

Accelerated Testing of Brake Hoses for Durability Assessment

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ABSTRACT

The durability performance of brake hoses is a crucial issue for such components. Accelerated fatigue testing of brake hoses is necessary for understanding achievable lifetime, actually computation of durability is quite cumbersome due to the many different materials the hoses are made from. Despite SAE standards are available, accelerated testing of brake hoses subject to actual torsional and bending stresses seem important to provide relevant feedback to designers. In this paper, an innovative methodology for assessing the fatigue behavior of brake hoses of road vehicles is proposed. A dynamic testbed is specifically designed and realized, able to reproduce the actual assembly conditions of the hoses fitted into a vehicle suspension. The designed testbed allows to replicate actual loading conditions on the brake hoses by simulating the vertical dynamics and steering of the suspension system together with brake pressure. A procedure to extract the relevant loading cycles for damage is proposed and applied. The tests performed by exploiting the new testbed are in good agreement with the reported lifetimes of actual brake hoses fitted into test vehicles.

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INTRODUCTION

Hydraulic brake hoses are important components for the safety of road vehicles. The braking performances of road vehicles depend on the capability of the brake hoses of withstanding the internal pressure that comes from the brake fluid. Moreover, due to the relative motion between the wheel and the vehicle body, the brake hoses are subjected to a combined bending and torsional stress state.

Brake hoses have a complex structure, made by three rubber layers and two layers of fiber reinforcements [1]. Because of this complex structure, numerical models employed for durability estimation require the accurate characterization of the many materials that are employed [2]. In [2] the durability of hydraulic brake hoses was numerically investigated. The actual structure of the brake hose under large deformation was modeled. The fatigue life was computed by means of several strain-based criteria and results were compared. All the methods locate the fatigue damage at the outer rubber layer. Experimental testing could have been useful to assess the effectiveness of the developed numerical methods.

Experimental testing of actual brake hoses is necessary for homologation. Standard durability tests referenced in the European and American standards [3, 4, 5] consider only bending of the hose and combined bending and internal pressure. In the Ozone Dynamic Test, the hose is subjected to a cyclic bending load in a controlled ozone atmosphere. The frequency of the loading cycle is 0.3 Hz, the hose is subjected to a 48 hours test during which no damage has to

occur. In the Whip Test the combined effect of cyclic bending and internal constant pressure is evaluated. The time duration of the test should be 35 hours.

Compared to the standards, durability under a more complex (and realistic) stress state in the hose can be evaluated by a specifically designed test procedure. In fact, the relative movement between the wheel and the vehicle body provides a complex stress state on the hose due to the combination of bending, twisting and internal pressure.

In [6] the authors performed experimental tests on automotive hydraulic brake hoses. The tested hoses were subjected to combined, constant-amplitude cyclic bending, torsion and internal pressure to approximate actual in-service loading conditions. Experimental tests were conducted in a thermal chamber at a temperature of 100 °C to accelerate the aging process of the rubber. Fatigue damage occurred at the metal clamping area. The damage mechanism of the hose was studied by analyzing the fracture surface.

In this paper a new testing method for fatigue assessment of hydraulic brake hoses is presented. The method accounts for the effect of variable-amplitude loading cycles. The hose is subjected to cycles of combined bending, torsion and internal pressure. The test reproduces the actual working conditions of the brake hoses when mounted on the vehicle. Steering motion and suspension rattle are simulated in the test. Steering and rattle motions are representative of the mission of the vehicle.



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To reduce the testing time, an accelerated test cycle is defined on the basis of the defined steering and rattle motions. The motion law of the suspension rattle is defined starting from the PSD (Power Spectral Density) of the road irregularity. The most severe loading cycles are identified by means of a rainflow cycle counting [7] and combined with a number of full steering maneuvers.

The paper is organized as follows. In the first section, the test bench designed for the durability test of the brake hoses is presented. The second section describes the procedure for the computation of the accelerated fatigue loading cycle. Experimental tests on actual brake hoses are presented in the final section and results are discussed.

1. BRAKE HOSE DURABILITY TEST BENCH

The hoses considered in this paper are part of the front braking system of a small high performance car. The car is a front wheel drive equipped with McPherson suspensions at the front axle. The front suspension is depicted in [Figure 1](#). From this picture, the connection of the brake hose can be seen. One end of the hose is connected to the vehicle body, while the other end is connected to the brake caliper. The hose is also fixed to the McPherson strut.

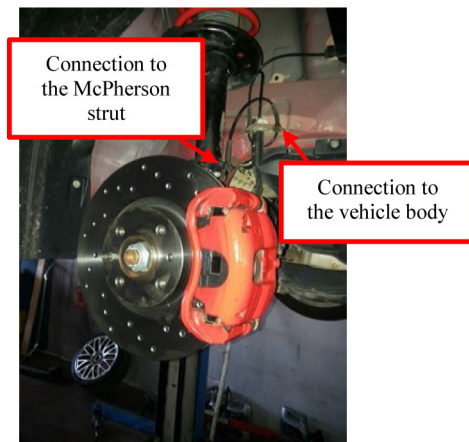


Figure 1. Brake hose fitting in the actual vehicle.

The test bench has been designed to reproduce the relative movement between the brake caliper and the vehicle body. This movement is given by two contributions, namely the steering and the suspension rattle.

[Figure 2](#) shows the solid model of the test bench. The steering axis is defined by the green shaft. (The steering axis has been defined after a 3D reverse engineering of the actual McPherson strut). The red plate is able to move along the steering axis to reproduce the suspension rattle. The axial movement of the plate is realized by means of a hydraulic actuator. The connection to McPherson strut is reproduced by the blue flange of [Figure 2](#). This flange is fixed in the axial direction and rotates with the driving shaft. The caliper-side connection is obtained through a rotating flange as shown in [Figure 2](#). The steering actuation is obtained by means of a pneumatic actuator ([Figure 3](#)).

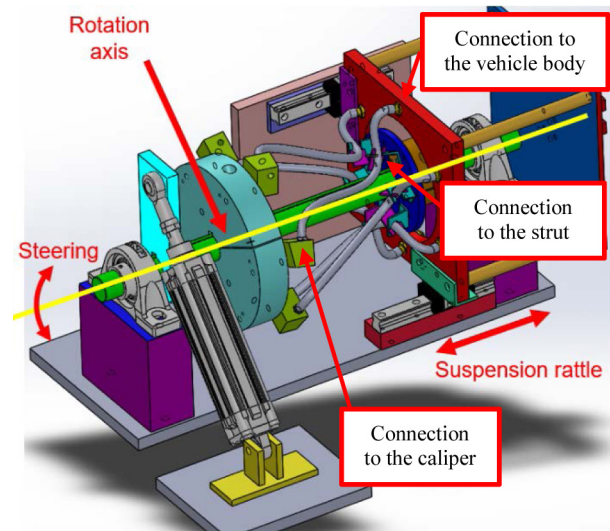


Figure 2. Designed test bench for indoor testing of brake hoses.



Figure 3. Left and right steering on the test bench.

The respective positions of the connection points is defined to replicate the actual 3D curvature of the hose fitted into the vehicle.

Optical measurements on the actual vehicle have been performed to identify the respective positions of the attachments and the working trajectory of them as shown in [Figure 4](#). 3D scanning was performed at six different spatial configuration of the McPherson strut, namely

- Full steering left – full bump condition (full up displacement)
- Zero steering - full bump condition (full up displacement)
- Full steering right – full bump condition (full up displacement)
- Full steering left – full rebound condition (full down displacement)
- Zero steering - full rebound condition (full down displacement)
- Full steering right – full rebound condition (full down displacement)

Additionally the position of zero steering and vehicle under curb weight was considered.

The trajectories of the points where the hose is connected respectively to the McPherson strut and to the caliper are shown in [Fig. 4](#). The point connected to the body is considered fixed and steady.