ABOUT THE TRANSITORY REGIME OF THE MINING EXTRACTION MACHINE

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Abstract: The paper studies the relation between the jerk at acceleration and deceleration in the mechanical systems powered by asynchronous machines depending to the machine parameters.

Key words: jerk, transitory regime, slip

1. INTRODUCTION

At the acceleration and deceleration of the mechanical systems powered by electrical machines occurs a shock, caused by the electrical motor. This shock proved to be an important parameter in the functioning of the system, and has been named jerk. It actually represents the variation of acceleration during the periods of transitory regime of the power engine, usually an asynchronous machine. Although theoretical diagrams consider acceleration as having a constant value during the start and stop periods, it actually has a variation, in a very short period of time. The diagram of acceleration during a cycle of functioning of a mechanical system powered by an asynchronous machine, as for example an elevator or a mining extraction machine, considering jerk at start and at deceleration, will be as shown in (fig. 1). Due to the human presence, in these systems the values of the cinematic and dynamic parameters, speed, acceleration and jerk, can't exceed certain values, experimentally determined as being supportable. For an elevator, these parameters, as well as others, which are also influenced by the human presence, are limited as shown in Table 1.

At an asynchronous machine, the characteristic electrical parameter is slip s. Slip characterizes the difference between the rotational speed of the rotational electro-magnetic field, n_0, and the actual rotational speed of the rotor, n. During the transitory

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regimes of the engine, meaning acceleration and deceleration periods, slip varies between s =1 and s =0, or close to 0. As follows, we try to establish the dependence between the value of the jerk, j=da/dt [m/s^3] and the slip s of the AC motor that powers the system.

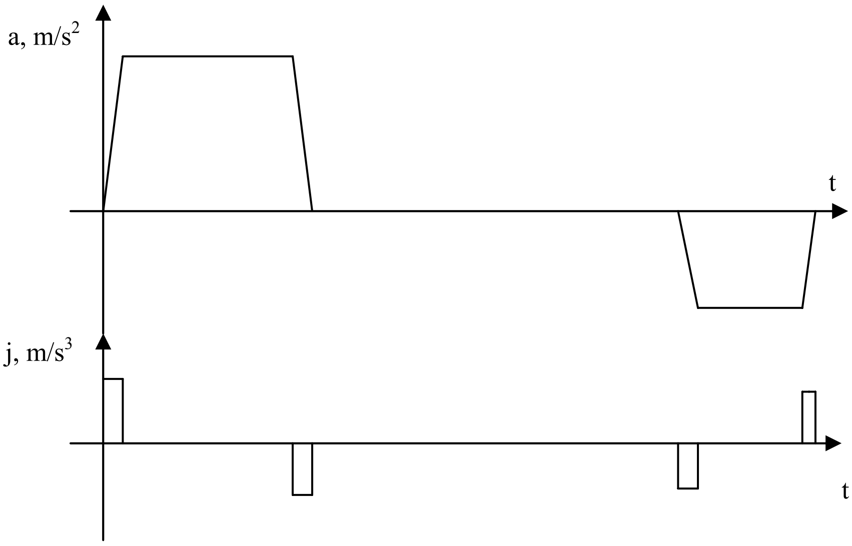

Fig. 1. The diagram of acceleration during a cycle of functioning of a mechanical system powered by an asynchronous machine

Table 1. **Elevator parameters**

Parameter	Limits
Vertical acceleration / deceleration	≤ 1.0 – 1.5 m/s^2
Speed	≤ 7 m/s
Jerk rate	≤ 2,5 m/s^3
Sound	≤ 50 dB
Ear pressure change	≤ 2000 Pa

2. JERK DURING THE TRANSITORY REGIME

During the transitory regime of the AC motor, the motion equation can be written as:

$$2\pi \cdot J \cdot \frac{dn}{dt} = M - M_r \tag{1}$$

where: J is the mechanical inertia moment of the rotating masses; $2\pi\ n = \omega$ is the angular speed; M is the electrical torque of the motor and M_r represents the resistant torque.

Considering the relation of Kloss:

$$M = \frac{2M_{\max}}{\frac{s}{s_k} + \frac{s_k}{s}} \tag{2}$$

where $M_{\max}$ is the maximum torque and s_k the critical slip of the motor. Considering the resistant torque as depending on the maximum torque as:

$$M_r = 2M_{\max} \cdot \alpha \tag{3}$$

relation (1) becomes:

$$2\pi \cdot J \cdot \frac{dn}{dt} = \frac{2M_{\max}}{\frac{s}{s_k} + \frac{s_k}{s}} - 2M_{\max} \cdot \alpha \tag{4}$$

After few transformations we get:

$$\frac{dn}{dt} = \frac{2M_{\max}}{2\pi \cdot J}\left(\frac{1}{\frac{s}{s_k} + \frac{s_k}{s}} - \alpha\right) \tag{5}$$

We introduce the electromechanical constant of the engine,

$$T_m = \frac{2\pi \cdot n_0 \cdot J}{M_{\max}} \quad [\text{s}] \tag{6}$$

in which n_0 is the synchronism rotational speed. T_m represents the time used by the engine to accelerate backlash from $s = 1$ to $s = 0$, if torque M is constant and at maximum value, $M = M_{\max} = \text{ct}$. As consequence:

$$\frac{2\pi \cdot J}{M_{max}} = \frac{T_m}{n_0} \tag{7}$$

Relation (5) becomes:

$$\frac{dn}{dt} = \frac{2n_o}{T_m}\left(\frac{1}{\frac{s}{s_k} + \frac{s_k}{s}} - \alpha\right) \tag{8}$$

Expression (8) can be considered as a function $n = n(s)$, where $s = s(t)$.

At the axis of the motor, the linear speed will be:

$$v = 2\pi \cdot n \cdot \frac{D}{2} \tag{9}$$

where D represents the diameter of the of the axis, therefore it is obvious that it is influenced by the variations of the rotational speed.

Considering a geared reducer having the reducing rate i between the axis and the drum of an elevator, the speed of the winding cable also depends on the rotation speed of the electrical motor. Considering the jerk j as:

$$j = \frac{da}{dt} = \frac{d^2 v}{dt^2} \tag{10}$$

results:

$$j = 2\pi \frac{D}{2} \frac{d^2 n}{dt^2} \tag{11}$$

Relation (8) will be derived with respect to time as follows:

$$\frac{d^2 n}{dt^2} = \frac{d\left(\frac{dn(s)}{dt}\right)}{ds} \cdot \frac{ds}{dt} \tag{12}$$

We obtain:

$$\frac{d^2 n}{dt^2} = \frac{2n_0}{T_{\max}} \frac{d}{ds}\left(\frac{1}{\frac{s}{s_k} + \frac{s_k}{s}} - \alpha\right) \cdot \frac{ds}{dt} \tag{13}$$

Knowing that:

$$n = n_0 (1 - s) \tag{14}$$

we get:

$$\frac{dn}{dt} = -n_0 \frac{ds}{dt} \tag{15}$$

and

$$\frac{ds}{dt} = -\frac{1}{n_0}\frac{dn}{dt} \tag{16}$$

Relation (12) becomes:

$$\frac{d^2n}{dt^2} = \frac{2n_0}{T_{\max}}\frac{d}{ds}\left(\frac{1}{\frac{s}{s_k}+\frac{s_k}{s}} - \alpha\right)\cdot\left(-\frac{1}{n_0}\frac{dn}{dt}\right) \tag{17}$$

and after several calculations,

$$\frac{d^2n}{dt^2} = \frac{4n_0}{T_m^2}\frac{s_k\cdot\left(s^2-s_k^2\right)}{\left(s_k^2+s^2\right)^2}\left(\frac{s\cdot s_k}{s^2+s_k^2} - \alpha\right) \tag{18}$$

If the motor accelerates backlash, α = 0, and relation becomes:

$$\frac{d^2n}{dt^2} = \frac{4n_0}{T_m^2}\frac{s\cdot s_k^2\ \cdot\left(s^2-s_k^2\right)}{\left(s_k^2+s^2\right)^3} \tag{19}$$

Using relation (11), jerk becomes, depending on slip *s*:

$$j(s) = 2\pi\frac{D}{2}\frac{4n_0}{T_m^2}\frac{s\cdot s_k^2\ \cdot\left(s^2-s_k^2\right)}{\left(s_k^2+s^2\right)^3} \tag{20}$$

or

$$j(s) = \frac{4\pi\cdot D\cdot n_0}{T_m^2}\frac{s\cdot s_k^2\ \cdot\left(s^2-s_k^2\right)}{\left(s_k^2+s^2\right)^3} \tag{21}$$

3. CONCLUSION

In a mechanical system such as an elevator, jerk represents a source of vibrations in the winding cable. This paper establishes the dependence of cable oscillations on the electrical parameters of the engine that powers the system.

During the acceleration period of the electrical engine, jerk is increasing to its maximal value than decreases to zero in a very short period. During deceleration, jerk gets negative values, but also a fast variation, as shown in (fig. 1). Relation (21) can be used for the calculus of jerk during the acceleration and deceleration processes in a mechanical system powered by an AC motor, in order to determine if it is actually smaller then maximal admitted value during the period of acceleration, either higher that it's minimal value during deceleration period. A graphical representation of the variation illustrated by relation above can also be drawn.

Also, relation (21) can be used in order to calculate the optimal value of critical slip s_k for an imposed value of jerk, if we know the value of the electro-mechanical constant T_m of the engine.

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