Synthetic Fibre Ropes for Forestry Use – further developments in finding Criteria for the replacement state of fibre ropes

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Abstract: *A research project, named "Ropesecurity 2+", started 2010 by the Austrian Federal Research Centre for Forests, Natural Hazards and Landscape (BFW), investigates the correlation between quantifiable loss of fibers and the associated reduction of the remaining tensile strength to find decision-making aids to be able to assess the state of wear of fiber ropes. As laboratory tests by cutting the strands of a 12-strand rope and measuring the residual strength showed, the ropes strength decreased to 92%, by cutting one strand, two strands cut reduced it to 81% while three strands dropped it to 60% (GARLAND, J., et al, 2003). Similar correlations between measurable loss of fibers through abrasion and residual strength are supposed. Finding the supposed correlation and also an easy way for measuring the loss of fibers in the operating rope are the main goals in this research project. - This paper presents first results.*

Keywords: Synthetic fiber ropes; abrasion; replacement state, criteria for replacement

1 Introduction

Fiber ropes for forestry use are offered by several manufacturers. According to studies, fiber ropes offer a wide range of advantages in comparison to steel wire ropes: For example the low weight of fiber ropes facilitates forest operations and serious accidents through broken wires are avoided. (GARLAND, J. et al, 2003; PILKERTON, S. et al., 2004; STAMPFER, K. et al., 2010).

For security reasons and to protect individuals working with this type of ropes, clear decision-making aids are needed in order to be able to assess the usability and replacement state of wear of a rope as applies to steel cables.

Visible damages to the ropes surface by increasing wear and a measurable loss of fibers are valid as possible indicators for the replacement state.

First test series of BFW have shown that the state of wear cannot clearly be identified through visible damages occurring during logging applications, analogous to the risk assessment of nautical ropes worn-out at different levels (NEMESTÒTHY, N., 2010; SAMSON ROPE, 2003). The harsh conditions prevailing in forestry make, that the ropes surface structure is worn-out so quickly, that no conclusions can be drawn to the residual strength of the rope. Also, the often cited assumption that the fibers fraying out would protect the residual fibers of the rope could not be confirmed by the abrasion tests.

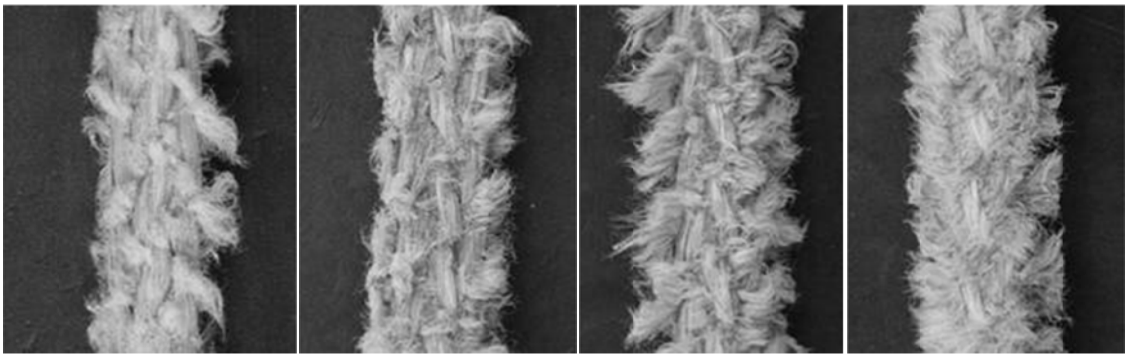

Figure 1 to 4: left to right, four levels of progressive artificial abrasion– it is hardly possible to distinguish the individual levels from their surface structure.

Contrary to not clearly identifiable visible damages, the residual strength of the ropes changed significantly according to abrasion levels 1 to 4.

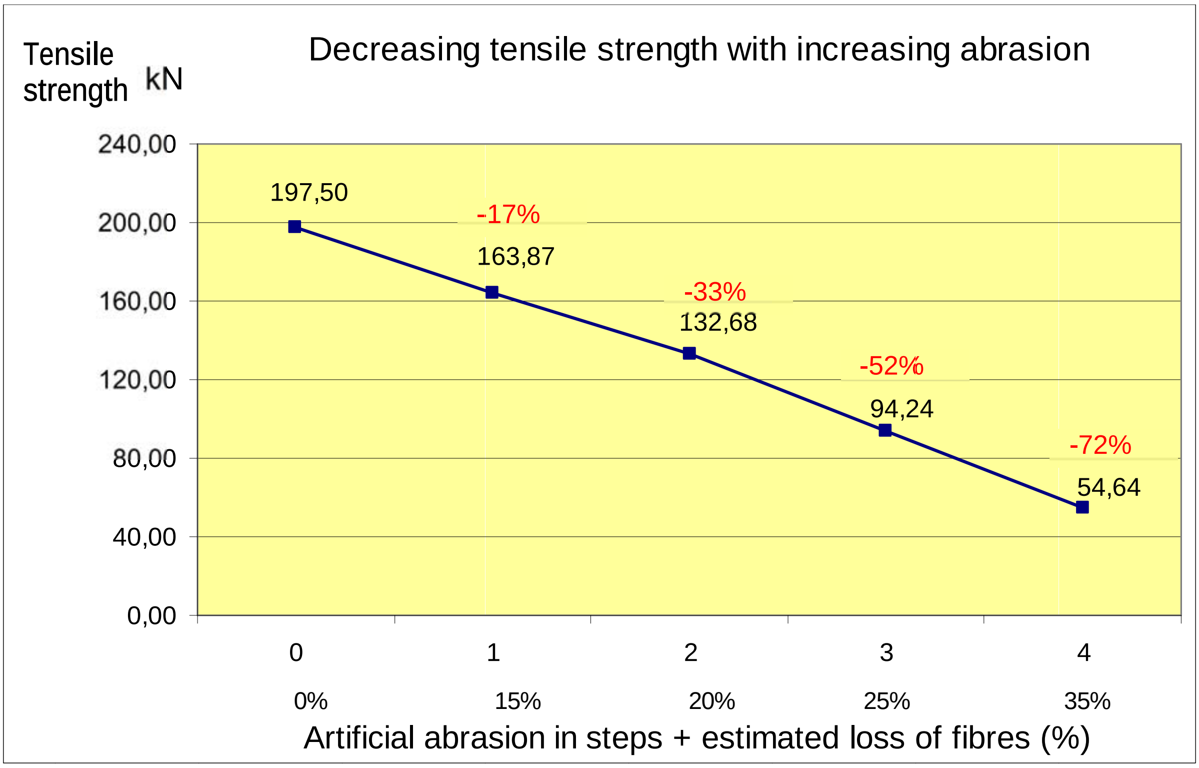

Figure 5: Loss of tensile strength with progressive abrasion at four abrasion levels departing from the unused rope (Level 0)

As citied before, laboratory tests conducted at the Oregon State University revealed that residual strength of a twelve strand braided rope dropped to 92%, 81% and 60% of the original strength by cutting 1, 2 or 3 strands, respectively. This test shows a disproportional high increase of tensile strength loss with a remaining fibre profile amounting to 92%, 83% and 75%. (GARLAND, J., et al., 2003). These findings are similar to the results of the BFW-tests shown in Fig. 5.

On the basis of these findings, BFW has initiated a research project aiming easily identifiable decision-making aids in order to be able to assess the usability and replacement state of wear for synthetic ropes from high molecular weight polyethylene (UHMWPE such as Dyneema©) as applies to steel cables. In this study an attempt is made to identify the ratio between quantifiable fibre loss and the subsequent loss of breaking strength.

It is important that the determination of fibre loss could be done easily with a simple method by the forest worker inspecting the rope during the logging operation.

2 Experimental Design and Methods

The experimental design is as follows: 10 different twelve strand braided ropes from Dyneema© fibre with 14 mm of nominal diameter in 5 abrasion levels with 4 repetitions each (= 200 rope samples at 6 m each). In this test, the most intensive abrasion level is selected in such a way that the coating of the coated synthetic ropes carried along for comparison reasons shows abrasion signs achieving the state of worn out for replacement. In order to get the required number of the rope samples worn-out at different levels within an adequate time span on the one hand, and to secure the repeatability and comparability of the results on the other hand, artificial abrasion were chosen. However, to assure a real abrasion effect, the presumed abrasion is being simulated by dragging the testing ropes over rough terrain using a special pilot station. (NEMESTÒTHY, N., 2010)

The damages produced through continued abrasion at the rope surface will be systematically documented through photography and fibre loss is quantified at the most heavily worked parts of the rope.

2.1 Methodology to Identify Fibre Loss

In this test, the fibre loss was identified first by assessing the profile reduction of the individual yarns of every second of the 12 strands. But this method caused a clearly stronger disaggregation of the rope structure than previously assumed.

Figure 6 & 7: The identification of the fibre loss by assessing the monofilaments of the separated strands caused a remarkable disaggregation of the rope

This was unsatisfactory, as – especially with more worn-out ropes – a stronger intervention into the remaining rope structure suggested an undesirable reduction of the residual strength. In addition, the assessment method was a problem from a scientific point of view due to subjective perceptions. The search for an objective measuring method with less disaggregation of the rope structure resulted in a method in which by means of a twine loop and a sliding calliper under constant measuring force (10 N = 1020g) the diameter of the individual rope strands was measured. This method follows the well known diameter measurement of round objects using a measuring tape. In this way, the cross-section area was calculated and compared with the values from the non damaged rope measured by the same method, in order to find out the profile loss. The trials for measuring the total rope diameter by the same method did not bring meaningful results which is due to the pretended profile increment caused by the fibers fraying out („fleece“).

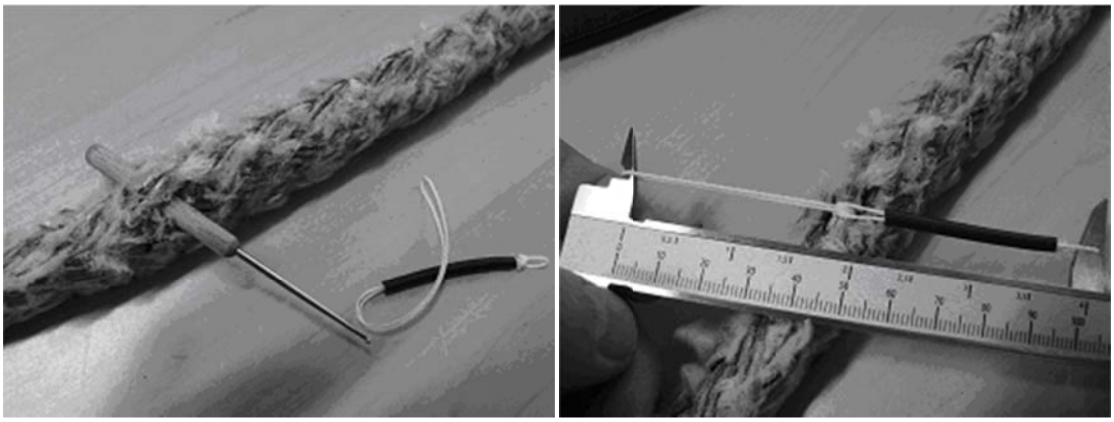

Fig. 8 & 9: Identification of profile loss by measuring the individual strands

3 Results

The results of the breaking strength tests on the first 76 rope samples (16 worn-out and 3 new rope samples each from 4 products of different manufacturers of ropes) suggest – and this is not surprising – a correlation between the measured residual breaking strengths and the identified profile loss (Fig. 10). The individual results are distributed rather widely around the exponential trend line so that at first sight it seems not to be possible to allocate a determined abrasion value to a determined remaining breaking strength – that is the desired correlation.

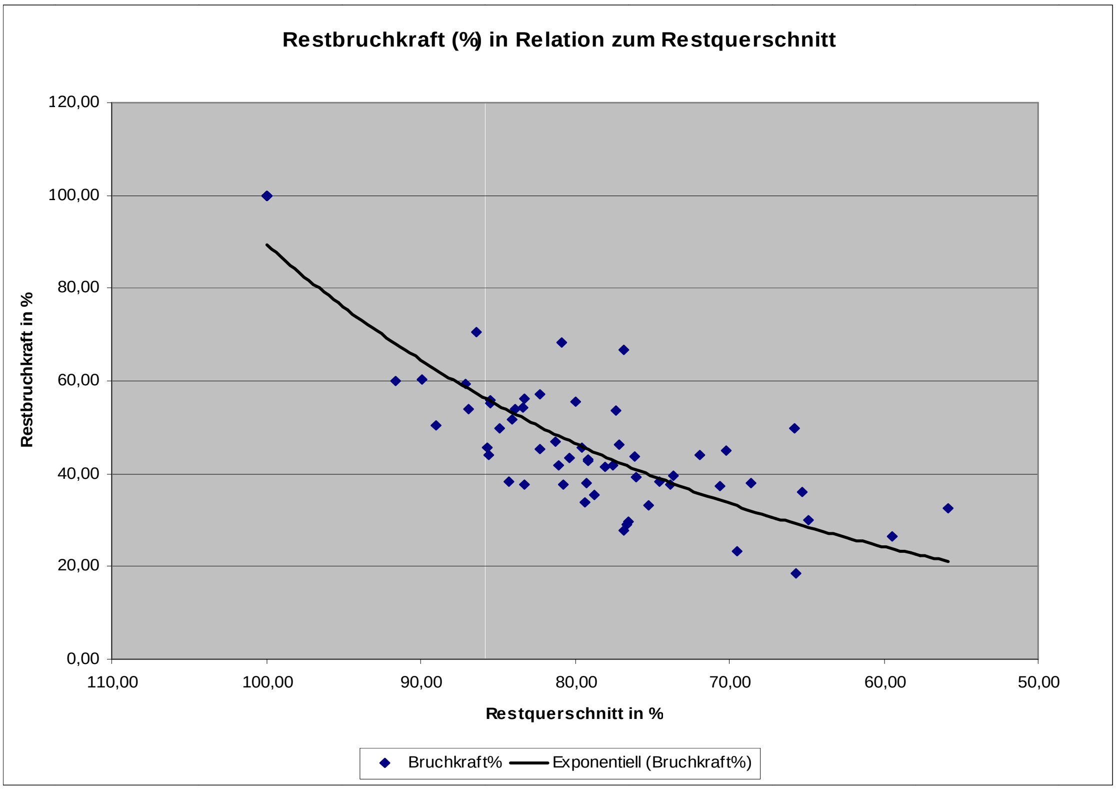

Figure 10: Remaining breaking strength (%) in relation to remaining profile (%) – all rope products

When allocating the results of the breaking strength tests to the various rope types, a clearly different picture appears despite similar rope dimension and similar breaking strength in the case of a new rope. The Graf in Figure 11 shows a much better correlation of individual values of different rope types with their best-fit curve. However, the results are not yet clear enough to draw any meaningful conclusions because of the low number of rope samples per individual product.

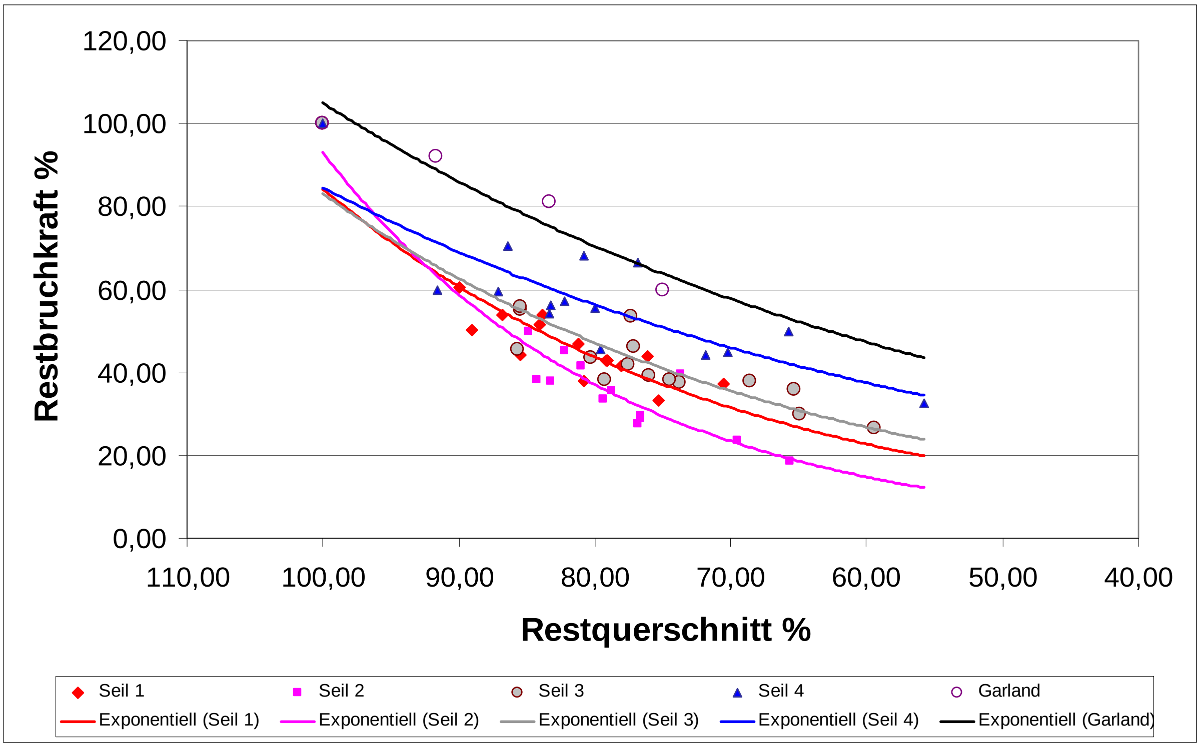

Figure 11: The remaining breaking force (%) in relation to the remaining profile (%) – according to rope type, supplemented by the above mentioned results from the laboratory tests by Garland et al.

4 Next steps

Because of the different development of the ratio between profile loss and breaking strength loss for rope material of various manufacturers (from the same material with the same diameter and the same nominal breaking load) it will be necessary to concentrate the study on the rope type of one manufacturer first.

In order to verify the results from the artificially generated abrasion samples it is planned to gain also worn-out rope samples (same dimension of the same manufacturer) from an actual logging operation and to analyse them by using the same method.

Furthermore, additional rope samples of other manufacturers as well as ropes of different dimension of one manufacturer shall be investigated in order to be able to better calculate the presumed differences in the development of the ratio between profile loss and breaking strength loss.

Specific projects:

Evaluation of 32 existent treated rope samples. On these samples the strands have been measured only in every second sample in order to be able to recognise a possible influence of the measurement on the breaking strength.

Preparation and evaluation of further rope samples of one product from the first series of the same dimension (14 mm). (30 to 40 rope samples)

Procurement of ropes already used for logging, measurement of reduced profile and testing of the remaining breaking force.

Preparation and evaluation of rope samples of further 3 rope manufacturers of the same dimension using a reference rope from the first series (around 100 rope samples)

Preparation and evaluation of rope samples of various dimensions from one manufacturer (10, 12, 16mm) (around 100 rope samples)

5 Summary

The trials conducted so far have shown that the reduction of the breaking strength reaches significant values already during relatively slight rope abrasion so that the required safety factor will not be met after short use. This underlines the urgent need for a method which will enable timely recognition of the ultimate limit state of the rope.

To find such a method would mean an important step in terms of safety for an ever increasing number of users who, after appropriate training, would have the possibility to timely recognise the ultimate limit state of the rope (time for replacement) and to effectively monitor the safety coefficient (rope resistance = twofold winch traction force) foreseen in the Standard for Forest Rope Winches (EN 14492-1).

The first results of the research project started by BFW show a possible way for continuous rope inspection by the user.

64 worn-out and 12 new rope samples were analysed and data pairs of the relative profile loss and the related relative breaking strength loss analysed and illustrated in a diagram. For measuring the profile loss deliberately a method was chosen which can be applied easily with readily available and low-cost equipment.

The results of the analysed products revealed a relatively wide distribution of the points around the best-fit curve. An allocation of a determined profile acceptance to the remaining breaking strength shows big insecurities.

The Splitting up the results according to individual rope types provides a clearly better correlation with the best-fit curve – which could be the basis for criteria. For evidence reasons, a larger number of tests with rope samples of the same product from one manufacturer should be conducted.

Risk assessment is the most important precondition for the smooth use of this ergonomically useful innovation. –Let’s hope that by means of this research project, safety and health improvement in forest logging operations could be improved substantially.

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