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Martin MANTIČ[1], Jozef KUĽKA[2], Melichar KOPAS[3], Eva FALTINOVÁ[4], Ján PETRÓCI[5]

SPECIAL DEVICE FOR CONTINUOUS DECELERATION OF FREIGHT CABLEWAY TRUCKS

Summary. This paper is focused on the design of an auxiliary braking device for freight cableway trucks. The device provides continuous deceleration for the trucks before they arrive at the unloading station. It presents an alternative to manual deceleration, which poses safety hazards and is therefore a less suitable option. The design distinctly accommodates the spatial disposition at the unloading station and involves minimal interventions to the existing steel structure. Above all, it aims to increase safety by eliminating the need for human input in the process of decelerating the trucks before they are emptied. The proposed design solution was successfully applied in a real operation.
Keywords: cableway, truck, friction brake, braking force, design solution

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[1] Faculty of Mechanical Engineering, Technical University of Košice, 9 Letná Street, 042 00 Košice, Slovakia. E-mail: martin.mantic@tuke.sk.
[2] Faculty of Mechanical Engineering, Technical University of Košice, 9 Letná Street, 042 00 Košice, Slovakia. E-mail: jozef.kulka@tuke.sk.
[3] Faculty of Mechanical Engineering, Technical University of Košice, 9 Letná Street, 042 00 Košice, Slovakia. E-mail: melichar.kopas@tuke.sk.
[4] Faculty of Mechanical Engineering, Technical University of Košice, 9 Letná Street, 042 00 Košice, Slovakia. E-mail: eva.faltinova@tuke.sk.
[5] Faculty of Mechanical Engineering, Technical University of Košice, 9 Letná Street, 042 00 Košice, Slovakia. E-mail: jan.petroci@tuke.sk.

1. INTRODUCTION

This paper focuses on the construction of an auxiliary device for material cableways. Cableways convey material in trucks pulled by a wire rope. Depending on whether the trucks move along ground rails or taut cables above the ground, either aerial cableways or cable railways are involved. Aerial cableways transport people and material over great distances or in an impassable terrain. The trucks move along taut cables suspended in air. The diversity of the terrain bears no influence on the function of the cableway, such that the space under it can be otherwise used. Aerial cableways can span valleys, mountains, rivers, roads and buildings. They are suitable for conveying both bulk material and unit loads [1, 8]. According to the construction type, there are bi-cable cableways, with a track cable and a haul rope, and mono-cable cableways, with a single cable used for both support and propulsion. Either circular or shuttle cableways according to the direction of movement [3, 4, 5]. Taking into consideration the above-mentioned facts concerning the cableway's construction, it is possible to say that one of the most important constructional parts of the cableway is simply the cable, which is designed as a steel wire rope. The steel wire rope is usually wound from six strands or it consists only of one strand and is constructed by laying several strands around a core. Two kinds of steel wire rope are applied in the case of a bi-cable cableway, i.e., the single-strand rope together with the six-strand rope. The single-strand rope fulfils a supporting function, while the main task of the six-strand rope is traction [6, 7].

The device on which this paper focuses involves a material cableway in a cement plant, which currently specializes in producing ground limestone and dolomites. It conveys limestone lumps from the quarry to the lime plant. It is a material aerial bi-cable circular system with a detachable grip for the truck. The concept behind the aerial bi-cable circular cableway is illustrated in the diagram in Fig. 1.

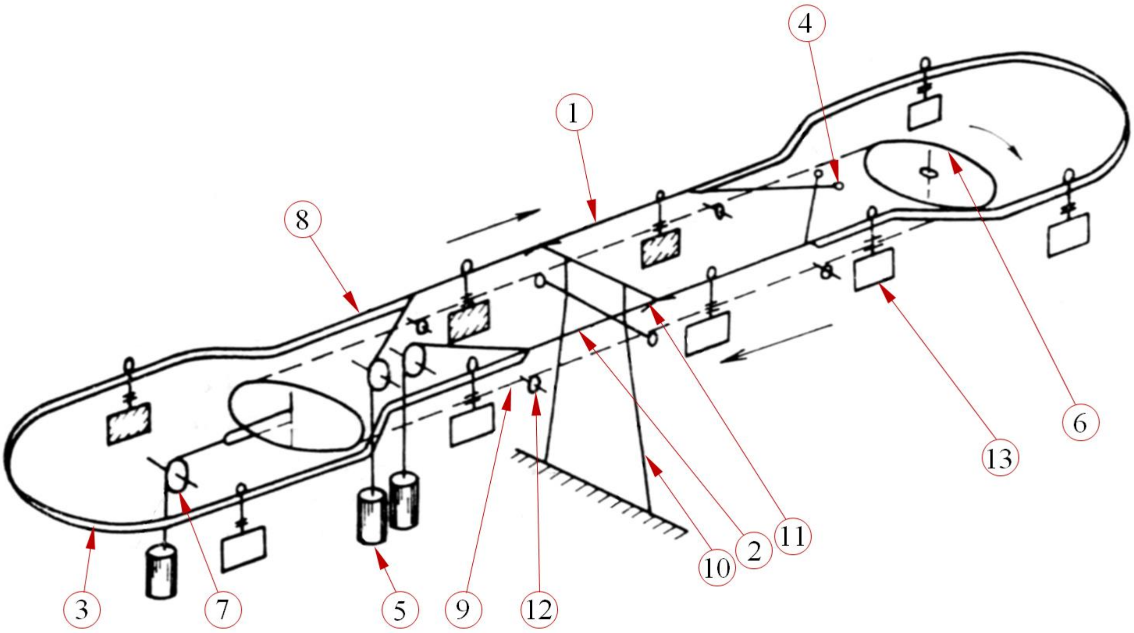

Fig. 1. Diagram of the aerial bi-cable circular cableway [2]
1 – track cable on the loaded side, 2 – track cable on the unloaded side, 3 – rail, 4 – track cable anchorage, 5 – track cable tensioning, 6 – drive, 7 – haul rope tensioning, 8 – attachment point, 9 – haul rope, 10 – support, 11 – saddle, 12 – haul rope sheave, 13 – load truck

The cableway was commissioned in 1948 and overhauled in 2005. Its transport capacity is 60 t/h. The bottom station is located at 370 m above sea level, while the top station is located at 660 m above sea level, meaning the cableway rises 290 m. There are 44 trucks, which service the cableway.

2. CURRENT SITUATION

The design presents a solution for the cableway's unloading station. When the trucks are detached from the haul rope, they roll along the gravity rail at 2.5 m/s by their weight to the point where they are decelerated in order to be emptied. Once unloaded, they roll by inertia to the point where they are reattached to the haul rope.

The trucks used to be decelerated by friction brakes, which created down pressure on the truck wheels between the rail and the steel load-carrying structure at the unloading station (Fig. 2).

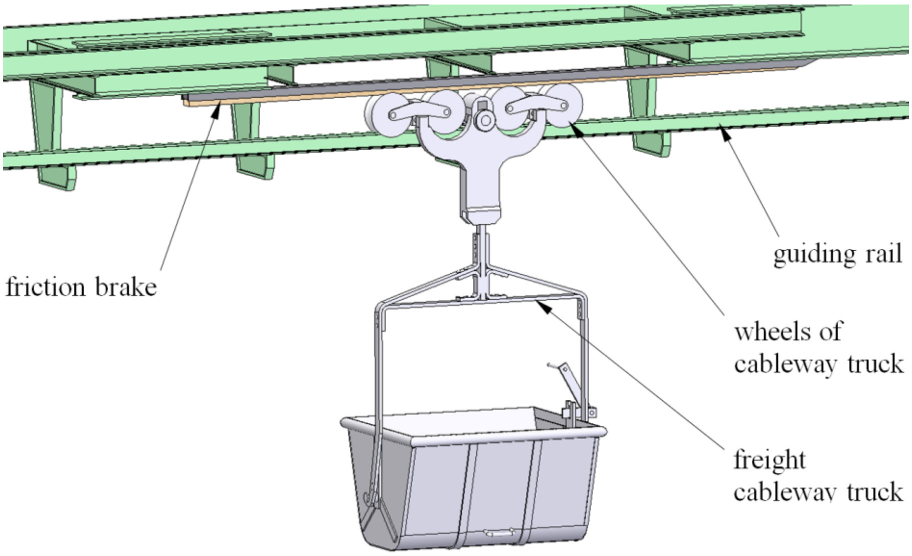

Fig. 2. Deceleration of a truck by friction brake

A wooden block was used as a friction element. This deceleration mode, however, was not effective enough, due to rapid wear to the braking element, as well as frequent damage (wood chipping) caused by the impact of moving trucks.

Fig. 3. Manual truck deceleration

Alternatively, the operating staff would decelerate the trucks manually before they were emptied (Fig. 3). This solution was effective, but it was inadequate due to the safety hazards it posed for the operators.

To eliminate these shortcomings, the operation has demanded a new conceptual solution design. It has to ensure the trucks are decelerated by a mechanical braking system without human input. The operating staff would only be responsible for emptying the decelerated trucks. Empty trucks must retain enough speed to keep rolling along the gravity rail to the point where they are reattached to the haul rope.

3. SOLUTION DESIGN

It is necessary to decelerate the trucks detached from the haul rope from 2.5 m/s to 0.5 m/s. The new solution assumes minimal interventions to the existing steel structure at the unloading station. It also needs to allow for the spatial constraints associated with its installation. The engineering design of the new solution is based on a principle of continuous deceleration of the trucks by using rotating wheels. Each wheel has a different frequency of rotation achieved by the interconnected toothed belts and reduction gears. Deceleration is ensured, due to the friction occurring between the truck wheels and the set of rotating wheels as their speed decreases (Fig. 4). Questions concerning dynamic phenomena, which occur during acceleration or braking, and mechanical losses are analysed in [9, 10, 11].

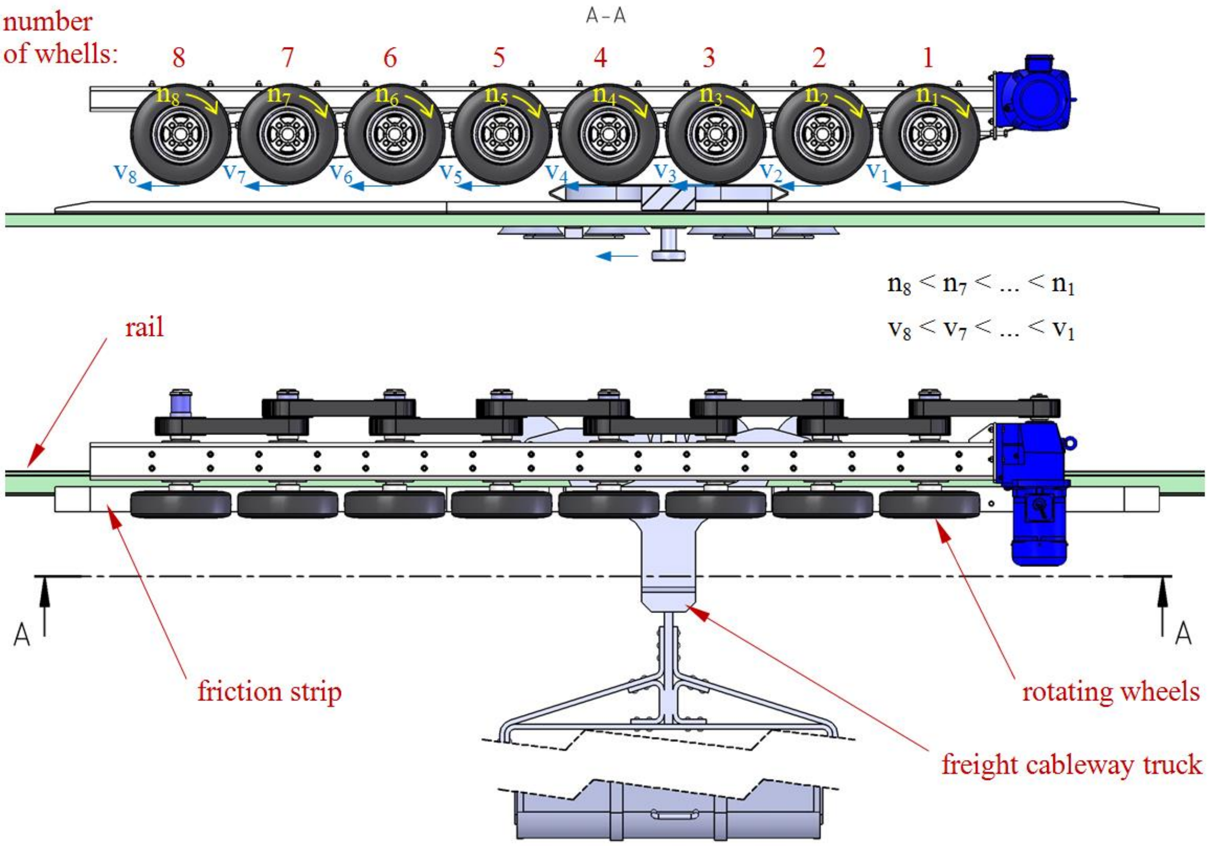

Fig. 4. Block diagram of the braking system

The toothed belts with the reciprocal meshing factor of 1.25 ensure the rotary motion of the wheels (Fig. 6). The meshing achieves gradual reduction in shaft revolutions (Fig. 5) and, consequently, in the circumferential speed from 2.5 m/s at the front wheel to approximately 0.5 m/s at the back wheel (Fig. 6).

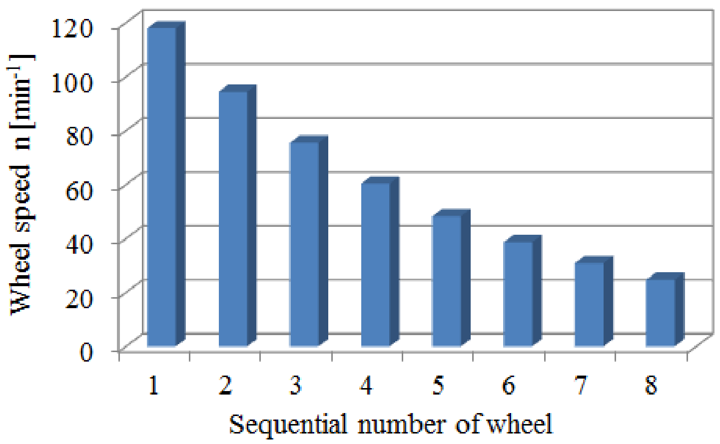

Fig. 5. Speeds of rotating wheels

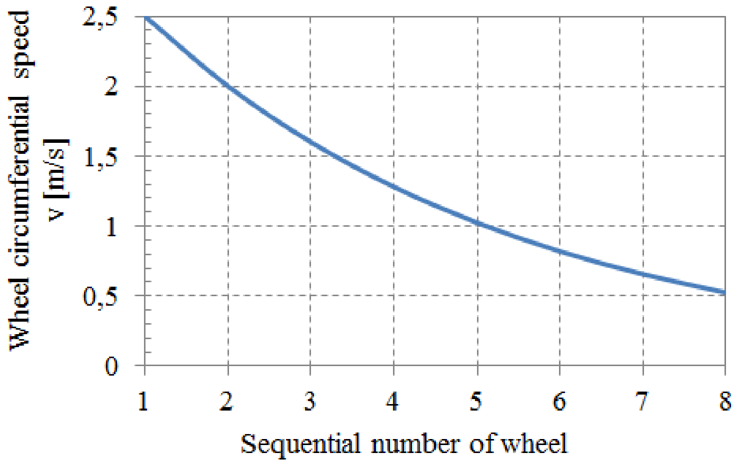

Fig. 6. Circumferential speeds of brake wheels

The calculation of the necessary power is based on the force ratios (Fig. 7), where F_N denotes the contact force, R denotes the wheel radius, v denotes the speed, F_{ob} denotes the circumferential force, e denotes the arm of the rolling resistance, $r_č$ denotes the arm of the pivot's resistance, and $F_{čt}$ denotes the pivot's frictional resistance.

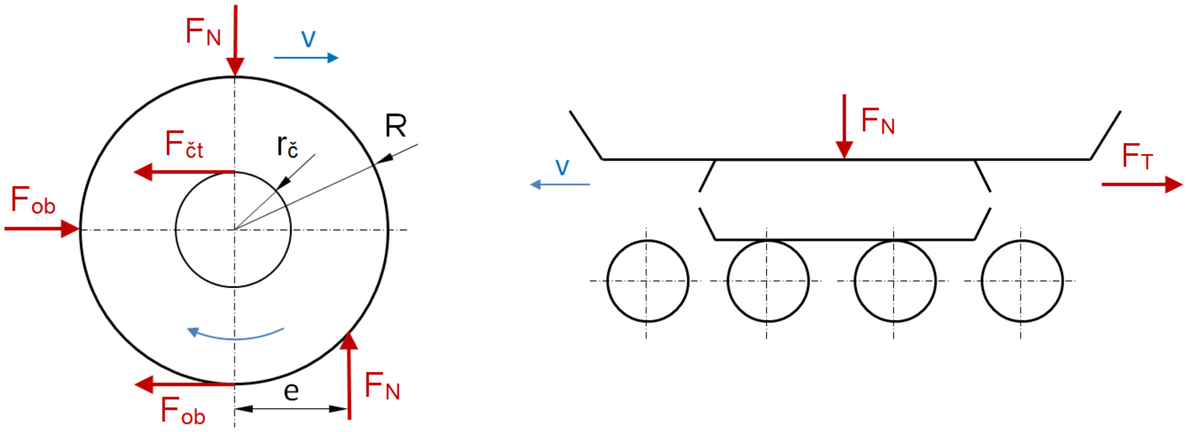

Fig. 7. Force ratios

According to the distribution of forces illustrated in Fig. 7, the circumferential force F_{ob} can be formulated as in Equation (1) and the required power as in Equation (2).

$$F_{ob} = \frac{F_N.e + F_{čt}.r_č}{R} \tag{1}$$

$$P = \frac{(F_{ob} + F_T).v}{\eta_c} \tag{2}$$

where η_c is the total efficiency of the whole assembly.

In terms of its construction, the braking system is made of braking segments (Fig. 8) with an alternating arrangement of toothed belts, which provide continuous and reciprocal speed reduction.

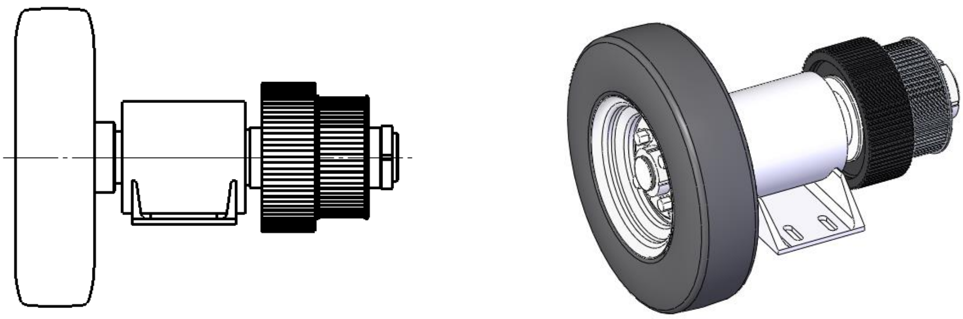

Fig. 8. View of the braking element

The braking segments are located on adjustable support brackets (Fig. 9), where a drive (a geared motor) is also mounted. Tensioning of the belts between the individual belt pulleys is individually designed for each of the braking segments by means of the tensioning screws. Application of commercially accessible belt stretchers was impossible with regard to the dimensional dispositions.

The bracket accommodates the space disposition of the existing structure, as well as the options available for its set-up and simple installation. The down pressure for the brake is designed in order to be exerted by the sliding mechanism in the support bracket, as well as by pumping up the tires.

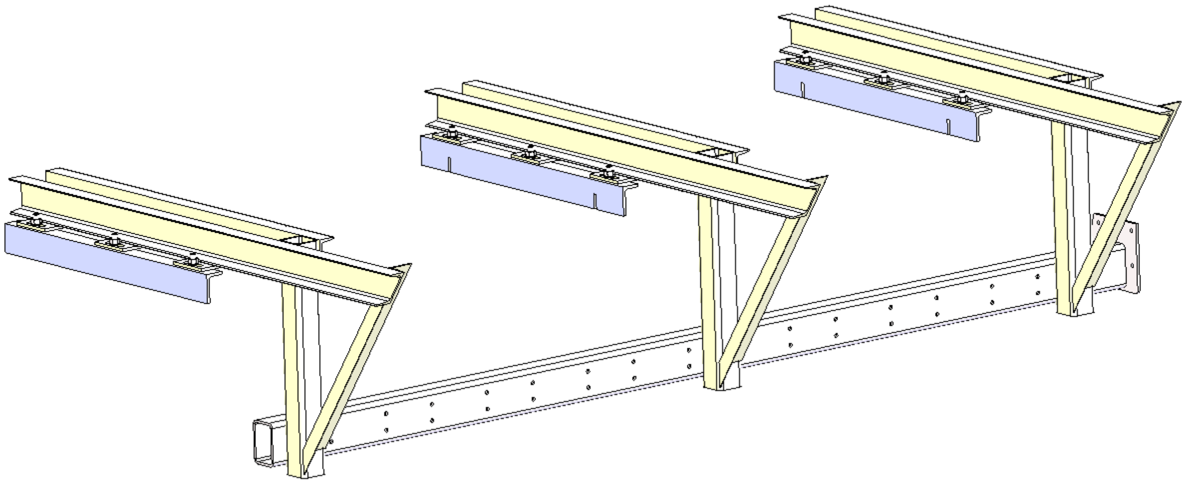

Fig. 9. Support bracket of the braking system

Fig. 10 presents the overall view of the conceptual solution for the braking system mounted on the existing steel structure.

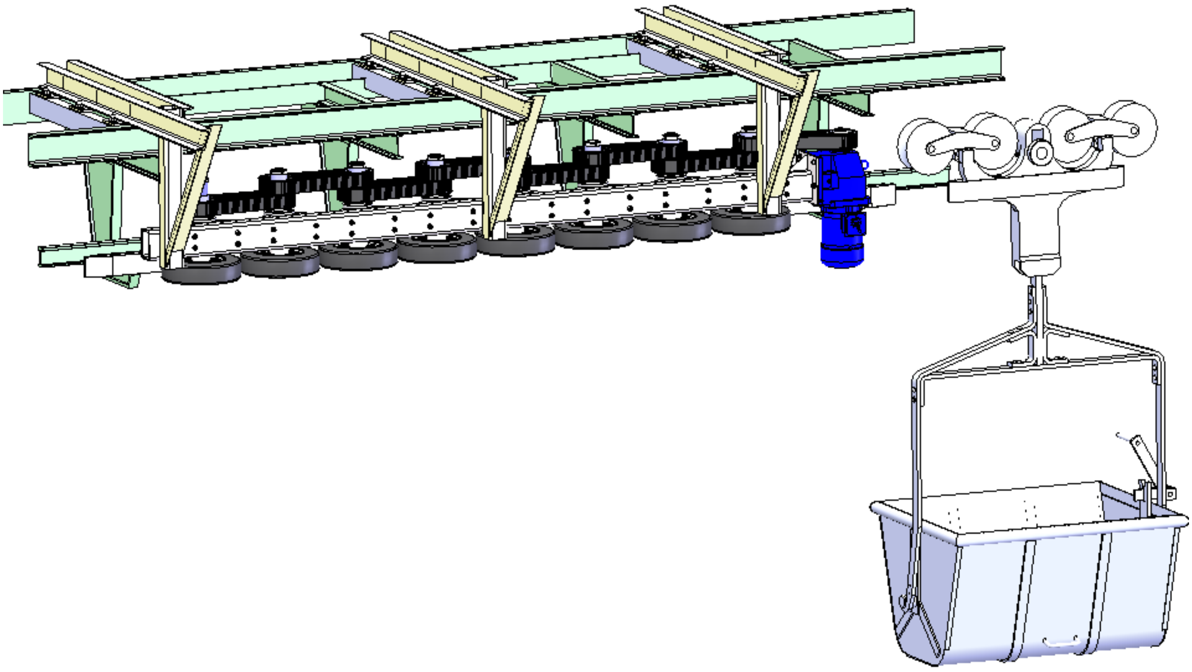

Fig. 10. Solution model of the braking system

The braking system was installed experimentally in a real operation for testing the whole equipment, as well as for tuning the operational parameters and possible constructional modifications. The ideal approach of the cableway truck towards the first braking wheel is important with regard to the elimination of undesirable vibrations in the construction.

This special braking system is now being utilized successfully during discharging of the cableway trucks within the discharging station of the freight cableway.

4. CONCLUSION

The designed braking device has sought to increase the level of safety for the operators as they empty the freight cableway trucks. The system is designed to operate with eight braking segments under continuous drive. Continuous deceleration of the circumferential speed of the presser wheel in the braking system ensures speed reduction for the incoming trucks at the unloading station. The next step will focus on an engineering design for the discharging system, which will ensure the complete elimination of human input in this section of the cableway in the near future.

This paper was elaborated in the framework of the following projects: VEGA 1/0198/15 – research on innovative methods for emission reduction of driving units used in transport vehicles and optimization of active logistic elements in material flows in order to increase their technical level and reliability; and KEGA 021TUKE–4/2015 – development of cognitive activities focused on innovations in educational programmes in the discipline of engineering, as well as building and modernizing specialized laboratories specified for logistics and intra-operational transport.

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