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Influence of Fuel Consumption and Instantaneous Exhaust Pollutants on Euro 4 Gasoline Vehicles at Traffic Signalized Intersections: Idling and Start/Restart Manoeuvre

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ABSTRACT:

Despite the more contribution of personal vehicles and transportation automobiles to environmental change, diminutive work has been done to overcome the arising issue regarding exhaust pollutants and fuel consumption. This paper includes the gasoline motor vehicle idling at red traffic signalized intersections using actual world operation statistics. The experimental work has been carried on gasoline vehicles under idling and start/restart manoeuvres on urban plain road conditions. The instantaneous exhaust pollutants such as carbon monoxide, hydrocarbon, carbon dioxide, and nitrogen oxides were evaluated using exhaust gas analyzer and fuel consumption was measured by precise instrument named as fuel flow meter in the Maruti-Suzuki authorized workshop. The results reveal that Maruti Alto vehicle and Maruti Swift vehicle engine should be turned off, if idling is to be over 10 and 11 seconds in duration at traffic signalized intersections respectively. Furthermore, during idling condition, the instantaneous pollutants are almost constant and hydrocarbons are decreased as idling time increased. Nitrogen oxides are function of high combustion temperature formed in an engine.

KEYWORDS:

Exhaust pollutant; European driving cycle; Fuel consumption; Idling; Start/Restart; Traffic signalized intersection

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ACRONYMS AND NOMENCLATURE:

cc	Cubic centimeter
ppm	Parts per million
e	Instantaneous emissions (ppm)
rpm	Revolutions per minute
BTDC	Before top dead centre
MPFI	Multi point fuel injection

1. Introduction

The stabilization and ultimate diminution of vehicle idling exhaust emissions and idling fuel consumption in the world is very crucial in order to minimize the green-house gas emissions and climate change. Within the India, the current issue is how to limit the idling emissions and fuel consumption of vehicles using clean fuel anti-idling technology and the monetary guidelines of industry. One efficient method to alleviate the catastrophic idling emissions is to impose the certain exhaust emission regulations. These emission level limits fluctuate from place to place according to the living culture, anti-idling fuel techniques and also depend on the red traffic signalized intersections. Another effective mode for diminutive these hazardous pollutants are to pinpoint the causes of exhaust pollutants from transportation and domestic sector.

The major problem tackled by the automobile company is the matter of idling condition of vehicle's engine. An idling vehicle is basically one whose engine is running when the vehicle is at traffic signals and parking or just started the vehicle. It simply wastes money, natural resources and contributes the emissions. The drivers generally keep the vehicle's engine in on-condition, whenever the vehicles are seeking for their chance to clear the traffic signals and this result in extra fuel consumption. Sometimes, the drivers want to keep the vehicle more comfortable, that's why more load is supplied to the vehicle's power, such as air-conditioning, heating and ventilation during idling. Studies showed that vehicle emission pollutants close to traffic signalized crossings were sensitive to vehicle speed, deceleration speed, red traffic signal period, traffic queue size, acceleration and ambient conditions [10]. The evaluation of consumption of fuel and exhaust pollutants during vehicle idling was done and related to human idling thinking and behaviour in passenger cars [6].

Furthermore, idling caused 93 million mega tons of carbon dioxide emissions and rate of gasoline consumption was 40.1 billion litres per year. The accurate and precise outcomes of exhaust pollutants and fuel consumption can be obtained by achieving proper driving conditions of vehicle. A possible and practical way is to run the vehicle on a certain driving pattern that represents the driving behaviour for every vehicle while crossing traffic signal junction. This behaviour indicates the driving cycle which illustrates the vehicle speed variation with respect to time for a definite time of travel. The impact of driving patterns on pollutants and consumption of fuel for gasoline automobiles are studied [11] [13]. European driving cycle (EDC) and the Bangkok driving cycle (BDC) was compared for estimating the pollutants as well as fuel consumption.

Health problems are also aggravating on increasing the idling emissions cause cardiac effects, skin diseases, breathing problems, nausea, headache, chronic bronchitis, asthma and even possibly death. To minimize these adverse effects, most of the countries are developing advanced anti-idling technologies. Some substitute anti-idling technologies are listed as: various fuel cells, inverters, auxiliary power units (A.P.U), direct fire heaters, thermal related storage system, and truck stop electrification. Thorough employment of these anti-idling devices offers a considerable declination of exhaust pollutants and fuel consumption through idling of vehicles [8-9] [12].

The objectives of the paper is to evaluate the fuel consumption and instantaneous pollutant characteristics of Maruti Alto and Swift vehicle during idling and start/restart conditions; to determine the optimum stopping time of vehicles at traffic signalized intersections; to determine the behaviour of instantaneous emissions with idling time and start/restart conditions.

2. Literature review

The literature review has been done to evaluate the fuel consumption and exhaust tailpipe pollutant characteristics during vehicle idling and start/restart conditions. Different driving conditions are very sensitive to vehicle emissions. The effect of different driving conditions on the exhaust emissions from European cars were measured using gas analyzer. Thirty vehicles were tested on urban, rural road, main rural road and motorway. Nitrous oxides and carbon monoxide increased by 22% and 27% when acceleration increased. Carbon monoxide and hydrocarbons emissions were sensitive to high speeds [5]. The vehicle cold start emissions were studied at different ambient conditions such as −20 °C, −7 °C and 23 °C [2]. The emissions were more critical during cold starting of vehicles. The cold start pollutants emitted from catalyst installed vehicles were analyzed [7]. Exhaust emissions were measured by constant volume sampling (CVS) method. Results showed that emissions were more significant when engine was cold. The oxides of nitrogen (NO_x), carbon monoxide (CO), particulate matter and hydrocarbons (HC) of passenger cars in different traffic driving conditions under stable and aggressive conditions were measured [16].

The exhaust pollutants were four times more during aggressive driving. Moreover, fuel consumption range elevated from 30% to 40%. The impacts of idling of vehicles on fuel consumption and exhaust pollutants for gasoline as well as diesel based vehicles were considered [1]. The idling emissions were 16500 gm/hr, 86.4 gm/hr, 5130 gm/hr, 4 gm/hr, and 375 gm/hr, for carbon dioxide, hydrocarbon, carbon monoxide, particulate matter and oxides of nitrogen respectively.

Fuel consumption rate during idling was 1.85gal/h. Fuel consumption and exhaust emissions were also strong function of accessory loading and ambient conditions. Idling reduction technologies such as fuel cells, inverters, auxiliary power units (A.P.U) and truck stop electrification were also reviewed. The fuel consumption and emissions using fuel flow meter and semtech emission analyzer during idling were evaluated [3]. The vehicle restart pollutants and fuel consumption were also evaluated and compared with idling conditions. The fuel consumption of vehicles during idling at traffic signals was obtained. Results indicated that maximum drivers (99%) did not turn off the vehicle's engine at signalized junctions and 389.68 litres of diesel, 810.38 litres of gasoline were wasted [4]. The loss of fuel consumption at signalized intersections was measured. Results indicated that 98% of drivers did not switch off the engines of their vehicle at traffic signals and 0.37 million kg of compressed natural gas, 0.13 million litre of gasoline was wasted everyday due to idling of vehicles [14]. An experiment on a passenger vehicle was conducted and fuel consumption was measured during idling and stop/start manoeuvre [17]. The idling stop support system on the vehicles were installed and measured the fuel loss at idling stops in Japan. In conclusion, saving rate of fuel consumption in total road, urban road and rural road were 5.8 %, 13.4 % and 3.4 %, respectively [15].

3. Experimental set-up

Tests are performed on 2007 Maruti Suzuki Alto Lxi and Swift Vxi of Euro 4 gasoline vehicles in Maruti Suzuki workshop. The description of the vehicles (2007 reg.) is given in Table 1. The vehicle instantaneous emission and fuel consumption was evaluated with accurate and precise instruments. The vehicle pollutants data were measured by AVL DIGAS-444 gas analyzer (emission analyzer) that included carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbon (HC), oxygen (O_2), oxides of nitrogen (NO_X) and air-fuel ratio. In the emission analyzer, carbon monoxide and carbon dioxide were precisely calculated by non-dispersive infrared absorption (NDIR), while hydrocarbon was calculated by flame ionization detector (FID) and NO_X were calculated by chemiluminescence detector (CLD). European driving cycle [13] was used to achieve proper driving conditions. The experimental apparatus is given in Fig. 1 and Fig. 2. The specifications of gas analyzer are given in Table 2. The fuel consumption was measured with Econotest fuel consumption meter capable of precise measuring of large flow variations and no need of any power supply. The specifications of Econotest fuel consumption meter are given in Table 3. The experiment is done on Maruti Alto and Swift vehicles when air conditioner is switched off. The fuel consumption and instantaneous pollutants are measured by installing Econotest fuel flow meter and emission analyzer on the gasoline vehicles during idling and start/restart condition.

Table 1: Description of Gasoline cars with MPFI fuel injection

Description	Vehicle A	Vehicle B
Model	Alto Lxi	Swift Vxi
Odometer reading (km)	53638	38967
Engine displacement (cc)	796	1197
Cylinder	3, inline	4, inline
Basic ignition timing (BTDC at idle speed)	5±1°	5±3°
Idle speed (rpm)	900±50	800±50
Compression pressure (bar)	0.83	0.93
Max. power (BHP@rpm)	48@6000	85@6000
Max. torque (Nm@rpm)	69@6000	114@4000
Emission standard	Euro 4	Euro 4
3-way catalytic converter	Yes	Yes
Exhaust gas recirculation	Yes	Yes
Fuel tank capacity (litres)	35	42

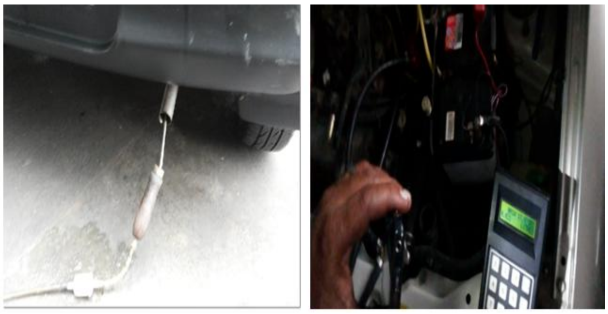

Fig. 1: Experimental set-up of Alto vehicle

Fig. 2: Experimental set-up of Swift vehicle

Table 2: Specifications of AVL Digas-444 gas analyzer

Description	Measurement range	Accuracy
CO (%volume)	0-10	0.01
CO_2 (%volume)	0-20	0.1
HC (ppm)	0-20000	1
O_2 (%volume)	0-22	0.01
NO_x (ppm)	0-5000	1
Oil temperature (°C)	-30 to 125	1
Lamda	0-9.999	0.001

Table 3: Specifications of Econotest fuel consumption meter

Parameter	Value
Construction	Brass with Teflon coated piston – viton Seals
Max. working pressure	20 bar
Working temperature	-10 to 60 °C
Flow range	1-100 litres/hr
Accuracy	±1.5% overall through the flow range
Power supply	4×6 V Duracell

4. Results and Discussion

The fuel consumption and exhaust characteristics outcome examined from Alto and Swift vehicles are demonstrated with the help of graphs. As shown in Fig. 3, the idling cumulative fuel consumption is continuously increasing with idling time. This is because more and more fuel is consumed by an engine as idling time increases. When an engine is started, enriched fuel is being sent to an engine so that the engine does not stall or hesitate during warm-up conditions. The optimum time for switched off Maruti Alto engine at traffic signalized junctions is '10 seconds'. This is because after 10 seconds idling cumulative fuel consumption becomes more than start/restart fuel consumption. The idling cumulative fuel consumption in 10 seconds is 0.008 litres and the start/restart fuel consumption is also 0.008 litres. As shown in Fig. 3, the optimum time for switched off Maruti Swift vehicle engine at red traffic intersections is '11 seconds'. The idling cumulative fuel consumption in 11 seconds is 0.0142 litres and the start/restart fuel consumption is also 0.0142 litres. As shown in Fig. 4, the total instantaneous emissions during idling condition are almost constant as idling time increases. Total instantaneous pollutants include carbon dioxide, carbon monoxide, oxides of nitrogen and hydrocarbon emissions. The instantaneous emissions are constant because there is no increase in idling speed of vehicle. In case of Alto vehicle, the maximum amount of idling instantaneous emissions is 28,765 ppm and minimum amount of idling instantaneous emissions is 28,660.2 ppm. The start/restart instantaneous emission is 17,375.40 ppm. In case of Swift vehicle, the maximum total instantaneous emissions are 71,165.5 ppm during idling state and the total instantaneous emission is 60,480 ppm during start/restart state.

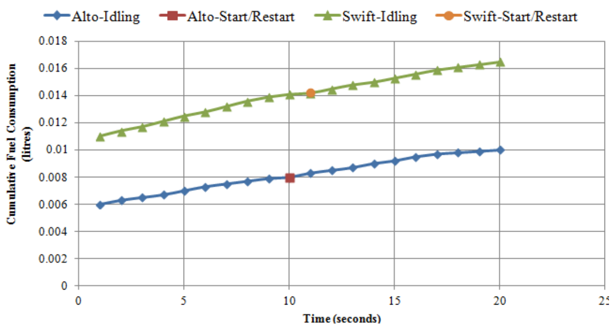

Fig. 3: Variation of idling and start/restart cumulative fuel consumption with idling time

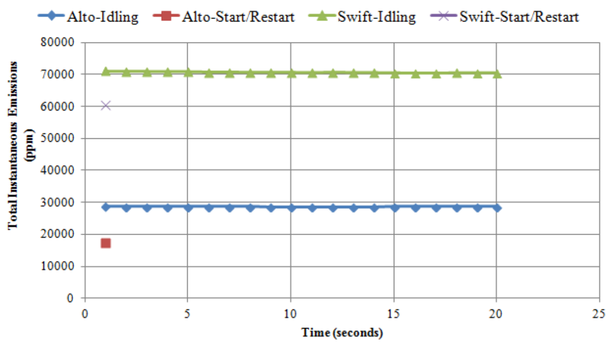

Fig. 4: Variation of idling and start/restart instantaneous emissions with idling time

As shown in Fig. 5, In case of Alto vehicle, the carbon dioxide (CO_2) emission is 16,000 ppm followed by oxides of nitrogen (NO_x) is 750 ppm, carbon monoxide (CO) emission is 580 ppm and hydrocarbon (HC) emission is 45.4 ppm during start/restart condition. In case of Swift vehicle, the instantaneous carbon dioxide (CO_2) pollutants are 51,400 ppm, oxides of nitrogen (NO_x) are 750 ppm, carbon monoxide (CO) emissions are 8,200 ppm and hydrocarbon (HC) pollutants are 130 ppm during start/restart state. CO_2 is a dominating factor because catalytic converter oxidizes most of the CO, NO_x and HC emissions to CO_2 and H_2O in the exhaust system using palladium, platinum and rhodium catalysts. Palladium and platinum promote the oxidation of CO and HC whereas rhodium promotes the reduction of NO_x. As shown in Fig. 6, In case of Alto vehicle, the instantaneous carbon dioxide (CO_2) emission is almost constant as idling time increases. The idling speed of vehicle is kept constant that leads to no change in instantaneous carbon dioxide emissions with idling time. The maximum amount of idling instantaneous carbon dioxide emissions is 28,000 ppm and minimum amount of idling instantaneous carbon dioxide emissions is 27,900 ppm. The start/restart instantaneous carbon dioxide emission is 16000 ppm. In case of Swift vehicle, the maximum amount of idling instantaneous carbon dioxide emissions is 65,200 ppm and minimum amount of idling instantaneous carbon dioxide emissions is 64,800 ppm. The start/restart instantaneous carbon dioxide emission is 51,400 ppm.

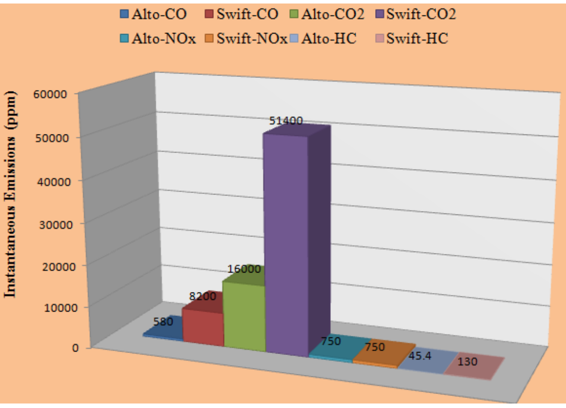

Fig. 5: Variation of start/restart instantaneous emissions

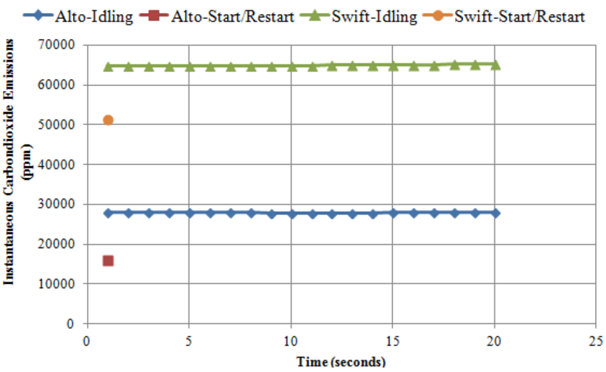

Fig. 6: Variation of instantaneous carbon dioxide emissions with idling time during idling and start/restart condition

Hydrocarbons (HC) are un-burnt particles and smaller particles of partially burnt fuel. The instantaneous hydrocarbon emissions during idling condition are decreasing, because catalytic converter is continuously oxidizing hydrocarbon into carbon dioxide and water as idling vehicle time of an engine is increasing. The palladium and platinum catalysts reacts with hydrocarbon to form carbon dioxide and water. Catalytic converter plays a vital role in reduction of exhaust hydrocarbon, carbon monoxide, nitrogen oxides. Catalytic converter works properly when the vehicle engine temperature reaches the light off temperature (250 to 300 °C). In case of Alto vehicle shown in Fig. 7, the maximum amount of idling instantaneous hydrocarbon emissions is 15 ppm and minimum amount of idling instantaneous hydrocarbon emissions is 8.5 ppm. The start/restart instantaneous hydrocarbon emission is 45.4 ppm as shown in Fig. 7. The instantaneous hydrocarbon emissions are more during start/restart condition because when an engine is started, enriched fuel is being sent to an engine. This leads to incomplete combustion of fuel and hydrocarbons are formed. In case of Swift vehicle, the maximum amount of idling instantaneous hydrocarbon emissions is 115.5 ppm and minimum amount of idling instantaneous hydrocarbon emissions is 62 ppm. The start/restart instantaneous hydrocarbon emission is 130 ppm.

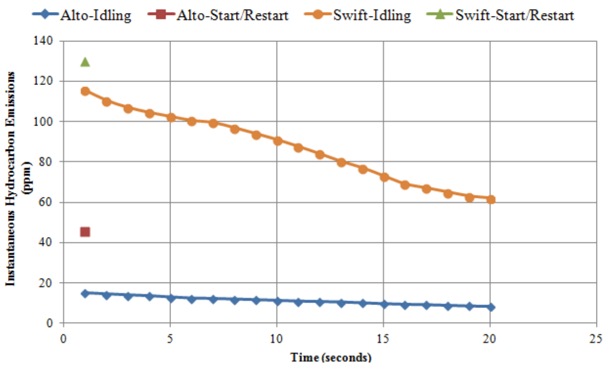

Fig. 7: Variation of instantaneous hydrocarbon emissions with idling time during idling and start/restart condition

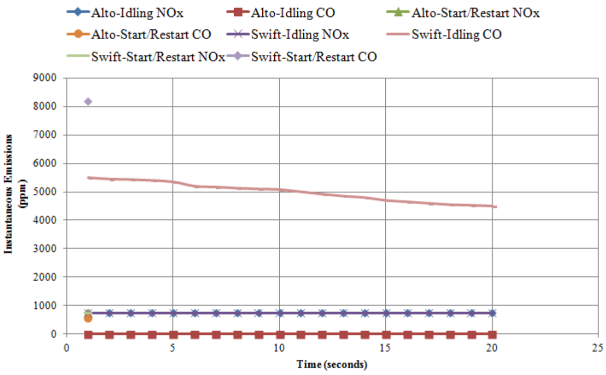

Fig. 8: Variation of instantaneous nitrogen oxides and carbon monoxide emissions with idling time during idling and start/restart condition

As shown in Fig. 8, the idling instantaneous NO_x and CO is constant as idling time increases. When sufficient amount of oxygen is not present then carbon monoxide is formed. Nitrogen oxides are strong function of high combustion temperature. In case of Alto vehicle, the instantaneous NO_x emission is 750 ppm during idling and start/restart condition. The instantaneous carbon monoxide is 580 ppm during start/restart condition because of incomplete combustion of fuel and there is no formation of instantaneous carbon monoxide during idling condition. In case of Swift vehicle, the idling and start/restart instantaneous nitrogen oxide pollutants are 750 ppm. The start/restart instantaneous CO is 8200 ppm. The maximum value of carbon monoxide during idling condition is 5,500 ppm and the minimum value of carbon monoxide during idling is 4,500 ppm.

5. Conclusions

Conclusions summarized from the experimental investigation are as follows:

- The Maruti Alto vehicle engine should be turned off, if idling is to be over 10 seconds in duration at traffic signalized intersections. Hence, the vehicle engine should be switched / shut off, if red traffic signal time goes beyond 10 seconds.
- The Maruti Swift vehicle engine should be turned off, if idling is to be over 11 seconds in duration at red traffic signals.
- The instantaneous emissions such as carbon dioxide, carbon monoxide, oxides of nitrogen and hydrocarbon during idling condition are almost constant as vehicle idling time increases.
- Carbon dioxide emissions are maximum during vehicle start/restart condition and hydrocarbon emissions are decreasing as vehicle idling time increases.
- Nitrogen oxide emissions are function of combustion temperature.

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