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 and fixed 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.

3.1 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 = 298K

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 s. 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 for the vehicle to decelerate from

$$V2 = V + \Delta V \text{ km/h} \text{ to } V1 = V - \Delta V \text{ km/h} : t1$$

$$\Delta V \leq 5 \text{ km/h}$$

5.1.1.2.4 Make 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

$$T = 1/n \sum_{i=1}^{n} Ti$$

is equal to or less than 2 percent ($p \leq$ 2 percent).

The statistical accuracy p is defined by :

$$p = \frac{t.s}{n} \times \frac{100}{T}$$

Where

t = coefficient given by the table below

$$s = \text{standard deviation} = \sqrt{\Sigma \quad (Ti - T)^2 / (n-1)}$$

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
t/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 :

$$P = m * V * \Delta V / 500T$$

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

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 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 percent. Speed measurement shall be accurate to within 2 percent.

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 percent for each second of the measurement period. The torque C_{T1} is the average torque derived from the following formula

$$C_{T1} = \int_{t}^{t+\Delta t} C(t)\, dt / \Delta t$$

5.2.1.2.4 Carry out the test in the opposite direction and find out the average torque i.e. C_{T2}.

5.2.1.2.5 Determine the average of these torques C_{T1} and C_{T2} 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 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 : $Mavg = {}_{t1}\sum^{t2} M(t)\, dt /(t_2 - t_1)$ with $M(t) > 0$, M is calculated from six sets of results.

It is recommended that the sampling rate of M be not less than samples per second.

5.3.3 Dynamometer setting The dynamometer load is set by the method described paragraph above. if Mavg (dynamometer) does not then match Mavg (road) 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 percent 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 percent deceleration shall be measured with an accuracy better than 1 percent; the slope of the road shall be measured with an accuracy better than 1 percent; time shall be measured with an accuracy better than 0.1 s. The measurement of the level of the vehicle on a reference horizontal ground: By comparison, it is possible to find 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:

$$\bar{Y}1 = 1/t * [{}_0\int^t \quad Y1\ (t)\ dt] - g \text{ Sin } \alpha_1$$

Where

$\bar{Y}1$ = 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

Y1 (t) = deceleration recorded with the time

g = 9.81 m/s².

5.4.1.2.4 Perform the same test in the other direction $\bar{Y}2$

5.4.1.2.5 Calculate the average declaration i.e.

$$\gamma i = (Y1 + Y2)/2$$

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

$$\gamma = [{}_{i=1} \sum^n \quad \gamma i\ ]/n$$

5.4.1.2.7 Calculate the average force absorbed F=m*y ,where m =vehicle reference mass in kg & y=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

$F_{total} = F_{road}$

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

$F_{indicated}$ is the force indicated on the force indicating device of the chassis dynamometer, F_{road} , (F_R)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 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 (t1 sec) for the speed to drop from V + Δ V km/h to V - Δ V 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 -

$$p = 24.24 * (t_i - t_m)^2 / t_m$$

where - t = average time for each consecutive set of reading, $(t_1 + t_2) / 2$

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

$$F = (W + W2)*V / (3.6 * t_m * g)$$

Where

F - in N

W - the weight of the test vehicle in N

W2 - 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

6 Methods for Chassis Dynamometer with Fixed Load Curve :

6.1 In the event that the resistance to progress on the road can not be reproduced on the chassis dynamometer between speeds of 10 and 50 km/h, the chassis dynamometer should meet the following characteristics :

6.1.1 Having set the load at 40 km/h by one of the methods described in paragraph 6.2 below, the characteristic of the chassis dynamometer K can be determined from Pa = KV where Pa is the power absorbed by the chassis dynamometer in kW and V is the vehicle speed in km/h. The power absorbed (Pa) by the chassis dynamometer and the chassis internal frictional effects from the reference setting to a vehicle speed of 40 km/h are as follows :

If V > 12 km/h :

$P_a = KV^3 +/- 5\% \; KV^3{}_{12} - 5\% \; PV_{40}$

(without being negative)

If V < 12 km/h:

P_a will be between 0 and

$P_a = KV^3{}_{12} + 5\% \; KV^3{}_{12} + 5\% \; PV_{40}$

where - PV_{40} is the power absorbed at 40 km/h

- K is a characteristic of the chassis dynamometer.

Please refer Fig.4 of this chapter..

6.1.2 Verification of the power absorption curve of the roller bench from a reference setting to a speed of 40 km/h :

6.1.2.1 Place the vehicle on dynamometer or device some other method of starting up the dynamometer.

6.1.2.2 Adjust the dynamometer to the absorbed power P_a at 40 km/h

6.1.2.3 Note the power absorb at 30-20-10 km/h

6.1.2.4 Draw the curve P_a verses V and verify that it meets the requirements of para 6.2 above.

6.1.2.5 Repeat the procedure of para 6.1.2.1 to 6.1.2.4 for other values of power P_a at 40 km/h and for other values of inertia.

6.1.3 The same procedure will be used for force or torque calibration.

6.2 Vacuum method :

6.2.1 Introduction : This method is not a preferred method and should be used only with fixed load curve type dynamometers for determination of load setting at 40 km/h for four wheelers.

6.2.2 Test Instrumentation and Accuracy : The vacuum (or absolute pressure) in the intake manifold of the vehicle shall be measured to an accuracy of ± 0.25 kPa. It shall be possible to record continuously this reading or at intervals of not more than 1 second. The speed shall be recorded continuously with a precision of +/- 0.4 km/h.

6.2.3 Road test : Drive the vehicle at a steady speed of 40 km/h recording speed and vacuum (or absolute pressure) within the requirement of paragraph 6.2.2 above.

6.2.4 Repeat procedure of paragraph 6.2.3 above three times in each direction. All six runs must be completed within four hours.

6.2.5 Data reduction and acceptance criteria :

6.2.5.1 Review results obtained in accordance with paragraphs 6.2.3 and 6.2.4 (speed must not be lower than 39.5 km/h or greater than 40.5 km/h for more than 1 second). For each run, read vacuum level at 1 second intervals, calculate mean vacuum (v) and standard deviation (s). This calculation shall consist of not less than 10 readings of vacuum.

6.2.5.2 The standard deviation shall not exceed 10 percent of mean for each run.

6.2.5.3 Calculate the mean value (v) for the six runs (three runs in each direction).

6.2.5.4 Chassis Dynamometer Setting :Perform the operations specified in paragraphs 5.1.2.2.1 to above.

6.2.5.5 Setting : After warm-up, drive the vehicle at a steady speed of 40 km/h and adjust dynamometer load to reproduce the vacuum reading (v) obtained in accordance with paragraph 6.2.3. Deviation from this reading shall be not greater than 0.25 kPa.

6.3 Additional setting methods for 2-wheeler vehicles :

6.3.1 The brake shall be so adjusted as to reproduce the operation of the vehicle on the level road at a steady speed between 35 and 45 km/h (or maximum speed in case of mopeds).

6.3.2 Road test :

6.3.2.1 Accuracies of test equipment : Time shall be measured accurate to within 0.1 s. Speed shall be measured accurate to within 2 percent.

6.3.2.2 An adjustable stop limiting the maximum speed to between 35 km/h and 45 km/h shall be mounted in the fuel-feed regulating device. The speed of the vehicle shall be measured by means of precision speedometer or computed from the time measured over a given distance on a level dry road in both directions, with the stop applied.

6.3.2.3 The measurements, which shall be repeated at least three times in both directions, shall be taken over a distance of at least 200 m and with a sufficiently long acceleration distance. The average speed shall be determined.

6.3.2.4 In case of 2-wheeler vehicles with maximum speed around 40 km/h, the maximum attainable speed on the road with throttle fully opened shall be measured within ± 1 km/h. This maximum attainable speed on the road shall not differ from the maximum design speed specified by the manufacturer by more than ± 2 km/h. In the case where the vehicle is fitted with a device to regulate its maximum road speed, the effect of the regulator will be taken into account.

6.3.3 Chassis Dynamometer setting :

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

6.3.3.2 The vehicle shall then be placed on the dynamometer bench and the brake so adjusted as to obtain the same speed as that reached in the road test (fuel-feed regulating device, if used, in stop position and same gear box ratio). This brake setting shall be maintained throughout the test. After adjusting the brake, the stop in the feed device, if used, shall be removed.

6.4 Alternative method for 2-wheeler vehicles : With the manufacturer's agreement the following method may be used :

The brake is adjusted so as to absorb the power at the driving wheel at a constant speed of 40 km/h in accordance with the following equation :

$$P_a = (aV^3 + bV)/3600$$

where

P_a = power absorbed, in kW

V = Vehicle speed in km/h

a = 0.0225 for 2-wheeled vehicles with engine less than 50cc capacity and

= 0.0250 for other 2-wheeler vehicles.

b = 0.18 x m (where m = reference weight of vehicle in kg.)

Fig. 4 : CHARACTERISTIC OF CHASSIS DYNAMOMETER WITH FIXED LOAD CURVE(PL.REF. PARA. 6.1.1. OF CHAPTER 4 PART 3)