Assessment of the current theory for projecting cableway routes in terms of the risk level in overloading

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Abstract: The article deals with the safety of labour and of technical equipment in timber skidding using forest cableways. It analyses the applicability of the current theory used for designing cableway routes from the point of view of safety in terms of an excessive overload. The analysis, which was carried out using situational models, has shown that the skyline will break as a result of several fold excess of the safe working load. The value of the buckling load is in such case at least 3.5 times higher than that of the safe working load. Our results have confirmed the applicability of the theory currently used in designing cableway routes.

Keywords: forest cableways; safety of technical devices; labour safety

From the point of view of safety, it is very dangerous to overload the mechanisms used for loads lifting (Figure 1). The accidents caused by overloading usually result in considerable material and human damage. It is the responsibility of the choker-setters not to overload the forest cableways. In the forest cableways, the variability of the load is very great and it is often impossible to estimate its precise weight in the operational conditions, which enhances the risk of overloading. Hereafter, we will try to analyse and quantify the rate of this risk. When determining the rate of the risk of overloading, we will rely on the current theory of cable transport systems, which was designed by Dukeľskij (1966) and further developed for the forest cable mechanisms in the former Czechoslovak Republic by Roško (1984).

The maximum tension of the skyline in the forest aerial cableways is calculated using the following formula:

$$F_m^3 + F_m^2 \left(\frac{E_l S}{24 F_0^2 L'} g^2 \sum l'^3 - F_0\right) = \frac{E_l S}{24 L'} \left[g^2 \sum l'^3 + 3Q l'_m (Q + g l'_m)\right] \qquad (1)$$

where:

$L' = \sum l'$ – total sum of span distances of the cable way (m)
l'_m – the span maximum distance (m)
F_0 – pretension of skyline (kN)
F_m – allowed tension of line (kN)
S – carrier cross of rope – section (mm^2)
g – weight of 1 m length of the rope (kN/m)
Q – weight of the load (kN)
E_l – module elasticity of the rope (kN/mm^2). Equals 0.35 ÷ 0.8 E; E is the module elasticity of steel – 210.10^3 MPa

The allowed tension of line F_m equals the breaking force of line F_H divided by surety factor n = 2.2 ÷ 2.5 (recommended by Roško), the quotient being diminished by the product of the rope weight g and the vertical interval from the upper anchor up to the middle maximum distance of the field h'_m:

$$F_m = \frac{F_H}{n} - g h'_m \qquad (2)$$

From relation (1), we can deduce the formula for the calculation of the pretension of skyline F_0:

$$F_0^3 + F_0^2 \left\{\frac{E_l S}{24 F_m^2 L'} \left[g^2 \sum l'^3 + 3Q l'_m (Q + g l'_m)\right] - F_m\right\} = \frac{E_l S}{24 L'} g^2 \sum l'^3 \qquad (3)$$

The calculation of the pretension of skyline from relationship (3) is possible by forest cableway re-

Supported by the Ministry of Education of the Slovak Republic, Projects No. V-07-013-00, K-08-003-00 and KEGA 3/6448/08.

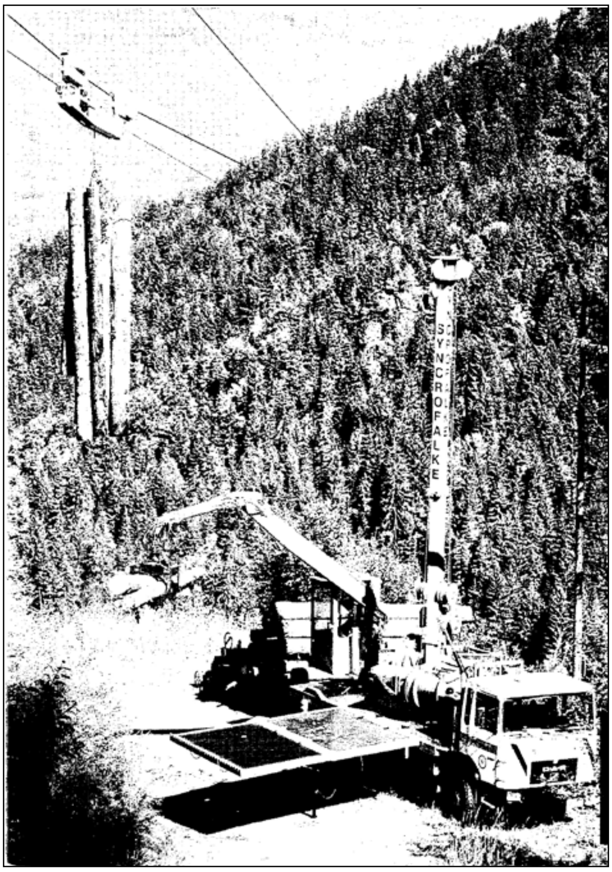

Figure 1. Illustration photograph (fy Mayr-Melnhof-Saurau)

duced with the element $g^2 \sum l'^3$, compared to another element very small. Further we will get:

$$F_0 = F_m - \frac{E_l S}{8F_m^2 L'} Q l'_m (Q + g l'_m) \qquad (4)$$

METHODICS TO PREPARE

By means of relationship (4), we can designate how bi the pretension of skyline F_0 has to be, simultaneously we suppose that the weight of the log equals the weight Q. When in relationship (4) instead of F_m F_H is used, the modified formula will be valid for the load Q, by which the skyline is stretched:

$$F_0 = F_H - \frac{E_l S}{8F_H^2 L'} Q_m l'_m (Q_m + g l'_m) \qquad (5)$$

By the modification of this relationship we will get:

$$\frac{E_l S l'_m}{8F_H^2 L'} Q_m^2 + \frac{E_l S g l'^2_m}{8F_H^2 L'} Q_m + F_0 - F_H = 0 \qquad (6)$$

By the calculation of this quadratic equation (6) we can designate maximum load Q_m, by which the skyline is stretched.

EXPERIMENTAL WORKS AND RESULTS

The derived relationship (6) for the maximum weight of the load Q_m will be applied to various model situations based on standard operation conditions commonly used in the forestry practice. On the basis of the results of these theoretical experiments, we will subsequently estimate the rate of the risk of breaking the skyline by overloading.

Situational model No. 1

The cable forwarding equipment has one field with the skyline fixed at both ends and in horizontal position, $L' = 500$ m. The skyline has 42 wires, standard type, construction 6(1 + 6) + v, STN 02 4320, $\Phi = 22.4$ mm, $S = 165.5$ mm^2, $F_H = 259.8$ kN, $g = 1.52$ kg/m. The weight of the load $Q = 2$ t.

Solution:

(1) Using the surety factor $n = 2.2$ we will get the following allowed tension of the skyline:

$$F_m = \frac{F_H}{n} = \frac{259.8}{2.2} = 118.1 \text{ kN} \approx 118 \text{ kN}$$

(2) We will calculate the magnitude of the pretension of skyline F_0. We will apply the calculation of $E_l = 85\,000$ MPa = 85 kN/mm^2 and further $L' = l'_m$:

$$F_0 = F_m - \frac{E_l S}{8F_m^2} Q (Q + g l'_m) =$$

$$= 118 - \frac{85 \times 165.5}{8 \times 118^2} 20 (20 + 0.0152 \times 500) = 49 \text{ kN}$$

(3) By the calculation of this quadratic Eq. (6) we will get:

$$\frac{E_l S}{8F_H^2} Q_{\mathrm{m}}^2 + \frac{E_l S g l'_m}{8F_H^2} Q_m + F_0 - F_H = 0$$

$$\frac{85 \times 165.5}{8 \times 259.8^2} Q_m^2 + \frac{85 \times 165.5 \times 0.0152 \times 500}{8 \times 259.8^2} Q_m +$$

$$+ 49 - 259.8 = 0$$

$$0.026\, Q_m^2 + 0.198 Q_m - 110.8 = 0$$

$$Q_m = 61.6 \text{ kN} \approx 6.2 \text{ t}$$

The skyline will break by the load of 6.2 t.

Situational model No. 2

The solution is achieved in the same manner as in the situational model number 1 but the cable forwarding equipment has two spans of the cable way, $L' = 1000$ m, $l'_m = 500$ m.

Solution:

(1) We will calculate the magnitude of the pretension of skyline F_0 by relationship (5):

$$F_0 = F_m - \frac{E_l S}{8F_m^2 L'} Q l'_m (Q + g l'_m) =$$

$$= 118 - \frac{85 \times 165.5}{8 \times 118^2 \times 1\,000} 20 \times 500\,(20 + 0.0152 \times 500) =$$

$$= 83.2 \text{ kN}$$

(2) By the calculation of this Eq. (6), we will get the size of the load causing breakage of the skyline:

$$\frac{E_l S l'_m}{8F_H^2 L'} Q_m^2 + \frac{E_l S g l'^2_m}{8F_H^2 L'} Q_m + F_0 - F_H = 0$$

$$\frac{85 \times 165.5 \times 500}{8 \times 259.8^2 \times 1\,000} Q_m^2 + \frac{85 \times 165.5 \times 0.0152 \times 500^2}{8 \times 259.8^2 \times 1\,000} Q_m +$$

$$+ 83.2 - 259.8 = 0$$

$$0.013 Q_m^2 + 0.099 Q_m - 176.6 = 0$$

$$Q_m = 112.7 \text{ kN} \approx 11.3 \text{ t}$$

The skyline will break by the load of 11.3 t.

Situational model No. 3

The cable forwarding equipment has one field with the skyline fixed at both ends and in horizontal position, $L' = 300$ m. The skyline has 114 wires, type SEAL, construction 6(1 + 9 + 9) + d49, STN 02 4341, $\Phi = 16$ mm, $S = 115$ mm^2, $F_H = 180.6$ kN, $g = 1.06$ kg/m. The weight of the load $Q = 1.5$ t.

Solution:

(1) By using the surety factor $n = 2.2$, we will get the following allowed skyline tension:

$$F_m = \frac{F_H}{n} = \frac{180.6}{2.2} = 82.1 \text{ kN}$$

(2) We will use $E_l = 110\ 000$ MPa = 110 kN/mm^2. Further:

$$F_0 = F_m - \frac{E_l S}{8F_m^2} Q\,(Q + g l'_m) = 82.1 - \frac{110 \times 115}{8 \times 82.1^2} 15 \times$$

$$\times (15 + 0.0106 \times 300) = 18\ kN$$

(3) The size of the load to break the skyline:

$$\frac{E_l S}{8F_H^2} Q_m^2 + \frac{E_l S g l'_m}{8F_H^2} Q_m + F_0 - F_H = 0$$

$$\frac{110 \times 115}{8 \times 180.6^2} Q_m^2 + \frac{110 \times 115 \times 0.0106 \times 300}{8 \times 180.6^2} Q_m +$$

$$+ 18 - 180.6 = 0$$

$$0.05 Q_m^2 + 0.15 Q_m - 162.6 = 0$$

$$Q_m = 55.5 \text{ kN} \approx 5.6 \text{ t}$$

The skyline will break by the load of 5.6 t.

CONCLUSION AND DISCUSSION

The analysis based on situational models has shown that the skyline will break as a result of several fold excess of the safe working load. Our analyses have proved that this excess must be at least 3.5-fold. The maximum weight of the load which will cause breaking the skyline is so great that we can eliminate with certainty the hooking of such a load of logs to the carriage in the operation. This demonstrates the appropriateness of the theory used in the forestry practice for designing workplaces with the forest cableways in Slovakia and the Czech Republic, and confirms the necessity to design a project before a particular cableway system is built.

Our analysis also implies the importance of keeping the skyline in good condition – lubrication, control of corrosion, broken wires, wear and tear, deformation faults, etc. (Figure 2). All the above factors significantly reduce the carrying capacity of the skyline and can lead to its destruction even at a small excess of the rated weight of the load. In order to prevent accidents, it will be necessary to pay an adequate attention to periodical checks and the tests of the cable devices.

In conclusion, we would like to draw the attention to an important principle of safety work. Dynamic stresses are very dangerous. They can originate as results of:

– drag during drawing-up and skidding of the load
– starting up and braking
– vibrations of the cable

These can greatly exceed static stresses, while our calculations take into consideration only the static

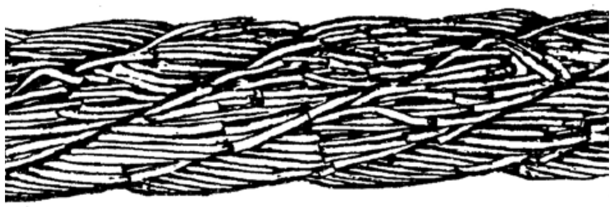

Figure 2. Steel rope with a large number of wires; great risks of breakage of the skyline by load

stress. The dynamic stress is only included in the safety coefficient. For this reason, it is important to operate cableways smoothly, without pulling and jerking, swinging of the load, etc.

References

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Received for publication February 2, 2007
Accepted after corrections November 18, 2008

Abstrakt

Štollmann V., Ilčík Š. (2009): **Posúdenie súčasnej teórie projektovania lanovkových trás na základe miery nebezpečenstva pri preťažení.** Res. Agr. Eng., **55**: 35–38.

Článok sa zaoberá bezpečnosťou práce a technických zariadení pri sústreďovaní dreva lesníckymi lanovkami. Analyzuje vhodnosť súčasnej teórie používanej pri projektovaní lanovkových trás z hľadiska bezpečnosti z titulu preťaženia neprimerane veľkým nákladom. Analýza vykonaná pomocou situačných modelov ukázala, že nosné lano sa roztrhne pri niekoľkonásobnom prekročení menovitej nosnosti. Hodnota kritického bremena je minimálne 3,5- násobkom menovitej nosnosti. Získané výsledky potvrdili, že v súčasnosti používaná teória pri projektovaní lanovkových trás je správna.

Kľúčové slová: lanovky lesnícke; bezpečnosť technických zariadení; bezpečnosť práce

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