Engineering Failure Analysis 67 (2016) 33–45

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Possibilities of failure analysis for steel cord conveyor belts using knowledge obtained from non-destructive testing of steel ropes

Gabriel Fedorko [a,*], Vieroslav Molnár [a], Želmíra Ferková [b], Pavel Peterka [a], Jozef Krešák [a], Marianna Tomašková [c]

[a] Technical University of Kosice, Letna 9, 042 00, Kosice, Slovak Republic
[b] Faculty of Electrical Engineering and Informatics, Technical University of Kosice, Letna 9, 042 00, Kosice, Slovak Republic
[c] Faculty of Mechanical Engineering, Technical University of Kosice, Letna 9, 042 00, Kosice, Slovak Republic

ARTICLE INFO

Article history:
Received 29 February 2016
Received in revised form 17 May 2016
Accepted 19 May 2016
Available online 20 May 2016

Keywords:
Failure analysis
Steel rope
Steel cord conveyor belt
Non-destructive testing

ABSTRACT

The steel cord conveyor belts are applied in many industrial branches. Current operation of the conveyor belts is closely connected with various kinds of mechanical loading, which causes wear or gradual degradation of the conveyor belts. One of the most often occurring failures in the steel cord conveyor belts is damage of the inner steel cord carcass of the belt. However, timely identification of this undesirable process is a problematic question. There is presented in this article an innovative approach concerning application possibility of the non-destructive testing tools, namely in the area of the steel cord conveyor belts. The realised experimental measurements, together with the performed simulation processes verified an important fact that the non-destructive testing methodology, which is used for the steel wire ropes routinely, can be applied for the steel cord conveyor belts, as well. The developed simulation models are in accordance satisfyingly with the real status, which is typical for standard operation of the steel cord conveyor belts. These simulation models can be applied during the next investigation activities performed in the given research area.

1. Introduction

Steel wire ropes are widely used in various kinds of industrial branches, such as mining, building and transportation. It is important to dispose of information concerning the rope operational conditions in order to provide replacement of the rope in time or to extend the safe working life of it when the retirement criteria have not been reached [1]. The wire ropes, which are employed extensively in the coal-mine hoists and in various transportation systems, are subjected to damage due to wear, corrosion and fatigue. The extent of damage and the carrying capacity of the steel wire ropes are closely related to the perception of safety concerning staff and equipment [2]. The steel wire ropes are commonly used in elevators, lifting machinery, passenger aerial ropeways and in other related fields. Fretting wear and the induced fatigue or fracture of the individual wires have been the major failure modes of the hoisting ropes [3]. The failures of the steel wire ropes are resulting mainly from rust and wear or from ruptures of steel wires [4].

The steel wire ropes are the relevant constructional parts of various transport machines and transport equipment, including the conveyor belts. The steel cord conveyor belt is a very important conveying element, which enables to perform continuous transportation of various bulk materials. Typical operational characteristics of the steel conveyor belts are as follows: the high-

* Corresponding author at: Technical University of Kosice, Faculty Letna 9, 042 00 Kosice, Slovak Republic.
E-mail address: gabriel.fedorko@tuke.sk (G. Fedorko).

http://dx.doi.org/10.1016/j.engfailanal.2016.05.026

level strength, operational reliability and long transport distances. But a fact that the steel ropes are situated inside the conveyor belt and are covered with rubber layer causes problems during identification of possible negative phenomena and degradation processes. From this reason it seems to be advisable to use the method of non-destructive testing (NDT), which is usually applied in the case of standard steel wire ropes, also in the area of the steel cord belts. However, this new application possibility of the NDT should be verified with regard to a suitability of it for testing of the steel cord belts.

There are several authors worldwide dealing with the NDT of the steel wire ropes very intensively [5]. The obtained results of their research are interesting and they promise a future perspective for a wide practical usage of the NDT diagnostics in the area of the steel wire ropes. The non-destructive testing and evaluating methods are being increasingly applied in order to monitor the wire ropes [6]. Wait [7] dealt with the basic concepts and techniques for testing of cylindrical conductors by both electric and magnetic methods. He dealt mainly with wire ropes used in mine hoists, but his results are also relevant for testing of support cables for ski lifts. There is an obvious need to perform tests of the integrity of transport ropes without in any way impairing of their function. Apart from a careful visual examination and measurement of the external diameter, the available non-destructive testing methods utilize the electromagnetic fields, X-rays or mechanical waves [8]. Moryia et al. [9] researched the magnetic non-destructive evaluation of corrosion in wire ropes. Peterka et al. [10] realised a non-destructive inspection of the new steel wire rope installed in the hoist system. Radovanovic et al. [11] resolved the signal acquisition and processing in the magnetic defectoscopy of the steel wire ropes. Implementation of the testing system should provide a complex monitoring of wire rope condition, according to the prescribed international standards. The measurement procedure enables a better understanding of the defects that can occur potentially, as well as the rejection criteria of used ropes and in this way to increase their security. Zhang et al. [3] demonstrated results that the fretting wear in depth of the steel wires increases with the cumulative fretting cycles and contact loads. The fatigue life of the steel wires with fretted damage was indirectly proportional to the wear depth; and then to the fretting cycles and contact loads. McColl et al. [12] examined an influence of low viscosity oils (with and without graphite additions) on the fretting behaviour of the wire. Oil bath lubrication suppresses effectively wear and friction during the tests. Wang et al. [13] dealt with the finite element analysis of a hoisting rope and three-layered strand for exploration of the fretting fatigue parameters and stress distributions in the rope cross-section. Guihong et al. [14] described the principles and method for detecting of localized magnetic flaws in the wire ropes by measuring of a leakage flux. Wavelet transformation and neural network are used for analysing and processing of the signals obtained from the broken wires in the steel rope in order to improve accuracy and sensitivity of the control device [15]. Liu et al. [16] researched the configuration of magnetostrictive transducers for both transmitter and receiver, whereas they were optimised for generation and reception of ultrasonic, longitudinally guided waves in seven-wire steel strands in a pitch catch arrangement. A new type of the wire rope non-destructive testing (NDT) performed by means of a special detection apparatus was presented by Chai et al. [17]. Cao et al. [6] resolved the non-destructive and quantitative evaluation of wire rope based on radial basis function of neural network using eddy current inspection. Casey et al. [18] applied the frequency analysis in the area of acoustic emission signals resulting from failures occurring in the steel wire ropes as well as in the individual wires taken from the ropes. Jomdecha and Prateepasen [19] presented a proposal and construction of a modified main-flux equipment for wire rope inspection, which has advantages concerning the in-service inspection and indirect axial-flux measurement used by ordinary main-flux and return-flux methods. This equipment can be adjusted by means of electromagnetic field, which is strong enough in order to produce a leakage flux caused by flaws in various large-diameter ropes. Raišutis et al. [20] investigated a propagation of the ultrasonic guided waves (UGW) along the multi-wire ropes with polymer cores and determined whether it is possible to detect defects and to identify a defective strand inside the internal structure of a multi-wire rope.

An interesting approach to the NDT defectoscopy offered Krešák et al. [21]. They combined the destructive and non-destructive measurements in order to detect disruptions of the ropes and chains. The performed experiments proved that on certain conditions is the application of thermovision just such method, which is suitable for detection of weak places in loaded ropes and chains. The steel wire ropes often deteriorate during their lifetime due to external or internal corrosion and abrasion, as well as due to dynamic mechanical stresses [6]. More authors investigated these influences using various methods and approaches. Yashiro et al. [22] developed a magnetic corrosion probe for non-destructive evaluation of concrete against corrosion of reinforcing bars. Liu et al. [23] developed the non-destructive evaluation technique, which is suitable for determination of location and severity of corrosion in embedded or encased steel bars and cables. Mietz and Fischer [24] investigated possibilities of flux measurement by means of two testing techniques based on magnetic leakage. Collini and Degasperi [25] presented and discussed the relevant experiences concerning the non-destructive method for detection of multiple cracks caused due to fretting fatigue inside the rope structure.

The main goal of this article is verification of the NDT application possibility in the area of steel cord conveyor belts. The steel-cord conveyor belts are widely used in the long-distance belt transport. However, application of the steel-cord conveyor belt is an expensive matter with regard to the investment costs and therefore these conveyor belts required an appropriate attention. There is a possibility to reuse or to recycle the worn-out steel-cord belts. [26,27]. High level of tensile stress in the belt often causes a damage of the steel-cord conveyor belt. [28]. There are applied various methods for identification of the tensile stress value, for example suitable experimental measurements [29] or using of computers simulation tools and modelling [30,31,32].

The performed experimental measurements of the steel wire ropes, together with their following verification using methods of the engineering failure analysis, established an initial base for a future investigation and practical applications. The principal purpose of the presented research work is a comparison of the proposed calculation model with the experimental measurements in order to create such simulation model, which will be helpful for investigation of possible damage or defects occurring in carcass of the steel cord conveyor belt and for verification of usability of the NDT-method with regard to possible identification of the above-mentioned kind of damaging processes in the steel cord conveyor belts.