METHODS FOR RUNNING STABILITY PREDICTION
AND THEIR SENSITIVITY TO WHEEL/RAIL CONTACT GEOMETRY

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EXTENDED ABSTRACT

1. INTRODUCTION

Bogie instability or bogie hunting is a safety criterion. The bogies are unstable for
all speeds higher than the critical speed. If the low frequency bogie movement is
coupled to carbody movement, a deterioration of the lateral comfort behaviour by low
damped carbody modes or by carbody instability can be observed. In comparison to
bogie hunting, carbody instability can usually be suppressed with increasing speed.

The paper concentrates on bogie stability. Methods are presented of nonlinear
stability analysis as they can, or may be used in industrial applications as well as the
comparison of their results for different wheel/rail contact geometries.

2. METHODS FOR NONLINEAR STABILITY PREDICTION

Various non-linear methods are feasible in regard to stability design during the
development of the vehicle. According to the type of excitation, differentiation can be
made between analyses with no excitation, with excitation by a singular irregularity
input (with certain one or with several amplitude values), or by excitation with
stochastic (measured) track irregularity.

These methods were compared with the aid of two differing examples of
wheel/track contact geometries. At a wheelset lateral movement amplitude of 3 mm,
both contact geometries demonstrate the same equivalent conicity of 0.4. As can be
seen in Fig. 1, one of the combinations (04A) demonstrates lower conicity for wheelset
movement with amplitude below 3 mm, whereas the other (04B) demonstrates higher
conicity. A four car articulated vehicle was investigated for comparison of the
methods. The results are given for the trailing wheelset of the first bogie, at which the
stability limits are first reached.

Method without excitation:

In this case a high speed during which the bogie moves in a limit cycle is used as
initial condition and a continuous speed reduction takes place. The speed at which the
vibrations subside is designated as being the critical speed, see Fig. 2. In one case
(04A) the vibrations stop abruptly whereas in the other case (04B) the wheelsets
continue to vibrate in a small limit cycle, only stabilising at a significantly lower
speed, which subsequently leads to differing critical speeds at the same conicity.
Fig. 1 Conicity diagram of examined combinations wheelset/track

Fig. 2 Simulations of run with decreasing speed

Fig. 3 Bifurcation diagrams

Fig. 4 Simulations of run on track with irregularities
Methods with single excitation:
Investigating damping behaviour following a single lateral track excitation, stability can be assessed; however the damping behaviour at the same conicity can differ for various contact geometries. If the amplitude of the stable limit cycle is presented in function of speed, a bifurcation diagram results, see Fig. 3. In certain cases the solution can vary – depending on the excitation amplitude – between a damped movement and a limit cycle. Differing forms of the bifurcation diagram can evolve depending on the profile combinations used.

Methods with stochastic excitation due track irregularity:
In order to predict bogie stability, methods specified for measurements and acceptance tests can also be applied. Running on straight track with measured irregularities is simulated and criteria for measurements and vehicle acceptance [1], [2] are applied for assessment:
- rms value of the sum of guiding forces (track shifting force)
- rms value of lateral acceleration on the bogie frame.

Another criterion still applied for on-line surveillance is the peak value of lateral acceleration on the bogie frame, as defined in the (now invalid) version of UIC 515 [3]. The limit value is seen to be exceeded when the value 8 m/s² occurs during more than 6 consecutive cycles. A comparison of the simulation results is given in Fig. 4. The criteria investigated are comparable against each other; however the criterion of the rms value of lateral acceleration on the bogie frame leads to a slightly lower permissible speed. In contrast to the method without excitation, the results for both contact geometries lie close to each other in this case.

Further examples of the results and discussion will be presented in the paper.

3. CONCLUSION

The non-linear methods enable a detailed stability analysis, but may lead to a partial differentiation in the results amongst each other, or with respect to the measurements during the vehicle acceptance tests. The results of the non-linear methods and the limiting values for the vehicle acceptance are similar if the potentially occurring limit cycles with low amplitude are not considered as a deviation from the stability limit. The best comprehension of vehicle behaviour on the stability limit is possible on the basis of a bifurcation diagram. The analysis of the linearization of wheel/rail contact can contribute to a better assessment of the non-linear analyses.

4. REFERENCES