Impact of Selected Parameters on the Fatigue Strength of Splices on Multiply Textile Conveyor Belts

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Abstract. Splices are the weakest points in the conveyor belt loop. The strength of these joints, and thus their design as well as the method and quality of splicing, determine the strength of the whole conveyor belt loop. A special zone in a splice exists, where the stresses in the adjacent plies or cables differ considerably from each other. This results in differences in the elongation of these elements and in additional shearing stresses in the rubber layer. The strength of the joints depends on several factors, among others on the parameters of the joined belt, on the connecting layer and the technology of joining, as well as on the materials used to make the joint. The strength of the joint constitutes a criterion for the selection of a belt suitable for the operating conditions, and therefore methods of testing such joints are of great importance. This paper presents the method of testing fatigue strength of splices made on multi-ply textile conveyor belts and the results of these studies.

1. Introduction

The strength and fatigue life of splices made on textile rubber conveyor belts remains a problem for conveyor belt users [1, 2]. Some belt splices exhibit limited fatigue life due to incorrect splicing procedures. Yet, even correctly performed splices may be prone to premature wear or separation. The strength and fatigue life of splices strongly depend on selecting the best adhesive material for the given type of conveyor belt [3]. This issue is currently researched at Wroclaw University of Science and Technology [4]. The investigations cover the influence of the properties of plies and of rubber mixtures on the strength of full scale splices as well as fatigue tests on laboratory test pieces [5]. Due to the number of factors that affect the results of tests [6], especially the results of fatigue tests, obtaining repeatable results requires a significant number of samples to be tested in identical conditions (including the temperature of samples).

2. Fatigue strength testing method

The shapes and dimensions of samples used in fatigue strength tests are shown in Figure 1. The samples were submitted to cyclical loading and unloading with force ranging from F1=270 N to F2=2700 N and with frequency of 1 cycle per 2 seconds. The tests were performed on a pulsator. During the tests, the computer records the number of cycles performed until the sample disconnects, as well as elongation, force and measurement time. The recorded data allow to observe and analyze the changes in load hysteresis that occurs during tests.

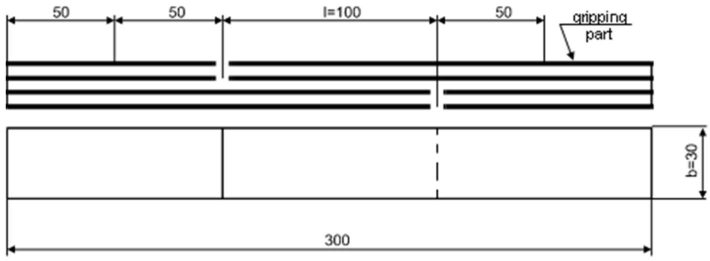

Figure 1. Dimensions (in mm) of a fatigue strength test sample

The following stresses occur in the sample tested with the adopted method:

- shear stress in the adhesive joint

$$\tau_1 = \frac{F_1}{b \times l} \text{ to } \tau_2 = \frac{F_2}{b \times l} \quad (1)$$

where: b – sample width is 30 mm; l – length of adhesive joint is 100 mm

thus $\tau_1 = 0{,}09 MPa$ and $\tau_2 = 0{,}9 MPa$

- tensile stress in the plies

$$R_1 = \frac{F_1}{b} = \frac{270}{30} = 9 \text{ N/mm to } R_2 = \frac{F_2}{b} = \frac{2700}{30} = 90 \text{ N/mm} \quad (2)$$

The distribution of shear stresses is shown schematically in Figure 2 and the maximum values at splice connection lines may be several times higher than average stress values.

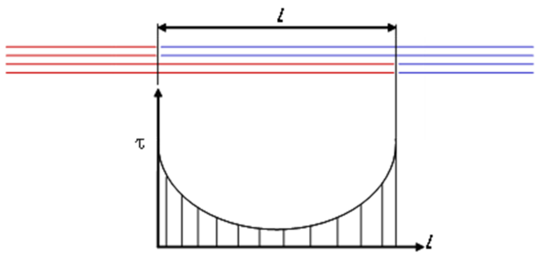

Figure 2. Shear stress distribution in the adhesive joint

Figure 3 is a schematic representation of tensile stress distribution in plies. In a 4-ply sample, at R2=90 N/mm, in an area outside the splice area, the average tensile stress in one ply is R2/4=22.5 N/mm, while at the splice connection line, where only two plies are used, the stress values are twice higher, as this is the area of shear stress concentration.

Fatigue tests were performed on splice samples made of various kinds of plies joined with various types of rubber mixtures. Due to the above, each type of ply and each type of rubber mixture was subjected to strength tests that allowed to measure elongation of plies at tensile load of 90 N/mm and rubber elongation at stress equal to 0.9 MPa. The tests also allowed to measure: shear strength of adhesive joint and splice delamination strength as per Polish standard [7]. Belt elongation tests were performed on rectangular samples (30x300) mm and rubber mixture elongation tests were performed on rectangular samples (2x15x300) mm.

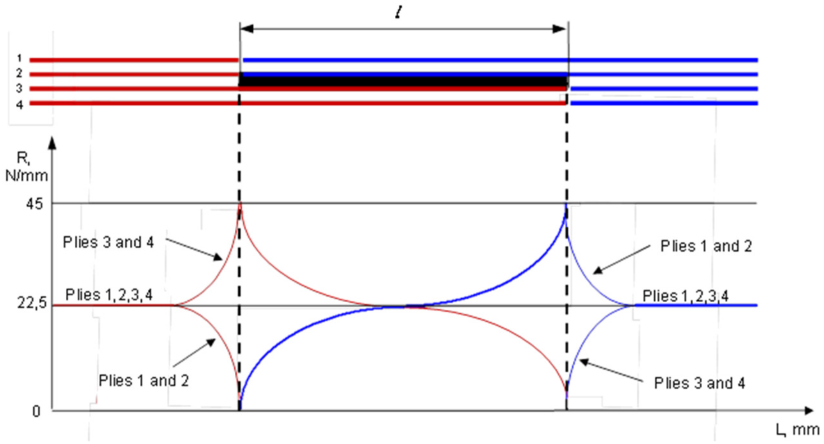

Figure 3. Schematic view of tensile stress distribution in the plies of conveyor belt splices

3. Test results

Tests were performed on 30 splices. The results were analyzed to determine the influence of the strength parameters of splice and of splice constituent elements on splice fatigue life. Example graphs provided in Figures 4 and 5 illustrate how strength parameters vary for different materials by showing the correlation between elongation and stress for conveyor belts type EP-1000/4 and P-1000/4 and for rubber mixtures type FPN and ANX.

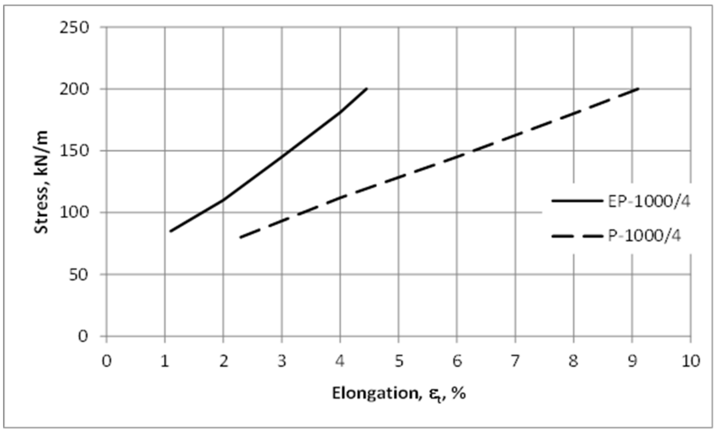

Figure 4. Relationship between elongation and stress for various belt types

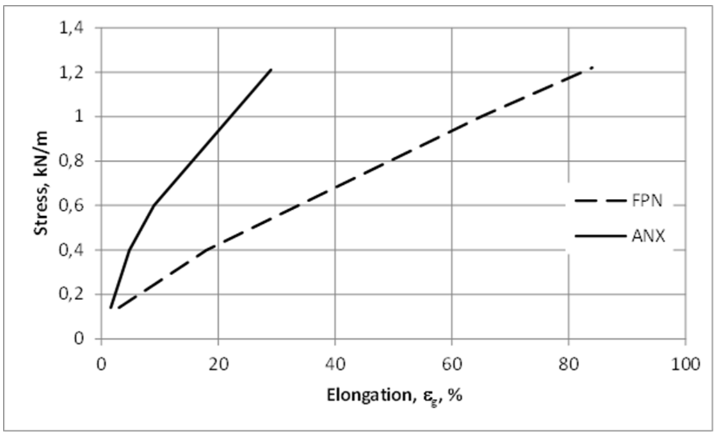

Figure 5. Relationship between elongation and stress for various rubber mixture types

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Figure 6 shows the relationship between fatigue life Z and splice shear strength τ. Significant spread of the results is natural here, as other splice parameters also have an influence on its fatigue life. The analysis of the parameters for particular points on Figure 6 allows to observe inter alia that most of the points located on the left side of the graph have a lower ply and rubber elongation than the points on the right side of the graph.

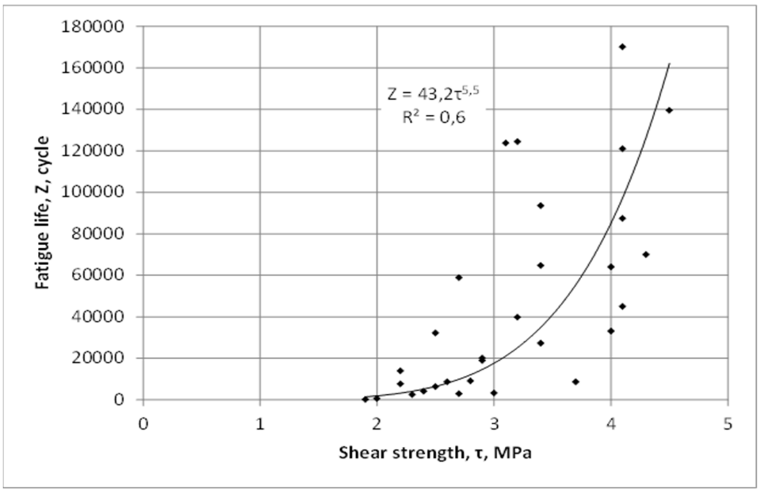

Figure 6. Relationship between fatigue life and shear strength

The influence of elongation on fatigue life was demonstrated through elongation products $N=\varepsilon_t x\ \varepsilon_g$, and separate graphs for $N \leq 50$ and $N > 50$. The results are shown in Fig. 7.
The two correlations Z = f(τ) have correlation coefficient $R^2 \geq 0.7$, which is higher than the correlation shown in Figure 6. This fact indicates that elongation has a significant influence on fatigue life. For elongation product $N \leq 50$, a $Z = 9.3\tau^{7.4}$ correlation was observed, and for elongation product N>50, a $Z=36\ \tau^{5.4}$ correlation was observed.

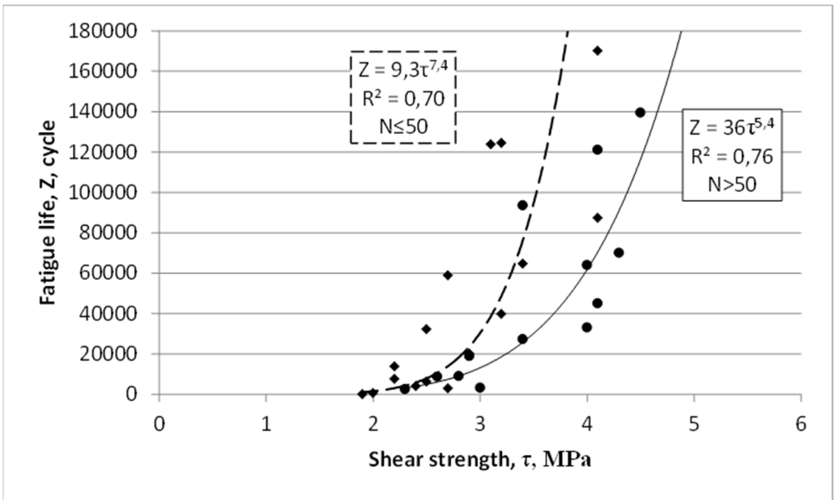

Figure 7. Relationship between fatigue life and shear strength and elongation N

The test results presented above allow to calculate splice fatigue life with a high accuracy, based on static strength parameters without the need to perform time-consuming fatigue tests. This can be done by finding shear strength τ and elongation εt for plies and elongation εg. for rubber adhesive. The next step consists in calculating the expected number of fatigue life cycles Z using correlation $Z=9.3\tau^{7.4}$ for materials of low elongation, which have $N \leq 50$, and using correlation $Z=36\tau^{5.4}$ for materials of high elongation, which have $N > 50$.

Figure 8 shows the test results for the relationship between fatigue life Z and delamination strength R. The obtained results suggest that delamination strength has a relatively limited influence on fatigue life. A relatively weak correlation was observed between the results for delamination strength and shear strength. Emphasis must be however placed on the fact that delamination strength values may have a significant spread, especially when, during tests, low tensile strength of the rubber adhesive causes the rubber to partially delaminate and at the same time to partially tear, whose phenomenon results in artificially higher recorded values for this parameter. Further analysis of the test results consisted in initial evaluation of fatigue life Z by analysing elongation graphs for samples recorded during fatigue tests.

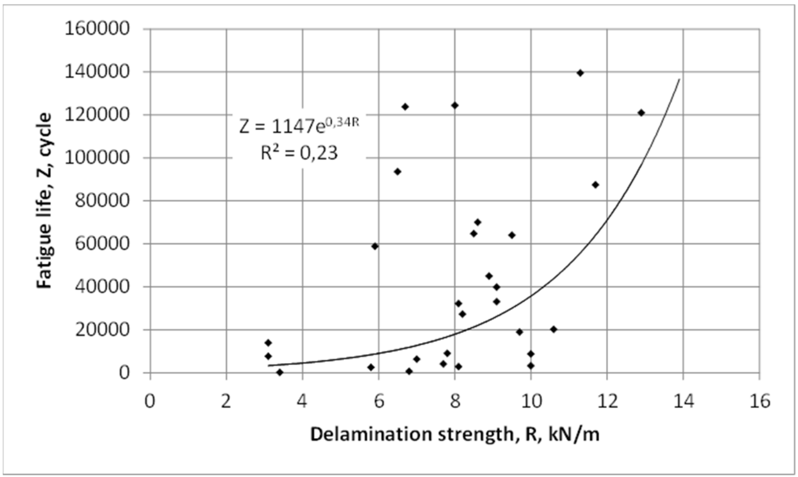

Figure 8. The relationship between fatigue life Z and delamination strength R.

Four types of splices were chosen for analysis: EP1000/4-FPN, P1000/4-FPN, EP1000/4-ANX and P1000/4-ANX. 2000 cycles were recorded for each of the splices, as shown in Figure 9

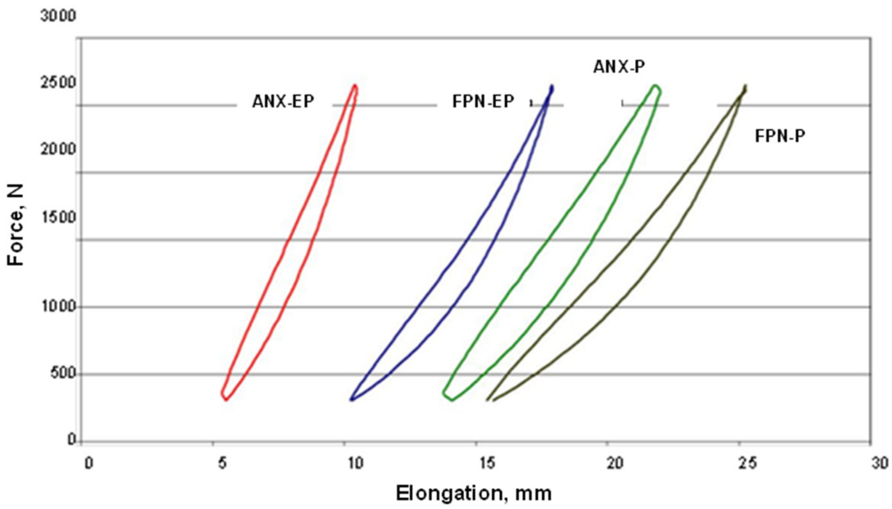

Figure 9. Graphs illustrating elongation during fatigue tests

Work required to perform one loading cycle was calculated for each splice and the results are shown in Figure 10.

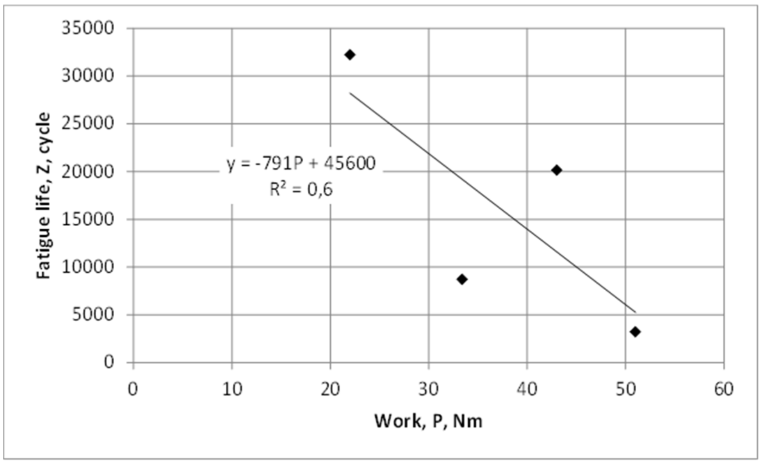

Figure 10. The correlation between fatigue life Z and work P required for a single loading cycle

The above results were obtained from the selected four splices and therefore cannot be used to evaluate a greater population of splices. However, they seem to offer a chance to reduce the cost of fatigue life by limiting the tests to single loading cycles.

4. Conclusions

The tests show that splice fatigue life depends mainly on the shear strength of the rubber joint, on ply elongation, on rubber adhesive elongation and also, to a limited degree, on delamination strength. The test results allow to use static strength parameters for calculating the approximate fatigue life of conveyor belt splices. Further research could be performed in order to reduce the cost of tests inter alia by evaluating fatigue life on the basis of single loading cycles.

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