ENGINEERING PROBLEMS DURING PULLING-DOWN OF HOP STRINGS AND THEIR ATTACHMENTS

Petr Hermanek, Adolf Rybka, Ivo Honzik, Jiri Masek, Lubomir Vent
Czech University of Life Sciences Prague
hermanek@tf.czu.cz

Abstract. The current way of hop strings attachment (being mostly wires of different diameter) to a supporting structure by means of polypropylene twines bears the risk of hop product contamination by these attachment residues. Hop-string attachments must enable the pulling machinery an easy and fluent hopvine pull-down, and the hop-string attachment residues on the supporting structure must not make the hanging in the following years impossible. The present conception does not present an ideal strength proportions between hop strings and their attachments. When the hopvines are being pulled down (during the harvest), the hop strings are mostly broken and the attachments, possibly together with some parts of wires, are left on the hop-field trellis. In the following years these attachments get loose of themselves and are one of the causes for penetration of impurities into another stage of technological process where they are separated only with difficulty. The paper presents a comparison of wire and twine strength measurements before and after the harvest. Furthermore, it mentions also a theoretical analysis of tensile strength calculation and measurement methodology.

Keywords: hops, hop string, tensile strength.

Introduction

Nowadays, when there is a relative overproduction of hops, its quality comes to the fore. To be able to increase this quality, first of all it is necessary to find out the current condition of all the aspects dealing with growing, and on the basis of the acquired results to suggest a new, progressive, and innovative design of hop strings and the way they are attached. Last year, for the purpose of long-term experiments, there was established a field experiment the first results of which are presented hereinafter.

Materials and methods

In 2010 the field experiment was based on seven combinations of hop strings and attachments, which were measured both before the experiment was established (before hanging) and after the hop harvest. The material used for hop string was wire, black annealed of 1.06 mm in diameter (by the producer Železárny a drátovny Bohumín) [1], and for attachment polypropylene twine (by JUTA Inc.) was used, of different strength labelled by the producer as 10000, 12500, 14000, and 17000 [2]. For each twine strength there were created two kinds of attachments, the so-called simple and double (Fig. 1) with the exception of twine 17000 with a double attachment only. Each combination was used in three rows with app. 30 hop strings per row.

Fig. 1. **Sample of simple and double hop-string attachment**

To measure the tensile strength the shredder Amsler-200 was used (Fig. 2), with the speed of the shredding mechanism shift of 100 mm·min^{-1} and with the shift controlled by an electromotor. The result of break tests was a record of breaking force and elongation of both measured hop string (wire) and attachment (twine), including the value of the strength needed for breakage.

The measurements resulted in a permanent deformation of the material. A material of the length of l (mm) is attached to the fixed jaw at its one end and to the movable jaw at the other end, where the force F (N) takes a tensile effect horizontally. By the effect of this force the material breaks. When taking the difference of the material length after breaking and at the beginning of the test, we can determine the elongation Δl (mm). Division of elongation Δl and original length l results in relative elongation ε (non-dimensional):

$$\varepsilon = \frac{\Delta l}{l} \tag{1}$$

Division of the force F which takes an effect in the direction of the normal to material cross-section S (mm^2) is direct stress σ (N·mm^{-2}):

$$\sigma = \frac{F}{S} \tag{2}$$

Wire or twine strength is the stress under which a material breaks.

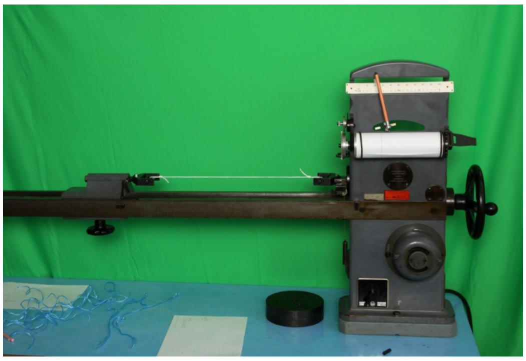

Fig. 2. **Shredder Amsler-200**

The measuring equipment was set up for the required parameters, 10 sample pieces of each kind of material were available for repeated measurements, and the recorded items were the measurement number, measured sample diameter – d (mm), horizontally (axially)-acting force needed for breakage – F (N), and corresponding elongation length at guide wire – Δl (mm). The length of the measured sample was always 300 m. For all of 10 repeats the calculation assessed relative elongation ε, direct stress σ (N·mm^{-2}) and their average values ($\bar{\varepsilon}$, $\bar{\sigma}$). The variability of ten repeats was assessed by the standard deviation and the variation coefficient.

Results and discussion

The measurements of new wires and twines were carried out in the laboratory of the Department of Agricultural Machines, the Faculty of Engineering, CULS in Prague, at the air temperature of 24 ºC and the air humidity of 22 %. The following tables show the measured values and statistic data characterizing the sets shown.

Table 1

Results of break test dealing with new guide wire with diameter of 1.06 mm

Parameter	Wire sample diameter, mm	Breaking force, N	Length after breakage, mm	Elongation, mm	Relative elongation, %
1	1.060	320	350.0	50.0	16.7
2	1.060	350	340.0	40.0	13.3
3	1.060	320	364.0	64.0	21.3
4	1.060	370	337.0	37.0	12.3
5	1.050	330	325.0	25.0	8.3
6	1.060	350	345.0	45.0	15.0
7	1.060	340	338.0	38.0	12.7
8	1.070	360	346.0	46.0	15.3
9	1.070	350	352.0	52.0	17.3
10	1.060	340	345.0	45.0	15.0
Average value	1.061	343	344.2	44.2	14.7

The strength of the new wire with a diameter of 1.06 mm was 388.1 ($N \cdot mm^{-2}$). The standard deviation was 15.5 (N) and the variation coefficient reached the value of 4.5 (%).

Table 2

Results of break test dealing with new twine

Producer's labelling	10000	12500	14000	17000
Tensile strength by the producer, N	395	475	600	700
Average breaking force, N	268.5	520.0	546.0	681.5
Standard deviation, N	21.2	25.1	28.9	42.8
Variation coefficient, %	7.9	4.8	5.3	6.3

Fig. 3 demonstrates a block diagram for a new guide wire with a diameter of 1.06 mm which is presently used by app. 90 % of hop growers for the variety of Žatec Semi-early Red. From the diagram the course of the breaking force (*F*) is apparent depending on the guide-wire elongation Δl. The diagram is supplemented with the course of the breaking force for a wire with a diameter of 1.12 mm which is the second most often used.

Fig. 4 represents a block diagram for twine labelled as 14000 and 17000. These two types are presently the most commonly used. When broken, the individual samples of polypropylene twines fray substantially, which is why it is impossible to measure the twine length after breakage. That is why the length measuring was abandoned when it comes to twines and neither it is recorded in the result table. It is only shown in the block diagram of Fig. 4.

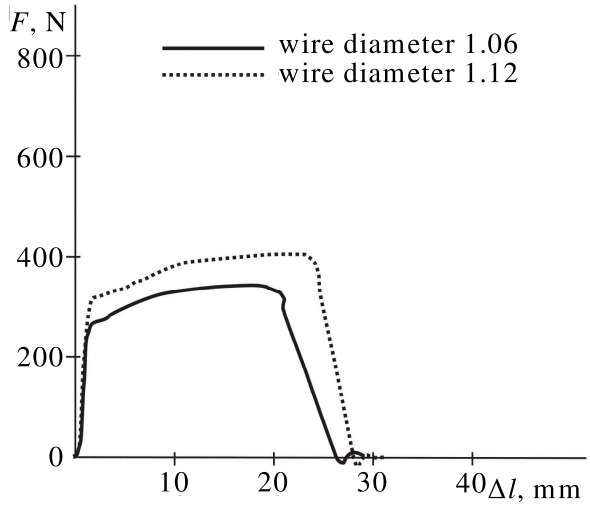

Fig. 3. **Diagram for black annealed wire with diameter of 1.06 mm and 1.12 mm**

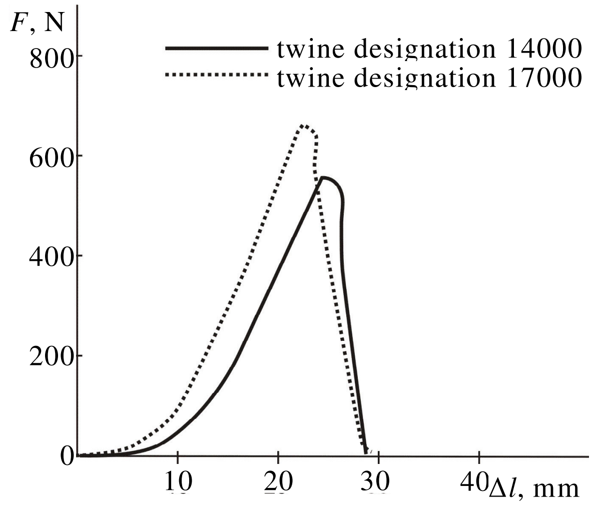

Fig. 4. **Diagram for twine labelled as 14000 and 17000**

Approximately 1 m of each of 10 pieces of guide wire was cut out when its weight was measured (app. 9 m altogether). The exact wire length and diameter at both endings and in the middle was measured before weight measuring. The measured values are to be seen in Table 3.

After the hop harvest laboratory break tests of samples of wires and twines taken from the experimental hop field were performed. Breakage was again carried out by means of the shredder Amsler-200.

The measuring equipment was set to the required parameters. As for the wires, there were 8 pieces of samples available, taken out from the lower, middle, and upper part of the hop string. With twines there were 10 pieces of samples taken from each variant of simple attachment hanging (3 variants with 10 pieces each) and 3 samples taken from each variant of double attachment (4 variants with 3 pieces each). The methodology was the same as with measuring of new wires and twines. The average values of the measurements are shown in Tables 4 and 5.

Table 3

Parameters of new guide wire (hop string) of 1.06 mm in diameter

Parameter	Diameter of wire sample at the edge, mm	Diameter of wire sample in the middle, mm	Diameter of wire sample at the opposite edge, mm	Average value of diameter, mm	Wire length, mm	Wire weight, g	Wire volume, mm^3	Wire specific weight, $g.cm^{-3}$
1	1.060	1.060	1.060	1.060	1000.0	6.73	882.03	7.63
2	1.060	1.050	1.060	1.057	1000.0	6.69	876.49	7.63
3	1.060	1.060	1.060	1.060	997.0	6.65	879.38	7.56
4	1.050	1.050	1.060	1.053	996.0	6.71	867.48	7.74
5	1.040	1.050	1.050	1.047	997.0	6.50	857.40	7.58
6	1.060	1.070	1.070	1.067	998.0	6.82	891.37	7.65
7	1.060	1.070	1.060	1.063	998.0	6.76	885.81	7.63
8	1.070	1.070	1.070	1.070	1000.0	6.71	898.75	7.47
9	1.070	1.070	1.070	1.070	997.0	6.81	896.05	7.60
10	1.060	1.060	1.060	1.060	998.0	6.75	880.26	7.67
Average value	1.059	1.061	1.062	1.061	998.1	6.71	881.50	7.62

Table 4

Average results of break test of guide wire samples of 1.06 mm in diameter after harvest

Parameter	Sample from the lower part of hop string – D			Sample from the middle part of hop string – S			Sample from the upper part of hop string – H		
	1	2	3	1	2	3	1	2	3
Unit	N	mm	%	N	mm	%	N	mm	%
Diameter	321	32	11	343	47	16	328	56	19
Standard deviation	23.8	11.6	3.9	24.0	8.4	2.8	21.9	10.0	3.3
Variation coefficient	7.4	36.7	36.7	7.0	17.9	17.9	6.7	18.0	18.0

1 – Breaking force, 2 – Elongation, 3 – Relative elongation

Table 5

Average results of break test of twines after harvest

Parameter	Breaking force, N	Standard deviation, N	Variation coefficient, %	Relative elongation, %
Twine labelled 10000	155	21.3	13.8	9
Twine labelled 12500	351	21.3	6.1	11
Twine labelled 14000	411	47.2	11.5	12

The break test revealed that the wire strength had not been influenced by the sampling point on the hop string. Compared to that wire elongation declines from the upper sample to the lower one.

After all the measurements had been processed, they were compared. The laboratory measurement of strength and elongation concerning wire and twine was compared to the subsequent laboratory measurement values dealing with the samples taken in the hop field. Table 6 demonstrates the comparison of the breaking force and relative elongation referring to a new wire and a wire exposed to the hop-field environment and taken during the hop-field measurement. Table 7 compares the breaking force of new twines and twines exposed to the hop-field environment and taken during the hop-field measurement.

Table 6

Comparison of breaking force and relative elongation of wire 1.06 mm

Parameter	Sampling point	Average breaking force, N	Average relative elongation, %
Laboratory measurement before hanging	-	343	14.7
Laboratory measurement after harvest	Lower sample	321	11
	Middle sample	343	16
	Upper sample	328	19

Table 7

Comparison of breaking force of twines

Parameter	Twine label by producer	Breaking force, N	Decline in twine strength, %
Laboratory measurement before hanging	10000	268	100
	12500	520	100
	14000	546	100
	17000	681	100
Laboratory measurement after harvest	10000	155	57
	12500	351	67
	14000	411	75

An annealed wire of 1.06 mm in diameter and twines with strength labelled as 10000, 12500, 14000, and 17000 were placed in the hop field during hop string hanging on the 19th April, 2010 for the hop variety of Žatec Semi-early Red – clone 72. Pulling down of hops and samples taking were carried out on the 2nd September, 2010. In this time span the hop field environment influenced the wires and twines. The measurements result in the change of wire elongation and substantial decline in twine strength due to the hop field environment (Fig. 5).

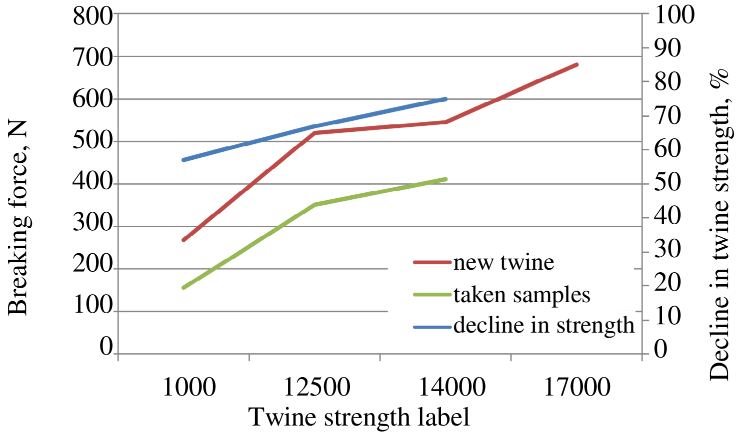

Fig. 5. **Graph of dependence of breaking force on twine strength and twine condition (new, taken during field measurement), and decline in strength due to hop field environment**

Conclusions

The measured values also demonstrate that a combination of the most often used hop string (guide wire) of 1.06 mm in diameter and the most often used attachment (twine) labelled as 14000 and 17000 is completely unsuitable due to an increased contamination of the harvested hops by polypropylene attachments twines. This combination, according to the measurement results, always leads to wire breakage when hop strings are being pulled down during the harvest. Therefore, on the supporting structure always remains the whole twine attachment together with a part of the guide wire of different length.

So far the most suitable combination of wire and twine is a wire 1.06 mm and a twine labelled as 10000 in the version of the simple attachment. In this case the attachment should be broken during the pulling.

From the point of view of the best elimination of undesirable impurities it is more convenient if the hop string breaks in the twine during the pulling, for then there is only a part of the twine left on the supporting structure. In the opposite case, when the hop string breaks in the wire, on the hop-field trellis the whole twine attachment remains together with the wire of different length which has to be later removed from the hop field at the cost of further financial expenses.

Acknowledgements

This paper was written with a contribution of MZe ČR as a part of research project NAZV QI101B071.

References

1. Železárny a drátovny Bohumín. *ŽDB Group, a.s.* [online]. Created 2008 [cit. 2010-10-02]. Availability from: http://www.dratovna.cz/czech/produkty/VK_sk3.asp.
2. Juta. *Juta Olomouc* [online]. Created 2007 [cit. 2010-10-02]. Availability from: http://www.jutaolomouc.eu/jutaolomouc/.