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JAMA Position on the Use of Biodiesel as a Generally Available Diesel Fuel in the Market

Fuel & Lubricants Subcommittee
Japan Automobile Manufacturers Association, Inc. (JAMA)

Introduction

JAMA has long endorsed the use of biodiesel in automotive fuel because it contributes to reduced carbon dioxide (CO_2) emissions in the earth's atmosphere. In recent years, moreover, the significance of biodiesel use has increased as more and more countries and regions pursue carbon neutrality goals to address global warming.

Automobile manufacturers' products must meet regulatory requirements and consumer needs with respect to operation, fuel efficiency, durability and exhaust emissions performances. Vehicle development is a multi-year process that includes verification procedures by manufacturers to ensure regulatory compliance as well as consumer satisfaction. Fuel quality is a critical factor in vehicle performance overall and manufacturers carry out their development and verification activities assuming some variability in market fuel quality. However, when actual market fuel quality exceeds the parameters of such variability, safe vehicle operation may be at risk.

Automobiles today have sophisticated fuel delivery and exhaust aftertreatment systems in order to comply with emissions requirements, and the specifications for those systems vary. The specific systems with which vehicles are equipped are determined on the basis of multiple factors including vehicle configuration and individual manufacturers' system design policies and criteria. Accordingly, there is in fact a very wide range of these integrated (i.e., fuel delivery and exhaust aftertreatment) systems and their fuel sensitivity—that is, their compatibility with variations in fuel quality—differs. (Generally speaking, however, systems comprising a large number of components and systems featuring advanced technologies will have stronger fuel sensitivity.)

JAMA has previously published three position statements on biodiesel fuel use (in 2009, 2015, and 2016, respectively) premised on circumstances prevailing at the time of their release. The drafting of the present position statement was deemed necessary by JAMA in view of the automobile industry's evolving circumstances as well as the progress made in relevant technologies and the results obtained from research activities conducted since 2016.

Biomass-Based Diesel Fuel: An Overview

There are two main types of biomass-based diesel fuel. The most common is biodiesel, frequently referred to as FAME (for fatty acid methyl esters) biodiesel or simply FAME, which is produced by the chemical reaction-based esterification (or transesterification) process using methanol. The other is renewable diesel, sometimes referred to simply as HVO (for hydrotreated vegetable oil), which is produced by hydrogenation or hydrocracking.

FAME or HVO blended with fossil diesel (also known as petroleum diesel) fuel become finished fuels deliverable at the pump and as such, their quality must conform to established fuel quality standards to prevent the occurrence of vehicle operational issues. FAME differs from fossil diesel fuel in key aspects because of its feedstock-derived components. Owing to its use of different feedstocks, its physical properties are not constant, and its oxidation stability is lower than that of fossil diesel fuel. Also, FAME's properties and characteristics become more prominent the higher the ratio of FAME blendstock in fossil diesel fuel.

The European standards (EN) and the U.S. standards (ASTM) specifying property requirements and test methods for FAME and FAME-blended diesel fuels are the standards that are generally applied. Because some of those requirements may not be optimal, JAMA would like to present its own recommendations with respect to some of FAME's properties, as follows below.

Key Characteristics and JAMA Recommendations

■ Oxidation Stability

FAME has lower oxidation stability than fossil diesel fuel owing to its double-bond components. Double bonds are easily decomposed by a chemical reaction and can be recomposed with another component through a further chemical reaction. When FAME is blended with fossil diesel fuel, such reactions will trigger the generation of organic acids and the formation of polymer-containing sludge. The acids will attack to materials in a vehicle's fuel system components and the sludge will be trapped by the fuel filter, causing it to clog (referred to as filter plugging). Moreover, trace metals that may be present in the fuel blend will accelerate the formation of injector deposits that can clog the holes in the injector nozzles, which will restrict fuel flow to the engine and thereby reduce engine power output. Oxidation stability performance in automotive FAME-blended diesel fuels should be the same regardless of the variations in their FAME concentration ratios and a uniform value for oxidation stability should therefore be stipulated in fuel quality standards. Oxidation stability is much less of an issue in hydrotreated renewable diesel fuels such as HVO because they do not contain double-bond components.

Recommended procedures for testing oxidation stability in B100 FAME and FAME-blended (BXX) diesel fuels

B100 (pure) FAME: 10 hours minimum by Rancimat method

BXX FAME blends: 35 hours minimum by Rancimat method
or 65 minutes minimum by PetroOXY method
or 0.12 mg KOH/g maximum by Delta TAN method

Potential adverse impacts on vehicles:

Engine start-up difficulty due to filter plugging; Poor acceleration; Deteriorated fuel efficiency

- **Cold Performances**

FAME contains some impurities from its feedstocks including monoglycerides, which cannot be removed in the FAME manufacturing process and whose amounts in FAME vary depending on the feedstock used and the specific manufacturing process applied. Monoglycerides transform from a liquid state to form solids ("precipitates") when pure FAME or a FAME-blended diesel fuel is stored at 20° Celsius or lower over an extended period of time. When, for example, precipitates form in a vehicle's fuel tank during a significant period of non-use of the vehicle, the precipitates will be trapped by the fuel filter and may completely plug the filter shortly after engine start-up. The higher the blend ratio of FAME in diesel fuel the greater the likelihood of this development occurring, a critical factor, therefore, when considering the use of FAME-blended diesel fuel in cold climates. Upper limits for monoglyceride content are stipulated only in B100—i.e., pure FAME, before blending with fossil diesel—standards (EN 14214, ASTM D6751). With the use of FAME-blended diesel fuels, monoglyceride content will vary depending on the FAME blend ratios. Therefore, JAMA's position is that the monoglyceride content stipulated in the B100 standards should be revised depending on the particular FAME blend ratio. HVO and other hydrotreated renewable diesel fuels do not contain monoglycerides because they are removed during the fuel manufacturing process.

Recommendations on monoglyceride content (B100)

Adoption of the upper limit for monoglyceride content stipulated in the current version of EN 14214 is recommended for diesel fuel blended with up to 7% FAME. If FAME concentration in diesel fuel exceeds 7%, field tests should be conducted in geographic regions that record the coldest temperatures to ascertain the extent of monoglyceride precipitate formation and thereby to determine a more appropriate upper limit for monoglyceride content in B100 or an appropriate upper limit for FAME concentration in diesel fuel for market supply. A FAME blend ratio in diesel fuel of up to 7% is recommended for countries/regions/areas that experience temperatures of 20°C or lower.

Potential adverse impacts on vehicles:

Engine start-up difficulty due to filter plugging; Poor acceleration; Deteriorated fuel efficiency

■ **Heating Value**

Since FAME consists of fatty acid methyl esters (oxygenated fuels) containing impurities in contrast to hydrocarbon-only fossil diesel fuels, the heating value per unit of volume of FAME is lower than that of fossil diesel—generally, about 10 to 12% lower. Because of this difference in heating values, the use of FAME-blended diesel fuel results in reduced fuel efficiency and lower full-load engine performance (torque). Moreover, the higher the blend ratio of FAME in diesel fuel, the more these performances deteriorate. Generally, heating values are not specified in automotive diesel fuel quality standards.

Potential adverse impacts on vehicles:

Poor acceleration; Deteriorated fuel efficiency and gradeability; Change in warm-up temperature profile of catalytic converter leading to white smoke production and filter plugging

■ **Distillation Characteristics**

FAME contains numerous components with molecular weights that are heavier than those of fossil diesel components and its evaporation points are generally higher than fossil diesel's evaporation points. Fossil diesel can evaporate at approximately 180°C to 360°C, with its lighter components evaporating at lower temperatures and its heavier components evaporating at higher temperatures. On the other hand, FAME contains a larger number of heavy components than fossil diesel and it has a far smaller number of components that can evaporate at 180°C to 320°C. As a representative example, if the temperature at which 10% of the fuel evaporates is defined as T10, the temperature at which 50% of the fuel evaporates defined as T50, and the temperature at which 90% of the fuel evaporates defined as T90, the evaporation points for fossil diesel/FAME (B100) are T10: 215°C/325°C; T50: 276°C/328°C; and T90: 330°C/336°C and the properties of FAME in the low evaporation-point temperature range are significantly inferior compared to fossil diesel. In the case of B7 (diesel fuel blended with a FAME concentration of up to 7%), the difference in distillation characteristics compared to fossil diesel is negligible, but that difference increases with higher FAME blend ratios and it can adversely impact vehicle operability. Diesel fuel quality standards for the most part specify distillation characteristics at T90 or T95, but with distillation characteristics for fossil diesel and FAME at T90 and T95 being similar regardless of FAME's blend ratios, diesel fuel quality standards generally do not specify any significant differences. It is therefore difficult to make recommendations on distillation specifications.

Potential adverse impacts on vehicles (particularly with higher FAME concentrations in diesel fuel):

Increases in engine lubricant oil (at gauge); Accelerated degradation of engine lubricant oil; Increased frequency of engine oil filter replacement; Shorter engine life (worst case); Tailpipe-emitted white smoke; Filter plugging due to unburned FAME and change in warm-up temperature profile of catalytic converter

■ **Permeability**

Specific characteristics of FAME biodiesel may cause the rubber used in seals and hoses in fuel delivery systems to harden and become distended. Higher concentrations of FAME in diesel fuel thus pose a potentially serious risk to the viability of rubber components in fuel delivery systems and in their design specifications-mandated performance, and could result in fuel leakage. Older in-use vehicles are particularly vulnerable to this risk since they were not designed to accommodate the use of FAME-blended diesel fuel. Daily inspection of such vehicles is therefore recommended as a risk-avoidance measure.

Potential adverse impacts on vehicles:

Swelling of rubber components in fuel lines; Fuel leakage

■ **Solvency**

Because of its composition, the solvency of FAME is such that it may loosen and even dissolve sediments in fuel lines and in fuel delivery system components. When FAME-blended diesel fuel, regardless of its particular FAME blend ratio, is used in an older vehicle that previously ran on fossil diesel, the accumulation of sludge in the fuel line resulting from such solvency can quickly lead to filter plugging.

Potential adverse impacts on vehicles:

Engine start-up difficulty; Engine stalling and power loss due to restricted fuel delivery

■ **Exhaust Emissions**

To ensure compliance with stringent emissions regulations such as Euro5/V and Euro6/VI, manufacturers equip their vehicles with various engine emission control technologies/systems such as advanced exhaust gas recirculation (EGR) and exhaust aftertreatment systems. Significantly reduced engine emissions enhance the operational efficiency of onboard emission control systems. Advanced fuel injection technology controls the amount of fuel injected in engine cylinders as well as the pressure and timing with which the fuel is injected, enabling more efficient engine performance, increased fuel efficiency, and reduced emissions. Fuel delivery systems and exhaust aftertreatment systems are installed onboard vehicles in a multiplicity of combinations, determined not only by vehicle configuration but also by manufacturers' system design policies and criteria.

The amount of soot (i.e., diesel particulate matter) emitted by an engine running on a FAME-diesel fuel blend is generally lower than the amount emitted by an engine running on fossil diesel. Furthermore, while the engine's nitrogen oxide (NOx) emissions tend to increase, its hydrocarbon (HC) and carbon monoxide (CO) emissions tend to decrease because of the oxygen contained in FAME. However, for vehicles equipped with advanced emission control technologies/systems enabling compliance with stringent emissions requirements this may not be the case. The impact on emissions when those vehicles run on diesel fuel blended with FAME at concentrations exceeding 7% will vary depending on the specific emissions reduction technologies/systems with which they are

equipped. Moreover, many of those vehicles will be equipped with an On-Board Diagnostics (OBD) system and the impact on OBD systems of diesel fuel blended with FAME at concentrations in excess of 7% is a serious concern.

Potential adverse impacts on vehicles:

Increases in tailpipe emissions resulting from degraded performances of emission control systems/devices; "Check engine" alert (dashboard light) as a result of non-standard diagnostic or faulty diagnostics; Drivability impacted by "limp home mode" diagnostic

- **Long-Term Storage (Degradation in Fuel Quality)**

Over time the quality of FAME in fuel storage tanks can deteriorate. Factors contributing to the degradation include storage temperature, moisture, water content, and microbiological and other contamination. Especially in geographic regions with high temperatures and high humidity, oxidation stability may deteriorate, resulting in the generation of organic acids. When FAME is stored at temperatures lower than 20° Celsius, the monoglycerides contained in FAME turn from a liquid to a solid state to form precipitates, a phenomenon which can take place in storage tanks, in underground tanks at service stations and, also, in vehicle fuel tanks depending on temperature conditions and storage duration (i.e., the length of time during which a vehicle is not in use).

Guidelines for the use of FAME in many cases recommend that FAME biodiesel should be consumed no later than six months after its manufacture. It is also recommended that FAME biodiesel used to fill a vehicle fuel tank should be consumed within one month, and that FAME not consumed within one month should be drained from the fuel tank and replaced with fresh fuel. JAMA endorses these recommendations in order to prevent potential problems caused by the use of aged and degraded FAME.

Potential adverse impacts on vehicles:

Engine start-up difficulty due to filter plugging; Engine stalling; Poor acceleration; Unstable idling

- **Conditional Use of Higher FAME Blends**

JAMA confirms the acceptability of using diesel fuel containing FAME concentrations not exceeding 20% (B20) when the conditions and requirements stipulated below are met. Meeting those conditions and requirements is necessary in order not to jeopardize safe vehicle operation and in order to avoid potential problems for vehicle operators.

<u>Conditions of use</u>

- Climatic conditions: Warm or hot climates
- Feedstock: PME (palm methyl ester) only
- Maximum FAME concentration: Must not exceed 20%
- Exhaust emission standards compliance level applicability: Vehicles complying with up to Euro4/IV standards or R83/R49 in the UN regulations

Requirements for use

- Oxidation stability:
  B100 (pure) FAME: 10 hours minimum by Rancimat method
  BXX FAME blends: 35 hours minimum by Rancimat method
  or 65 minutes minimum by PetroOXY method
  or 0.12 mg KOH/g maximum by Delta TAN method
  The above requirements apply only when BXX does not contain a cetane booster.
- Monoglyceride content for B100:
  Upper limit value must be specified in the national B100 standard, based on real-world verification testing conducted in geographic regions that record the lowest temperatures in the country concerned.
- Water content for BXX: 200 ppm maximum
- Public notification:
  Government/relevant stakeholders must notify the public of the problems that may arise—for example, plugged filters (to be avoided by shorter fuel-filter maintenance intervals)—for vehicle operators using diesel fuel containing high FAME concentrations.

Summary

Recognizing that the use of biodiesel-diesel fuel blends will contribute to reduced carbon and other greenhouse gas emissions in the earth's atmosphere, JAMA carries out research and studies on optimizing the safe and secure use of biodiesel in automobiles without posing any burden on vehicle owners/operators.

Appropriate fuel quality is key to the safe and secure use of FAME-blended diesel fuel. Compliance with established fuel quality standards will ensure that fuels of the appropriate quality are delivered to the market. Fuels blended with FAME at a ratio of up to 7% must meet the requirements of EN 590 or ASTM D975. For fuels with FAME concentrations higher than 7% but not higher than 20%, there is concern that actual market fuel quality could exceed the parameters the automobile industry assumes in regard to the variability of such fuel quality. JAMA therefore strongly recommends compliance with the requirements for their use which are stipulated herein.

In order to comply with increasingly stringent automotive exhaust emission regulations, automobiles today are equipped with systems, technologies and devices of increasing complexity that, in turn, may impact vehicle performance when diesel fuel blended with FAME at concentrations higher than 7% is used. Particularly in countries/regions where stricter emission regulations such as Euro5/V or Euro6/VI are in force and where B7+ FAME-blended diesel fuel is supplied at the pump, government and other relevant stakeholders must provide the public with the information it needs for the safe and secure operation of new and in-use vehicles running on B7+ FAME-blended diesel fuel. At the

same time, the market supply of B7 diesel fuel (i.e., EN 590-compliant) must be assured for vehicles adversely impacted by the use of diesel fuel blended with FAME at concentrations higher than 7%.

The supply of hydrotreated renewable diesel such as HVO is expected to expand worldwide in the near future as a result of the adoption of policies and actions taken in pursuit of carbon neutrality. JAMA takes this opportunity to strongly recommend the use of HVO as a preferable alternative to the use of B7+ FAME-blended diesel fuel.

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