AERODYNAMIC DRAG MEASUREMENTS OF BICYCLE WHEELS

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EXPERIMENTAL PROCEDURE

The aim of the study was to determine the magnitude of the drag force acting on stationary and rotating bicycle wheels at various incident angles to the wind. A rig was designed and constructed for mounting the wheels. The rig was designed to accommodate any standard bicycle wheel and six wheels were tested whose details as listed in Table 1. All wheels were a standard 700C size (28" diameter). Photographs of the wheels mounted in the testing rig are shown in Fig. 1.

Each wheel was tested by exposing it to the free air stream in the No. 1 boundary layer wind tunnel at the Department of Civil Engineering. The tunnel is 6' by 8' with a blockage tolerant testing section, blockage corrections were not applied. The wheels were tested at yaw angles of 0°, 5°, 10°, 15°, 20°, 30°, 40°, 50°, and 60°, except the disc wheel which was only measured up to a yaw angle of 40°. In each test, force components of drag were measured using the test rig. The test rig consisted of a wheel support mounted on a pair of orthogonal strain bridges. The voltage output from these strain bridges allowed the determination of the force components in the side and axle directions as defined in Fig. 2.

The wheels were all tested when stationary and rotating, with the mean wind tunnel speed at 40km/h. Measurements of the stationary wheels were sampled for 10 seconds. For the rotating test, the wheel was driven by a motor manually applied to the tyre. The motor was removed to eliminate its influence on the flow pattern around the wheel, and the wheel allowed to rotate freely. Drag measurements were taken for one minute from the time the rotational speed of the wheel decelerated to represent a road speed of 40km/h. The required rotational speed was determined by the use of a strobe light set to the appropriate frequency. Previous studies by Tew and Sayers, 1999 and Greenwell et al., 1995 indicated that the rotational speed of the wheel has little influence on the aerodynamic drag characteristics, therefore measurements were recorded at only one rotational speed.

RESULTS

All results presented in this report are mean results from the entire sample taken and have been corrected for the wind drag on the support frame. This was determined by measuring the drag forces on the frame with no wheel attached and subtracting it from the measured value with the wheel. All forces in this report are presented in grams, and the experimental error in the force measurements is ±5g. The axle drag force represents the resistance to forward motion and the side forces provides an indication on how difficult the bicycle would be to control.

As the results indicated that the differences between the stationary and rotating wheels drag forces were negligible, only the results for the rotating cases are presented here. The stationary forces compare favourably with other published data on stationary wheels, Kyle 1986, Kyle 1996, Greenwall et al. 1995, and Tew and Sayers 1999.

Comparative results between the various wheels tested are shown graphically in Fig. 3 for the rotating axle force. From an inspection of the raw data, there was no significant difference in the measured drag forces during the rotating tests as the wheel speed decelerated or accelerated. At zero angle of yaw the variation in the axle drag is not significant within the bounds of the experiment. With increasing yaw angle, the axial drag on the spoked wheels tends to increase, decrease, and increase again before decreasing. At low yaw angles, the fluctuations in drag force are caused by the relative effects of shielding of the spokes from the incident wind, the number and size of the spokes, and the attachment of the flow to the wheel rim. The drag coefficient for the bladed and disk wheels is dependent on the lifting characteristics of the foil section in combination with the flow pattern over the rim. The wider the blades the better the foil performance and the higher the stall angle: compare the X-treme tri spoke, Mavic 5 spoke, and the Zipp disc wheels.

Comparative results between the various wheels tested are shown graphically in Fig. 4 for the rotating side force. The spoked wheels behave as bluff bodies with side force increasing with yaw angle. The magnitude of the side force increase with the solidity of the wheel. The disc wheel acts as a lifting wing, the change in gradient indicating the angle of stall, which occurs between 20° and 30°.

On the tri-spoked wheel, significant rotational speeds were generated due to lift forces acting on the wide spokes of the wheel at higher yaw angles. Once a steady state speed was attained, the strobe light was tuned to determine the free rotation speed of the wheel in km/h. The maximum road speed attained was 58.1km/h, at a yaw angle of 60°, for the X-treme tri spoke wheel. This self sustaining rotation speed is a function of the aerodynamics of the wheels and the frictional resistance of the bearings. The measured speeds would not be generated on the road, but act as an indication of the large rotational forces generated by the wheel.

CONCLUSIONS

Six bicycle wheels were tested while stationary and rotating to obtain aerodynamic drag forces for various yaw angles. There was no significant difference between the drag measurements for a stationary or rotating wheel. Significant differences between the performances of the wheels were found, both between wheel types and for the same wheel at different yaw angles.

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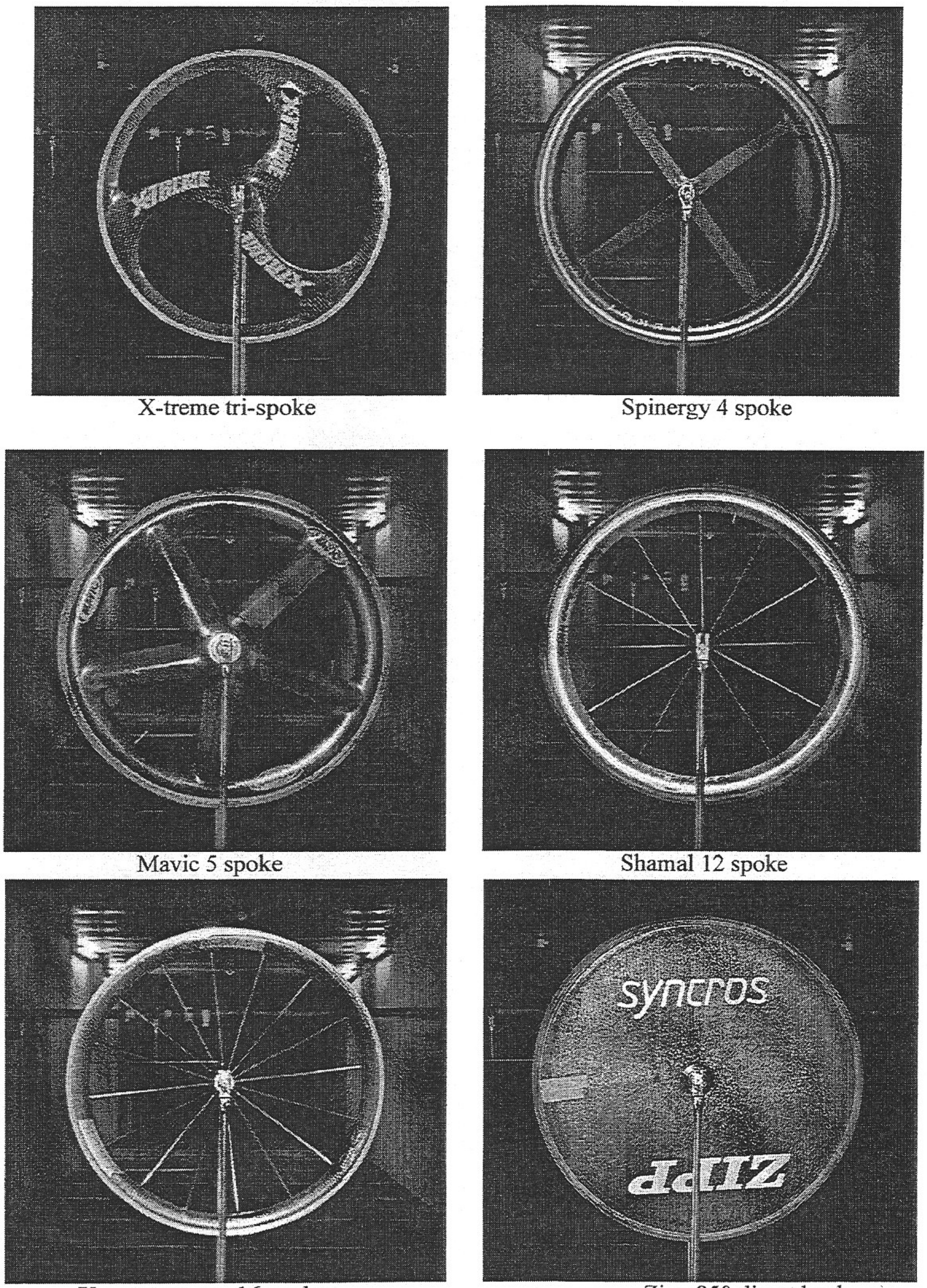
Wheel	Front/Rear	Tyre	Total Mass /g
X-treme tri-spoke	Front	Vittoria Prof. Dry Road	n/a
Spinergy 4 spoke	Front	Veloflex pavé	1170
Mavic 5 spoke	Front	Vittoria Atl Gold CS	1080
Shamal 12 spoke	Front	Vittoria Corsa CX	1080
X-treme ac-pro 16 spoke	Front	Vittoria Prof. Dry Road	965
Zipp 950 disc wheel	Rear	Vittoria Prof. Dry Road	1255

Table 1: Bicycle Wheels Tested



X-treme tri-spoke

Spinergy 4 spoke

Mavic 5 spoke

Shamal 12 spoke

X-treme ac-pro 16 spoke

Zipp 950 disc wheel

Figure 1: Test Wheels Mounted in Rig

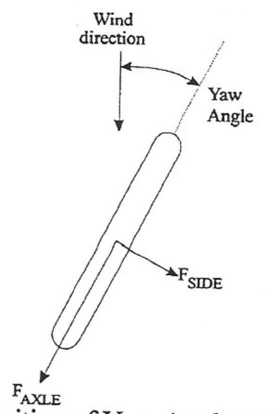


Figure 2: Definition of Yaw Angle and Force Axes

Figure 3: Rotating axle forces at various yaw angles

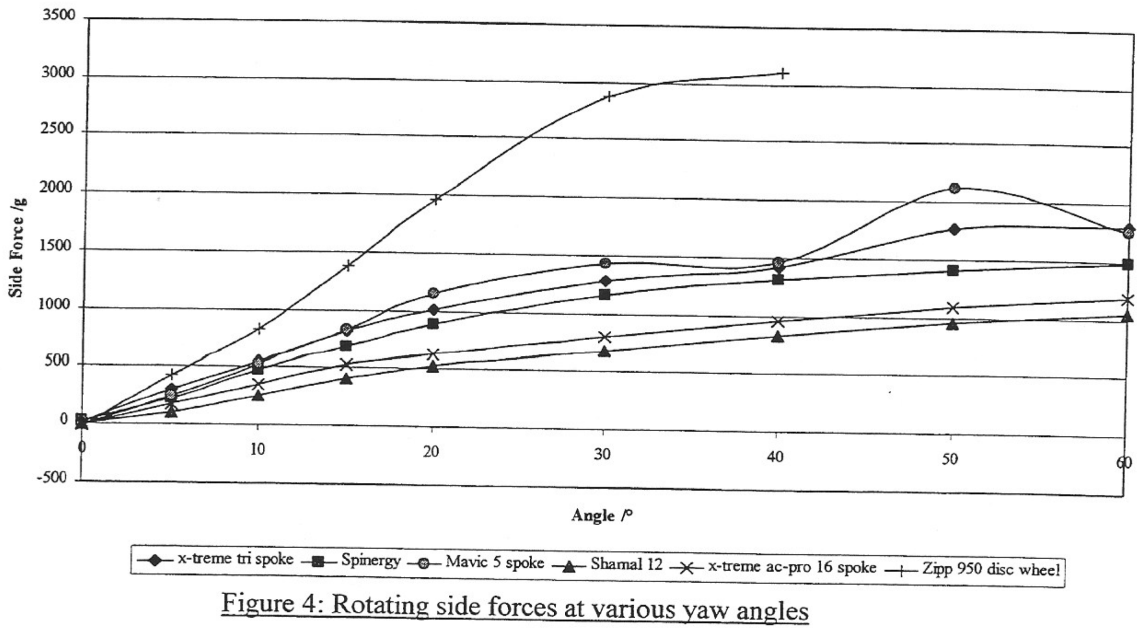


Figure 4: Rotating side forces at various yaw angles