Engineering Analysis Report
of
E-Grizzly Electric Fat-Tire Bicycle
by Xtreme Fat Tire Bikes & Components, LLC
Report release date: 27 October 2016

Prepared by
Robert van der Plas, P.E.
Mechanical Engineer
California Professional Engineer License No. 19522

1. Introduction
This report is condensed from the Engineering Analysis Report for Products Submitted by Thomas Coghill Jr. of Xtreme Fat Tire Bikes & Components [see Note 8 below]. The current report addresses only the essential elements relating to the E-Grizzly electric fat-tire bicycle.

2. Summary of Conclusions
The E-Grizzly electric fat-tire bike tested for this report has a significant advantage over other electric fat-tire bikes on the market today due to its use of a hub motor in the front wheel. Other available electric fat-tire bikes have the motor mounted either in the rear wheel or the bottom bracket.

Only the front hub system offers the advantage of allowing the rider to balance torque over both wheels (the rider’s effort on the rear wheel, combined with the electric motor on the front wheel). This feature can prevent the bike either skidding out of control when traction of the driving wheel is lost, or getting “bogged down” in e.g. soft sand.

In addition, the tires on the E-Grizzly were larger than on many other electric fat-tire bikes, thereby offering slight advantages in efficiency, comfort, and traction.
3. Items Received for Analysis

3.1. Hardware Summary

<table>
<thead>
<tr>
<th>Item</th>
<th>Qty.</th>
<th>Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>“E-Grizzly” electric bike</td>
<td>Fat-tire electric-assist bike, with 48 V front-hub motor</td>
</tr>
</tbody>
</table>

3.2. Documentation Summary

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Reference / Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>“Fat Tire E-Bikes: E-Grizzly and E-Cherokee”</td>
<td>Manufacturer’s description of item 1 in table 1.1 above</td>
</tr>
<tr>
<td>5</td>
<td>Catalogue images of fat-tire bike rims</td>
<td>Shows use of non-balanced cut-outs in commercially available fat-tire rims from several manufacturers</td>
</tr>
<tr>
<td>6</td>
<td>Photograph showing clearance at front fork</td>
<td></td>
</tr>
</tbody>
</table>

The various items of documentation listed in table 3.2 above were read, consulted, and referenced in evaluating the hardware item described in the preceding table 3.1.

4. Summary of Work Performed for this Report

4.1. Documentation provided (per table 3.2 above) was read, analyzed, and referenced to the hardware items provided (per table 3.1 above).

4.2. Hardware item provided (per table 3.1 above) was examined, analyzed, measured, weighted, and where possible tested in actual use.

4.3. Where appropriate, engineering theory was used to predict suitability in use of the individual product and its individual components.
5. Evaluation of Item 1, E-Grizzly Bicycle

The E-Grizzly is a fat-tire bike with electric assist by means of a 48 V, 500 W rated front hub motor made by BaFang (also known as 8-Fun), a well-established China-based manufacturer of electric motors for bicycle use, and a 48 V, Li-ion battery with a rated capacity of 11.6 Ah (calculated energy content: 48 V x 11.6 Ah = 557 Wh). Specification data as observed on the bicycle provided are summarized as follows:

| Frame and associated parts | Fat-tire bike specific welded aluminum alloy frame; frame number J51206451; 120 mm bottom bracket; 135 mm front hub spacing; 190 mm rear hub spacing; plastic platform pedals; 27 mm diameter seatpost; padded plastic seat; 28” wide 32 mm diameter handlebars |
|-------------------------------------------------|
| Dimensions                                       | Wheel base: 1105 mm (43.5”)  
Center of front wheel to bottom bracket: 635 mm (25.0”)  
Bottom bracket to center of rear wheel: 482 mm (19.0”)  
Bottom bracket height (with currently installed tires): 317 mm (12.5”)  
Seat height range (center of bottom bracket to top of seat): 635–900 mm (25”–35.5”)  
Q-Factor (distance between pedal attachment points on left and right cranks): 228 mm (9.0”) |
| Wheels                                           | 29” x 4.8” Xtreme Warrior fat tires on 559 BSD, 106 mm (4.2 in.) outside width rims with 36 spokes front and rear; rims with circumferentially symmetrical weight-reduction cutouts; inner tubes with Schrader valves; rated fire pressure: 30 psi maximum; measured un-loaded outside tire diameter 762 mm (30.0 in.) with tire at 15 psi. |
| Gearing                                          | Shimano Alivio rear derailleur with 11–32-tooth rear sprocket 8-speed cassette and 38-tooth single front chainring (no front derailleur). |
| Brakes                                           | Avid BB-series mechanical (i.e. cable-operated) disk brakes with HS-series rotors front and rear. |
| Electric motor                                   | BaFang front hub motor, marked BPM 48 V 500 W 26 (17) 1601165029-6; with 36 spoke holes; installed with torque-arm in the form of a retainer plate held on to an eyelet mounted on the fork-end (or front dropout) on one side only. |
| Battery                                          | Li-ion 48 V, 11.6 Ah (557 Wh); weight 3.25 kg (7.25 lbs.) |
| Electric motor controls                          | Handlebar-mounted thumb throttle control; handlebar-mounted output-control 3-level selector switch; handlebar-stem-mounted display panel; battery-management system in battery mount; motor control circuitry mounted at back of seat tube. |
| Weight of complete bike                          | 26.3 kg (57.9 lbs.) without battery; 29.55 kg (65.15 lbs) with battery. |

The most obvious characteristics that distinguish the E-Grizzly bicycle from most other bikes are the extremely large, fat tires, and the...
front-hub mounted electric motor, and these features will be discussed in the following sections 6 and 7 respectively.

6. Tire Size and Pressure
Fat-tires bikes, also known simply as “fat bikes” have been introduced by a number of manufacturers and dealers since about the year 2010 and are particularly recommended for use on soft surfaces (most typically sand or snow). They form a sub-category of the mountain bike, characterized by the size of their tire: whereas conventional mountain bikes typically have 2.12” wide tires, fat-tire bikes have tires that are at least 3.0” wide.

For a thorough analysis of the advantages of large diameter tires, please refer to reference item 8, from which this paper is condensed.

The E-Grizzly bike came equipped with tires that were marked 29” x 4.8” (26 x 4), and were mounted on 559 BSD rims (i.e. on rims with a SD not typically associated with 29-inch tires but those normally associated with 26-inch tires). This should result in an outside wheel diameter of 559 + 244 = 803 mm (31.6”). Due to the fact that the center of a rim is deeper than the bead seat diameter and tires are not perfectly round in cross-section, the actual outside diameter as measured, with the tire inflated to 15 psi, was 762 mm (30.0”), which is about the same as for a 3” wide tire mounted on the 622 BSD rims used for nominal 29” tires.

7. Electric Assist
The E-Grizzly fat tire bicycle is equipped with a BaFang 48 V electric front-hub motor rated at 500 W and a downtube-mounted 48 V 557 Wh battery with the auxiliary components listed in the table on page 3. Unlike some other electric-assist bikes (especially those legal for road use in Japan and Europe) on which the electric output is activated only as an assist to pedaling, this electric motor can be used as sole propulsion, and its output can be controlled by the rider, with or without simultaneous pedaling input. Thus, in effect, this bike is not a bicycle with electric assist but rather an electric bike with pedal assist.
The amount of electric power can be controlled by means of the control switch (levels 1, 2, or 3) and by means of the thumb throttle lever.

The level of electric output required of any electric vehicle depends largely on the speed, steepness of terrain, headwind, and tire rolling resistance. At a leisurely pace of 16 km/h (10 MPH) on a level road, the required output to propel a bicycle of this kind can be calculated to be approximately 100 W (0.13 hp). In theory, with a fully charged battery (557 Wh), this level of output should be adequate for continuous riding during 5½ hours, covering a distance of 88 km (55 miles). In practice, power surges, such as to accelerate from stops, overtaking, and hill-climbing, will cut into that range significantly, probably reducing the range to about 44 km (27 miles).

The above would apply only to use on a smooth road, which for the use of the E-Grizzly is generally less relevant than its intended special use on soft and/or very rough surfaces, where power consumption is significantly higher. In such more demanding terrain (and also at higher speeds) the range will be further reduced, especially when uphill riding and frequent stop-and-go are involved.

There are three categories of electric motors for electric-assist bicycles: front-wheel-drive, rear-wheel-drive, and center-drive. Each of these three types is more suitable for certain types of use. For the kind of use typical of fat-tire bikes, the front wheel drive offers the advantage over the other forms in that it makes it possible to operate the bike with power to both the front wheel (with the electric motor) and the rear wheel (by pedaling). For a bicycle, two-wheel drive has the same advantages that all-wheel drive has in cars: the machine can be ridden and controlled even when one of the wheels slips or gets "bogged down" e.g. in soft sand or snow, and this tester was able to successfully negotiate soft sand using this technique.

Due to the high torque rating of the motor when driving, as well as due to the effect of strong braking when applying the front disk brake, there is a risk on this kind of arrangement of the front wheel either coming out of the fork or twisting within the fork. To combat this danger, the E-Grizzly is equipped with a retainer plate attached to an eyelet on the fork’s dropout. [This device was installed on
only one side, though it is potentially possible to install such a
device on both sides of the wheel.] In combination with adequately
tightened axle bolts, this device effectively keeps the front wheel
in place under all foreseeable circumstances.

8. Conclusions
The E-Grizzly electric fat-tire bicycle is an excellent product, with
significant advantages on a variety of surfaces over other elec-
tric-assist fat-tire bikes due to its use of a front-hub motor (in-
stead of the conventional arrangements in which the rear wheel is
riven both by the electric motor and the rider when pedaling), al-
lowing the rider to add rear-wheel input when needed.

Reference Notes:
A. Observations about tire rolling resistance, including the effects of
wheel diameter, tire width, road surface, and tire flexibility, can be
found in the following sources:
1. Van der Plas, Robert & Stuart Baird. Bicycle Technology. San
Tech, April 1983.
B. Observations regarding the specific benefits of increased wheel size and
tire width can be found in the following sources:
5. Pinkerton, John, Alberto E. Minetti & Paola Zamparo. “From Bipedalism
to “Bicyclism: Evolution in Energetics and Biomechanics of Historic
Bicycles.” Cycle History 12: Proceedings of the 12th International
6. Steiner, Thomas, Beat Müller, Thomas Maier & Jan-Peter Wehrlin.
“Performance Differences when using 26- and 29-inch wheel bikes in Swiss
National Team Cross-Country Mountain Bikers.” Journal of Sports
Sciences, 2015.
7. “Could Wider Tires Make You Faster?” Mountain Bike Action, October
2016.
C. Source of the present report:
Submitted by Thomas Coghill Jr. of Xtreme Fat Tire Bikes & Components.”
October 2016.