CHAPTER 4 :RESISTANCE TO PROGRESS OF A VEHICLE-MEASUREMENT METHOD ON THE ROAD-SIMULATION ON A CHASSIS DYNAMOMETER

1. Scope :

This Chapter describes the methods to measure the resistance to the progress of a vehicle at stabilised speeds on the road and to simulate this resistance on a chassis dynamometer with adjustable load curves in accordance with paragraph 4.1.7.3 of Chapter 3 of this part.

2. Definition of the road :

2.1 The road shall be level and sufficiently long to enable the measurements specified below to be made. The longitudinal slope shall not exceed 1.5% and shall be constant within ± 0.1 % over the measuring strip.

3. Atmospheric Conditions :

3.1 Wind : Testing must be limited to wind speeds averaging less than 3 m/s with peak speeds less than 5 m/s. In addition, the vector component of the wind speed across the test road must be less than 2 m/s. Wind velocity should be measured 0.7 m above the road surface.

3.2 Humidity : The road shall be dry .

3.3 Pressure - Temperature : Air density at the time of the test shall not deviate by more than ±7.5 percent from the reference conditions:
P = 100 kPa & T = 293.2 K

4. Vehicle Preparation :

4.1 Running in : The vehicle shall be in normal running order and adjusted after having been run-in as per manufacturer's specifications. The tyres shall be run in at the same time as the vehicle or shall have a tread depth within 90 and 50 percent of the initial tread depth.

4.2 Verifications : The following verifications shall be made in accordance with the manufacturer's specifications for the use considered :

- wheel, wheel trims, tyres (make, type, pressure),
- front axle geometry,
- brake adjustment (elimination of parasitic drag)

- lubrication of front and rear axles,
- adjustment of the suspension and vehicle level, etc.

4.3 Preparation for the test :

The vehicle shall be loaded to its reference mass. The level of the vehicle shall be that obtained when the centre of gravity of the load is situated midway between the "R" points of the front outer seats and on a straight line passing through those points.

4.3.1 In case of road tests, the windows of the vehicle shall be closed. Any covers of air climatization systems, headlamps, etc., shall be in the non-operating position.

4.3.2 The vehicle shall be clean.

4.3.3 Immediately prior to the test the vehicle shall be brought to normal running temperature in an appropriate manner.

5. Methods for chassis dynamometer with adjustable load curve

5.1 Energy variation during coast-down method :

5.1.1 On the road

5.1.1.1 Accuracies of test equipment

Time shall be measured accurate to within 0.1 second. Speed shall be measured accurate to within 2 percent.

5.1.1.2 Test procedure

5.1.1.2.1 Accelerate the vehicle to a speed of 10 km/h greater than the chosen test speed, V.

5.1.1.2.2 Place the gear box in "neutral" position.

5.1.1.2.3 Measure the time taken (t_1)for the vehicle to decelerate from

$$V_2 = V + \Delta V \text{ km/h to } V_1 = V - \Delta V \text{ km/h : with } V \leq 5 \text{ km/h}$$

5.1.1.2.4 Perform the same test in the opposite direction : t_2

5.1.1.2.5 Take the average T, of the two times t_1 and t_2.

5.1.1.2.6 Repeat these tests several times such that the statistical accuracy (p) of the average

$$T = \frac{1}{n}\sum_{i=1}^{n} t_i$$ is not more than 2% (p ≤ 2%)

The statistical accuracy (p) is defined by :

$$p = \frac{t * s}{\sqrt{n}} * \frac{100}{T}$$

where,
t = coefficient given by the table below
s = standard deviation = $\sqrt{\sum \frac{(T_i - T)^2}{(n-1)}}$
n = number of tests

N	4	5	6	7	8	9	10	11	12	13	14	15
T	3.2	2.8	2.6	2.5	2.4	2.3	2.2	2.2	2.2	2.2	2.2	2.2
$\frac{t}{\sqrt{n}}$	1.6	1.25	1.06	0.94	0.85	0.77	0.73	0.66	0.64	0.61	0.59	0.57

5.1.1.2.7 Calculate the power by the formula :

$$P = \frac{m * V * \Delta V}{500 * T}$$

where,

P is expressed in kW
V = speed of the test in m/s
ΔV= speed deviation from speed V, in m/s
m = reference mass in kg
T = time in seconds

Alternatively, the coast down shall be carried out as per IS 14785-1999 to establish “a” and “b” coefficients for setting on chassis dynamometer.

5. 1.2 On the chassis dynamometer :

5.1.2.1 Measurement equipment and accuracy : The equipment shall be identical to that used on the road.

5.1.2.2 Test procedure :

5.1.2.2.1 Install the vehicle on the test dynamometer.

5.1.2.2.2 Adjust the tyre pressure (cold) of the driving wheels as required by the chassis dynamometer.

5.1.2.2.3 Adjust the equivalent inertia of the chassis dynamometer.

5.1.2.2.4 Bring the vehicle and chassis dynamometer to operating temperature in a suitable manner.

5.1.2.2.5 Carry out the following operations specified in paragraph 5.1.1.2 with the exception of paragraphs 5.1.1.2.4 and 5.1.1.2.5 and with changing m by I in the formula of paragraph 5.1.1.2.7 above.

5.1.2.2.6 Adjust the chassis dynamometer to meet the requirements of paragraphs of 4.1.6.1 of Chapter 3 of this Part.

5.2 Torque measurements method at constant speed :

5.2.1 On the road:

5.2.1.1 Measurement equipment and error :

Torque measurement shall be carried out with an appropriate measuring device, accurate to within 2 %. Speed measurement shall be accurate to within 2 %.

5.2.1.2 Test procedure

5.2.1.2.1 Bring the vehicle to the chosen stabilised speed, V.

5.2.1.2.2 Record the torque C(t) and speed over a period t(of at least 10 s) by means of class 1000 instrumentation meeting ISO standard No. 970, over small intervals of time t.

5.2.1.2.3 Differences in torque, and speed relative to time shall not exceed 5% for each second of the measurement period. The torque C_{t_1} is the average torque derived from the following formula

$$C_{t_1} = \frac{1}{\Delta t} \int_{t}^{t+\Delta t} C(t)\,dt$$

5.2.1.2.4 Carry out the test in the opposite direction and find out the average torque i.e. C_{t_2}.

5.2.1.2.5 Determine the average of these torques C_{t_1} and C_{t_2} i.e C_t.

5.2.2 On the chassis dynamometer

5.2.2.1 Measurement equipment and error

The equipment shall be identical to that used on the road.

5.2.2.2 Test procedure

5.2.2.2.1 Perform the operations specified in paragraphs 5.1.2.2.1 to 5.1.2.2.4 above.

5.2.2.2.2 Adjust the chassis dynamometer setting to meet the requirements of paragraph 4.1.6.1. of Chapter 3 of this Part.

5.3 Integrated torque over vehicle driving pattern :

5.3.1 This method is a non-obligatory complement to the constant speed method described in paragraph 5.2 above.

5.3.2 In this dynamic procedure the mean torque value $\overline{M}$ is determined. This is accomplished by integrating the actual torque values,M(t) , with respect to time during operation of the test vehicle with a defined driving cycle. The integrated torque is then divided by the time difference t_2 - t_1,

The result is :

$$\overline{M} = \frac{1}{t_1 - t_2} \int_{t_1}^{t_2} M(t) * dt \quad \text{(with M(t) > 0)}$$

M is calculated from six sets of results.

It is recommended that the sampling rate of $\overline{M}$ be not less than two samples per second.

5.3.3 Dynamometer setting The dynamometer load is set by the method described in paragraph 5.2 above. If $\overline{M}$ (dynamometer) does not match $\overline{M}$ (road) then the inertia setting shall be adjusted until the values are equal within ± 5 percent.

Note : This method can only be used for dynamometers with electrical inertia simulation or fine adjustment.

5.3.3.1 Acceptance criteria :

Standard deviation of six measurements must be less than or equal to 2 % of the mean value.

5.4 Method by deceleration measurement by gyroscopic platform :

5.4.1 On the road :

5.4.1.1 Measurement equipment and accuracy:

- Speed shall be measured with an accuracy better than 2 %.
- Deceleration shall be measured with an accuracy better than 1 %.
- The slope of the road shall be measured with an accuracy better than 1%.
- Time shall be measured with an accuracy better than 0.1 s.
- The level of the vehicle is measured on a reference horizontal ground: as an alternative, it is possible to correct for the slope of the road (α_1).

5.4.1.2 Test procedure :

5.4.1.2.1 Accelerate the vehicle to a speed 5 km/h greater than the chosen test speed V.

5.4.1.2.2 Record the deceleration between V + 0.5 km/h and V - 0.5 km/h.

5.4.1.2.3 Calculate the average deceleration attributed to the speed V by the formula:

$$\overline{\gamma_1} = \frac{1}{t}\int_0^t \gamma_1(t)dt - (g.\sin \propto_1)$$

where:

$\overline{\gamma_1}$ = average deceleration value at the speed V in one direction of the road

t = time between V + 0.5 kmph and V - 0.5 kmph

$\gamma_1(t)$ = deceleration recorded with the time

g = 9.81 m/s².

5.4.1.2.4 Perform the same test in the other direction $\overline{\gamma_2}$

5.4.1.2.5 Calculate the average deceleration i.e.

$$\gamma_i = \frac{\gamma_1 + \gamma_2}{2} \text{ for test I.}$$

5.4.1.2.6 Perform a sufficient number of tests as specified in paragraph 5.1.1.2.6 above replacing T by γ where

$$\gamma = \frac{1}{n}\sum_{i=1}^{n}\gamma_i$$

5.4.1.2.7 Calculate the average force absorbed F=m* γ ,where m =vehicle reference mass in kg & γ =average deceleration calculated as above.

5.4.2 On the chassis dynamometer :

5.4.2.1 Measuring equipment and accuracy

The measurement instrumentation of the chassis dynamometer itself shall be used as defined in para 5.1.2.1 of this Part.

5.4.2.2 Test procedure

Adjustment of the force on the rim under steady speed.

On chassis dynamometer, the total resistance is of the type:

$F_{total} = F_{indicated} + F_{driving\ axle\ rolling}$ with

$F_{total} = F_{road}$

$F_{indicated} = F_{road} - F_{driving\ axle\ rolling}$

where : $F_{indicated}$ is the force indicated on the force indicating device of the chassis dynamometer.

$F_{(road)}$ is known.

$F_{driving\ axle\ rolling}$, can be measured on chassis dynamometer driving axle rolling able to work as generator.

The test vehicle, gear box in neutral position, is driven by the chassis dynamometer at the test speed; the rolling resistance, R_R, of the driving axle is then measured on the force indicating device of the chassis dynamometer.

Determination on chassis dynamometer unable to work as a generator.

For the two-roller chassis dynamometer, the R_R value is the one which is determined before on the road.

For the single-roller chassis dynamometer, the R_R value is the one which is determined on the road multiplied by a coefficient R which is equal to the ratio between the driving axle mass and the vehicle total mass.

Note : R_R is obtained from the curve F = f(V).

5.4.2.2.1 Calibrate the force indicator for the chosen speed of the roller bench as defined in para 2 Chapter 5 of this Part.

5.4.2.2.2 Perform the same operation as in paragraphs 5.1.2.2.1 to 5.1.2.2.4 above.

5.4.2.2.3 Set the force, $F_A = F - F_R$ on the indicator for the speed chosen.

5.4.2.2.4 Carry out a sufficient number of tests as indicated in paragraph 5.1.1.2.6 above, replacing T by F_A .

5.5 Deceleration Method applying coastdown techniques :

5.5.1 On the Road

5.5.1.1 Accuracies of the test instrument shall be the same as specified in 5.1.1.1.

5.5.1.2 Drive the vehicle at a constant speed of about 10 km/h more than the chosen test speed, V km/h, along a straight line.

5.5.1.3 After this speed is held steady for a distance of at-least 100 m, disconnect the engine from the drive line by bringing the gear to neutral or by other means in the case of vehicle where manual shifting to neutral is not possible.

5.5.1.4 Measure the time taken (t_1 sec) for the speed to drop from V + ΔV km/h to V - ΔV km/h. The value of ΔV shall not be less than 1 km/h or more than 5 km/h. However, same value of Δ V shall be used for all the tests.

5.5.1.5 Repeat the test in the opposite direction and record the time (t_2 sec.).

5.5.1.6 Repeat the test 10 times such that the statistical error of the time t_i (arithmetic average of t_1 and t_2) is equal to or less than 2%.

5.5.1.7 The statistical error 'p' is calculated as -

$$p = \frac{24.24 * (t_i - t_m)^2}{t_m}$$

where t = average time for each consecutive set of reading, $\frac{t_1 + t_2}{2}$

t_m = Arithmetic average of 10 such t_i .

5.5.1.8 The basic equation of motion to calculate the road load resistance force, F, is

$$F = \frac{(W + W_2) * V}{(3.6 * t_m * g)}$$

where,

F - in N

W - the weight of the test vehicle in N

W_2 - equivalent inertia weight of rotating axle (0.035 x mass of the test vehicle for four-wheeled vehicles) in N

V - vehicle speed difference during the coast down, in km/h

t_m - coast down time, in seconds

g - acceleration due to gravity, 9.81 m/s².

5.5.1.9 Using least square curve fitting method and values of F and V, the coefficient of aerodynamic and rolling resistance of the vehicle viz. a and b respectively are found from the following equation :

$F = a * V^2 + b$

5.5.2 Chassis Dynamometer Setting : The values of a and b are set on the dynamometer.

5.6 Alternate Method of Two-Wheelers

With the manufacturers` agreement for this method, the following values of a and b are set on the dynamometer as per the following equation :

$F = aV^2 + b$

where - F = the load, in N

a = 0.0225 for 2-wheeled vehicles with engines less than 50 cc capacity and 0.0250 for other 2-wheeled vehicles .

b = 0.18 x reference weight of vehicle, in kg

5.7 Alternative method for three wheelers : With the manufacturer's agreement, the following method may be used. The brake is adjusted so as to absorb the load exerted at the driving wheels at constant speed of 50 km/h in accordance with the table I of this chapter.

5.8 Alternative method for vehicles other than two and three wheelers : With the manufacturer's agreement, the following method may be used. The brake is adjusted so as to absorb the load exerted at the driving wheels at constant speed of 80 km/h in accordance with coefficients "a" and "b" of the table II of this chapter.

5.9 When the alternate method as per Para 5.7 or 5.8 is followed, the initial calibration of the chassis dynamometer shall be carried out without placing the vehicle on the chassis dynamometer.

Table I of Chapter 4 of Part IX : Power setting for three wheelers.

Reference Mass of Vehicle RW(kg)		Equivalent Inertia(kg)	Absorbed power at 50m/h (kW)
Exceeding	Upto		
	105	100	0.88
105	115	110	0.90
115	125	120	0.91
125	135	130	0.93
135	150	140	0.94
150	165	150	0.96
165	185	170	0.99
185	205	190	1.02
205	225	210	1.05
225	245	230	1.09
245	270	260	1.14
270	300	280	1.17
300	330	310	1.21
330	360	340	1.26
360	395	380	1.33
395	435	410	1.37
435	480	450	1.44
480	540	510	1.50
540	600	570	1.56
600	650	620	1.61
650	710	680	1.67
710	770	740	1.74
770	820	800	1.81
820	880	850	1.89
880	940	910	1.99
940	990	960	2.05
990	1050	1020	2.11
1050	1110	1080	2.18
1110	1160	1130	2.24
1160	1220	1190	2.30
1220	1280	1250	2.37
1280	1330	1300	2.42
1330	1390	1360	2.49
1390	1450	1420	2.54

1450	1500	1470	2.57
1500	1560	1530	2.62
1560	1620	1590	2.67
1620	1670	1640	2.72
1670	1730	1700	2.77
1730	1790	1760	2.83

Table II of Chapter 4 of Part IX

Table II: Power setting for vehicles other than two and three wheelers.

Reference Mass of Vehicle		Equivalent Inertia	Power & load absorbed by dynamometer at 80km/h		Coefficients	
					a	B
RW(kg)		Kg	kW	N	N	$N/(km/h)^2$
Exceeding	Upto					
---	480	455	3.8	171	3.8	0.0261
480	540	510	4.1	185	4.2	0.0282
540	595	570	4.3	194	4.4	0.0296
595	650	625	4.5	203	4.6	0.0309
650	710	680	4.7	212	4.8	0.0323
710	765	740	4.9	221	5.0	0.0337
765	850	800	5.1	230	5.2	0.0351
850	965	910	5.6	252	5.7	0.0385
965	1080	1020	6.0	270	6.1	0.0412
1080	1190	1130	6.3	284	6.4	0.0433
1190	1305	1250	6.7	302	6.8	0.0460
1305	1420	1360	7.0	315	7.1	0.0481
1420	1530	1470	7.3	329	7.4	0.0502
1530	1640	1590	7.5	338	7.6	0.0515
1640	1760	1700	7.8	351	7.9	0.0536
1760	1870	1810	8.1	365	8.2	0.0557
1870	1980	1930	8.4	378	8.5	0.0577
1980	2100	2040	8.6	387	8.7	0.0591
2100	2210	2150	8.8	396	8.9	0.0605
2210	2380	2270	9.0	405	9.1	0.0619
2380	2610	2270	9.4	423	9.5	0.0646
2610	--	2270	9.8	441	9.9	0.0674
In case of vehicles, other than passenger cars, with a reference mass of more than 1700 kg, or vehicles with a permanent all wheel drive, the power values given above are multiplied by the factor 1.3. However at the manufacturer's request, the factor of 1.3 need not be applied for measurement of fuel consumption.						