Design Considerations to Minimise Energy Consumption and Costs of Belt Conveyors

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Overview of Presentation

• Introduction and Overview
• Energy Consumption of Belt Conveyors
• Influence of Key Design Variables
• Cost Analysis - Case Study
Introduction

• When designing a belt conveying system, designers are faced with the complex task of selecting many variables, including; belt width and speed, idler roll pitch, diameter and troughing configuration, etc.

• System variables should be selected to meet, not only the functional requirements of the system, but also to minimise costs.

• This presentation provides an overview of the influence of key conveyor design variables in relation to energy consumption and life-cycle cost.
Overview

• Excluding the energy to lift the bulk material, the energy consumption of a belt conveyor is dependent on the resistance to motion. The main resistances to motion are:
  - Idler roll rotating resistance
  - Belt and bulk material flexure resistance
  - Indentation rolling resistance

• Each of these main resistances will be discussed in relation to key system design variables.

• Furthermore, designers must also minimise the life-cycle cost of the system at the design stage. This process is best demonstrated by an example, where life-cycle cost vs idler pitch is compared for a 1km long conveyor handling coal.
Motion Resistances of Belt Conveying Systems
(Typical Values for a 1km Long Horizontal System)

- Bulk Solid Flexure Resistance (18%)
- Indentation Rolling Resistance (61%)
- Idler Roll Rotating Resistance (6%)
- Belt Flexure Resistance (5%)
- Secondary Resistances (10%)
Idler Roll Rotating Resistance Test Facility
Idler Roll Rotating Resistance
Typical Experimental Results

Ø152mm Idler Roll at 6m/s

20°C Ambient Temperature

0°C Ambient Temperature
Idler Roll Rotating Resistance
Typical Experimental Results - Breakdown

@ 20°C, \( v = 4 \text{m/s} \) and 250N Vertical Load
Bulk Solid and Belt Flexure Resistance

Coal
Bulk Solid and Belt Flexure Resistance

Belt Cross-section

DEM Simulation
Belt Speed = 5m/s, Belt Width = 1.2m, Sag Ratio = 2%, $\rho = 1000\text{kg/m}^3$, $\phi_w = 30^\circ$
Bulk Solid Flexure Resistance

Belt Speed = 5m/s, Belt Width = 1.2m, Sag Ratio = 2%, $\rho = 1000\text{kg/m}^3$, $\phi_w = 30^\circ$
Indentation Rolling Resistance

Belt Indentation
Rubber (Viscoelastic) Properties

$E' \sim$ Elastic Response
(Elastic Modulus)

$E'' \sim$ Energy Loss in Internal Motion (Loss Modulus)

$$\tan \delta = \frac{E''(\omega, \varepsilon)}{E'(\omega, \varepsilon)}$$
Indentation Rolling Resistance Test Facility

Capabilities:
- Fabric and steel cord belts
- Belt speeds 1 to 10 m/s
- Roll diameters 100 to 219 mm
- Belt widths 400 to 600 mm
- Endless pre-spliced belts 29 m long
- Multiple compounds in a single loop
- Temp. range -20°C to +50°C
Application to Design

Indentation rolling resistance versus load

Assumed load distribution at the belt and idler roll interface

Indentation rolling resistance distribution (bottom view)
Experimental Results
Ø127-178mm Rolls – LRR Cover @ 20°C

Increased Idler Roll Dia Benefits
- Lower indentation rolling resistance
- Increased bearing life due to reduced angular velocity
- Increased idler roll pitch due to lower contact stress at idler and belt interface
Experimental Results
Ø178mm Roll – LRR vs Conventional Cover @ 20ºC

Low Rolling Resistance (LRR) Cover

Conventional Cover
Economic Analysis

- Costs can be divided into two categories:
  - Capital Costs
    - Drive system
    - Belt
    - Idlers
    - Structure
  - Operating Costs
    - Labour
    - Repairs and maintenance
    - Energy

- Considering component life, salvage value, taxation rate and rate of return on capital, costs may be expressed as Annual Equivalent Costs over the life of the installation.
Example - Optimising Idler Roll Pitch

Main Resistances vs Idler Pitch

Annual Equivalent Costs vs Idler Pitch

Horizontal Conveyor: Throughput = 1000 t/hr,
Length = 1km, Belt Speed 3m/s, Belt Width = 1m
Conclusions

• When designing a belt conveyor, system variables can be selected at the design stage to minimise energy consumption. Key selection parameters to consider include:
  • Idler roll diameter, pitch and troughing configuration
  • Belt width, speed and bottom cover properties
• System variables should be selected to meet, not only the functional requirements of the system, but also to minimise energy consumption and life cycle costs.
Thank You