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Correlation of rubber based conveyor belt properties and abrasive wear rates under 2- and 3-body conditions

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ABSTRACT

Predicting the lifetime of a conveyor belt from lab-scale tests has become increasingly important, as the cost for the belt represents up to 70% of the acquisition and maintenance costs of a transport system. In practice, belt selection relies strongly on the well-established ISO 4649 abrasion test, where fixed corundum paper is utilised as the abrasive medium, resulting in 2-body abrasion. In the present article, this is compared to the ASTM G65 test with rolling, round abrasive particles, leading to 3-body abrasion. To evaluate the lab-scale results, they were compared to a conveyor belt that had been used to transport sintered charge for eight years. The comparability and reproducibility of wear patterns encountered on this particular belt was matched with the lab test and then correlated with mechanical properties of the rubber materials.

It was found that the ISO 4649 tests, where abrasive wear is dominant, rarely reflect wear patterns and wear mechanisms occurring in real applications. In contrast, the ASTM G65 3-body abrasion test entails fatigue dominated wear, which is found in real applications. The ISO 4649 test results showed a strong dependence on tensile strength and Shore A hardness, while tear strength was the most influential factor for the ASTM G65 test.

1. Introduction

Conveyor belt transport systems play an important role in mining, handling of bulk material, timber industry and many other fields where large quantities of goods have to be transported over distances ranging from few metres to several kilometres. The main reason for their widespread use may lie in their constructive and economical adaptability [1]. Unfortunately, the costs for acquisition, maintenance, repair and renewal of a conveyor belt often exceed even the costs of the rest of the transport system, such as the steel supports and machines [2] attached to it, considering their respective lifetimes. With a cost share of 30–70% [3,4], the conveyor belt is of special economic importance. It is therefore not surprising that enhancing the lifetime of conveyor belts, which usually means reducing wear, is a priority.

Fabric conveyor belts usually consist of a wear resistant top layer (‘top cover’), a fabric carcass providing tensile strength, skim layers for adhesion between rubber and carcass, and a bottom layer (‘bottom cover’) to cover the carcass and provide sufficient friction to the drive pulley [5]. In practice, the top layer is always the tribologically most stressed component of the belt and is therefore of special interest. Usually a top layer's polymer basis consists of Natural Rubber (NR) or Styrene-Butadien Rubber (SBR), while Ethylene Propylene(Diene) Rubber (EP(D)M) or Acrylonitrile Butadiene Rubber (NBR) is preferred in case of exposure to heat or oil [5]. As NR/SBR conveyor belts are amongst the most commonly used and cost-efficient conveyor belt materials, the present paper will concentrate on these particular materials.

In principle, abrasive wear can be divided into two categories: 2- and 3-body abrasions [6]. The first body is usually denoted as the material which exhibits the most wear during the test. The second body, usually the harder material, causes wear on the first body by transmission of direct or indirect forces. In case of 3-body abrasion, a third body is also present, which consists of interfacial elements either created autogenously or foreign matter introduced into the system. Examples are wear debris, lubricants, entrained particles or even reactive chemicals. Another classification scheme for abrasion is the separation into high- and low-stress abrasions [7]. High-stress abrasion occurs when the abrasive material is split during the process, generating new sharp edges. Abrasion caused by sand paper is still considered high-stress, even though the abrasive does not split, because it remains sharp during the process [8]. The ISO 4649 test is a good example for such a high-stress test.

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In general, abrasive wear of polymers is a major topic in literature. Here, 2-body abrasion often occurs during tribological tests, while 3-body abrasion is more often present in practical applications [9,10,11]. A good example for the dependence of different intensities of wear is given by the work of Evans and Lancaster [12], where low-density polyethylene showed the lowest wear rate out of 18 different polymers against rough mild steel, but the highest against coarse corundum paper.

Hence, abrasive wear of polymers is not an easy matter to discuss. Also the work of Budinski [13], who investigated 21 different kinds of polymers (but no rubber) with an ASTM G65 tester, revealed no simple or conclusive correlations, although hardness, friction and scratch resistance were taken into account. In general, the wear processes in polymers are still widely recognised as incompletely understood [14].

Another very important part that determines the abrasive properties of rubber in conveyor belts is aging at elevated temperatures. Oxygen reacts with the sulphur cross-links between the rubber molecules and reduces the rubber's elastic properties. At an uptake of just 1% oxygen, natural rubber loses practically all of its elasticity and wear resistance is impaired [15].

The aim of this work is to compare the ISO 4649 and ASTM G65 tests with each other, as well as with real applications, to determine suitable tests for the latter. Furthermore, the present paper correlates wear rates with the mechanical properties of rubber and enhances the understanding of the predominant wear mechanisms.

2. Experimental

In order to compare wear patterns and wear mechanism to real applications, a NR/SBR-based conveyor belt (1000 EP 800/4 10/3 D) was investigated regarding wear patterns and reduction of the cover thickness. This particular belt transported sintered materials in an open hall for eight years, at a output of ~350 t/h. The remaining cover thickness was determined by comparing the loss of material in the centre to that in the rim regions, while the wear patterns were examined with a high-resolution stereo microscope. The results were then compared to wear patterns from lab-scale tests.

In practise, the abrasive properties of rubber conveyor belts are mostly determined by conducting a 2-body abrasion test according to ISO 4649 [16], where a sample is drawn over abrasive paper on a rotating drum (Fig. 1a). The abrasive paper contains an edged and fixed abrasive, which, unfortunately, rarely simulates the abrasive stress applied in real conveyor belt applications. Different tests are therefore needed to tailor a product's abrasive properties to its actual application. One appropriate alternative is the 3-body ASTM G65 abrasion test [17], which uses a loose abrasive and a rubber wheel (Fig. 1b). Such a test rig also offers flexible parameter variation, which can prove useful for reproducing wear phenomena. Namely parameters such as velocity, temperature, applied load, wheel material, as well as shape and size of the abrasive, can be changed to fit relevant applications [18]. Hence, five commercially available conveyor belts were acquired (Table 1) and their mechanical properties were determined. The ASTM G65 standard procedure was modified and the tests were run according to the parameters listed in Table 2. The test is therefore referred to as ASTM G65M to make it clear that it was modified.

For the ASTM G65M tester, $70 \times 25 \times 6\ mm^3$ pieces were cut out from the conveyor belt samples using a box cutter. Analogously, cylindrical samples (Ø $16 \times 6\ mm^2$) were punched out of the conveyor belts with a die cutter for the ISO 4649 tester. The top layers of both kinds of samples were then tested according to

Table 1
List of SBR conveyor belt covers materials used in this study.

Sample number	Shore A hardness [dimensionless]	Tensile strength [MPa]	Tear strength (ISO 34-1 method A) [MPa]	Max. abrasion according to data sheet (acc. ISO 4649) [mm³]	Rubber base
A	55	18.3	11.8	120	SBR
B	58	19.9	17.7	90	NR/SBR/BR
C	59	22.9	14.0	120	NR/BR
D	60	21.9	20.7	70	NR/BR
E	56	16.7	10.2	100	SBR

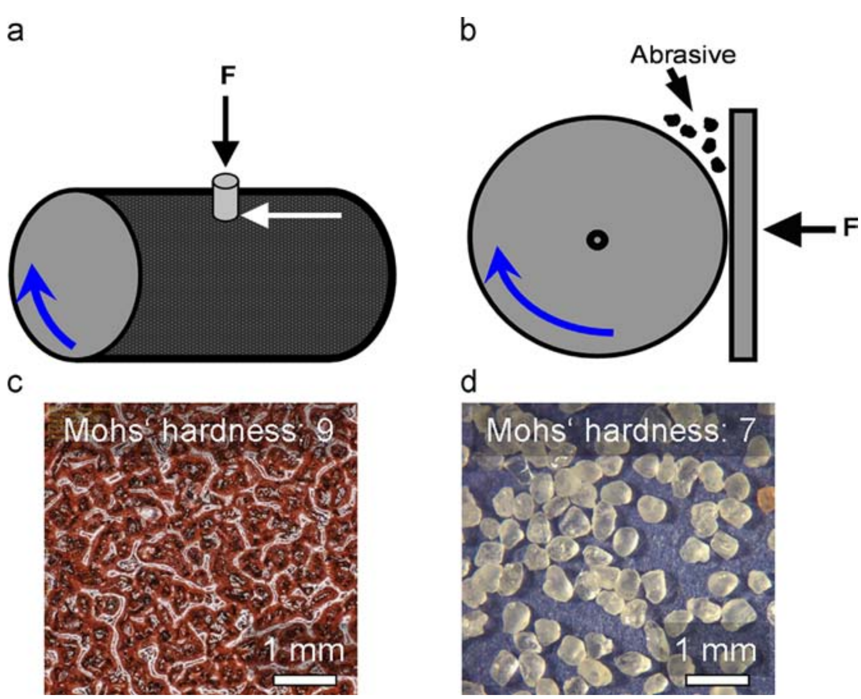

Fig. 1. Schematics of the ISO 4649 2-body abrasion test (a) and the ASTM G65 3-body abrasion test (b).