Bicycle Testing Capabilities

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1.0 Introduction

This document describes the existing equipment available to perform tests on bicycle frame and frame components including the following:

- Fatigue and ultimate failure testing on a range of bicycle frames
- Lateral and vertical deflection testing on a range of bicycle frames
- Testing bicycle tubes in torsion and bending
- Fatigue and ultimate failure testing of rear disc brake mounts

1.1 Summary

The equipment is in place to do the testing listed above along with other tests and it is described in this document. The capability exists to do tube bending and torsional testing, frame vertical deflection testing, comparative lateral deflection testing and dynamic and fatigue testing of rear disc brake mounts.

Test equipment presently available includes:

- Pedaling force fatigue tester (Figures 2 and 3)
- Horizontal force fatigue tester (Figure 5)
- Lateral and vertical frame deflection test fixture (Figures 6-12)
- Cantilever beam test fixture (Figure 13)
- Fork deflection test fixture (Figure 14)
- Strain gage amplifiers and bridges
- National Instruments USB DAQ
- Rear triangle fatigue test fixture (Figure 17)
- Fork vibration testing fixture (Figures 18-20)
- Rear disc brake mount dynamic testing fixture (Figures 24-26)
- Rear disc brake mount fatigue testing fixture (Figures 27 and 28)
- SENSR 3 axis accelerometers (Figures 21 and 22)
- Bump test section (Figure 23)
- Powertap hub
- Various rollers and trainers

This equipment is discussed in more detail later in this document. Mechanical testing and analysis of materials including tensile and impact testing, metallography,
SEM and other capabilities can be sub-contracted through the testing laboratories in the Materials Research Center at Rensselaer.

Design and manufacturing capabilities exist to produce additional test fixtures as required.

1.2 Pedaling and Horizontal Force Fatigue Testers

To provide the ability to test frames to international standards (EN 14781) several fixtures were built. These are for Fatigue Testing with Pedaling Forces as shown in Figures 1, 2 and 3 and Fatigue Testing with Horizontal Forces as shown in Figures 4 and 5.
4.8.5 Frame — fatigue test with horizontal forces

4.8.5.1 General

All types of frame shall be subjected to this test.

It is not necessary for a genuine fork to be fitted, provided that any substitute fork is of the same length as the intended fork and it is correctly installed in the steering-head bearings. For a suspension fork, lock it at a length equivalent to that with an 80-kg rider seated on the bicycle either by adjusting the spring/damper or by external means.

Where a suspension frame has adjustable brackets or linkages to vary the resistance of the bicycle against the ground-contact forces or to vary the attitude of the bicycle, the positions of these adjustable components as used in the fatigue test shall be arranged to ensure maximum forces in the frame.

Figure 1: Frame Fatigue Testing with Pedaling Forces
Figure 2: Pedaling Force Fatigue Tester-Side View

Figure 3: Pedaling Force Fatigue Tester-Front View
4.8.5.2 Requirement

When tested by the method described in 4.8.5.3, there shall be no visible cracks or fractures in the frame and there shall be no separation of any parts of any suspension system.

For carbon-fibre frames, the peak deflection during the test in either direction from the mean position shall not increase by more than 20 % of the initial values.

4.8.5.3 Test method

For a rigid frame, mount the frame in its normal attitude and secured at the rear drop-outs so that is not restrained in a rotary sense (i.e. preferably by the rear axle) as shown in Figure 28.

For a frame incorporating a rear suspension system, lock the moving part of the frame in to a position as would occur with a 80-kg rider seated on the bicycle. This may be achieved by locking the suspension unit in an appropriate position or, if the type of suspension system does not permit to be locked, then the suspension system may be replaced by a solid link of the appropriate compressed size. Ensure that the axes of the front axle and rear axle are horizontally in line as shown in Figure 28.

Apply cycles of dynamic, horizontal forces of +600 N in a forward direction and -600 N in a rearward direction to the front fork drop-outs on an axis through the front and rear axles for 100,000 cycles as shown in Figure 28, with the front fork constrained in vertical direction but free to move in a fore/aft direction under the applied forces. The maximum frequency shall be 25 Hz.

Key
1. Free-running guided roller
2. Rigid, pivoted mounting for rear axle attachment point

Figure 28 — Frame — fatigue test with horizontal forces

Figure 4: Frame Fatigue Testing with Horizontal Forces
1.3 Deflection Testing Apparatus

Lateral deflection testing is shown in Figures 6-9. The concept behind this fixture was to allow loading on the frame when the crank is at the bottom of the pedal stroke. Because of the way the frame is constrained most of the load is lateral. The frame is allowed to rotate about the center of the rear axle and the center of the head tube. The head tube can also rotate and translate horizontally in the plane of the frame. This emulates the frame laterally flexing about the rear tire contact patch and the fork steerer.
Figure 6: Lateral Deflection Testing

Figure 7: Head Tube Support

Figure 8: Rear Dropouts Support
Figure 9: Lateral Force Mechanism
Vertical deflection testing is shown in Figures 10-12. The concept behind this fixture was to load the bicycle frame and have the back of the bicycle frame rotate about a rear axle and the front of the bicycle frame translate horizontally and rotate in the plane of the frame. This emulates a bicycle frame sitting on its wheels.

Figure 10: Vertical Deflection Testing

Figure 11: Head Tube Mount

Figure 12: Vertical Frame Loading
The cantilever beam test fixture shown in Figure 13 allows deflection testing of tubing sections. This fixture was used for strain gage testing and calibration. This fixture was also used to do the deflection testing on forks as shown in Figure 14.

Figure 13: Cantilever Beam Test Fixture
The tubing sample or fork steerer is clamped in a v-block by two clamping bars (Fig. 15). For cantilever beam testing a two inch bore cylinder actuates a roller that loads the tubing (Fig. 16). For fork deflection testing, a two inch bore cylinder loads an axle bolted to the fork ends through a bearing and clevis assembly (Fig. 14).
1.4 Rear Triangle Fatigue Test Fixture

To provide a way to fatigue test the rear triangle, a system was designed and tested. Besides testing the bottom bracket/chain stays junction as shown below, the system could be adapted to test other frame sub-sections.

![Rear Triangle Fatigue Test Fixture](image)

**Figure 17: Rear Triangle Fatigue Test Fixture**

This would allow the frame designer and/or builder to evaluate various material and geometry choices without having to build and destroy a complete frame.

A fixture shown in Figure 17 was designed and built to fatigue test the rear triangle of a bicycle frame. The fixture consists of a welded steel base (A) with mounts for two pneumatic cylinders (B) used to flex the frame. A PLC (C) controls the activation of the pneumatic solenoid valves (D). A counter (E) counts the number of cycles and a digital indicator (F) measures displacement. Not shown is a pressure
transducer used to accurately measure the air pressure supplied to the cylinders to
determine force. This fixture loads just the chain stays rather than the complete frame.
The bottom bracket is rigidly bolted to the fixture. The chain stays are rigidly tied
together by an axle as they would be while riding by the rear wheel.

1.5 Vibration Testing Apparatus

Fork vibration testing can be done using the fixture shown in Figures 18 through
20. A brief description of this fixture follows.

The vibration input into the fork is provided by a pneumatic actuator coupled to a
dummy axle as shown in Figure 19. The end of the steerer is loaded by a pneumatic
cylinder with the force controlled by a pressure regulator. Between the steerer and the
cylinder is a spring damper assembly guided on linear bearings. This is shown in Figure
20.
On-road data collection can be done using two SENSr three axis accelerometers attached to the bike at the seatpost and stem using custom machined mounts. The mounts and accelerometers attached to a bicycle are shown in Figures 21 and 22. Besides collecting on-road data on a standard test loop, a test section of bumps was built to provide a repeatable test surface. This is shown in Figure 23. The bumps are 0.18 inch high by 1 inch wide and are spaced 6.25 inches apart. There is a total of 24 bumps.
Figure 22: Close-up of Front Accelerometer

Figure 23: Bump Test Surface
1.6 Rear Disc Brake Mount Testing

Figures 24-26 show the fixture used to test the frame disc brake mount under dynamic loading. The flywheel was sized to be equivalent to a 200 pound total bicycle and rider. The motor driving the flywheel has a variable speed drive. A tachometer measures the flywheel rpm. The brake is actuated by a pneumatic cylinder and the braking force is adjustable through a pressure regulator. Both contact and non-contact temperature sensors are used to measure the heat transfer into the caliper and frame. A dial indicator measures stay deflection.

Figures 27-28 show the fixture used to do fatigue testing on the frame disc brake mount. A pneumatic cylinder is used to load the mounting boss in the direction it will see loading under braking. The loading is adjustable through a pressure regulator. Load frequency is adjusted by changing the timing on a PLC. Deflection is measured by a dial indicator. A digital counter measures the number of cycles.

Figure 24: Dynamic Fixture, Side View
Figure 25: Dynamic Fixture, Front View

Figure 26: Frame/Fork Compliance
Figure 27: Fatigue Testing Fixture

Figure 28: Fatigue Testing Fixture, Close-up