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Design of a Chassis Dynamometer Facility for the European Type-Approval of Passenger Cars Manufactured in Pakistan †

Kashif Usman [1,2], Muhammad Kashif [1], Muhammad Haroon [2,3,*], Muhammad Ahmed [3], Haseeb Ahmad [4] and Al-Bara Shalaby [2]

[1] Department of Mechanical Engineering, University of Central Punjab, Lahore 54782, Pakistan; kashif.phdme51@iiu.edu.pk (K.U.); muhammad.kashif@ucp.edu.pk (M.K.)
[2] Department of Mechanical Engineering, International Islamic University, Islamabad 44000, Pakistan; albara.phdme55@iiu.edu.pk
[3] Department of Mechanical Engineering, Capital University of Science and Technology (CUST), Islamabad 44000, Pakistan; ahmedislam123@gmail.com
[4] Department of Mechanical Engineering, Superior University, Lahore 54782, Pakistan; haseeb.ahmed@superior.edu.pk
* Correspondence: muhammad.haroon@cust.edu.pk
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Abstract: The objective of this research is to develop a suitable chassis dynamometer to test new vehicles for compliance with emission standards for type-approval in Pakistan. There is a lack of facilities and protocols for testing new passenger vehicles to measure vehicle exhaust gas emissions. This study is performed to fill this gap and might help local authorities in the implementation of exhaust emission test procedures. Assessment of exhaust emissions can be performed by placing the vehicle over the chassis dynamometer. An air-cooled eddy current dynamometer is selected for this purpose. The road load equation is used to simulate the real-life performance of a vehicle while driving at different speeds.

Keywords: chassis dynamometer; emission regulations; European type-approval

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1. Introduction

Pakistan currently has emission standards of Tiers Pak-II that are equivalent to standards of EURO 2. The measuring method for Tier Pak-II is the New European Driving Cycles (NEDC). Therefore, it is the latest technology recently adopted by automobile manufacturers in Pakistan. Now, it is mandatory for all automobile manufacturers in Pakistan to follow the emission standards. However, the problem is that there is no independent approval authority within Pakistan that can offer testing services to vehicle manufacturers to make sure that the specific emission standards are met. Table 1 (first two columns) shows the specifications shared by one of the leading manufacturers in Pakistan, in which the emission standards followed by the manufacturer can be seen clearly. However, on the other hand, any CO_2 emission data in compliance with EURO-II cannot be seen.

Researchers are performing experimental and numerical investigations on a chassis dynamometer design. Lourenco et al. [1] proposed a model for a vehicle and twin roller chassis dynamometer to improve mobility systems. Zhang et al. [2] enclosed the latest research (on vehicle chassis dynamometer development) in a review article and proposed the AC chassis dynamometer as a mainstream trend. Different measurement aspects, road simulation, and control systems are also discussed.

This research is targeted to design a chassis dynamometer for type-approval of new passenger vehicles manufactured in Pakistan underneath environmental legislations in force. This chassis dynamometer could be used as a test platform for direct performance

testing of new passenger vehicles in the laboratory. Another feature of this study is to obtain insight into the real-world emissions behavior of road vehicles in varying operating situations. Exhaust emissions are analyzed by a vehicle driving on the chassis dynamometer inside the modern emission testing laboratory (SGS Pakistan Pvt. Ltd.) at Karachi to verify the fitness of the vehicle in terms of pollutant emissions. Initially, roller design calculations are performed using numerical design tools. Then, the structure of the chassis dynamometer is designed for the power absorption from the chassis dynamometer at the time of the emission test.

Table 1. Technical specifications of passenger cars manufactured in Pakistan (first two columns) and other important parameters of various vehicles manufactured in Pakistan (last five columns).

Description	Specifications	Manufacturer	Model	Max Power (hp)	Weight (Kg)	Tire Reference
Model	Toyota Corolla Altis	Suzuki	Mehran	40	800	145/70R12
Power	138 hp	Suzuki	Swift	90	1050	185/70R15
RPM @ Max Power	6400	Honda	Civic Oriel	140	1273	215/55R16
Max Torque	173 nm	Honda	BRV	120	1230	195/60R15
RPM @ Max Torque	4000	Toyota	Altis	138	1275	205/55R16
Engine displacement	1798 cc	Toyota	GLI	84	1275	196/65R15
Fuel type	Gasoline					
Number of cylinders	Four					
Top Speed	240 km/h					
Tire	205/55R16					
Kerb Weight	1275 kg					
Emission Standards	Euro-II					
CO_2 Emissions (g/km)	-------					

2. Materials and Methods

2.1. Design of Chassis Dynamometer

The vehicle behavior under different road conditions is described by the road load equation (RLE). This RLE (Equation (1)) is a fundamental requirement of a chassis dynamometer. In order to simulate the real-life performance of a vehicle, RLE is used to calculate the change in torque with the change in vehicle speed. Its primary importance is that it provides a linkage between performance on the road and performance in the test cell.

$$F_{roadload} = a + bV + cV^2 + M\frac{dV}{dt} + Mg\sin\theta \quad (1)$$

where $F_{roadload}$ is the resistance to progress (N), V is the vehicle speed (km/h), a is the value equivalent to rolling resistance (N), b is the value equivalent to frictional resistance N/(km/h), c is the value equivalent to the coefficient of air resistance N/(km/h)^2, M is the mass of the vehicle (kg), and θ is the road slope in radians.

Power required at any vehicle speed is shown in Equation (2) [3]:

$$\text{Power} = F_{roadload} * V \quad (2)$$

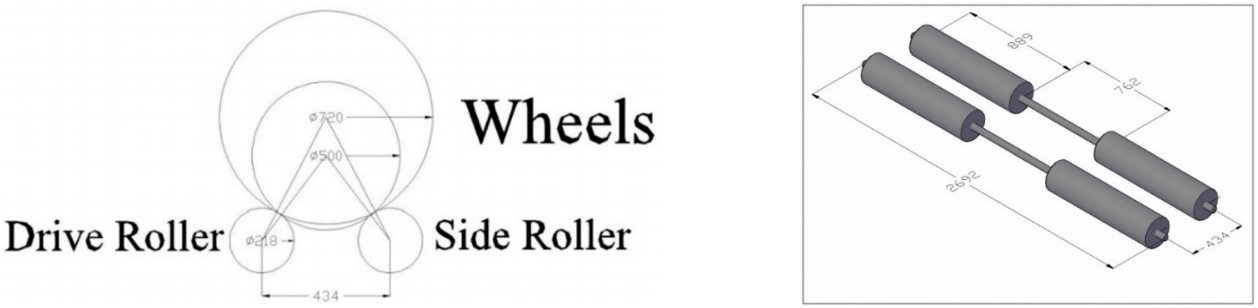
First, there is the need to conduct an elementary survey of vehicle specifications manufactured in Pakistan. In this context, Table 1 (last five columns) presents power and some other performance parameters for many light-duty cars manufactured in Pakistan.

2.2. Components Selection

Detailed information regarding the selection of the dynamometer, transmission shafts, and roller design is included in Table 2. Figure 1a shows the position of front and rear rollers with maximum and minimum angles of tires, and Figure 1b shows the isometric view of rollers and shaft with designed dimensions.

Table 2. Important final designed specifications of chassis dynamometer.

Sr. No	Parameters	Optimum Designed Values
1.	Maximum power	250 hp
2.	Power absorber dynamometer	Mustang air-cooled eddy current dynamometer (model: MDK-70); Precision-machined and dynamically balanced rollers;
3.	Rollers	Four rollers of diameter 217 mm; rollers center-to-center distance is 434 mm; Inner and outer track widths of 762 and 2692 mm, respectively;
4.	Inertia	Base mechanical inertia of 2200 lbs and rollers rotational inertia of 5.92 kg.m^2;
5.	Transmission shafts	Two shafts of 44 mm diameter and 2692 mm length;
6.	Driving cycle	New European driving cycle (NEDC) with 460 lb ft maximum torque and 3500 maximum roller rpm at the speed of 140 km/h;
7.	Control system	Dyn Pro2 from Dyne systems;
8.	Structure	Durable steel structure frame and restrained system;
9.	Air requirement	A blower fan with maximum airflow rate of 8000 m^3/h;
10.	Electricity requirement	230 V AC (30 Amp) for the eddy current dynamometer and 15 Amp (115 V AC) for the computer system.



(**a**) (**b**)

Figure 1. (**a**) Position of front and rear rollers with maximum and minimum angles of tires. (**b**) Isometric view of rollers and shaft with designed dimensions.

A wheel's rpm (N) is calculated by using Equation (3) [3], where R is the tire radius.

$$N = \frac{V}{2\pi R} \tag{3}$$

As in this research, the design of the chassis dynamometer is for a European type-approval test in which the maximum vehicle speed is 120 km/h, but to incorporate some tolerances, a 140 km/h maximum is considered. To calculate roller rpm, Equation (4) is used [3]:

$$N1\ D1 = N2\ D2 \tag{4}$$

where $N1$ and $N2$ are the rpms of the tire and roller, and $D1$ and $D2$ are the diameters of the tire and roller. For rollers (having 889 mm face length), a mild steel schedule 40 pipe is employed.

3. Results and Discussion

The final designed specifications of the chassis dynamometer are enclosed in Table 2. This test platform will be able to measure exhaust emissions when integrated with emission testing equipment. It will be the first step in testing the performance and ensuring the emission limits of new passenger cars manufactured in Pakistan.

As per NEDC, the complete testing requires around 20 min if performed without any interruption. NEDC consists of two segments. In the first segment, the vehicle under testing is driven through an urban driving cycle (ECE), which is completed four times. Every ECE comprises 15 phases. In the second segment, one extra-urban driving cycle

(EUDC) is completed, which comprises 13 phases. Table 3 encloses the sample testing data for gaseous pollutants and the EUDC gear shift breakdown summary.

Table 3. Sample testing data for gaseous pollutants and EUDC gear shift breakdown summary.

Gaseous Pollutants Measurement for FWD Transmission			**Gear Shift Breakdown Summary of EUDC**		
	ECE	**EUDC**	**Operations**	**Duration (s)**	**Percent**
Cycle distance (km)	4.06	6.65	Idle phases	20	5%
Sampling time (s)	780	400	Idle phases for gear shifts	20	5%
CVS venturi (m^3/min)	12.2	12.2	Gear shifts	6	1.5%
CVS volume at 20 °C (m^3)	137.3	70.4	1st gear	5	1.3%
PM filter volume (L)	1040.29	532.59	2nd gear	9	2.2%
CVS ambient baggage (ppm)			3rd gear	8	2%
CO	1.45	1.66	4th gear	99	24.8%
HC	4.1	4.56	5th gear	233	58.2%
NOx	0.141	0.121	Complete cycle	400	100%
CO_2	455.44	448.06			
CVS sampling baggage (ppm)					
CO	28.51	23.94			
HC	10.01	11.68			
NOx	15.18	22.14			
CO_2	4279.3	6850.1			

4. Conclusions

This study is focused on the design of a chassis dynamometer facility for European type-approval of new passenger vehicles manufactured in Pakistan. Exhaust emissions examination can be performed by putting the vehicle over this chassis dynamometer. For this purpose, an air-cooled eddy current dynamometer from Mustang having a maximum load absorption capability of 250 hp is selected, and RLE is used to simulate the real-time performance of a vehicle while driving at varying speeds.

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