CUSH CORE
Tire Suspension

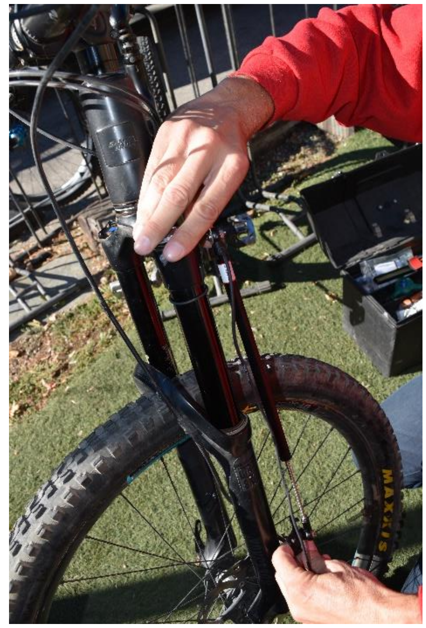
MOTION INSTRUMENTS

Data Acquisition Test Report and Analysis

December 2018

Contents

Methodology



Motion Industries' Rob Przykucki fitting a travel sensor to the fork.

Motion Instruments, an independent data acquisition specialist, conducted a series of tests to better understand how CushCore affects mountain bike performance.

In biking and motorsports, **data acquisition** is the process of gathering real-world physical data about vehicle performance. Motion Instruments fitted test bikes with travel position sensors, accelerometers, and data loggers to measure suspension travel usage, suspension velocity and acceleration, G-forces resulting from bump impacts, vibration and other variables. They tested with and without CushCore, then compared the results.

For the test track, Motion Instruments' Rob Przykucki selected a rough 15-mile descent near Downieville, California. Two test riders used their personal bikes setup to their liking. Each run included over one hour of descending, so the two test riders together accumulated over four hours of data. Robert explained that long runs with continuous data acquisition would even out inconsistencies between runs and produced a reliable, accurate comparison.

Tires, tire pressures, and suspension settings were held constant. The riders attempted to produce identical runs – riding at the same speed and using the same lines. In the end, their two runs came in only 6 seconds apart.

Rugged testing terrain in Downieville.

Prepping tires for the test.

Results

Better Suspension

At the conclusion of testing, Motion Instruments' data shows that the suspension of both test bikes used 15-16% less travel; meaning CushCore absorbed some of the bump forces before they were passed on to the suspension. The suspension worked more efficiently, and the riders took less of a beating.

Or in Rob Przykucki's words, *"it's like taking fewer punches in a fight."*

Table ***1***

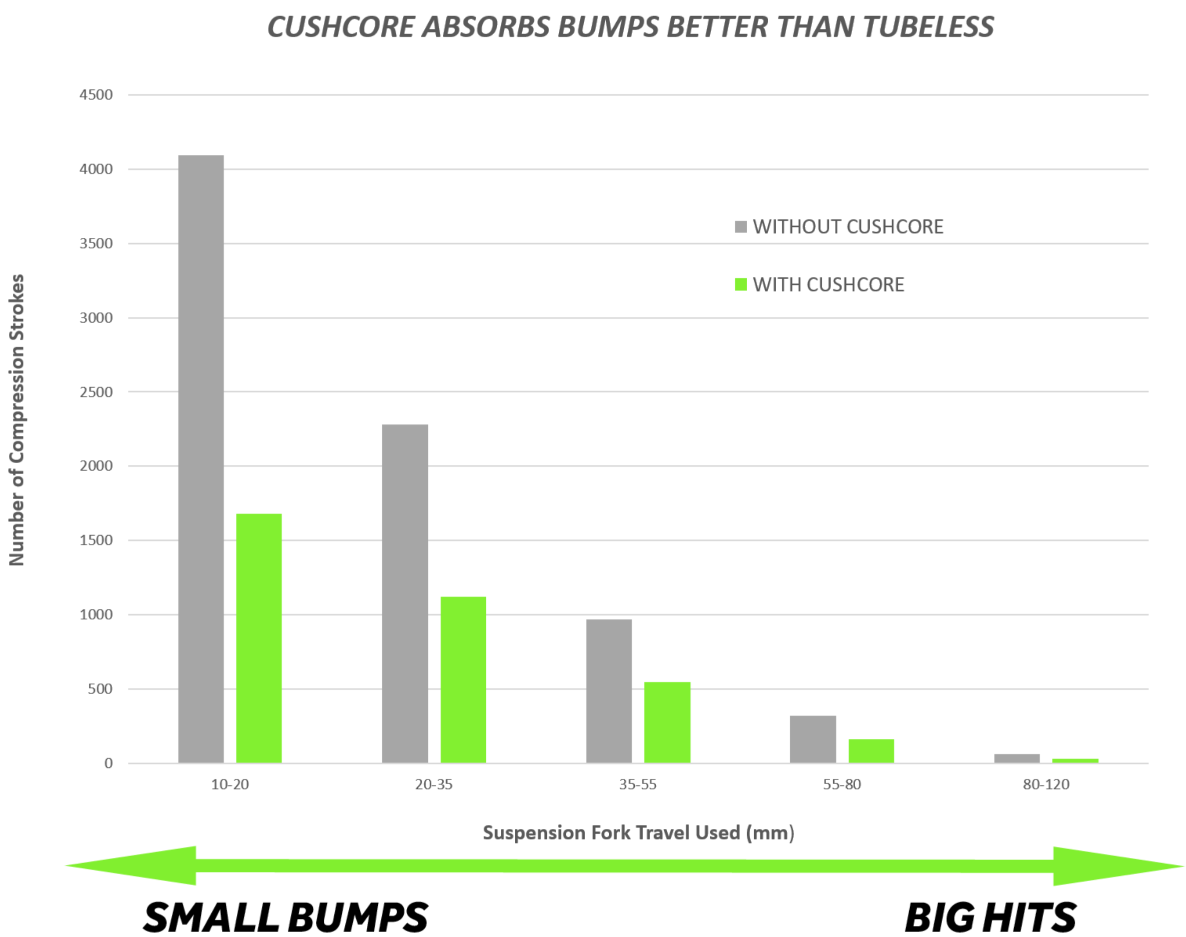
Cummulative compression stroke travel (mm)*	**RIDER 1**	**RIDER 2**
Travel Without CushCore (mm)	107,907	81,745
Travel With CushCore (mm)	91,281	69,111
% REDUCTION	**15%**	**16%**

*The sum of all compression stroke travel recorded throughout the test.

Benefits

- Suspension works more efficiently, requiring less travel to absorb bumps.
- A 150mm travel bike *feel* like it has 173mm of travel, but without the negative side-effects of a longer travel bike.
- Plush ride.
- More travel available for big hits.
- Improved ability to maintain momentum on rough ground.

Compression Stroke Count by Suspension Travel Group



Impact Force Transmitted to the Rider (G-Force)

Accelerometers mounted to the head tubes of both bikes measured vertical accelerations ("G-force"). The location and orientation of the accelerometer allows it to record bump forces as they are experienced by the rider.

Table 3 provides the cumulative G-forces resulting from bump impacts during four hours of testing. CushCore reduced impact G-forces by 11-12%.

Table 3

Cumulative G-force	**RIDER 1**	**RIDER 2**
Without CushCore	8,258	6,079
With CushCore	7,263	5,435
% REDUCTION	**12%**	**11%**

Benefits

- Smoother ride
- More control
- Less rider fatigue – the rider takes 12% less abuse

Interpretation

These findings explain the total average bump force reduction throughout the entire ride. A separate test described below ("Big Hits") examines bump force reduction on a single large impact.

Additional Analysis

In addition to Motion Instruments' testing, we conducted other testing to show how CushCore affects bump response, rolling resistance, cornering performance, and "big hit" absorption.

Lateral Stability & Tire Roll

CushCore configured our MTS Roehrig EMA-2K suspension dynamometer to measure the effect CushCore has on the tire's lateral stability and tire roll (Fig. 3).

CushCore increases sidewall stiffness 35% and reduces lateral deflection (tire roll) by 25%.

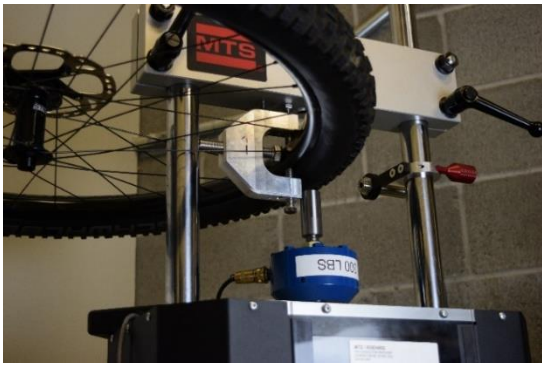


Fig. 3. Testing tire roll on our suspension dyno.

[Video Link: Testing Tire Roll on a Suspension Dyno]

Benefits

- Improved cornering performance.
- Damps unwanted lateral tire rebound in corners.
- Prevents "tire burp."

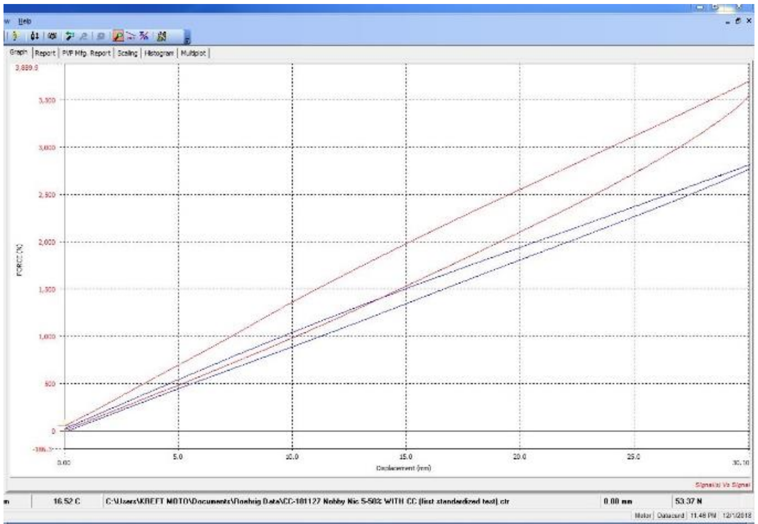


Fig. 4. Screen shot of dynamometer software comparing tire lateral stiffness with CushCore (red) and without CushCore (blue). The ovalized shape of the CushCore trace shows CushCore is creating rebound damping.

Interpretation

- Figure 3 is a plot of lateral stiffness vs deflection distance. CushCore (in red) is stiffer.
- Note the ovalized shape of CushCore's trace in Figure 4. It is stiffer on compression than on rebound due to CushCore's rebound damping effect.
- CushCore's tight radial fit around the rim is an integral part of the design. Radial tension makes it possible to support the lower portion of the tire sidewalls without reducing resilience at the tread patch.

Rolling Resistance

Wheel Energy Oy, an independent tire and wheel testing contractor based in Finland, performed rolling resistance tests for CushCore. They apply a fixed load to simulate the rider's weight and roll the wheel on a drum (Fig. 2). We compared a Schwalbe Nobby Nic 2.35 tire setup tubeless with and without CushCore.

Wheel Energy found that CushCore reduced rolling resistance by 3.2% compared to tubeless.

More about rolling resistance HERE.

Fig. 2. Rolling Resistance testing machine at Wheel Energy.

Benefits

- Less rolling resistance / fast rolling
- Helps maintain momentum

Interpretation

- On small deflections under normal load ("just riding along"), a tire with CushCore maintains the resilient, elastic qualities of a normal tubeless tire. This part of the design is critical for low rolling resistance.
- On rough terrain, CushCore's shock absorption properties help preserve forward momentum in the same way good suspension makes a bike faster on rough ground. More about "suspension losses" and momentum preservation HERE.

High Speed Video Analysis

Fig. 1. What really happens during a bump impact?

Video Link: Slow-Mo Bump Impact Analysis

We used high speed video to analyze the bike's response to bump impacts. We focused on the front wheel, fork, and head tube area.

Sequence of Events in a Bump Strike

1. The tire deforms immediately upon impact (Fig. 1).
2. The suspension fork *does not* begin compressing at the moment of impact. **Suspension action is delayed.**
3. The front suspension begins to compress after the tire is fully compressed.
4. Next, the tire begins to rebound and return to its original shape.
5. **Tire rebound and suspension compression occur *simultaneously*.** The suspension has to absorb the bump and the tire rebound at the same time.
6. Finally, the tire clears the bump and the fork extends.

Dissipating Impact Force

- A tire can respond instantly to a bump impact, where suspension cannot. This means tires are ideal for absorbing abrupt, square-edged bumps, whereas suspension works better for larger bumps that accelerate the wheel more slowly. CushCore maximizes the tire's inherent advantage by **absorbing more shock at the moment of impact** – before it is transmitted to the rider.
- Compressed air inside the tire is an efficient spring. A tire without CushCore returns most of the energy to the rider in the form of tire rebound.
- CushCore foam converts some of the impact energy into heat (like suspension fluid in a damper). This damps compression and rebound forces at the tire.
- Without CushCore, the tire often collapses to the rim during a bump strike. When this happens, impact force increases dramatically. CushCore foam is stiffer than air pressure alone, so it reduces the risk of fully collapsing the tire.

Tire Rebound Damping

- Tire rebound coincides with suspension compression, making the suspension to do extra work.
- It is preferable to control or "damp" tire rebound. This reduces the total force acting on the suspension.
- CushCore's rebound damping also reduces lateral deflection caused by hitting bumps off-center or bumps at an angle to the tire. This partially explains the improved ability to "hold a line" described by CushCore test riders.

Big Hits

CushCore designed and built a drop test tower in order to measure impact force (Fig. 5). An accelerometer mounted on the carriage measures the deceleration rate when it impacts the tire. The test simulates a rock impact at speed. Figure 6 is a graph of the test result.

CushCore reduces "big hit" impact force by up to 50%.

Benefits

- Rim protection
- Flat tire protection
- Reduced rider fatigue
- Improved control

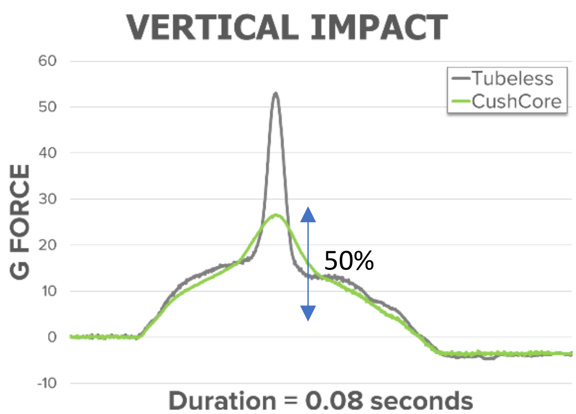


Fig. 6. The spike in G-force in the tubeless tire occurs when the tire bottoms out against the rim.

Fig. 5. Measuring impact force dissipation on our drop test tower.

Video Link: Drop Tower Testing

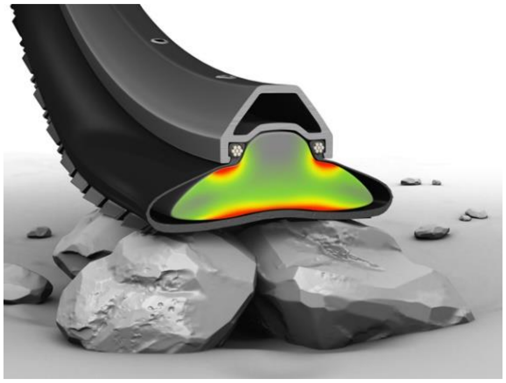
The Three Stages of Tire Suspension

Like a traditional suspension system, a constant damping force doesn't work well. It has to be dynamic. We want suspension that is supple on small bumps but gets stiffer on big hits.

CushCore responds differently depending on the tire loading scenario. We break it down into small, medium, and large tire deflections:

<table>
<tr><td></td><td>Small tire deflections
Under normal load or "just rolling along"

• Little or no damping
• Lively feel
• Less rolling resistance than tubeless</td></tr>
<tr><td></td><td>Medium tire deflections
Bumps and corners that flex the tire sidewalls

• Moderate damping
• Interacts with tire sidewalls
• Supports tire sidewalls (stable/less tire roll)
• Controlled rebound (less bounce and deflection)
• Less vibration</td></tr>
<tr><td></td><td>Large tire deflections
Impacts that fully collapse the tire

• CushCore provides a high level of damping
• Dissipates the impact energy
• Reduces bump force experienced by the rider
• Damps rebound force, helping tire to remain in contact with the ground
• Protects the rim and helps prevent flats</td></tr>
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