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AUTOMATABLE SPLICING METHOD FOR STEEL CORD CONVEYOR BELTS – FINDING A SUITABLE PREPARATION PROCESS

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Abstract

The increasing demand of raw materials leads to longer conveyor belt systems with higher mass flows all over the world. Due to logistic reasons, conveyor belts are produced in segments to guarantee manageability. The different segments are spliced at the conveyor system to form an endless belt, which can amount up to multiple kilometres. This process shows a high level of optimization potential since currently the different work steps are performed manually. An automation of this process can minimize the downtime of the conveyor system and improve the splice quality.

In this study, a suitable preparation process is evaluated to automate the stripping process, where the rubber has to be removed from the steel cords. Therefore, the application of water jetting and laser processing is investigated.

INTRODUCTION

The most important component of a conveyor belt system is the belt itself, regarding design and investment costs. The shipping of a belt is limited by weight and dimensions. Therefore, conveyor belts are produced segmentally. The splicing is performed directly at the conveyor system. In the splice, the force transmission takes

place via the skim rubber instead of the tension member, due to splice layout. This leads to the fact that splices are the weakest points of a conveyor belt. The tension member of a conveyor belt can be made of textile fabric or steel cords. Steel cord belts are used for high tensile strength and can reach a nominal belt strength up to 10.000 N/mm. [1] The general setup of a steel cord conveyor belt is shown in figure 1. The carcass of the belt consist of steel cords embedded in rubber. The cords are produced with a right and a left twist and are arranged alternately to each other. This prevents adjacent cords from carving out. The steel cords are galvanised. The resulting zinc coat has two additional effects, besides protecting the steel cord from corrosion. It functions as vulcanization accelerator and leads to better adhesion, because of the potential to create a zinc sulfide layer during vulcanization process between rubber and steel cords. Thus, the zinc coat is an active part of the adhesion forming. The driving force is transferred via the bottom cover into the belt and the top cover protects the carcass from impacts of bulk material. [2, 3]

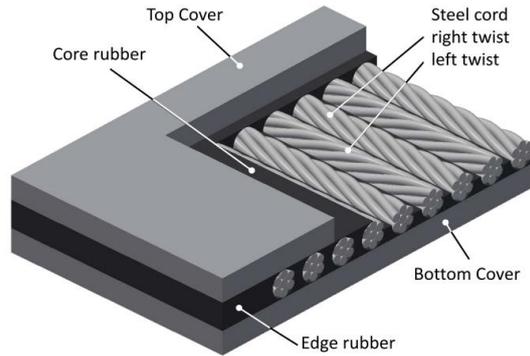


Figure 1: Steel cord conveyor belt [4]

Current research to improve splicing is focused on design optimization using FEA [5,6], where the adhesion mechanism is neglected. In the upcoming research about the automation capability of the splicing process for steel cord conveyor belts, the adhesion will be one main part. It is the key point to achieve a higher splice quality. Another criterion is the time needed for the preparation process. Thus, a suitable processing procedure must fulfil time and quality requirements.

1. Splicing process of steel cord conveyor belts

To show the potential of automation for the preparation of the splicing process, the actual conventional method has to be examined. The preparation process consists of several steps that are all performed manually with different types of cutting tools. First, the rubber has to be removed completely from both belt ends, see figure 2. The top and bottom cover are cut off with an oscillating cutting edge. Then a stripping machine is used, to cut the steel cords apart. To remove the biggest amount of rubber from the steel cords, so-called piano wires are used. The remaining quantity of rubber is removed with knives and mechanical wire brushes. At the end, the steel cords have to be shorten to the required length.



Figure 2: Preparation process [ContiTech CBG]

The next steps to finish the splicing is to place the steel cords according the required splice layout, see figure 3. Then new skim rubber has to be put between the individual steel cords. Then the new covers are added on top and bottom of the splice before the vulcanization press is installed and the final vulcanization process is performed. Thus, the total splicing process of a steel cord conveyor belt is very time consuming and the quality depends on the qualification of the technicians.

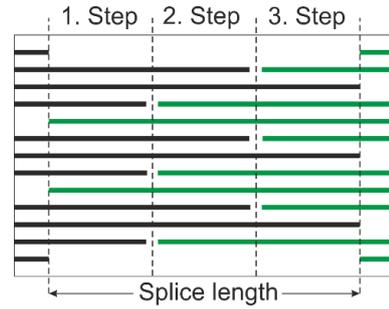


Figure 3: Layout of a 3-step steel cord splice [4]

2. Examination of new preparation process

Time and splice quality are the two points to focus on by finding a new process. Time reduction shall be achieved by the automation of the process with a suitable machining. The attainable adhesion of skim rubber on steel cords defines the quality of the splice. Due to the fact that the zinc coat is responsible for adhesion mechanism it must not be damaged with the new preparation process. Two processes that are promising to fulfil these requirements are laser processing and water jetting. Thus these two applications are investigated in this study. As evaluation process the efficiency, the homogeneity and the selective removal of the rubber without damaging the zinc coating of the steel cords shall be determined objectively.

2.1 Laser processing

This investigation tests the efficiency of rubber removal from zinc coated conveyor belt steel cords by applying laser radiation. Four laser systems, varying in terms of wavelength and laser power have been compared. The investigation is conducted using the laser systems presented in table 1.

Table 1: Utilised laser systems

	CO ₂ -laser	Fibre laser	Solid-state laser	Solid-state laser
Wavelength λ [nm]	10,600	1,064	532	355
Max. laser power P [W]	200	40	12	23

The rubber-coated steel cord samples were fixed in a holder and placed in the lens's focal plane. Correct positioning was achieved via available axis systems and a pilot laser that identified the laser's working area on the sample. Rubber ablation was performed on areas of 50 mm x 10 mm from four sides of the steel cords with various sets of parameters. The Laser system that has shown the best efficiency in processing time is the CO₂-laser. Thus, this laser system is used for further investigation of the potential of the adhesion of rubber on laser processed steel cords.

2.2 Water jetting

Investigations using water jetting as preparation process have been performed utilizing a servo-driven high-pressure intensifier pump according to the actual state of the art, connected to high-pressure valve holding a nozzle. Inside the nozzle, the water is decompressed to ambient pressure and a high-speed jet is generated. Environmental effects like air friction and inner turbulences effect a progressive jet disintegration, which leads to a state where the jet predominantly consists of droplets. This state is advantageous for selective milling applications, since the impact of multiple droplets creates higher peak loads than a continuous jet. Therefore, the rubber removal can be obtained using pure water with no abrasive particles added. After preliminary tests with different nozzle types, flat-jet nozzles showed to be well suited and have been utilized for this investigation. The cutting equipment was mounted on a gantry-style manipulator to ensure correct positioning. The specimens included in this investigation were machined using a water pressure of $p = 300$ MPa. The flat jet nozzles had an equivalent inner diameter of $d = 0,4$ mm and a jet angle of $\alpha = 20^\circ$.

After preparation, an extra process step is necessary to ensure that no water remains on the steel cords. Water can have two negative effects on steel cord conveyor belts. It may cause air pockets in the rubber during the vulcanization process and can lead to corrosion on the cords if the zinc coat is damaged. In this investigation, water is removed with a simple air drying process using air pressure. More details have been already presented in [4].

3. Surface analysis of processed steel cords

To characterize the quality of the processed steel cords, a visual evaluation is used at first. Figure 4 shows all processed steel cords (top: conventional preparation, middle: water jetting and bottom: laser processed).



Figure 4: Processed steel cords (top: conventional preparation, middle: water jetting and bottom: laser processed)

Using the conventional way to prepare the steel cords, the remaining rubber still

encloses the cord. The rubber is removed using a knife until the outer surface. Therefore, the gaps between the individual wires still contain rubber. Using water jet or laser system, the rubber can be removed up to the inner core of the cords. The surface of the laser processed steel cord partially shows blackened areas resulting from the rubber removal process, see figure 5. Due to the very high power input, the rubber catches fire if not suppressed by nitrogen gas. The rubber is removed on the entire surface.



Figure 5: Laser processed steel cord

The surface of the processed steel cord used water jetting, has no visible alteration, see figure 6. The rubber is also removed on the entire surface.



Figure 6: Water jet processed steel cord

As described before, the zinc coat is an active part of adhesion forming. The zinc layer cannot be detected by visible inspection. This analysis are performed using metallography. With this method, the processed steel cords are analysed on the micro section. This optical analysing method detects the zinc coat on the processed steel cords. Figure 7 shows a processed steel cord using cutting tools. There is still rubber between the individual wires. The micro section shows also the zinc coat on top of the individual wires.

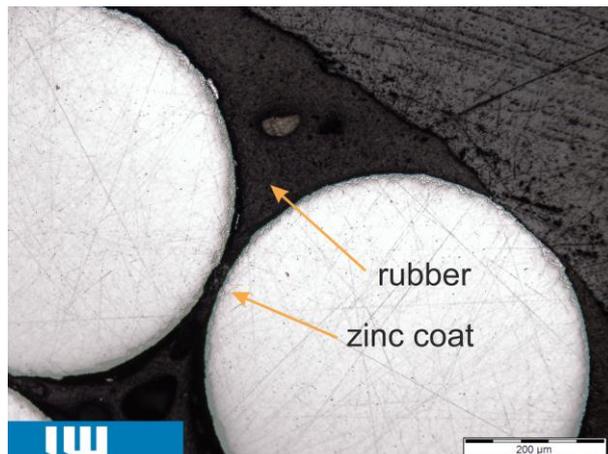


Figure 7: micro section of a processed steel cord using conventional preparation method

As figure 8 shows, the zinc coat is still intact after processing the steel cords with a laser system or a water jet. There is less rubber remaining on the steel cords compared to the conventional preparation.

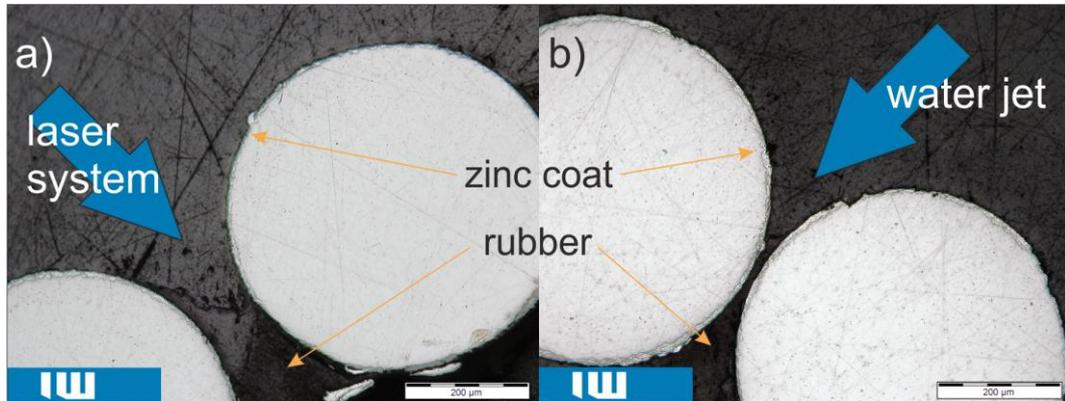


Figure 8: Micro section of a processed steel cord using a) laser system and b) water jet

4. Experimental testing of achievable adhesion of rubber on processed steel cords.

To investigate the achievable adhesion of rubber on the processed steel cords, using laser processing, water jetting and the conventional processing, experimental tests have been performed. The test method to determine the adhesion of rubber on steel cords is standardized in DIN 22129-3 [7]. Therefore, the so-called n-rope specimens are applied. They can consist of either 3, 5 or 7 steel cords. The adhesion is determined with the needed pull-out strength for the single steel cord. The tests have been performed at quasi-static conditions using a speed of 100 mm/min. The tensile tests to determine the pull-out strength are shown in figure 9. The highest pull-out force has been achieved for the specimen that consist processed steel cords using water jet as preparation method. The steel cords that has been processed with a laser system show the lowest force. Thus the best adhesion has been achieved using a water jet. The calculated pull-out force per millimetre splice length is shown in table 2.

Table 2: Pull-out force per millimetre splice length

Preparation method	Length of splice area l_{Fa} [mm]	Max. tensile force [N]	Pull-out force F_a [N/mm]
Conventional	100	9199	91,99
Laser system	100	8021	80,21
Water jet	100	11030	110,30

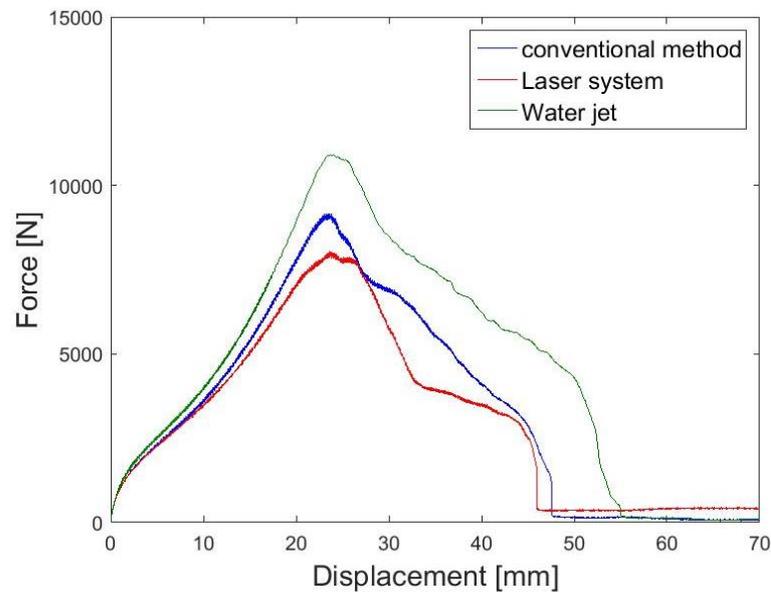


Figure 9: Results of tensile tests

Figure 10 shows the rubber residues on the steel cords that have been pulled out of the specimen. There is less rubber remaining on the steel cords, processed with a laser system, than on the ones using water jet for preparation. The low adhesion on the laser-processed cords can result on the sooty particles that remain on the surface after preparation.

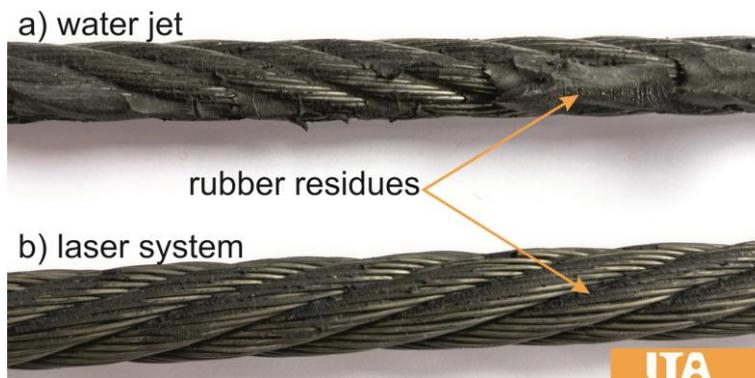


Figure 10: Rubber residues on steel cord, using a) water jet and b) laser system

CONCLUSIONS and OUTLOOK

The presented investigation have been performed to examine if the preparation method of the splicing procedure for steel cord conveyor belts can be automated. Therefore, the steel cords have been processed using a laser system and water jet. The micro section of both process variants show that the zinc coat is still intact. Therefore, both processes fulfil the requirements for adhesion forming between steel cords and rubber. The

Analysis of the cords show no visible damage of the cords processed with water jet. Using a laser system, the rubber catches fire during removal. This leads to blackened areas on the cords. Thus, the laser preparation leads to sooty particles on the steel cord surface. The experimental testing of the achievable adhesion of rubber on the processed steel cords shows that the cords using water jet as preparation process lead to the best results. Comparing the cords processed with water jet and the conventional method show that the total removal of the rubber on the cords reaches better adhesion. This effect is negative affected by the sooty particles, but needs further investigation if this problem can be solved by integrating an extra processing step to clean the cords. In terms of time, is the process using water jet more efficient than the laser system. Thus, water jetting shows to be a promising preparation method for steel cord conveyor belt splicing and comes along with a great potential of automation. Further investigation are necessary to determine optimal process parameter for the removal of rubber from steel cords. This includes machine techniques, as for example different types or number of nozzles, and machine setup, as jet angle, beam distance or water pressure.

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