Evaluation of Internal Defects in Fabric Belt Joints using NDT Techniques

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Abstract

Fabric conveyor belts (consisting of multilayered rubber and fabric material) are widely used in steel industries for bulk handling of raw materials like coal, coke, iron ore etc., and they need to be highly reliable. It is impossible to make the conveyor belt systems for transporting the raw materials without having any joints. These joints are done by either cold or hot vulcanisation process. During this process, there are chances of formation of air pockets/delamination in the joint of the conveyor belt. This defect is mainly due to improper vulcanising pressure or curing temperatures during the joining process. If the joints contain air pockets / delamination, it will fail during its use at harsh condition in the plant. Failure of joints in conveyor system can lead to increase the downtime of the plant as well as the maintenance costs.

The present work was intended to identify and establish a suitable non-destructive technique for finding out the air pockets or delamination inside the conveyor belt joints. Various non-destructive testing (NDT) techniques were probed for assessing belt joint quality in order to identify the most sensitive and feasible technique. Digital X-ray, capacitive and air coupled ultrasonic techniques were deployed for assessing the joint quality. Among these NDT techniques, it is established that the air coupled ultrasonic technique is capable of finding out the air pockets in fabric belt joints. The smallest size of the delamination can be detected by air coupled ultrasonic technique is 30 x 30 mm². This paper presents different NDT techniques, methodologies and the results of different techniques to evaluate fabric belt joint defects.

1. Introduction

Conveyor belt systems form an integral part of almost every bulk material handling operation in any industry. Fabric reinforced conveyor belting system is commonly used in steel industries to convey materials such as coal, coke, iron ores, sintered products etc. It is basically a composite material with two distinctly different materials composed orthogonally to achieve both strength in one direction and bending flexibility in the other direction. A number of fabric ply-layers are used in the belt construction [1]. These layers are bonded to the inter-rubber layers and to the covers by a vulcanising process. The fabric material is made up of either polyamide fibers commonly referred to as nylon [2] or polyester. Because of its composite nature conveyor belts are challenging material for testing non-destructively. Fig.1 shows the cross sectional view of the conveyor belt. Splicing is one of the main activities during belt installation at site. It is the method of joining the two conveyor fabric belt ends together to form one continuous belt which is capable of carrying the raw materials [3]. Vulcanisation is one of the methods of splicing fabric conveyor belts. It can be done either in hot or cold process depending on the application and type of the conveyor belt. In any conveyor system, the joint portion is the weakest area in the belt. Failure of joints or splices in conveyor system can lead to increase in plant downtime as well as maintenance costs. Air pockets or delamination is one such severe defect which occurs at joints during the vulcanisation
process. This defect is due to contaminated material used in splicing or poor vulcanising pressure or curing temperature. Detection of air pockets or delamination by non-destructive way has not been established well so that the defective joints can be avoided from being put in services. The present work aims to find out and establish a suitable non-destructive technique for finding out air pockets or delamination inside the conveyor belt joints. Advantages and disadvantages of various techniques like capacitive technique, digital radiography and air coupled ultrasonic testing have also been discussed elaborately in this work.

![Diagram of conveyor belt joint](image)

**Fig. 1** Cross sectional view of the step splice in plied belting

2. Literature Survey

Failure of conveyor belt system finds its roots from many causes like poor joints, weak places in parent belt, belt mis-tracking, idler or pulley wear etc. Poor joint quality is the most frequent cause for conveyor system failure. Premature joint failure is a serious problem for any conveyor installation and avoiding such joint failures are the inevitable need of industries. Based on literature survey, it is found that capacitive, X-ray radiography and ultrasonic techniques are the techniques likely to be suitable for monitoring the condition of fabric belt.

The capacitive sensor is an active device which generates a high frequency electric field. Capacitive sensor technique of co-planar approach contains two metal plates kept separately at certain distance on the samples. When an AC voltage is applied between the plates, it generates an electric field distribution within the test material. This electric field distribution is affected due to property change in the sample such as the presence of a defect within the volume covered by the electric field [4].

X-ray radiography technique yields good results in defect detection where the defects produce significant density difference from the background. The other technique i.e. ultrasonic testing technique compromises sensitivity for the sake of achieving adequate penetration in belt sample[5].

An air-coupled ultrasonic source and receiver are coaxially aligned and placed in the two sides of the conveyor belt in normal incident through transmission configuration with air as the coupling medium.
Ultrasonic source introduces longitudinal waves in one side of the sample, travels across the thickness and it is received by the receiver in the other side of the sample. A small fraction of the incident energy is transmitted into the sample where it propagates through the material and interacts with any boundaries and defects[6].

3. Experimental Setup of Different Techniques

3.1 Digital X-ray technique

Ultra heat resistant conveyor belt specimen was considered for this technique. Three specimens were collected from the new conveyor belt. The size of each specimen was 150 mm x 150 mm x 16 mm. Initially the specimens were cut into two equal pieces in thickness direction. Flat bottom holes were made for different sizes (ø3 mm, ø5 mm, ø8 mm and ø10 mm) in one-half portion of the conveyor belt specimen. This portion was joined with another half portion by cold vulcanisation process. Two more belt samples were collected from plants as shown in Fig. 2.

Balteau NDT Digital X-ray equipment was used for taking the radiographic image of the prepared samples. All the five samples were kept between x-ray source (130 KV) and flat panel detector for imaging one by one. Detected data was acquired by the data acquisition and digital image processing unit and in turn the output of the processed image is read in display unit or monitor. An actual digital radiography setup is shown in Fig. 3. The quality of the sample is interpreted based on the radiographic image.

Fig. 2 Photographic image of plant samples

Fig. 3 Digital Radiography Testing Setup for Conveyor Belt Sample
3.2 Capacitive technique

This technique works on measuring the change in capacitance of dielectric medium like rubber due to the presence of defects in them. Microepsilon capaNCDT 6100 was used to measure the variation in the belt joint quality. Fig. 4 shows the complete set up of parallel plate capacitance sensor method for conveyor belt quality evaluation. Conveyor belt is kept between the capacitive sensor and metal target in such a way that it work as a parallel plate capacitor.

![Capacitive method for conveyor belt defect evaluation](image)

Capa- NCDT instrument was integrated with computer to read out its output. Capacitance probe was held by stand to maintain constant distance between probe and top surface of the belt and the conveyor belt was placed on metal sheet, which is one of the target plates where the probe will act as the other target plate. After setting the instrument, sensor reading for the sound portion was compared with the defective portion.

3.3 Air coupled ultrasonic technique

Ultra heat resistant conveyor belt samples were torn off at middle to produce artificial delamination. They were then joined by applying gum only in preferred area to produce desired sizes of disbond in the samples. The size of the each sample was 150 x 150 square mm. Delamination sizes of each sample is listed in Table 1.

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Delamination Size in mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>130 x 130</td>
</tr>
<tr>
<td>2</td>
<td>110 x 110</td>
</tr>
<tr>
<td>3</td>
<td>90 x 90</td>
</tr>
<tr>
<td>4</td>
<td>70 x 70</td>
</tr>
<tr>
<td>5</td>
<td>50 x 50</td>
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<tr>
<td>6</td>
<td>30 x 30</td>
</tr>
<tr>
<td>7</td>
<td>10 x 10</td>
</tr>
<tr>
<td>8</td>
<td>No delamination</td>
</tr>
</tbody>
</table>

The air coupled ultrasonic system employed for delamination detection consists Ritec RPR 4000 Pulser-Receiver system and 200 KHz, 150 mm focused air coupled transducer. Through
transmission mode was chosen, because of the large attenuation of ultrasonic signal in conveyor belt. Fig. 5, shows the actual air coupled ultrasonic testing setup. During testing the sample was held by fixture between transmitter and receiver. Transmitter-receiver set up was positioned identically and it was moved for complete scanning of the sample with indexing of 0.3 mm and the C scan system recorded the images for interpretation.

![Image of experimental setup](image)

**Fig. 5** Experimental Setup of Air Coupled Ultrasonic Testing Technique

4. Results and Discussions

Results of artificial samples and plants samples are presented in Fig. 6 & 7 respectively. In artificial sample results of all the flat bottom holes were seen with high contrast which indicates that holes like defects can be readily detected by digital radiography in conveyor belts.

![Image of artificial samples](image)

**Fig. 6** Results of Digital Radiography for Artificial Samples

On plant samples, the cut marks in sinter plant samples were seen but, delamination in Blast Furnace samples was not detected because X-rays were travelling in perpendicular direction of delamination which could not cause any density variation. Radiography falls short in detecting delamination and air pockets in conveyor belts.
In capacitive technique, the experimental results failed to distinguish the defective portion from sound portion. The reason for this was presence of carbon block with rubber in the conveyor belt samples in order to increase the strength. Fig. 8 depicts the relationship between conductivity and the volume fraction of the carbon black in the conveyor belts. The graph clearly shows the drastic increase in conductivity after a particular carbon black weight fraction called as percolation threshold. The value of percolation threshold is 0.06 weight fraction, but in conveyor belt carbon black weight fraction is 0.12 [7]. So conveyor belt dispersed with carbon black is not allowing the material to behave as dielectric medium and that is the sole reason why capacitive technique could not detect the defects in conveyor belt samples.

![Fig. 7 Digital radiography results of sinter plant and blast furnace samples](image)

**Fig. 8** Conductivity Vs. volume fraction of carbon black

All eight samples prepared as mentioned in experimental part were tested by air coupled ultrasonic testing system. Delaminated portion allows less energy of ultrasonic waves through them and this tendency of delamination is the key principle deployed for detecting the defects from the good region. The test results are presented in Fig.9. The delaminated portions in yellow colour denote less energy and the red region is the portion adhered tightly.
In C scan result of sample 1, the delamination indication size is $121 \times 121 \text{ mm}^2$, whereas the original size of delamination is $130 \times 130 \text{ mm}^2$. In the same way, delamination size of other samples observed from the result was little different from the original size, as listed in Table 2. C scan result of sample 8, was uniform color which indicates no delamination in the sample.

Table 2 Delamination Sizes observed through testing

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Delamination Size in mm$^2$</th>
<th>Actual</th>
<th>Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>130 x 130</td>
<td>121 x 121</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>110 x 110</td>
<td>110 x 110</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>90 x 90</td>
<td>95 x 95</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>70 x 70</td>
<td>77 x 77</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>50 x 50</td>
<td>64 x 64</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>30 x 30</td>
<td>30 x 26</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>10 x 10</td>
<td>Not detected</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>No delamination</td>
<td>No delamination</td>
</tr>
</tbody>
</table>

The observed deviation from the original size of the delamination might be because of two reasons: one is edge effect of the probe which depends on the size of the probe and it leads to greater size than original. The second possibility is from sample preparation, since the samples were pressed after applying gum, it must have squeezed into the area where it was not intended to join, but this effect will not cause considerable changes in making bigger delamination size. Indication size is approximately equal to the original delamination size and the results significantly distinguished the delaminated portion from good portions.
5. Conclusions

Digital radiography found to be effective for detecting defects like cracks and porosity in the fabric belt samples. But it is not an efficient technique to detect delamination/air pockets.

Higher amount of carbon black added in the belt causes rubber behave as a conductor and the same reason makes capacitive technique not suitable for conveyor belt inspection.

Air coupled ultrasonic testing technique was found to be very sensitive technique for detecting defects in conveyor belts as discussed in results and discussion. Smallest delamination detected was 30 x 30 mm\(^2\). Air coupled ultrasonic testing can therefore be deployed for testing conveyor belts to detect delamination at the joint portion.

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References