WHITEPAPER

EFFICIENT BRAKE FORCE TESTING ON ALL-WHEEL DRIVE VEHICLES

CHALLENGES AND SOLUTIONS FOR PRECISE AND SAFE TEST METHODS

Optimising brake testing on all-wheel drive systems, taking specialised test benches and procedural requirements into account.

MAHA

Abstract

Brake force testing is one of the most critical measures for ensuring road safety, as it verifies a vehicle's ability to perform in critical situations. All-wheel drive vehicles, however, present considerable challenges. Their complex torque distribution and diverse drivetrain configurations call for specialised testing approaches. Standard test benches frequently fail to meet these requirements, potentially leading to incorrect measurement results and mechanical damage to vehicles.

This whitepaper examines the technical characteristics of brake force testing on all-wheel drive systems, including viscous couplings, Haldex systems and rigid drive shafts with rear axle differentials. It explains why specialised test benches with all-wheel drive mode (like those from MAHA) are essential for achieving precise, reliable results and avoiding drivetrain damage. The risks arising from testing with pseudo-systems or unsuitable standard equipment are also highlighted.

Finally, this whitepaper offers practical solutions and recommendations to ensure the safety and functionality of all-wheel drive vehicles in the long term. It is aimed at test engineers, workshops and decision-makers working in the field of vehicle maintenance who are seeking a firm foundation for effective and accurate brake force testing.

WHITEPAPER

Efficient brake force testing on all-wheel drive vehicles
Challenges and solutions for precise and safe test methods

Optimising brake testing on all-wheel drive systems,
taking specialised test benches and procedural requirements into account

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SECTION

1 Introduction 8

1.1 The importance of brake force testing . . . 8

1.2 Challenges encountered with all-wheel drive vehicles . . . 8

1.3 The complexity of all-wheel drive systems . . . 8

1.4 Specialised test methods . . . 8

1.5 Aim of this whitepaper . . . 9

2 Fundamentals of all-wheel drive 9

2.1 Significance of all-wheel drive . . . 9

2.2 Challenges encountered in brake force testing . . . 9

2.3 Types of all-wheel drive . . . 10

2.3.1 Switchable all-wheel drive . . . 10

2.3.2 Viscous coupling . . . 10

2.3.3 Haldex system (electrohydraulic all-wheel drive) . . . 11

2.3.4 Rigid drive shaft (permanent all-wheel drive) . . . 11

2.3.5 Torque vectoring systems . . . 12

2.3.6 Electric all-wheel drive (electrohydraulic or hydraulic) . . . 12

2.4 Significance of specialised test methods . . . 12

3 Challenges encountered when testing the brakes of all-wheel drives 13
3.1 Technical challenges . . . 13
3.2 Test method requirements . . . 13
3.3 Summary of the affected systems . . . 14
3.4 Overview of susceptibility by drivetrain configuration . . . 15
3.5 Significance of specialised test benches . . . 15
4 Methods for testing the brakes on all-wheel drive vehicles 15
4.1 General steps. . . . 15
4.2 Test method with a counter-rotating wheel drive . . . 16
4.3 Specific test methods . . . 17
4.4 Significance of calibration and adaptation . . . 18
5 Technical implementation 18
5.1 Technical implementation requirements . . . 18
5.2 Using reflective strips, light barriers and wheel crosses . . . 19
5.3 Testing gear play (gear play mode) . . . 19
5.4 Learning mode and adjustment of drive motors . . . 20
5.5 Handling specific all-wheel drive systems . . . 20
5.6 Advantages of technical implementation . . . 21

6 Common mistakes and how to prevent them 21

6.1 Significance of avoiding mistakes 21

6.2 Common sources of error and solutions 21

6.2.1 Light barriers or wheel crosses mounted incorrectly 21

6.2.2 Neglecting chain tension and its effects 22

6.2.3 A lack of wheel synchronisation with a rigid drive 22

6.3 Summary 22

7 Recommendations and best practices 22

7.1 Standardised test modes based on drive type 22

7.2 Training test personnel 24

7.3 Using damping software for specific vehicle types 24

8 Conclusion 25

1 INTRODUCTION

1.1 THE IMPORTANCE OF BRAKE FORCE TESTING

Brake force testing is an indispensable part of vehicle maintenance and absolutely essential for road safety. Fully functional brakes ensure that a vehicle can reliably come to a controlled stop in critical situations. Regular brake effectiveness testing helps to identify defects at an early stage and prevent accidents [1].

1.2 CHALLENGES ENCOUNTERED WITH ALL-WHEEL DRIVE VEHICLES

Modern all-wheel drive vehicles present particular challenges for brake force testing that extend far beyond those encountered with conventional types of drivetrain. These vehicles distribute torque evenly or, as needed, across all wheels, so each wheel receives only a portion of the total braking torque. This adaptive force distribution considerably complicates the precise and independent measurement of brake force at each wheel. Standard test benches often cannot meet these requirements, leading to incorrect results or even damage to vehicle components such as differentials, drive shafts and coupling systems [2].

1.3 THE COMPLEXITY OF ALL-WHEEL DRIVE SYSTEMS

The sheer variety of all-wheel drive systems only exacerbates these challenges:

- **Viscous couplings:** Uncontrolled torques between the axles can distort measurement results.
- **Haldex systems:** React automatically to slippage and require special test methods to prevent undesirable system responses.
- **Rigid drives with rear axle differentials:** Require precise synchronisation of wheel speeds to avoid mechanical stresses and vehicle component damage [3, 4].

1.4 SPECIALISED TEST METHODS

Only purpose-developed test benches, such as MAHA's all-wheel drive brake testers, enable accurate and reliable brake force testing. This equipment offers special test modes that are tailored to the complexity of modern all-wheel drive vehicles. In contrast, unsuitable test benches inevitably lead to inaccurate or even incorrect results and an increased risk of mechanical damage to the vehicle [3, 4].

1.5 AIM OF THIS WHITEPAPER

This whitepaper examines the technical characteristics and challenges encountered when testing the brake force of all-wheel drive vehicles. It presents practical solutions for carrying out these tests effectively and safely to ensure both vehicle integrity and road safety.

2 FUNDAMENTALS OF ALL-WHEEL DRIVE

2.1 SIGNIFICANCE OF ALL-WHEEL DRIVE

All-wheel drive (AWD) distributes engine power to all four wheels of a vehicle, improving traction and stability on slippery or uneven road surfaces in particular. This technology has proven its worth for both everyday road use and challenging off-road conditions. Various types of all-wheel drive systems (either permanent or switchable) exist, using different mechanisms for torque distribution [1].

2.2 CHALLENGES ENCOUNTERED IN BRAKE FORCE TESTING

All-wheel drive vehicles bring specific challenges to brake force testing. On conventional roller dynamometers, tension can develop in the drivetrain, as the rigid connection between the front and rear axles does not compensate for differences in speed. This can cause inaccurate measurement results or even mechanical damage to vehicle components. Modern test benches with all-wheel drive mode drive the rollers in counter-rotation to avoid tension and achieve accurate results [2]. Additionally, all-wheel drive influences the function of brake control systems such as ABS and ESP, requiring special test methods to ensure vehicle stability and safety [3].

2.3 TYPES OF ALL-WHEEL DRIVE

2.3.1 SWITCHABLE ALL-WHEEL DRIVE

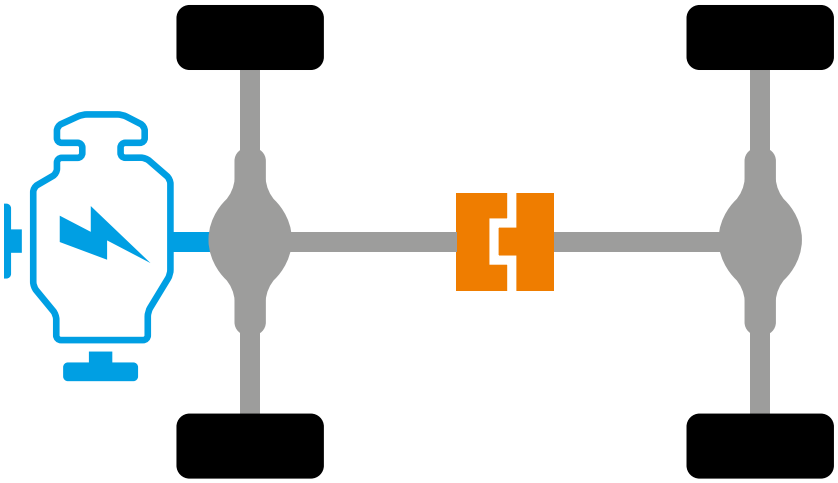

Figure 1: Switchable drive

- **Operating principle:** The all-wheel drive mode can be activated and deactivated manually or automatically. When deactivated, the vehicle behaves like a two-wheel drive.
- **Advantage:** Saves fuel and offers flexibility depending on road conditions.
- **Disadvantage:** Response delays during activation may occur

2.3.2 VISCOUS COUPLING

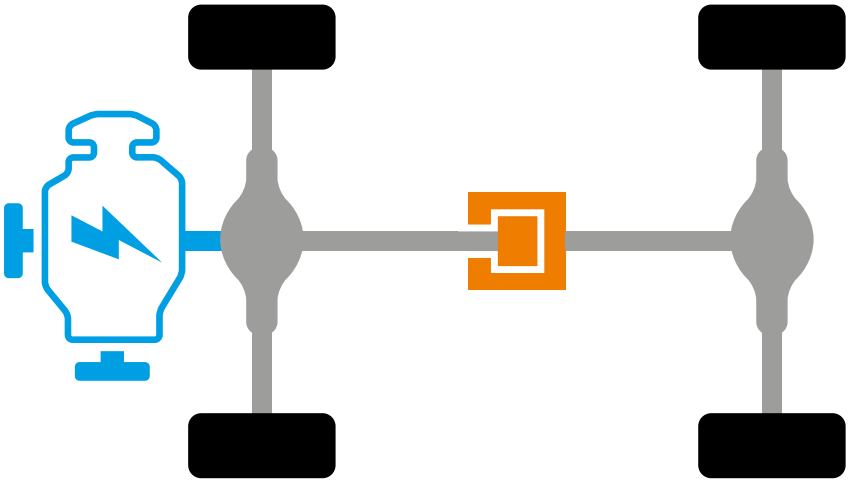

Figure 2: Viscous coupling

- **Operating principle:** A fluid inside the coupling reacts to differences in speed between front and rear axles and automatically transmits torque.
- **Advantage:** Automatic adaptation without any need for additional electronics.
- **Disadvantage:** Delayed response (depending on the fluid viscosity) to sudden traction changes.

2.3.3 HALDEX SYSTEM (ELECTROHYDRAULIC ALL-WHEEL DRIVE)

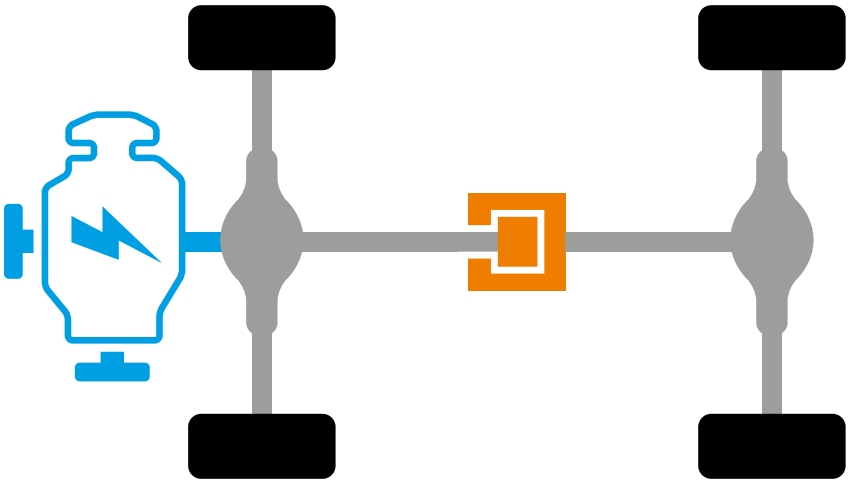

Figure 3: Haldex system (equivalent to viscous coupling engagement)

- **Operating principle:** An electronically controlled system that distributes torque to the rear axle as required.
- **Advantage:** Rapid response, ideal for front-wheel drive vehicles.
- **Disadvantage:** Higher costs and more complex maintenance.

2.3.4 RIGID DRIVE SHAFT (PERMANENT ALL-WHEEL DRIVE)

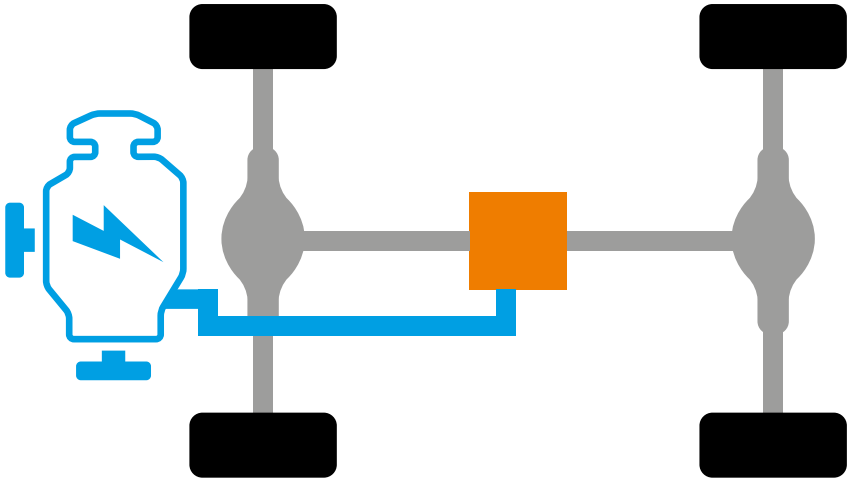

Figure 4: Permanent all-wheel drive

- **Operating principle:** Distributes torque rigidly to all four wheels by means of a rear axle differential.
- **Advantage:** Maximum traction, ideal for off-road vehicles.
- **Disadvantage:** Higher energy consumption and more complex testing requirements.

2.3.5 TORQUE VECTORING SYSTEMS

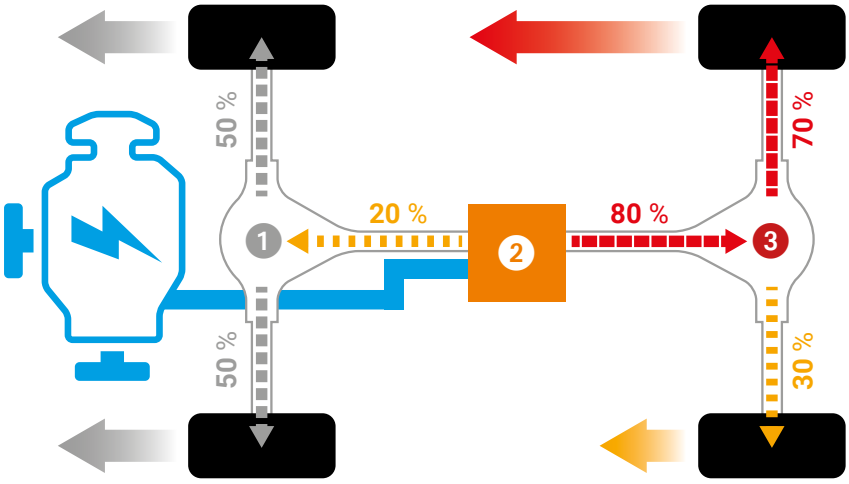

Figure 5: Distributed torques. ❶ Front open differential, ❷ Active centre differential, ❸ Active rear differential

- **Operating principle:** Distributes torques selectively between the front and rear axles and within the wheels of an axle.
- **Advantage:** Better cornering stability and traction.
- **Disadvantage:** Technically complex and costly.

2.3.6 ELECTRIC ALL-WHEEL DRIVE (ELECTROHYDRAULIC OR HYDRAULIC)

- **Operating principle:** Separate electric motors on the front and rear axles enable precise torque distribution.
- **Advantage:** High level of efficiency and ease of maintenance.
- **Disadvantage:** Dependent on battery performance; currently less widespread in off-road vehicles.

2.4 SIGNIFICANCE OF SPECIALISED TEST METHODS

The combination of all-wheel drive and brake force testing requires specialised test methods to ensure both accurate results and vehicle integrity. The variety of drivetrain configurations in particular makes it clear that conventional test benches cannot meet the requirements. Modern test benches with all-wheel drive mode are therefore absolutely essential to ensure safety and performance [2, 3].

3 CHALLENGES ENCOUNTERED WHEN TESTING THE BRAKES OF ALL-WHEEL DRIVES

3.1 TECHNICAL CHALLENGES

All-wheel drive technology brings specific challenges to brake testing, as torque distribution and drive characteristics require adapted test methods:

- **Torque transmission through the differential:** Differentials enable different speeds on an axle's wheels, which can lead to uncontrolled torque transmission during brake testing. These effects distort measurement results and impair testing, particularly in precision-based systems such as torque vectoring [2].
- **Risk of measurement errors and damage:** With incorrect test methods, braking torques can be distributed in an uncontrolled manner by means of drive shafts and differentials. This results in defective wheel brakes being incorrectly assessed as functional. Additionally, risks arise for mechanical damage to sensitive components such as viscous couplings or differentials [3].
- **Synchronisation problems with rigid and electric drives:** Rigid all-wheel drives with rear axle differentials or electric all-wheel drives with separate motors require precise wheel synchronisation. Without this, tension can occur, leading to both inaccurate results and physical damage to test benches and vehicles [4].

3.2 TEST METHOD REQUIREMENTS

Correct brake testing on all-wheel drive vehicles requires specialised test methods that account for the unique mechanics and dynamics of different all-wheel drive systems:

- **Roller dynamometers with counter-rotating drive:** These test benches drive an axle's wheels in counter-rotation, preventing torque build-up against the drive shaft in the differential gear. This stops torque transmission between the axles and enables 'load-free' torque distribution. Mechanical tension in the drivetrain is thus avoided, improving measurement accuracy and protecting the test bench technology.

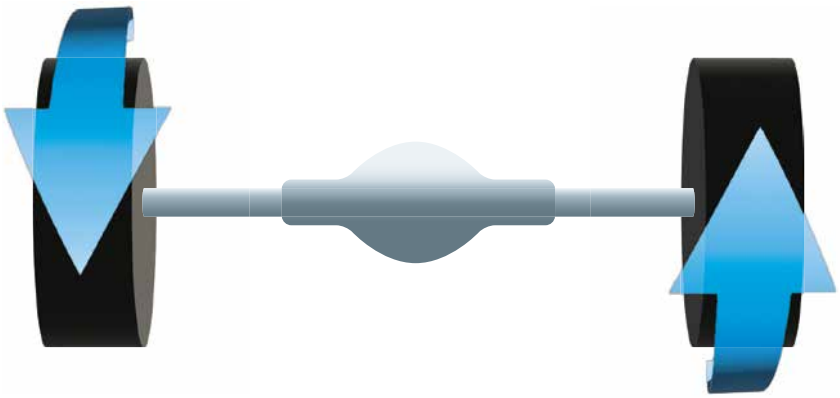

Figure 6: Counter-rotating wheel direction (Source: MAHA)

- **Individual wheel testing in counter-rotation:** For accurate results, brake testing is performed separately for each wheel. This method ensures that the braking torque of the forward-rotating wheel is measured, as brake pads, discs and drums are typically bedded in in the forward direction.
- **Using pedal force meters or pressure sensors:** To correctly compare the braking forces of both wheels on an axle, the greatest common denominator must be determined using pedal force after the measurement, or equal pedal force must be applied during testing. Alternatively, for pneumatic brakes, the axle's control pressure can be measured to ensure that the braking performance is comparable.
- **Dynamic test methods:** These methods take into account the specific requirements of modern all-wheel drive systems, such as torque distribution and automatic control mechanisms (e.g. in Haldex systems). Dynamic methods ensure accurate and realistic measurements, all the while taking the respective vehicle design into account.

By combining these test methods, the complex requirements encountered in modern all-wheel drives can be met to achieve reliable results while avoiding damage to both the vehicle and the test bench at the same time.

3.3 SUMMARY OF THE AFFECTED SYSTEMS

Susceptibility varies according to drive type:

- **High susceptibility:** Rigid drives with rear axle differentials and torque vectoring systems demonstrate the greatest susceptibility to errors and loading on test benches due to rigid or high-precision torque distribution.
- **Medium susceptibility:** Electric all-wheel drives and viscous couplings can be influenced by asynchronous motors or sudden torque changes.
- **Low susceptibility:** Switchable all-wheel drives and Haldex systems exhibit fewer problems, as they can be operated in two-wheel drive mode.

3.4 OVERVIEW OF SUSCEPTIBILITY BY DRIVETRAIN CONFIGURATION

All-wheel drive type	Torque transmission through differential	Risk of measurement errors and damage	Explanation
Switchable all-wheel drive	Low	Low	Standard brake testing is possible with all-wheel drive switched off. Problems are minimised in two-wheel drive mode.
Viscous coupling	Medium	Medium	Torque transmission can impair testing.
Haldex system	Low to medium	Low to medium	Deactivating all-wheel drive prevents many problems.
Rigid drives with rear axle differentials	High	High	Permanent torque distribution causes tension.
Torque vectoring systems	High	High	Unequal distribution leads to distorted measurements.
Electric all-wheel drive	Medium to high	Medium to high	Asynchronous motors can cause tension and errors.

3.5 SIGNIFICANCE OF SPECIALISED TEST BENCHES

Specialised test benches with all-wheel drive mode are absolutely indispensable if incorrect results and damage are to be avoided. This equipment enables precise synchronisation and prevents uncontrolled torque distribution. Modern test methods make a crucial contribution to ensuring the safety and functionality of all-wheel drive vehicles.

4 METHODS FOR TESTING THE BRAKES ON ALL-WHEEL DRIVE VEHICLES

4.1 GENERAL STEPS

Brake testing on all-wheel drive vehicles requires a systematic approach that both takes into account the technical characteristics of the vehicles and avoids potential damage to test benches and vehicles. Modern brake testers are not exclusively used to test all-wheel drive vehicles. Every vehicle that is driven onto the tester can have a different drivetrain configuration, and the tester needs to adapt accordingly.

To reliably avoid vehicle damage, the system must not depend exclusively on the operator's presettings. The first essential step is therefore to automatically recognise if the vehicle has

all-wheel drive during test bench startup. The standard test method must then be automatically aborted and the test sequence adapted to the specific requirements of an all-wheel drive.

The following basic measures are necessary regardless of the drive type:

- **Switching switchable all-wheel drive systems and locks off:** For vehicles with all-wheel drive that can be deactivated manually, it must be switched off before testing. Similarly, differential locks must be deactivated to avoid uncontrolled torque distribution between the wheels.
- **Individual wheel testing in counter-rotation, with precise control:** Testing is ideally performed separately for each wheel in forward rotation. This requires precise control of the drive motors on the test bench to ensure the wheels' synchronous speed and counter-rotating movement.

4.2 TEST METHOD WITH A COUNTER-ROTATING WHEEL DRIVE

Why is a counter-rotating drive necessary?

When testing the brakes of all-wheel drive vehicles, conventional test benches without a counter-rotating drive can produce distorted measurement results. This is because, during brake testing, torque is transmitted to the other axle's wheels by means of the drive shaft. This could push the vehicle out of the test bench, yielding incorrect results. The counter-rotating drive ensures that one wheel rotates forwards and the other backwards. This prevents torque build-up against the drive shaft in the axle differential, enabling correct brake force measurement on both wheels. Without this method, both wheels would display the same braking torque, even if one brake is defective.

Advantages of the counter-rotating test method

- **Elimination of torque transmission:** The counter-rotating drive prevents torques from being incorrectly transmitted to the other axle.
- **Precise individual wheel measurement:** The method enables accurate determination of an individual wheel's braking torque, without any distortion due to axle dynamics.
- **Error detection:** Defective brakes are reliably identified, as the faulty wheel does not generate any braking torque, while the intact wheel displays the actual braking force.
- **Protection of the vehicle's drivetrain:** Mechanical loads on the differential of the axle to be tested and the drivetrain are prevented, particularly during test roller startup.

How is measurement performed?

Counter-rotating wheel movement:

- One wheel rotates forwards, while the other moves backwards. Both wheels rotate at the same speed.

- This movement prevents torque build-up against the drive shaft and the second axle that is supported by the floor in the differential gear.

Direction-dependent brake measurement:

- Since brake pads and brake drums are typically bedded in in the forward direction only, the braking torque of the forward-rotating wheel is measured.
- Testing is repeated separately for each wheel (individual wheel testing) so as to obtain exact measurement results for both wheels.

Use of pedal force meters:

- A pedal force meter can be connected to the test bench to determine the difference in braking forces at an equal maximum pedal force after testing.
- The pedal force is recorded during testing to enable comparison of the braking forces between the left and right wheels.

Alternative pressure measurement:

- For pneumatic brakes, the axle's control pressure can be measured with a pressure sensor to ensure that the braking forces can be compared.

Conclusion

The counter-rotating test method ensures that each wheel's braking force is measured exactly without distortion caused by torque transmission or mechanical stresses. This method increases brake testing accuracy, minimises sources of error and protects both the vehicle components and test bench technology.

4.3 SPECIFIC TEST METHODS

The choice of test method depends greatly on the type of all-wheel drive system. The following procedures apply to the most common systems:

- **Viscous coupling (soft/hard):**
  - **Soft viscous coupling:** This permits a certain twist between the axles. Here, it is adequate to keep the speeds of the counter-rotating wheels synchronous to minimise the possibility of measurement errors caused by torque transmission.
  - **Hard viscous coupling:** This requires exact wheel synchronisation due to its limited twisting tolerance. Even small differences in speed transmit torques and distort measurement results.

- **Haldex drive:**
  - The Haldex all-wheel drive is often only active when the engine is running. Before testing, the ignition must be switched off to ensure that the system is not activated automatically.
  - Automatic restart of the test rollers once testing is complete must be prevented, as when the ignition is switched on or at the latest when the vehicle's engine starts up, the Haldex coupling re-engages and the high torque of the counter-rotating test rollers can cause damage to the differential.

- **Rigid drive shaft:**
  - Vehicles with a rigid drive with rear axle differential require the utmost precision. The speeds of the counter-rotating wheels must be synchronised exactly to prevent mechanical stresses.
  - Gear play must be taken into account by bringing the differential into a 'state of equilibrium' where no torques are transmitted between the axles.

4.4 SIGNIFICANCE OF CALIBRATION AND ADAPTATION

The choice of the correct test methodology depends on the design of the vehicle in question and its all-wheel drive system. Test equipment must be calibrated and adapted accordingly to guarantee correct results. Regular maintenance and test software updates are essential to keep pace with the technical requirements encountered in modern vehicles.

5 TECHNICAL IMPLEMENTATION

5.1 TECHNICAL IMPLEMENTATION REQUIREMENTS

Brake testing of all-wheel drive vehicles imposes specific requirements on test bench technology to accurately record the unique characteristics of both the drive and the brakes. Modern test benches must combine advanced measurement technologies and automated control systems to exactly control speeds, braking torques and the way in which the drive shafts interact. Particular attention is paid in this regard to controlling the wheels' counter-rotating drive and synchronising speeds, especially for vehicles with rigid drive shafts or hard viscous couplings.

5.2 USING REFLECTIVE STRIPS, LIGHT BARRIERS AND WHEEL CROSSES

Specialised measuring instruments such as reflective strips, light barriers and wheel crosses are absolutely indispensable for precise and error-free brake testing:

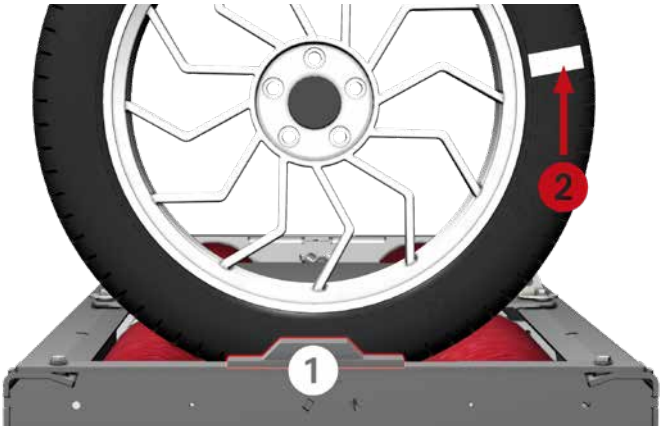

Figure 7: Arrangement and principle of light barrier ❶ with reflective strip ❷

- **Precise speed measurement:** A high-resolution speed sensor on the sensing roller, reflective strips and light barriers record wheel rotation movements with a high level of accuracy.
- **Wheel crosses for increased resolution:** The pulses from the light barriers are multiplied by wheel crosses, making speed control faster and more accurate. This is particularly important for large wheel circumferences, rigid drives with rear axle differentials or hard viscous couplings, as even minor deviations can cause torque transmission.
- **Correct mounting of light barriers:** Light barriers must be secured in a stable manner and aligned horizontally at axle height. Changes in the viewing angle due to steering movements or vehicle suspension compression can impair measurement accuracy and cause unnecessary readjustments.

5.3 TESTING GEAR PLAY (GEAR PLAY MODE)

'Load-free' brake testing is required for vehicles that have rigid drives with rear axle differentials or hard viscous couplings to avoid torque transmission.

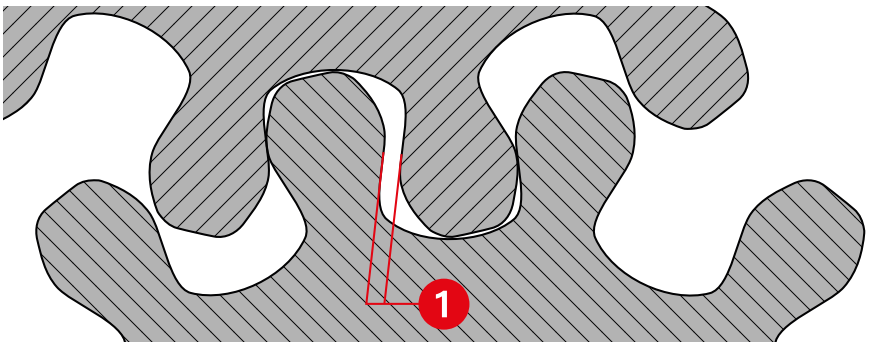

Figure 8: Schematic representation of gear play ❶ (Source: MAHA)

- **Learning mode to determine the centre position:**

- First of all, one wheel is rotated forwards and the other is dragged along by means of the differential gear's force transmission until the differential gear's tooth flanks rest on one side. The limit position is measured.
- Then the other wheel is rotated backwards to make the tooth flanks rest on the opposite side, and the second limit position is determined.
- The gear play's centre position is calculated from these limit positions.

- **Speed synchronisation:**
  - During brake testing, the wheels are controlled so that the gear play's centre position is maintained. One wheel rotates forwards and the other backwards, preventing braking torques from being transmitted by means of the drive shaft.
  - The slowly rotating wheel is readjusted as needed.

5.4 LEARNING MODE AND ADJUSTMENT OF DRIVE MOTORS

The test bench's drive motors are crucial for precise wheel control during testing.

- **Learning mode:** At the start of each test, the test bench determines the tooth flank play to ensure that speeds and torques are recorded and processed correctly.
- **Dynamic adjustment:** The speeds of the drive motors are continuously adjusted to compensate for minimal differences in wheel movement caused by application of the wheel brakes. This ensures that the gear play's centre position is maintained.
- **Taking wheel differences into account:** Wheel circumferences differ in practice due to different tread depths and air pressures. The drive motors therefore regulate the required speed to ensure that both wheels move with the same rpm.

5.5 HANDLING SPECIFIC ALL-WHEEL DRIVE SYSTEMS

- **Soft viscous coupling:** For vehicles with a soft viscous coupling, approximately equal drive motor speed control is adequate, as no braking torques are transmitted during minor rotational movements.
  - Often, a maximum dwell time (specified by the vehicle manufacturer) in the brake tester must be observed to stop the fluid from foaming in the viscous coupling.

- **Hard viscous coupling:** Here, exact synchronisation of wheel speeds is required, as even minor deviations can transmit torques / braking forces, leading to distorted measured values.
- **Haldex drive:** Brake testing must be performed when the vehicle's ignition is switched off, as Haldex systems are only active when the engine is running. After testing, it must be ensured that the rollers do not start automatically to avoid damage to the differential.
- **Rigid drive with rear axle differential:** For vehicles with rigid drive shafts, the wheels must be exactly synchronised in counter-rotation. The learning mode for tooth flank play in the differential gear ensures that the differential gear is in a state of equilibrium and that no braking torques are transmitted by means of the drive shaft.

5.6 ADVANTAGES OF TECHNICAL IMPLEMENTATION

The technologies and methods described offer several advantages:

- **Precise measurement results:** Maximum accuracy in brake force measurement is achieved due to dynamic control and the use of high-resolution speed sensors, reflective strips, light barriers and wheel crosses.
- **Protection of test bench technology and vehicle components:** Mechanical stresses and torque transmission are avoided, increasing the service life of test benches and vehicle drivetrains.
- **Enhanced efficiency:** The test process is optimised and delays are minimised due to rapid and precise speed control.

This technical implementation ensures that the brakes of all-wheel drive vehicles can be tested reliably and safely, even with complex drivetrain configurations.

6 COMMON MISTAKES AND HOW TO PREVENT THEM

6.1 SIGNIFICANCE OF AVOIDING MISTAKES

Testing the brakes of all-wheel drive vehicles is a complex process where minor mistakes can have a serious impact on the measurement results or vehicle components. Common sources of error must be identified and eliminated to ensure reliable results and avoid damage to vehicles or test benches.

6.2 COMMON SOURCES OF ERROR AND SOLUTIONS

6.2.1 LIGHT BARRIERS OR WHEEL CROSSES MOUNTED INCORRECTLY

- **Problem:** Incorrect mounting of light barriers or wheel crosses leads to inaccurate measured values. Even slight changes in the viewing angle, due to the likes of vehicle suspension compression or steering movements, can influence speed measurement.
- **Prevention:**
  - Mount light barriers stably and exactly at axle height to keep the angle to the wheel cross constant.
  - Opt to align light barriers horizontally. Alignment from above should be avoided.
  - Regularly inspect and readjust components before each test.

6.2.2 NEGLECTING CHAIN TENSION AND ITS EFFECTS

- **Problem:** Insufficient chain tension in the test bench leads to juddering or delays in test roller adjustment. This complicates wheel synchronisation and can distort brake force measurement.
- **Prevention:**
  - Ensure that the test bench chains are tightly tensioned before testing.
  - Check the chain tension regularly and schedule as an integral part of the maintenance routine.
  - Ensure judder-free roller movement to guarantee constant wheel control.

6.2.3 A LACK OF WHEEL SYNCHRONISATION WITH A RIGID DRIVE

- **Problem:** For vehicles with rigid drive shafts, even minimal asynchronicity between the wheels can cause mechanical stresses that damage the differential or other drivetrain components.
- **Prevention:**
  - Ensure exact synchronisation of the test bench motor speeds.
  - Use gear play mode consistently to prevent undesirable torque transmission.
  - Actively monitor motor adjustment and continuously adapt throughout testing.

6.3 SUMMARY

The most common mistakes can be avoided through careful preparation, regular maintenance of the test equipment and strict adherence to test specifications. Training of test personnel is another key aspect for efficiently and safely testing the brakes of all-wheel drive vehicles. Avoiding mistakes not only helps to ensure accurate results, but also protects test benches and vehicle components from damage.

7 RECOMMENDATIONS AND BEST PRACTICES

7.1 STANDARDISED TEST MODES BASED ON DRIVE TYPE

The choice of test mode should be exactly tailored to the type of all-wheel drive to ensure both accuracy of results and safety of test processes.

Fundamentals

Many mechanics, developers, engineers or even drivers themselves often do not know exactly which all-wheel drive system is installed in their vehicle. It is simply established that the vehicle ‘has all-wheel drive’ – without taking into account whether it is a switchable all-wheel drive, a viscous coupling or a rigid drive shaft. Taking a systematic approach is therefore essential.

Pre-testing checklist

Ask whether the all-wheel drive is switchable:

- If it is, always switch off the all-wheel drive and test in normal mode. This must be done without exception, as switchable all-wheel drive systems often contain an inter-axle differential or compensator that can cause problems during the adjustment attempt.

Ask whether locks are active:

- Always switch off locks to avoid uncontrolled torque distribution.

Selection of the correct test mode

1. **First attempt in standard mode with individual wheel testing:**

   Testing starts through starting the motor manually by remote control. Stand at the right wheel and start the left wheel:

   Reaction of the right wheel:
   - If it rotates in the opposite direction, the vehicle is an all-wheel drive.
   - If it remains stationary, all-wheel drive is not active, and the vehicle can be tested in standard mode.

2. **Testing without reflective strips and wheel cross in viscous mode:**
   - For all-wheel drives, test in viscous mode first of all without any additional aids such as reflective strips or wheel crosses.

3. **Use reflective strips or wheel crosses as needed:**
   - If viscous mode does not work, use reflective strips or wheel crosses (depending on the wheel circumference). If the vehicle still does not adjust correctly, activate rigid all-wheel drive mode.

4. **Test all axles**
   - For vehicles with multiple axles, it must be noted that the axles will not necessarily all respond in the same way. Testing must be performed on all axles to ensure that no axle is overlooked.

Best practices

- **Identify the vehicle drive type:** Use a pre-testing checklist to determine the type of all-wheel drive and active or deactivated functions (e.g. locks).
- **Use test benches with pre-configured modes:** Test benches should have pre-configured modes for different all-wheel drive systems to enable quick and error-free adjustments.
- **Test one wheel at a time in standard mode when uncertain:** If the drive type is not clear, it is recommended to test one wheel at a time in standard mode.

Remember!

- The correct test mode depends on the vehicle's design and configuration.
- Using standardised methods and suitable test modes reduces errors and improves the efficiency of test processes.
- When uncertain, always work one step at a time, as described above, to safely determine the drive type and apply the correct test methods.

7.2 TRAINING TEST PERSONNEL

It is essential for test personnel to have a sound understanding of how all-wheel drive systems work and their testing requirements.

- **Recommendation:** Regular training should ensure that test personnel remain up to date with the latest vehicle and test bench technologies.

Best practices

- Training content includes correct use of test bench software, equipment calibration and analysis of test protocols.
- Practical exercises with different vehicle types promote routine and confidence in handling various drivetrain configurations.

7.3 USING DAMPING SOFTWARE FOR SPECIFIC VEHICLE TYPES

Conventional test methods may be insufficient for vehicles with special requirements (e.g. crane trucks with special tyre treads and wheel circumferences).

- **Recommendation:** Purpose-developed damping software should be deployed for accurate and stable measurement results.

Best practices

- Deploy damping software only for vehicles that need it to avoid unnecessary complications.
- Ensure that software is configured correctly and remains compatible with the test bench.
- Provide clear documentation of use cases to avoid misunderstandings and misapplication.

8 CONCLUSION

Testing the brakes of all-wheel drive vehicles is an essential part of modern vehicle maintenance and a key safety standard. The complex mechanics and technology of these vehicles present particular requirements that can only be met through specialised test methods. Such methods ensure accurate results, avoid damage to vehicles and test benches alike and guarantee that all-wheel drive vehicles can be operated safely and reliably.

Correct brake testing ensures that a vehicle's brakes work perfectly in all conditions. This minimises the risk of unexpected brake failures that could lead to serious accidents. Particularly for all-wheel drive vehicles with variable torque distribution, precise measurement of braking force is absolutely essential to ensure road safety and correctly assess complex dynamic systems.

Regular and reliable brake testing additionally extends the service life of brake components and reduces wear on drivetrain parts. It helps to avoid major damage and repairs through identifying incorrect loading or defects at an early stage. At the same time, these test methods increase the efficiency of maintenance processes by minimising sources of error and making optimum use of the test bench technology.

Continuous development of test methods is absolutely indispensable to meet the high demands of brake testing on all-wheel drive vehicles. Similarly, regular training of specialist personnel and deployment of state-of-the-art test bench technologies are crucial for guaranteeing accurate results. Investment in specialised technologies and qualified personnel pays dividends by not only increasing road safety, but also ensuring the reliability and efficiency of test processes in the long term.

Annex

Summary table of test modes for different all-wheel drive types

ALL-WHEEL DRIVE TYPE	TEST MODE	SPECIAL FEATURES
Switchable all-wheel drive	Standard mode	Switch off all-wheel drive and locks; individual wheel testing possible.
Soft viscous coupling	Viscous mode	Speed control only needs to be approximately equal
Hard viscous coupling	Synchronous mode	Exact speed synchronisation required to prevent torque transmission.
Haldex drive	Standard mode with ignition switched off	Switch off ignition to avoid automatic roller startup.
Rigid drive shaft	Gear play mode	Exact speed synchronisation; differential must be maintained in a state of equilibrium.

Technical data for light barriers and wheel crosses

COMPONENT	DESCRIPTION	TECHNICAL SPECIFICATIONS
Light barriers	Optical sensors for recording wheel movements	• Detection accuracy: <1 mm movement • Mounting height: At axle height • Viewing angle: Horizontally aligned
Wheel crosses	Mechanical measuring aids for improving resolution	• Pulse resolution: Four-fold refinement • Material: Aluminium or plastic • Compatibility: Reflective strips and light barriers
Reflective strips	Support optical detection by means of light barriers	• Length: 10–20 cm depending on wheel size • Adhesive strength: Up to 60°C ambient temperature

Examples of typical problems and solutions in brake testing

PROBLEM	POSSIBLE CAUSE	SOLUTION
Light barriers deliver inaccurate values	Incorrect mounting or unstable viewing angle	Ensure correct horizontal alignment at axle height
Juddering during testing	Insufficient chain tension	Tighten chains before testing
Torque transmission between the wheels	Speed asynchronicity	Perform exact synchronisation of the test bench motors
Errors on vehicles with Haldex system	Automatic activation through ignition	Switch off ignition and ensure that the rollers do not start automatically.
Irregular results with a rigid drive	Differential not in a state of equilibrium	Activate gear play mode and correctly adjust centre position

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'Learn more about efficient brake force testing on all-wheel drive vehicles and the challenges they pose in this whitepaper.'

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