyor segment. Analysis of the movement of conveyor segments is known by using SAM 6.0 software. The use of SAM 6.0 software to facilitate the process of elaborating the results of kinematic charts and movement graphs.

2. METHODS

This research was conducted using analytical methods to obtain valid results in order to obtain the right solution. Analytic method is a method that satisfies the original equation exact [3]. The analytical method is carried out through several stages [4]. The stages of the analytical method are described in the following flowchart methodology:

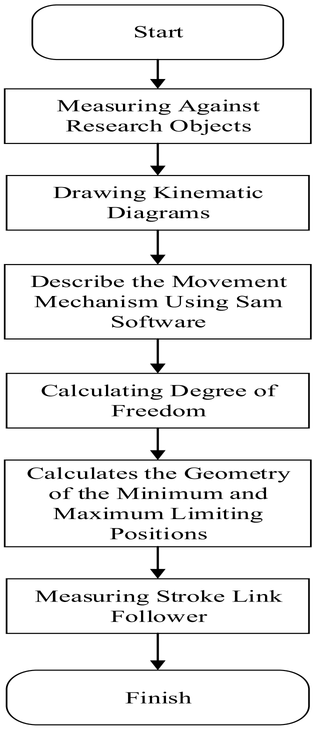

Figure 1. Flow Chart

The first stage measures the conveyor segment that is the object of research, the second depicts kinematic diagrams, the third stage illustrates the mechanism of conveyor lifter segment movement using SAM software, the fourth performs DOF (Degree of Freedom) calculations to determine the direction of conveyor segment movement, the fifth performs the geometry calculation of the position minimum and maximum limit, and end with a stroke link follower measurement.

3. RESULTS AND DISCUSSION

This section outlines the results and discussion of the stages of the research conducted.

3.1 Measurement of Conveyor Lifting Segments

This section is carried out by measuring the segment of the conveyor device using a length measuring instrument (a ruler). The results of the measurements made are shown in the following figure:

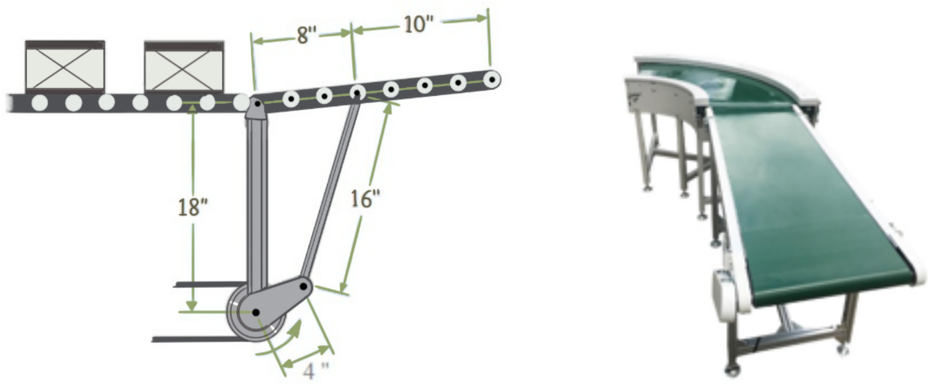

Figure 2. Conveyor Segment Size Details

In the description of Figure 1, it is known that the length of the flexible segment on the conveyor is 18 inch with 8 inch between the driving lever and the fixed lever and 10 inch in front of the driving lever. The length of the drive lever is 16 inches. The length of the connecting lever is 4 inches, and the length of the lever is fixed at 18 inches.

3.2 Kinematic Portrayal of Diagrams

This sub-chapter is carried out to describe the kinematic diagram of the conveyor device segment. The kinematic diagram illustrates the connectivity of the link and joints mechanism of the dimensions of the component shapes [5]. Kinematic Diagramming Results are shown in the following figure:

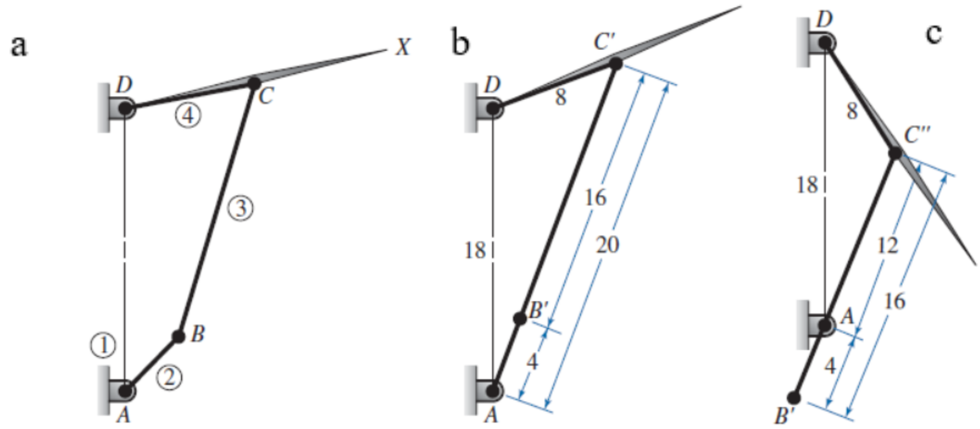

Figure 3. (a) Starting Position from Mechanism of the Conveyor Segment Movement. (b) Up Position from Mechanism of the Conveyor Segment Movement. (c) Down Position from Mechanism of the Conveyor Segment Movement

The translation of Figure 2 shows that the process of conveyor segment movement is preceded by a left image where the condition of the conveyor segment is normal and does not lead to a specific destination. Image of the movement of the conveyor segment directing the flow of an object that is distributed upward is shown by the middle image where the position of the driving lever and the connecting lever forms a straight line along 20 inches.

3.3 Portrayal of Conveyor Movement Mechanism Using SAM Software

This section explains the mechanism of movement of conveyor using SAM software. SAM (Simulation and Analysis of Mechanisms) is an interactive PC-software package for the motion and force analysis of arbitrary planar mechanisms, which can be assembled from basic components including beams, sliders, gears, belts, springs, dampers and friction elements [6]. The high school software is used to find out in detail every movement that occurs in changing the position of the conveyor lifting segment. The results of depicting the mechanism of conveyor movement are divided into 3 phases where there is a starting position, a half movement position, and a final position. The phases contained in the movement of conveyor segments are explained by the following figure:

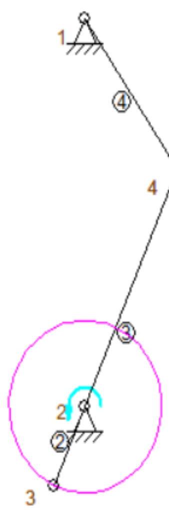

Figure 4. Initial Position of the Conveyor Segment Movement Mechanism in SAM Software

The explanation of Figure 3 shows that the initial position of the conveyor segment consists of two fixed pins, the first pin to move the conveyor and the second pin to make the drive lever move up and down. There are 3 links shown by link 2 as the connecting lever is in a position parallel to link 3. Then there is link 3 as the driving lever that is moving the link in the direction of the conveyor going down. Finally, there is link 4 as a form of the final output of the movement produced by the conveyor segment.

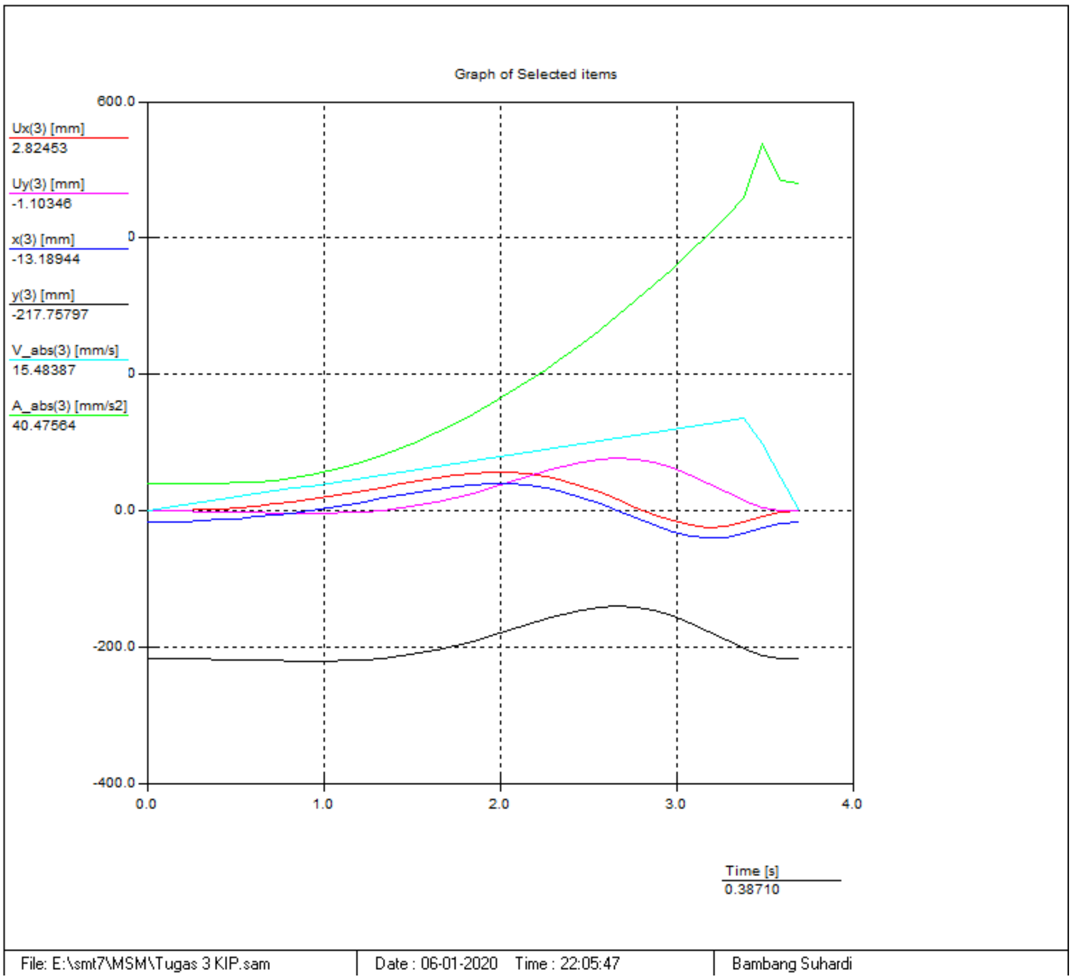

Figure 5. Initial Position Graph of Conveyor Segment Movement in SAM Software

The translation of the initial position graph image of the conveyor segment using SAM software is known that the indicators listed include x and y positions, x and y displacement, displacement speed and displacement acceleration. The initial position indicates that the x and y positions are at point 0. The x and y displacements are still 0 (not moved). Transfer speed 0 mm / s. The acceleration is 4.0 mm/s^2.

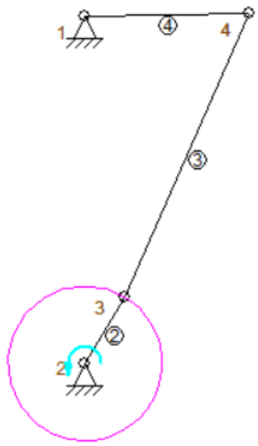

Figure 6. Position of Half Movement Mechanism of Conveyor Segment Movement in SAM Software

The elucidation of Figure 5 shows that the position of the half conveyor segment consists of two fixed pins and 3 links. The first link is shown by link 2 as the connecting lever which is connected with pin 2 and link 3. Then there is link 3 as the driving lever that is moving the conveyor direction link to the top. Finally there is link 4 connected to pin 1 and link 3. Link 4 is the form of the final output of the movement produced by the conveyor segment to the top.

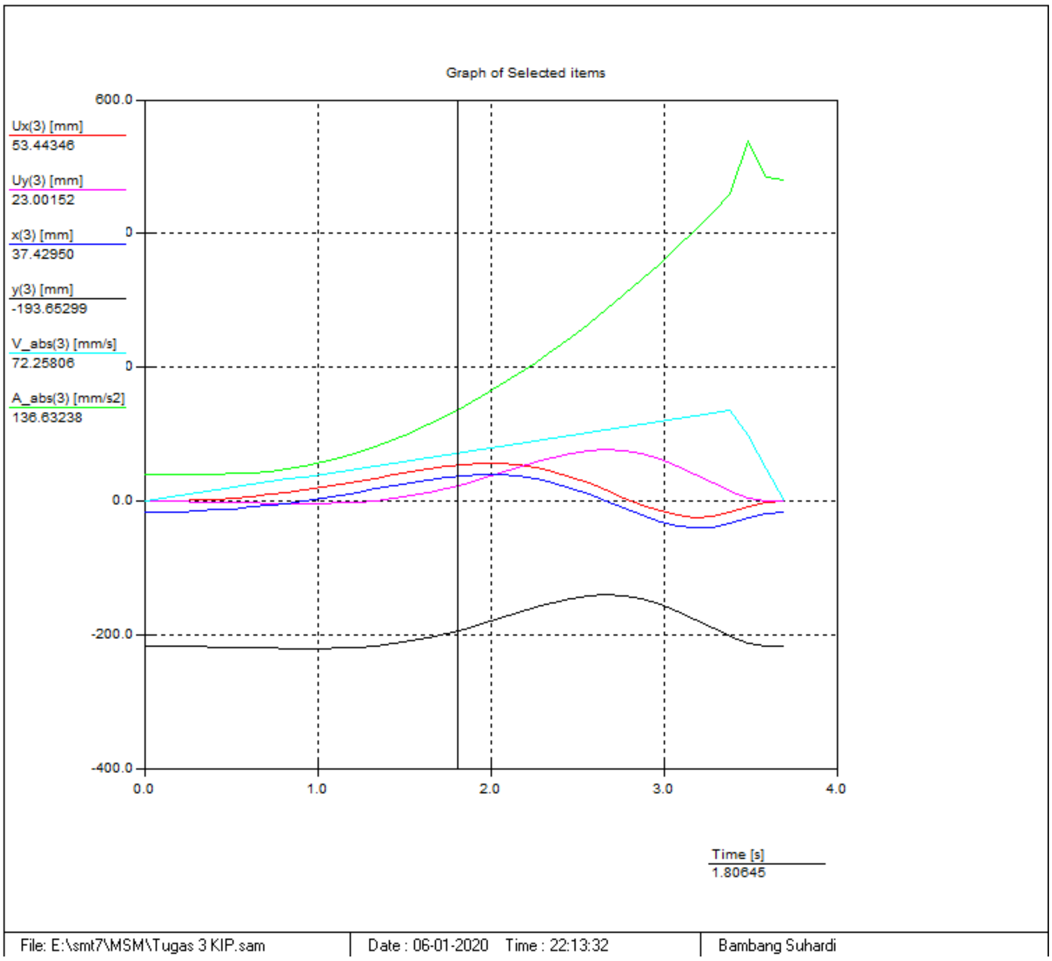

Figure 7. Graph Position of Half Moving Segment Conveyor in SAM Software

The elaboration of the half-position graph movement of conveyor segments using SAM software is known that the indicators listed include x and y positions, x and y displacement, displacement speed and displacement acceleration. The initial position indicates that the positions x and y are at the points of 10.704 and (-141.159). The displacement of x and y is 26.718 at x and 75.196 at y. The displacement speed is 102,490 mm/s and the acceleration is 265,636 mm/s^2.

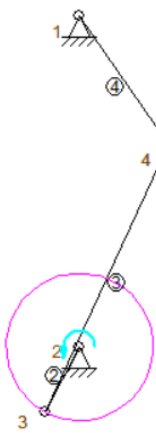

Figure 8. Final Position of the Conveyor Segment Movement Mechanism in SAM Software

The elucidation of Figure 7 shows that the final position of the conveyor segment consists of two fixed pins and 3 links. The first link is shown by link 2 as the connecting lever that returns to the initial position or the right will be parallel to link 3. Then there is link 3 as a driving lever that is moving the conveyor direction link back to the starting position. Finally there is link 4 connected to pin 1 and link 3. Link 4 is a form of the final output of the movement generated by the conveyor segment back to the initial position.

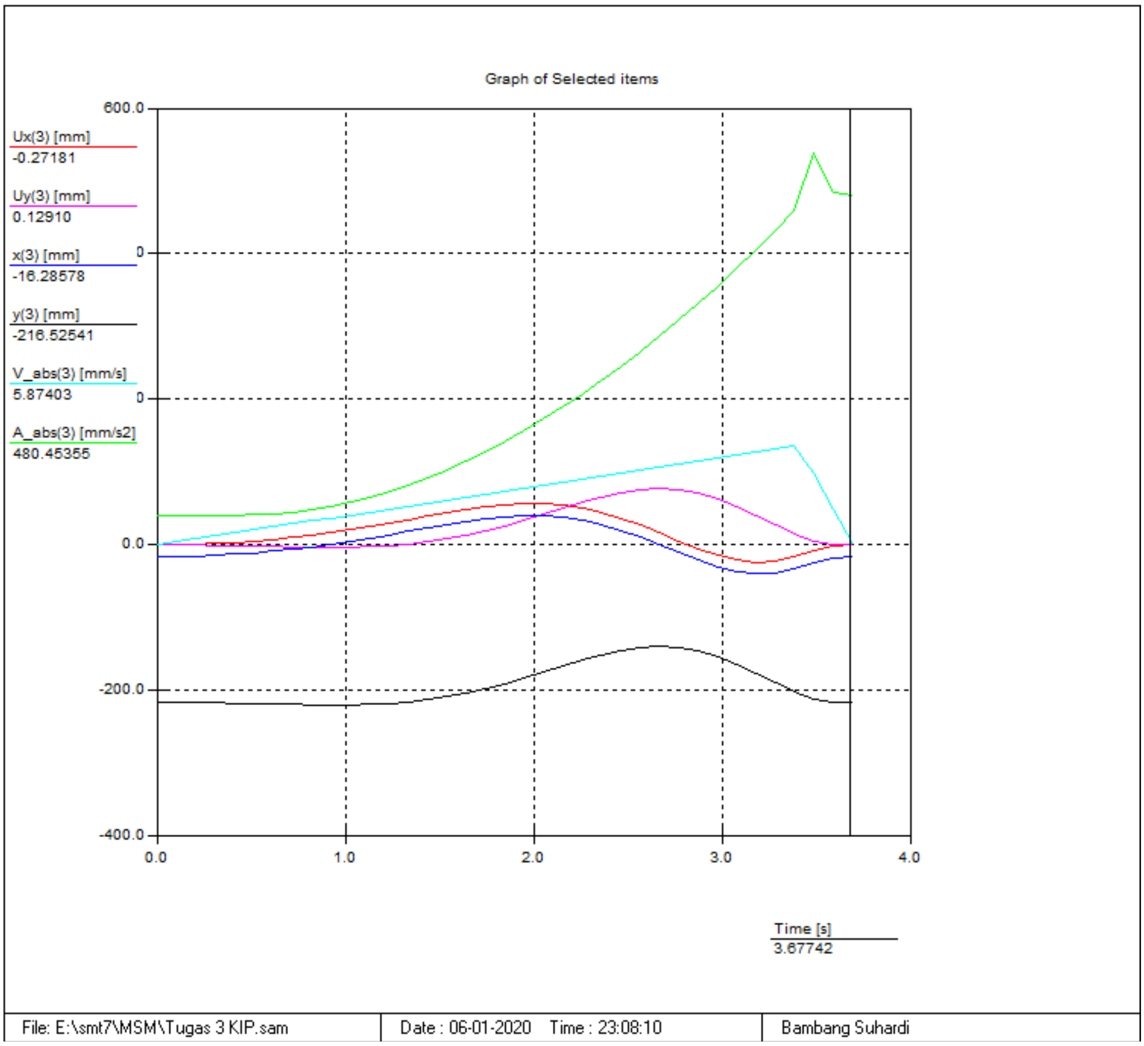

Figure 8. Graph Position of Half Moving Segment Conveyor in SAM Software

The elaboration of the final position graph image of the conveyor segment using SAM software is known that the indicators listed include the x and y positions, x and y displacement, displacement speed and displacement acceleration. The initial position shows that the positions x and y are at points (-18,291) and (-215,573). The x and y transfers of (-2,277) on the minus x form on the displacement indicate that the position returns to its previous position and 1.081 to y. The displacement speed is 49,195 mm / s and the acceleration is 483,798 mm / s^2.

Table 1. Acquisition of Movement Mechanism Results Using SAM Software

Nr: [-]	Time [s]	Ux(3) [mm]	Uy(3) [mm]	x(3) [mm]	y(3) [mm]	V_abs(3) [mm/s]	A_abs(3) [mm/s2]
0	0.000	0.000	0.000	-16.014	-216.655	0.000	40.000
1	0.102	0.193	-0.084	-15.821	-216.738	4.100	40.002
2	0.205	0.774	-0.328	-15.240	-216.983	8.199	40.035
3	0.307	1.750	-0.716	-14.264	-217.370	12.299	40.178
4	0.410	3.133	-1.215	-12.881	-217.869	16.398	40.561
5	0.512	4.937	-1.781	-11.077	-218.436	20.498	41.356
6	0.615	7.175	-2.357	-8.839	-219.011	24.598	42.764
7	0.717	9.857	-2.869	-6.157	-219.523	28.697	44.988
8	0.820	12.986	-3.231	-3.028	-219.885	32.797	48.199
9	0.922	16.555	-3.342	0.541	-219.996	36.897	52.520
10	1.025	20.537	-3.089	4.523	-219.743	40.996	58.012
11	1.127	24.884	-2.350	8.870	-219.004	45.096	64.690
12	1.230	29.520	-0.996	13.506	-217.651	49.195	72.531
13	1.332	34.333	1.096	18.319	-215.559	53.295	81.500
14	1.435	39.175	4.042	23.161	-212.613	57.395	91.554
15	1.537	43.855	7.934	27.841	-208.721	61.494	102.653
16	1.640	48.142	12.826	32.128	-203.828	65.594	114.761
17	1.742	51.770	18.724	35.756	-197.931	69.694	127.848
18	1.845	54.445	25.562	38.431	-191.093	73.793	141.890
19	1.947	55.864	33.192	39.850	-183.462	77.893	156.867
20	2.050	55.735	41.370	39.721	-175.284	81.992	172.763
21	2.152	53.810	49.749	37.796	-166.906	86.092	189.564
22	2.255	49.918	57.880	33.904	-158.775	90.192	207.260
23	2.357	44.006	65.228	27.992	-151.426	94.291	225.841
24	2.460	36.175	71.202	20.161	-145.452	98.391	245.302
25	2.562	26.718	75.196	10.704	-141.459	102.490	265.636
26	2.665	16.135	76.654	0.121	-140.000	106.590	286.839
27	2.767	5.140	75.148	-10.874	-141.507	110.690	308.906
28	2.870	-5.375	70.455	-21.389	-146.199	114.789	331.834
29	2.972	-14.393	62.644	-30.407	-154.011	118.889	355.621
30	3.075	-20.870	52.134	-36.884	-164.521	122.989	380.264
31	3.177	-23.868	39.730	-39.882	-176.924	127.088	405.761
32	3.280	-22.703	26.607	-38.717	-190.048	131.188	432.111
33	3.382	-17.105	14.224	-33.119	-202.430	135.287	459.312
34	3.485	-8.637	5.153	-24.651	-211.501	98.391	537.563
35	3.587	-2.277	1.081	-18.291	-215.573	49.195	483.798
36	3.690	0.000	-0.000	-16.014	-216.655	0.000	480.000

Explanation of table 1. Explain that the indicators listed include 36 movement segments, time of movement, position displacement x and y, position x and y in each displacement segment, speed of movement each time, and acceleration of movement each time of movement. The highest speed value occurs in the 33rd displacement segment of 135.287 mm / s. The highest acceleration occurred in the 34th displacement segment at 459,312 mm/s^2.

3.4 DOF (*Degree of Freedom*) Measurement

The degree of freedom is the number of independent inputs required to precisely position all links of the mechanism with respect to the ground [7]. This section explains the calculation of DOF (Degrees of Freedom) using the Gruebler's equation. DOF (Degrees of Freedom) calculation has a function to determine how the direction can be achieved by the mechanism of conveyor segment movement. The following is the Gruebler's equation used to determine the DOF (Degrees of Freedom) mechanism of the conveyor lifting segment:

M = DoF = 3 (n-1) - 2J_p – J_n
n = Number of links on the mechanism
Jp = Primary total connection (pin connection or slide connection)
Jn = Total higher-order connections (cam or gear connections)

Diketahui : n = 4

J_p = 4 *pin connections* = 4

J_n = 0

DOF = 3 (n-1) - 2J_p – J_n (1)
= 3 (4-1) – 2(4) – (0)
= 1

Thus, *Degrees of Freedom* of mechanism *Conveyor* is 1.

3.5 Geometry Calculation of Minimum and Maximum Positions

This section explains geometry calculations for the minimum and maximum positions when the conveyor segment is distributing goods. The minimum position is obtained when the conveyor segment reaches the lowest point on the y axis or is pointing down. The maximum position is obtained when the conveyor segment reaches the highest point on the y axis or when the conveyor segment is pointing up.1

3.5.1 Geometry Calculation of Minimum Position Conveyor Segments

This section explains the calculation of the geometry of the conveyor segment at a minimum position. Calculations are obtained by using the equations cos, sin and trigonometry so as to obtain an angle in the geometry of the minimum limiting position. The calculation of the geometry of the minimum position conveyor segment is elaborated as follows:

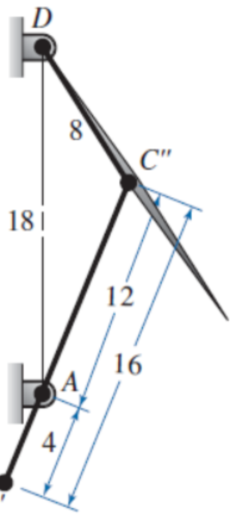

Figure 9. Movement Mechanism for Conveyor Segment Minimum Position

Internal *joint* on point A :

$$C''D^2 = AD^2 + AC''^2 - 2(AC'' \times AD)cos\angle C''AD \quad (2)$$

$$8^2 = 18^2 + 12^2 - 2(12 \times 18)cos\angle C''AD$$

$$(432)cos\angle C'AD = 468 - 64os\angle C''AD = \frac{404}{432}$$

$$cos\angle C''AD = \frac{101}{108}rc\ cos\frac{101}{108} = cos^{-1}\frac{101}{108} = 20{,}74°$$

$\angle C''AD = 20{,}74°$

Internal *joint* on point D :

$$\frac{\sin(\angle C''AD)}{8} = \frac{\sin(\angle AC''D)}{18} \quad (3)$$

$$\sin(\angle AC''D) = \frac{\sin(\angle C''AD)}{8} \times 18$$

$$\sin(\angle AC''D) = \frac{\sin(20{,}74)}{8} \times 18$$

$$\sin(\angle AC''D) = \frac{0{,}35}{8} \times 18$$

$$\sin(\angle AC''D) = \frac{6{,}3}{8}$$

$$\sin(\angle AC''D) = 0{,}7875$$

$$\arcsin(\angle AC''D) = \sin^{-1}(0{,}7875) = 51{,}95°$$

Internal *joint* pada titik C″ :

$\angle ADC'' = 180° - (\angle C''AD + \angle AC''D)$

$\angle ADC'' = 180° - (\angle 20{,}74° + 51{,}95°)$

$\angle ADC'' = 107{,}3°$

The geometry at the boundary position drawn from the conveyor has an inner angle of:

1. $\angle C''AD = 20{,}74°$
2. $\angle AC''D = 51{,}95°$
3. $\angle ADC'' = 107{,}3°$

3.5.2 Perhitungan Geometri Segmen Conveyor Posisi Maksimal

This section explains the calculation of the geometry of the conveyor segment at its maximum position. Calculations are obtained using the equations cos, sin and trigonometry so that the angle in the geometry of the maximum limiting position is obtained. Calculation of the geometry of the maximum position conveyor segment is described as follows:

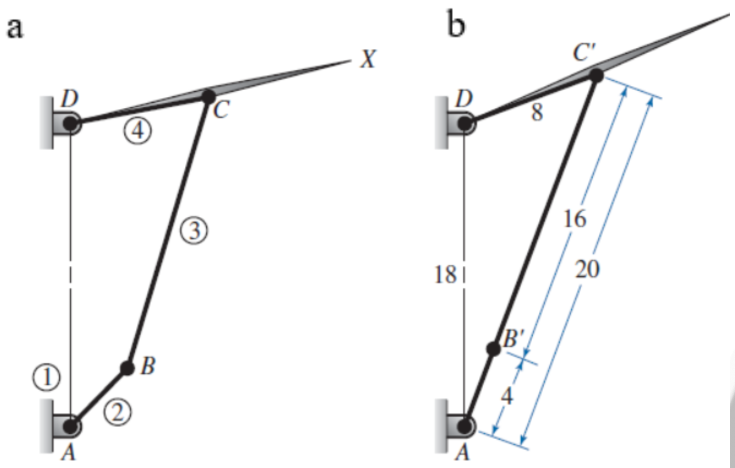

Figure 10. (a) Starting Position Conveyor Segment Movement Mechanism. (b) Maximum Position Conveyor Segment Movement Mechanism

Internal *joint* on point A :

$$C'D^2 = AD^2 + AC'^2 - 2(AC' \times AD)cos\angle C'AD$$

$$8^2 = 18^2 + 20^2 - 2(20 \times 18)cos\angle C'AD$$

$$2(20 \times 18)cos\angle C'AD = 18^2 + 20^2 - 8^2 os\angle C'AD = \frac{660}{720}$$

$$cos\angle C'AD = \frac{11}{12} rc\ cos\frac{11}{12} = cos^{-1}\frac{11}{12} = 14{,}8351$$

$$\angle C'AD = 14{,}8351°$$

$$\frac{\sin(\angle C'AD)}{8} = \frac{\sin(\angle AC'D)}{18}$$

$$\sin(\angle AC'D) = \frac{\sin(\angle C'AD)}{8} \times 18$$

$$\sin(\angle AC'D) = \frac{\sin(14{,}8351)}{8} \times 18$$

$$\sin(\angle AC'D) = \frac{0{,}256038}{8} \times 18$$

$$\sin(\angle AC'D) = \frac{2{,}304342}{4}$$

$$\sin(\angle AC'D) = 0{,}5760855$$

$$\arcsin(\angle AC'D) = \sin^{-1}(0{,}5760855) = 35{,}17568592°$$

$$\angle AC'D = 35{,}17568592°$$

$$\angle ADC' = 180° -$$

$$(\angle C'AD + \angle AC'D)$$

$$\angle ADC' = 180° - (\angle 14{,}8351° + 35{,}17568592°)$$

$$\angle ADC' = 129{,}9°$$

The geometry at the boundary position extended from the conveyor has an inner angle of :

1. $\angle C'AD = 14{,}84°$
2. $\angle AC'D = 35{,}18°$
3. $\angle ADC' = 129{,}9°$

3.6 Measurement of Link Follower Stroke

Stroke link follower measurement is used to determine the maximum range that can be done from the movement of the conveyor lifting segment. The measurement of the stroke link follower of the internal angle conveyor segment in the connection cycle between 129.9 ° and 107.3 °, which is measured upwards from the vertical axis, is described by the following equation:

$$107{,}3° < \theta < 129{,}9°$$

$$|\Delta\theta| = 129{,}9° - 107{,}3° = 22{,}6°$$

4. CONCLUSION

Analysis using analytical methods with kinematic systems produces findings of various factors needed in optimizing the conveyor lifting segment. Factors that can optimize the conveyor device segment include the required size of the conveyor device segment in accordance with the use in distributing goods, depicting kinematic diagrams to determine the moving parts of the conveyor, depicting conveyor motion mechanism using SAM software to determine the movement of conveyor segments when carrying out the distribution of goods , calculation of degree of freedom (DOF) to determine the direction of motion of the conveyor when working, calculation of the geometry of the position of the minimum and maximum to know the maximum range of movement of the conveyor lifting segment mechanism. The conveyor segment moves with different speed and acceleration in each segment of the trailer due to the adjustment of motion requirements in distributing different types of goods. Separation of conveyor direction based on weight of distributed object. The maximum speed is obtained when the conveyor is heading downwards due to the influence of the force of gravity. The minimum speed is obtained when the conveyor is going upwards due to opposing gravity. The weight of the object so that the conveyor segment can be stable work adjusted, with heavy objects poured down and light objects directed upwards. The direction of the conveyor that moves up and down shows that the mechanism of the conveyor segment only moves in one axis (y axis), this shows that the conveyor segment lifter mechanism has only 1 degree of freedom.

5. ACKNOWLEDGEMENT

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