State-of-the-art wheel slide protection with the air-free braking system
from Siemens Mobility

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State-of-the-art wheel slide protection systems must conform with the requirements of the wheel slide protection standard EN 15595 and UIC Technical Leaflet 541-05 to be usable for rolling stock. The Siemens SIBAS GS Compact wheel slide protection system is both UIC and EC certified. The new air-free braking system extends this wheel slide protection system to incorporate an air-free brake actuator to reduce the braking force when the vehicle wheels slide.

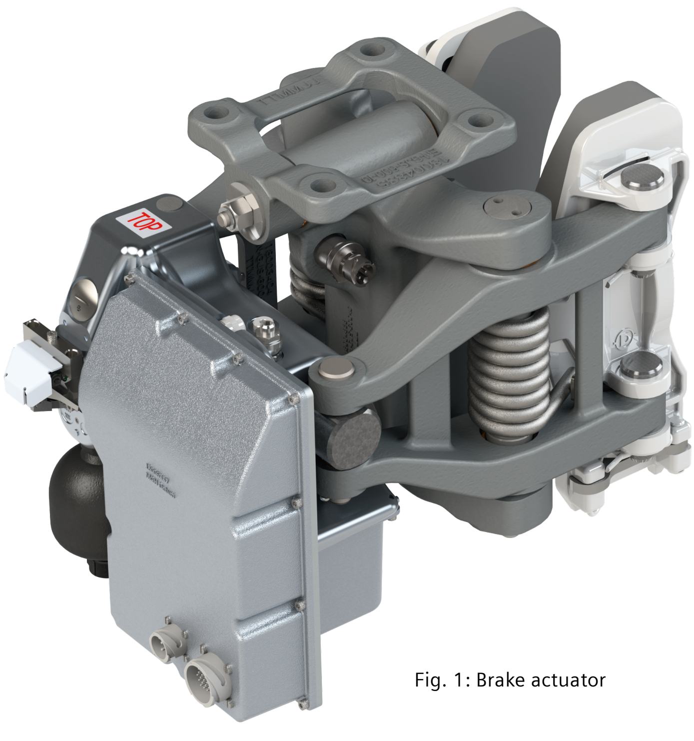

Fig. 1: Brake actuator

The fast actuator control response times to reduce and establish the braking force help to optimize wheelspin control. In particular, the considerably faster brake force control in comparison to conventional pneumatic calipers leads to a better prevention of excessive wheel slip and wheel standstill during braking.
Due to this the slip can be actively controlled and therefore the adhesion optimally utilized. The X-Wagen train for Vienna was the first series application for this innovative system. The requirements laid down in EN 15595 were used as basis when accepting the wheel slide protection system.

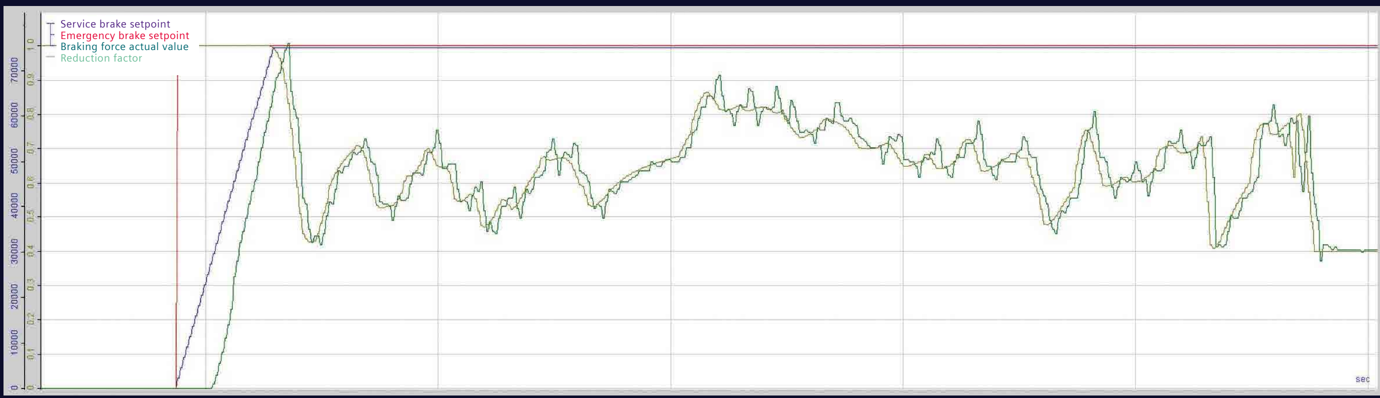

Fig. 2: Example of reduced braking force

Introduction

With the wheel slide protection function as integral component, the air-free braking system essentially consists of the Siemens Mobility brake control unit and the electrically controlled, intelligent brake actuators. The intelligent brake actuator (Fig. 1) comprises a compact, autonomous electro-hydraulic unit as well as the brake caliper for the specific running gear, combined with all the components required to generate braking force. The brake actuator is integrated in the train using a basic electrical interface and connected to the brake control unit via a CAN bus. This transfers all the setpoints and status information required between the actuator and brake control unit. The brake actuator is directly integrated in the brake safety circuit of the train, as well as in the higher-level control system of the specific vehicle via the electronic brake control unit. This means that the command of the emergency/safe brake loop is transferred redundantly to the brake actuator. The service brake setpoints are sent to the brake actuator from the brake control unit via the CAN bus instead of via an electropneumatic controller. In the event of unfavorable rail conditions and resulting wheel slide during braking, the brake control unit specifies the reduction factor to avoid wheel slide.

The basis of the wheel slide protection system is the SIBAS GS Compact that is UIC and EC-certified, where the brake actuators are controlled directly instead of via the wheel slide protection valves. To control the braking force while the wheel slide protection function is intervening, an analog reduction signal (100 – 0%) is sent to the brake actuator via the local bus. After this has been checked for plausibility, the actual braking force setpoint is multiplied by the reduction factor and the resulting braking force is implemented accordingly. Therefore, the brake is controlled using an analog signal in the case of wheel slide. The reduction factor is rejected if the plausibility check detects an error.
From a functional perspective, based on this architecture, the requirements as described in DIN EN 15595: 2021-07-01 (Railway applications – Brake – Wheel slide protection; German edition EN 15595:2018+AC:2021) and the UIC Technical Leaflet 541-05: 2016-03-01 (Brakes – Specifications for the construction of various brake parts – Wheel Slide Protection device) can be complied with

As a result of the system's architecture, the brake actuator is able to implement the required braking force significantly faster in case of wheel slide. In particular, brake force reduction as well as build-up can be realized significantly faster. Response times of less than 100 ms can be achieved, which is the time between sending the reduction factor to actually achieving the required brake force and signaling back the reduced braking force (Fig. 2).

Objectives of wheel slide protection

Wheel slide protection should become active if excessive wheel slide occurs, i.e. the difference between the wheel speed and vehicle speed becomes excessive. In the event of wheel slide, it is crucial that the braking distance extension should be kept to a minimum. Further, it should be avoided that the wheels come to a complete standstill. DIN EN 15595 and UIC 541-05 define conditions and test criteria to evaluate the quality of a wheel slide protection system. These must be complied with, both when generally accepting the wheel slide protection system as well as when checking the integration of the braking system in the vehicle itself. To do this, unfavorable rail conditions with reduced adhesion (simulation of 5 – 8% of the initial adhesion) are simulated. This means that the adhesion between the wheel and rail is not sufficient to transfer the required braking force to the rail. The resulting increase in the braking distance when compared to braking under dry conditions cannot be higher than that specified – i.e. braking without wheel slide protection interventions. In this case, the maximum available adhesion μmax falls below the required nominal adhesion, and the wheel slip would increase until the wheels come to a complete standstill. By intelligently controlling the braking force, the wheel slide protection system controls wheel slip so that it is in a range that allows to fully utilize the maximum available adhesion μmax. Since this point is transient (unsteady), the braking force can only be controlled around it. A variant of such an adhesion characteristic as a function of the slip is shown in Fig. 3; however, these characteristics vary significantly depending on the rail conditions. The wheel slide protection system must be able to handle this variance. For extremely low adhesion values, which can be simulated using oil or paper, the wheel slide protection system should prevent wheels coming to a standstill and the braking distance increase is no longer evaluated for these extreme situations.

Advantages of an air-free wheel slide protection system

By using an air-free brake and state-of-the-art wheel slide protection algorithm embedded in SIBAS GS Compact, the experience gained from the pneumatic domain is leveraged and intelligently combined with the fast closed-loop control using intelligent brake actuators.

The fast system response times allow wheel slip to be precisely controlled, therefore optimizing the utilization of the maximum adhesion available. In addition, wheel blockage can be reliably avoided, especially at speeds below 30 km/h. The characteristics of 24 axles of the X-Wagen train during an acceptance run for the wheel slide protection system are shown in Fig. 4.
Here, it could be clearly demonstrated that the braking distance increase of 25% from 80 km/h specified for the project was able to be significantly undershot, even without a payload and significantly higher nominal adhesion utilization than 0.15.

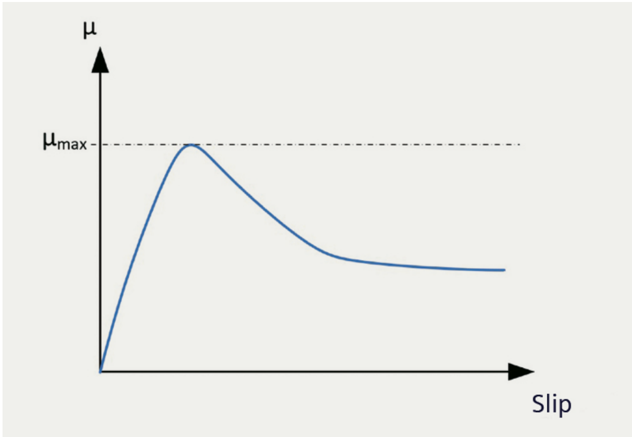

Fig. 3: Slip characteristic

For extremely low adhesion values, wheel blockage is avoided at an early stage by quickly de-braking (very fast brake force reduction of) the wheels. Further, also for the service brake, braking forces can be quickly and intelligently redistributed to the carrying axles to reduce the adhesion utilization at the powered axles. As a consequence, when the wheel slide protection system intervenes, not only does the friction brake reduce the vehicle speed, but also the performance of an electrodynamic brake is utilized to a maximum to guarantee wear-reduced operation. The air-free Siemens braking system was deployed for the first time in the X-Wagen train for Vienna, and all the requirements of the EN 15595 standard have already been successfully verified during the acceptance runs.

Fig. credit: 1 to 4: Siemens Mobility GmbH

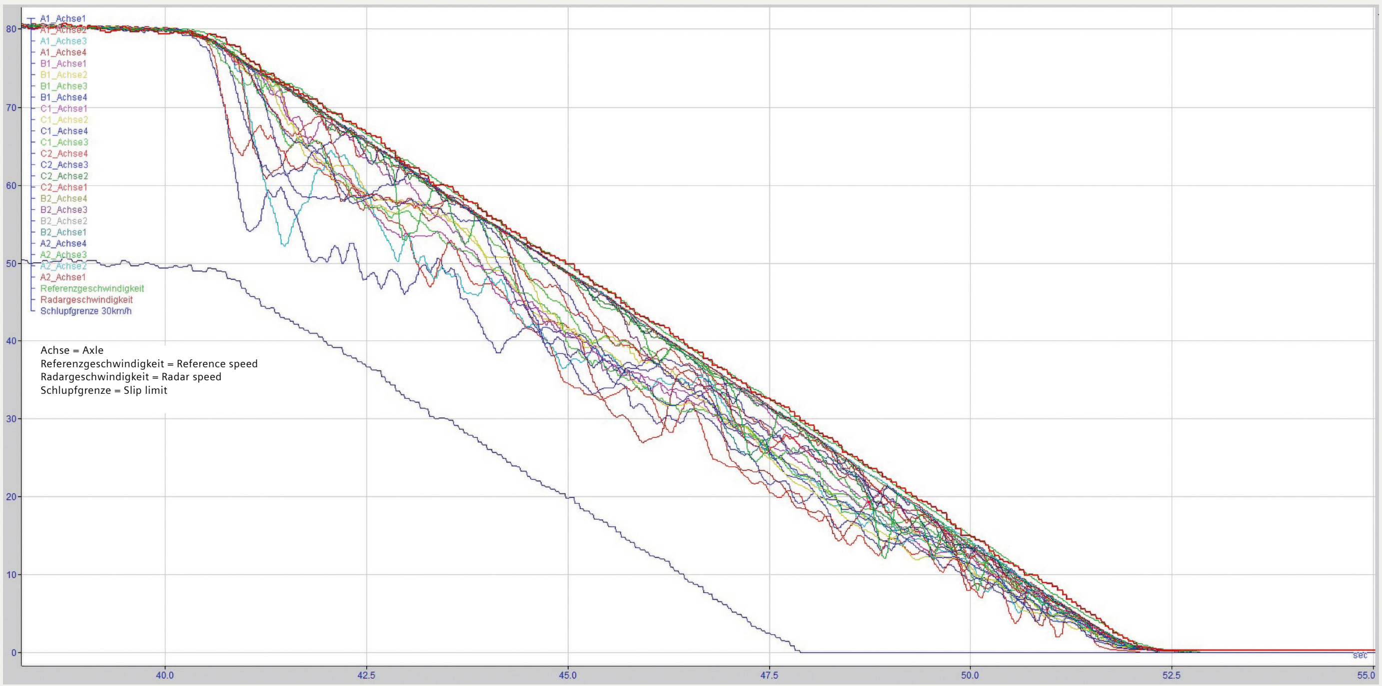

Fig. 4: Example, axle characteristics under poor rail conditions

Jens Lichterfeld is "Senior Expert Brake" for Siemens Mobility GmbH and heads up the R&D project for the air-free braking system. He has been with the company since 2004, and has held various positions in engineering, software and hardware testing and validation, commissioning and project management. He received his training to become an associate engineer for mechatronic systems at the Siemens Technical Academy Berlin. With over 18 years of experience in this domain, he has a wealth of knowledge and experience in the area of braking systems.

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Siemens Brakes

Since the business unit was formed back in 2003, Siemens Brakes has implemented pneumatic brake systems in a wide range of projects (including all Metro projects since 2003). The in-house electronic brake control and wheel slide protection system (SIBAS GS Compact) as central part of the brake system have been used exclusively in all these projects. Highest quality and reliability is achieved by using state-of-the-art tools and through close collaboration with railway proven suppliers.

To provide seamless support over the complete project execution – including the supply of spare parts – qualified and experienced personnel work at our Erlangen, Krefeld, Wien and Graz facilities. The in-house test center is equipped with test stands that allow realistic vehicle simulations comparable to operation scenarios on the physical train, and provide the appropriate components and system tests as well as a testing laboratory accredited according to DIN EN ISO/IEC 17025.