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Classification of Impact Damage on A Rubber-Textile Conveyor Belt: A Review

A conveyor belt is one type of goods transportation in technological processes, particularly in the mining industry. The belt is the important material and principal part of the conveyor belt. The overall quality of the conveyor belt as its service life and impact loads are very important factors. Therefore, the purpose of this paper is to classify the types of impact damage that may occur in rubbertextile conveyor belts. In many works, many types of conveyor belts are tested at various levels and the type of impacting material. The level of damage occurred is investigated by using probability theory. Particularly, the evaluation of experimental test data and predictive modeling is carried out using the Naïve Bayes classification.

Keywords: Conveyor; belt; impact; damage.

1. INTRODUCTION

In the mining industry, the conveyor belt is among the most frequently used conveying systems for coal transport. (Figure 1). The conveyor belt has efficiency speed, long transport distances, low energy consumption, operating safety and simple operations and maintenance [1,2]. The belt is particularly used for conveying the coal from the extraction site to the site of its consumption as well as further processing or storage. Conveyor belts are made from a great number of components. The properties components which significantly impact and effective operation.



Figure 1: Exemplary use of a rubber-textile conveyor belt in mining industry [1]

The important material properties and technological parameters of a conveyor belt are contact forces and dynamic resistance. They play a very important role in construction and operation [3]. Conveyor belt construction is the awareness of the impact factors. The design of driving, angle pulley are a suitable type of conveyor belt. Conveyor belt which translates directly into operating costs and lifetime of the conveyor belt, i.e. aspects to be weighed in when deciding on the conveyor belt replacement. For the stated reason, the new knowledge in this field can bring significant economic profits to the operator of this kind of raw material continuous transport system [4-6]. Indian Standards IS 4776 gives 2 specifications for through belt conveyors. Those are through belt conveyors for surface installation and through belt conveyors for underground installation. First, covers the requirements for troughed belt conveyors using rubber and canvas belts conforming to IS: 1891 'Specification for rubber conveyor and elevator belting' for handling loose bulk materials within the range of belt widths from 300 mm to 2000 mm.

Types of conveyor belt are used requirements in the standard which relate to belt tensions and take up allowances may not be applicable. Second, covers the requirement for sectional type electrically driven through belt conveyors commonly used underground in coal mines, metal mines and non-metallic mines for handling loose bulk materials using fire resistance conveyor belting, conforming to IS 3181 'Specification for resistant of fire conveyor belting for underground use in coal mines', within the belt width from 500 to 1600 mm. The belt is the most important element of a belt conveyor installation.

The conveyor belt primarily consists of the top cover, carcass, and bottom cover (**Figure 2**). The belt is a costly item in a conveyor. Therefore, the conveyor belt must be very carefully selected. The material of the conveyor.non-carrying the face of the conveyor is also called a pulley surface or the running side. It should be capable of fulfilling the tasks e.g transport the load, absorb the impact energy at the loading point., withstands temperature and chemical effects (heat, oil, acidity, etc.) and meets safety requirements (flame resistant, antistatic, etc) [7]. As the conveyor belt is in extensive contact with the transported material, i.e. CoA in this case, the conveyor belt wear is due to impact, abrasion, etc.





2. AVAILABLE TECHNOLOGY

Conveyors belt has a tension component consisting of synthetic fabrics or steel cables with rubber or synthetic covers [8]. The belts are supported by straight or through shaped idlers or have sliding support on a smooth base as a tension and support member. The actual of the conveying is done on the top run, in special cases on the top run and the return run. Belts with cleated top covers, special-purpose belts or sandwich belts are used for steep-angle conveying. The most important part of the belt is rubber textiles. **Figure 3** shows the 17 components of the conveyor belt.

Rubber-textile conveyor belt offers a wide range of applications across all industries. It is used in the transportation of bulk and piece materials in various operating conditions. The carcasses are consists of several textile plies coated with the layer of a special rubber mixture providing the adhesive properties between the plies. It consists of polyamide fibers P or polyester fibers E. Polyamide (P) is a fully synthetic fiber resistant to humidity and chemicals. Polyester (E) is a fully synthetic fiber with high strength and good tensile properties and has a high resistance to acids, bases, and humidity. The carcass of a conveyor belt consists of polyester fibers in the warp and polyamide fibers in the transversal direction (in the weft, EP).



Figure 3: Component of conveyor belts [7]

- 1. Feed
- 2. Discharge
- 3. Head pulley (drive pulley)
- 4. Snub or deflecting pulley
- 5. Tail pulley (take-up pulley)
- 6. Top run (tight side)
- 7. Return run (slack side)
- 8. Top run idlers
- 9. Return run idlers
- 10. Feed rollers
- 11. Flat-to-through transition
- 12. Through-to-flat transition
- 13. Feed chute
- 14. Belt cleaner (transverse scraper)
- 15. Belt cleaner (plough-type scraper)
- 16. Drive unit
- 17. Counterweight



Rubber-textile conveyor belt.







Complete damage to the top cover layer



Puncture

Undamaged conveyor belt

Crack on the top cover layer Figure 4: Some examples of the caused damaged [7]

The conveyor belt has the carcass equipped with breakers to increase their puncture resistance [9]. fiber is a unit of matter having a length at least 100 times and the diameter and which can be spun into a yarn. Carcass located under top cover layers facilitates the contact between the belt and the transported material or between the conveyor rollers and drums [10]. Rubber protects the carcass against the mechanical damage which in many cases is caused by the transported material. Humidity, chemical and thermal effects also affect the service life of the conveyor belt. The rubber thickness depends on the properties of the transported material. Filament fibers refer to fibers of long continuous lengths, while staple fibers refer to those of shorter lengths, which are about a few inches (3/4" to 2 1/2") long.

Most natural fibers, such as cotton and wool, staple fibers [11]. The synthetic fibers, such as nylon and polyester, are considered filament fibers. Natural fiber silk is also a filament fiber when filament fibers are cut short, it considered staple fibers. A generic term for a strand of textile fiber, filament material in a suitable for knitting, weaving, or otherwise intertwining to form a textile fabric it called yarn. Yarns made fro, staple fibers are called spun varns. Whereas varns made from continuous filament fibers are called filament varns. However, the varn processing methods for spun varns are very different from those of filament varns. The filament varns stronger than the same-size spun yarns of the same synthetic material. The textile fabric belts are the most commonly used belts for conveyors and elevators.

Belts have carcass made of textile fabric [12]. The carcass is composed of a special ply or more number of plies. The ply is the fabric (fabric body) which is designed to take loads. The ply is formed by weaving (usually at right angles) of warp yarns (threads), which run lengthwise, and weft (filling) yarns, which run crosswise. The tensile strength of warps is more because the same is required to withstand the main tension occurring in the belt. The manufacture of textile fabric requires the use of an apparatus called a loom or weaving machine. This mechanical device weaves the fabric by interlacing a series of parallel yarns in the longitudinal (or warp) direction with a series of parallel yarns in the transverse (or weft/filling) direction [13]. Warp yarns are delivered to the loom in the form of a "sheet." The weft yarns, on the other hand, are normally delivered one at a time, either by a "shuttle" (as was typical of earlier loom designs) or by a yarn gripping device called a "rapier" (as with the more modern looms available today).

Briefly, the loom provides the means to interlace the warp and weft yarns, bringing them together at the designed frequency and style, required in the woven fabric. After weaving, for most rubber-based belting (Natural, SBR, NBR, CR, EPDM, etc.), the textile fabric is dip-treated with Resorcinol-Formaldehyde-Latex (RFL) coating to provide adequate adhesion with rubber compounds. For the thermoplastic type belt, the treatment can involve acrylics, polyurethane, PVC or other treatment for the respective textile reinforcements. The yarns of required size and strength are used to make a ply. It appears similar to cloth/mat but is very strong, tough and flexible to suit tension rating of carcass/belt. The textile fabric carcass is made from cotton, cellulose (viscose), ravon (viscose), nylon (polyamide), polyester, fiberglass, and aramid. Fabric strengths have size ranged from 63 N/mm up to and including 630 N/mm are generally available. The standardized strength sequence is: 63, 80, 100, 125, 160, 200, 250, 315, 400, 500 and 630 N/mm [13]. The textile fabric carcass has properties of textile yarns. Properties of common textile yarns (for carcass) in Table 1.

TYPE OF YARN	COTTON	CELLULOSE STAPLE FIBRE	SUPER STRONG RAYON	POLYAMID E (NYLON)	POLYESTER
Breaking length* (km)	12 to 15	22	51 to 54	80 to 81	75
Elongation at break (%)	12	19 to 20	11.5 to 12	17 to 18	12 to 13
Change of tensile strength due	+8	-20 to -25	-20 to -25	-10	0
to moisture					
Density (g/cm ³)	1.50 to 1.54	1.50 to 1.52	1.50 to 1.52	1.14	1.38

 Table 1: Properties of common textile yarns [7]

*Vertically freely suspended self-supporting length, under gravity.

International nomenclature for various carcass materials is as under. Cotton - B (C is also used in India) Viscose - Z (In DIN standard, R is used for Rayon), Polyamide (Nylon) - P (N is also used in India) same with Polyester-E, Aramid-D, Steel-St is a carcass material made with a combination of above materials also. Cotton fabric (warp cotton, weft cotton): Cotton nylon (warp cotton, weft nylon):

- Cellulose fabric (warp cellulose, weft cellulose)
- Rayon nylon (warp rayon, weft nylon)
- Nylon (warp polyamide, weft polyamide). Polyamide is commonly called as nylon.
- Polyester (warp polyester, weft polyester)
- Polyester polyamide (warp polyester, weft polyamide i.e. nylon)

In polyester polyamide (EP) belts, the low-elongation polyester fibers are used in the warp (lengthwise yarns) [14]. Polyester polyamide is more elastic polyamide (nylon) fibers are used in the weft (crosswise yarns). It combines both textiles properties, offering high strength but a low stretch of conveyor belt with excellent impact resistance. Textiles can also improve the ability to bond fibers in conveyor belts [15]. In textile fabric belts, carcass composed of single special ply (mono-ply) is used as it has special advantages, e.g. some of the fabric belts have the superior ability for metal fasteners. However, the tensile strength range is less for such belts compared to multi-ply belts [16].



Figure 5: Textile fabric multi-ply conventional belts [7]

A belt with two or more plies (layers of fabric) is called a multi-ply (poly-ply) belt [17]. Textile fabric multi-ply conventional belts are extensively used for general conveying applications. A typical multi-ply carcass can consist of between two to six plies in the required tensile strength. For elevator belting, three to six plies may be necessary due to the risk of tearing at the bucket holding bolts [7]. **Figure 5** is a textile fabric multi-ply conventional (without constructional feature) belt. In this type of belts, the plies are overlaid and combined to form the carcass of required strength. Step splice method is applicable for splicing (jointing) of multiply belts with more than two plies.

3. FUTURE OPPORTUNITIES

Classification is the most frequent problem in the field of machine learning [17]. The purpose of classification is to identify the class to which we can assign a new observation, based on a training set of observations. Classification is the basic task within damage detection. The present article deals with the analysis and classification of the belt conveyor damage caused by the impact of the material falling onto a conveyor belt. The damage classification will be carried out using the Naïve Bayes Classifier.

The Naïve Bayes Classifier is a useful tool that is used for various monitoring and prediction purposes. The use of the Naïve Bayes Classifier for the monitoring of tool conditions is described in [18]. In this paper, the tool wear level was predicted using the Naïve Bayes Classifier method. On the basis of the Naïve Bayes Classifier, Fan et al. [19] proposed a procedure for the evaluation of the wear of a pair of piston ring-cylinder liners. The Naïve Bayes Classifier was then used to process the OLVF (On-Line Visual Ferrograph) monitoring data [18]. Kumar [20] also examined the wear of bearings by using the Naïve Bayes Classifier to classify them. The Naïve Bayes Classifier and the Bayesian Network Algorithm were also used in the monitoring and the vibration-based fault diagnosis of a monoblock centrifugal pump [21]. Feng used the Naïve Bayes Classifier for the prediction of slope stability [22]. Applications of the Naïve Bayes Classifier method have also been documented in the field of medicine [23]. The Naive Bayes classification algorithm assigns a class to an element of a set which is most probable according to Bayes' theorem [24]. Let A and B be probabilistic events. P(A) the probability of A being true. P(A|B) the conditional probability of A being true given B is true (eq. 1).

$$P(A|B) = (P(B|A) * P(A))/P(B)$$

(1)

(2)

P(A) is the prior probability of A being true without the knowledge of the probability of P(B) and P(B|A). P(A|B) is the posterior probability of A being true, taking into consideration additional knowledge about the probability of B being true. The theorem using elementary set theory on the probability spaces of the events A and B. This is a probability event will be defined as the set of the possible outcomes in the probability space. From Fig. 6 we can state the correlations between A and B (eq. 2):

$$P(A|B) = P(A \cap B)/P(B)$$
$$P(B|A) = P(A \cap B)/P(A)$$



Figure 6: Probability space for the two events [18]

The algorithm of Naïve Bayes works on the basis of Bayes rule that assumes the all attribute X1, ..., Xn is conditionally independent of each other, for a given Y [25,26]. This assumed value dramatically simplifies the representation of P(X / Y), and difficulty in its estimation form training data. Example, a case where X = (X1, X2) (eq. 3).

$$P(XY) = P(X_1, X_2 | Y)$$

$$P(XY) = P(X_1 | X_2, Y) P(X_2 | Y)$$

$$P(XY) = P(X_1 | Y) P(X_2 | Y)$$
(3)

Generally, when X contains n attributes and they are conditionally independent of each other for a given Y, then, (eq. 4).

$$P(X_1 \dots X_n | Y) = \prod_{i=1}^n P(X_i | Y)$$
⁽⁴⁾

There is a need for only 2nd parameters to define P(Xi = xik | Y = yj) or necessary i, j and k when Y and Xi are Boolean variables. This is a reduction when this is compared to 2(2n - 1) parameters where there is absolutely no conditional independence assumption. This algorithm is derived after making the assumption that Y is a variable with a discrete value and X1 ... Xn is attributed to real and discrete values. The main objective is to train the classifier. The mathematical expression for the computation of the probability of Y will take its kth value, according to Bayes rule (eq. 5).

$$P(Y = y_k | X_1 \dots X_n) = \frac{P(Y = y_k) P(X_1 \dots X_n | Y = y_k)}{\sum_j P(Y = y_j) P(X_1 \dots X_n | Y = y_j)}$$
(5)

Here the sum is all possible values of yj of Y. if we assume that are conditionally independent for a given Y, the modified equation will be as described in (eq. 6).

$$P(Y = y_k | X_1 \dots X_n) = \frac{P(Y = y_k) \prod_i P(X_1 \dots X_n | Y = y_k)}{\sum_j P(Y = y_j) \prod_i P(X_i | Y = y_j)}$$
(6)

This fundamental equation represents the NB classifier and it also gives a new instance Xnew = (X1 ... Xn). This equation shows how to calculate the probability that Y will take on any given value if the observer attribute value of Xnew and from training data distributions P(Y) and P(Xi | Y) are estimated. The most probable value of Y according to the NB classification rule follows (eq. 7).

$$Y \leftarrow \operatorname*{arg\,max}_{y_k} \frac{P(Y = y_k) \prod_i P(X_i | Y = y_k)}{\sum_j P(Y = y_j) \prod_i P(X_i | Y = y_j)}$$
(7)

Which further get simplified to the following as the denominator in the above does not depends upon yk (eq. 8)

$$Y \leftarrow \arg\max_{y_k} P(Y = y_k) \prod_i P(X_i | Y = y_k)$$
⁽⁸⁾

During its operation, the belt conveyor is subjected to various loads that can induce wear and damage to the conveyor belt, which thus reduces its service life. The service life of a conveyor belt is a very important feature for its practical use, as it is a decisive parameter for the cost-effectiveness and efficiency of the belt. It is affected by a number of factors, i.e. the belt conveyor structure, structural parameters and properties of the conveyor belt, types of transported materials, chute design, conveyor belt repairs and surface maintenance, maintenance of the rotating parts of the conveyor belt (drums, rollers), etc. The type of falling materials, and the drop height as the factors affecting the occurrence of damage.

The experiment damage occurred at the position of the chutes where the transported material fell onto the conveyor belt from various heights. The impact heights were determined by the chute heights. This type of impact will simulate a free-falling material. The intended purpose of testing the samples of conveyor belts is to provide end-users with the relevant information on the potential damage to the belt. The users may subsequently apply the results of the testing when determining the acceptable heights of the chutes and adjust the weight of the falling material, while using the crushers, to avoid the foreseeable damage to the conveyor belt. That might lead to the belt destruction and the subsequent replacement of the belt.

4. CONCLUSION

This paper introduces the classification of rubber textile damage to the conveyor belt. The classification of rubber textile damage in the conveyor belt is very useful in the industrial world. The classification method used is the Naive Bayes method. This method is inexpensive. The formulation theory and its application are quite easy. Manufacturing industries that use this method are those that have the aim to categorize things such as engine failure. This method used to give decisions determining the time to repair the machine. In this paper can categorize the damage to the material moving used conveyor belt. The advantage of using the Naive Bayes classifier method is the production department. This facilitates the engine maintenance team in predicting and anticipating damage to the belt. The production process will not be hampered due to the handling of undetected belt damage. Another advantage is that it can streamline production time and costs as well as maintenance costs.

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