VALIDATION OF MULTI-BODY MODELS FOR SIMULATIONS IN AUTHORISATION OF RAIL VEHICLES

O. Polach[1], A. Böttcher[2], D. Vannucci[3], J. Sima[4], H. Schelle[5], H. Chollet[6], G. Götz[7], M. Garcia Prada[8], D. Nicklisch[9], L. Mazzola[10], M. Berg[11], M. Osman[12]

[1)]Bombardier Transportation (Switzerland) AG, Switzerland, [2)]Alstom Transport Deutschland GmbH, Germany, [3)]Ansaldobreda, Italy, [4)]Siemens AG, Germany, [5)]TU Berlin, Germany, [6)]IFSTTAR, France, [7)]Bombardier Transportation GmbH, Germany, [8)]CAF, Spain, [9)]DB Netz AG, Germany, [10)]Polimi, Italy, [11)]KTH, Sweden, [12)]RSSB, UK

Received: June 12, 2013

EXTENDED ABSTRACT

1. INTRODUCTION

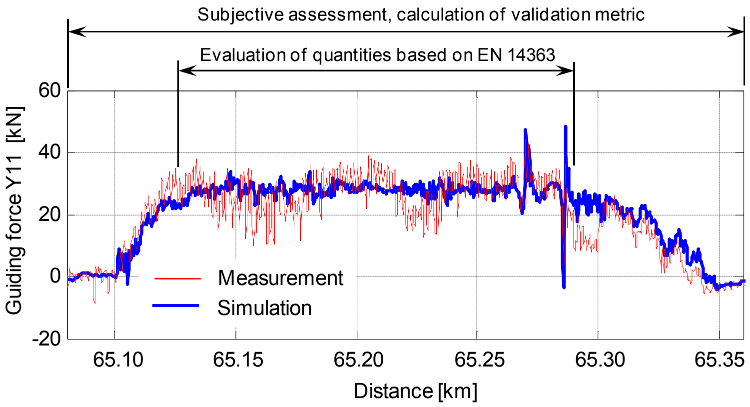
It is possible to reduce the cost and duration of vehicle acceptance in regard to running dynamics by using multi-body simulations instead of on-track testing. This, however, is only possible if there is confidence that the simulation results have been produced by using a validated railway vehicle model. The model validation was the topic investigated in Work Package 5 of the research project DynoTRAIN.

The investigations regarding the definition of objective criteria and quantitative limits for model validation were carried out by comparing simulations with measurements from a test campaign carried out in four European countries in October 2010 and accompanied with continuous measurement of track irregularities and rail profiles. The following vehicle models were assessed:

- 2 models of locomotive DB BR 120 (in simulation tools Simpack and VOCO)
- 2 models of DB passenger coach Bim (in simulation tools Simpack and VOCO)
- 2 models of empty freight wagon Sgns with Y25 bogies (in simulation tools Simpack and VOCO)
- Model of loaded freight wagon Sgns with Y25 bogies in Simpack
- Laas freight unit consisting of two 2-axle freight wagons with UIC link suspension modelled in Simpack.

2. EVALUATION OF VALIDATION CRITERIA AND LIMITS

The comparisons simulation-measurement were carried out for all vehicle models under the same conditions over selected track sections of the test runs. The analyses of about 1 000 simulation runs considered about 50 000 pairs of values evaluated by analogy with EN 14363 [1], together with more than 6 000 plots assessed subjectively by the project partners as well as 120 selected plots during a workshop with experts. Furthermore, deviations of simulation results and measurements in the time histories were assessed by so-called validation metrics [2] calculating error factors related to magnitude and phase deviation. This provided an opportunity for quantifying comparisons between simulation and measurement, while still maintaining a correlation with experts' opinions. An example of a comparison between simulation – measurement and its assessments can be seen in Fig. 1.



Quasi-static guiding force Y_{qst}	Simulation	28.09 kN
	Measurement	27.81 kN
	Difference	0.28 kN
	Rel. difference	1.0%
Maximum guiding force Y_{max}	Simulation	46.19 kN
	Measurement	43.17 kN
	Difference	3.02 kN
	Rel. difference	7.0%
Positive assessment workshop		73%
Positive assessment partners		80%
Validation metric	M_{SG}	0.019
	P_{SG}	0.080
	C_{SG}	0.082

Fig. 1 Example of validation diagram and assessment results: Guiding force on the leading wheel of passenger coach Bim at 68 km/h in a curve with 312 m radius

Correlations between the quantities evaluated by analogy with EN 14363, the assessments by validation metric and the subjective assessments of plots were analysed. The relationship between the assessments and the simulation results achieved was investigated in order to specify criteria and limits ensuring reliable and objective model validation and at the same time allowing a successful validation applying the state of the art modelling and simulation, see Fig. 2. The effects of using the actual track data (measured track irregularities, rail profiles) as opposed to random track data and the usage of stationary tests for the model validation in regards to simulation of the on-track tests were also investigated.

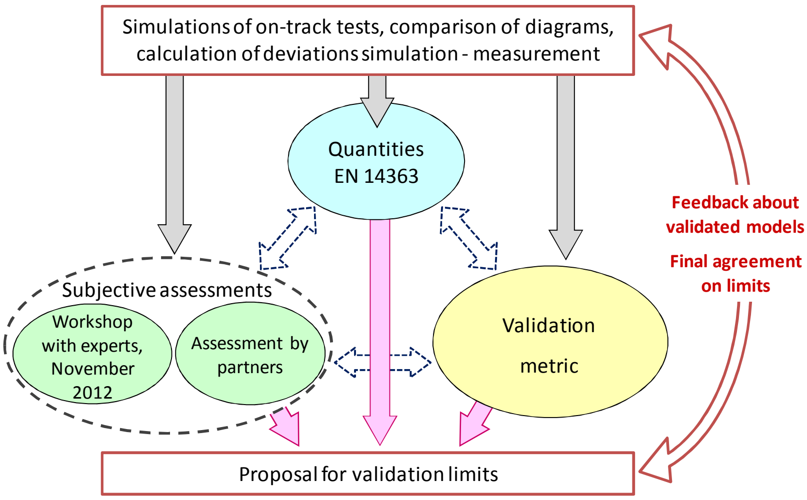


Fig. 2 Evaluation of validation criteria and limits carried out in DynoTRAIN WP5

The investigations show that the quantities based on EN 14363 so far provide the best potential for an objective validation assessment. An application of these criteria on a few single pairs of compared simulation – measurement values, however, does not provide sufficient information about an overall model assessment. It is therefore proposed to assess a whole set of simulation – measurement pairs for each quantity. The proposed model validation process considers a minimum of 12 test sections and a minimum of 2 signals (sensors) per quantity. The assessed quantities are quasi-static values and maximum values of wheel/rail contact quantities (Y, Q, Y/Q and ΣY) and rms and maximum values of vertical and lateral car body accelerations. The validation is assessed comparing the mean and standard deviation of differences between simulation and measurement for each particular quantity with the validation limits.

Fig. 3 shows an example of validation results of four vehicle models developed using available parameters including measured profiles of wheels and rails and measured track irregularities, however without any model adjustments. The mean and standard deviation of differences between simulation and measurement are normalised by the proposed validation limits. A vehicle model is thus validated if magnitudes of all values are lower than 1. From the four vehicle models compared, only the initial model of the Bim coach fulfils the validation limits. The other vehicle models must be adjusted to be validated.

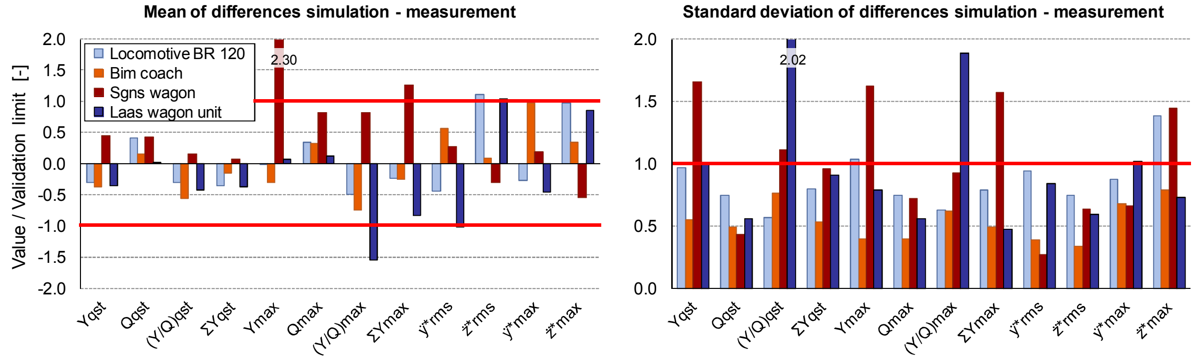


Fig. 3 Normalised values of mean and standard deviation of differences between simulation and measurement for the models of locomotive (Siemens), Bim coach (Bombardier), loaded wagon Sgns (TU Berlin) and freight wagon unit Laas (Alstom)

3. CONCLUSIONS

The validation investigations in the DynoTRAIN project represent unique work in regard to both simulations as well as on-track measurements. The presented investigations provide criteria and proposed limits for validation of multi-body vehicle models in regard to simulations of on-track tests in the context of railway vehicle authorisation.

4. ACKNOWLEDGEMENTS

This abstract describes work undertaken in the context of the DynoTRAIN project, Railway Vehicle Dynamics and Track Interactions: Total Regulatory Acceptance for the Interoperable Network (www.triotrain.eu). DynoTRAIN is a collaborative project – medium-scale focused research project supported by the European 7th Framework Programme, contract number: 234079 and is led by UNIFE.

5. REFERENCES

[1] EN 14363 Railway applications—Testing for the acceptance of running characteristics of railway vehicles—Testing of running behaviour and stationary tests, CEN, Brussels, 2005

[2] Schwer, L.E.: Validation metrics for response histories: perspectives and case studies. Engineering with Computers 23 (2007), pp. 295–309