THE IMPACT OF JOINTS' QUALITY ON THEIR STRENGTH IN ST 3150 CONVEYOR BELTS

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Abstract: Article discusses issues related to the weakened strength of the joints in conveyor belts. Joints are the weakest element of the belt and should be taken aimed at eliminating the errors made that may be caused by multiple factors. Every breakdown generates additional costs in the company so this is important to decrease their number.

All analyzed joints were made using belts with steel cords. The results were obtained from the Conveyor Transport Laboratory at the Wroclaw University of Technology. The assessment showed a significant impact of the working defects on joint strength. Also the trend analysis performed on the samples of regenerated belts showed a linear decrease in strength along with the degree of regeneration.

Keywords: conveyor belt, joint's strength, joints' defects

1. INTRODUCTION

In line with the requirements of the currently applicable standard related to vulcanising belt joints (PN-C-94147:1997), tensile strength of St type belts should be equal to the strength of the belt's joint. In practice, however, it significantly differs from the required value. It results in weakened strength of the joint, which thus becomes the weakest element of the belt, with most exposure to damaging. It is fully justified that actions should be taken aimed at eliminating the errors made by the maintenance staff when making joints.

Reduction in the strength of the joints may be caused by multiple factors. They include the condition of the cores that are connected. Each damage to them, i.e. corro-

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sion of the cords, individual wires breaking or rubber being detached from the cords influences the lowered strength of the belt and of the joint. In order to avoid any working errors, the joints should be made by employees with relevant qualifications. This will allow us to achieve possibly the highest strength in the joints, thus reducing the number of damages to them (Żur and Hardygóra, 1996).

Conveyor belts are the most expensive element of the conveyor in the investment and operating phase (Błażej et al., 2012). For economic reasons, the lasting and fault-free operation of the conveyor should be ensured, through controlling the quality of belts and joints. This warrants maximised capacity and income for the company, as each unplanned break in the conveyor's operation is a cost that must be covered by the entrepreneur (Bancroft et al., 2003; Błażej et al., 2011).

Regeneration of belts increases their working time and reduces operating costs of conveyors. Cost of regeneration is 20-50% of the cost of purchasing a new tape. In this process, the top cover and core rubber are detached in order to repair the core. Then applied to the new cover and core rubber to vulcanized. Properly regenerated steel cord conveyor belts allow to obtain the same durability as the new belts (Żur and Hardygóra, 1996).

2. JOINTS TESTING

The joint's strength is tested by destroying a sample on the testing machine. The measurements are taken on a ZP-40 tensile tester for belt joints in the certified Conveyor Transport Laboratory at the Wroclaw University of Technology (Fig. 1). The test consists in snapping the joint of the belt using samples with dimensions of up to 300 mm in width and 1500÷4000 mm in length. On the contracting party's request, it was possible to analyse the causes for reduced strength of the joint.
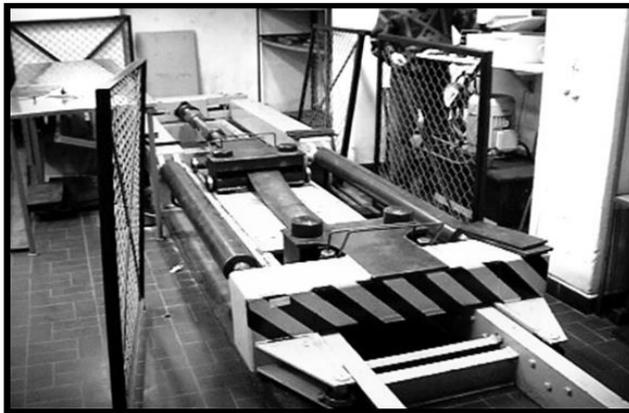
Fig. 1. ZP-40 tensile tester for belt joints (http://www.ltt.pwr.wroc.pl)

The results used in the analysis were obtained from the Conveyor Transport Laboratory at the Wroclaw University of Technology. The data comes from testing the strength of 36 vulcanised joints. All joints were made using belts with steel cords. According to the standard referred to above (PN-C-94147:1997), when ascertaining the joint's tensile strength, each test should be performed on three samples. Therefore, the 36 joints were used to obtain a database of 108 samples. The joints were made using tapes with various nominal strengths, and their share by number is presented on Fig. 2.
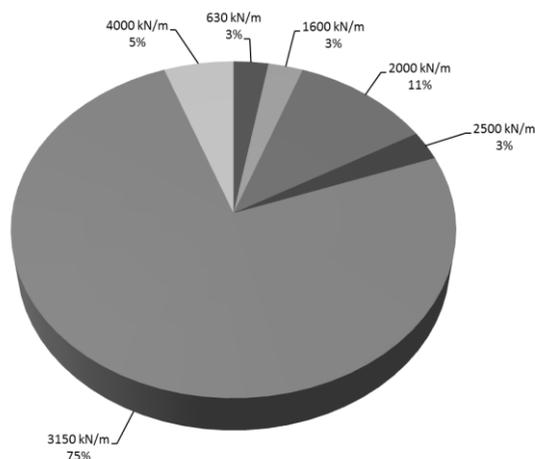
Fig. 2. Share of the theoretical strength of the joints

3. ANALYSIS OF THE RESULTS

Fig. 3. presents the strengths of the tested joints in relation to nominal strengths of the belts that were used to make them. The distribution of the results of joints' strength test is presented on Fig. 4. In order to obtain the information on the variance of those factors, the coefficient of variance was used. Its value for each test was presented on Fig. 5 and 6.

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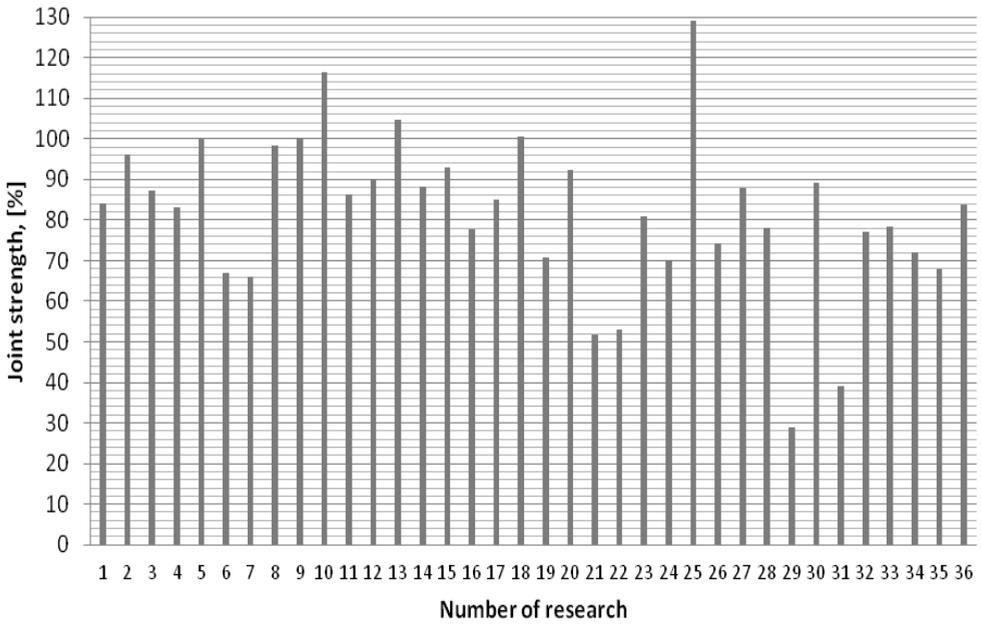
Fig. 3. The strength ratio of the tested joints to nominal strengths of the belts
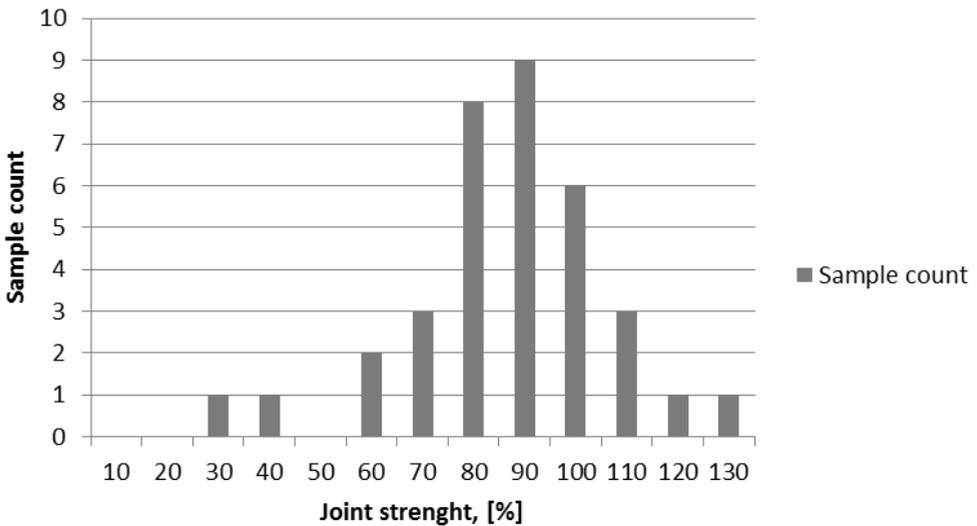
Fig. 4. The distribution of the strength ratio of the tested joints to nominal strengths of the belts
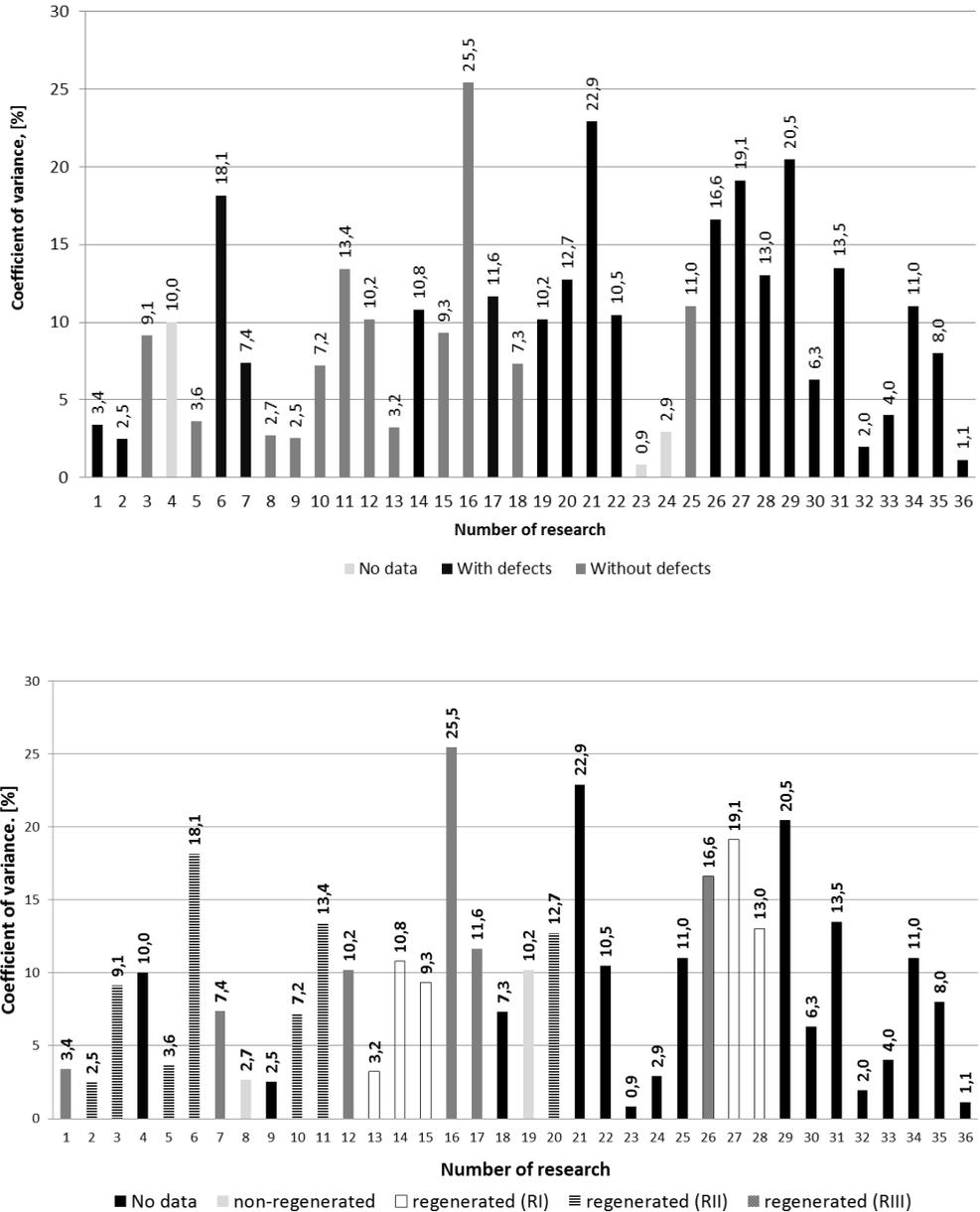
Fig. 6. Coefficient of variance for each test taking account of the degree of the belt's regeneration

The coefficient of variance took various values, regardless of the quality of the joint or the degree of the belt's regeneration. It was not possible to determine the dependencies between that data due to the low number of results.

The information on the causes of the lowered strength of the joints was obtained from expert studies. They consisted of 33 studies. These expert studies showed that most of the samples tested had working defects, translating directly to lowered strength of the joints. Most of the departures from the standard were caused by direct errors of the staff and incorrectly selected material. The results are presented in Table 1. All causes of lower joint strength and the number of such occurrences are presented in Table 2. It should be noted that some of the samples had more than one defect.

Table 1. Samples by defects

Comment	Number of samples
Working and structural defects	43
Defects resulting from the use of the joint	21
No defects	35

Table 2. The causes of lower strength of the joints and their number

Defect	Number
Corrosion of the cords	19
Damaging of the cords	6
Structural defects	30
Stains, cords failing to adhere to rubber	30
Distortions, porosity and low quality of rubber	23

The tests of the joints of St 3150 rubber represented the majority of the results obtained from the laboratory. They were the only test that covered belts that were both regenerated and those that were not (RI, RII, and RIII), and those were the only results that were analysed further. The analysis covered the tests in which the average percentage strength of the joint was in the range of $60\% \leq x \leq 110\%$. The remaining results were deemed not representative due to their low number.

Each of the samples was qualified into one of five categories:
- Non-regenerated (n),
- After one regeneration (RI),
- After two regenerations (RII),
- After three regenerations (RIII),

No data (nd) if the contracting party provided no data on the belt.

In the case of sections of the band with various degrees of regenerations, the joint was qualified as having the larger number of regenerations. The spread is presented in Table 3.

Table 3. Qualification of ST 3150 belt joints

Category	Number of samples with no defects	Number of samples with defects	Total samples
n	2	4	6
RI	3	9	12
RII	11	7	18
RIII	6	12	18
nd	3	12	15
			$\sum$=69

The results for regenerated belts cannot be used for further analysis due to their low number. The trend analysis (Fig. 7) showed that for regenerated belts, joint strength drops linearly with the degree of regeneration according to the following dependence:

- $y = -4.4101x + 98.639$ with correlation coefficient $R^2=0.7776$; for joints with no defects,
- $y = -4.0044x + 88.896$ with correlation coefficient $R^2=0.997$; for defective joints.
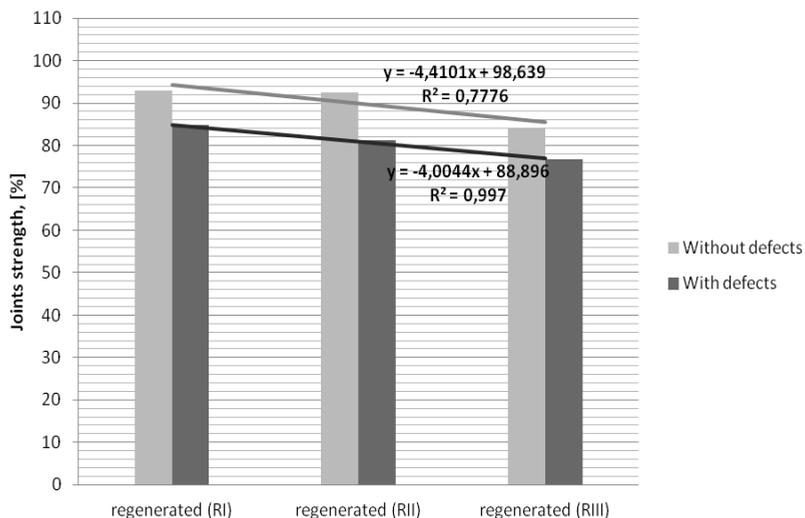
Fig. 7. Average joint strengths in regenerated belts (RI+RII+RIII)

4. SUMMARY

Joint strength in belts that are new and have no defects is higher than in regenerated belts from 5 to 14%. This means the band regeneration process impacts a joint's strength.

The assessment of incorrectly made joints in bands with steel cords was conducted using data obtained from the certified Conveyor Transport Laboratory at the Wroclaw University of Technology. The coefficient of variance took various values regardless of the quality of the joint or the degree of the belt's regeneration (Fig. 5 and 6). It was not possible to determine the dependencies between that data due to the low number of results.

The expert studies made in 33 tests showed 64.6% of all samples had at least one defective joint (Table 1).

A detailed analysis was related to joints of St 3150 belts, as this sample covered both non-regenerated and regenerated belts (RI, RII, and RIII). The assessment showed a significant impact of the working defects on joint strength. The decrease in the joint strength in RI, RII, and RIII bands was respectively at 8.1%, 11.4% and 7.2%. The trend analysis performed on the samples of regenerated belts showed a linear decrease in strength along with the degree of regeneration. The linear functions describing this dependency have a high correlation coefficient: R^2=0.7776 for joints with no defects, R^2=0.997 for defective joints.

The tests showed most of the causes of lowered joint strength are direct working errors of the staff and incorrectly selected materials (glue mixes). Therefore, actions must be taken to eliminate such errors, which will undoubtedly increase the strength of such joints.

Increased number of results from research enable the relation between the type of defect and the degree of joint weakening. This would help to evaluate which defects have the greatest impact on reducing the strength of the joints. A customer does not in any case gives an information about the degree of the belt's regeneration. Such a message would increase the amount of data that could be analyzed.

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