BST.

TECHNICAL DOCUMENT

AV TEK WHEEL RANGE

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CONTENTS

1. PURPOSE

The purpose of this document is to report the proposed technical requirements for carbon fibre monocoque wheel. The document then goes further to report the technical data for Blackstone TEK's (BST) AV TEK wheels, that may be used by adventure motorcycle riders.

2. BLACKSTONE TEK BACKGROUND

Blackstone Tek (BST) is the internationally recognized leader in the design and manufacture of carbon composite wheels and structural parts for the motorcycle and automotive industry. With 22 years' experience and over 30 000 motorcycle wheels on the roads today, BST is uniquely positioned to develop, manufacture, and supply safe and reliable carbon composite wheels.

All wheels produced by BST are manufactured using Carbon Fibre which is pre-impregnated with an epoxy resin. Each wheel is made up of a combination of 4 variations in weave and modulus of fibre. These materials are accurately and precisely hand placed in the desired position and orientation to ensure an optimal structure.

Following the layup of the fibre plies, the wheels are cured in a pressure and temperature-controlled process. This ensures the consolidation of all the layers, resulting in a strong and rigid monocoque structure. These wheels are then inspected by a full CT Scan and geometrically scrutinized to ensure the absence of any structural defects which would jeopardize the structural integrity of the wheel.

Wheels produced by BST have been documented to provide the following benefits:

- ✓ Lower Rotational Inertia
- ✓ Quicker Acceleration
- ✓ Later Braking
- ✓ Improved Handling
- ✓ Higher Stiffness
- ✓ Improved Fuel Efficiency
- ✓ Composite resilience offering long service life.

BST is a supplier to many OEM manufacturers and BST wheels are produced in accordance with the ISO9001:2015 standard – **our certificate can be found here**. BST is audited and certified by TÜV Rheinland, in accordance with ISO9001:2015 standard, the manufacturing process retains full material traceability throughout. All details pertaining to manufacture, including all processes, are recorded and can be made available.

3. INTRODUCTION

This new range of wheels was developed to meet aftermarket motorcycle wheel demands of Blackstone TEK. This range includes two sizes of composite wheels specially designed for adventure motorcycles.

Each wheel has a unique serial number. To ensure that every wheel meets the stringent quality requirements, a 100% inspection rate will be implemented along the AV Tek range. The following inspections are performed on every wheel:

- Visual cosmetic inspection
- Dimensional and ETRTO profile inspection

The wheel designs are characterised to ensure that the performance requirements set in the initial phase are met. These include weight, bending stiffness, and rotational inertia.

These wheels are designed to meet the JWL test standard. The maximum static load rating on the front wheel is 205 kg and offset rear wheel is 300 kg. This is calculated from the Gross Vehicle Weight Rating (GVWR) of the 2019 – 2023 BMW R 1250 GS. These values may be seen in Table 1. The execution of the tests and the required loads are described section 4. The test results of the 7053 and 9023 wheel types are included in section 5 and the appendices.

Table 1 **Allowable GVWR**

Maximum Allowable GVWR	465 kg
7053 (AV TEK FW 19" x 3") Static Load Rating	205 kg
9023 (AV TEK ORW 17" x 4.5") Static Load Rating	300 kg

4. WHEEL CHARACTERISATION

Through the characterisation process the design's suitability and relevant inspection criteria can be determined. The properties of primary concern are the mass at various production points and the rotational inertia of the wheel.

4.1 ROTATIONAL INERTIA MEASUREMENT

The rotational inertia is defined as "a measure of a body's resistance to angular acceleration". A lower rotational inertia requires less torque to obtain the same acceleration. Thus, inertia governs the rate at which potential energy (ΔU_g) is converted to translating (ΔK_T) and rotating (ΔK_R) kinetic energy. A lower inertia allows the wheel to accelerate faster which gives a higher final velocity and a lower time to cover the same distance.

In Figure 1, a diagram of the rotational inertia test rig can be seen. The inertia is calculated by using the final velocity of the wheel. The final velocity is calculated by recording the time the wheel takes to roll down a 4° (Ø) slope over a known distance. The slope is 2.555 m in length (L) and the height difference between the start and end point is 177 mm (H). The time to roll down the slope is recorded 10 times for each wheel, with the average being used.

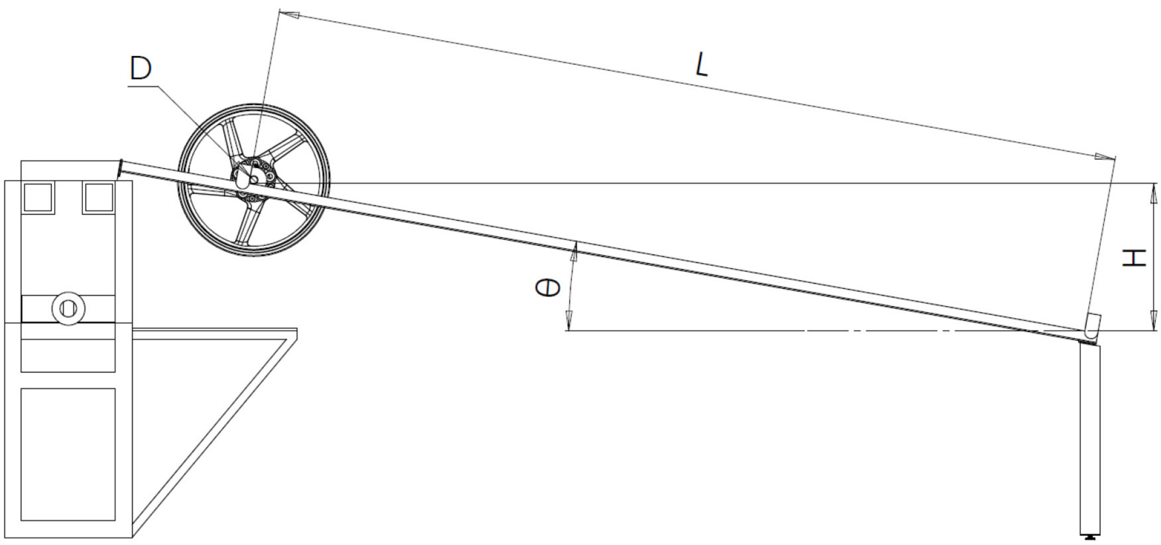

Fig. 02 ***Rotational Inertia Test Rig***

4.2 BENDING STIFFNESS MEASUREMENT

A high bending stiffness generally improves the handling characteristics of the vehicle as it governs the wheel's deflection during cornering manoeuvres. BST wheels are designed to have increased bending stiffness over the OEM wheels for optimal performance.

The edge of the wheel is mounted onto a rigid plate. An adapter is fixed to the wheel's hub. The nuts are torqued to the manufacturer's specification. The load arm is then connected to the adapter. The bending stiffness is measured in line with a spoke.

The stiffness is calculated from deflection measurements at a known load (F), as seen in Figure 3. The load is then divided into horizontal and vertical components by using angle Ø. The deflection of this arm (X_B) is measured at a distance of H_B from the hub face. The deflection of the hub (X_A) is measured at a distance of H_A from the hub face. From these measurements the number of degrees that the hub's face deflects (ß) can be calculated. The bending stiffness is then calculated by dividing the moment (M_B) by the angle deflected (ß).

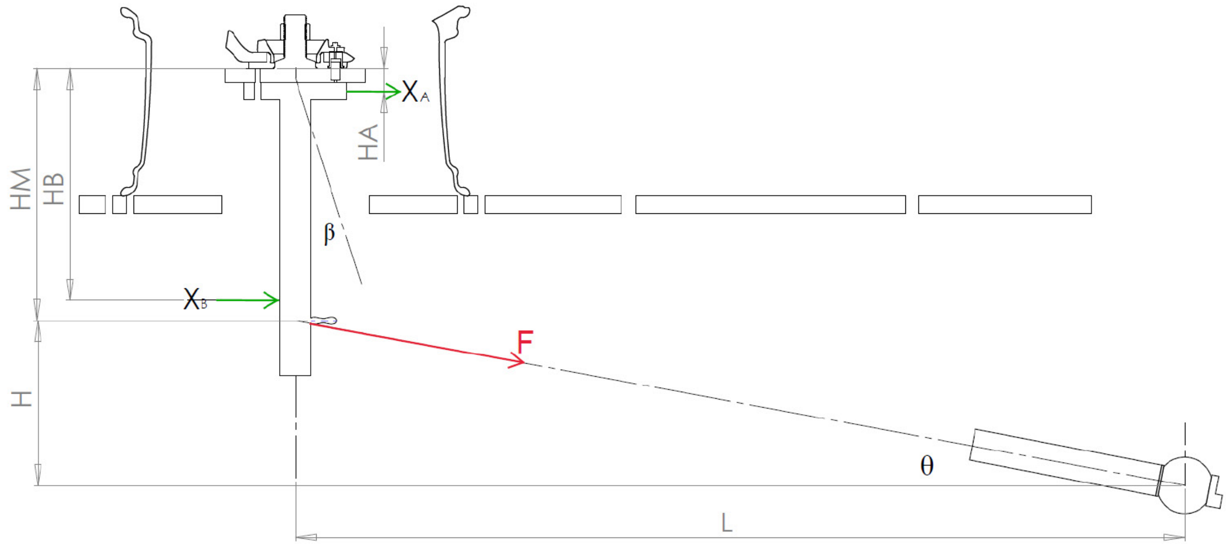

Fig. 03 ***Bending Stiffness Experiment***

5. WHEEL REQUIREMENTS

For motorcycle applications the TUV & JWL standards specify the loads required for the wheel design to pass. The loads specified are used as a baseline to decide on the design load. These loads depend on the on the static load rating required as well as the size of the wheel.

5.1 ROTATION BENDING FATIGUE TEST

In the cornering fatigue test, the side forces acting on the wheel during a cornering manoeuvre are simulated. This test was done in accordance with the TUV No. 287 StVZO 1998 requirements. The standard specifies that the wheel design will be tested at 100 % of the calculated moment (M_B) for 100 000 cycles. The moment is calculated with Equation 1 below:

Eq. (1) $M_B = f * F_R (R_{dyn} + e + l)$

Where:

M_B = Reference moment for load levels [Nm]

f = Wheel load increase factor

F_R = Permissible static vertical wheel load [N]

R_{dyn} = Dynamic tyre radius [m]

e = AOffset [m]

l = Half width of tread [m]

The wheel is clamped on the flange of the outer lip. Spacers take the place of the bearings and an axle is fitted to the wheel. The axle is torqued as required by the motorcycle manufacturer.

The load arm is connected to the axle with an eccentric weight. An electric motor spins the eccentric weight. This creates a force F that is at a known distance away from the hub face. Strain gauges, placed on the load arm, are used to calculate the bending moment on the wheel and count the number cycles. As the frequency of the motor increases, the speed at which the eccentric weight spins at increases. Spinning the weight faster produces a greater force F, and hence a greater bending moment. The motor frequency, and hence the load, typically changes when the stiffness of the mounts or wheel changes. There are frequency variations in the motor frequency that is caused by the motor controller; however small changes are of little concern. The motor controller outputs the motor frequency against the number of cycles at the end of the test. A significant decrease in motor frequency is indicative of a loss in stiffness.

5.2 ALTERNATING TORSION FATIGUE TEST

In the alternating torsion fatigue test, the tangential forces acting on the wheel during braking and accelerating are simulated. his test was done in accordance with the TUV No. 287 StVZO 1998 requirements. The TUV standard specifies that the wheel design will be tested the calculated torsional moment (M_T) for 1 000 000 cycles.

The torsional moment is calculated with Equation 2 below:

Eq. (2) $M_T = f \times F_R \times R_{dyn}$

Where:

M_T = Alternating torsional moment [Nm]

f = Wheel load increase factor

F_R = Permissible static wheel load [N]

R_{dyn} = Dynamic tyre radius [m]

The wheel is clamped on the outside surface. The electric motor turns an eccentric shaft that creates a sinusoidal variation of the force. The crank arm acts through a linear bearing so that the wheel only sees a horizontal force. This horizontal force is measured by the load cell and creates a moment around the axle.

5.3 RADIAL IMPACT TEST

The JWL standard specifies the load that must be dropped radially onto the wheel. This simulates the wheel striking a road surface defect. The wheel is required to hold some air pressure after impact, such that the motorcycle can be brought to a controlled stop. The load is split into two weights; the auxiliary weight that is fixed and the main weight that is changed as required. These two weights are connected via two springs. The JWL standard specifies that the wheel design will be tested with a drop weight.

The mass of the drop weight is calculated with Equation 3 below:

Eq. (3) $m_1 + m_2 = K \frac{W}{g}$

Where:

W = Permissible static wheel design load [kg]

M_1 = The mass of main striker weight [kg]

M_2 = The mass of auxiliary striker weight [kg]

W = Permissible static vertical wheel load [N]

K = Design load coefficient

g = Gravitation acceleration [m/s^2]

The wheel is fixed radially and fitted with a tubeless tyre of the motorcycle manufacturer's specified size. A pass is considered to be no through-thickness cracks and the wheel must still have a tyre pressure of 1.5 bar after 30 seconds.

6. AV TEK TEST RESULTS

Below is a summary of the characterisation and test results that the wheel designs have been subjected to.

Table 2 **Wheel Types**

Wheel	Wheel Type	Static Load Rating	Wheel Size
7053	Front	205 kg	FW 19" x 3"
9023	Offset Rear Wheel	300 kg	ORW 17" x 4.5"

Table 3 **Wheel Fitment Information**

Assembly Code	Description	Wheel Type
21019-7053-16-400	2019 (and onwards) BMW R 1250 GS ABS	Front Wheel
21019-9023-16-400	2019 (and onwards) BMW R 1250 GS ABS	Offset Rear Wheel

Table 4 **Wheel Characteristics**

Wheel	Packaged Weight	Rotational Inertia	Bending Stiffness
Front (7053)	4.25 kg	105 876 kg · mm²	1,709 N · m/°
Rear (9023)	3.05 kg	93 640 kg · mm²	2,342 N · m/°

Table 5 **Cornering Fatigue Test**

Wheel	Applied Load	Required Load	Cycles	Pass/Fail
Front (7053)	672 N · m	672 N · m	1 000 000	Pass
Rear (9023)	791 N · m	713 N · m	1 000 000	Pass

Table 6 **Radial Alternating Torsion Fatigue Test**

Wheel	Applied Load	Required Load	Cycles	Pass/Fail
Front (7053)	718 kg	709 kg	1 000 000	Pass
Rear (9023)	1 077 kg	1 029 kg	1 000 000	Pass

Table 7 **Radial Impact Load**

Wheel	Applied Load	Required Load	Pass/Fail
Front (7053)	514 kg	514 kg	Pass
Rear (9023)	488 kg	488 kg	Pass

Table 8 **Weight Comparison AV Tek**

Wheel	OEM Weight	BST Weight	Percentage Weight Saving
FW (with brake carriers + bearings but without spacers)	6.38 kg	4.25 kg	33
ORW	5.47 kg	3.05 kg	43