

STUDY OF KINEMATICS OF MULTI-ROPE HOISTING MACHINERY STATICALLY, BALANCED USING SOLIDWORKS®

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ABSTRACT

The study of kinematics of hoisting machines is highly important, considering that they ensure the link between surface and underground mine in terms of transportation of useful mineral substances and personnel. In this context, special functional requirements are demanded in order to avoid the damage brought upon both goods and human. In the first part of the present study, several types of tachogram for hoisting machines are presented. Their curves are determined by type of actuation. In the second part, starting from the acceleration variation, it is shown a numerical method for the curves provided by tracing, using software program SolidWorks®.

1. INTRODUCTION

The operation of hoisting machinery has a cyclical nature. The tachogram curves and the stage have direct influence upon the absolute value of the actuation force, electrical and mechanical loss in various sub-assemblies, absorbed energy, global efficiency of the installation, as well as its productivity.

The effective curves of a tachogram is mainly determined by the actual distance of the transportation process, aspect that directly influences both the number of stages and the maximum transportation velocity.

The hoisting machinery actuation mode influences – as we are going to see later on – the tachogram rate. The technological conditions, as well as the operation safety ones, influence the number of stages and the speed and acceleration limitations all along the tachogram.

The actual tachogram tracing is performed starting from the acceleration variation, which is determined by the machinery actuation mode. Knowing that velocity is the integral of acceleration with respect to time, the velocity variation mode is subsequently determined on various intervals of a hoisting cycle. Finally, knowing that covered distance is the integral of velocity in relation with time, the distances corresponding to the stages of a transportation cycle can be determined.

2. ANALYTICAL TACHOGRAM TRACING

The curves of transportation velocity is mainly determined by the hoisting machinery actuation mode. Within the present section, we will present the case studies of hoisting machines actuated by asynchronous and direct current engine.

2.1 Curve for hoisting machinery actuated by asynchronous engine

For the present case, the variation diagram for velocity and acceleration is shown in Figure #1. According to this tachogram, the maximum speed is $v_{\max} = a_1 t_1$.

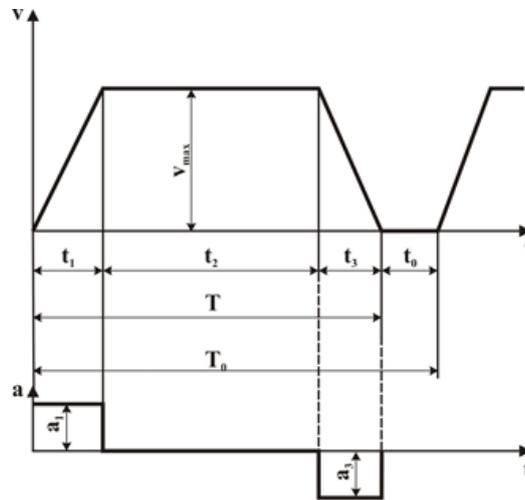


Fig.1 Velocity curves with constant acceleration

The distances of the three tachogram intervals (acceleration, constant velocity and braking) are determined using the following relations:

$$h_1 = \frac{v_{\max}}{t_1} \cdot \frac{t_1^2}{2} = \frac{v_{\max} \cdot t_1}{2}; \quad h_2 = t_2 \cdot v_{\max}; \quad h_3 = \frac{t_3 \cdot v_{\max}}{2} \quad (1)$$

2.2 Hoisting machinery actuated by direct current engine

The peculiarity of such actuation type is the linear acceleration variation during the first interval, which determines the parabolic variation of velocity (Fig.2).

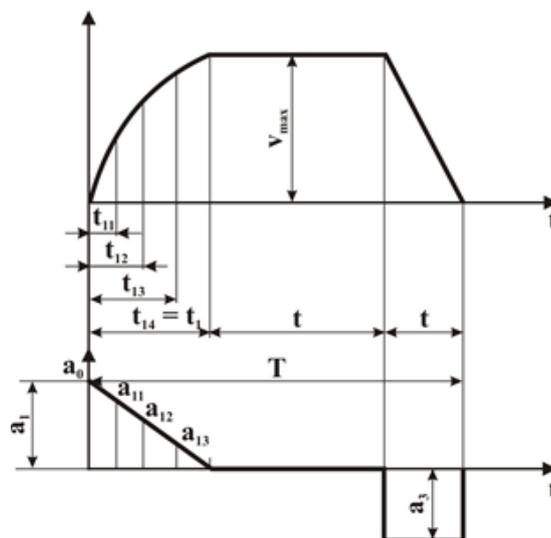


Fig.2 Velocity curves with linear acceleration variation in first interval

In the beginning of the transportation cycle, the acceleration has a_1 maximum value. In order to determine the time functions we will calculate as:

$$y = y_1 + (y_1 - y_2) \frac{x - x_1}{x_1 - x_2} \quad (2)$$

In the present scenario, the acceleration passes through $(0, a_1)$ and $(t_1, 0)$ coordinate points, that is:

$$a = a_1 + (a_1 - 0) \cdot \frac{t - 0}{0 - t_1} \Rightarrow a = a_1 - a_1 \cdot \frac{t}{t_1} \quad (3)$$

As velocity is the integral of acceleration, with respect the time, the variation (under null initial circumstances) will be the following one:

$$v = \int a \cdot dt = \int (a_1 - a_1 \cdot \frac{t}{t_1}) \cdot dt \quad \text{or} \quad v = a_1 \cdot t - \frac{a_1 \cdot t^2}{2 \cdot t_1} \quad (4)$$

Relation (4) represents the equation of a parabola, therefore on the first time interval the velocity will be parabolic variation.

3. TACHOGRAM TRACING USING SOLIDWORKS® SOFTWARE PROGRAM

In order to study the kinematics of statically balanced multi-rope hoisting machinery, We have created – using SolidWorks® – a model, materialized into an assembly (Fig.3).

As shown in Figure 4, an engine was attached to the drive component (Kope wheel), and the acceleration variation of the actuation engine was expressed either by points (Fig.5) or by mathematical expressions (Figure #10). For every tachogram to be further presented, the acceleration values were determined either by points or expressions.

We herein mention that imposing an acceleration variation according to a step function (similar to the analytical method case) leads to the impossibility of numerical approximation of tachograms. For this reason, the acceleration variation in the shown instances does not have a Heaviside type function form.

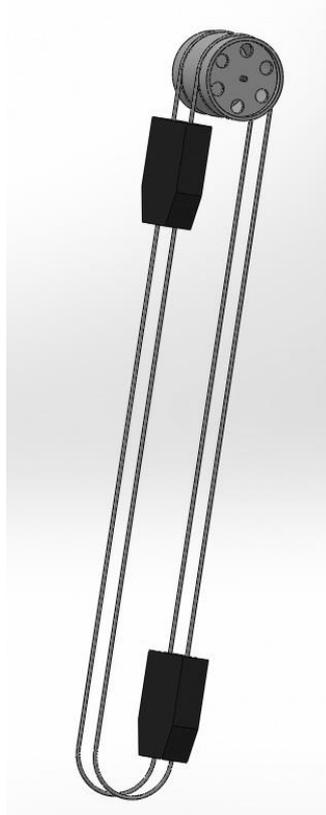


Fig.3 Assembly of statically balanced multi-rope hoisting machinery

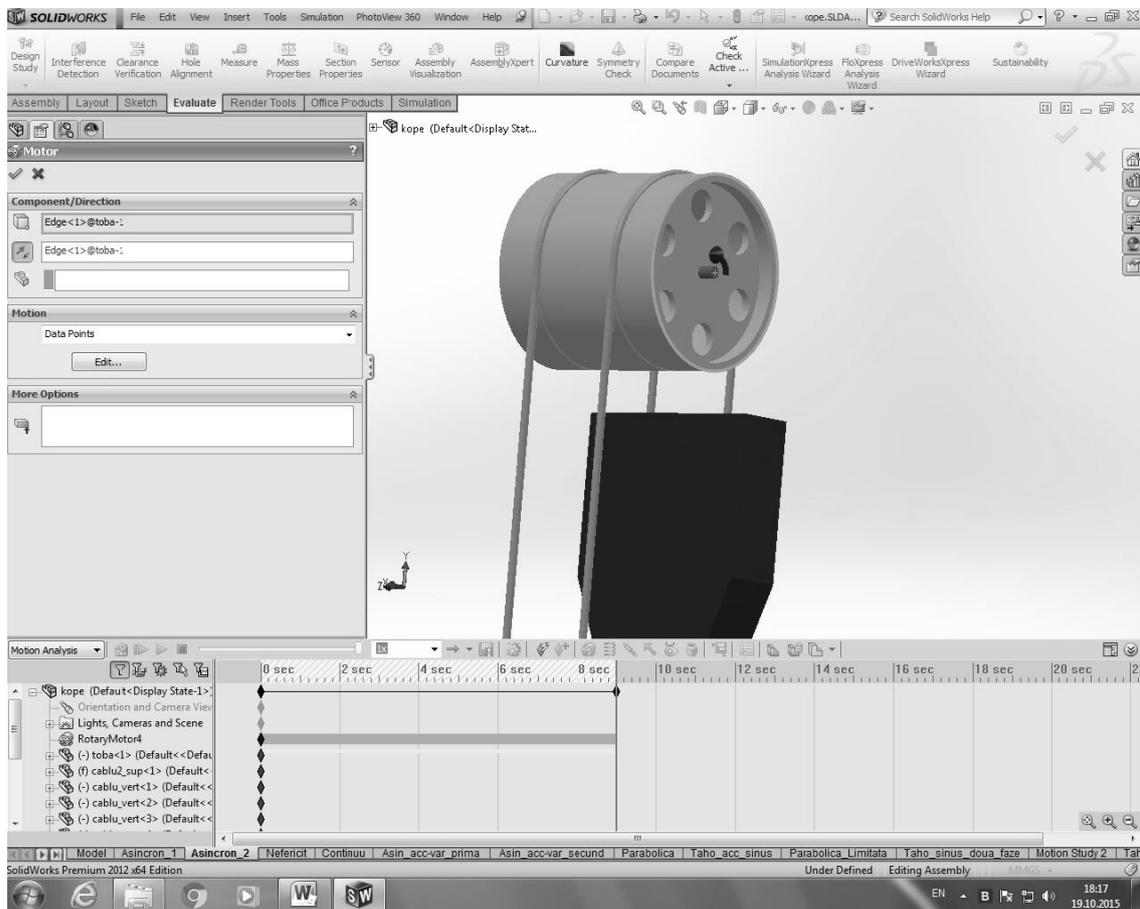


Fig.4 Actuation engine attachment

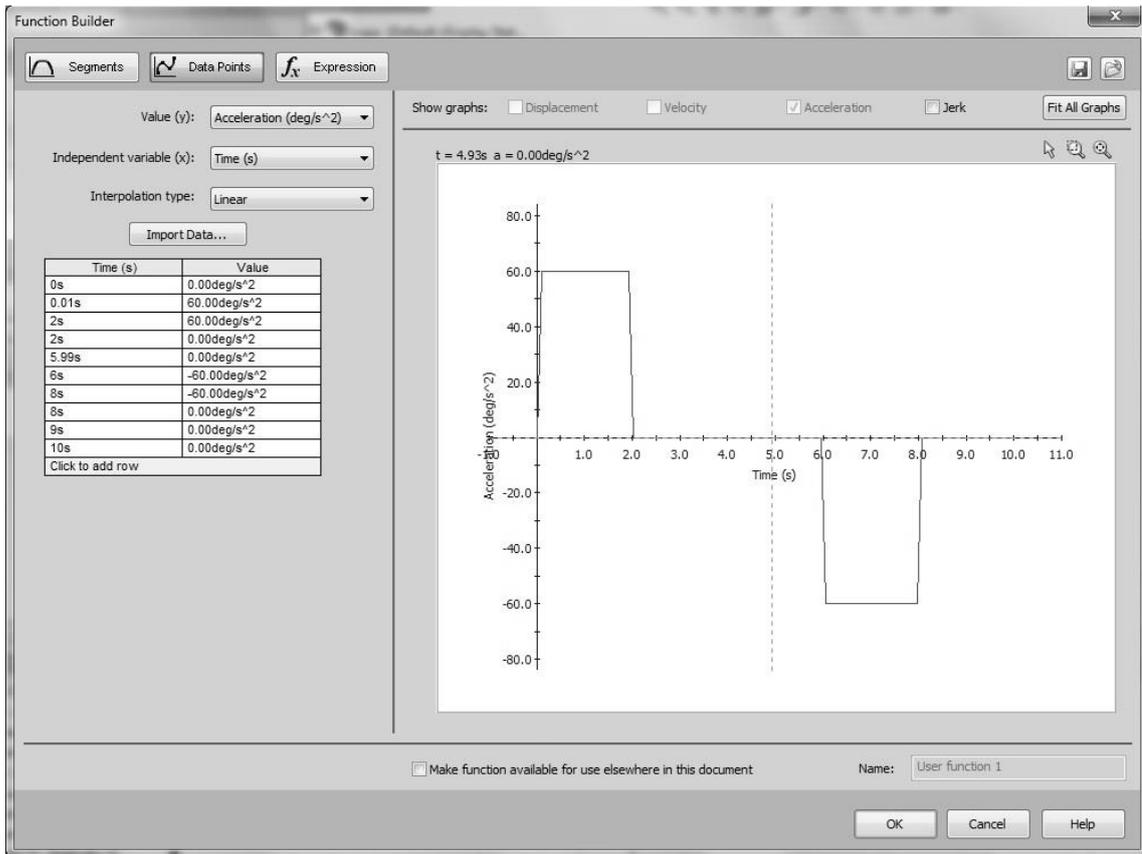


Fig.5 Imposing variation acceleration by points

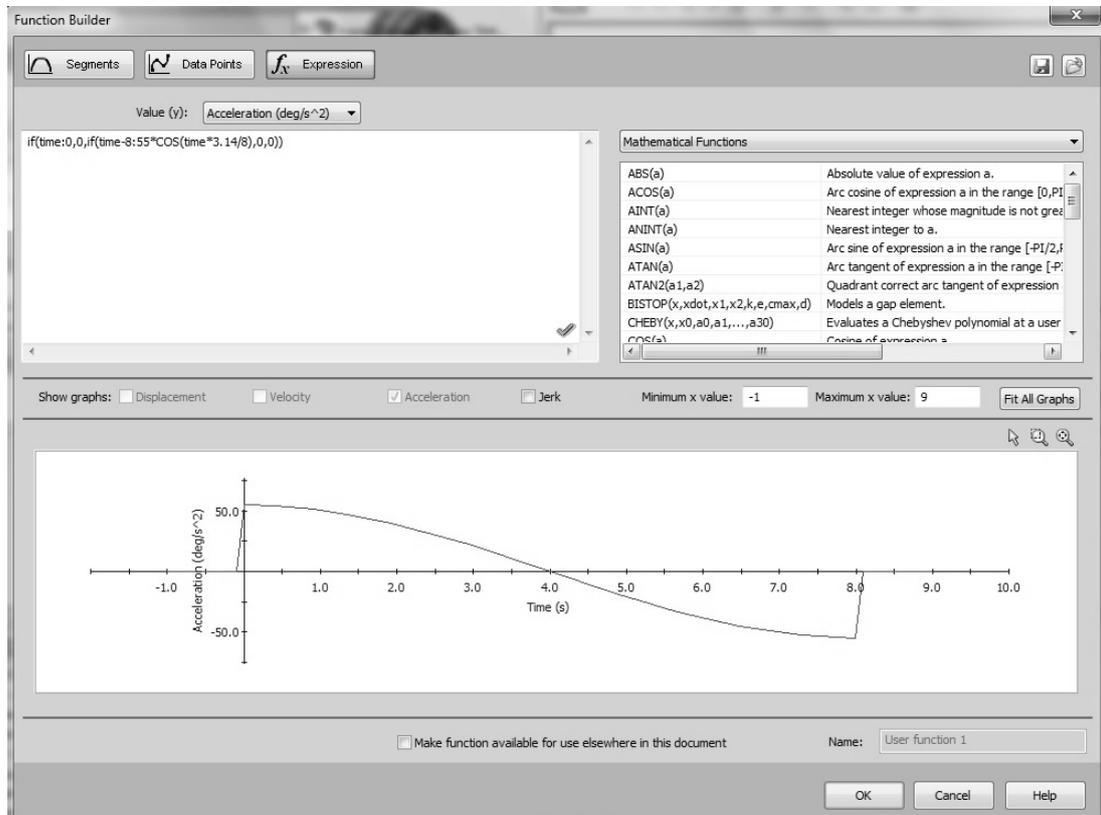


Fig.6 Imposing acceleration variation by expressions

3.1. Trapezoidal tachogram, asynchronous engine actuation

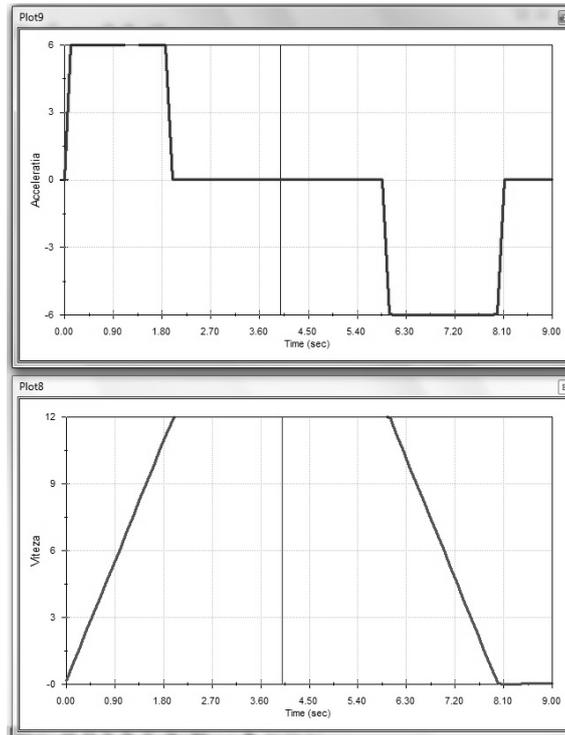


Fig.7 Asynchronous engine actuation

3.2. Direct current engine actuation

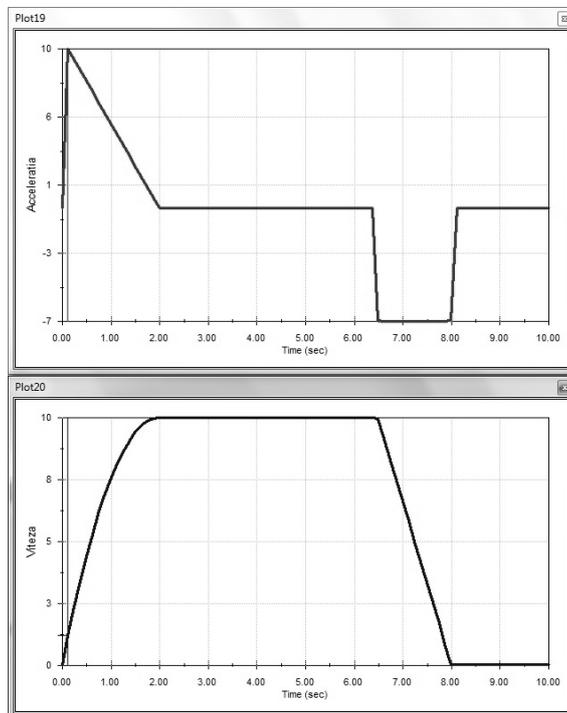


Fig.8 Direct current engine actuation

Analysing Figures 7 and 8, it is noticeable that both tachograms are similar to those traced in section 1 using analytical methods.

3.3. Five-intervals tachogram with acceleration variation in second interval

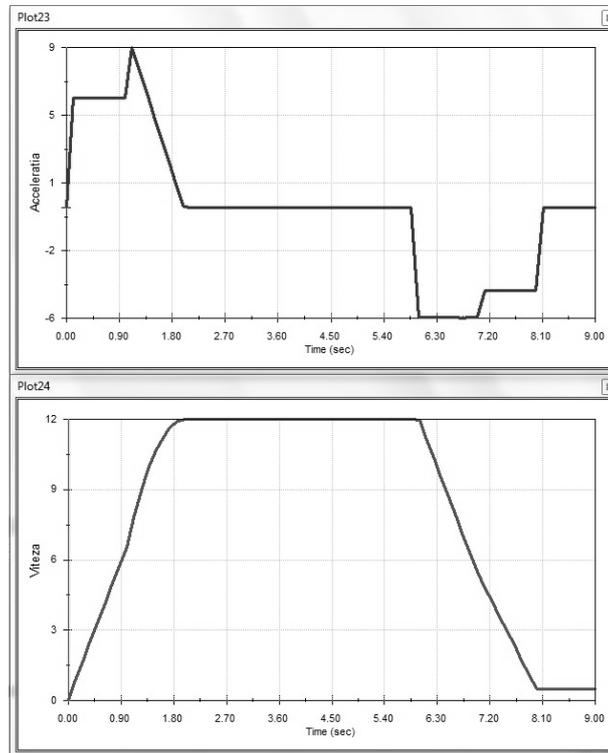


Fig.9 Acceleration variation in second stage tachogram

4. CONCLUSIONS

The hoisting machinery tachogram functions is highly diverse, the number of intervals being imposed by either the desire to eliminate power peaks, or the decrease of dynamic loads during movement of hoisting enclosures through guides (shaft skips and tipping pit cages).

Choosing the optimal tachogram is one difficult matter with analytical methods, therefore using numerical simulation methods is the best solution to address such an issue.

Tachogram tracing using software SolidWorks[®] falls within the ever-rising trend of using computer-assisted design and simulation. Thus, the kinematics of hoisting machinery can be accomplished starting from a graphic model (the proposed assembly).

Following the assessment of the results achieved by application of numerical methods, it is ascertained that they are comparable to those deriving from analytic calculation methods. The advantage of numerical methods is the possibility of performing a large number of alternatives in a relatively small time.

Considering the content of the present study, it can be concluded that software program SolidWorks[®], besides being an instrument for graphics generation, is also suitable for design and simulation procedures.

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