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Title:

Aerodynamic Design of a Competitive Freight Wagon

Authors & affiliations:

*Emir Öngüner, Arne Henning, Claus Wagner**
German Aerospace Center (DLR), Institute of Aerodynamics and Flow Technology,
Bunsenstr. 10, 37073 Göttingen, Germany
**Technische Universität Ilmenau, Institute of Thermo- and Fluid Dynamics*
Helmholtzring 1, 98693 Ilmenau, Germany

Abstract: (Your abstract must use **Normal style** and must fit in this box. Your abstract should be no longer than 1200 words. The box will 'expand' over 2 pages as you add text/diagrams into it.)

Preparation of Your Abstract
1. The title should be as brief as possible but long enough to indicate clearly the nature of the study. Capitalise the first letter of the first word ONLY (place names excluded). No full stop at the end.
2. Abstracts should state briefly and clearly the purpose, methods, results and conclusions of the work.
Introduction: Clearly state the purpose of the abstract
Methods: Describe your selection of observations or experimental subjects clearly
Results: Present your results in a logical sequence in text, tables and illustrations
Conclusions: Emphasize new and important aspects of the study and conclusions that are drawn from them

Introduction (300 words)

The energy efficiency of rail freight by means of reduced drag can be increased significantly by technical and operational measures. Previous studies have shown that optimizing the car sequence can result in a drag reduction by at least a factor of 2 (Barkan, 2009). Consequently, an aerodynamic optimization of freight trains includes intelligent logistics concepts. Such concepts can be supported by means of providing priority lists for operational measures, resulting from experimental and numerical studies. But the aerodynamic resistance of a freight train with an optimized car sequence is still about 50% higher compared to a passenger train of the same length (Li, 2011). It is clear from this fact that there is a high potential for aerodynamic optimization of the individual wagon in the freight transport sector. As part of the FR8RAIL-Project in the framework of the EU joint undertaking Shift2Rail, an innovative freight wagon will be developed.

A look at the existing freight wagon fleet shows that their design gives little consideration to aerodynamics. The entire contour of the existing wagons is determined by the laws of traditional steel construction. UIC (International Union of Railways) compatibility also greatly restricts the options for optimizing drag reduction which is the case for the air flow both underneath and along the sides of the vehicles. In contrast to previous approaches making modification to existing vehicles, a conceptually new approach offers far more options with regard to innovative aerodynamic optimization of single wagons and freight trains. This work needs to ensure the compatibility of the solutions with the logistics systems developed in the framework of the FR8RAIL project, for example by planning a rapid and low-cost assembly of the aerodynamic components. The investigations are performed concomitantly, so the safety-relevant aspects are considered continuously during the aerodynamic design of the freight wagon.

Methods (300 words)

The aerodynamic investigations are conducted in the cross wind facility Seitenwindkanal Göttingen (SWG) at the Institute of Aerodynamics and Flow Technology at DLR Göttingen. It is a Göttingen-type atmospheric wind tunnel with a 3.13 contraction and can be operated in the flow-speed range $2 < U < 65$ m/s, driven by a 0.5 MW compressor. The maximum Mach number feasible in the SWG is $Ma = 0.21$. The SWG is equipped with a 9m long test section, divided into

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four segments. The cross-section of the test section is 2.40m (width) x 1.60m (height). The test section is equipped with a turn table to study side-wind effects. To study the underbody flow of road vehicles, a moving belt is available.

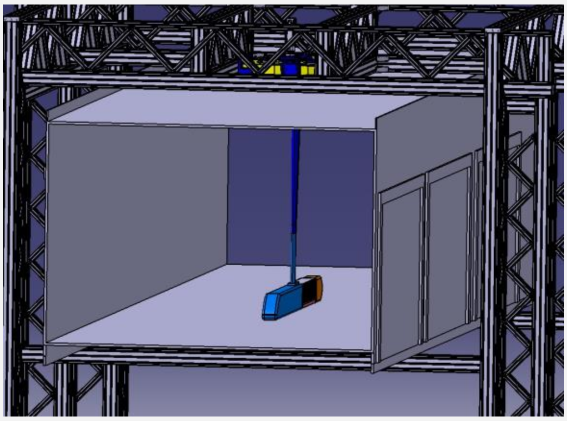
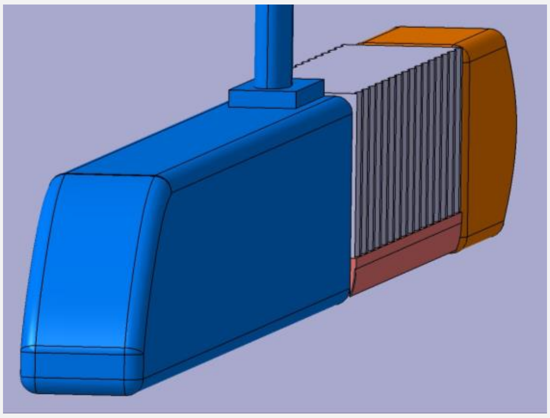

Figure 1 (left): Placement of the model in wind tunnel test section using vertical sting
Figure 2 (right): Preliminary concept with upstream (blue) and downstream (orange) dummy vehicles

The main model configuration consists of three sub-bodies (Figure 1 and 2). First and third bodies act as dummy vehicles; they are placed in upstream and downstream locations and the freight wagon is located between these two dummies. A vertical-rotating sting with a NACA profile is attached to the ceiling of the test section which is directly integrated to the first dummy vehicle in upstream location in order not to manipulate the freight vehicle model. The attachment position is close to the rear end of upstream vehicle. The sting is attached to an internal piezo-electric force transducer which can be excited by incoming flow and acquire resulting aerodynamic forces and moments. This sting can also be rotated in the vertical axis to study crosswind effects.

Results (300 words)

At the beginning of the design process a priority list for the aerodynamic optimization is compiled. Resulting from experimental and numerical studies adjusted to new concepts, the ranking identifies the most effective measures in terms of drag reduction. Part of the work includes an inventory and analysis of existing datasets from the aerodynamic development of rail vehicles. After an analysis and inventory of the drag contribution from a single vehicle and the share of the position-dependent total resistance of the train, a parameter space is defined, describing the technical potential to optimize the aerodynamics of the rail freight transport system. The existing analysis and calculation methods are evaluated, documented and adapted to the changed conditions of an innovative new wagon design. The effective and implementable aerodynamic measures are identified and will be brought to the application in the subsequent work.

The study of different configurations belongs to the scope of the measurements of the train itself, which consists of a succession of Lorries, as well as various loading conditions in the form of different bodies. Experiments are conducted in order to examine the crosswind behavior under various flow conditions to make statements about the safety of the respective configuration.

The requirements for a successful optimization of the flow resistance of individual freight wagons and their combinations are very different from previously conducted aerodynamic designs of passenger trains. The resistance of the complete train varies with the different aerodynamic interaction of individual wagons and their order in the trainset. In contrast to passenger trains the

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flow of a freight train is typically fully separated and is dominated by large scale turbulent flow structures. Therefore the analysis tools are adapted to these complex flow conditions in order to make reliable predictions of the flow resistance.

Conclusions and Contributions (300 words)

The new development of a freight wagon requires a strong and well defined working interface between the lightweight concepts and the aerodynamic design and should include a conceptual design of easily mountable, aerodynamic optimized attachments. It is expected that the developed vehicles will then have significantly improved aerodynamics in order to reduce the drag drastically and increase the efficiency of transportation process. In an ideal case the design of the underfloor area will be done analog to modern passenger trains and the intercar-gaps need to be optimized by passive flow-controlling systems like spoilers and baffle plates.

References

Barkan, C. (2009), Railroad transportation energy efficiency, Presentation at University of Illinois Urbana-Champaign, Urbana-Champaign, IL, USA

Li, Y. T. (2011), Aerodynamic drag analysis of double-deck container vehicles with different structures , Journal of Central South University of Technology, Vol. 18, pp. 1311-1315