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"MOVABLE PLATFORM" - THE IDEA AND ENERGY CONSUMPTION

Summary. This paper presents the application of the concept of moving sidewalks at railway stations (the movable platform) including the calculation of electricity consumption. Particular focus was placed on issue of energy profit and loss in two stages - through the loss (consumption) of energy by using a moving sidewalk at a railway station platform and the profit (reduced consumption) of energy, by the lack of having to start the train, that supports movable platform, from the initial speed of 0 km/h.

„RUCHOMY PERON" - KONCEPCJA I ENERGOCHŁONNOŚĆ

Streszczenie. Praca przedstawia koncepcję zastosowania ruchomych chodników na peronach kolejowych (tzw. ruchomy peron) z uwzględnieniem obliczenia zużycia energii elektrycznej niezbędnej do eksploatacji tego typu rozwiązania. Szczególny nacisk położony został na kwestię zysku i straty energii rozpatrywaną dwustopniowo – poprzez stratę (zużycie) energii przez zastosowanie ruchomego chodnika na peronie kolejowym oraz zysk (zmniejszenie zużycia) energii przez brak konieczności rozruchu pociągu obsługującego ruchomy peron od prędkości początkowej równej 0 km/h.

1. INTRODUCTION

"Movable platform" is an idea for an innovative passenger platform project on which the means of transport (rail vehicle) does not stop during the exchange of passengers [1], but only reduces the speed to the so-called "safe speed" [2]. To make this possible on the platform must be built a special moving sidewalk with an accelerating section to entry and discharging section to exit. The speed will be synchronized with the speed of a passing rail vehicle. So moving rail vehicle – without stopping on the platform – will have a higher hourly capacity, and travel speed will grow, what is not without significance at steadily growing number of travelers. Reaching the appropriate safe speed on the platform is achieved by controlling the supply voltage of the driving engine [2-4].

Moving sidewalks have long been used to improve and facilitate the movement of persons at a distance of several tens to several hundred meters. They are used, inter alia, in airports, subway stations, exhibition halls and in large shopping centers where, next to the escalators, match perfectly their missions, which purpose is to facilitate and accelerate the process of transporting people [5].

Such innovation as movable platform could reduce the time schedule and for sure increased the attraction of train journeys, and after that its popularity. All that could effect on evolution of train journeys. That also ensure right evacuation canals for passengers who finished their journey and makes possible easy and unbounded leaving out of platform and whole station.

2. SELECTION OF BASIC PARAMETERS AND DIMENSIONS OF "MOVABLE PLATFORMS"

The movable platform principle of operation is getting the same speed of moving sidewalk and train going along it. The speed should not be too high, because not only young and fit, but also older one, children and handicapped persons will use it. That's why the maximum safety and comfort is needed. Too high speed could scare away the users and lead to situations when not every passenger will be able to walk in or out the train at the station. To low speed is also not desirable because of the waste of time. The average speed of walking people is in range of 1.1 m/s to 1.4 m/s, that's why for safety and comfort the moving sidewalk speed is assumed as 1 m/s with fluently speed change.

One of the most widely used multiple railway units in suburban traffic (in Poland) is an electric traction unit EN57, and therefore parameters of the "mobile platform" will be adapted to its specifications. Subsequent modifications of this unit will relate to items that do not affect the subsequent calculations, therefore, these platforms can also be used to support later generations EN57.

The assumption of moving sidewalk length for passengers waiting for train depends on their average number at station platform. For the sake of this concept it is assumed that there will be around 50 people at a platform waiting for one train. There should be about 0,3-0,5 m^2 area for one person, therefore for maximum comfort and liberty this area should be in the amount of 25 m^2. By the standard width of moving sidewalks 1,4 m it results as 17,9 m length. This is of course the minimal value. In practise the length should also depend on the distance between train doors – for EN57 the moving sidewalk length is 25 m assumed. There are 6 door pairs in EN57 at each side, therefore passengers that will be getting out of the train should use the first three doors, however passengers getting in the train will use the other three – doors will be opened and closed automatically (fig. 1) [3].

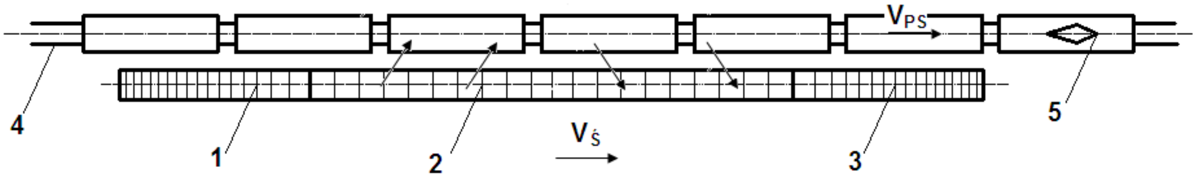

Fig. 1. One-sided movable platform
Rys. 1. Jednostronny ruchomy peron

In order to ensure greater passenger comfort would be necessary to install a moving sidewalks on both sides of the rail vehicle (fig. 2), one of which would operate with passengers getting on and getting off passengers second. This solution is due to the high cost of implementation may appear in the service but at a much later time, therefore in the present publication it was decided to consider a variant in which the movable sidewalk is only on one side of a rail vehicle.

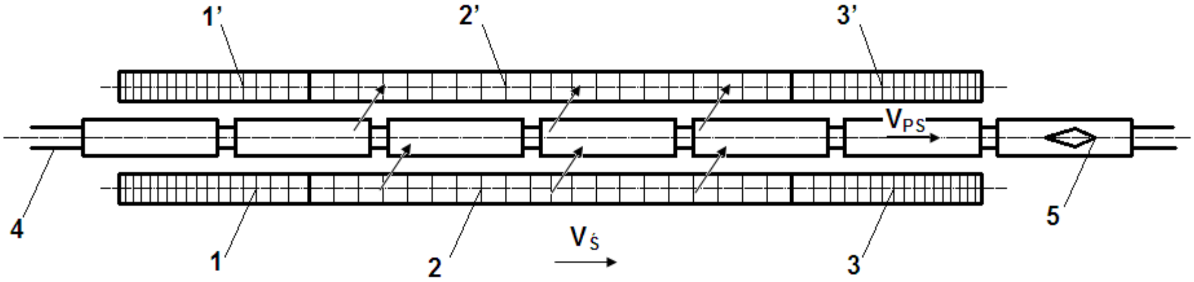

Fig. 2. Two-sided movable platform
Rys. 2. Dwustronny ruchomy peron

Similarly as exit doors the entrance doors will be also closed automatically. Closing will proceed after 80 s in the same order as opening. Such long time should be enough for safety and comfortable getting off the train and also getting in for passengers being late. Exactly the same as for exit doors also here will sound a special signal twice. Taking into consideration the length of waiting pavement, distance covered by moving sidewalk for getting in and off the train it is assumed that the length should be 90 m.

For the sake of costs reduction the best way for “movable platforms” building is to build in a normal platform a walking sidewalk with the same construction as already existing ones, used for people transport e.g. at the airports. In the case of safety walking in and walking off the moving sidewalk through its length, the balustrades should only be built at the ends covering only the drives. Standard wideness of such moving sidewalks are 1000 and 1400 mm. In this concept the bigger one is assumed, taking into consideration safety and liberty of passengers during getting in and getting off the train and also the “bottleneck” avoidance

3. EXPECTED BENEFITS FROM “MOVABLE PLATFORM” USAGE”

The main advantage of mobile platforms is to reduce the travel time between two stops for the platforms equipped with moving sidewalks in comparison with the traditional solution. Another positive feature of the "mobile platform" is that it can be used not only for a particular fleet, equipped with an integrated automated starting mechanism, but also by any other train not equipped with such systems. Then, sidewalk is not running and it is described as the usual fixed edge of the platform, which is allowed by no build balustrades on both sides of the conveyor for almost its entire length.

For the sake of an easy programming of the parameters of this type of conveyors, their adoption is possible to work with various types of rolling stock, thus increasing their functional characteristics. In today's era of technology it could be an easy way to parameterize the software settings for the moving sidewalks and adapt them to work with several types of trains, as well as easily could be set a time of opening and closing doors for the different types of trains.

Eliminating the need to stop at intermediate stations, in connection with the use of moving sidewalks, means undoubtedly the saving of energy consumed at the stage of acceleration of the train [6]. In the case of the usual platforms, start-up of the train need substantial amounts of energy to generate force initiating motion, which value must exceed the value of the friction force in order to propel the train and generate its motion. In order to obtain accurate values of difference between the amount of energy consumed starting from zero km/h and starting from a certain speed are measurements in real conditions needed. Within this publication theoretical calculations of profits and losses of energy for the platform equipped with an automated sidewalk and the platform without such solution was carried out.

4. ENERGY CONSUMPTION OF "MOVABLE PLATFORM"

Calculations were performed in two different cases, first when the platform is equipped with a movable sidewalk and the second when the concept of "mobile platform" was not applied. To facilitate the calculation of energy consumption, the route of the train was divided into different sections corresponding to the type motion (table 1). In the first step in both cases the train movement is at a fixed speed of 16.66 m/s (60km/h) time taken 70 seconds. The first step for both cases at the time of 70 seconds is indicated with "A".

The next step for both cases is braking. It was assumed that this is not the way of electrodynamics braking but only mechanical. Braking deceleration was adopted as 0.25 m/s^2. In the case of the "mobile platform" usage the braking time is 62.68 seconds, and the stage is called "B1". For the second case braking time is 66.68 seconds, and this is the stage "B2".

For the first case in next stage the train moves along “movable platform” for 200 at a fixed speed rate of 1 m/s (3.6 km/h). This stage is called "C1". In the second case where the train stops at a station it is a stage of "C2", and the waiting time is 192 seconds. Shorter waiting time results from the difference of time for braking and acceleration, which in the case of braking deceleration and acceleration equal to 0.25 m/s^2, results in 8 seconds.

The next step is the acceleration in the first case marked as "D1", for the second case as "D2". In the first case, starting up with an initial speed of 1 m/s (3.6 km/h) to the end speed of 16.66 m/s (60 km/h) takes 62.68 seconds. In the latter case, the starting up is longer by 4 seconds and lasts for 66.68 seconds.

The last step is movement of a train with a fixed rate of 16.66 m/s (60 km/h) towards the next station. For ease of calculation it was assumed that this stage lasts for 70 seconds and is called “E”. In the second case, the train journey is prolonged by the time needed to overcome the road section that the vehicle from the first case (movable platform) crossed in the stage "C1". The vehicle in step “C1” moved 200 seconds with constant speed of 1 m/s, passing 200 meters. In the second case during the stages "B2"and "D2"train moves 4 seconds longer during braking and starting up.

During deceleration from 1 m/s to 0 m/s and start-up from 0 m/s to 1 m/s, the train in the second case crosses in total 4 meters, so the way that must make up for it is 196 meters. At this stage, called "F" the train moves at a constant speed of 16.66 m/s (60km/h) and running time is increased by 11.77 seconds.

The purpose of further calculations is to obtain the difference of energy consumption in two cases. At first, when at the platform a moving sidewalk is used, the total consumed energy is:

$$E_{C1} = E_A + E_{B1} + E_{C1} + E_{D1} + E_E \tag{1}$$

where: E_A, E_{B1}, E_{C1}, E_{D1}, E_E – energy consumed in each stage of case one (“movable platform”).

In second case – traditional platform without movable sidewalk built in – the total consumed.energy is calculated:

$$E_{C2} = E_A + E_{B2} + E_{C2} + E_{D2} + E_E + E_F \tag{2}$$

where: E_A, E_{B2}, E_{C2}, E_{D2}, E_E, E_F – energy consumed in each stage of second case (traditional platform).

The result from a formula $\Delta E_C = E_{C1} - E_{C2}$ is the difference in energy consumption in both cases.

In the case of starting, the increase in energy used to move the energy calculated "on wheels" is the result of losses in start-up resistors, and small energy consumed from the power source to the needs of the vehicle. Assuming, for example, that the drive system consists of four engines connected in parallel, the impact of losses in the starter resistors and motor resistance into energy needed for movement is much larger than in the case of alternately motors connecting. In the period $0 \le t \le t_R$ vehicle consumes electricity equal to four times of starting the engine. Energy taken from the power system is defined as [7]:

$$E = U_S 4 I_R t_R \tag{3}$$

where:

U_S – power system voltage,

I_R – starting current of one motor, t_R – time of starting.

The energy lost in the motor winding resistance is equal to:

$$\Delta E_S = \Delta U_S 4 I_R t_R \tag{4}$$

where ΔU_S is defined as voltage drop in the resistance of the engine, equal to about 5% of the power supply voltage.

Energy lost in start-up resistors

$$E_R = 0.5(U_S - \Delta U_S) 4 I_R t_R \tag{5}$$

The efficiency of the starting system is thus equal to:

$$\eta_R = \frac{E - \Delta E_s - \Delta E_R}{E} = \frac{4U_s I_s t_R [1 - 0{,}05 - 0{,}5(1 - 0{,}050]}{4U_s I_s t_R} = 0{,}457 \tag{6}$$

This means that at start-up resistor, without swapping engines, the energy spent on the ride is approximately equal to 47.5% of the energy drawn from the power system. Using the non-resistor starting obtained efficiency is equal to 95%. Calculations were performed in the case of switching engines according to the scheme: four engines connected in series in the period $0 \le t \le t_1$, then in two parallel groups of two motors at time $t_1 \le t \le t_R$ and the four motors in parallel.

Energy consumed by the moving train in set motion is determined by the formula:

$$E_U = \int_{t_0^+}^{t_1^+} \frac{1}{\eta(F_p, v)} F_p(t) v(t) dt \tag{7}$$

where:

$\eta(F_p, v)$ – propulsion system efficiency dependent on the tractive force and speed,

t^+ – time of energy consumption from the power source.

Table 1 shows the data needed to calculate energy consumption for a traction vehicle EN57 with an engine LKa-470 [8, 9].

Table 1

Data for energy consumption calculations

Parametr		**Jednostka**	**LKa-470**
U_s	Power supply voltage	V	3000
I_R	Starting current of one motor	A	140
z_s	Number of engines	---	4
N_s	Power of engines	[kW]	195
t_R	Starting time	s	62,64
ΔU_s	The voltage drop in the resistance of the motor	V	150
d_k	The diameter of the drive wheel	[m]	1
$\eta(F_p, v)$	Efficiency of drive system	---	0,85
η_n	Gear efficiency	---	0,98
z	Gear ratio	---	70:19
n_s (at 1 m/s)	Rotational speed of motors	[obr/min]	70,3983
n_s (at 16,66 m/s)	Rotational speed of motors	[obr/min]	1173,315
n_k (at 1 m/s)	Rotational speed of drive wheels	[obr/min]	19,116
n_k (at 16,66 m/s)	Rotational speed of drive wheels	[obr/min]	318,6

5. CONCLUSIONS

There is, in the case of application of the "mobile platform" concept, a reduction of electricity consumption of 0.339 kWh compared to solutions with traditional platform (tab. 2).

To completely summarize the energy consumption of a “movable platform”, also the consumption of electricity by a moving sidewalk should be included. For the purposes of this calculation it was assumed that the total working time of a moving sidewalk is 184 seconds. This time allows for seamless use of "mobile platform" for about 50 passengers. Engine of moving sidewalk with a length of 90 meters, 1.4 meters wide belt and speed of 1 m/s at the maximum possible load requires 35 kW. The calculations show that energy consumption during the 184 second cycle is 1.79 kWh.

Energy consumption by the moving sidewalk is greater than the possible savings by eliminating the train stops at the platform. But this is not an argument against such an idea. It was previously demonstrated that, with the moving sidewalk on a platform the travelling time between two stations is reduced by almost 12 seconds. Moving sidewalks of this type are installed primarily to improve, streamline and discharging pedestrian traffic. The use of "mobile platform" can significantly improve the check of passengers at stations and reduce energy consumption by electric traction vehicle.

It is also necessary to make a poll around the passengers to get their opinions about “movable platforms in passenger railway transport. for some of the passengers such idea won’t be interesting, especially older people and those with problems with motion could be against. On the other side some passengers will appreciate an idea of "moving platform" and accept it. Such way of platforms is effective as well as showy, therefore could mean a bigger interest in passenger railway transport.

Table 2

Energy consumption results

Stage	Time [s]	Speed [m/s]	Acceleration [m/s^2]	Energy consumption [kWh]
„Movable platform"				
A	70,00	16,66	0	13,970
B1	132,68	16,66 – 1	-0,25	0
C1	332,68	1	0	2,390
D1	395,36	1 – 16,66	0,25	21,710
E	465,36	16,66	0	13,970
			TOTAL	52,04
Traditional platform				
A	70,00	16,66	0	13,970
B2	136,68	16,66 – 0	-0,25	0
C2	328,68	0	0	0
D2	395,36	0 – 16,66	0,25	22,090
E	465,36	16,66	0	13,970
F	477,13	16,66	0	2,349
			TOTAL	52,379

Before taking decision about installing or not such "movable platforms" at standard platforms a lot of tests are to be considered. Most important are passengers with their safety and comfort. The traditional railway has'n't change from centuries – a "movable platform" could be an innovation that will change it as never before, increase the attraction of train journeys, and after that its popularity. One or more such platforms should be made at standard stations as a test and promotion.

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