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CONSTRUCTION OF HIGH-SPEED TRACKS

The current situation and conditions of construction of high speed tracks (HST) in the Slovak Republic and the comparison with the situation abroad. The speed of train sets and the track quality for high speed trains. The dynamics of railway running. The speeds of the HST trains are limited by the respective track state. The tilting train set wagons - increasing the new levels of speeds in railway curves. The time comparison of the high speed trains to air and road transport "from city centre to city centre". The required conditions and parameters of construction of high speed tracks up to $V_{max} = 200–240\ km.h^{-1}$ *within the track modernizations.*

1. Introduction

The prospective solution of concentrated traffic, which is considered in the world as well as in the European Union, is faster and comfortable movement of high-speed trains on railway tracks. Quality eco-friendly railways will be competitive to roads and highways that pollute the environment at an increasing rate. At medium distance transport the railways may also compete to air transportation systems, by the system known as "from city center to city center" of connected cities. Of course, we speak about the high-speed trains for passengers and freight transport. The other possibility is a railway transport system with connections to these high-speed tracks, as it is supposed to be adopted before the emission transport that will have limited natural resources for fuel production.

In this paper we exclusively address to high-speed trains and the need of track construction to secure the utilization of high speeds of respective train sets. At present, all lines, (foreign speed-tracks), which are used by the trains that run faster than $V = 200$ km.h^{-1}, are considered high-speed tracks (HST). The traction vehicles with their sets can run at higher speed $V = 300$ km.h^{-1}, possibly even higher, but they are limited by the current track state at $V = 200–240$ km.h^{-1}. This can be demonstrated by the experience of foreign railways.

Concerning the new track modernization, in Slovakia this is not an issue in question at all because by the modernization of tracks only the speed $V_{max} = 160$ km.h^{-1} is considered. The only possibility for Slovakia is the construction of high-speed track in the length of 1500 km of Paris – Bratislava line. The complete putting into operation is scheduled for 2020 (Paris – Strasbourg – Stuttgart – Munich – Vienna – Bratislava). If we want to use these train units in our country, it is necessary to prepare the new parameters of existing lines and turnout layouts of railway stations on associated tracks, otherwise Bratislava would remain a terminal station. And vice versa, besides their utilization in Slovakia our train sets could be also used at high speeds on these new HST tracks outside Slovakia.

The trains are also limited by the prescribed maximum allowed speed V_{max} according to the rules and standards in the respective country or by the maximum speed in particular track sections. The stagnation of research and development should be prevented and therefore it is necessary to create new research challenges and gain experience abroad, including new railroad materials.

2. Basic conditions of the HST lines

The fastest trains on the line need certain preferential right of way before the slower types of trains (EC, IC, R, Ex, Os, Pn, Mn etc., for example at $V \leq 160$ km.h^{-1}). At the same time these slower trains present certain barriers for HST trains. They need to be "hidden" in the railway station track area during HST train passing. This procedure is a standard in the countries, where the already existing HST tracks are used and modernized.

Alternatively, the HST track can be built on a separate railway body, especially for trains running at speed $V = 300$ km.h^{-1} and higher. In the case of high-speed tracks it would not be economical to use it for high-speed trains only. Already in the preparation of high-speed tracks the exploration of specific conditions and traffic carrying capacity of tracks using different types of train vehicles (with the necessary reserve for a future capacity) is needed.

The most important components are two basic ones. The traction vehicles (*hv*) with the sets of transported vehicles, which are able to run at the required V_{max}^{hv} speed. On the other hand the

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railway track which has to ensure the transit safety of these sets at V_{max}^{i} in particular track sections (i). Both speeds are related to the maximum permissible V_{max} speed on the track which vary by individual standard criteria depending on a particular country. From the point of view of track geometry, in the track sections there is necessary to expand the curve radiuses in the R_{max} sections within the reconstruction (including quality geometric transitions and vertical spirals [3]), because the HST trains would be slowed down by these small radiuses.

The turnout layouts are other speed-limiting elements, i.e. connections and branching in railway stations (mainly in large urban areas), that the trains run through, and the speed V_{max}^{zh} is also limited by the turnouts structures (zh).

3. Track structures for high speeds

The trains have to run on time and therefore it is necessary to build high quality railway corridors which will be sustainable for high speed V_{max} with its geometric spatial position within the criteria of critical horizontal and vertical deviations. The stability of the geometrical position is strictly required to avoid unnecessary rails repairs of tracks and to prevent the tamping machine becoming another barrier for speed-trains on the track.

The stable track geometry is ensured by a durable track grid that uses reinforced concrete sleepers which transmit force load resulting from the dynamic behavior of driving trains into the lower layers of railway subgrade [1]. The ideal solution is building solid trackbed constructed from concrete and modern reinforcing materials that have good force transmission effects and also prevent the noise emissions releasing into the environment. An integral part is a flexible spring fastening system (Pandrol, Vossloh, etc.) of rails on the sleepers within the track grid [5], or their installation into a solid trackbed.

Finally, we must not forget the quality and stability of sleeper ballast and subgrade that in the case of any instability would deform the superstructure as well as the track grid and the collapse of track geometry position would become a real threat.

The track geometry is necessary to be controlled in the prescribed time intervals by surveying groups and by the track measuring machines, while the horizontal and vertical conditions are maintained in the state required by the project documentation. The quality tracks generally have minimum deviations from the designed axis in a long-time perspective. In our paper we consider the speed zones at RP4 V_{max} = 160–220 km.h^{-1} and RP5 at V_{max} = 220–300 km.h^{-1} in accordance with the upcoming new STN 73 6360 [6], as the CSN 73 6360-1 [7] CSN 73 6360-2 [8] in the Czech Republic. The criteria are applied from European standards EN [9] due to the approximation and harmonization of regulations and standards within the common European area.

High speed turnouts: for maximum speed the straight direction (s) of turnout (t) is required, in the of case of direction change it is necessary to consider the $V_{max}^{t,R}$ speed of the radius (R) as in Table 1 (the transformed turnouts have two curves). The high-speed turnouts are designed for speeds in a straight line $V_{max}^{t,s} \leq$ $\leq$ 300 km.h^{-1}. In the case of higher speeds specific turnout structures have be manufactured in accordance with the train set load with the fluent progress of curvature (e.g. clothoid).

Turnouts of high-speed tracks – HST Table 1

Speed into turnout branches $V_{max}^{t,R}$ [km.h^{-1}]	Turnout	Structural length [m]	Central angle [°]
110	1:21.5-1600	74.338	2.3671
120	1:22-1800	81.776	2.6025
130	1:26.5-2500	94.306	2.1611
140	4500/2800*/straight	120.959	1.8977
160	6000/4000*/ straight	142.800	1.5931

There are two different views of these turnouts. The high-speed track passes only in a straight line (s), but other trains also run into branches at $V_{max}^{t,s}$ = 50 to 110 km.h^{-1} for turnout as from 1:26.5-2500 to 1:12-500. The second view is that the trains into branches require $V_{max}^{t,R}$ = 110 to 160 km.h^{-1} and higher, see Tab. 1, [2].

At higher speeds for branches $V_{max}^{t,R} \geq$ 130 km.h^{-1}, a clothoid spiral is designed (EU and outside EU railways), otherwise at lower speeds the circular curves are produced. In turnouts of Table 1, the clothoid progress between radiuses of 4500/2800 m and 6000/4000 m into branches at their speeds of 140 and 160 km.h^{-1} is changed.

For the curves with transitions of high-speed lines we can already design clothoid spirals instead of cubic parabolas (updated equation with correction factor γ), which are geometrically of a better quality. Of course, as well as the Bloss spiral and other spirals with the fluent curvature [3].

4. Driving at high speed on a curve

The stable position of vehicles and elimination of the adverse effects of centrifugal forces are necessary to be ensured during the high-speed trains passing a curve at a high speed. By the speed increasing at a particular maximum elevation of rails we are limited by the critical V_{max}^{R} speed in particular radius (R) and superelevation (D). We can increase the speed in a given track section taking following measures:

1. reduction of the weight of the sets (mainly passenger vehicles),
2. lower center of gravity by the mass distribution of sets and materials,
3. using only sets with tilting body of wagon with $\Delta\alpha$ = 0° to 8° (Fig. 1),
4. sets as a single unit (aerodynamic resistance).

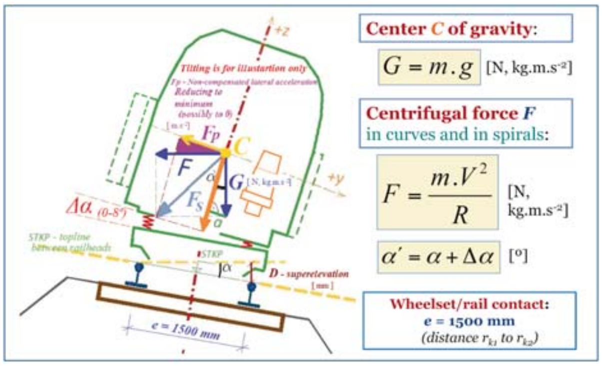

Fig. 1 Forces influence – tilting railway wagons

Besides the stable position we have to keep in mind the comfort of passengers and also avoiding damage to transported goods. Of course, the train sets must overcome all the active (the primary energy source driving the vehicle and all transfers from engine to a point on the rail) and passive driving (track and vehicles) resistances - the dynamics of rail driving.

If you choose to compare the high-speed trains that have fulfilled all of the conditions above and the conventional trains (EC, IC, R, EX, Os, Mn train sets etc.) in the same curve, the high-speed trains can move at a speed of 1/4 to 1/3 higher. To demonstrate this, in our example V_{max}^R = 180–240 km.h^{-1} for HST train sets and for others V_{max}^R = 120–160 km.h^{-1}, where by the centrifugal forces (F) different speeds developed. An important fact is the aerodynamic shape factor of the first front drive wagon, including the mutual connections of individual wagons in the set with minimal added aerodynamic resistance of each carriage.

Small radiuses tend to slow the train sets down, therefore it is necessary to ensure a minimum radius of curvature R_{min} for the required speed V_{max}^R by the designers. Nowadays it is necessary to modernize railway lines and use this modernization to increase the speeds (if it is not possible to construct separate track corridors). The high-speed trains may also be limited by the maximum speed allowed in a particular country, as in some federal states within the U.S.A., V_{max} = 240 km.h^{-1} is the speed limit. It usually is the speed in straight track sections. In the curves and spirals it will decrease to lower values of speed V_{max}^R = 160–190 km.h^{-1} using the sophisticated modernized tracks.

5. Railway transport from "city center to city center"

The speed and high-speed trains, according to various studies, can compete with air transport at distances between cities of 600–900 km. The passengers spend equal time in comfortable transport vehicles at the same distance and they directly board the train with their luggage and will get off on platform in the next city center. The train sets usually stop at city centers of two or three other cities. We can mention the Washington – Philadelphia – New York – Boston line as a classic example of a speed-track, there are many more similar examples. As rather uncomfortable there could be seen the fact that airports are principally placed outside of city centers at a distance of 20–40 km.

The location of nodal points and end points of high-speed railway stations will considerably increase appreciation of this area and will also increase its attractiveness (growth of real estate construction and miscellaneous services, etc.). In the surroundings of these stations there will be created a locality with higher added value, the unused parts of municipal plans might possibly be evaluated and they can be recovered within the urban planning, because it is a usual course by concentrating the traffic into the respective transport junction of HST trains.

The study of follow-up and associated transport has to be processed for these high-speed trains, including urban railways, and underground transport systems as dynamically developing environment. The railway transport has a great future in the city centers, as it can solve the environmental and traffic situation after the exhaustion of fossil fuels of other competitive transport systems. In principle, we can speak about railways as a perspective, comfortable and rapid transport, as opposed to slow streams of cars on the roads and highways. Using the railway transport we experience no stress compared with driving on the roads with different traps, because the trains will bring you comfortably to your destination while you can dedicate your time to work or simply relax.

6. Conclusion

The staff of the Department of the Railway Engineering and Management of Civil Engineering of the University of Zilina (http://svf.uniza.sk/kzsth) has dealt with the design and operational criteria of standards and rules of high-speed (HST) tracks for a long time. We have gained valuable experience from foreign designers in the field of railway engineering, as the Slovak Republic is only at the beginning of perspective practical implementation with a maximum modernization up to the V_{max} = 160 km.h^{-1} from the current modernization. In the coming years the construction of rapid railway transit will be in operation at the intended speed V_{max} = 300 km.h^{-1} on the track from Paris to Bratislava and it will give us the opportunity of using HST trains in Slovakia. In the future there is pressure to build these lines through the territory of the Slovak Republic in the direction of the main European railway corridors.

Although the manufactured high-speed train sets are already available, there is a recent need to rebuild the track for a specific track speed with the required parameters. Alternatively, there is a possibility of section construction, where in some track sections the V_{max} = 200–240 km.h^{-1} will be used and in the limited track sections we can keep the current V = 160 km.h^{-1} speed. The prerequisites also are the financial resources, which can be obtained e.g. from the European Union funds for developing the ecological transport infrastructure.

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