TIMING BELT FAILURE GUIDE

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A transdev technical report

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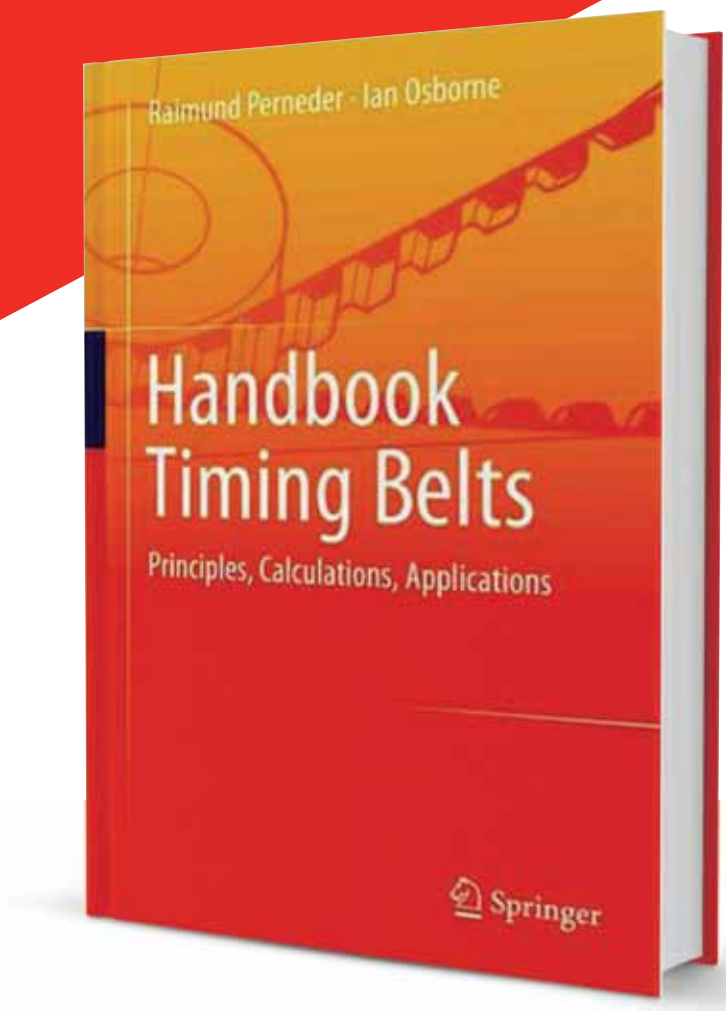

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Chapter 6
Timing Belt Failure

Abstract Timing belt failure is the loss of function before the end of the component's life, where the belt loses some or all of its properties in a predetermined manner and can no longer operate. The following analysis shows illustrations of the types of failure and helps to clarify the root cause of damage during failure. This section is recommended for troubleshooting, safety and achieving improved quality, safety and economy.

6.1 Sources of Failure

6.1.1 Design

Designing is a process to generate technical solutions for both production and use. The task consists of solving the given request from a set of requirements and secondary conditions. The desired result of a design is to measure and consider all appropriate influences and conditions which will affect the equipment over the entire life span and enable a correct drive deployment.

Typically, a belt driven assembly or machine has been designed in advance of its creation. Errors can occur if all operating conditions are not sufficiently known at the time of development. Further problems may occur through improper interpretation or misinterpretation of the drive calculation rules. The designer should always correctly implement the latest detail design techniques. For example, a flanged pulley drive (see Chapter 2.10) needs to be designed. The belt tension is not the only adjustment to be considered (see Chapter 3.7) as it is also necessary to know both the pre-tension and be able to give the final assembly department a plus/minus tolerance range for these values (see Chapter 2.17).

R. Perneder and I. Osborne, *Handbook Timing Belts*,
DOI: 10.1007/978-3-642-17755-2_6, © Springer-Verlag Berlin Heidelberg 2012

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6.1.2 Manufacturing

Other possible causes of failure are manufacturing variations in the production of the belt and improper handling during storage and shipping. This also includes sources of error in the associated pulleys or other installation components that are directly related to the function of the drive.

6.1.3 Assembly

The installation of timing belts and pulleys into machinery requires a high degree of technical competence. For example, the running of long belts when their associated pulleys are far apart can be difficult. The assembly department therefore should have adequate measuring equipment available for testing the alignment and angularity of the installed components. Incorrect pre-tension is a frequently mentioned cause of drive problems. The provision of an electronic tension meter is a worthwhile quality assurance measure to prevent errors during assembly.

6.1.4 Operation

Drive system users must take into account maintenance and repair requirements as with increasing length of use the probability of drive damage rises. Slight deviations from the desired drive state will eventually lead to damage and the machine operator should pay attention to changes in the running of the drives (e.g. noise). After experiencing an initial problem he should try to estimate the remaining drive life and start preparations for changing the belt.

> After a problem incident, a failed timing belt should be kept and its installation position and direction of travel marked for further investigation.

6.2 Fault Analysis

In analyzing any case of belt/component failure it is important to establish the cause of failure amongst all the variables, then document any suspicious drive property deviations and distinguish between primary and secondary material damage. Table 6.1 lists possible causes of failure relating to visible modes of damage. This then provides a basis for subsequent drive optimization in order to increase reliability, safety and quality. Any aspect of failure analysis investigation is an important tool in all sectors of mechanical engineering. Failure analysis is also an integral part of FMEA in the field of quality management [43].

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Table 6.1 Fault analysis

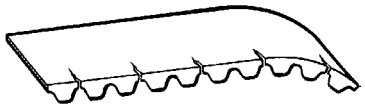
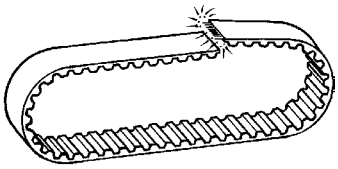
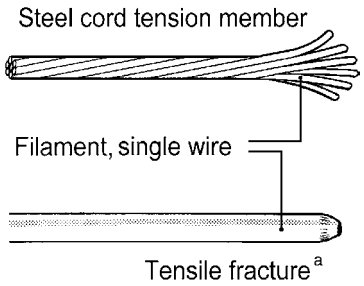
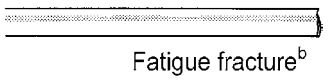
Fault type	• Possible causes ◦ Remedial measures
1. Tension members starting to break on one edge  Tension member failure starts on one side of the belt	• Through parallel offset, angular error, or pulley eccentricity giving uneven load distribution across the belt section (see Chapter 2.10). This results in excessive tensile forces in the outer tension members ◦ Check and correct installation and pulley alignment
2. Broken belts   	• Initial damage with partially broken tension members as described in fault type 1 • Initial damage due to bent or crimped belts • Tensile damage due to pulleys being too small. By repeated bending and/or contraflexure developing fatigue breaks • Damage to the tension member through wear and tear, see fault type 6 • Catastrophic tension member failure due to a single, over-design shock load when starting, emergency braking or by accident • Belt pre-tension too low leading to tooth-jump on the driven pulley where the tension member cannot absorb the tooth-jump force which is followed immediately by total failure due to tension member failure ◦ Component examined for early damage. Check the drive dimensioning. Check minimum bending and flex diameters and compare with recommended values ◦ A tension member failure is normally unpredictable. Investigate proper pre-tension as per Chapter 2.7 and check the belt installation in accordance with Chapter 2.17. Compensate for a possible reduced pre-tension ◦ Distinguish whether the broken steel tension members have been subject to either a tensile[a] or fatigue[b] fracture ◦ Glass-fibre tension members show a frayed (fibrillar) mode and Aramid tension members go frizzy

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Table 6.1 (continued)

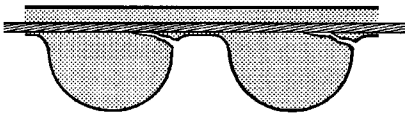
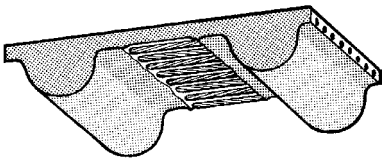
Fault type	• Possible causes ◦ Remedial measures
3. Cracks on the tooth base radius  Cracks are formed at the tooth base radius and continue along the boundary between the tension member and the elastomer body	• Pulley tooth-tip radius too small • Load carrying limit beyond belt tooth capability • Back tension idler is too small thus building high tensile stresses in the elastomer of the tooth base radius • Extremely low temperatures will reduce the resilience of the elastomer and increase the tendency of the elastomer to crack ◦ On a damaged belt cracking develops in the direction of rotation. Thus it can be determined which of the paired pulley flanks takes the main load and therefore where belt damage can be expected ◦ Replace pulleys where the tooth tip radius is incorrect ◦ Increase pulley sizes in drives with contraflexure ◦ Check drive design in respect to tooth shear strength For borderline cases change to a wider belt ◦ Use an elastomer specifically produced for low temperature applications
4. Individual belt tooth or tooth group shear  The shear line of tooth and belt carcass is formed along the boundary between the tension member and the elastomer carcass	• Initial damage includes damage as described in fault type 3 • Initial damage, as per fault type 3, has continued up to the loss of individual or multiple teeth • Individual teeth or multiple teeth torn off due to overload ◦ Make the same assessments and apply the same measures as described in fault type 3 ◦ If teeth are shearing due to overload first check the drive layout and where appropriate increase number of pulley teeth

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Table 6.1 (continued)

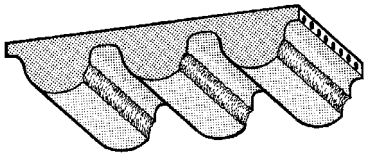
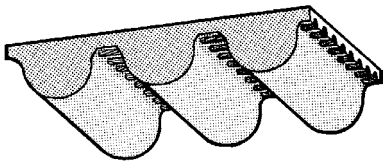
Fault type	• Possible causes ◦ Remedial measures
5. Wear on the belt tooth flanks  When flanks of a belt with polyamide tooth facing are abraded the material generates fluff and pellet formation however on a purely elastomer belt the tooth material is abraded away. Polyurethane belts will also show defects on the tooth flanks. Damage occurs over the entire length of the belt. For drives with a single direction of rotation material loss takes place on a single flank and on both flanks with a bi-directional drive	• Different pitching between the timing belt and the timing pulley caused by (a) Pre-tension too low (b) Pre-tension too high (c) Pulley outside diameter too large (d) Pulley outside diameter too small (e) Belt stretch • Pulley tooth tip radius too small (sharp edges) • Belt and pulley profiles do not match ◦ Flank wear and material loss can indicate a pitch difference between belt and pulleys. For a description see Chapter 2.7 (a) If wear is found on the working flank of the driven pulley then pre-tension is too low (b) If wear is found on the working flank of the driving pulley then pre-tension is too high ◦ Check drive dimensioning ◦ Measure the pulley outside diameter. Measure the belt pitch. Determine the pitch difference between the belt and pulleys ◦ Check the pulley tooth tip radius. Replace timing pulleys if necessary
6. Belt tooth base wear  The wear starts with visible fibres and fluff from the fabric tooth facing. It continues with loss of belt material and exposes the tension member. With the complete loss of fabric the tension members are abraded to destruction	• Tribological abrasive wear on the base line of the belt (in bottom of the tooth gap) where the belt tooth moves transversely across the pulley tooth gap, see Chapter 2.9. The pressure forces on the base line (the pulley outside diameter) results in friction and wear • Base wear is promoted by high frequency load changes such as in camshaft drives in automotive applications ◦ Use special toothforms with restricted backlash ◦ Use toothforms where the belt tooth rests in the pulley tooth gap (for example AT-series) ◦ Use belts with wear-resistant special fabrics on the toothed side of the belt

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Table 6.1 (continued)

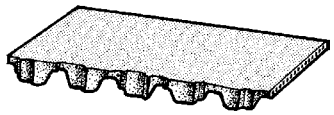
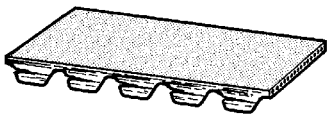
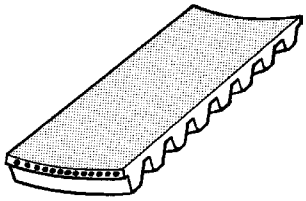
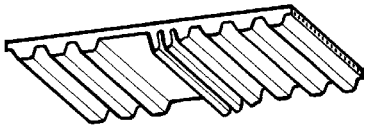
Fault type	• Possible causes ◦ Remedial measures
7. Edge wear   Belt edge vertically or longitudinally grooved	• Offset pulleys, angular errors or pulley run-out gives an uneven tensile load distribution in the tension members. The belt run-off force is the highest in the direction of the largest belt tension • The wider the belt and the shorter the span length the greater the belt run-off forces. The friction point is the contact surface of the flange • No flange lead-in, sharp edges ◦ The flanges should be supplied to the recommendations in Chapter 2.10. Correct build quality and pulley alignment problems. Check lead-in and edges on the flanges
8. Belt transverse bowing 	• Causes as in fault type 7 • Side forces cause a compression of the belt perpendicular to the direction of travel ◦ Remedial measures such as fault type 7
9. Deformed teeth  Displacement and deformation of individual teeth or groups of teeth on the tension members	• Bond between tension members and elastomer is insufficient. Lack of bonding agent or inappropriate application. Production process problems • The combined effect of high temperatures with high tooth flank stress can cause plastic deformation of individual teeth and tooth groups • The elastomer strength is reduced by aggressive media (oil, solvents, etc.). Flank forces may also cause deformities ◦ Quality of the adhesion agent to be checked by the manufacturer. Prevent high temperatures by changing environmental conditions. Use heat-resistant belt materials. Exclude contact with aggressive reagents ◦ Tension member embedment to be checked by the manufacturer and optimized where appropriate [118]. See description in Chapter 2.5

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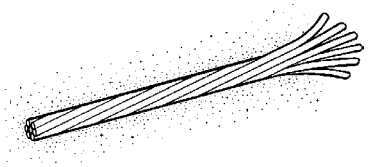
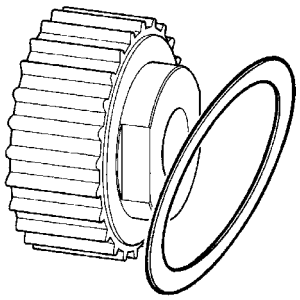
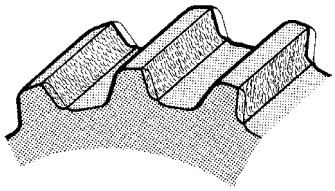
Table 6.1 (continued)

Fault type	• Possible causes ◦ Remedial measures
10. Corroded steel tension members  Red/brown colouring, visible rust build-up	• Long-term effects of aggressive environmental factors such as acids, detergents or seawater • Frictional corrosion formation (rare) due to high speeds in conjunction with small idler pulley diameters ◦ Use special stainless steel tension members ◦ Frictional corrosion: Tension member embedment to be checked by the manufacturer and optimized where appropriate [118]. See description in Chapter 2.5
11. Loose flanges, Wear on guide elements  Flanges damaged or loose	• Manufacturing variations in flange mounting. Improper attachment. Damage during handling, shipment or during installation • Drive alignment deviations can cause considerable side loads on the flanges • Protruding steel tension members can be abrasive on lateral guide elements ◦ Apply featured flange designs and mounting as in Chapter 2.10 ◦ Remove protruding tension members
12. Pulley tooth wear  Tooth material removal on the loaded flank	• Environments containing dust, scale and gritty substances work together with the rotating belt to erode the pulley teeth ◦ Cover the drive. Preferred materials for timing pulleys under abrasive conditions, if applicable, are PA, PE or POM plastics

[a] A *tensile fracture* is a failure in which a single, rapid and unidirectional stress, or peak load, which alone or together with a superimposed pre-tension exceeds the tensile strength of the tension member and brings about a complete material failure. Tension members at the fracture faces of the individual wires will exhibit typical necking

[b] A *permanent* or *stress fracture* occurs when the amplitude and the number of belt cycles lead to an overall load situation where the border area of statistical fatigue strength (according to *Wöhler*) is reached. A stress fracture includes time-dependent weakening in the form of either mechanical or chemical assaults which act by removing material or cracking the wire surface. With increasing crack growth, the effective tension rises in the remaining cross-section, until the eventual fracture occurs. It fractures *without* necking. The material break is characterized by a visible primary crack and final fracture

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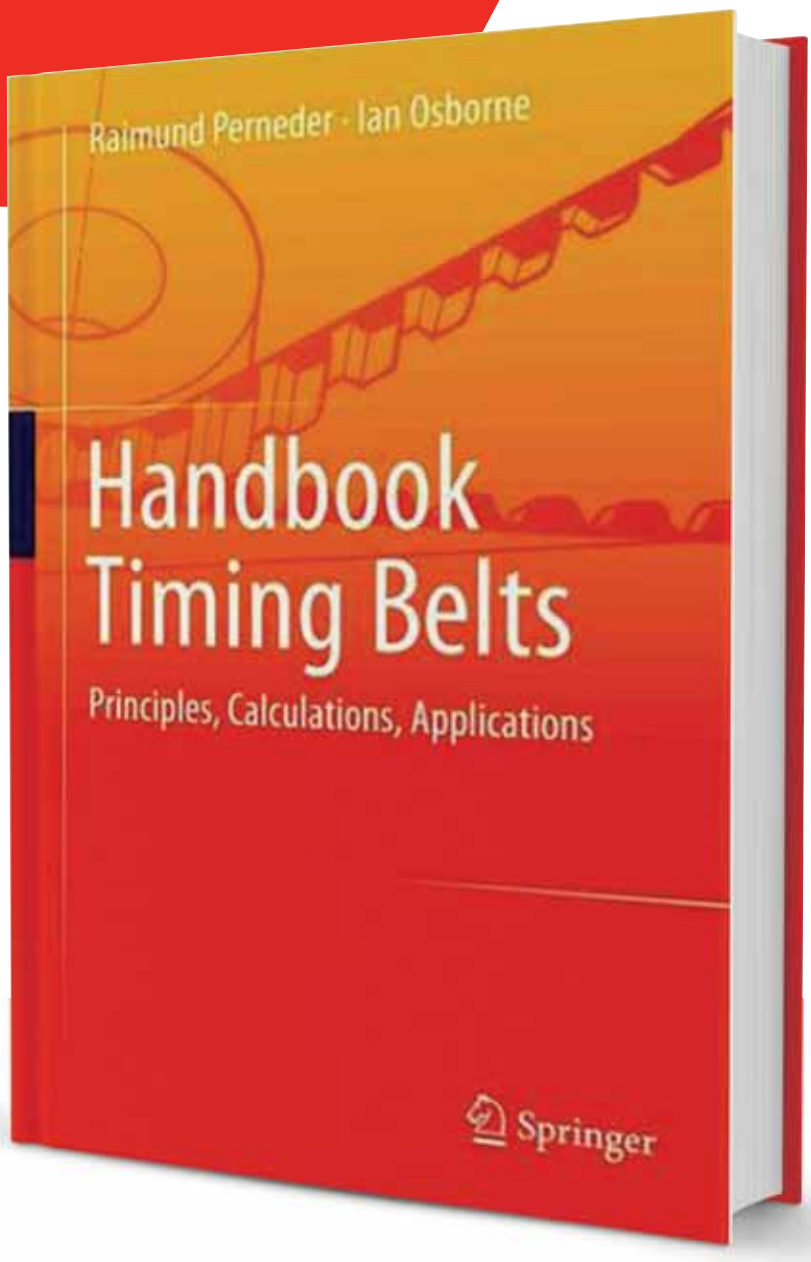
Handbook Timing Belts
Principles, Calculations, Applications

This publication, originally written and published in German by Raimund Perneder in 2009 has been translated into English with additional content contribution from its co-author Ian Osborne – Chairman of Transmission Developments Co (GB) Ltd.



Based on over 60 years of combined professional experience and with 269 pages and 237 illustrations, the hardcover book is a complete resource on all matters related to synchronous belt technology. Detailed chapters cover brand-neutral synchronous belt profile geometries and specifications, manufacturing process and materials; with application and sizing related chapters for drive systems, linear motion and product transport systems.

An extensive bibliography will guide readers to various manufacturers through their websites whilst further chapters deal with timing belt failure and drive design. Comprehensive subject index and glossary information sections are also included.

The book addresses both the needs of application engineers and system integrators working in design, development and machine-building, as well as providing comprehensive textbook material for students at universities and vocational schools.

'Handbook Timing Belts – Principles, Calculations, Applications' is published by Springer-Verlag Berlin and is available for purchase at £90.00. The www.springerlink.com website provides PDF reading of specific sections for evaluation purposes and links to the main site for purchasing. The book is also available for purchase from Amazon in both hardback and Kindle versions.

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Transmission Developments Co (GB) Ltd
Dawkins Rd, Poole, Dorset, BH15 4HF
T +44 (0)1202 675 555 F +44 (0)1202 677 466

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