POSSIBILITIES OF USING TRAIN UNITS WITH TILTING SYSTEM IN REGIONAL LINES

Ing. Pavol Meško, PhD.[1] – Ing. Vladimír Ľupták[1] – Ing. Martin Ľoch[1]
Faculty of Operation and Economics of Transport and Communications, Department of Railway Transport - University of Žilina, the Slovak Republic[1]
vladimir.luptak@fpedas.uniza.sk

Abstract: *The paper is focused on a benefit of urban traction units with tilting system particularly in regional transport, on reducing travel times and on increasing the competitiveness of railway transport. The paper describes the importance of its utilization in such traffic especially if the infrastructure is unable to provide options of higher efficiency for railway undertakings. In this cases are the investments for line optimization not available, so railway undertakings cannot be more efficient by usage of classical vehicles. There is space for research of the possibilities of increasing the quality of transportation process despite the state of the infrastructure.*

Keywords: INFRASTRUCTURE, TITLING SYSTEM, TECHNICAL SPEED, TRAVEL SPEED

1. Introduction

The main barrier for a high competitiveness of railway passenger transportation is a travel time of passenger from boarding station to the destination station. This is not due to carrier´s ability to provide fast, comfortable and safe transportation only, but also due to infrastructure conditions in which a railway passenger carrier operates. One of these conditions is the maximum track speed, which cannot be increased by its reconstruction in many cases, due to the current lack of economic profitability or natural conditions under which the line is built.

Therefore the deployment of modern rolling stock of conventional construction to the operation may not bring a sufficient and desired effect, which ultimately cannot contribute to the achievement of targeted competitiveness. As the one option for reducing travel times on the line section is an entry of tilting units into service in this case which thanks to its tilting device can drive the curves at higher speed and thus reduce travel times, but on the other hand the comfort can be increased when traveling.

2. General principles of the line selection

For the best use of tilting units in passenger transport the current lines should be selected in addition to modernized main corridors, which are held in harsh natural conditions and the direction is characterized by many curves. That is why it is possible to increase technical speed of passenger trains in such conditions easy and this step leads to increase of its efficiency and attractiveness.

Railway lines are generally divided into five speed zones (Table 1) expressing the upper track speed limit and its related demands on infrastructure maintenance. As the tilting system can be used only for velocity over 70 km.h^{-1} (included) for vehicles of classical construction there is no need to consider further the lines included in the first speed zone SZ1.

Table 1: *The speed zones distribution*

Zone	Speed
SZ_1	up to 60 km.h^{-1}
SZ_2	from 60 km.h^{-1} to 90 km.h^{-1}
SZ_3	from 90 km.h^{-1} to 120 km.h^{-1}
SZ_4	from 120 km.h^{-1} to 160 km.h^{-1}
SZ_5	over 160 km.h^{-1}

Track speed of each line is limited by many factors such as:

- small curve radius,
- insufficient cant of outer rail in a curve (superelevation),
- improper outlook conditions for horizon ahead,
- inappropriate length or shape of curve transition (for radius and cant),
- technical condition and low safety level of switches,
- a state of the railway superstructure and substructure and so on.

Thus the suitability assessment for engagement of tilting units is required, needs to be done and undergo a thorough analysis of the line according to the current standards (norms) for the geometric position of the normal gauge tracks.

3. The suitability assessment for deployment of considered units

Units with tilting system mainly serve to shorten travel times without the high cost for upgrading an existing infrastructure. Active tilting devices allow 20 to 30 % time savings with higher speed driving the curves at tilting up to 8 ° against the level of wheel and rail contact, respectively to 6.5 ° without the comfort of the passenger being marred.

By actual valid standards (norm) STN EN 73 6360 for geometric position of normal gauge tracks while assessing the state of infrastructure in relation to engagement the units with tilting system it is required to undergo a thorough analysis of the route on the basis of all relations arising from strictly injunctive or recommended values. These relations and limits are subject to this standards (norm) in which certain principles are selected:

- tilting system works by the speed limit at least Vt = 70 km.h^{-1} in the curves with cant. In the sections with track line speed limit less than is mentioned above for a vehicles of conventional construction, it cannot be taken in consider to increase speed limit by using the tilting units,
- to take advantage of tilting system, the value of track cant in curves needs to be at least p = 30 mm. In folded curve with a cant should intermediate transitions have a cant difference at least $\Delta p = 30\ mm$,
- the value of insufficient cant (the difference between theoretical and real cant) for the track without solid parts is reduced to $I_k = 250\ mm$,
- the value of insufficient cant for the track without solid parts in comparing to the value of cant should be at least $I_k = 3.0$p (in the most cramped proportions up to Ik = 3.5p)
- for the curves without cant, the usage of tilting units in higher speed limit than the basic limit is, cannot be considered,
- to use an advantage of tilting system, these conditions are required:
    - curves with cant must have the outer transitions,

- o folded curves with an intermediate cant transition must have an intermediate radius transition,
- o cant and radius transitions must have the same proper length,
- o the shape and course of curvature increases the same way for both cant and radius transitions,
- outer transitions with a linear increase of curvature and cant shall comply with requirements of STN EN 7363 60, the same applies for intermediate transition curves.

Trains with the tilting system allow for a reduction of travel times on such a lines that meet with the requirements of standards for increase the line speed, but mostly thanks to its tilting on the lines with limiting factor of achieving higher speeds right in a curve. All train carriages (wagons) are equipped with an active hydraulic system, partially offsetting the effect of lateral acceleration on passengers when running the curves to greatly increase the average speed and convenience of traveling on curved lines.

4. Applications of several principles into the selected ŽSR track line section Bratislava hl. st. – Banská Bystrica

To verify the suitability of the considered units and thus achieve the desired results, the track line section Bratislava hl. st. - Palárikovo - Šurany - Zvolen os. st. - Banská Bystrica were used considering intensive directional disparity in the vast length due to the river Hron.

Figure 1 shows an existing static velocity profile (marked as green), which is varies in the range from 70 to 100 km.h^{-1} in the section Palárikovo - Banská Bystrica and from 100 to 140 km.h^{-1} in the section Bratislava hl. st. - Palárikovo. Static velocity profile for considered tilting units (marked as blue) following an analysis of line geometry represents discontinuous and inefficient progress with frequent alternation of velocity extremes, therefore it was necessary to create reduced profile (marked as red), which respects the fundamental dynamic options of adhesive rolling stock.

This course can then be forwarded for further analysis by computing the travel dynamic of the unit with tilting system and plotting the course curve of actual speed according to traveled distance. In this case, the position km 0.000 is the position of station Bratislava hl. st. and km 230.200 represents the position of station Banská Bystrica.

4.1. Forced infrastructure adjustments

For such a velocity profile would be necessary to establish the curve cants at this track line section for three curves with its transitions and for one curve to increase projected value of cant while this step takes into account the current length of cant transitions of the curves corresponding to the newly proposed value of cant (superelevation).

5. Comparison of selected indicators

For calculation of new qualitative indicators that result after the introduction of units with tilting system to operation, three basic types of passenger trains of category Express (Ex), long distance fast train (F) and commuter local passenger train (Ps) were designed and therefore we assume the deployment of existing trains, which are operating in the current timetable without regardless of their regularity (5).

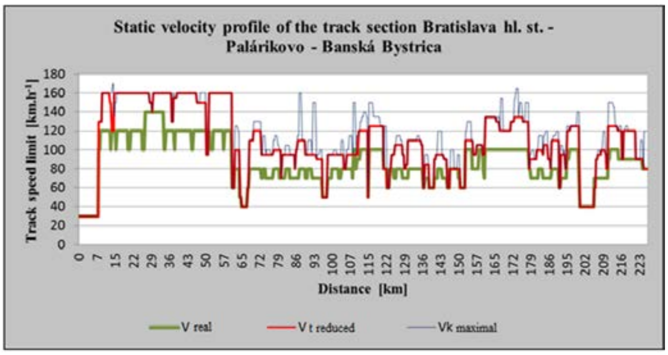

Fig. 1 *Static velocity profile of chosen track line section*

New travel times were calculated indirectly using the approximate method of estimation from static velocity profile, which has been selected for the initial orientation detection of time savings due to engagement of tilting units and it was designed so that the running time under static velocity profile of current speeds was calculated and compared with actual running times of passenger trains in the current timetable, in result of the dynamic difference coefficient to the static velocity profile. The resulting approximate travel time saving for this 223 km long track line section is about 20 minutes.

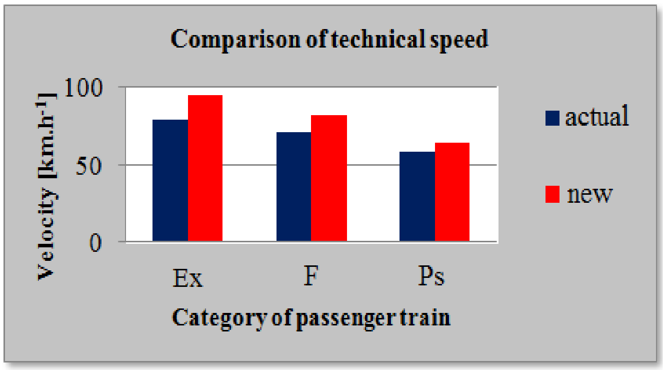

Fig. 2 *Comparison of technical velocity*

Comparison of a new and existing technical speed of passenger trains is graphically shown in Figure 2. As can be seen in case of fastest train (Ex) using tilting units improved its technical velocity from the current 78.93 km.h^{-1} to an approximately speed of 94.93 km.h^{-1}. Fast train (F) also increased its technical speed from the original 70.47 km.h^{-1} to an approximately speed of 81.87 km.h^{-1} and local passenger train (Ps) increased the technical velocity from the original 57.79 km.h^{-1} to an approximately speed of 64.03 km.h^{-1}.

For sectional travel speeds (technical speed with respect to dwell times) of passenger trains it is the similar pattern in terms of the introduction of tilting units (Figure 3). As can be seen in case of fastest train (Ex) using tilting units improved its sectional travel velocity from the current 75.48 km.h^{-1} to an approximately speed of 84.01 km.h^{-1}. Fast train (F) also increased its sectional travel speed from the original 63.36 km.h^{-1} to an approximately speed of 69.69 km.h^{-1} and local passenger train (Ps) increased the technical velocity from the original 43.43 km.h^{-1} to an approximately speed of 50.78 km.h^{-1}.

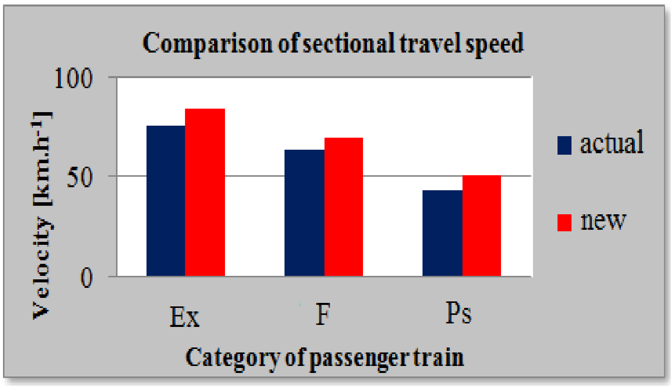

Fig. 3 *Comparison of sectional travel velocity*

6. Conclusion

Thorough these analyses of the track line section Bratislava hl. st. - Banská Bystrica it was found that given track line in the vast majority of its length is likely to deploy regional tilting units to the operation, respectively for their deployment would be necessary to make some low-cost steps to adjust the infrastructure. With an approximate method of estimating the travel time savings was found indicative shortening of the fastest train travel time (Ex) about 20 minutes, which represents a fundamental value for increasing competitiveness against other transport modes in passenger transport.

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