

Oscillation Effects of Ropeways Caused by Cross-Wind and Other Influences

Klaus Hoffmann

University Professor
Vienna University of Technology
Faculty of Mechanical and Industrial
Engineering

Ropeways are widely used for public transport as well as for transportation of goods in mountain resorts and also in urban areas. Safety engineering aspects of ropeways are always basic criteria which call for special attention during the planning phase, initial operation and require routine and periodic checks. In this context, the question of cross-oscillation stability of ropeways is of particular importance.

Not only strong crosswinds result in unacceptable cross-inclination of the gondola; there are also observations that substantial cross-oscillations of cabins are discernible during very different wind conditions and wind directions – even in calm weather conditions without strong crosswinds. These effects have been observed on ropeways as well as on chairlifts. The presentation reports on some recent investigations carried out at the Institute for Engineering Design and Logistics Engineering, Vienna University of Technology. Beside problems with cross-oscillations, this paper also supplies information about the dynamic effects of track rope breaking. In the first section of the paper some information concerning the system development including the historical aspect is presented.

Keywords: aerial ropeways, funiculars, cable car, crosswind, oscillations.

1. INTRODUCTION

Ropeways are used for the transport of goods or passengers, whereby the passengers or goods are conveyed or drawn in cars by means of a towing device. The cars are borne by one or more ropes or a track and movement is controlled by one (or two) rope(s).

This paper is subdivided into two parts. In the first part, both a historical overview and a brief description of the various systems of aerial ropeways and funiculars are presented. The second part deals with recent investigations concerning cross-oscillation and some other dynamic effects.

2. HISTORICAL OVERVIEW

The transport of men and goods by means of cable-drawn transport systems was known even in ancient times. Early Chinese historical drawings demonstrate that this principle was already in use very early for material transport. The ropes used were made of plant fibres, e.g. bamboo fibres. Figure 1 shows the earliest known picture of passenger transportation in South China from 250 B.C. [1]. In the Middle Ages and at the start of the modern age, ropeways were used to transport goods and building materials faster and in larger quantities to building sites.

During the course of the Industrial Revolution there was a great need to develop more efficient means of

transport. Only with the invention of the steel cable by the German mining official Albert in 1834 did a period of lively development of the various cable-drawn transport systems begin.

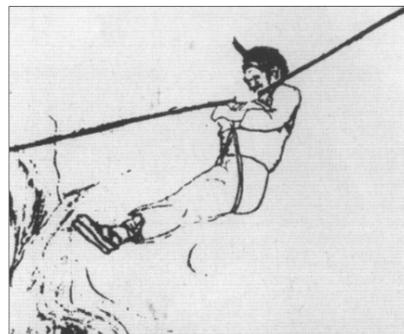


Figure 1. Brush drawing of a Chinese aerial ropeway dated 250 B.C. [1]

While initially development mainly focused on funicular railways such as the Cable Car Line in San Francisco, constructed in 1872, later interest turned to aerial ropeways, which only came into operation for passenger transport shortly before 1900.

More information about the development during the centuries can be found in [1-3].

3. ROPEWAY – SYSTEMS

Various technical systems have evolved over the decades. For example, more recent systems can be classified according to the type of track (carrier) used. Figure 2 shows an overview of the various systems, which are naturally in use with very varying frequency [3]. In addition, inclined lifts are intrinsically a modified form of funicular railway, but are subject to lift regulations and therefore cannot be directly regarded as funiculars.

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Correspondence to: Dr Klaus Hoffmann
Faculty of Mechanical and Industrial Engineering,
Institute for Engineering Design and Logistics Engineering
Getreidemarkt 9, A-1160 Wien, Austria
E-mail: hoffmann@ikl.tuwien.ac.at

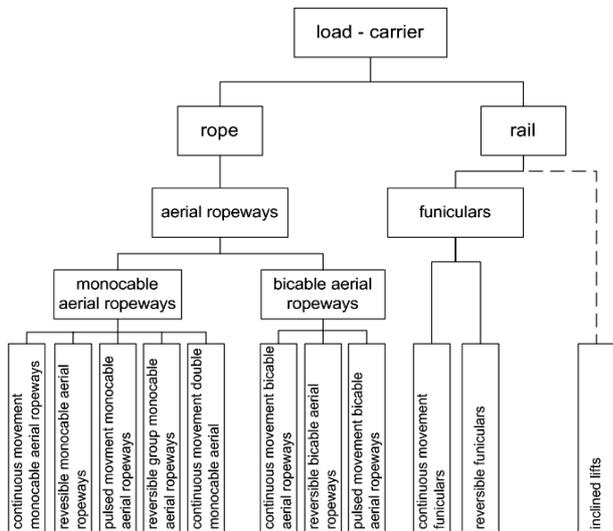


Figure 2. Classification of ropeways

3.1 Aerial ropeways

The main difference between continuous movement monocable aerial ropeways and bicable aerial ropeways is simply the number of rope systems. While with a monocable ropeway one or two ropes assume the carrying and hauling function (carry-hauling cable), with a bicable aerial ropeway the cars are carried by one or more ropes (track ropes) and moved by a further rope system (haul rope).

Both the monocable aerial ropeways and the bicable aerial ropeways are equipped with operationally releasable clamping devices. In the station, the cars are separated from the haul rope, decelerated and guided onto an overhead monorail which leads the cars through the embarkation and disembarkation area at low speed. In mountainous regions, continuous movement monocable aerial ropeways are very commonly used. One example is shown in Figure 3. The mode of operation of detachable bicable aerial ropeways is as described in Figure 4.



Figure 3. Monocable ropeway – Kitzsteinhorn, Austria [4]

As the high carrying capacity is independent of track length and intermediate stations along the route are easy to implement, this ropeway system is admirably suitable for covering long distances not only in touristic developed areas but also in inner urban areas.

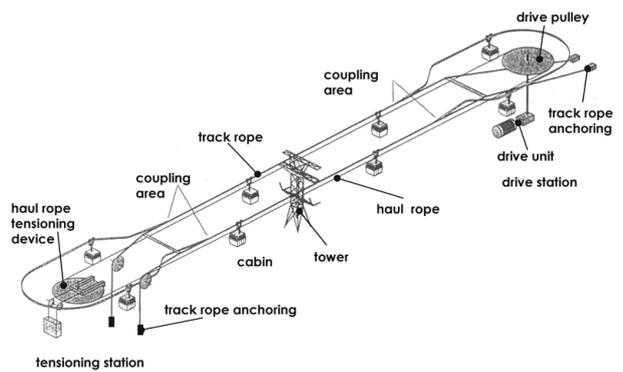


Figure 4. Scheme of a detachable bicable aerial ropeway

If particularly wide distances have to be spanned, two parallel supporting cables are used, through which particularly high wind stability is achieved. A widely-acclaimed example of a bicable areal ropeway with three ropes (two track ropes + 1 haul rope) is presented in Figure 5.



Figure 5. 3S Peak 2 Peak – Whistler, British Columbia, Canada [4]

A special system of a monocable aerial ropeway with two ropes which assume the carrying and hauling function (carry-hauling cable) was recently developed by the Austrian company Doppelmayr. The so-called FUNITEL [4] is designed with a double loop cable so that in each direction or “lane”, the cabins are secured to two carry-haulage cables by releasable clamping devices (Fig. 6). As a result of the two cables which are strung at a relatively large distance from one another, the system is very stable in windy conditions and is therefore of great benefit in high mountain regions. An example of this is illustrated by Figure 7.

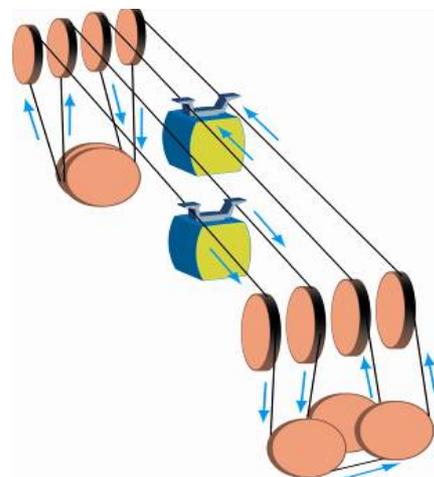


Figure 6. FUNITEL – rope system [4]

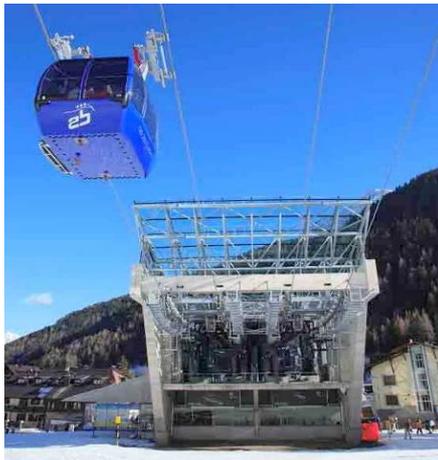


Figure 7. Funitel – Galzig, Austria [4]

3.2 Reversible funiculars

Figure 8 shows the basic layout of a funicular railway in shuttle operation. Two cars are linked together by a haul rope and this moves them along the route. The cars travel on tracks using steel rollers on rails. The drive unit for the system is housed in one of the stations. Passengers embark and disembark when the car is stationary. Funiculars are normally designed as single-track systems. For this reason, a passing point is provided in the middle of the route.

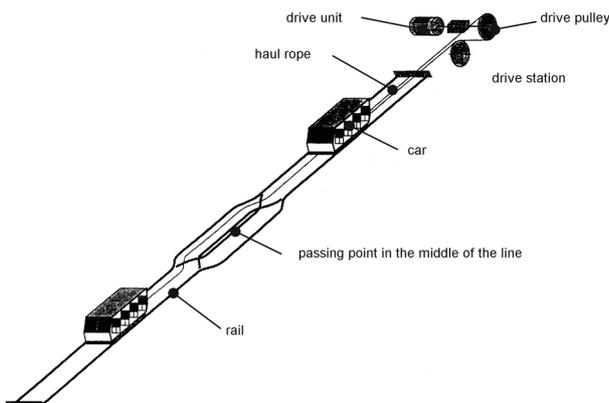


Figure 8. Layout of a reversible funicular

A very interesting example of a reversible funicular, which was recently put into service, is the Hungerburgbahn in Innsbruck, Austria. The Leitner construction company, Sterzing, Italy [5] provided a partially-underground funicular railway from the Innsbruck old city to the Hungerburg. The architectural designs were drawn up by the world-famous architect Zaha Hadid, who was also responsible for the design of the new Bergisel ski jumping hill. Figure 9 shows the interesting design of a station building.

The layout of the line of the funicular railway starts out almost on the level at the Congress Centre, but ends up very steeply at the Hungerburg (mountain) station. A special development for this feature was the automatic inclination correction system for funicular carriages with five passenger cabins (Fig. 10). The inclination correction system ensures that passengers can embark and disembark comfortably from a horizontal passenger compartment at all stations. The two carriages of the



Figure 9. Station design by star architect Zaha Hadid [5]

funicular railway, each with a capacity of 130 persons, will be able to transport up to 1,300 p/h in each direction.



Figure 10. Carriage of the Hungerburg funicular railway [5]

One important alternative for passenger transport over short or medium distances (up to several kilometres) is the cable liner shuttle. This is a train that normally consists of several coupled single cars, which is moved between the stations on a horizontal route by a haulage rope. The cars normally roll along on steel rails, but there are designs where the cars are supported on air cushions. Such cable liner shuttles are often used on airports as a link between different terminals (Fig. 11).



Figure 11. Airport Link, Pearson International Airport – Toronto [4]

3.3 Continuous movement funiculars

In contrast to shuttle operation, a funicular in circular operation requires two completely separate tracks. The cars are coupled to the haulage rope at specific distances by normal releasable clamping devices. Placement of stations along the line is possible without technical

limits, according to local service requirements. In the stations the cars are automatically detached from the cable and moved by an independent conveyor system.

This ropeway system is particularly suitable as a means of transportation for small and medium sized cities, for connections from public car parks to commercial centres, or between centrally-located train or metro stations and peripheral suburbs. It is also known as an automated people mover, or APM system.

Such a system was put into operation in 2008 in the Italian city of Perugia, linking the Pian di Massiano district with the historic city centre located on a hill [5]. With a difference in elevation of 160 m, the route is 3 km long, of which 1.5 km is on line support structures and more than 1 km passes through tunnels. A total of 25 cars are in service between seven stations, each with space for 50 passengers. This system can convey up to 3,000 passengers at a maximum speed of 25 km/h. Figure 12 shows a part of the track.



Figure 12. Perugia Minimetro – track [5]

4. INVESTIGATIONS OF OSCILLATION EFFECTS ON ROPEWAYS AND CHAIRLIFTS

Safety engineering aspects of ropeways are always basic criteria which call for special attention during the planning phase and initial operation, and require routine and periodic checks. Just recently major efforts have been made to achieve further improvements in system security. In this context, the question of cross-oscillation stability of ropeways is of particular importance for ropeway manufacturers and the responsible authorities as well as the ropeway operators.

Not only strong cross-winds result in unacceptable cross inclination of the gondola but there are also observations that substantial cross-oscillations of cabins are discernible during very different wind conditions and wind directions – even with calm weather conditions without strong cross-winds. These effects have been observed on ropeways as well as on chair lifts.

At present, no meaningful measuring results are available concerning the correlation between the real cross angle of the gondolas and wind speed and wind direction. Only observations of the operating staff have been noted without strong correlations between the different physical parameters. For this reason, some years ago the Institute for Engineering Design and Logistics Engineering started a research project to acquire better information concerning correlations between oscillation

and wind situation. Both measurements and numerical calculations were performed.

4.1 Measuring method for bicable ropeways and chair lifts

Bicable ropeways

For the first step a measurement system was developed and patented [6]. For applications on bicable ropeways a 2d-ultrasonic anemometer is used for measuring wind speed and direction. A rotation speed sensor enables the determination of the speed and position in the span of the carrier. The cross-oscillation of the carrier is measured by an inclinometer which is positioned near the approved centre of rotation (contact point between running carriage and the track rope). Two aluminium boxes containing the stand-alone data acquisition system and the batteries are located in the passenger compartment [7].

For the first time, the system was used for the acquisition of the oscillation effects of the gondolas (Fig. 13), basically analysing crosswind stability of bicable ropeways during gusty wind conditions [8].

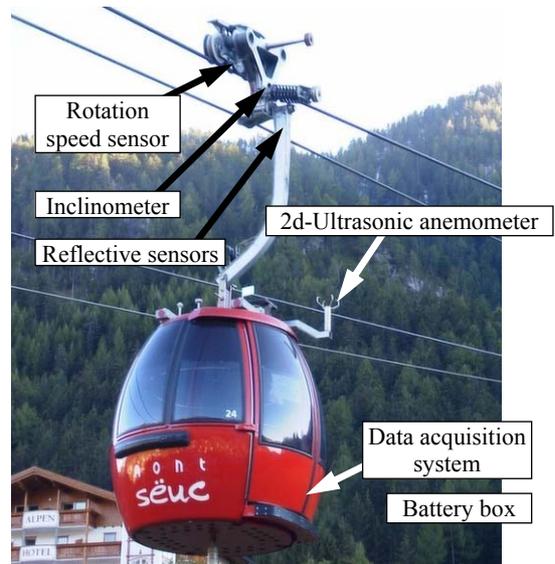


Figure 13. Arrangement of the measuring sensors on the carrier of a detachable bicable ropeway [9]

The second application of the mobile measurement system was to investigate the cross-oscillation of the gondolas in calm weather conditions, where vortex effects are involved [10,11]. Some results are described in Section 4.3.

Chairlifts

In cooperation with the company Doppelmayr, the measurement system was improved and adapted for chair lifts. The most significant improvements have been: 3d-wind sensor, additional inclinometers and an acceleration sensor (Fig. 14).

Due to the sag of the traction rope, the chair oscillates together with the rope around an unknown centre of rotation. This fact is different to the oscillation of bicable ropeways. For checking the accuracy and reliability of measurements, a completed chair was mounted in the laboratory of the institute and equipped

with the full measuring system. A principal drawing with the geometric positions of the inclinometers which measure the accelerations in their sensitive axis is shown in Figure 15.

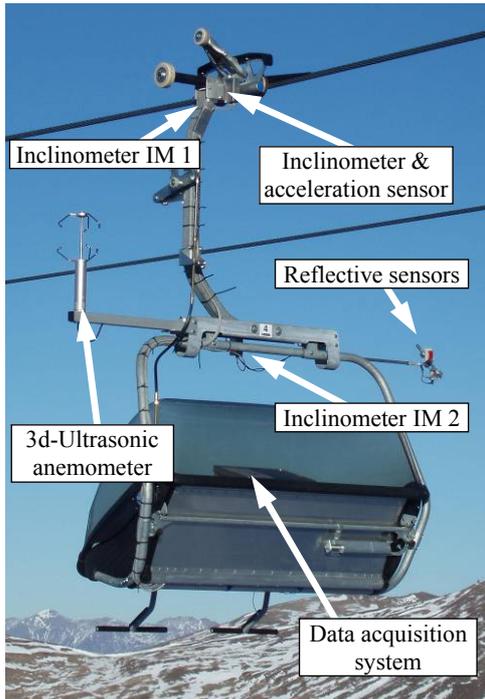


Figure 14. Arrangement of the measuring sensors on a chair [9]

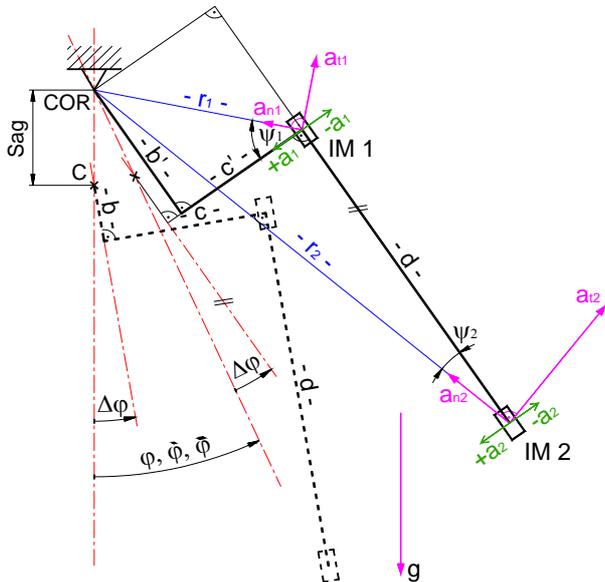


Figure 15. Geometric position of the inclinometers in static condition and inclined state as to the unknown centre of rotation (COR) [9]

The angle $\Delta\varphi$, in the resting state ($\varphi = 0$), represents a small inclination of the chair in relation to clamp C where the chair is fixed to the rope. If the chair is inclined, the position of both sensors can be described to the unknown centre of rotation (COR) by rectangular triangles and those angles (ψ_1, ψ_2). The acting acceleration upon each inclinometer (a_1, a_2) is the resultant of the gravity, the normal and tangential acceleration of the pendulum motion (1).

Assuming a harmonic oscillation both signals are:

$$\begin{aligned} a_1 &= g \sin(\varphi + \Delta\varphi) + r_1 \ddot{\varphi} \sin \psi_1 - r_1 \dot{\varphi}^2 \cos \psi_1 \\ a_2 &= g \sin(\varphi + \Delta\varphi) + r_2 \ddot{\varphi} \cos \psi_2 - r_2 \dot{\varphi}^2 \sin \psi_2. \end{aligned} \quad (1)$$

The difference of these measured accelerations is given in (2), where the geometric correlations were taken into account.

$$a_1 - a_2 = -d\ddot{\varphi}. \quad (2)$$

Neither the angular velocity $\dot{\varphi}$ nor the unknown distances b' and c' between the oscillation axis and the inclinometer IM 1 are included in (2). The second differential derivative of the cross-oscillation angle φ is:

$$\ddot{\varphi} = -\omega^2 \varphi \quad (3)$$

with:

$$\omega = \frac{2\pi}{T}. \quad (4)$$

Using the formulas (2), (3) and (4) the oscillation angle becomes:

$$\varphi = \frac{a_1 - a_2}{d} \cdot \frac{T^2}{4\pi^2}. \quad (5)$$

To achieve accurate measuring results it is necessary to know the exact value for T . This value is determined by averaging over some periods of laboratory oscillation test results.

Evaluation of wind data

The output signals of the anemometer are the components of the wind velocity vector in relation to its local coordinate system. It is necessary to refer the measurement results on a global coordinate system (see Figure 16).

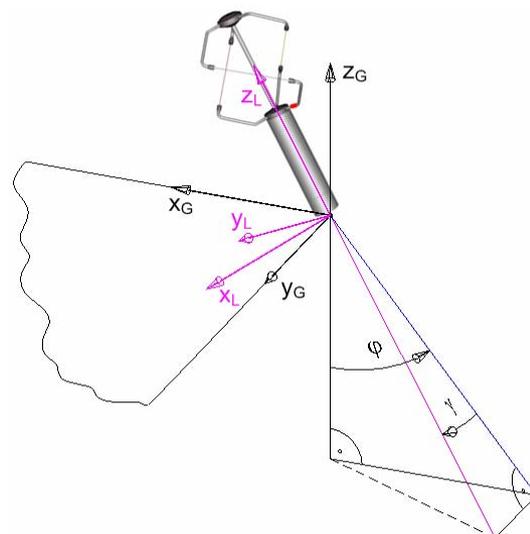


Figure 16. Coordinate transformation: local to global system (cross-oscillation φ , longitudinal oscillation γ) [9]

The transition from the global to the local system is carried out by two partial rotations: At first the coordinate system is turned around its y_G -axis with the cross inclination angle φ and secondly about the x_L -axis with the longitudinal angle γ .

From the combination of these partial rotations follows the transformation matrix (6) which enables a conversation of the measured anemometer values.

$$\underline{v}_G = \begin{bmatrix} \cos \varphi & \sin \varphi \cdot \sin \gamma & \sin \varphi \cdot \cos \gamma \\ 0 & \cos \gamma & -\sin \gamma \\ -\sin \varphi & \cos \varphi \cdot \sin \gamma & \cos \varphi \cdot \cos \gamma \end{bmatrix} \cdot \underline{v}_L \quad (6)$$

The three-dimensional wind direction has to be calculated for each octant separately and is defined by the horizontal angle (azimuth) and the vertical angle (elevation) according to Figure 17.

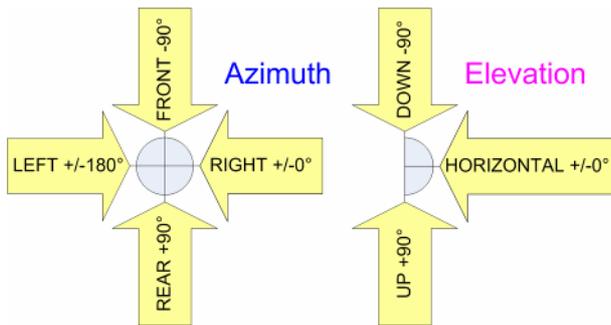


Figure 17. Wind rose

4.2 Measuring results for bicable ropeways and chair lifts

Bicable ropeway

The mobile measuring system was used on a detachable bicable ropeway in St. Ulrich, Italy. Figure 18 shows the cross inclination of the carrier and the wind speed depending on the horizontal position of the measuring carrier in the span, beginning at the lower tower 1 and ends in the middle of the span. The diagram shows the slowly increasing cross-oscillation of the carrier as a result of the higher crosswind. In addition, the full wind speed, wind direction and the driving speed of the carrier are also shown in the diagram.

Chairlift

Reports of the operating staff of a specific chairlift pointed out that an air stream against the back face of the chair can cause a considerable cross-oscillation. For

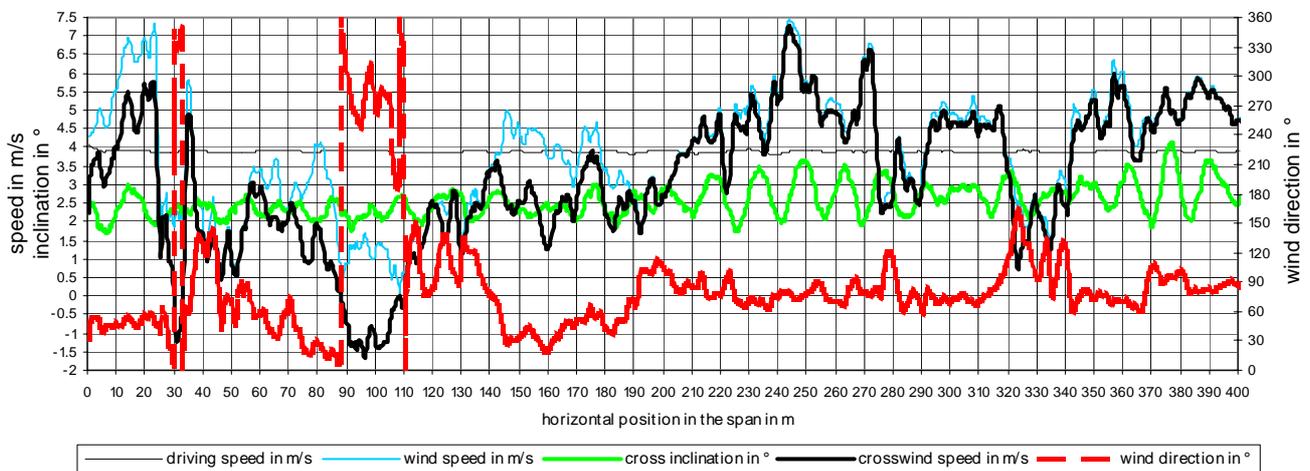


Figure 18. Example of measuring results of field test of a bicable ropeway [8]

this reason measurements were performed on this specific chairlift.

On occurrence of a gentle breeze of about 4 m/s down into the valley the chair passed the upper station and was stopped in the following span. Due to the braking action, the chair performed a longitudinal oscillation that faded away rapidly to an almost constant inclination of about 0.7°. At the same time the chair also started a cross-oscillation of about ±2.5° for several minutes stimulated by the as shown in Figure 19. These increasing cross-oscillations during a standstill of the chairlift leads one to suppose that vortex effects or self-excited oscillations could be involved. Investigations to clear up these effects are still going on including measurements and simulations.

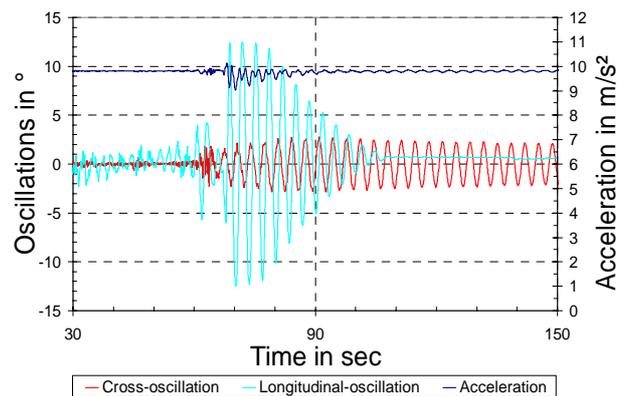


Figure 19. Measuring result of field test of a chair lift (wind directions: azimuth ~110°, elevation ~ -10°) [9]

4.3 Investigation of vortex excited cross-oscillation of bicable ropeways

Observations and reports of various aerial ropeways by operating personnel have time and again shown significant cross-oscillations of the cabins to occur and build up even during meteorologically calm periods in the absence of wind. This was described most recently in the case of bicable ropeways which were equipped with barrel-shaped cabins (circular cross-section). These oscillations always appeared only at reduced operating speeds.

Similar behaviour has been observed in the past for ropeways with cylindrical cabins; turbulence was clearly identified as the cause of these oscillations [12]. This led

to the speculation that here, too, the forces which excite the oscillations are the result of periodic vortex forces acting on the cabin due to the relative wind. In order to confirm these suspicions, this was examined from a theoretical point of view, on the one hand, and by measurements taken of two different bicable ropeways while in operation, on the other [11]. As it is described later in greater detail, computer simulations have been carried out in the meantime regarding the behaviour of the cabins when subjected to vortex effects [13].

The measurements were made with equipment as illustrated in Figure 13. Figure 20, for example, shows the values measured in relation to elapsed time while travelling over a valley at a reduced speed of 2.5 m/s. Significant increases in the amplitude of the cabin oscillations are discernible for the valley crossing between towers 2 and 3. In comparison, no increase in the amplitude of oscillations can be detected at a rated travelling speed of 6 m/s (Fig. 21).

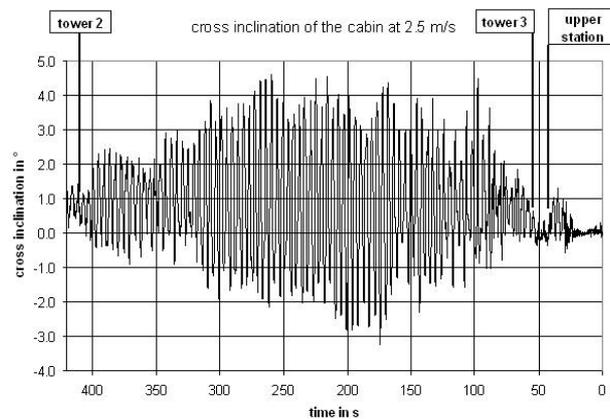


Figure 20. Measuring result of drive down, velocity 2.5 m/s

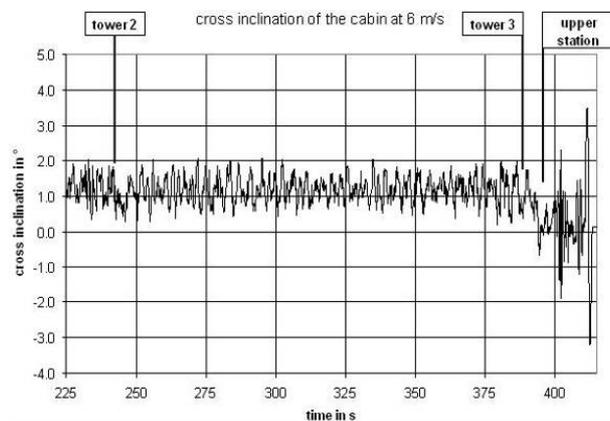


Figure 21. Measuring result of drive down, velocity 6.0 m/s

The maximum swing amplitudes measured in conditions of virtually zero wind speed and for different travelling speeds and thus different horizontal relative airflow speeds which are caused by the airstream reach distinct peak values at approximately 2.5 m/s (see Figure 22). However, this is also the area in which the theoretically determined vortex caused excitation frequency and the measured characteristic frequency of oscillations perpendicular to the longitudinal axis of the ropeway cabin correspond.

By means of these measurements performed on a bicable ropeway and a comparison with theoretical results, it was possible to prove that the observed

oscillations are indeed caused by vortex excitation. A remedy to reduce or largely prevent these cross-oscillations which build up slowly can only be created by avoiding travelling in the critical speed zone for longer periods of time or by influencing the break-off frequency, e.g. by equipping the cabins with suitable spoilers.

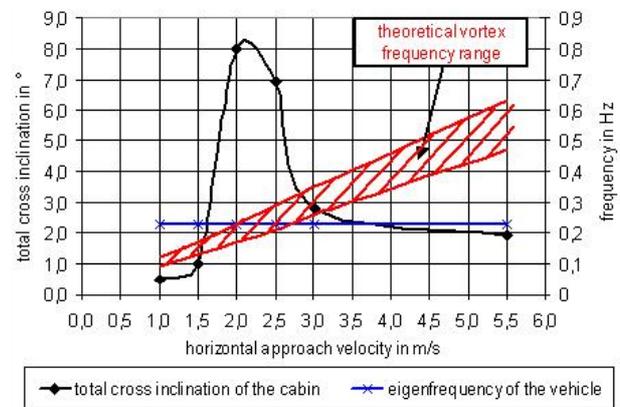


Figure 22. Amplitude of cross-oscillation and vortex frequency as functions of relative airflow velocity [11]

4.4 Simulation of cross-oscillation of bicable ropeways

In addition to measurements a mathematical model for simulation was developed in order to gain a better understanding of the cross-wind behaviour of bicable ropeways. This model was established for a numerical dynamic simulation of the movement of gondolas with stiff connections, “hanger-cabins”, due to arbitrary cross-wind loads acting at a section of the studied span of the ropeway. With this modelling system, extensive calculations of the oscillation behaviour of the gondolas and investigations of the whole ropeway system were carried out [14].

Mechanical model

The design and mode of operation of a detachable ropeway is shown in Figure 4. It can be assumed that the cross-oscillation of the cabins and the movement of the cables in one span between two towers are not transmitted to the next span. In making this assumption, numerical studies can be reduced to one span (Fig. 23) of the track.

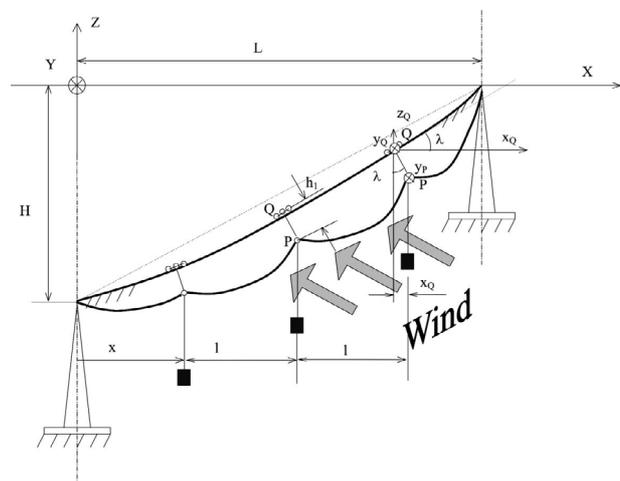


Figure 23. Scheme of one span of a bicable ropeway

In normal operation, the cabins move along the span with constant velocity. The trajectory along the span follows the elastic line of the track cable. The horizontal tension force and the dead weight of the cable and the cabins influence this line. For this simulation, it can be assumed that the elastic line of the track cable is constant and fixed in a vertical direction. This means that there is neither vertical oscillation effects nor swinging of the cabins in the $x - z$ plane.

Every gondola is modelled as a mechanical system with two degrees of freedom (DOFs) – rotation angle, φ , and horizontal movement of the connection between the track cable and the gondola, y_T (Fig. 24).

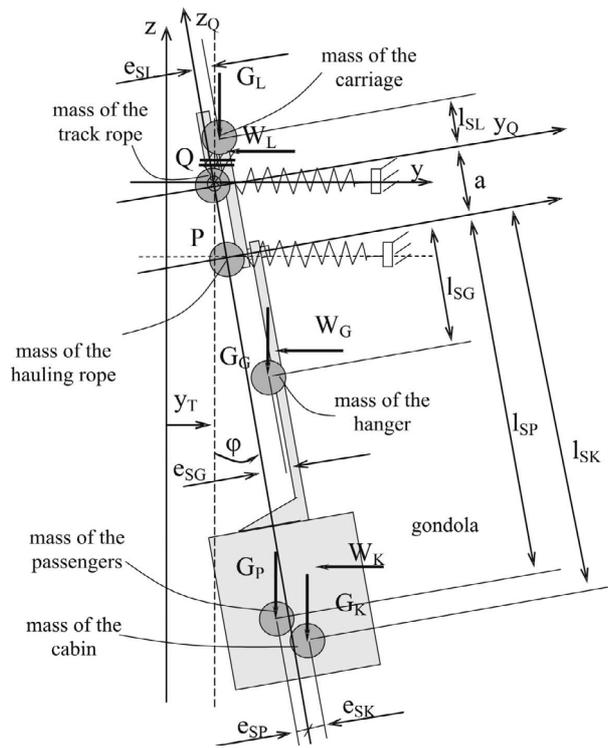


Figure 24. Model of a gondola

In accordance with the relation between gondola distance l , and the distance between the towers L , a certain number of gondolas are moving in the span. In this technical system, all damping forces are very small. If the damping forces for every gondola are neglected, the differential equation for both degrees of freedom is as follows:

$$\begin{bmatrix} A & B \\ B & C \end{bmatrix} \begin{Bmatrix} \varphi_i \\ \dot{y}_{Ti} \end{Bmatrix} = \begin{Bmatrix} f_1 \\ f_2 \end{Bmatrix} \quad (7)$$

where: φ_i is angle of rotation of gondola number i round axis x_Q and y_{Ti} is horizontal coordinate of the connection between the gondola number i and the track rope (point Q).

In equations (7) A, B, and C are functions of the masses and geometric parameter according Figure 24.

The generalized forced f_1 and f_2 including wind forces W_L , W_G , W_K and the elastic forces from the ropes R_{Ti} and R_{Zi} are as well time dependent as position dependent functions.

Wind forces

The cross-wind loads are time dependent. For the

numerical simulation experimental data or mathematical functions can be used. In the presented model the wind loads are described as follows:

$$W_I(t) = \begin{cases} W_{MAX} \sin \frac{2\pi(t-t_{2n-1})}{T} & \text{if } t_{2n-1} \leq t \leq t_{2n} \\ 0 & \text{if } t_{2n} \leq t \leq t_{2n+1} \end{cases} \quad (8)$$

where

$$W_{MAX} = \frac{A_{WI} c_{WI} \rho V_{MAX}^2}{2} \quad (9)$$

The time dependency of the above-described mathematic function of wind loads is shown in Figure 25. It can be assumed, based on experimental data, this function is a half period sin-function combined with periods without wind. The periodic forces are acting on a certain part of the span.

Generalized graph of the wind load

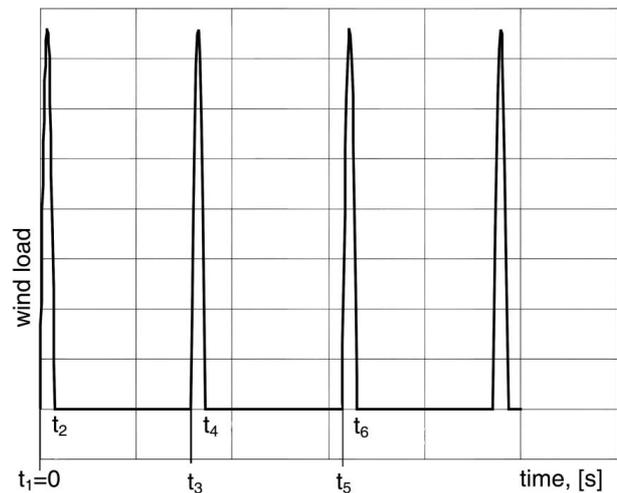


Figure 25. Generalized graph of the wind load as a mathematical function of time

The horizontal length of the wind influence (Fig. 23) depends on the geographic situation of the ropeway and is established as:

$$\Delta w_e = w_R - w_L .$$

That means that during the periodic time window

$$t_{2n} \leq t \leq t_{2n+1}$$

the wind load can act as a line load to both cables and as a single force to the cabin, if the cabin is moving during the certain time window within the wind field Δw_e .

Elastic forces

Regarding the theory of cables [15], the horizontal deflection of the track cable and the haul cable caused by wind forces and elastic forces at the contact points P and Q can be put together. Elastic forces, with which gondolas act over the cables, are calculated for each position of the gondolas at every integration step of the simulated movement.

Simulation results

All equations were solved using the program MATLAB1 and the toolbox SIMULINK1. Some simulation results are presented in [14]. As an example Figure 26 shows the time dependency of the first DOF (φ ...angle of rotation of the gondola) along the span.

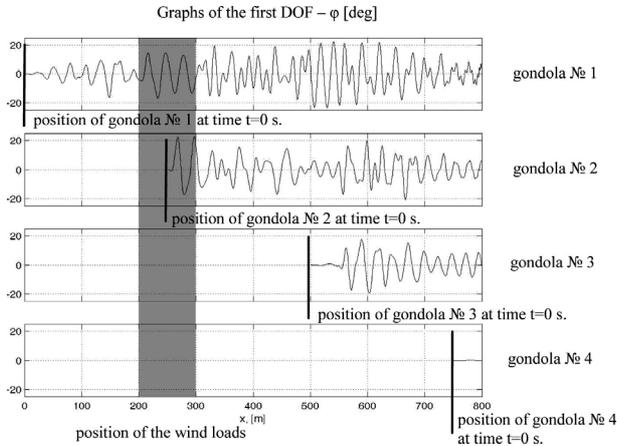


Figure 26. Functions of the first DOF of all gondolas along the span, with $w_L = 200$ m and $w_R = 300$ m

5. INVESTIGATIONS OF TRACK ROPE BREAKING

Another very powerful method to simulate transient processes is the use of multibody systems software. In the case which is dealt with in the following, the ADAMS[®] system was used. The transient behaviour of a cabin under braking was examined for a reversible bicable aerial ropeway with a double track rope [16]. Normally the vehicles of such aerial ropeways must be equipped with track rope brakes. Upon activation of the brake in an emergency (e.g. if the haulage rope breaks), very strong longitudinal oscillations may arise which could possibly result in the vehicle colliding with the track rope or with other ropeway components. Unacceptable load relieving on the track wheels may also occur; this could lead to derailment.



Figure 27. Cabin, reversible aerial ropeway – Corvatsch, Suisse [5]

In order to make predictions for a planned ropeway project, computer simulations like these are necessary. In a project carried out together with a manufacturer of

aerial ropeways [5], calculations were performed for a ropeway installation in Switzerland (Fig. 27).

Modelling of the vehicle

On account of the complexity of the vehicle structure and to reduce computing time, the model had to be greatly simplified. Figure 28 provides an overview of the multibody modelling of the vehicle.

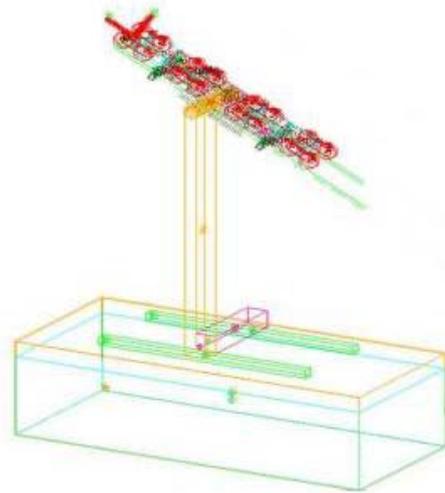


Figure 28. Model of the cabin, reversible aerial ropeway – Corvatsch, Suisse

Modelling of the breaking force

Braking systems are very often split up into two brake groups, whose braking forces come into effect at different rates and possibly also reach different maximum values (Fig. 29).

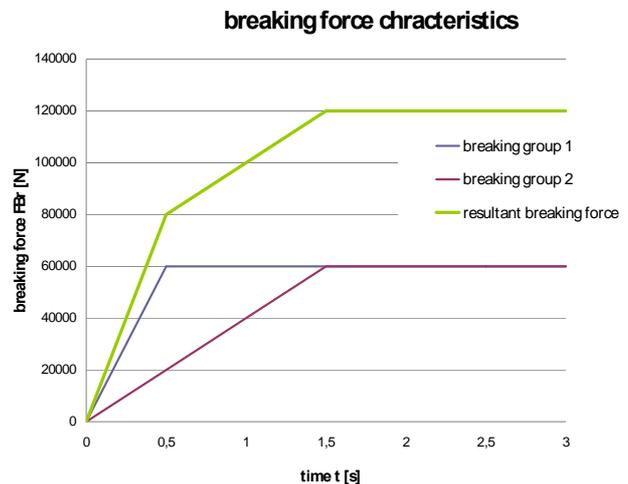


Figure 29. Time-dependent braking force

Parameter study

An extensive parameter study was carried out to ensure that the vehicles can be brought safely to a halt under any operating conditions with the brake parameters as selected (max. braking force, build-up time). Figure 30 shows an example of the calculated travelling speed in relation to the cabin load. The outcome is that slight collisions with the track rope can occur at these given parameters in the case of empty and half-full cabins.

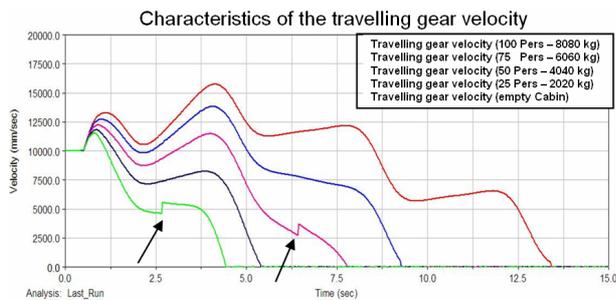


Figure 30. Travelling speed during the braking process with collision events [16]

6. CONCLUSION

Apart from a very brief historical overview modern developments in ropeway construction are of course the main focus of attention in this paper.

Modern passenger transport systems must meet high safety standards. In this connection, new research has been presented which examines the issues surrounding cross-oscillations of cable cars and chairlifts. The research was carried out using metrology equipment as well as with the aid of numerical simulation. A further safety issue in the case of reversible aerial ropeways is the track rope brake.

On the basis of these examples, it was demonstrated that analytical calculation methods (MATLAB, SIMULINK) as well as the multibody dynamics approach (ADAMS) can be successfully applied for numerical simulation.

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ЕФЕКТИ ОСЦИЛОВАЊА ЖИЧАРА КАО ПОСЛЕДИЦА БОЧНОГ ВЕТРА И ОСТАЛИХ УТИЦАЈА

Клаус Хофман

Жичаре се широко користе као средство јавног превоза, као и за превоз добара у центрима планинског туризма и урбаним срединама. Инжењерски аспекти безбедности жичара су увек основни критеријуми који захтевају посебну пажњу у току планирања, почетног пуштања у погон и захтевају регуларне и периодичне провере. У овом контексту, питање стабилности жичара услед бочних осцилација је од изузетног значаја.

Неприхватљиво нагињање гондоле није узроковано само јаким бочним ветром; наине, примећено је и да се значајне бочне осцилације кабине јављају током различитих временских услова и правца дејства ветра – чак и при мирним временским условима без значајног дејства бочног ветра. Ови ефекти су уочени како код кабинских жичара тако и код седешница. У раду су приказани резултати недавних истраживања која су спроведена у Институту за машинске конструкције и техничку логику Техничког Универзитета у Бечу. Осим проблема везаних за бочне осцилације, у раду су такође дати подаци о динамичким ефектима киданања вучног ужета. У првом делу рада дате су информације у вези са развојем система и историјским аспектима.