The New BMW HP2 Sport

Following the HP2 Enduro and the HP2 Megamoto, the HP 2 Sport is the third model in the High Performance Series from BMW Motorrad featuring the boxer power unit so rich in tradition and a wide range of innovative solutions. The new HP2 Sport is indeed the most sporting, powerful and, at the same time, lightest production boxer of all times. Through the participation of BMW Motorrad in the World Endurance Championships, the Company's engineers and technicians have been able to prove the supreme performance and high standard of the concept, at the same time gaining experience in engine and suspension technology subsequently transferred into series production.

1 Short Description

With its dry weight of 178 kg (392 lb), the BMW HP2 Sport is another 12 kg (26.5 lb) lighter than the current BMW R 1200 S Sports Boxer. Engine output has been increased to 133 hp at 8750 rpm, with maximum torque of 115 Newton-metres/85 lb-ft at 6,000 rpm. Operating via drag arms, two overhead camshafts on each side (dohc) activate the valves in the newly developed cylinder heads. Featuring a gearshift assistant, the new six-speed gearbox with its tighter gear increments allows the rider to shift up under full load without de-clutching and without taking back engine power. The fairing is made completely of carbon-fibre compound (CFP), for the first time on a production motorcycle with load-bearing rear and front sections. Adjustable to a wide range of different settings, the sports suspension as well as the adjustable footrests and extra-short handlebar may be set up as required for different race tracks and for road use. Apart from providing the usual information, the instrument cluster is also able to present lap times, the fastest lap in a given session, maximum engine speed, and many other data relevant to motorsport. The picture of the HP 2 Sport and technical data are shown by **Figure 1** and **Table**.

2 Drivetrain

The HP2 Sport is based on the drivetrain of the R 1200 S and benefits from a wide range of new construction features making this the most powerful production boxer in the range. Maximum output of 133 hp (98 kW) and maximum engine speed of 9,500 rpm required complete modification of the valve operating system. Peak torque of 115 Newton-metres/85 lb-ft at just 6,000 rpm, on the other hand, again reflects the practical everyday riding qualities so typical of a BMW Boxer.

Interacting with the stainless-steel exhaust system and a three-way catalyst, BMS-KP electronic engine management complete with an oxygen sensor serves to fulfil the European EU3 emission standard. The high-performance engine comes with a compression ratio of 12.5:1 and runs on premium plus gasoline (98 octane), but may also make do, thanks to knock control, with the usual premium gasoline (min 95 octane).

To meet the greater requirements in terms of engine output and speed, both the engine block and the cylinders have been appropriately modified. The new cylinder heads allow the use of shorter and, accordingly, more stable thread rods fastening the cylinders and cylinder heads (pull anchors). With the distance between the pull anchors being enlarged in the engine block, the engine features new nikasil-coated cylinders with cylinder liners almost twice as thick (4.2 mm/0.17") as usual, **Figure 2**.

2.1 Crankdrive

By and large, the HP2 Sport features the proven crankdrive of the EVO Boxer introduced in 2004 appropriately modified in this case in consideration of the high-

Figure 1: Sideview HP2 Sport

Authors

Dipl.-Ing.
Peter Müller
is Director of Development and Model Series at BMW Motorrad in Munich (Germany).

Dipl.-Ing. (FH)
Franz Berkmann
is Director of the R Model Series at BMW Motorrad in Munich (Germany).

Dipl.-Ing. (FH)
Jörg Schneppenheim
is Project Manager HP2 Sport at BMW Motorrad in Munich (Germany).

Table: Specifications HP2 Sport

Engine	
Type	Air/oil-cooled 2-cylinder 4-stroke flat twin (‚Boxer'), two camshafts, four valves per cylinder in radial arrangement, central balancer shaft
Bore x stroke	101 mm x 73 mm
Capacity	1170 cm^3
Rated output	98 kW (133 bhp) at 8,750 rpm
Max. torque	115 Nm at 6,000 rpm
Compression ratio	12,5 : 1
Mixture control	Electronic intake pipe injection
Engine management	BMS-K digital engine management with overrun fuel cut-off, single-spark ignition
Emission control	Closed-loop 3-way catalytic converter, emission standard EU-3
Performance / Fuel Consumption	
Maximum speed	over 200 km/h
Acceleration	0–100 km/h 3 sec.
Fuel consumption per 100 km	4.1 l (at constant 90 km/h)
	5.8 l (at constant 120 km/h)
Fuel type	Unleaded premium, octane number 98 (RON); automatic knock control permits operation with minimum octane number 95 (RON)
Electrical System	
Alternator	Three-phase alternator 480 W
Battery	12 V / 12 Ah, maintenance-free
Power Transmission	
Clutch	Single dry plate clutch, hydraulically operated
Gearbox	Constant mesh 6-speed gearbox with helical gear teeth
Drive	Shaft drive
Chassis / Brakes	
Frame	Tubular steel space frame, front and rear made of self-supporting carbon
Front wheel location / suspension	Telelever, spring pre-load continuously variable, compression damping, rebound damping and vehicle height adjustable
Rear wheel location / suspension	EVO Paralever, Öhlins central spring strut, spring pre-load continuously adjustable, rebound and compression damping adjustable, vehicle height adjustable
Suspension travel front / rear	105 mm / 120 mm
Wheelbase	1487 mm
Castor	86 mm
Steering head angle	66°
Wheels	Milled cast aluminium wheels
Rim, front	3.50 x 17"
Rim, rear	6 x 17"
Tyres, front	120/70 ZR 17
Tyres, rear	190/55 ZR 17
Brake, front	Dual disc brake, floating brake discs, 320 mm diameter, Brembo monobloc 4-piston caliper
Brake, rear	Single disc brake, diameter 265 mm, double-piston floating caliper
Dimensions / Weights	
Seat height	830 mm
Unladen weight, road ready, fully fuelled	199 kg
Dry weight	178 kg
Permitted total weight	330 kg
Usable tank volume	16 l
Reserve	approx. 3 l
Width (incl. mirrors)	750 mm

er running loads. One such modification is the ancillary shaft driven by the crankshaft via a roller chain at a ratio of 2:1 and now incorporating sprockets with 23 (previously 17) teeth serving to drive the timing chains for the camshafts. The new roller chains with smaller chain units reduce friction while running and enclose the sprockets more tightly.

2.2 Cooling

To cope with the higher thermal loads acting on the flat-twin power unit also under racing conditions, the principle of combined air/oil cooling has been developed to an even higher standard. The cooling oil ducts next to the outlet ducts in the cylinder heads have been enlarged appropriately, a thermostat valve opening as of an oil temperature of approximately 95°C allowing the oil to flow into the two oil coolers arranged parallel to one another in the front fairing.

To keep the frontal area and, accordingly, the drag coefficient of the new HP2 Sport as low as possible, while at the same time to make the cooling surface larger, the two oil coolers are positioned behind one another. The CFP side fairing and the engine spoiler serve to guide the flow of air appropriately, thus ensuring an optimum flow of air around the cylinder head.

2.3 Valve Drive

The most significant modification involves the re-construction of the valve operating units, where in each of the two four-valve cylinder heads two overhead, chain-driven camshafts (dohc) now operate the valves via drag arms and polished hemispherical operating units as on the new BMW K 1200 models. The camshafts are arranged flat in the direction of travel and each feature one intake and one outlet cam.

To keep the combustion chambers with their central spark plug even more compact and to improve flow conditions, the valves come in radial arrangement. The outlet valves are positioned at a vertical angle leaning 6° to the front and the intake valves lean 5° to the rear. In addition, the outlet valves are fitted in the cylinder head at a horizontal angle offset by 4.6° to the top and bottom, the intake valves are offset by 3° to the top and bottom, fitted at a slanted angle in the cylinder head.

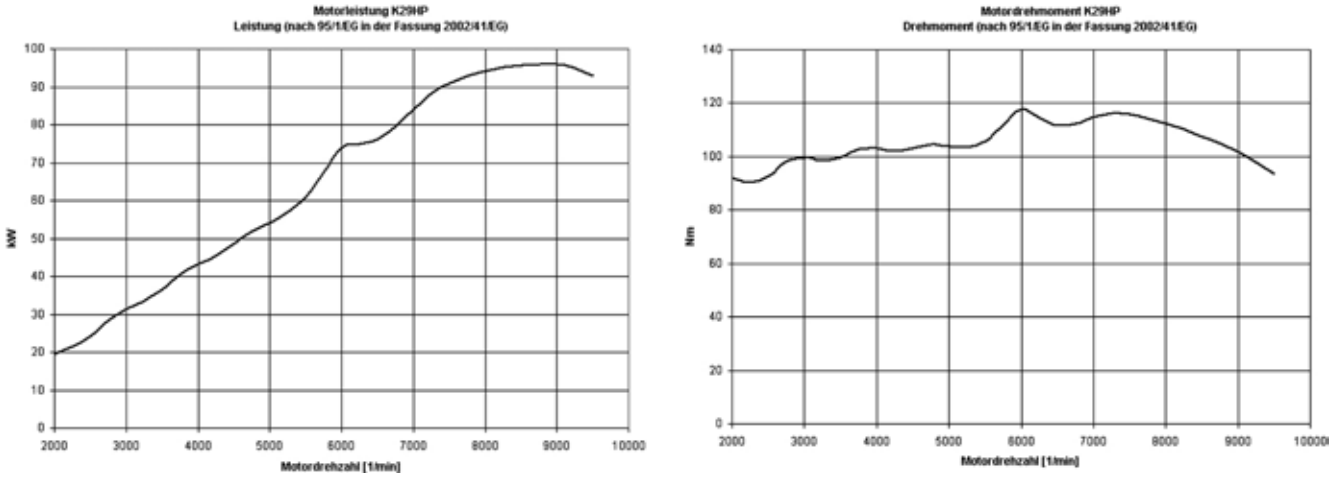

Figure 2: Full load curves HP2 Sport

The intake valves have been enlarged in diameter by 3 mm to 39 mm (15.4“) and the sodium-filled outlet valves are 2 mm larger, now measuring 33 mm (13.0”) in diameter. All valves are nitride-hardened on their seat surfaces to improve their resistance to wear.

The valve guides are sintered out of powder metal offering better anti-friction and wear behaviour than brass guides and therefore able to make do with smaller overlap in the intake and outlet ducts. Valve shaft diameter has been increased from 5 to 5.5 mm (0.20 - 0.22”), the intake valve seat comes in a 45°, the outlet valve seat in a 60° angle in order to improve the dissipation of heat.

Each valve is closed by two progressive valve strings wound in the opposite direction. Two spring-loaded, hydraulic chain tensioners and optimised guide rails ensure the largest possible mesh area on the timing chain gears, thus driving the camshafts with minimum vibration and superior smoothness also at high speeds. The intake canals are 1 millimetre larger in diameter and benefit from high-precision machine finish. With the ducts being optimised in this way for perfect flow conditions right from the start, there is no need for ancillary spark plugs, **Figure 3**.

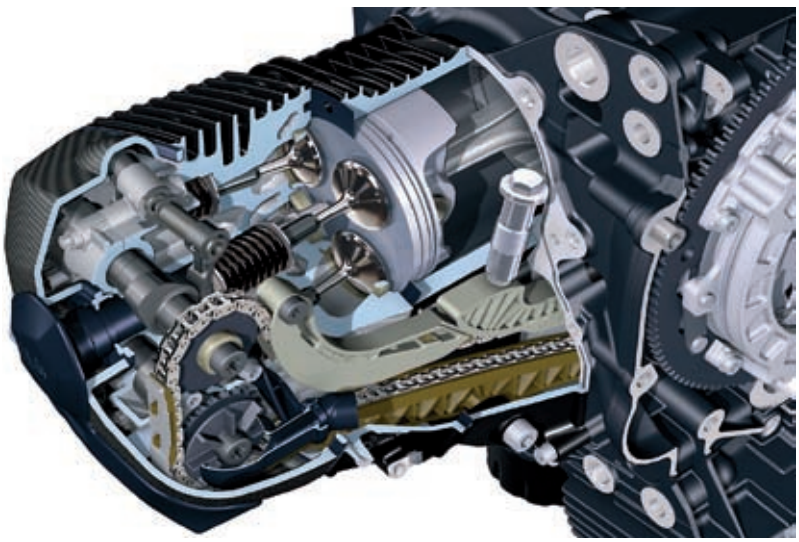

Figure 3: Cutaway drawing DOHC cylinder head on HP2 Sport

2.4 Pistons

Use of forged light-alloy pistons with wear-reducing Grafal-coating on the piston shaft serves to reduce the oscillating masses in each cylinder by approximately 80 grams. Production tolerances in the weight of the piston are set off by piston pins likewise classified by weight. The compression height of the new pistons, in turn, is 3 millimetres lower.

Due to the use of lower pistons, the connecting rods also come in different dimensions than on the other boxer models: The new high-strength steel-forged cracked connecting rods (36MnVS4) are 3.1 mm (0.12”) longer and run in reinforced connecting rod shells in the crankshaft. On account of the longer connecting rods, the side forces acting on the pistons and cylinder walls are reduced accordingly, ensuring greater resistance to high running speeds and less wear on both the pistons and cylinders.

2.5 Intake System

The newly designed airbox with its longer intake funnel optimised for smooth flow conditions increases air throughput by 20 percent. Air entry directly into the side fairing at the front right has been optimised by way of CFD calculations and tests in the wind tunnel. Particularly at high speeds this improves the cylinder charge cycle. The air filter is an oil-immersed and washable sports air filter also improved in its air throughput, **Figure 4**.

2.6 Exhaust System

The exhaust system is made completely of stainless steel, the exhaust manifolds are fitted beneath the engine for leaning over to a lower angle in bends and

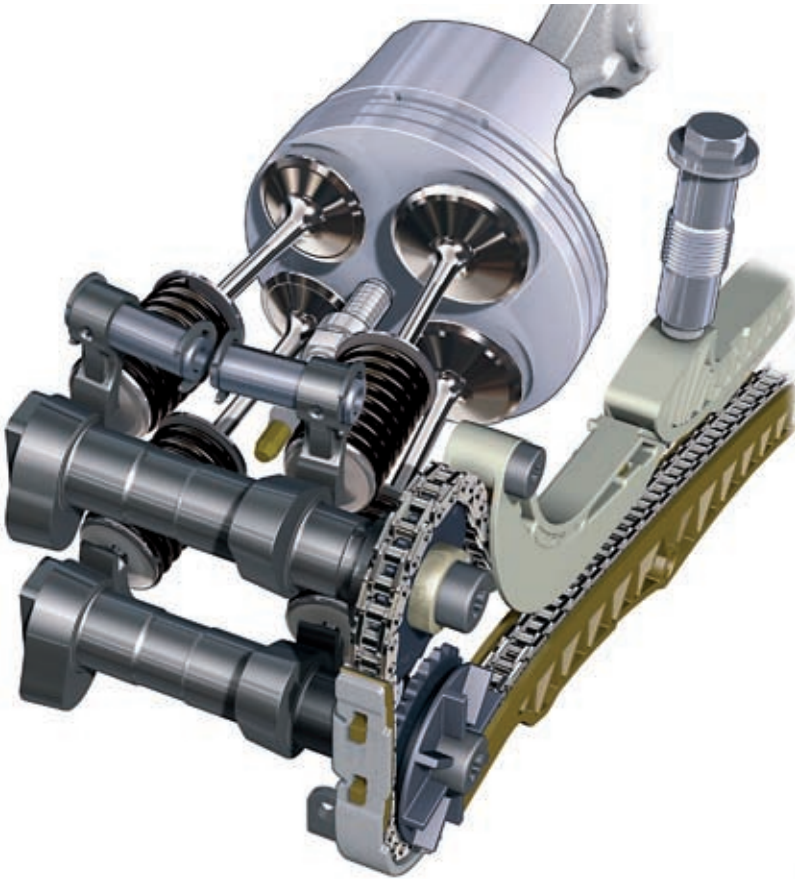

Figure 4: Valve drive HP2 Sport

in the interest of enhanced aerodynamics, and merge into a metal-based catalytic converter increased in diameter by 15 millimetres (0.59“) to 105 millimetres (4.13“).

The new, particularly short interference pipe with its inner-mounted perforated cover measuring 12.5 mm (0.49”) in diameter helps to significantly increase engine torque at low running speeds.

The two oxygen sensors are arranged in the flow of exhaust gas upfront of the interference pipe in order to ensure a particularly rapid response. The double-tube rear silencer, in turn, is designed for top performance in terms of its volume and pipe cross-section. This also generates the typical “throaty” sound of the boxer engine coming from the silencer fitted beneath the seat on the load-bearing CFP rear fairing. The entry pipe leading into the rear silencer incorporates an exhaust flap measuring 65.5 millimetres (2.58”) in diameter, a return spring opening the exhaust flap in full when not in use. A cable then closes the flap infinitely either in part or in full whenever required via an electronic actuator with a worm gearing. This is done by means of control maps for the engine speed and throttle butterfly angle (gas lever position) in the engine control unit (BMS-KP) controlling the actuator accordingly. This intentionally increases exhaust gas back-up at low and medium engine speeds, and when quickly turning the rotating gas handle, thus improving the charge cycle and reducing noise emissions (EU3 standard).

2.7 Clutch/Transmission

In consideration of the enormous forces encountered particularly at the start of a race, the friction pads on the single-disc 180-mm (7.1“) dry clutch on the BMW boxer models free of asbestos and heavy metals are not just riveted on to the pad mount, but also bonded in position.

The transmission housing on the six-speed gearbox with its helical gears shifted by glide sleeves is a new design serving to optimise the bearing points and the arrangement of the individual gearbox shafts. To provide closer and more sporting increments between the individual gears, the first and second gear are somewhat longer and the primary transmission ratio has been adjusted to the 8 per cent increase in engine speed (9,500 rpm).

2.8 Gearshift Assistant

The rider shifts gears on the HP2 Sport not, as is generally the case, through a shift bar between the foot lever and the gearshift shaft. For instead of the usual, rigid threaded bar, the BMW HP2 Sport features a sliding, spring-loaded connection unit covering 3.5 millimetres (0.14”) travel and featuring an integrated hall IC. When shifting down, the gearshift assistant behaves in the same way as a conventional rigid connection. When the rider pulls the clutch to shift up, gears are again shifted without electronic intervention via the spring in the gearshift assistant pre-loaded at 200 N.

Should the rider not pull the clutch to shift up, the BMS-KP engine control unit will register via the hall IC fitted in the gearshift assistant that the rider wishes to shift up, briefly interrupting fuel injection and retarding the ignition angle in order to shift gears up under full load without the rider having to take back the gas handle manually, **Figure 5**.

3 Electrical System

The BMW HP2 Sport features BMW CAN-bus technology, just like other models in the range. The network of control units is made up of the BMS-KP engine control unit, the CVE Central Vehicle Electrics, and the instrument cluster.

The BMS-KP control unit features all the control functions on HP2 Sport already known from BMW’s current boxer models. New functions are the gearshift assistant and the electronically operated exhaust flap. Fuel system pressure is 4.0 bar and is maintained consistently by a mechanical fuel pressure regulator.

In the interest of lower weight, the BMW HP2 Sport comes with a light 12V/12Ah battery and a small 40A alternator. The rear light is a power- and weight-saving LED light-emitting unit.

3.1 Instrument Cluster

The instrument cluster (2D dashboard) is able to present a wide range of information relevant in motorsport. It may be extended by adding a data logger, a transponder or a GPS tracking module. This provides the option to record data for up to 100 laps in a racing session, with individual laps being saved either by the transponder or manually by pressing the SET button when crossing the finish line.

The row of light-emitting diodes in the instrument cluster shows the rider the ideal point for shifting gears and may be freely programmed in the Race Mode. As long as the engine is warming up, the rider sees the appropriate, lower engine speed limit currently allowed, **Figure 6**.

Overview of the most important functions:

- ROAD: Road speed, engine speed, gear in mesh, total distance covered, trip 1, trip 2, (remaining range when running on reserve fuel), time, stopwatch
- RACE: Road speed, engine speed and gear currently in mesh may be exchanged, number of laps, overall time, lap time – fastest, – last, minimum speed, maximum speed, instant shift time adjustable
- INFO (Information on up to 100 race laps): Lap times, minimum speed, maximum speed, average speed, maximum engine speed, gearshifts, throttle butterfly, brake time
- SETUP: Options for time set-up, instant shift time, brightness, reset, etc

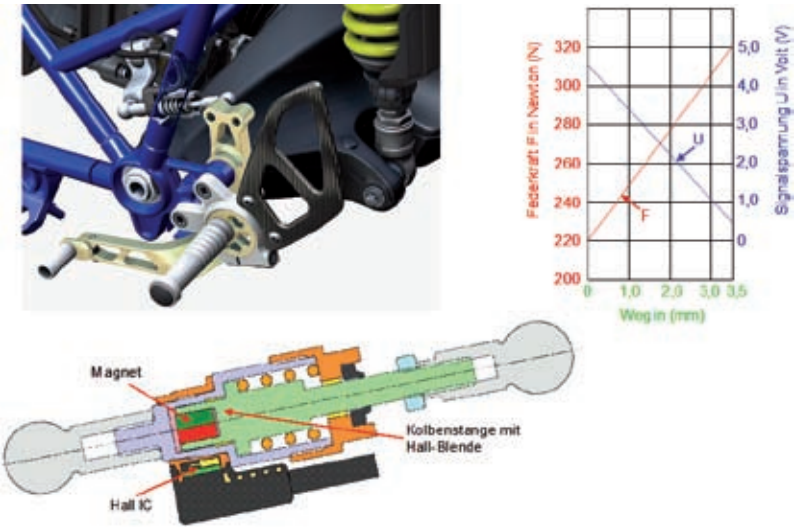

Figure 5: Gearshift assistant HP2 Sport

4 Suspension and Running Gear

4.1 Frame Concept

Acting as a load-bearing element, the engine/transmission unit forms the backbone for the suspension and running gear. The steel front frame holding the upper fork bridge and the front spring strut is bolted on to the engine block. The longitudinal arm for the BMW Telelever pivots on the engine block, the central steel tubular frame holding the spring strut and the swinging arm mount of the BMW Paralever is bolted on to the engine and gearbox.

Since the HP2 Sport is for solo riding only, there is no need for a rear frame. Instead, the rider's seat, the exhaust mounts and the rear light together with the numberplate support are fastened to the load-bearing rear section made of CFP.

While the basic geometry of the suspension, that is the steering head angle, camber and wheelbase, shows very good results and confirms the qualities of the R 1200 S, it has nevertheless been slightly modified once again. The reason is that the fully adjustable Oehlins sports suspension featured as standard provides the option to adjust the set-up to various tracks and racing requirements.

4.2 Telelever

Thanks to its kinematic anti-dive function, the well-known BMW Telelever suspension offers adequate residual spring travel, especially in extreme braking manoeuvres. The sports spring struts front and rear feature a gas-pressure damper complete with a pressure reservoir in order to keep temperature-induced changes in damper characteristics to a minimum. The system itself is filled with nitrogen at a pressure of 12 bar. The degree of damping in the pressure stage as well as the speed of the front wheel moving in under spring pressure may be varied by a knurled wheel on the pressure reservoir. In this process the piston pin diving into the oil forces the oil through an adjustable valve into the pressure reservoir, while in the rebound stage with the spring pulling the damper piston apart the oil will flow back through the adjust-

Figure 6: Instrument cluster HP2 Sport

Figure 7: Suspension and running gear HP2 Sport

able needle valve on the piston pin. The oil forced into the compensation reservoir in the inbound motion, in turn, is forced back by the gas pressure via a separate one-way valve.

The spring pre-load force may be adjusted infinitely by two counter-locking aluminium nuts in order to provide adequate, positive spring travel also under higher front wheel loads (with a rider weighing more than 85 kg). By moving the two slide tubes down in the slide-tube holder, ground clearance on the HP2 Sport at the front may be increased by up to 23 mm (0.91"). This, first, extends wheel camber in the interest of even greater directional stability and, second, increases the possible side angle in bends due to the increase in ride height.

4.3 Paralever

The BMW Paralever ensures extremely precise and stable guidance of the rear wheel also on the HP2 Sport. Low unsprung masses and low return forces under load change give the rear wheel good ground contact and, as a result, superior power transmission at all times. With its ratio of 1:2.75, the rear-wheel drive does not require any service or maintenance, with the exception of one single oil change after 1,000 km. With no need to lubricate, tighten or align a chain, and with the option to change the wheel quickly whenever necessary, the rider enjoys significant benefits in the pit lane thanks to the BMW Paralever.

The rear-wheel suspension and damping is supplemented by an Oehlins sports spring strut also adjustable to numerous different positions. A further point is that ride height on the HP2 Sport may be raised also by means of the rear spring strut, irrespective of the suspension and damping set-up. To do this, the spring strut may be extended by up to 12 mm (0.47") with the help of the on-board toolkit. With the spring strut pivot point being positioned about one-third down the overall length of the swing arm, this adjustment travel raises the rear end of the motorcycle almost 30 mm (1,18"). And contrary to the increase in ride height on the front wheel, the increase in ride height at the rear shortens wheel camber in the interest of easier handling, **Figure 7**.

4.4 Wheels/Tyres

The HP2 Sport comes as standard on very soft sports tyres measuring 120/70 at the front and 190/55 at the rear and running on high-strength light-alloy forged wheels measuring 3.5 and, respectively, 6 inches in width.

Compared with cast rims, the forged 17-inch rims offering the same strength are much more slender in design and construction, reducing weight in each case by 700 grams. This reduction of weight where it really counts, at the relevant point in terms of gyroscopic forces and unsprung masses, improves handling quite significantly.

4.5 Brakes

On the front wheel a monobloc brake system from Brembo proved and tested in motorsport comes with two 320-mm (12.6") stainless-steel brake discs in floating arrangement. The single-piece monobloc structure of the radially bolted brake callipers maintains a stable pressure point also under high thermal loads. Four pistons per brake calliper, each measuring 34 mm (1.34") in diameter, operate the sintered metal brake pads.

On the rear wheel a two-piston floating-calliper brake weighing only 790 grams and a 265-mm (10.4") brake disc bolted firmly in position ensure adequate stopping power.

BMW HP2 Sport features an optimised two-channel Bosch 8M ABS anti-lock brake system without an integral function. Carried over from the R 1200 S, this system on the HP2 Sport may also

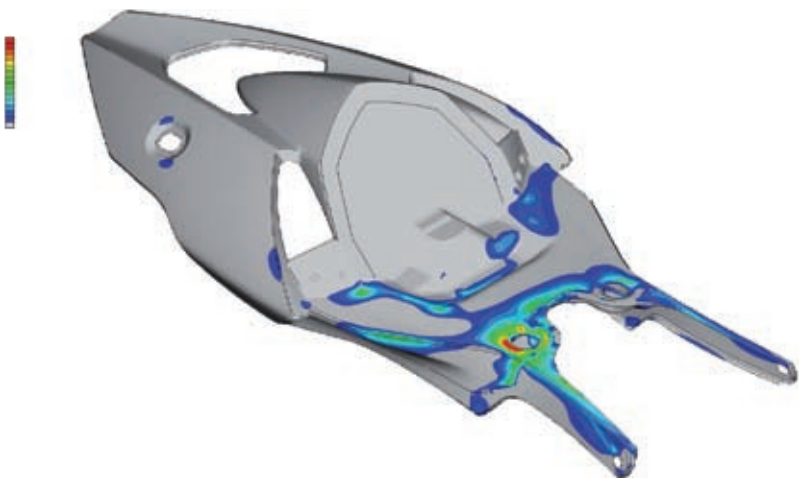

Figure 8: FEM calculation CFP rear section or CFP Body

be deactivated when required. A new feature is the pressure sensor fitted between the hydraulic unit and the front brake callipers. The pressure sensor informs the electronic control unit of the current brake pressure every time the brakes are applied on the front wheel, enabling the control unit to draw precise conclusions as to surface conditions and the risk of the rear wheel lifting off. Such a risk is therefore determined more reliably and the quality of the control process is enhanced significantly.

4.6 Ergonomics

The pre-forged and milled aluminium (ALSi 1MgMn) fork bridge encompasses the two fixed tubes through its clamp connections and rests on a ball pivot in the front frame. The two ends of the handlebar may be adjusted in their angle versus the fixed tubes. An eccentric bush enables the rider to choose either the 9° position conceived for the race track or the 6° handlebar position optimised for road use.

The brake and clutch pedal on the radial hydraulic controls are adjustable by means of a knurled bolt for personalised grip width in 14 stages of 25 mm (0.98") each.

The footrests are also made of a forged and milled aluminium alloy, with the surfaces of the individual components being partly polished or eloxy-plated in a gold colour. For optimum accommodation of the driver, the footrests and foot operating pedals can be adjusted independently of one another. The foot controls for the brake and gearshift levers adjust infinitely by means of an eccentric adjuster, the footrests may be set to four different positions by way of an eccentric mount. A special feature for racing is the inverted gearshift arrangement reversing the gearshift pattern in particular for shifting up even more quickly in left-hand bends.

5 Body

All body and fairing components on the HP2 Sport are made of multi-layer laminated carbon-fibre compound (CFP) and are constructed as load-bearing units. The fairing has been optimised in elaborate CFD computations and wind tunnel tests for air resistance, lift forces on the front wheel, protection from wind and weather, intake openings and cooling air guidance. As a result, air resistance is down 10 per cent versus the R 1200 S and front-wheel lift has been reduced by an even more significant 20 per cent.

The fuel tank is made of polyethylene and offers a useful capacity of 16 litres including 3 litres reserve. The number-plate support complete with the direction indicator and LED rear light may be removed very quickly and easily, just like the mirror, for racing on the track.

The load-bearing CFP rear body section holding not only the rider but also the exhaust system and featured for the first time on a production motorcycle. has been awarded the 1st Prize 2007 by the German Industrievereinigung Verstärkte Kunststoffe (AVK), the German Industrial Federation for Re-Enforced Plastics.

Conducting elaborate FEM calculations and optimising the CFP mat layer arrangement, BMW Motorrad has succeeded in reducing the weight of this component to just 2.5 kg. This is a weight-saving of 40 per cent versus the covered aluminium rear frame on the R 1200 S, **Figure 8**.

6 Conclusions

The HP2 Sport Project has already successfully proven the high performance of the air-cooled boxer concept also in international long-distance endurance racing (winner of the 2007 Open Class Endurance World Championship). Now, introducing the new HP2 Sport, BMW Motorrad is able to offer the customer the most innovative motorsport technology in standard trim also for road use.

Reflecting BMW Motorrad's HP2 philosophy, the HP2 is a motorcycle built without compromises for its specific purpose in a small and exclusive production series, **Figure 9**. ■

Figure 9: HP2 Sport in the 2007 Endurance World Championships