Development of Optimum Assessment Technique for Railway Infrastructure Clearances

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ABSTRACT
There should be adequate clearances between trains on adjacent tracks and between trains and structures and fixed equipment to ensure safe passage. For this mean, the swept envelope, which represents the bounds that a vehicle can sweep through when traversing a particular section of track, is served separately for each structure or for sections of the route and should take account of all railway vehicles using the line. Also the structure gauge as the boundary, which encloses the clearances required outside the swept envelope, is considered to enable the railway to be operated in safety. In current applications, however, the real dynamic and operational conditions of railway vehicles (i.e. speed or load geometry) as well as real geometry of around structures are not completely and directly considered in developing swept and structure envelopes. In this paper, a new approach is introduced in which the optimum clearances of railway tracks are resulted based on the real vehicle dimensions and around structure geometries. According to the investigation of different international criteria, basically the provisions of International Union of Railways (the 505 series of leaflets), the dominated formulation for development of optimum assessment technique for railway clearances were obtained. Concerning this formulation and entrance information of real geometry of vehicles and structures as well as operational conditions, different optimum railway gauges including kinematic gauge, line side structure gauge and installation gauge were determined. To come up with the applicability and practicality of the new approach, a Code in C++ program is finally developed and presented.

KEYWORDS:
Clearance, Envelope, Kinematic Gauge, Structure Gauge

1- Introduction
To ensure that safe and adequate clearances are provided and maintained between vehicles and track infrastructure and between vehicles passing each other, different envelopes are served with regard to the maximum vehicle dimensions for traction and rolling stock. The swept envelope represents the bounds of the volume that the vehicle can sweep through in traversing a particular section of track. This envelope is the combinations of kinematic envelopes and curve overthrows at all cross-sections along a vehicle as the vehicle moves along the track. The kinematic envelope is the dynamic envelope enlarged to allow for the permitted tolerances in track gauge, alignment, level and cross-level and the dynamic and static effects of track wear. The kinematic envelope is speed dependent and should also take into account all the possible effects of curvature, including super-elevation of the track, and end and centre throw of the vehicles. On the other hand, clearances between swept envelope and around fixed structures should be considered. These clearances which are called as structure gauge define with regard to the geometry of around structures and railway individual margins [1].

In common techniques for geometrical design of railway infrastructures, the swept gauge for a candidate vehicle is compared with a reference gauge to which vehicles have been previously constructed and are known to have acceptable clearances on the proposed route or routes of operation. The swept gauge for the candidate vehicle shall not infringe the reference gauge. However, the dynamic and operational conditions (i.e. the wagon type, operational speed, the loading conditions and the load geometry) as well as the real geometrical characteristics of track and around structures (i.e. tunnels, bridges, station platforms and adjacent tracks) affect directly on providing the swept envelope. Another important issue, besides the safe passage of the normal rolling stock is that, whether the cargos and wagons larger than normal conditions can safely pass through a route or not? The answer needs a technique which considers the technical specifications and real geometries of track, vehicles and adjacent structures all together. Hence, development of a new process for assessing the optimum gauging can be concluded.
In the present paper, the investigation of optimum gauging with consideration of all effective dynamic and geometrical parameters are provided. For this mean, different standards and guidelines such as provisions of UIC leaflets [2, 3 & 4], European Committee for Standardization [5], TCRP Standard for light rail transit systems [6], guidelines of UK railways [7] and national Iranian railway codes [8] are investigated. Finally the provisions of UIC leaflet (the 505 series) are based according to its universality and detailed calculations. According to the obtained formulations and utilizing a procedure for gathering real geometrical data from the field, the optimum swept and structure gauges are resulted. For gathering the geometrical data, application of laser scanners and obtaining the images for point’s clouds are served. To reach a user friendly calculation tool, a compatible code is finally developed and presented in a C++ program.

2- UIC Provisions for Railway Clearances
The 505 series of UIC leaflets explain the criteria and formulations for different railway clearances. These leaflets include two main parts: firstly, the 505-1 series which investigates the rolling stock construction gauge and the kinematic gauge profiles [2]; secondly, the 505-4 series which investigates the effects of the application of the kinematic gauges on the positioning of structures in relation to the tracks and of the tracks in relation to each other [3]. Moreover, the 505-5 series explains the basic notes on the preparation and provisions of leaflets 505-1 to 505-4. Figure 1 presents the different gauge profiles of these leaflets.

As illustrated in figure 1, the no.1 profile is the maximum rolling stock construction gauge which can be considered as the maximum limits for loading of wagons or maximum traction vehicle dimensions. The no. 2 profile also presents the reference profile with predefined dimensions as a criterion for definition of other related gauges. This profile includes the semi-static movements of vehicles (z) plus the reduction values (E). The no.3 profile shows the situation of the rolling stock considering lateral throw of the vehicles (S). The total lateral movement of rolling stock (D) includes parameters of z, E and S all together. The total vertical movement can be also obtained as ∆V parameter. The no.4 profile is the rolling stock kinematic gauge which considers as the main swept envelope. The no.5 and no.6 profiles are also the lineside structure and the installation gauges, respectively. The last gauge is equivalent to around real structure limits considering installation equipments such as light, ventilation and overhead systems. The no.7 parameter is the semi-static movements because of track cant deficiency. Additionally, the oscillation movement is illustrated as no.8 parameter which defines through the railway administrations and depends on track wear conditions. Finally, the railway specific margin as no.9 parameter can be pointed out which
illustrates the required spaces in specific situations such as specific freight loads and the effects of aerodynamic forces (like the resistant flows via entrance of trains into the tunnels or required spaces for ventilation).

3- The Optimum Assessment Methodology
Two sets of data should be considered and analyzed for obtaining the optimum swept and structure gauges. Firstly, the geometric specifications of different vehicles as well as their related loading geometries shall be defined. According to these data, and based on the operational conditions such as speed and axle load, the total lateral (D) and vertical (∆V) movements plus the semi-static and the oscillation movements in each specific point can be obtained and hence the swept envelope or kinematic profile can be resulted. Secondly, the geometry and dimensions of around structures shall be entered. This step can be based on real data gathering from around structures such as tunnels via laser scanning technique which is considered in the current paper. This outcome considers as the installation profile which results the lineside structure gauge with reduction of railway specific margins. Finally, the obtained kinematic and structure gauges are compared and the safe pass of the vehicles can be assess through this comparison. The mentioned methodology is presented in figure 2.

4- Providing the Tunnel Cross-Sections via Laser Scanners
As mentioned in the last section, one of the effective techniques for field mapping which can be utilized for definition of real geometry of around structures is application of laser scanners and consequently obtainment of point’s cloud for each structure cross-section. Laser scanning is a relatively new technology, having been used as a precise survey instrument only since 1998. Now, it is quickly becoming the new industry standard as a way to make very accurate measurements in complicated environments. This is precisely why using this technology is the best solution for measuring as-built conditions inside buildings and structures. This instrument collects survey data points at a rate of 50,000
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points per second. With several “scan” setups inside a place, a complete 3D model can be made of the existing conditions. These models are then used to create 2D civil or architectural drawings, 3D computer models, and final survey documents. Laser scanners have many advantages in comparison to the other mapping techniques such as high accuracy of collected data, time effectiveness and cost efficiency. However, the weathering conditions should be considered because of impossible data collection in the rainy or foggy weathers [1]. Figure 3 shows this mapping equipment as well as point’s cloud of a sample railway tunnel. A sample cross section of the tunnel in the CAD format as the installation profile is also presented in figure 4.

Fig.3. Laser scanners and point’s cloud of a sample tunnel

Fig.4. A sample cross-section of tunnel resulted via laser scanner

5- Development of Optimum Gauging Code
For obtaining the optimum gauge profiles and evaluation of safe passage of different rolling stocks, a user friendly code should be developed which can consider different effective parameters as well as sketch of required gauge profiles.

5-1-Definition of Input Parameters
The developed code in this paper includes 3 main parts for input parameters: general data form, loading geometry and finally route selection.

The submenu of general data form includes 3 data categories of Infrastructure, operation condition and rolling stock specification. The infrastructure data consist of the type of track (ballasted or ballast-less), maintenance condition (suitable or unsuitable) and geometry conditions (vertical and horizontal radius
curve, lateral inclination angle, cant deficiency and cant excess). The operational condition contains the load weight, the permissible axle load and the operation speed. The rolling stock data comprise different wagon and traction features such as wagon length, center to center distance of bogies, center to center distance of wheels in a bogie, the bottom height of wagons from the rails and etc. The entrance of these data can be done individually, while an option is also developed which can select the specifications of different predefined wagons from the program data base.

In the loading geometry submenu, the dimensions of cargo on the bottom of wagon can be entered in different heights. These data along with the geometry data of wagons is considered as the maximum rolling stock structure gauge (profile 1 in fig.1). Moreover and in the route selection submenu, a particular section of track is defined as the route through which the wagons are considered to be passed. With the route selection, the code can estimate the around structure geometry in the most critical points which leads to the target installation gauge (profile 6 in fig.1.). Additionally and with reduction of railway individual margins, the lineside structure gauge can be resulted. It should be noticed that the around structure data can be gathered via different mapping techniques such as laser scanning method which was described in the last section.

5-2- Calculations and Drawings of Optimum Gauges

After definitions of input parameters, the required calculations for obtainment of different optimum gauges can be accomplished. Hence, the drawings of different profiles can be completed as presented in figure 5. A special feature for controlling and evaluating different points and distances between gauges is also considered in the developed code. For this mean, with a click on the surface, the coordinates of related point as well as its distance from the other predefined point can be resulted.

![Fig.5. Drawings of Different Calculated Profiles (Plus tunnel cross section)](image)

5-3- Control and Evaluation of Safe Passage

The drawing results from the last part make it possible to compare different optimum gauges with each other. The followings may be concluded:

1- No confliction between the kinematic and free structure profiles shows the complete safe passage of rolling stock without any incident.
2- Confliction between the kinematic and free structure profiles, but no confliction between kinematic and installation profiles shows the probability of incidents with the individual railway margins however, the passage of rolling stock considering the limits of individual margins and with permission of railway operational administration can be followed (for example for special cargos and with reduction in the speed).

3- Confliction between kinematic and installation profiles shows the unsafe passage of rolling stocks and high probability for incidents of wagons with around structures such as tunnels.

5- Conclusion
In the current paper, a new calculation process for definition of optimum railway clearances was presented and the related developed code was investigated. For this mean, the provisions of UIC leaflets, was utilized because of its universality and detailed calculations. According to the UIC formulations and utilizing a procedure for gathering and inputting the real geometrical data of around structures (i.e. laser scanning technique) as well as the real geometry of rolling stock and loading conditions, the optimum swept and structure gauges was obtained.

6- References
3- UIC 505-4, "Effects of the application of the kinematic gauges defined in the 505 series of leaflets on the positioning of structures in relation to the tracks and of the tracks in relation to each other", 1977.
4- UIC 505-5, "Basis conditions common to leaflets 505-1 to 505-4 - Notes on the preparation and provisions of these leaflets", 1977.