TEST RESULT SHEET

TITLE: Rolling resistance testing of 20" bicycle tyres

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Test Date(s): 8-9th July 2002

Client: Inspired Cycle Engineering Ltd

Client Liaison Engineer: Neil Selwood

Test Objective/Method/Specification No:

The objective of the test was to measure the coefficients of rolling resistance (C_{rr}) of 4 popular 20" bicycle tyre types. The testing was performed indoors in the MIRA crash laboratory on a sand textured painted concrete floor. The test vehicle was the chassis of the 'Lindley Special', MIRA's entry into the 2002 Goodwood Soapbox Challenge, fitted with 4 tyres. The vehicle, of mass 100kg including driver, was equally loaded on all 4 wheels and allowed to coast down for 43m between two vehicle speed measurement units. Each set of tyres was tested at pressures of 80, 100 and 120 psi, four tests at each pressure carried out and an average value calculated.

Data collected from MIRA's full scale wind tunnel testing of the 'Lindley Special' enables the coefficient of rolling resistance to be calculated for each tyre type. The ride height was kept constant between the different section tyres to maintain the same aerodynamic properties as the wind tunnel testing.

Specimen Description/Part No(s):

4off Tioga Comp Pool 20"x1.75" Tyres
4off Primo Comet 20"x1.75" Tyres
4off Continental Grand Prix 20"x1 1/8" Tyres
4off Schwalbe Stelvio 20"x1 1/8" Tyres

Test Equipment:

2off MIRA vehicle speed measurement units.
1off PCL Tyre inflator.
1off Salter vehicle weighing system.
1off 'Lindley Special' chassis.

Results:

The Schwalbe Stelvios were found to have the lowest rolling resistance of the types tested with a coefficient of rolling resistance of 0.0047 at 120psi. All the tyre types were found to have decreasing rolling resistance with increasing pressure. The calculated coefficients are tabulated in Tables 1-4 and plotted in Figure 1. The method of calculation is described in Appendix A.

Attachments/Notes:

Tables 1 to 4 - Tyre testing data
Figure 1 - Coefficients of rolling resistance for the tested tyre types at different pressures
Figure 2 - The 'Lindley Special'
Appendix A - Calculation of Coefficient of rolling resistance
Appendix B – Quality assurance numbers for calibrated equipment.

	Name	Position	Signature	Date
Prepared By	C Cook	Engineer	C Cook	29/8/02
Concurred By	Dr G Bacon	Assistant Director	Dr G Bacon	4/9/02

Pressure	psi	80				100				120			
Initial Velocity	mph	7.603	7.211	7.598	7.264	7.445	7.175	7.336	6.963	7.368	6.971	7.638	7.285
Final Velocity	mph	4.978	4.415	4.989	4.595	4.951	4.611	4.812	4.393	5.032	4.547	5.209	4.896
Crr		0.0054	0.0056	0.0054	0.0054	0.0050	0.0050	0.0050	0.0049	0.0046	0.0046	0.0049	0.0047
Average Crr		**0.0054**				**0.0050**				**0.0047**			

Table 1 - Schwalbe Stelvio Data

Pressure	psi	80				100				120			
Initial Velocity	mph	6.619	6.661	6.787	6.969	6.837	7.053	7.15	7.013	6.945	7.166	7.348	7.568
Final Velocity	mph	3.308	3.311	3.527	3.734	3.841	4.136	4.222	4.09	4.195	4.397	4.502	4.775
Crr		0.0062	0.0063	0.0062	0.0064	0.0058	0.0058	0.0059	0.0058	0.0053	0.0055	0.0058	0.0058
Average Crr		**0.0063**				**0.0058**				**0.0056**			

Table 2 - Continental Grand Prix Data

Pressure	psi	80				100				120			
Initial Velocity	mph	6.822	7.58	6.327	7.512	7.18	7.081	7.333	7.63	7.616	6.79	7.39	7.142
Final Velocity	mph	3.754	4.64	3.046	4.572	4.347	4.176	4.419	4.807	4.862	3.938	4.547	4.393
Crr		0.0059	0.0062	0.0058	0.0062	0.0057	0.0058	0.0060	0.0060	0.0058	0.0055	0.0058	0.0055
Average Crr		**0.0060**				**0.0058**				**0.0056**			

Table 3 - Tioga Comp Pool Data

Pressure	psi	80				100				120			
Initial Velocity	mph	7.012	7.648	7.603	7.324	7.345	7.576	7.424	7.589	7.711	7.609	7.610	7.410
Final Velocity	mph	3.472	4.418	4.276	3.943	4.304	4.451	4.234	4.591	4.808	4.670	4.575	4.454
Crr		0.0070	0.0070	0.0071	0.0070	0.0063	0.0067	0.0067	0.0064	0.0062	0.0062	0.0065	0.0061
Average Crr		**0.0070**				**0.0065**				**0.0063**			

Table 4 - Primo Comet Data

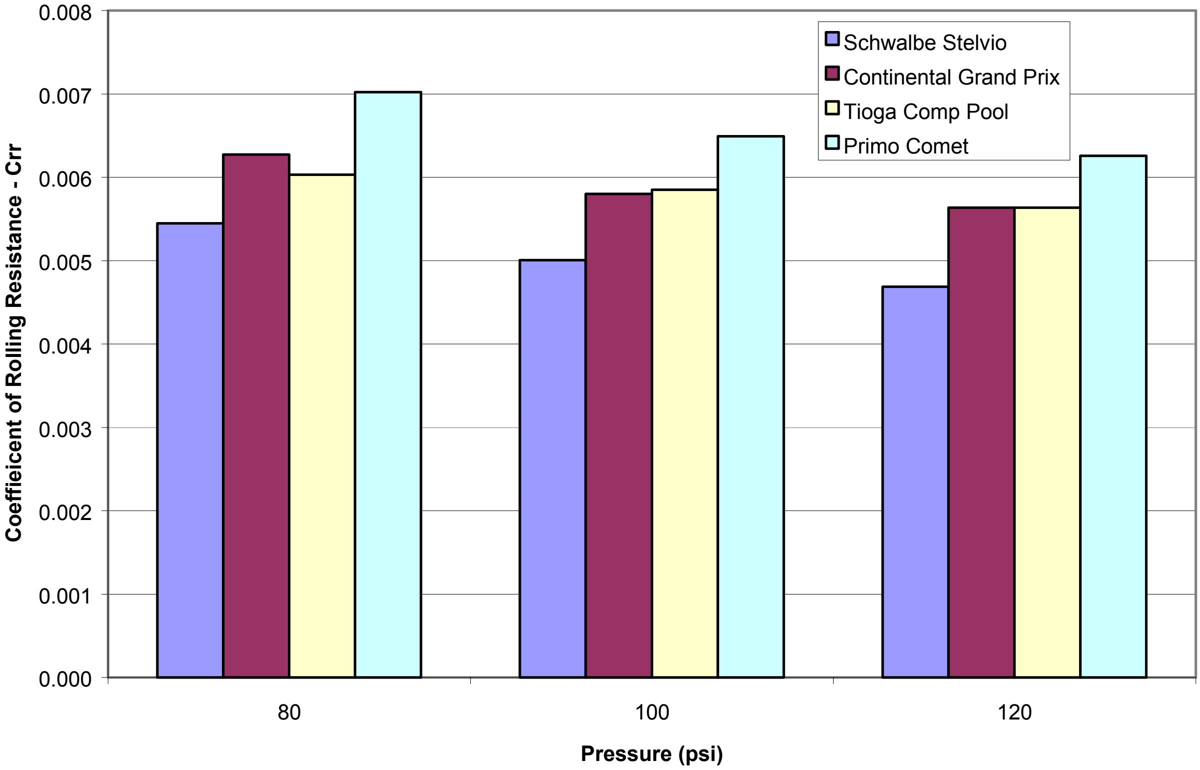

Figure 1 - Coefficients of rolling resistance for the tested tyre types at different pressures

Figure 2 - The 'Lindley Special’

Appendix A

Calculation of Coefficient of rolling resistance

Definition of terms:

x = 43m = distance (m)
a = acceleration (m/s^2)
m = 100kg = mass of vehicle (kg)
ρ = 1.293kg/m^3 = density of air (kg/m^3)
C_d = drag coefficient
A = frontal area of vehicle (m^2)
C_d x A = 0.435 m^2 (Of bare chassis with driver from wind tunnel testing)
V = velocity (m/s)
u = initial velocity (m/s)
v = final velocity (m/s)
C_{rr} = coefficient of rolling resistance

Calculation:

$$F = ma = -C_{rr}mg - \frac{1}{2}\rho C_d A V^2$$

$$mV\frac{dV}{dx} = -C_{rr}mg - \frac{1}{2}\rho C_d A V^2$$

$$\frac{mV}{C_{rr}mg + \frac{1}{2}\rho C_d A V^2}\frac{dV}{dx} = -1$$

$$\int_u^v \frac{mV}{C_{rr}mg + \frac{1}{2}\rho C_d A V^2} dV = -\int_0^x dx$$

$$\frac{m}{2}\int_u^v \frac{1}{C_{rr}mg + \frac{1}{2}\rho C_d A V^2} dV^2 = -x$$

$$\frac{m}{2}\left[\frac{1}{\frac{1}{2}\rho C_d A}\ln\left(C_{rr}mg + \frac{1}{2}\rho C_d A V^2\right)\right]_u^v = -x$$

$$\frac{m}{\rho C_d A}\left(\ln\frac{\left(C_{rr}mg + \frac{1}{2}\rho C_d A v^2\right)}{\left(C_{rr}mg + \frac{1}{2}\rho C_d A u^2\right)}\right) = -x$$

$$\therefore C_{rr} = \frac{\rho C_d A(v^2 - u^2 e^{-\frac{x\rho C_d A}{m}})}{2mg(e^{-\frac{x\rho C_d A}{m}} - 1)}$$

Appendix B

Quality Assurance of Measurements

The means of calibrating test equipment is checked on a regular schedule to traceable standards in an International Assurance of Measurements (QAM) procedure. Each item of equipment is issued with a QAM number.

The numbers for the equipment used in these tests were: -

Description	QAM No.
MIRA Vehicle speed measurement unit	Q017899
MIRA Vehicle speed measurement unit	Q017291
Salter vehicle weighing system	Q011320
PCL Tyre Inflator	Q014681