STUDY FOR ELEVATOR CAGE POSITION

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Abstract: Establishing an elevator position at its stop moment is a problem that requires collaboration between the studies in the field of mechanics and the implementation of positioning determination with electric drive applications devices. If the classical approaches to establish the elevator kinematic parameters are position, velocity and acceleration, the modern studies performed in order to determine the positioning by introducing supplementary another parameter - the shock- which is derived with respect to time of acceleration. Maximum shock acceptable values are imposed by standards.

Key words: jerk, acceleration, speed, position.

1. INTRODUCTION

One way of obtaining the appropriate charges, both in terms of the desired effect (final position) as well as compliance with relevant constraints of the electrical and mechanical system, is planning the trajectory of motion [5]. In these conditions, it is necessary a detailed study of elevator kinematics motion, which represent the basis for electric drive applications.

Starting with approaches based on models made in other fields of scientific interests or for other purposes [1] [2] [4], we propose a kinematic study model based on the derivative of acceleration with the following advantages:

- Opportunity of assessment based on kinematic parameters required for maximum impact;
- Possibility of path planning for the cab. This is done based on the equation of variation of shock, and by successive integration, results the cab positive displacement, assuming that the suspension cable is neglected;
- Jerk limitation for a motion stage is important to suppress transient vibration and to reduce the settling time [6].

2. THEORETICAL STUDY OF KINEMATICS PARAMETERS FOR SINUSOIDAL VARIATION OF ACCELERATION OF ELEVATORS

We consider the theoretical speed diagram for the considered elevator (Fig.1), where can be determined also the following diagram for acceleration. If during the acceleration and deceleration periods we have a sinusoidal variation, the derivative of acceleration -which is the jerk, will have a co sinusoidal variation (Fig.1).

We assume that the function \( a(t) \) on the interval \( t \in (0,t_1) \) is:

\[
a(t) = a_s \sin pt
\]

This determines:

\[
j(t) = pa_s \cos pt
\]
The boundary conditions are:

- at $t = 0$
  
  \[ j(0) = j_1 \]
  \[ a(0) = 0 \]
  \[ v(0) = 0 \]
  \[ x(0) = 0 \]

- at $t = t_1$
  
  \[ j(t_1) = -j_1 \]
  \[ a(t_1) = 0 \]

- at $t = \frac{t_1}{2}$
  
  \[ a\left(\frac{t_1}{2}\right) = a_i \]

Results:

\[
\begin{align*}
0 &= a_i \sin p0 \\
-j_1 &= pa_i \cos 0 = p \cdot a_i \\
-j_1 &= pa_i \cos pt_i \\
0 &= a_i \sin pt_i \\
a_i &= a_i \sin p \frac{t_1}{2}
\end{align*}
\]
Therefore:

\[ p = \frac{j_1}{a_1} \]  
(5)

\[ \cos pt_1 = -1 \Rightarrow pt_1 = \frac{j_1}{a_1} \cdot t_1 = (2k + 1)\pi, \quad k \in \mathbb{Z} \]  
(6)

For \( k = 1 \)

\[ \frac{j_1}{a_1} \cdot t_1 = \pi, \]  
(7)

Results:

\[ t_1 = \frac{a_1}{j_1} \cdot \pi. \]  
(8)

During the braking period, the variation of acceleration is given by the function:

\[ a(t) = -a_2 \sin q(t-t_2), \]  
(9)

And jerk:

\[ j(t) = -qa_2 \cos q(t-t_2). \]  
(10)

The boundary conditions are:

\[ a(t_2) = 0 \quad j(t_2) = -j_2 \]
\[ v(t_2) = v_{\text{max}} \]

\[ t = t_2 \quad j(t_2) = -j_2 \]
\[ a(t_3) = 0 \quad v(t_3) = 0 \]
\[ x(t_3) = H_{\text{max}} \]  
(11)

With these values, one can find the equations:

\[ -j_2 = -qa_2 \cos(t-t_2) \quad \Rightarrow \quad q = \frac{j_2}{a_2} \]  
(12)

The equations of jerk variations are:

\[ a(t) = -a_2 \sin qt \]
\[ j(t) = -qa_2 \cos qt \]

\[ j(t) = \begin{cases} j_1 \cos \frac{j_1}{a_1} t, & \quad t \in (0,t_1], \\ j(t) = 0, & \quad t \in (t_1,t_2), \\ j(t) = -j_2 \cos \frac{j_2}{a_2} t, & \quad t \in [t_2,t_3). \end{cases} \]  
(13)
The variation of jerk during deceleration

Substituting the values at time zero for jerk, determined by measurements, in the equations using MathCAD, the following diagrams have resulted (see fig.3 and fig.4):

1. For the start period, cinematic parameters are [3, 7]: $a=1.2 \, \text{m/s}^2$, $j_1=2.5 \, \text{m/s}^3$, $t_1=2 \, \text{s}$. Substituting these values in the first equation from the system (13), results the variation diagram of jerk during the acceleration period, (see fig.2).

2. For the decelerating period, the cinematic parameters are: $a=-1.2 \, \text{m/s}^2$, $j_2=2.5 \, \text{m/s}^3$, $t_3=2.5$. After substituting values in the last equation (13), one can obtained the variation diagram of jerk shown in figure 3.

![Jerk diagrams for the start period](image1)

![Jerk diagrams for the decelerating period](image2)

The displace profile during deceleration

The planning of the trajectory of the cage is done by starting from the jerk variation equations, and by consecutive integrations results the cage position with respect of hypothesis of neglecting of the suspension cable elongation. By these consecutive integrations results also the speed and the acceleration of the cage.

The position of the cage as a function of jerk and accelerations, in the stopping zone is given by the following equation:

$$x(t) = \frac{a_1^2}{j_1}(t + t_2 - t_1) + \frac{a_2^3}{j_2^2} \sin \frac{j_2}{a_2}(t - t_2), \quad t \in (t_2, t_3)$$

(14)

![Position diagram for the decelerating period](image3)
In fig. 4 is represented with the help of the soft MathCAD, for the cinematic parameters $a_1 = a_2 = 1.2 \text{ m/s}^2$, $j_1 = j_2 = 2.5 \text{ m/s}^3$ the position of the cage for the deceleration zone.

The time intervals are as in graphs in Fig. 1: the acceleration interval last 2 seconds, the regular interval last 35.5 seconds, and the deceleration interval last 2.5 seconds. The analysis from the position diagrams for the decelerating period one can notice a smooth displacement without sharp picks which can ascertain discomfort for the persons transport.

3. CONCLUSIONS

If during the acceleration and deceleration periods we have a sinusoidal variation, the derivative of acceleration, which is jerk, will have a co sinusoidal variation (fig. 2 and fig. 3). The position of the cage, especially at the stopping zone, it is especially important in order to achieve a settlement at the exact level in minimum time and as lower as possible vibrations. The equation 14 supply information about the cage position at the stopping time, and more precisely, about the slope of the graph.

REFERENCES

5. Romeo Păduraru, Contribuții privind optimizarea energetică a sistemelor de acționări electrice de c.c. cu funcționare la flux variabil, Galați, 2011
7. *** Directive 95/16/EC relating to Elevators