Inclined Belt Conveyor Simulation, Test and Comparison Study

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Keywords: Conveyor numerical model, Simulation, Test, Comparison study.

Abstract. This paper puts forward the application of AMESim to a belt conveyor model. Based on discrete element method, a conveyor numerical model is studied. A belt, idler and material are represented by a spring, damper and mass. The model of function of input and linear signal source is selected to build a model of a drive system and brake system. The performance simulation on belt velocity of a inclined conveyor during starting and stopping process is carried out. A velocity test on spot for the whole operation is conducted. The simulation is compared to a velocity test on spot. The comparison study shows that both simulation and test are in good agreement.

Introduction

For a traditionally designed belt conveyor, its operational performance is difficult to be exactly determined before its setup. Also the parameter or scheme should be redesigned in order to satisfy the design requirements if its dynamic behavior is not reasonable. And a quick and exact modeling method is key to study conveyor performance for engineers.

Conveyor dynamic simulation has several main applications: dynamic performance analysis, prediction and modification. Many authors studied them with simulation\textsuperscript{[1–8]}. For example, G.Lodewijks studied the stopping behavior of a decline conveyor and mentioned a method called dynamic tuning for the brake torque and flywheel\textsuperscript{[2]}. And A.Harrison simulated the effect of reducing dynamic loads in belts powered by three wound rotor motors\textsuperscript{[7]}. However, it seems that the conveyor design example by the help of dynamic performance prediction and modification is limited in number. Therefore, the engineering application in the conveyor dynamic simulation should be enhanced.

On the other hand, modeling methods and business software become more and easier with technology developed. Here in this paper quick and exact modeling software, AMESim, is introduced. AMESim is designed to develop and analyze multi-disciplinary system models. It is the ideal version for users who need to share models with other departments or with outside partners.

Via the easy and interactive graphical interface, AMESim users can build complex multi-domain system models in minutes by simply combining validated components from various libraries covering different physical domains. The result is a straightforward system model representation, which is easy to understand and investigate. Users create models by connecting physics-based building blocks. This innovative concept avoids cumbersome numerical model creation and code writing. Users are plunged directly into the critical aspects of design like analysis and optimization.

Based on the most advanced numerical techniques, the AMESim solver supports ordinary differential equation (ODE) and differential algebraic equations (DAE). The solver automatically and dynamically selects the best-adapted calculation method from 17 algorithms, depending on the system dynamics.

This paper predicts dynamics performance of a long inclined belt conveyor based on AMESim. A velocity test on spot for the whole operation is conducted. And the comparison between the simulation and test is carried out.
Conveyor Model Based on AMEsim

A conveyor is a loop machine which can be divided into units from the view of finite element method. Belts, material, idlers, drive systems, brake systems and a take-up can find their position in each unit. For belt, idler and material unit, each can be described using a spring, damper and mass. Thus, the force acting on ith unit of spring and damper

\[ F_i = K_i (x_{i2} - x_{i1}) + C_i (v_{i2} - v_{i1}) \]

the force acting on ith unit of mass

\[ F_i = M_i x_i + F_f \pm M_i g \sin \alpha_i \]

Here \( K_i, C_i \) —— spring rate and damper rating of each unit,
\( x_{i2}, x_{i1}, v_{i2}, v_{i1} \) —— displacement and velocity besides spring rate and damper,
\( M_i, x_i \) —— mass and acceleration of each unit,
\( \alpha_i \) —— conveyor angle,
\( F_f \) —— friction force,

\[ F_f = \left( f_1 + (f_2 - f_1) e^{-\frac{|v_0|}{v_0}} \right) \times \text{sign}(x_i) \]

\( f_1 \) —— Coulomb friction force,
\( f_2 \) —— stiction force,
\( v_0 \) —— velocity threshold,
\( \text{sign}(x_i) \) —— sign.

A typical conveyor AMEsim Model is shown in Figure 1. In its sketch mode one drive system and gravity take-up is mounted on the head of conveyor. Each unit is chosen and fit together; AMEsim will automatically build conveyor system equation and calculate it according to initial values. The model of linear mass, spring-damper, drive and return sheave, reducer and rotary load may be found in Mechanical warehouse of AMEsim. They consist of the mechanical part of conveyor model. In Signal warehouse of AMEsim, the model of function of input and linear signal source is selected to build a model of drive systems or brake system.

![Conveyor AMEsim Model](image)

**Figure 1. Conveyor AMEsim Model.**

**Simulation, Test and Comparison**

This section predicts belt performance in the process of conveyor start-up and stop.
The basic data of a belt conveyor studied is as following. It is 108.54 meter in length with a lift 3 m. The belt is canvas with the width of 800 mm and layers of five. The conveyor velocity is 2 m/s. It transports material 300t/h in full load condition. Idler spacing is 1 m on the carry strand and 1.2 m on the return strand. One motor is built at the head of conveyor with the power of 30 kW and rotation speed of 1470 rpm. The rotation ratio of a reducer is 31.5. And the diameter of drive pulley is 800 mm. The take-up is mounted near the drive pulley.

The simulation and test is carried out in the case of zero-load condition. And the start process of the conveyor employs the direct start of the motor. The stop process of the conveyor exists when no power is on the motor and no brake torque on the drive drum. So the belt velocity varies during the process of start and stop in Figure2 and Figure3 based on a conveyor AMESim model. From Figure2 and Figure3, the start process lasts around 3s during which belt velocity increases from zero to 2 m/s, and the stop process is about 4.3s during which belt velocity decreases from 2 m/s to zero.

![Figure 2. Belt velocity simulated in start process.](image1)

![Figure 3. Belt velocity simulated in stop process.](image2)

![Figure 4. Tested belt velocity of the whole process.](image3)

Figure 4 shows the tested belt velocity history which includes start, normal operation and stop processes. From the test results, the start and stop time are 3.2s and 4s, respectively. Tab.1 finds a small time difference between simulation and test. Also from Figure4 and Figure3, a small velocity
rebound is different, with the previous velocity negative and the latter velocity positive. After all, a good agreement reaches comparing Figure 2, Figure 3 and Figure 4.

Table 1. Comparison of start and stop time simulated and tested.

| Operation condition | simulation | test  |
|---------------------|------------|-------|
| Start time (s)       | 3          | 3.2   |
| Stop time (s)        | 4.05       | 4     |

Summary
This paper illustrates how the new software AMESim is used to build and simulate conveyor system performance before its setup. By comparing the simulation with the test of belt velocity, a good agreement is reached.

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