A New Conveyor Belt Wear Test Stand

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Summary

One of the main reasons for conveyor belt wear is the stress caused by the impact of lumpy material. In order to simulate loading-point stress conditions a new conveyor belt wear test stand has been developed and built by the Department of Conveying Technology at the University of Karlsruhe, Germany. A new contactless scanning technique has been introduced in order to determine the abrasion of the cover plate experimentally. With the help of this conveyor belt test stand experiments will be conducted which will allow the calculation and prediction of the service life of a conveyor belt in advance for specific operating conditions.

1. Introduction

A conveyor belt is both an investment and an item subject to wear. Analyses conducted by belt manufacturers and users show that the total costs of purchase, maintenance and replacement of the belt exceed the total costs of the remaining system components over the service life of the conveyor system [3, 4].

The design of conveyor belts is primarily based on the tensile stress resulting from the necessary driving power according to the Eytelwein formula. One can attempt to cope with above average stress by increasing the dimensions of the tension member as well as by increasing the thickness of the cover plates, and previous operating experience usually determines the selection of the cover plate material. As this experience is always closely related to the operating conditions, which change from installation to installation, it is not surprising that users and manufacturers often have different opinions concerning the optimal technical and economic design. As a consequence of the resulting uncertainty, competition tends to produce a variety of new products, a fact which does not necessarily represent the optimum solution for either user or manufacturer.

Conveyor systems with a large center distance show only slight wear in relation to length, so that normally the service life of the belt amounts to several years [1].

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This rather useful fact, however, leads to the situation that a certain belt design, particularly of a modified cover plate material, cannot be assessed until several years have passed. Also, the operating conditions of a certain installation do not remain constant during this long period, and therefore there is considerable uncertainty in applying present operating experience to similar projects. Useful attempts to classify damage, e.g., the VDI-Standard 3610, are only in the development stage [5].

Even today there exists no scientifically based analysis concerning the reasons for and the effect of belt wear, which, provided the later operating conditions were known, would enable the belt to be designed in advance or at least would allow one to make predictions as to the expected service life of the belt.

The quality tests specified in DIN-Standards 22102 and 22131 do not take into account the discontinuous dynamic stresses arising in practice. The same applies to the standard quality test for the mechanical characteristics of the cover plate material, such as the tensile strength and breaking strain tests according to DIN 53504, the hardness test according to DIN 53505, the determination of the tear resistance according to DIN 53507 and the determination of the abrasion resistance according to DIN 53516.

The importance of these data for production control is undoubtable. However, it is doubtful whether there is a clear and reproducible relationship between the observance of certain quality values and the service life of the conveyor belt.

In practice, wear of the cover plates is caused by discontinuous forces, and these are also considerably influenced by the type of support structure of the conveyor system and the belt construction. This means that different wear characteristics may result for completely identical loading conditions, identical cover plate quality and thickness but a different tension member.

Based on the knowledge that testing under static conditions is not sufficient for the assessment of the operational suitability of belts, manufacturers and users have started to build large-scale test stands in which testing can be conducted under actual operating conditions.

As technological tests are of major importance, the Department of Conveying Technology at the University of Karlsruhe has designed and built a new conveyor belt test stand which allows one to predict the service life of conveyor belts under defined and reproducible conditions. The testing method chosen is closer to reality than any other testing machine known so far.

Before going into technical details of this conveyor belt test stand, the term "belt wear" must be defined. According to DIN 50320, wear means the continuous abrasion of material at the surface of a solid body arising within a tribological system. This definition considers the time-dependent change in a homogeneous component under quasi-constant strain as may be observed in the case of the friction lining of automobile brakes. Considering the time and strain dependent mechanism which results in the belt becoming unfit for use and need of repair, this definition proves to be too restricted for several reasons.

Each running increment of the carrying side cover plate of a conveyor belt is exposed, during a single rotation, to several strains, different in type and extent, such as uni-axial strain, quasi-constant tensile strain, multi-axial deflection strain, multi-axial tensile and compressive strain, which all influence each other.

The wear of the carrying side cover plate may occur at best regularly over the total belt width and at worst in the form of short and deep longitudinal cracks down to the level of the tension member. In the latter case, assuming a constant abrasion rate, the tension member would be unprotected against corrosion and increased danger of slitting would arise for a steelcord belt.

Initial test results on the belt test stand seem to indicate that the wear characteristics depend on the design and construction of the tension member. Therefore, belt wear will be defined as: "The process in which the conveyor belt becomes unfit for use during a certain minimum service life, which to a considerable extent results from, or is related to, continuous damage of the cover plates."

As steelcord and textile belts show different wear behaviour, it is necessary to define a criterion of comparison, even if in doing so a certain arbitrary assumption is unavoidable. Consequently, the criterion for the steelcord belt shall be that the wires of the tension member become visible, and for textile belts that destruction starts at the upper layer of the textile tension member.

On the new wear test stand the belt to be tested runs in a normal troughed manner, with an initial tension typical for actual installations including a safety factor of 10 against belt breaking. Furthermore the belt can be subjected to a wide range of impact strains.

2. Description of Test Wear Stand

Fig. 1 shows schematically the wear test stand. In the right hand corner a simplified sketch of the measuring and monitoring arrangement is shown.

The test stand consists of a conveyor with drive (1), gear box (2), drive pulley (3), take-up pulley (4), supporting framework (12), take-up station (13), a loading device with test cylinder (5), 24 sharp-edged impact test objects (6), torque indicator (7), two-stage gear box (8), eddy current brake (9), measuring device (10), subframe (11), equipment for scanning the cover

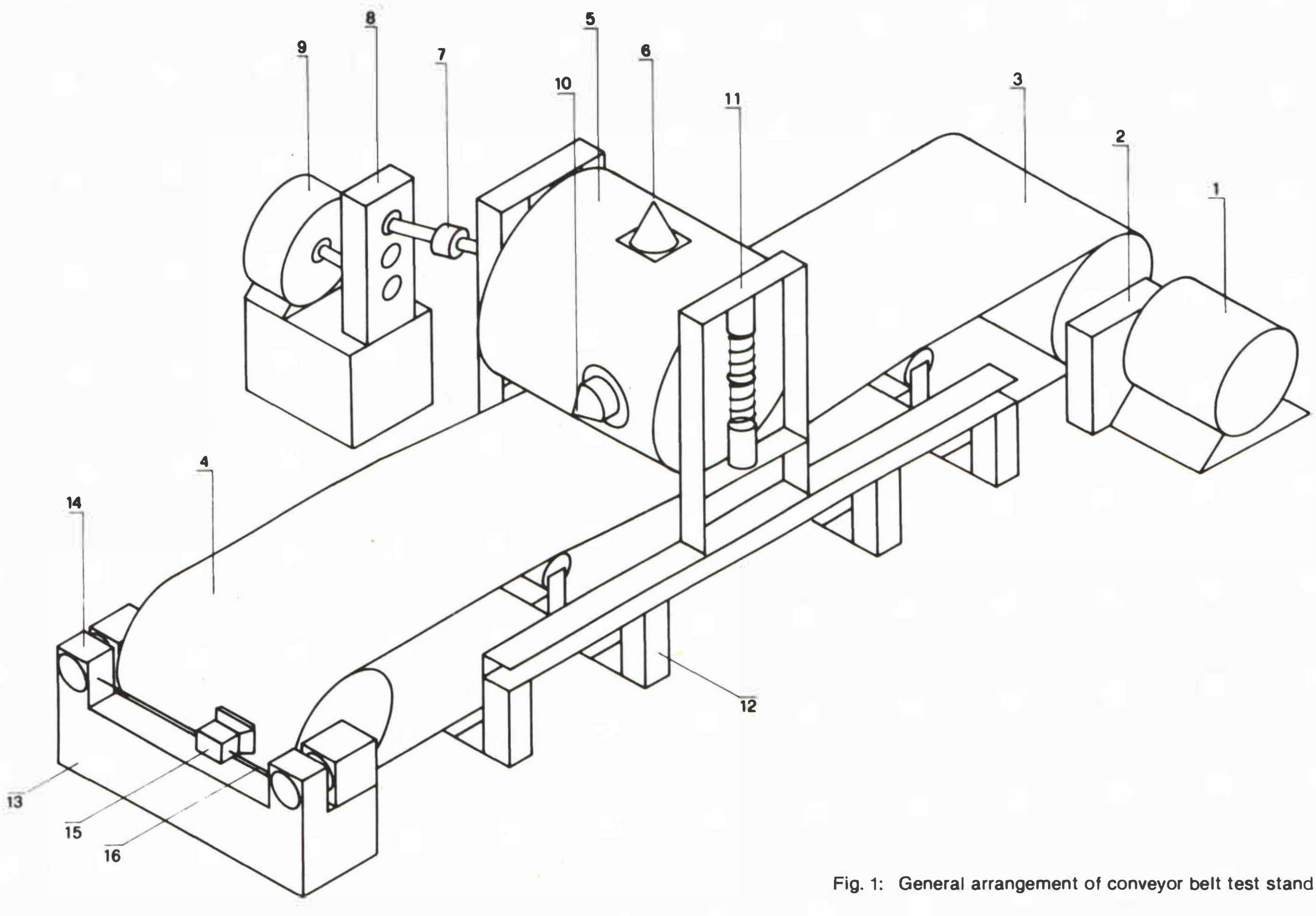

Fig. 1: General arrangement of conveyor belt test stand

plate mounted on a linear guide (16), and a precision sliding carriage (15) for mounting appropriate contact tips. The main specifications are:

center distance	11.0 m
belt width	800 mm
belt speed	0.5 — 7.0 m/sec
brake power	0 — 75 kW
pulley diameter	610 mm
test cylinder diameter	820 mm
initial tension	0 — 100 kN

The test cylinder is spring supported and can vibrate in two planes vertical and transverse to the belt. It is pressed against the belt with a defined force by means of the pretensioned springs. The running belt forces the test cylinder to rotate in an oscillating, tumbling motion as a result of the quasi-stochastic impact of the test objects. At the same time a constant braking moment is transferred from the dynamometrical brake to the test cylinder. Thus the belt is stressed by every test object by impulse forces acting simultaneously tangential and normal to the cover plate, as they would occur by the impact of lumpy material onto the belt.

By means of the measuring object, bearing a tip of the same material as mounted on the remaining test objects, the time-dependent shape of the impulses exchanged between the test objects and the belt is measured. The impulse forces generated by the impact of a test object, dropped in free fall onto the running belt have been determined in separate tests [2] and can be used for comparison.

Fig. 2 shows the maximum acceleration resulting from the impact of a test object weighing 28 kg as a function of height of fall and belt speed.

Based on this knowledge, realistic operating parameters for simulated impact stresses may be chosen for the wear stand. The direction and strength of the impulses exchanged between the test objects and the belt depend on the elastic and damping characteristics of the belt for a given mass of the test cylinder, given spring coefficient, given belt troughing and identical initial tension. This fact does not speak against but rather in favour of the test stand concept. When normally measuring the loading competence, at least some of the degrees of freedom a belt rotating on a real conveyor show, are suppressed. Initial tests with textile and steelcord belts on the conveyor belt test stand show the real influence of these parameters.

A steelcord belt Type ST 630 and a textile belt Type EP 630/4, with identical tensile stress, were tested under the following identical test conditions: initial tension: 50 N/mm; rotational speed of the test cylinder: approximately 77.50 rpm; belt speed: 4 m/sec; the transmitted average braking moment: 210 Nm. Despite the identical external loading conditions the maximum impulse values of the textile belt differed considerably from the impulse values of the steelcord belt. The average data measured over a period of 20 test cylinder rotations were as follows:

vertical:	1,640 N : ST 630
	550 N : EP 630/4
tangential:	1,570 N : ST 630
	510 N : EP 630/4

The ratio of tangential to vertical forces is nearly identical at approximately 0.9.

Let us now have a look at the wear characteristics of the steelcord belt ST 630 and the textile belt EP 630/4, obtained under identical test conditions.

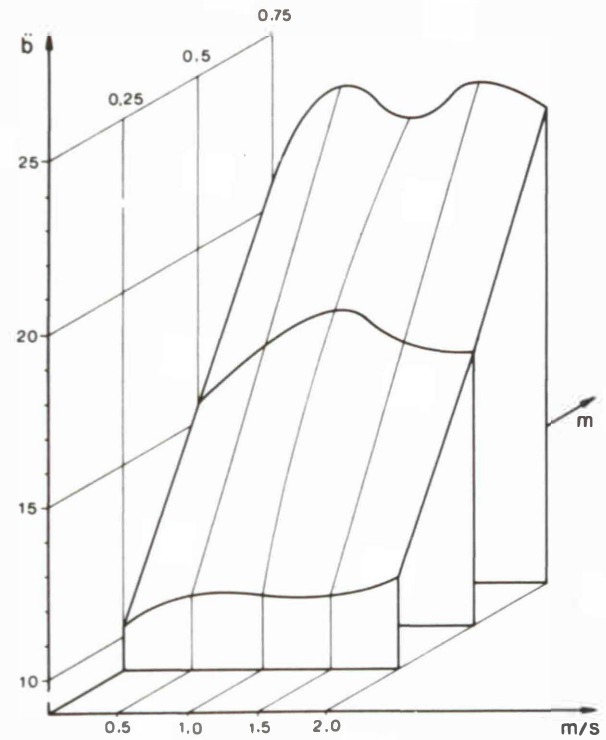

Fig. 2: Maximum acceleration of a 28 kg test object as function of height of fall and belt speed

The steelcord belt was removed after a longitudinal crack several meters long had appeared, this was not caused by additional application of force or impact. The textile belt was removed after initial damage occurred to the upper insert layer of the tension member, spread over the whole length of the belt (Figs. 3 and 4).

If one converts the total number of rotations achieved, linearly into a center distance of, say 120 m, using a belt speed of 3 m/sec and assuming identical specific load condi-

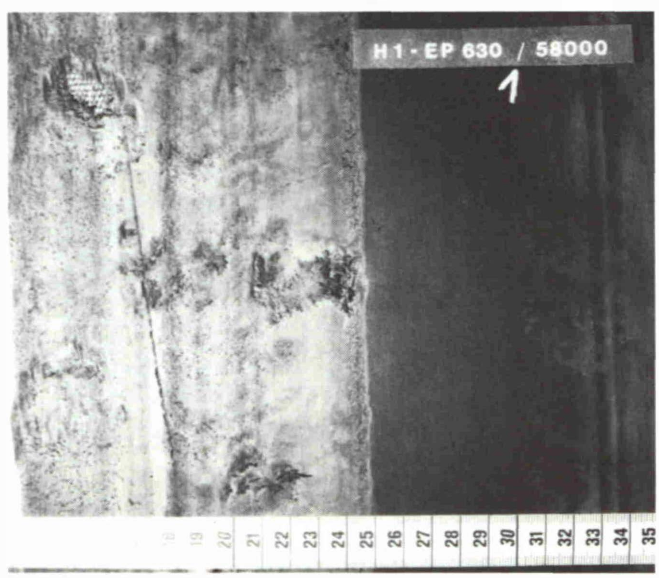

Fig. 3: Wear occurring in a steelcord belt ST 630 after 31,225 rotations on the test stand

Fig. 4: Wear occurring in a textile belt EP 630 after 58,000 rotations on the test stand

tions, then a minimum service life of 1,360 h for the textile belt would result. The test duration was 90 h.

The assessment of wear naturally cannot be restricted to mere inspection and photographic documentation. Rather it is necessary to render the wear process measurable. Wear in respect of the cross-section of the belt, as it is understood here, means any deviation of the profile from the original outline, i.e. from a straight line. The wear procedure can be quantified and documented by tracking the actual wear profile at lines previously marked, over the entire belt width, at regular intervals during the test.

Fig. 5 shows a detail of a profile plotted by scanning the cover plate of the textile belt EP 630/4 in the area where the tension member, i.e., textile cord, is damaged, immediately before the belt was removed (see also Fig. 4 top, left hand side).

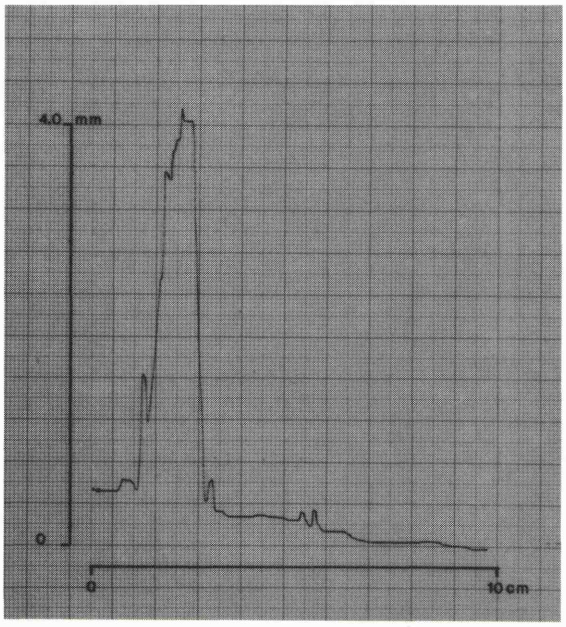

Fig. 5: Profile of cover plate

The criterion for identical wear could be defined, from the point of view of measurement, as the equality of areas under comparable profile sections for different cover plates. In order to track these profile sections of already damaged rubber surfaces in practice, a multitude of specific problems have to be overcome. These problems are mentioned briefly below.

In tracking a contour, a time signal is obtained as a function of the scanning velocity, which contains a certain frequency spectrum. Thus accurately reproducing the surface outline to be scanned is only possible if the inherent frequency of the scanning instrument is higher than the maximum significant signal frequency.

Fig. 6 shows the contact tip as used in the test stand measurements, as well as the linear guide arrangement by which the contact tip is conducted over the full width of the belt. With this arrangement the profile shown in Fig. 5 was plotted.

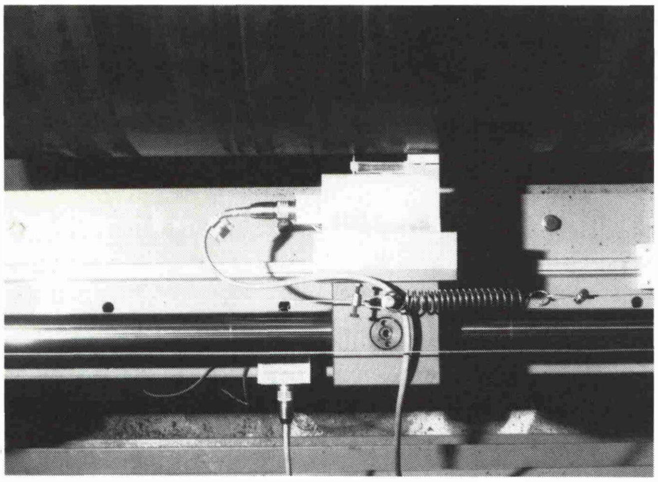

Fig. 6: Inductice contact tip

3. Ultrasonic Surface Scanning Sensor

Testing a conveyor belt cover plate for damage is, from a measurement point of view, the continuous scanning of the surface profile with subsequent determination if the admissible maximum limit values were exceeded. This, however, is not possible with this type of equipment due to the low scanning speed and because the running belt would destroy the wiper of the inductive contact tip immediately. Therefore, a completely new instrument for scanning surfaces was developed and a prototype was built on the basis of stationary ultrasonic waves. This instrument, suitable for the contactless supervision of cover plates of any conveyor belt with respect to changes of any kind, and therefore also suitable for the detection of longitudinal cracks in steelcord belts, is of simple and robust construction and offers the great advantages of not touching the belt or influencing it in any other way. The belt does not need to be prepared in any special way as is the case for the induction coil method. As there are no mechanical parts involved in the measuring procedure, the instrument is low in inertia and thus enables the scanning of the moving belt surfaces.

Fig. 7 shows the ultrasonic sensor, in this case mounted on calibrating equipment.

Fig. 8 shows the electronic part of the instrument which in the case of the proto-type was not yet mounted on the

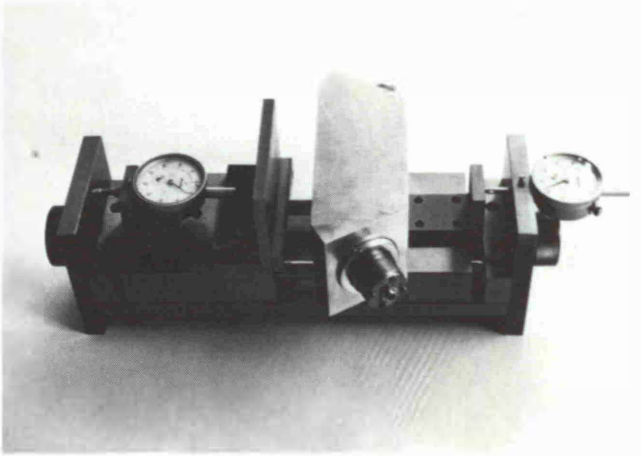

Fig. 8: Sensor for ultrasonic surface scanning

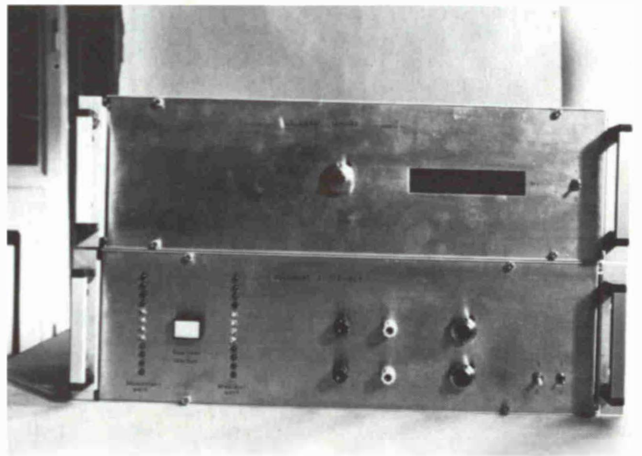

Fig. 9: Electronics for the scanning instrument

sensor. This, however will be accomplished later due to rapid progress in micro-electronics.

Fig. 9 shows the sensor mounted on the motor driven carriage of the linear guide. A detailed description of the surface scanning instrument, for which patents have been applied in Germany, Europe, Japan and the USA, cannot be given here.

The new test stand described here is part of a long-term reseaarch project on conveyor belt wear. The objectives can be divided into four stages: In the first stage a basic knowledge concerning the process of belt wear due to the impact of lumpy material will be obtained by means of the conveyor test stand. The second stage will try to determine the value of the various DIN quality tests with regard to the prediction of belt wear. In the third stage proposals for an improved design of conveyor belts for high impact stresses will be made. In a fourth stage methods will be developed, based on a synthesis of operating experience and scientific findings, which can be used in practice to determine mathematically predicted belt service lives.

This ambitious program can of course, only be carried out with the intensive co-operation of manufacturers, sub-contractors, users, and research organisations.

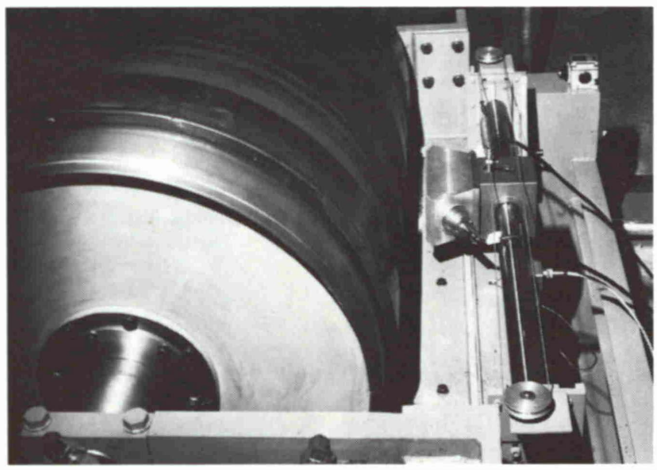

Fig. 10: View of the ultrasonic sensor

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