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Review

Review of the troughability test ISO 703 for quantifying a uniform transverse bending stiffness for conveyor belts

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ABSTRACT

This paper presents a review of the troughability test specified in standard ISO 703 and associated models for quantifying the effective modulus of elasticity for uniform belt bending stiffness. For the interpretation of the test results, four analytical methods are employed: two theoretical ones that assume inextensible nonlinear bending of the belt's structure using the Euler–Bernoulli beam theory, and a Finite Element Method (FEM). The latter includes not only bending, but also stretching and shear effects, accommodating the Timoshenko theory for model with beam elements and the Mindlin–Reissner theory for model with shell elements. The present study compares the models, gives recommendations regarding their application and usage limitations. The impact of the varying effective modulus of elasticity, line mass and geometry on the belt's troughability is investigated within established parameters and limitations inherent to conveyor belts. The results indicate that the troughability test (ISO 703) in combination with an appropriate choice of the model for data extraction can be used for quantifying the effective modulus of elasticity. This conclusion is limited to small strain conditions (up till 5%). Analyses reveal that thick and narrow belts with a small belt width-to-thickness ratio reach this strain limitation at smaller troughability values.

1. Introduction

Nowadays belt conveyors are the most popular and effective continuous systems in bulk handling operations. They are used for conveying various bulk materials as an attached component of special bulk handling equipment (see e.g. mobile belt conveyors for stackers, reclaimers, bucket wheel excavators, described by Bošnjak et al. [1], Rusinski et al. [2], Smolnicki and Macelak [3]) or as a self-sufficient mean of transportation at substantial distances (overland belt conveyors). Mazurkiewicz [4] states that belt conveyors became the lowest cost transport equipment for bulk solids, especially compared to the truck haulage in open pit mining.

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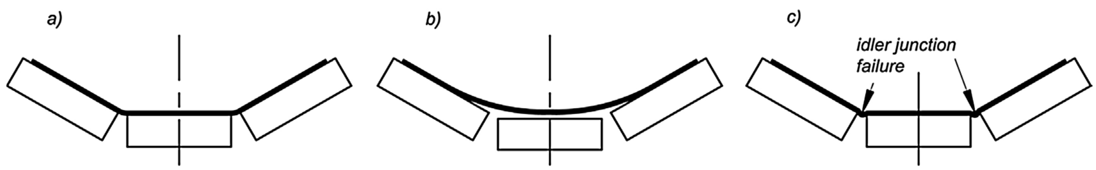

Fig. 1 – Troughability characteristics of conveyor belt: (a) proper troughing; (b) belt is excessively stiff, causing it to rest on the wing idler rolls; (c) belt is too compliant, causing it to pinch in idler junction gap.
Figure from Fayed and Skocir [15].

Practicing engineers construct belt conveyors based on the requirements developed according to various national and international standards, like ISO (e.g., [5–10]), DIN (e.g. [11–13]), CEMA [14]) and others. These standards provide recommendations reflecting the majority of the design aspects of a conveyor system and its components.

The mechanical properties of a conveyor belt are important parameters that need to be controlled at the system design stage. Different belt constructions e.g., steel cord and/or fabric structural reinforcements, exhibit a different mechanical response to tensile and bending in both longitudinal and lateral directions.

The longitudinal mechanical response to tensile loads needs to be carefully controlled because the belt's minimum breaking strength is a crucial parameter for the belt's selection. In the conveyor belting industry a number of various standards (*i.a.* ISO 283 [5], 7622 [6], 9856 [7], DIN 53504 [11]) exists that explicitly describe how the belt's tensile stress/strain characteristics can be quantified, including information on the measurement procedure, apparatus configuration, test samples sizes, load conditions, etc.

The belt's bending stiffness in the lateral direction also has a significant impact on the conveyor operation and needs to be carefully regulated. For conventional trough conveyors, the belt has to conform to the idler stations, as shown in Fig. 1a. However, if the belt is too stiff transversely, it mostly rests on the wing idler rolls and does not touch the centre roll (see Fig. 1b). This belt position leads to spillage of bulk material and deterioration of belt tracking. In case of pipe conveyors, excessive bending stiffness implies high energy losses and also possible pipe opening between the idler stations.

On other hand, if a belt is too flexible in the lateral direction then a conventional trough conveyor belt can be pinched by the idler rolls and cause idler junction failure (see Fig. 1c). Fayed and Skocir [15] state that if the problem of junction failure occurs then the overall belt needs to be replaced with the one with proper bending stiffness. In the case of pipe conveyors, too flexible belts tend to collapse their pipe shape and therefore do not suit for the correct operation in a pipe conveyor system (see experimental results of Zamiralova and Lodewijks [16]).

Typical problems due to the incorrect belt bending stiffness of conventional trough conveyors are shown in Fig. 2.

For the conveyor belt industry, there is only one standardized procedure that allows investigation of the belt's lateral bending flexibility. This procedure is described in ISO 703 [8] (analogical testing method in ASTM D378 [17]) and is named the troughability test. This test was established based on practical experience and describes the belt troughability as a ratio of the maximum deflection, produced by a belt sample under its own weight, to the belt width. The purpose of the troughability test is to replicate the belt's capability to sufficiently conform a trough sufficient for reliable conveyor operation.

The current European standard ISO 703 version 2007 [8] for the troughability test has several drawbacks, which make it less effective to serve for the purpose of its development. One of the drawbacks is that the current version of ISO 703 2007 [8] stipulates only a measurement procedure. In contrast to the previous version of 1988 [18], the current standard does not provide any recommendations about the minimum required belt troughability with respect to the idler rolls trough angle.

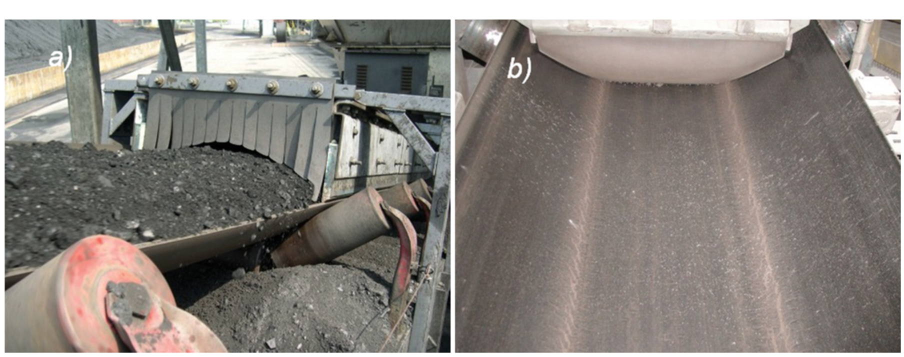

Fig. 2 – Typical problems due to the incorrect belt bending stiffness of conventional trough conveyors: (a) Excessively stiff belt causes spillage of the material; (b) excessively flexible belt causes damage of the belt, observed as two wear lines, due to the idler junction failure.
Courtesy of Siethom Technisches Büro GmbH.