Fuel 107 (2013) 371–381

Contents lists available at SciVerse ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

Fuel formulation for recent model light duty vehicles in Mexico base on a model for predicting gasoline emissions

I. Schifter *, L. Díaz, U. Gonzàlez, C. González-Macías

Instituto Mexicano del Petróleo, Dirección de Seguridad y Medio Ambiente, Eje Central Lázaro Cárdenas No. 152, San Bartolo Atepehuacan, DF 07730, Mexico

HIGHLIGHTS

- ▶ Exhaust and evaporative emissions were characterized in recent vehicles.
- ▶ Low sulfur gasoline was employed.
- ▶ Fuel quality parameters were investigated.
- ▶ An statistical model was developed to predicts emissions.
- ▶ Prediction allows refineries to optimized fuel composition.

ARTICLE INFO

Article history:
Received 6 August 2012
Received in revised form 18 October 2012
Accepted 20 October 2012
Available online 5 November 2012

Keywords:
Gasoline properties
Light duty vehicles
Predictive model
Regulated and toxic emissions
Dynamometer

ABSTRACT

Effects of gasoline properties on exhaust and evaporative emissions on light duty vehicles ranging in model year from 2008 to 2010 were tested on a chassis dynamometer over the US FTP-75 driving cycle. Tailpipe emissions were characterized for criteria pollutants (CO, NOX, NMHC, and NMOG), and a suite of unregulated emissions including important air toxics, carbonyls, and ozone reactivity. Measurements were performed under three different driving conditions, i.e. cold transient, stabilized and hot transient. These three driving conditions were simulated using the US FTP-75 driving cycle. Hot soak and diurnal evaporative emissions were quantified and characterized for NMHC. The fuel quality parameters investigated include RVP, oxygen, olefins, aromatics, distillation parameters and sulfur in the range from 5 to 19 ppm. The results of the study were used to update a previous statistical model developed for predicting emissions based on fuel quality. The procedures and statistical methods employed to develop the predictive model for this test program were similar to those used to construct the United States Complex models for regulated and toxics emissions. The predictive model allows refineries to optimized gasoline compositions providing they can show that certain emission outcomes (as prescribed by regulation) will be achieved.

1. Introduction

The largest source of emissions in most urban areas of Mexico is vehicles, which includes tailpipe and evaporative emissions [1]. Anthropogenic volatile organic compounds (VOCs), carbon monoxide (CO), and nitrogen oxides (NOx) are important precursor compounds to ozone and secondary organic aerosol (SOA) formation [2]. Understanding ozone precursors and being able to model them accurately to derive the impact of emissions changes is important for policy-makers and the improvement of air quality in many urban areas [3–5]. Certain VOCs are very reactive in the atmosphere (e.g. xylenes and benzene compounds) and therefore have very high potential for ozone and SOA formation [6]. Accurate modeling of the individual VOCs will lead to better predictions of secondary organic aerosols formation and ozone levels.

Motor vehicles and other combustion sources emit also many air toxics whose levels are not regulated, but that are known or suspected, with sufficient exposure, to cause adverse health effects. Among these are mobile-source air toxics (MSATs), compounds based on their emissions and reported toxicity, pose the greatest risk to health—benzene, toluene, 1,3-butadiene, formaldehyde, polyaromatic hydrocarbons, MTBE, n-hexane and xylenes [7]. Additionally, carbonyls in urban areas are known as key compounds of photochemically generated air pollution, since they are precursors to free radicals (HOx) and peroxyacyl nitrates [8,9].

Mobile-source emissions in the Metropolitan Area of Mexico City (MAMC) have been studied since the early 1990s using several measurement techniques including remote sensing [10,11], dynamometer studies [12], tunnel studies [13], and more recently with

* Corresponding author. Tel.: +52 9175 8507; fax: +52 9175 8484.
E-mail address: ishifter@imp.mx (I. Schifter).

0016-2361/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.fuel.2012.10.046

on-road sampling techniques [14]. Observed historical trends of ozone, CO, and NOx suggest that ozone production in MAMC has changed from a low to a high VOC-sensitive regime over a period of 20 years. Results of model analyses predict that significant benefits can be achieved by controlling anthropogenic emissions, particularly VOCs [15]. Three primary strategies have been employed to reduce emissions from vehicles: (1) engine modifications, such as fuel injection; (2) after treatment, such as catalytic converters; and (3) fuel reformulation [16].

Exhaust emissions from vehicles are not dependent only on automotive technologies, but also on fuel qualities. With more stringent emission standards around the world, fuel quality is becoming a great concern for the automobile and oil industries. In the USA, the Auto/Oil Air Quality Improvement Program examined potential improvements in vehicle emissions and, ultimately, air quality from reformulated gasoline [7,17,18].

In year 1996 the Mexican environmental agency mandated reformulated gasoline (RFG) requirements as a measure to reduce emissions from gasoline-powered vehicles in certain geographic areas. The principal driver for changing to fuel quality standards in Mexico is an environmental one – the need to provide fuels that facilitate the adoption of emerging vehicle engine and emission control technologies, a key strategy in managing air pollution and greenhouse gas emissions. This is supported by the need to better manage those fuel parameters that do not impact directly on vehicle technology, but nevertheless contribute to ambient levels of pollutants identified as posing health or environmental problems.

Up to these days, the "flat limits" model used to formulate gasoline in Mexico requires that each liter of fuel supplied must comply with a certain limit (maximum, minimum) for specific fuel parameters. Industry generally concurs that it is appropriate to apply flat limits to parameters where consistency is necessary to allow vehicle engines to operate efficiently in terms of performance, fuel economy and emissions.

The approach to formulate gasoline in the USA is based on predictions of the effects of changes in fuel properties rather than fuel composition. Hence, the United States Environmental Protection Agency's (USEPA) Complex model and the California Air Resources Board's Predictive Model are used to certify reformulated gasoline by calculating emissions performance reductions from a statutory baseline gasoline on Tier 0 vehicles (1990 and earlier model years) [19–21].

These emissions models allow other legislation to set emissions standards. The Complex set the seasonal emission reduction standard to 25% for VOCs and 5.5% for NOx, while also tightening the year-round total air toxics standard to 20%. The pooling problem minimizes cost by optimally selecting flow rates on a predetermined network structure of feed stocks, pooling tanks, and final products. In a refining application, temporary storage tanks or pools, which are subsequently mixed into final products, are monitored to ensure that the concentration of regulated qualities does not exceed environmental limits in the final products [20].

In year 2010 RFG with less than 30 ppm average sulfur was mandated in high polluted areas of the country. Extensive studies have shown that sulfur in gasoline and diesel fuel negatively affects the performance of after-treatment systems and also contributes to particulate sulfate and sulfur oxides emissions. Hence, the benefits of sulfur reduction are twofold. First, lower sulfur enhances the performance of emission control devices by improving their efficiency, as is the case of the three-way catalyst for gasoline vehicles. Second, lower sulfur fuel enables the adoption of certain emission control technologies, such as diesel particulate filters, that otherwise would render unacceptable performance and risk damage.

Previously we developed an emission model that relate gasoline properties to the exhaust emissions and evaporative emissions changes which result when the gasoline is used to fuel a motor vehicle. The model predicts changes for seven pollutants (NOx, CO, VOCs, 1,3-butadiene, benzene, formaldehyde, and acetaldehyde) for two technological classes of light duty cars and trucks, ranging in model year from 1993 to 2002 [22]. Vehicles were classified into two different technological groups: "Tier 0" fleet where vehicles complying emission limits of 2.1 g km^{-1} for CO, 0.25 g km^{-1} for THC and 0.62 g km^{-1} for NOx. "Tier 1" fleet is made up of vehicles meeting certification emission standards of 2.1 g km^{-1} for CO, 0.156 g km^{-1} for non-methane hydrocarbons, and 0.25 g km^{-1} for NOx.

The fuel quality parameters investigated include RVP, oxygen, sulfur, olefins, aromatics, and distillation parameters. The end result of our model is a general qualitative agreement with the Complex model, with some quantitative differences pertaining to the vehicles and fuels used in each model's development [23].

Consequently, this study was undertaken to update the model to cover gasoline reformulation at low sulfur levels and calculate the impact on the most advanced technology light-duty vehicles available in Mexico in order to provide to industry with flexibility in terms of compliance options. With the introduction of low sulfur gasoline vehicles must fulfill the emissions regulations limits for new vehicles (CO, 2.11 g km^{-1}; non-methane hydrocarbons (NMHCs), 0.047 g km^{-1}, and NOx, 0.068 g km^{-1}).

A comprehensive pollutant emission evaluation, including regulated pollutants (CO, NOX, and total hydrocarbons), individual organic compounds and carbonyls was conducted on a chassis dynamometer with a fleet of light-duty gasoline vehicles model years 2008–2010. Evaporative emissions were quantified and characterized for non-methane hydrocarbons. The ozone forming potential of volatile organic compounds in the exhaust and evaporative emissions were calculated to provide useful information related to the potential impact of the physicochemical parameters of the gasoline.

2. Methods

2.1. Fuels

A total of seven fuels were blended with distillate fractions selected aromatic, paraffinic and olefinic refinery components to produce a test fuel matrix to separate physical and compositional effects. The main physicochemical characteristics of the test fuels are listed in Table 1. The inspection data for the gasoline components was performed following American Society for Testing Materials procedures [24].

Fuels coded A, B, and C is used to investigate the effect of aromatic content on emissions. Fuel B served as the base fuel for comparisons, as it is the properties of the fuel are similar to the one currently used in the ozone non-attainment areas, such as the MAMC. Test fuels coded D and E are used to compare the effect of varying the olefin content. Fuel F is formulated with the lowest RVP value, while fuel G is blended without oxygenated compounds.

2.2. Vehicles selection and preconditioning

The vehicle definition included make, model year, engine size, and exhaust and evaporative emission certification classes. The vehicles tested exactly met the requested vehicle specifications. Test vehicles were procured from private parties specifically for use in this program. The specific details of the vehicles recruited are listed in Table 2. Accumulated odometer mileages were appropriate for the model year procured, ranging from 12,600 km to 23,800 km. The vehicle model years ranged from 2008 to 2010.