

Overview of the Catesby Aero Research Facility (CARF), a Tunnel-Based Aerodynamic Proving Ground

Hiroshi Shimoyama¹⁾ Hiroki Nagano¹⁾ Satoshi Yoshizawa²⁾ Wataru Kato²⁾ Keiichi Watanabe²⁾

1) SUBARU CORPORATION, 1-1 Subaru-cho, Ota-shi, Gunma 373-8555, Japan (E-mail: nagano.hiroki@subaru.co.jp)

2) SUBARU CORPORATION, 3-9-6 Osawa, Mitaka-shi, Tokyo 181-8577, Japan (E-mail: watanabe.keiichi.a@subaru.co.jp)

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1. Introduction

Vehicle aerodynamic performance is evaluated by combining computational fluid dynamics (CFD), wind-tunnel tests, and road tests. CFD provides detailed flow information and efficient comparison of configurations, while wind tunnels provide controlled conditions for force and flow measurements. Road testing evaluates a moving vehicle with road-surface and vehicle-motion effects, but outdoor measurements are influenced by wind and weather. A proving ground that combines vehicle motion with a stable flow environment can improve correlation among these complementary development tools.

2. Facility Characteristics

Catesby Aero Research Facility (CARF) is a tunnel-based aerodynamic proving ground in Northamptonshire, UK. The facility uses a former railway tunnel 2.74 km long. The course is approximately straight and has a working cross-sectional area of about 40 m², a road width of 6.0 m, a maximum width of 8.2 m, and a longitudinal gradient of 0.57%. Shutters at both portals isolate the test section from external conditions. Turntables at the ends of the course allow vehicles to change direction for repeated runs.

The road surface consists of a reinforced-concrete base and two asphalt layers. The measured International Roughness Index (IRI) is 0.35 mm/m, and the surface flatness has a standard deviation below 0.5 mm. The smooth surface reduces variations in rolling resistance and road-induced vehicle motion. The enclosed environment also suppresses wind input. Wind-direction fluctuation has a standard deviation of 0.06°, and turbulence intensity is approximately 0.5%. These characteristics provide stable conditions for comparing vehicle configurations and separating aerodynamic effects from road and weather disturbances.

3. Coast-Down Testing

Coast-down testing determines running resistance from vehicle deceleration while no driving force is applied. On an outdoor proving ground, small changes in headwind or tailwind affect speed decay and delay convergence. CARF permits continuous measurement from high speed to very low speed in one run. Repeated measurements show clearer convergence than corresponding outdoor measurements. The converged results improve the separation of aerodynamic drag and rolling resistance and facilitate comparisons among aerodynamic configurations under consistent test conditions.

4. Full-Scale PIV Measurement

Particle image velocimetry (PIV)⁽¹⁾ was conducted with a roadside laser and three high-speed cameras on the opposite side. Repeated passes produced ensemble-averaged streamwise velocity fields on a plane 2 m behind the vehicle. The PIV results reproduced the principal velocity-loss regions observed in CFD, while differences remained in the magnitude and lateral extent of some low-velocity areas. The results provide flow-field information for interpreting resistance measurements and examining correlation between road tests and CFD.

5. Six-Component Force Measurement and Test Platforms

At CARF, hub-unit sensors⁽²⁾ and full-scale or half-scale electric test platforms can be used for aerodynamic testing with moving vehicles. The hub-unit sensor incorporates a tubular-shaped load cell that detects three-axis forces and moments from strain on a cylindrical surface. Its integration into the hub unit preserves the production wheel environment and avoids external structures around the wheel. The sensor therefore enables six-component force measurement under road-running conditions.

The configurable test platforms allow measurements to be conducted using moving test vehicles of different sizes. Together, the hub-unit sensor and the test platforms expand the range of aerodynamic measurements available at CARF.

References

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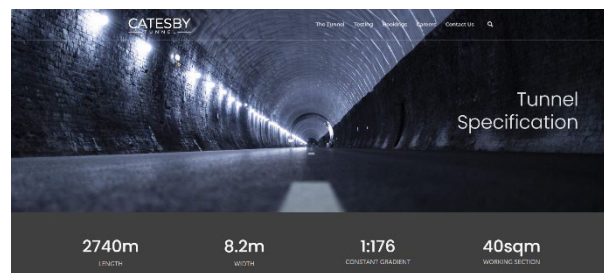


Fig. 1 Overview and principal specifications of CARF

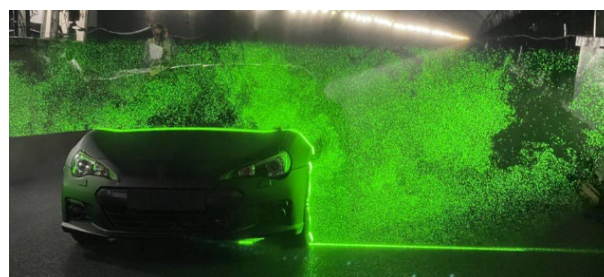


Fig. 2 Full-scale PIV measurement at CARF