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Exhaust Emissions and Fuel Economy of Three Prototype Honda Motorcycles

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Technology Assessment and Evaluation Branch
Emission Control Technology Division
Office of Mobile Source Air Pollution Control
Environmental Protection Agency

Background

The Environmental Protection Agency receives information about many systems which appear to offer potential for emission reduction or fuel economy improvement compared to conventional engines and vehicles. EPA's Emission Control Technology Division is interested in evaluating all such systems, because of the obvious benefits to the Nation from the identification of systems that can reduce emissions, improve economy, or both. EPA invites developers of such systems to provide to the EPA complete technical data on the system's principle of operation, together with available test data on the system. In those cases in which review by EPA technical staff suggests that the data available show promise, attempts are made to schedule tests at the EPA Emissions Laboratory at Ann Arbor, Michigan. The results of all such test projects are set forth in a series of Technology Assessment and Evaluation Reports, of which this report is one.

The conclusions drawn from the EPA evaluation tests are necessarily of limited applicability. A complete evaluation of the effectiveness of an emission control system in achieving performance improvements on the many different types of vehicles that are in actual use requires a much larger sample of test vehicles than is economically feasible in the evaluation test projects conducted by EPA. For promising systems it is necessary that more extensive test programs be carried out.

The conclusions from the EPA evaluation test can be considered to be quantitatively valid only for the specific test vehicle used. However, it is reasonable to extrapolate the results from the EPA test to other types of vehicles in a directional or qualitative manner, i.e., to suggest that similar results are likely to be achieved on other types of vehicles.

Early in 1976, the Honda Motor Company, Ltd., of Japan, offered to make available for EPA testing three prototype motorcycles designed to meet the proposed 1978 Federal emission standards for motorcycles. These motorcycles incorporated improvements in fuel metering and combustion control to reduce exhaust emissions and improvements in durability to maintain the reduced exhaust emissions over the useful life of the vehicle. One motorcycle would be equipped with an auxiliary hydrocarbon control device in the exhaust system. Data supplied by Honda indicated that the prototype motorcycles would achieve the proposed 1978 standards with considerable improvement in fuel economy over that delivered by their current production motorcycles.

The EPA agreed to test the three prototype motorcycles, and also requested that three current production motorcycles (which have uncontrolled exhaust emissions) be supplied with the prototype motorcycles so that comparisons between current production motorcycles and the prototype motorcycles could be made.

Test Vehicle Descriptions

The three models of Honda motorcycles supplied to the EPA were a CB750, a XL250, and a MT250. Except for emission controls, the production and prototype motorcycles were identical.

The CB750 is a large-displacement street motorcycle. The engine is a four-stroke, overhead cam four-cylinder, with a displacement of 736 cc. One carburetor is used for each cylinder. The engine is air-cooled, and is in a vertical configuration (I-4). The transmission is a five speed manual. The CB750 was tested at an inertia mass of 330 kg. Emission control is by engine modifications.

The XL250 is a medium displacement on/off road motorcycle. The engine is a single cylinder, overhead cam four-stroke, with a displacement of 248 cc. The engine has 4 valves, 2 intake and 2 exhaust. A single carburetor is utilized for fuel metering and the engine is air-cooled. The transmission is a five-speed manual. The XL250 was tested at an inertia mass of 230 kg. Emission control is by engine modifications.

The MT250 is also a medium displacement on/off road motorcycle. The engine is an air-cooled single cylinder two-stroke, with a displacement of 248 cc. The transmission is a five-speed manual. The MT250 was tested at an inertia mass of 210 kg. Emission control is by engine modifications and auxiliary HC control in the exhaust.

Test Program

Exhaust emission and fuel economy tests were conducted in accordance with the Notice of Proposed Rule Making (NPRM), Federal Register, October 22, 1975, Part III. The NPRM contains the proposed Federal exhaust emission regulations and test procedures for motorcycles (scheduled to become effective in 1978). Because the road load specified in the NPRM for each inertia mass class has been determined to be in error, the motorcycles were tested at road load values supplied by Honda. The road load values supplied by Honda are in close agreement with revised EPA road load values (which had not been published at the time of this test program).

On each of the prototype motorcycles, the following series of tests were conducted: 1975 Federal Test Procedure ('75 FTP), EPA Highway Fuel Economy Test, steady state tests and the EPA Sulfate test cycle (SC-7). Two '75 FTP's and Highway tests were run on each prototype motorcycle (three on the CB750). One set of steady state tests and sulfate cycles were conducted.

The production motorcycles were tested twice in accordance with the '75 FTP and Highway Fuel Economy Test.

Steady state emissions and fuel economy were measured at idle, 10 kph, 30 kph, 50 kph, 70 kph and 90 kph. A five minute sample was taken at each speed.

In discussions with Honda engineers, it was pointed out to EPA personnel that exhaust emissions from air-cooled motorcycles are very sensitive to engine temperature. Therefore, to achieve repeatable steady state emissions, it is necessary to continuously monitor some indicator of engine temperature (such as oil temperature). Because of the need to complete the EPA testing of the motorcycles within a limited time frame, a rigorous control of engine temperature during steady state testing was not attempted. Each motorcycle was warmed up until the oil temperature reached 65°C. Steady state tests commenced at this time, beginning with the idle test and proceeding through the test speeds up to 90 kph.

Sulfate and particulate emissions were measured from all six motorcycles. It was expected that sulfate emissions could successfully be measured from the prototype MT250 which operates on unleaded fuel. However, the other five motorcycles had previously been operated on leaded fuel. Lead is known to interfere with the sulfate analysis procedure, so problems were anticipated when attempting to measure sulfate emissions from these motorcycles.

A brief description of the sulfate test procedure is given at the end of this report. A detailed description of the EPA sulfate test procedure can be found in SAE publication number 760034, titled "Sulfuric Acid Emissions from Light Duty Vehicles".

Driveability testing consisted of a short test drive of each production motorcycle followed by a test drive of the same model prototype motorcycle, and evaluating the two motorcycles relative to each other. No attempt was made to conduct a rigorous evaluation of driveability. The purpose of the driveability testing was to determine if the prototype motorcycles had any obvious driveability faults that the production motorcycles did not have.

Test Results

The following exhaust emissions and fuel consumption were measured from the three prototype motorcycles.

Summary of Prototype Motorcycle Test Data
'75 FTP Composite Mass Emissions
in grams per kilometer

	HC	CO	NOx	Fuel Consumption
CB750 Average of 3 tests	1.47	8.3	0.71	4.5 liters/100 km
XL250 Average of 2 tests	0.77	8.7	0.29	2.8 liters/100 km
MT250 Average of 2 tests	3.92	9.9	0.02	3.2 liters/100 km

For comparison, the proposed 1978 Federal motorcycle emission standards are (in grams per kilometer):

Displacement	HC	CO	NOx
736cc	13.77	17	1.2
248cc	6.21	17	1.2

The emissions from all three prototype motorcycles are well within the proposed 1978 standards.

Highway fuel consumption of the prototype motorcycles is presented in the following table.

Highway Cycle Fuel Consumption
in liters/100 km

CB750	3.7
XL250	3.0
MT250	4.1

Highway cycle emissions are presented in Table V.

Exhaust emissions and fuel consumption of the three production motorcycles are presented in Tables I, II and III. Additional '75 FTP test data for the prototype motorcycles are also found in these Tables.

Both the XL250 and MT250 had higher fuel consumption during the Highway Cycle than they did during the '75 FTP (urban driving). This is probably due to the fact that these two motorcycles were operating near wide open throttle during the Highway Cycle, which resulted in enrichment of the fuel-air mixture.

Steady state emissions of the prototype motorcycles are presented in Tables VI, VII and VIII.

Results of the driveability tests indicate that the prototype MT250 and CB750 had slightly degraded driveability when compared to the production motorcycles. The prototype and production XL250 had comparable driveability. Both versions of the XL250 could be driven immediately following a cold start without requiring any warmup. The prototype XL250 did not exhibit any symptoms of lean carburetion.

The production MT250 generally had good driveability characteristics. The prototype MT250 exhibited several driveability faults that were not experienced with the production MT250. When operating the engine at constant speed below 4000 rpm in 1st, 2nd and 3rd gears, symptoms of lean carburetion were evident. The engine would not operate smoothly in this speed range, making the motorcycle difficult to drive at low speeds that would be encountered in urban-suburban driving. In addition, the engine returned to idle very slowly when declutching on decelerations.

The production CB750 had one significant driveability fault: it was necessary to warm up the engine for one to two minutes after a cold start before the motorcycle could be driven.

The prototype CB750 had symptoms of lean carburetion. The idle speed was slightly variable, and some lean surge was evident in all gears when driving at constant speed. A significant hesitation occurred when accelerating hard (WOT) from engine speeds below 3500 rpm in 4th and 5th gears. However, this is probably a lower engine speed than one might normally use in these gears. The driveability of the prototype CB750 improved with engine running time. Unlike the production CB750, the prototype could be driven immediately following a cold start.

Sulfate and particulate emissions measured over the EPA Sulfate Cycle are presented in Table IX. Attempts to measure sulfate emissions from all the motorcycles except the prototype MT250 were unsuccessful, possibly due to residual lead interference. (A recent modification to the sulfate analysis system recommended by the EPA Office of Research and Development may eliminate lead and various anion interference.)

In addition, high levels of liquid condensate were noted in the exhaust collection manifold that connects to the motorcycle exhaust pipes. This condensate appeared to contain organic type compounds, possibly from unburned oil or higher molecular weight hydrocarbons. The condensate was also found to contain some sulfate when a sample was analyzed on the barium chloranilate system. These phenomena would affect the results for all six motorcycles.

With these caveats, it can be noted that the prototype MT250 seemed to emit only small quantities of sulfate. However the particulate emissions from this motorcycle are very high (110 mgpm for the controlled version and 340 mgpm for the uncontrolled version), compared to particulate emissions from automobiles. The other two motorcycles (XL250 and CB750) showed very low particulate emissions.

Conclusions

The prototype motorcycles met the proposed 1978 emission regulations with considerable improvement in fuel consumption compared to current production motorcycles.

All three prototype motorcycles demonstrated substantial reductions in HC and CO emissions compared to the production motorcycles. Reductions in HC emissions ranged from 26% (XL250) to 73% (MT250). Reductions in CO ranged from 44% (XL250) to 81% (CB750). The XL250 and CB750 had increases in NOx emissions of 93% and 318% respectively. However, even with this large percentage increase, the NOx emissions from the CB750 were only 0.71 grams per kilometer.

Fuel consumption was improved by 13 to 40% during urban driving ('75 FTP). Reductions in highway fuel consumption ranged from 17% to 43%.

In the case of the XL250 and CB750, these reductions in exhaust emissions and fuel consumption have been achieved with relatively minor modifications to the engine and fuel system, and have not affected maximum power output. The modifications made to the MT250 were somewhat more extensive and involved a 5% loss in peak power output.

Data supplied by Honda regarding these prototypes indicate that the savings in fuel costs over the life of the motorcycle would pay for the engine and fuel system modifications.

Both the MT250 and CB750 prototypes demonstrated some deterioration of driveability when compared to the production models. Driveability of the prototype XL250 was comparable to the production XL250.

The driveability of the CB750 and MT250 could probably be improved by slightly decreasing the air-fuel ratio. Both motorcycles are sufficiently below the proposed 1978 emission levels to allow some mixture adjustment.

Table I

MT250 '75 FTP Mass Emissions
in grams per kilometer

Test #	HC	CO	CO_2	NOx	liters/100 km (miles/gal.)
Production MT250 (uncontrolled)					
18-1051	13.19	28.2	33.5	0.02	5.1 (46.1)
18-1061	15.92	29.6	32.2	0.02	5.5 (42.8)
Average	14.56	28.9	32.9	0.02	5.3 (44.5)
Prototype MT250					
18-714	3.96	10.2	46.2	0.02	3.2 (73.5)
18-850	3.87	9.6	46.3	0.02	3.1 (75.9)
Average	3.92	9.9	46.3	0.02	3.2 (74.7)
% change from baseline	-73%	-66%	+41%	0	-40% (+68%)

Table II

XL250 '75 FTP Mass Emissions
in grams per kilometer

Test #	HC	CO	CO_2	NOx	liters/100 km (miles/gal.)
Production XL250 (uncontrolled)					
18-1053	0.99	15.1	44.3	0.15	3.0 (78.4)
18-1065	1.08	15.7	48.9	0.15	3.3 (71.3)
Average	1.04	15.4	46.6	0.15	3.2 (74.9)
Prototype XL250					
18-791	0.82	9.0	52.0	0.31	2.9 (81.1)
18-789	0.71	8.3	48.9	0.27	2.7 (87.1)
Average	0.77	8.7	50.5	0.29	2.8 (84.1)
% change from baseline	-26%	-44%	+8%	+93%	-13% (+12%)

1978 Federal Motorcycle Emission Standards for 248cc displacement.

HC	CO	NOx
6.21 gm/km	17 gms/km	1.2 gms/km

Table III

CB750 '75 FTP Mass Emissions
in grams per kilometer

Test #	HC	CO	CO_2	NOx	Liters/100 km (miles/gal.)
Production CB750 (uncontrolled)					
18-1045	2.81	47.0	78.5	0.20	6.9 (34.1)
18-1057	2.41	39.9	67.4	0.14	5.9 (39.9)
Average	2.61	43.5	73.0	0.17	6.4 (37.0)
Prototype CB750					
18-778	1.57	8.0	88.7	0.75	4.5 (52.3)
18-857	1.51	8.8	85.5	0.68	4.4 (53.5)
18-776	1.32	8.2	88.5	0.70	4.5 (52.3)
Average	1.47	8.3	87.6	0.71	4.5 (52.7)
% Change from baseline	-44%	-81%	+20%	+318%	-30% (+42%)

1978 Federal Motorcycle Emission Standards for 736cc displacement

HC	CO	NOx
13.77 gms/km	17 gms/km	1.2 gms/km

Table IV

Individual Bag Emissions
in grams per kilometer
Prototype Motorcycles

	Bag 1: Cold Transient					Bag 2: Stabilized					Bag 3: Hot Transient				
Test #	HC	CO	CO_2	NOx	ℓ/100km	HC	CO	CO_2	NOx	ℓ/100km	HC	CO	CO_2	NOx	ℓ/100km
CB750															
18-776	1.97	4.9	96.6	0.84	4.7	1.18	10.6	87.2	0.35	4.6	1.08	6.2	85.0	1.24	4.2
18-778	2.78	5.6	98.3	0.94	5.0	1.32	9.8	87.7	0.40	4.6	1.14	6.5	83.4	1.27	4.1
18-857	2.49	5.8	98.4	0.88	4.9	1.36	11.2	83.2	0.34	4.5	1.06	6.6	80.3	1.18	4.0
MT250															
18-714	5.09	13.1	52.3	0.03	3.8	3.51	6.7	44.4	0.01	2.8	3.95	14.6	45.1	0.02	3.4
18-850	5.55	14.6	53.1	0.03	4.0	3.32	5.5	43.8	0.01	2.7	3.61	13.6	46.0	0.03	3.4
XL250															
18-789	0.87	8.6	55.2	0.32	3.0	0.69	7.7	46.0	0.18	2.6	0.63	9.3	49.7	0.38	2.8
18-791	0.93	8.6	59.2	0.35	3.2	0.83	8.4	49.2	0.23	2.8	0.72	10.2	51.5	0.41	3.0

Table V

EPA Highway Cycle
Mass Emissions in
grams per kilometer

Test #	HC	CO	CO_2	NOx	Liter/100km (miles/gal.)
Production Motorcycles					
MT250					
18-1052	10.69	38.2	34.9	0.02	5.5 (42.8)
18-1063	10.81	38.1	34.2	0.02	5.5 (42.8)
Average	10.75	38.2	34.6	0.02	5.5 (42.8)
XL250					
18-1054	0.47	22.2	45.8	0.17	3.5 (67.2)
18-1067	0.49	25.0	44.9	0.15	3.7 (63.6)
Average	0.48	23.6	45.4	0.16	3.6 (65.4)
CB750					
18-1050	1.96	61.1	61.1	0.14	7.0 (33.6)
18-1059	1.80	54.1	50.6	0.11	6.0 (39.2)
Average	1.88	57.6	55.9	0.13	6.5 (36.4)
Prototype Motorcycles					
MT250					
18-667	3.98	27.7	41.3	0.02	4.1 (57.4)
18-788	3.86	27.5	39.0	0.02	4.0 (58.8)
Average	3.92	27.6	40.2	0.02	4.1 (58.1)
% change from baseline	-64%	-28%	+16%	0	-25% (+36%)
XL250					
18-790	0.45	12.4	51.0	0.39	3.1 (75.9)
18-792	0.40	10.4	51.0	0.49	2.9 (81.1)
Average	0.43	11.4	51.0	0.44	3.0 (78.5)
% change from baseline	-10%	-52%	+12%	+175%	-17% (+20%)
CB750					
18-777	0.68	1.7	80.8	1.97	3.6 (65.4)
18-779	0.72	2.2	83.9	2.06	3.8 (61.9)
Average	0.70	1.9	82.4	2.02	3.7 (63.7)
% change from baseline	-63%	-97%	+47%	+1454%	-43% (+75%)

Table VI

MT250 Steady State
Mass Emissions in
grams per kilometer

	HC	CO	CO_2	NOx	Liters/100km
Idle (300 secs)	5.63 gms	6.3 gms	22.9 gms	0.0	
10 kph, 1st gear	8.26	6.6	50.3	0.01	3.7
30 kph 2nd gear	2.59	2.2	37.4	0.01	2.1
50 kph, 4th gear	1.79	0.3	39.9	0.01	2.0
70 kph, 5th gear	2.07	6.9	40.5	0.03	2.5
90 kph, 5th gear	1.05	37.5	39.7	0.02	4.3

Table VII

XL250 Steady State
Mass Emissions in
grams per kilometer

	HC	CO	CO_2	NOx	Liters/100km
Idle (300 secs)	0.74 gms	7.0 gms	36.1 gms	0.01 gms	
10 kph, 1st gear	0.62	17.9	69.1	0.02	4.2
30 kph, 2nd gear	0.41	14.1	49.4	0.04	3.1
50 kph, 4th gear	0.34	8.7	40.4	0.12	2.4
70 kph, 5th gear	0.33	9.7	45.6	0.25	2.6
90 kph, 5th gear	0.51	18.2	55.3	0.42	3.6

Table VIII

CB750 Steady State
Mass Emissions in
grams per kilometer

	HC	CO	CO_2	NOx	Liters/100km
Idle (300 secs)	2.22 gms	12.1 gms	87.0 gms	0.05 gms	
10 kph, 1st gear	1.48	27.7	101.5	0.06	6.4
30 kph, 1st gear	0.89	20.3	90.7	0.10	5.3
50 kph, 3rd gear	0.49	7.6	56.2	0.13	3.0
70 kph, 5th gear	0.51	0.6	67.1	0.94	3.0
90 kph, 5th gear	0.54	0.8	83.8	1.95	3.7

Table IX

EPA Sulfate Cycle Emissions in
milligrams per kilometer

Prototype Motorcycles

	H_2SO_4 Emissions	Particulate Emissions
MT250	1.3	116.5
	1.3	63.6
	2.2	151.0
Average	1.6	110.4
XL250	*	12.9
	*	2.5
Average		7.7
CB750	*	6.8
Production Motorcycles		
MT250	*	381.2
	*	293.8
Average		337.5
XL250	*	1.7
	*	7.4
Average		4.6
CB 750	*	14.8
	*	15.1
Average		15.0

* H_2SO_4 measurements unsuccessful due to possible residual lead interference.

TEST VEHICLE DESCRIPTION

Chassis model year/make - 1975 Honda CB750
Emission control system - Engine Modifications

Engine

type	4 stroke, Otto cycle, I-4, ohc
bore x stroke	61 x 63 mm
displacement	736cc
compression ratio	9.2:1
fuel metering	one carburetor per cylinder
fuel requirement	leaded fuel

Drive Train

transmission type	5 speed manual

Chassis

type	motorcycle
tire size	4.00 x 18 (rear)
curb weight	246 kg
inertia weight	330 kg
passenger capacity	2
actual road load	30.7 lb. ft at 65 kph

TEST VEHICLE DESCRIPTION

Chassis model year/make - 1975 Honda MT250
Emission control system - Engine modification and exhaust treatment

Engine

type	2 stroke, Otto cycle, single cylinder
bore x stroke	70 x 64.4 mm
displacement	248cc
compression ratio	6.4:1 (6.8:1 production)
fuel metering	1 barrel carburetor
fuel requirement	unleaded fuel

Drive Train

transmission type	5 speed manual

Chassis

type	motorcycle
tire size	4.00 x 18 (rear)
curb weight	130 kg
inertia weight	210 kg
passenger capacity	1
actual road load	24.9 lb ft at 65 kph

Emission Control System

basic type	Engine modifications with auxiliary HC control in the exhaust

TEST VEHICLE DESCRIPTION

Chassis model year/make - 1975 Honda XL250
Emission control system - Engine modifications

Engine

type	4 stroke, Otto cycle, single cylinder, ohc
bore x stroke	74 x 57.8 mm
displacement	248cc
compression ratio	9.1:1
fuel metering	1 barrel carburetor
fuel requirement	leaded fuel

Drive Train

transmission type	5 speed manual

Chassis

type	motorcycle
tire size	4.00 x 18 (rear)
curb weight	148 kg
inertia weight	230 kg
passenger capacity	2
actual road load	25.9 lb. ft at 65 kph

Procedure for Measuring Sulfate Emissions

1. The fuel was drained from the test motorcycle. The motorcycle was re-fueled with Indolene HO containing 0.03 wt. % sulfur. This fuel was used throughout the sulfate testing.

2. The motorcycle was driven over one LA-4 cycle in preparation for the test series.

3. The following sequence of test cycles was used to measure sulfate emissions:

   a) Cold start '75 FTP.
   b) One hot start sulfate cycle.
   e) One EPA Highway Driving Cycle
   d) One hot start sulfate cycle.

4. The barium chloranilate procedure was used to determine the concentration of sulfates in the exhaust.