Mercedes-AMG GTR: Aerodynamics for the Record

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Abstract. Mercedes-AMG continues to grow. The sports car and performance brand of Mercedes-Benz expanded the top end of its product range with the introduction of the new Mercedes-AMG GT R. Never before has Mercedes-AMG packed so much motorsport technology into a production vehicle than it has in the new AMG GT R. The challenge for the aerodynamic engineers was the development of a unique car with special requirements: distinctive proportions, clean coupe design, front-mid-twin-turbo V-8 engine rated at 430 kW/585 hp, singular package, light weight, transaxle, extreme cooling requirements and above all, the goal of being the fastest of its class on the world's most demanding racetrack. The result is an intelligent, distinctive and innovative combination of aerodynamic features that fits the complex requirements of this vehicle. The interaction of the active aerodynamic features provides the right aerodynamic performance for each driving situation. This allows the combination of driving dynamics of a Mercedes-AMG GT3 race car with the everyday practicality of the Mercedes-AMG GT, assuring race circuit performance and low fuel consumption. The result is a lap time of 7:11 min (Journal Sport Auto 1/2017) at the Nordschleife. Benchmark.

1 About the Mercedes-AMG GT

The AMG GT R is the new spearhead of the AMG model range. Featuring pioneering technologies, the AMG GT R was designed with racetrack use firmly in mind. Its development was largely based on vast motor-racing experience in AMG GT3 customer sport and the German Touring Car Masters. Figures such as 3.6 s from zero to 100 km/h and a top speed of 318 km/h, combined with the outstanding driving dynamics, will undoubtedly translate into extremely fast laps on the racetrack.

Sharpened racetrack performance comes courtesy of the intelligent lightweight construction incorporating aluminum and carbon, specific reinforcements in the body shell, the uprated twin-turbo V-8 engine with the specifically adapted seven-speed dual-clutch transmission, the innovative aerodynamics with active components, and the new suspension with active rear-wheel steering and uniball joints.

The concept with front mid-engine and transmission in transaxle configuration on the rear axle, a tried-and-tested feature of the AMG GT and AMG GT S, makes for a beneficial rear-based weight distribution of 47.3 to 52.7. In conjunction with the vehicle's low centre of gravity, this translates into extremely agile handling and permits

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high cornering speeds. With a power-to-weight ratio of 2.66 kg/hp, the Mercedes-AMG GT R takes up pole position in its segment.

The data at a glance:

	Mercedes-AMG GT R
Engine	4.0-litre V-8 with twin turbochargers and direct injection
Displacement	3982 cm^3
Output	430 kW (585 hp) at 6250 rpm
Peak torque	700 Nm at 1900-5500 rpm
Driven wheels	Rear-wheel drive
Transmission	AMG SPEEDSHIFT DCT 7 speed dual-clutch transmission
Fuel consumption - urban/extra-urban/combined	15.0/9.2/11.4 l/100 km
Combined CO_2 emissions	259 g/km
Efficiency class	G
Weight (DIN/EC)	1555*/1630** kg
Power-to-weight ratio	2.66*/2.79** kg/hp
Acceleration 0-100 km/h	3.6 s
Top speed	318 km/h

*Kerb weight according to DIN, not including driver and luggage; **Kerb weight according to EC, including driver (75 kg)

2 Aerodynamics

The aerodynamic development of a Mercedes-AMG GT is pushed by multiple challenges. First of all, the vehicle's proportions as shown in Fig. 1 mean a hard starting point to reach the lift and drag targets. From the thermal point of view, considering the package characteristics and the cooling requirements, it demands intelligent solutions in order to reach the hotspots with fresh air. Furthermore, the goal of the conception of light weight solutions pushed the aerodynamic development to its limit.

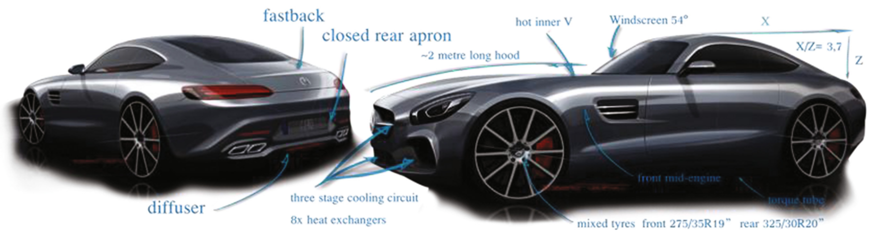

Fig. 1. Silhouette and proportions of a Mercedes-AMG GT

3 The Front End

Challenge: extreme cooling requirements, three stage cooling circuit, eight radiators, twin turbochargers inside the V configuration ("hot inner V") vs. low drag C_D and reduced frontal lift C_{LF}.

The low-slung front section and the forwards-inclined radiator grille create a distinctive "shark nose". This shape lowers the vehicle's stagnation-pressure point, enhancing the flow of cooling air and the car's aerodynamic performance. Two air inlets in the centre and one outer air inlet each side at the wheel arches are necessary to fulfil the cooling requirements. The vertical grille's bars at the nose of the car, trademarked as Panamericana Grille, are designed as tapered profiles to force air into the radiators, and there is nearly no air recirculation to the engine compartment (Fig. 2).

Fig. 2. Mercedes-AMG GT R front end

For optimum power output even when outside temperatures are high, Mercedes AMG uses indirect air-to-water intercooling. With optimum flow of air and water, the intercoolers have a separate, two-stage low-temperature water circuit. The first cooler stage involves two parallel coolers in the left and right wheel arch. The outer air intakes in the front fascia ensure that the increased cooling-air requirements of the AMG GT R drive system are met (Fig. 3).

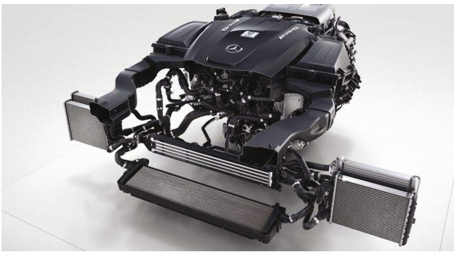

Fig. 3. Cooling system (without main radiator) and engine of a Mercedes-AMG GT R

A second radiator stage includes a large radiator at the front of the vehicle. The downstream water-cooled intercoolers ensure that the charge air compressed and heated by the turbochargers is cooled effectively prior to entering the combustion chambers. It therefore remains at a constantly low level even under full load. A large radiator at the car's front end ensures controlled cooling of the water circulating in the low-temperature circuit.

To fulfil the requirements of frontal lift (C_{LF}) reduction while increasing of mass flow for the cooling system, the wide front splitter was integrated in the design. In this way, these elements have an inherent technical benefit and a proportion that fits the vehicle's design.

Additional Air Curtains on the outside of the front fascia guide the air specifically towards the wheel arches, optimizing the flow properties in this area. The result is an improved C_D value and a further reduction of frontal lift (C_{LF}).

3.1 All-New Active Aerodynamics Profile in the Underbody

Challenge: reduce frontal lift (C_{LF}) without increasing drag (C_D) and without modifying the vehicle's shape or proportions vs. light weight.

A special engineering feature is the completely new active aerodynamics profile, which is concealed almost invisibly in the underbody in front of the engine and thus blends in harmoniously with the overall silhouette.

Multiple functions are combined when the device is deployed: a reduction of frontal lift (C_{LF}); an increase of engine cooling and also an increase in brake cooling. This multi-purpose feature reduces the drag (C_D) at the same time without increasing of the rear lift (C_{LR}) of the car (Fig. 4).

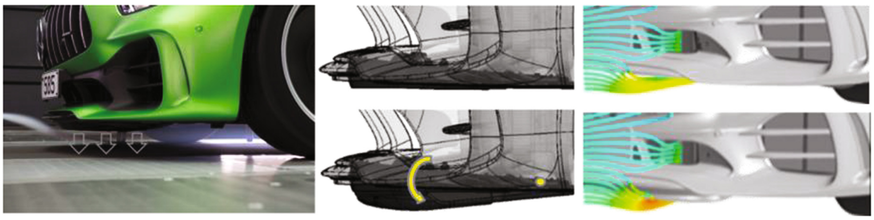

Fig. 4. Aerodynamic profile in the underbody

The aerodynamic profile deployed on the underbody at a speed of 80 km/h in "RACE" mode, and at 120 km/h in "Comfort", "Sport" and "Sport Plus" modes. This carbon fibre element, which only weighs around two kilograms, automatically moves approximately 40 mm down (Fig. 5).

This process involves considerable change in the airflow and results in what is known as the Venturi effect, which additionally presses the car onto the road and reduces the front-axle lift by around 40 kg at 250 km/h. When the AMG GT R in "RACE" mode drives slower than 60 km/h or slower than 80 km/h in "Comfort", "Sport" and "Sport Plus" modes, the aerodynamics profile moves back in. To protect against damage, the component is spring-mounted and can therefore flex upwards easily.

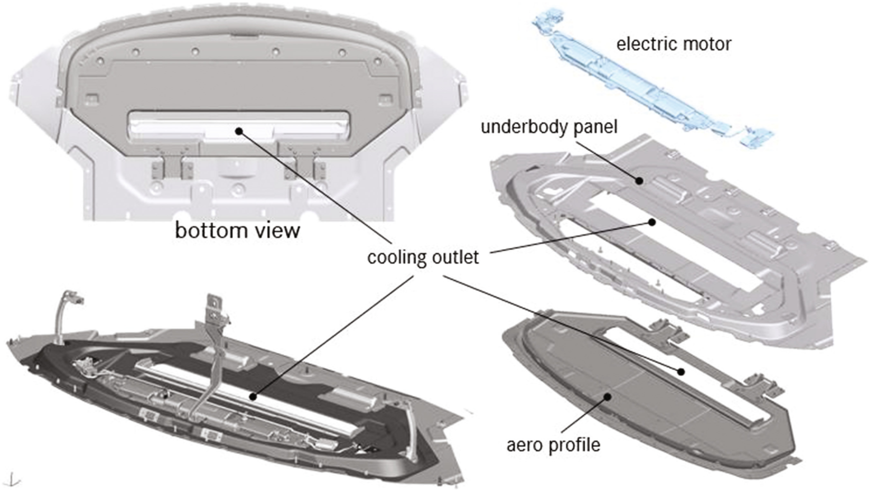

Fig. 5. Description of the underbody aero profile

The driver can feel the advantages of this aerodynamic feature at the steering wheel: the AMG GT R is even more precise to steer when cornering at high speed and exhibits even better directional stability. Specially during fast cornering and under high lateral acceleration, the AMG GT R delivers far more agile response with clear steering-wheel feedback while remaining easily controllable at all times.

The efficiency of this feature can be proved comparing it to standard features such as a splitter and flics (Fig. 6). In order to generate the same lift forces and lift balance, it would be necessary to mount a 60 mm (almost 24 in.) front splitter and flics, increasing the drag coefficient significantly.

Fig. 6. Splitter proportions and flics to generate similar frontal lift (C_{LF}) as the active aero system on the underbody

When the electrically operated profile is extended, the radiator air outlet opens at the front end and precisely guides the air flow towards the double rear diffuser, which therefore also benefits from an optimal flow of air (Fig. 7).

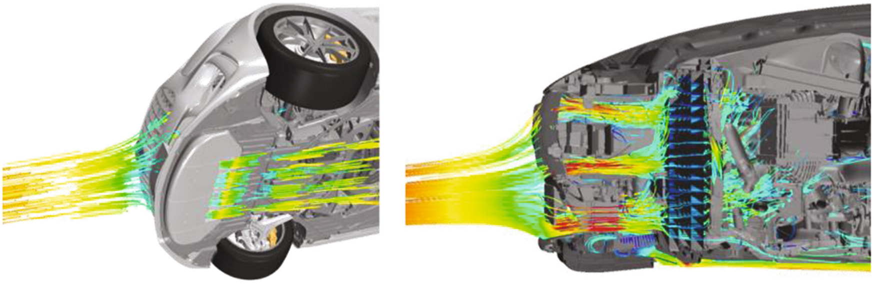

Fig. 7. Flow through the cooling system when the aerodynamic profile is deployed and front louvres are opened

This improves the handling stability of the rear axle while reducing the temperature level of the hotspots at the rear. At the same time, the aerodynamic package ensures optimized braking power by routing more cold air to the wheel discs specifically. When the profile is deployed, the braking-duct-diffusor on the underbody increases its depth by almost 50%, directing the necessary clean cold air to the brakes.

3.2 Louvres Control the Airflow: The Active Air Management System

Challenge: High engine power and high cooling needs vs. drag reduction in combination with frontal lift control. Cold air "just when you need it".

Another technical highlight improving the aerodynamics of the AMG GT R is the active air management system. This system has vertical louvres positioned in the lower area directly behind the front fascia. These louvres are electronically controlled and can be opened and closed in approximately one second by an electric motor to improve the airflow and consequently the aerodynamic performance (Fig. 8).

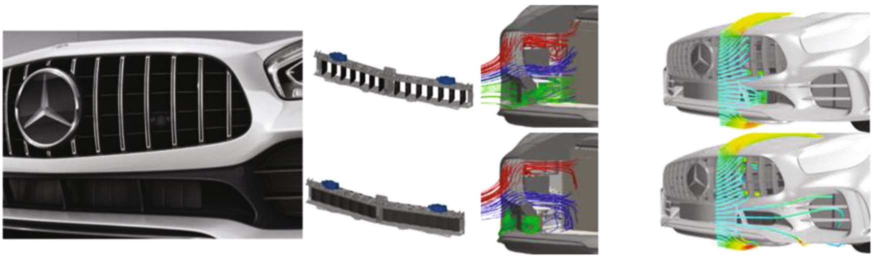

Fig. 8. Frontal louvres for thermal requirements and control of aerodynamic coefficients

The louvres are normally closed - including at top speed, during braking and when cornering at high speed. This position lowers drag and makes it possible to route the air to the underbody to reduce front lift even further. Only once predefined components have reached certain temperatures and the demand for cooling air is particularly high, the louvres quick open and allow the maximum amount of cooling air to flow to the heat exchangers. This calls for highly intelligent and fast control. The direction of rotation of the louvres is optimized for the fast response at the heat exchangers.

4 Emphasis on Width and Aerodynamic Optimization: The Rear End

Challenge: Coupe form, clean and compact shapes, a trunk, high temperatures produced from the exhaust system, closed underbody vs. no big openings or meshes to exhaust the heat at the rear apron and the requirement of 150 kg of downforce at Vmax.

4.1 Diffuser

The wider design of the rear fascia with large outer vent openings and vertical swaging improves the airflow at the rear end, as does the double diffuser. A further distinguishing feature of the AMG GT R is the large exhaust tip with centre spar, which is centrally positioned in the rear fascia. It is flanked by two more black exhaust tips on left and right in the diffuser (Fig. 9).

Fig. 9. Rear view and exhaust system

As in Fig. 10 described, the hot surroundings of the titanium muffler is exhausted with fresh and clean air coming from the underbody.

This flow was accelerated and directed thanks the aerodynamic profile at the front of the vehicle and it is redirected to the mufflers without any physical conducts but based on pressures differences.

The overall heat dissipation of the silencers is in this way exhausted by the double diffuser while driving.

But the function of the double diffuser wouldn't be possible without the interaction with the rear wing.

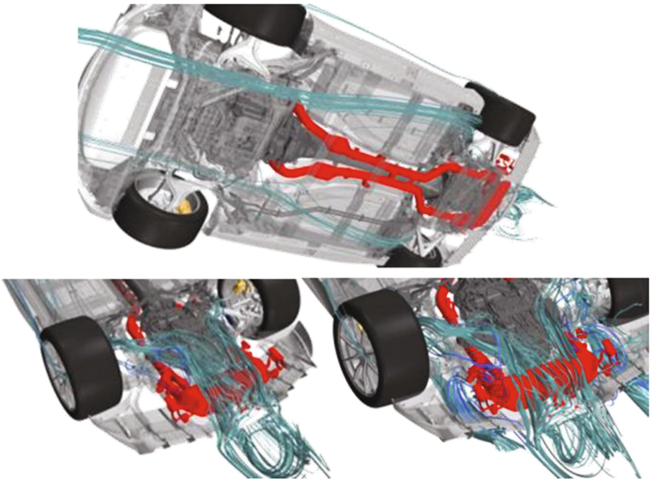

Fig. 10. Streamlines started at upper side of titanium muffler

4.2 The Rear Wing

The large rear wing is rigidly mounted on the hatch and increases the downforce on the rear axle. Depending on the type of use or racetrack conditions, the precise angle of the blade can be adjusted manually. This is possible because the active underbody aero system was developed to have almost no negative effect on the rear end's dynamics. This means that the wing doesn't need to compensate the reduction of the frontal lift C_{LF}. This advantage means a reduction of weight and complexity and the chance for the drivers to feel free to adjust the rear wing to their liking in a range of just 10° (Fig. 11).

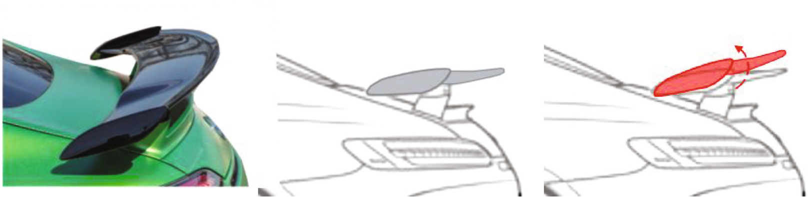

Fig. 11. Manually adjustable rear wing

5 The Result: Some Aerodynamic Values

The impact on drag and lift of the three aerodynamic active features is shown in Fig. 12. The results are given in reference to the vehicle in the following configuration:

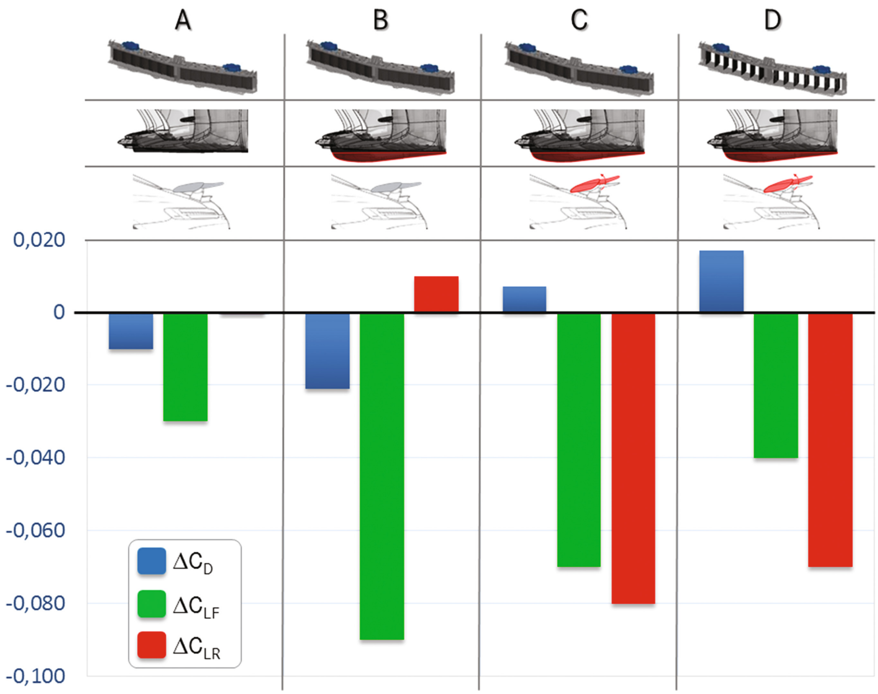

Fig. 12. Aerodynamic effects of the AMG GT R features referred to the configuration: louvres opened + underbody profile retracted + rear wing low

Reference: louvres opened + underbody profile retracted + rear wing low

The **Configuration A** represents the closing of the active air management system (louvres)

A: louvres closed + underbody profile retracted + rear wing low

showing the reduction of drag (C_D) and frontal lift (C_{LF}) but no increase of rear lift (C_{LR}). This configuration is possible to drive at low speed (lower than 80 km/h in "RACE" mode, or 120 km/h in "Comfort", "Sport" and "Sport Plus" modes) providing sufficient ground clearance and meeting daily practicality.

At the **Configuration B**,

B: louvres closed + underbody profile deployed + rear wing low

the profile at the underbody is deployed, producing a massive reduction of frontal lift (C_{LF}) and even a higher reduction in drag (C_D). The rear axle loses marginal some downforce, but without affecting the rear end's dynamics. At this point, the vehicle is ready to drive at higher lateral dynamics even with the wing in the lower position. The driver is able to modify the wing (adapting the lift balance) according to their needs.

At the **Configuration C**

C: louvres closed + underbody profile deployed + rear wing high

the rear wing is adjusted at its max angle. The rear downforce (C_{LR}) increases to its maximum. This configuration can be driven up to Vmax. The louvres will open in case more cooling air is needed (**Configuration D**) and they will close again when the required engine and hotspots temperatures are reached.

It is clearly to see the interaction of the active features, giving each driving situation the right aerodynamic performance. The intelligent, distinctive and innovative combination of aerodynamic devices fits the vehicle to reach its complex requirements. This allows the combination of driving dynamics of a Mercedes-AMG GT3 race car with the everyday practicality of the Mercedes-AMG GT, assuring race circuit performance and low fuel consumption. The new AMG GT R therefore offers maximum grip, perfect drivability and a powerfully proportioned design that integrates the aerodynamic functions harmoniously.