An assessment of the durability and reliability of typical hydraulically operated parking brakes fitted to quadricycles

by C J Grover
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AN ASSESSMENT OF THE DURABILITY AND RELIABILITY OF TYPICAL HYDRAULICALLY OPERATED PARKING BRAKES FITTED TO QUADRICYCLES

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By C J Grover (TRL Limited)

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Executive summary

TRL Ltd. was commissioned by the UK Department for Transport (DfT) to perform an assessment of the durability and reliability of typical hydraulically operated parking brakes fitted to quadricycles. Although not common on quadricycles, some manufacturers fit a latch device on the hydraulic service brake allowing it to serve as a parking brake.

The performance of the parking brake system on three previously used quadricycles was assessed in accordance with the requirements as laid down in paragraphs 2.3 and 2.4 of Directive 93/14/EEC on the braking of two or three wheel motor vehicles. The quadricycles were instrumented to measure the hydraulic parking brake system pressure and the force applied to the parking brake control.

When tested with the parking brake applied sufficiently to hold the quadricycle stationary on the gradient all three vehicles failed the test. The parking brake system pressure decayed and the vehicle moved during the 14 day test period.

When a force of 400N was applied to the handbrake lever two of the three quadricycles passed the test, remaining stationary on the gradient throughout the 14 day test period. However both vehicles exhibited a trend for the parking brake system pressure to decay. One of the vehicles failed the test. The parking brake system pressure decayed and the vehicle moved during the 14 day test period.

These results show that the method of using the energy stored in a hydraulic system to provide the parking brake function has not proved reliable. A reliable means of providing the parking brake function is having the braking elements being applied and then held in the locked position by a purely mechanical device that ensures a sufficient clamping force is maintained.
1 Introduction

TRL Ltd. was commissioned by the UK Department for Transport (DfT) to perform an assessment of the durability and reliability of typical hydraulically operated parking brakes fitted to quadricycles. Although not common on quadricycles, some manufacturers fit a latch device on the hydraulic service brake allowing it to serve as a parking brake. Typical operation involves depressing the brake lever and manually activating the latch device, preventing the lever from returning to its original position thus maintaining pressure in the system.

The objectives of the project were to:

- Source two previously used quadricycles from different manufacturers; a recent vehicle (two to four years old) and an older vehicle (five to seven years old);
- Assess the condition and suitability of the parking brake disc/drum and linings for testing purposes;
- Instrument the hydraulic parking brake system to measure system pressure and the force applied to the parking brake control;
- Test the parking brake system to the requirements as laid down in paragraphs 2.3 and 2.4 of Directive 93/14/EEC on the braking of two or three wheel motor vehicles.

This report describes the test procedure and instrumentation used, the quadricycles sourced, their suitability for testing and the performance of the parking brakes during the tests.

2 Test procedure and instrumentation

2.1 Test method

Upon receipt the quadricycles were inspected, paying particular attention to the transmission, braking system, suspension and tyres, to ensure satisfactory operation. The brake assemblies that were active when the parking brake was applied were identified. The condition and suitability of the brake disc and linings at these locations were assessed and measurements of the brake disc and pad thicknesses recorded.

As specified in the Directive, tests were performed with the quadricycles parked on an 18% gradient. The parking brake was applied using the handbrake lever for all the vehicles tested. Two tests were performed with each vehicle with different forces applied to the handbrake lever:

- The force sufficient to hold the vehicle stationary on the gradient was applied;
- A force of 400N (the maximum force permitted for manual parking brake controls in the Directive) was applied.

The point of application of the force was 50mm from the outer end of the lever as specified in the Directive.

The duration of each test was 14 days unless movement of the vehicle was detected earlier, in which case the test was terminated and the time at which movement occurred was recorded. The force applied to the handbrake lever and pressure in the brake system were recorded to note any variation or decay during the test period. The brake disc temperature was also recorded at the start of the test.

2.2 Instrumentation

Each quadricycle was instrumented with a handbrake lever clamp incorporating a load cell to measure the force applied to the handbrake lever, and a hydraulic pressure transducer to measure the system pressure. Figure 1 and Figure 2 show this instrumentation fitted on the Polaris Diesel.
A string potentiometer was also mounted on the test ramp with the string extended and attached to the quadricycle to measure the position of the vehicle. The output of the transducers was sampled and recorded at two minute intervals for the duration of the tests. For safety a chock was placed approximately half a metre behind the rear tyres to arrest the vehicle should the parking brake fail during the tests.
3 Test vehicles

The quadricycles were hired for the testing. Sourcing appropriate test vehicles proved difficult because of the limited number of vehicles available that were fitted with hydraulically operated parking brakes. Initially the tests were performed with the Dinli 270 and the Polaris 400 with the vehicles in an unladen condition. The same vehicles were not available for hire when the laden testing was performed. Attempts to source similar vehicles proved unsuccessful, therefore the laden testing was performed using the Polaris Diesel.

3.1 Dinli 270

The Dinli 270 was a 2005 road legal vehicle with a single cylinder 270cc four stroke petrol engine driving the rear axle via an automatic gearbox. It was fitted with a rear loading rack. The vehicle had an unladen weight of 206kg and a gross vehicle weight of 371kg. The parking brake was activated by the handbrake lever, secured in position using the latch (Figure 3) and operated the single disc brake assembly on the rear axle only (Figure 4).

Figure 3: Dinli 270 handbrake lever and latch
When inspected the disc and pads were found to be in a satisfactory condition for testing. Measurements of the disc and pad thicknesses are shown in Figure 5.

**Figure 4: Dinli 270 rear axle brake assembly**

**Figure 5: Dinli 270 brake disc and pad measurements**
3.2 Polaris 400

The Polaris 400 was a 2002 scrambler off-road vehicle that was not road legal. It had a single cylinder 400cc two stroke petrol engine which drove the rear axle via an automatic gearbox. This vehicle was not fitted with any loading racks. The parking brake was activated by the handbrake lever, secured in position using the latch (Figure 6) and operated the disc brake assemblies at both front wheels (Figure 7) and on the rear axle (Figure 8).

![Figure 6: Polaris 400 handbrake lever and latch](image1)

![Figure 7: Polaris 400 front brake assembly](image2)
When inspected the disc and pads were found to be in a satisfactory condition for testing. Measurements of the disc and pad thicknesses are shown in Figure 9.

**Figure 8: Polaris 400 rear axle brake assembly**

**Figure 9: Polaris 400 brake disc and pad measurements**
3.3 Polaris Diesel

The Polaris Diesel was a 1999 road legal vehicle with a 455cc single cylinder four stroke diesel engine with optional four wheel drive via an automatic gearbox. It was fitted with front and rear loading racks. The vehicle had an unladen weight of 366kg and a gross vehicle weight of 544kg. The maximum load capacities of the front and rear racks were 41kg and 82kg respectively. Similar to the Polaris 400, the parking brake was activated by the handbrake lever, secured in position using the latch (Figure 10) and operated the disc brake assemblies at both front wheels (Figure 11) and on the rear drive (Figure 12).

![Figure 10: Polaris Diesel handbrake lever and latch](image)
When inspected the disc and pads were found to be in a satisfactory condition for testing. Measurements of the disc and pad thicknesses are shown in Figure 13.
For the testing the front and rear loading racks were loaded to their maximum capacity. Additional ballast was added on the saddle, replicating the rider, to achieve the gross vehicle weight. The front and rear axle weights were 222kg and 322kg respectively, giving a gross vehicle weight of 544kg.

4 Results and analysis

4.1 Dinli 270

A force of 60N was required on the handbrake lever to hold the unladen Dinli 270 stationary on the gradient. With this force applied the pressure in the brake system was initially 23bar. The brake disc temperature at the start of the test was 16°C. Figure 14 shows the decay of this pressure during the test period.
Figure 14: Dinli 270 holding on gradient test

The string potentiometer trace indicated the vehicle moved 18 hours after the test started, rolling down the gradient coming to rest against the safety chock. The change in displacement occurred over a period of one sample (an elapsed time of two minutes) indicating a sudden movement rather than the vehicle gradually rolling away.

Figure 15 shows the results obtained when a force of 400N was applied to the handbrake lever of the unladen Dinli 270. With this force applied the pressure in the brake system was initially 93bar. The brake disc temperature at the start of the test was 14°C.

Figure 15: Dinli 270 400N force test
Although there was substantial daily variation and a general trend indicating that the brake system pressure was decaying, the vehicle remained stationary on the gradient for the 14 day duration of the test. The daily variation may be attributed to changes in the ambient temperature.

It was noted that when the handbrake lever was held in position with the latch as in normal operation, it was depressed a greater distance (generating a greater pressure in the brake system) than when the force was applied such that the vehicle was holding on the gradient. Also when a force of 400N was applied the distance the lever was depressed was substantially greater than that when the lever was held on the latch.

### 4.2 Polaris 400

When attempting to apply a force to the unladen Polaris 400 handbrake lever such that the vehicle held on the gradient difficulty was experienced because of the rapid decay of the pressure. The vehicle would only remain stationary for a short period of time before rolling away. Therefore this test was abandoned and the 400N force was applied to the lever. Figure 16, Figure 17 and Figure 18 show the results of multiple tests carried out. The brake disc temperature at the start of these tests was 14°C, 14°C and 15°C respectively.

![Figure 16: Polaris 400 400N force test 1](image-url)
With the 400N force applied the pressure in the brake system was initially 41bar, 43bar and 55bar for each test. In the first test the pressure decayed rapidly at a steady rate, resulting in the vehicle suddenly rolling down the gradient after 82 minutes. When the test was repeated the rate at which the pressure decayed reduced, however the vehicle began to move after three and a half hours then suddenly rolled away. In the third test the pressure initially decayed at a similar rate as that in the
previous tests, but then the rate at which it reduced decreased, almost maintaining constant pressure for 14 hours. However the vehicle suddenly rolled away almost one day after the test started with the pressure decaying over a period of four hours.

4.3 **Polaris Diesel**

A force of 63N was required on the handbrake lever to hold the fully laden Polaris Diesel stationary on the gradient. With this force applied the pressure in the brake system was initially 13bar. The brake disc temperature at the start of the test was 20°C. Figure 19 shows the decay of this pressure during the test period.

![Figure 19: Polaris Diesel holding on gradient test](image)

Daily fluctuations in the pressure similar to those seen in the Dinli 270 test are evident, however the handbrake lever force also follows the same pattern in this test. Six hours after the test began the pressure recorded exceeded 19bar, and subsequently peaked at over 23bar. Although there was substantial daily variation the general trend was decay in the brake system pressure. The string potentiometer trace indicated the vehicle moved soon after the test was initiated, and then remained stationary for almost four days. The vehicle then moved again during day five and proceeded to move in small steps before coming to rest against the safety chocks late in day six.

Figure 20 shows results obtained when a force of 400N was applied to the handbrake lever of the fully laden Polaris Diesel. With this force applied the pressure in the brake system was initially 57bar. The brake disc temperature at the start of the test was 20°C.
Similar to the Dinli tests, there was substantial daily variation, but only a slight decay in the brake system pressure. The vehicle remained stationary on the gradient for the 14 day duration of the test.

Again it was noted that when the handbrake lever was held in position with the latch as in normal operation, it was depressed a greater distance (generating a greater pressure in the brake system) than when the force was applied such that the vehicle was holding on the gradient. Also when a force of 400N was applied the distance the lever was depressed was substantially greater than that when the lever was held on the latch.

## Discussion

When tested with the parking brake applied sufficiently to hold the quadricycle stationary on the gradient all three vehicles failed the test. The parking brake system pressure decayed and the vehicle moved during the 14 day test period. When a force of 400N was applied to the handbrake lever the Dinli 270 and the Polaris Diesel passed the test, remaining stationary on the gradient throughout the 14 day test period. However both vehicles exhibited a trend for the parking brake system pressure to decay. The Polaris 400 failed the test. The parking brake system pressure decayed and the vehicle moved during the 14 day test period.

These results show that the method of using the energy stored in a hydraulic system to provide the parking brake function has not proved reliable. The pressure decay occurred as a result of internal leakage within the parking brake system. A reliable means of providing the parking brake function is having the braking elements being applied and then held in the locked position by a purely mechanical device that ensures a sufficient clamping force is maintained. Directive 93/14/EEC on the braking of two or three wheel motor vehicles specifies the working parts must be applied and then held in the locked position by a purely mechanical device.
6 Conclusions

- Three previously used quadricycles fitted with hydraulically operated parking brakes were sourced:
  - A recent vehicle (two to four years old) – Dinli 270 road legal vehicle manufactured in 2005;
  - An older vehicle (five to seven years old) – Polaris 400 off road scrambler manufactured in 2002;
  - A third vehicle was also required to complete the testing – Polaris Diesel road legal vehicle manufactured in 1999.

- The quadricycles were instrumented to measure the hydraulic parking brake system pressure and the force applied to the parking brake control. The parking brake system was then tested in accordance with the requirements as laid down in paragraphs 2.3 and 2.4 of Directive 93/14/EEC on the braking of two or three wheel motor vehicles;

- The performance of the unladen Dinli 270 was:
  - When the parking brake was applied sufficiently to hold the vehicle stationary on the gradient the parking brake system pressure decayed and the vehicle failed the test on day one, rolling down the gradient after 18 hours;
  - When a force of 400N was applied to the handbrake lever there was a general trend indicating a decay in the parking brake system pressure, however the vehicle passed the test remaining stationary on the gradient for the 14 day duration of the test.

- The performance of the unladen Polaris 400 (note this quadricycle was not fitted with load carrying racks) was:
  - When attempting to apply a force to the handbrake lever such that the vehicle held on the gradient difficulty was experienced because of the rapid decay of the pressure. The vehicle would only remain stationary for a short period of time before rolling away. Therefore this test was abandoned;
  - When a force of 400N was applied to the handbrake lever the pressure decayed rapidly at a steady rate. The vehicle failed the test on day one, rolling down the gradient after 82 minutes. The test was repeated and the vehicle failed on day one again, rolling away after three and a half hours. In a third test the vehicle failed on day one again, rolling away after 23 hours.

- The performance of the fully laden Polaris Diesel was:
  - When the parking brake was applied sufficiently to hold the vehicle stationary on the gradient the parking brake system pressure decayed slightly and the vehicle failed the test. The vehicle moved soon after the test was initiated, and then remained stationary for almost four days. The vehicle then moved again during day five and proceeded to move in small steps during day six when the test was terminated;
  - When a force of 400N was applied to the handbrake lever there was a slight decay in the parking brake system pressure, however the vehicle passed the test remaining stationary on the gradient for the 14 day duration of the test.

- These results show that the method of using the energy stored in a hydraulic system to provide the parking brake function has not proved reliable. A reliable means of providing the parking brake function is having the braking elements being applied and then held in the locked position by a purely mechanical device that ensures a sufficient clamping force is maintained.
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Abstract

TRL Ltd. performed an assessment of the durability and reliability of typical hydraulically operated parking brakes fitted to three previously used quadricycles in accordance with the requirements as laid down in paragraphs 2.3 and 2.4 of Directive 93/14/EEC. When tested with the parking brake applied sufficiently to hold the quadricycle stationary on the gradient all three vehicles failed the test. When a force of 400N was applied to the handbrake lever two of the three quadricycles passed the test. However, both vehicles exhibited a trend for the parking brake system pressure to decay. The other vehicle failed the test. These results show that the method of using the energy stored in a hydraulic system to provide the parking brake function has not proved reliable.