ARAI Journal of Mobility Technology
Volume 1 • Issue 1 • October–December, 2021, pp. 1-8
Research Paper
https://doi.org/10.37285/ajmt.1.0.1

Impact of 20% Ethanol-blended Gasoline (E20) on Metals and Non-metals used in Fuel-system Components of Vehicles

Moqtik A. Bawase and Sukrut S. Thipse

Environment Research Laboratory, Automotive Research Association of India, Survey No. 102, Vetal Hill, off Paud Road, Kothrud, Pune - 411 038

ABSTRACT

Ethanol is considered as a potential biofuel for blending with gasoline and, in India, it is planned to increase the ethanol content to 20 percent in gasoline by year 2025 from present allowable limit of maximum 10 percent. It is important to evaluate the impact of E20 fuel on the materials used in fuel-system components. An evaluation of 8 metals, 6 elastomers and 4 plastics used in various fuel-system components was conducted through systematic exercise of laboratory immersion following standard methods like SAE J1747 and SAE J 1748 with all the quality and quality assurance measures. The study was conducted with E20 as test fuel and commercial gasoline (BS IV) as a baseline fuel for comparative assessment. Impact of E20 on metals was evaluated through calculation of corrosion rates in mm/year based on data obtained for change in mass post-immersion in above fuels. Similarly, impact of elastomers and plastics was evaluated through observed changes in properties like mass, volume, tensile strength, elongation, impact strength and hardness.

Impact of E20 on metals tested was found to be insignificant based on the corrosion rates. Polychloroprene, SBR, HNBR and Fluoroelastomer were found to perform similar or better in most of the properties with E20. Impact of E20 on NBR-PVC and Epichlorohydrin was more as compared to commercial gasoline. Similar changes in properties of PA12, PBT and Acetal were observed in both the fuels. Impact of E20 on tensile strength and volume change properties of PA66 was found to be more than commercial gasoline. The vital information generated can be utilised by design engineers for selection, modification of materials for various components of fuel-system of vehicles.

KEYWORDS: E20 fuel, material compatibility, ethanol, biofuels, fuel system, alternate fuels.

Introduction

Use of biofuels like ethanol as a blending component with gasoline, as an alternate fuel, has certain distinct benefits like reduced emission levels, reduced dependence on imported crude oil, savings on import duty. In India, ethanol is mainly produced from sugarcane, thus lead to local job creations providing socio-economic benefits also through increased income to farmers due to value addition to the sugarcane feedstock. Advantages of ethanol, produced from different feedstocks, as a potential alternate fuel for blending with gasoline has been discussed by various researchers (Thummadetsak, 2008; MPCA, 2015; Ramadhas, 2010; Goldemberg, 2013; Gajendra Babu and Subramanian, 2013; Peason and Turner, 2014; Stradling et al., 2013).

Presently, in India, 10 percent of ethanol is allowed to be blended in the gasoline (E10) and it is planned to increase the ethanol content in gasoline-ethanol blend to reach to 20 percent (E20) by 2025. The older and new technology vehicles running on Indian roads are designed to run on gasoline fuel with maximum 10% ethanol as per the specification IS:2796. It is, therefore, imperative to evaluate performance of vehicles, not only in terms of operational parameters like combustion, power, driveability but also with respect to the compatibility of materials used in fuel-system components, with higher ethanol blend like E20. This is important for the component to perform its function effectively for its intended life without any problem.

Various metallic and non-metallic materials (polymers) are used in fuel system components(ACC, 2014; Szeteiová, 2010).Metals mainly, aluminium, brass, copper and steel alloys are used for fuel, tank, fuel-pipes and engine components (Table 1). Similarly, elastomers are used in flexible hoses, seals and gaskets and plastics are used for flex and rigid piping, sumps, tubing of vapour recovery system (Table 2). These materials, which come in contact with fuel are prone to swelling when they are exposed to higher alcohol blends like E20 and may also exhibit deterioration in mechanical properties like tensile strength, hardness, etc. due to leaching of material, plasticization. Similarly, metals are impacted by galvanic corrosion, pitting, etc. (Kameoka et al., 2005; Gailis, 2015; Nihalani et al., 2004; Wagner et al., 1979; SAE International, 1982; 2015; Thomas, 2009; Jones et al., 2008; Dhaliwal et al., 2014; Black, 1991; Owen and Coley, 1990; DiCicco, 2010).

TABLE 1

Typical metals used in Vehicle Fuel Systems.

Alloy	Typical Use
Aluminium alloy	Carburettor, accelerator pump, Fuel pump casing, pistons
Magnesium alloy	Fuel pump casing, plate on steel, brass component specialty-purpose two-cycle engine transmission housings.
Copper	Tubing, fuel rails
Carbon steel	Fuel line, fuel pump fitting and casing, fuel filter, fuel tank, Carburettor fuel Inlet, accelerator pump.
Cartridge brass	Fuel line fittings, Carburettor jets and Inlet needle, fuel bowl float, power valve, valve seat.
Aluminium bronze	Fuel pumps, fuel distribution system.
Stainless steel	Carburettor fuel Inlet needle, Carburettor springs, catalytic converter, and EGR valve.
Aluminium alloy (cast)	Carburettor accelerator pump, fuel pump casing, fuel tank fill pipe, intake manifold, pistons
Iron (cast)	Carburettor body, iron plates, engine block, intake and exhaust manifolds, piston ring.
Zinc alloy (cast)	Carburettor body, plate on steel, Carburettor diaphragm.
Terne coating	Fuel tank, fuel line, air cleaner assemblies.

TABLE 2

Elastomers / Plastics used in vehicle Fuel Systems.

Materials	Typical use in Fuel System Components
Fluoroelastomers (fluorocarbons)	Rubber Tips, valve stem seals, O-rings, engine head gaskets, filter casing gaskets, diaphragms for fuel pumps and fuel hoses
Styrene Butadiene Rubber (SBR)	Gaskets, O-rings, rubber seals
Nitrile Rubber or Buna N	Gaskets, O-rings, Fuel pressure Regulator, Carburettor seals
Neoprene Rubber or polychloroprene	Gaskets, seals, Hose covers
Hydrogenated Acrylonitrile-butadiene rubber	O-rings, Engine seals
Polyvinyl chloride/Nitrile butadiene rubber blend (PVC/NBR)	Gaskets, sleeves, pipes and caps
Epichlorohydrin (CO/ECO)	Seals, hoses, gaskets and 'O' rings

Evaluation of compatibility of typical materials used in fuel-system components with E20 was conducted through laboratory immersion technique as per the guidelines given in SAE J1747 (for metals) and SAE J1748 (for non-metals). Experiments were conducted also with commercial gasoline fuel (BS IV) as a baseline for comparison.

Methodology

Laboratory immersion study was conducted on identified materials as per the guidelines given in SAE J1747 and SAE J1748. Details of identified materials, test conditions and properties evaluated are given in following sections. Process overview for laboratory immersion testing of metals and polymers is presented in Figure 1 and Figure 2 respectively.

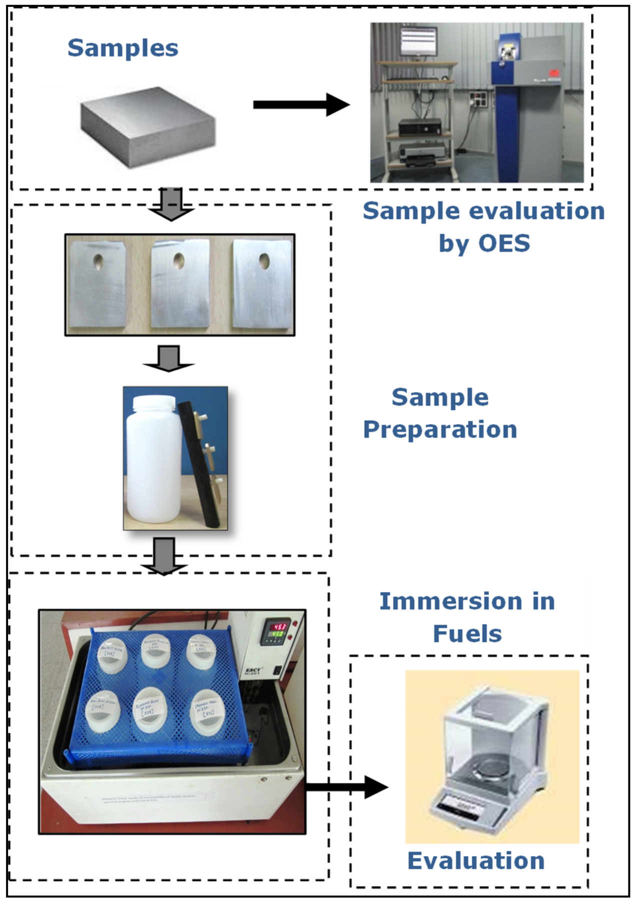


Fig. 1. Flow-chart for metals compatibility study procedure.

Material Selection and Sample Preparation

Metals, elastomers and plastics to be evaluated were identified based on the information available in literature, possibilities of impact of E20 and application requirement of a component where the material is used. Table 3 presents the list of identified materials for laboratory immersion study. The identified metals and polymers were tested using Optical Emission Spectrometer (OES) and Fourier Transform Infra-Red Spectrometer (FTIR) for compositional analysis for quality assurance purpose. Subsequently, test sample pieces were prepared as per the shapes and dimensions given in the standard methods for evaluation of properties before and after immersion.

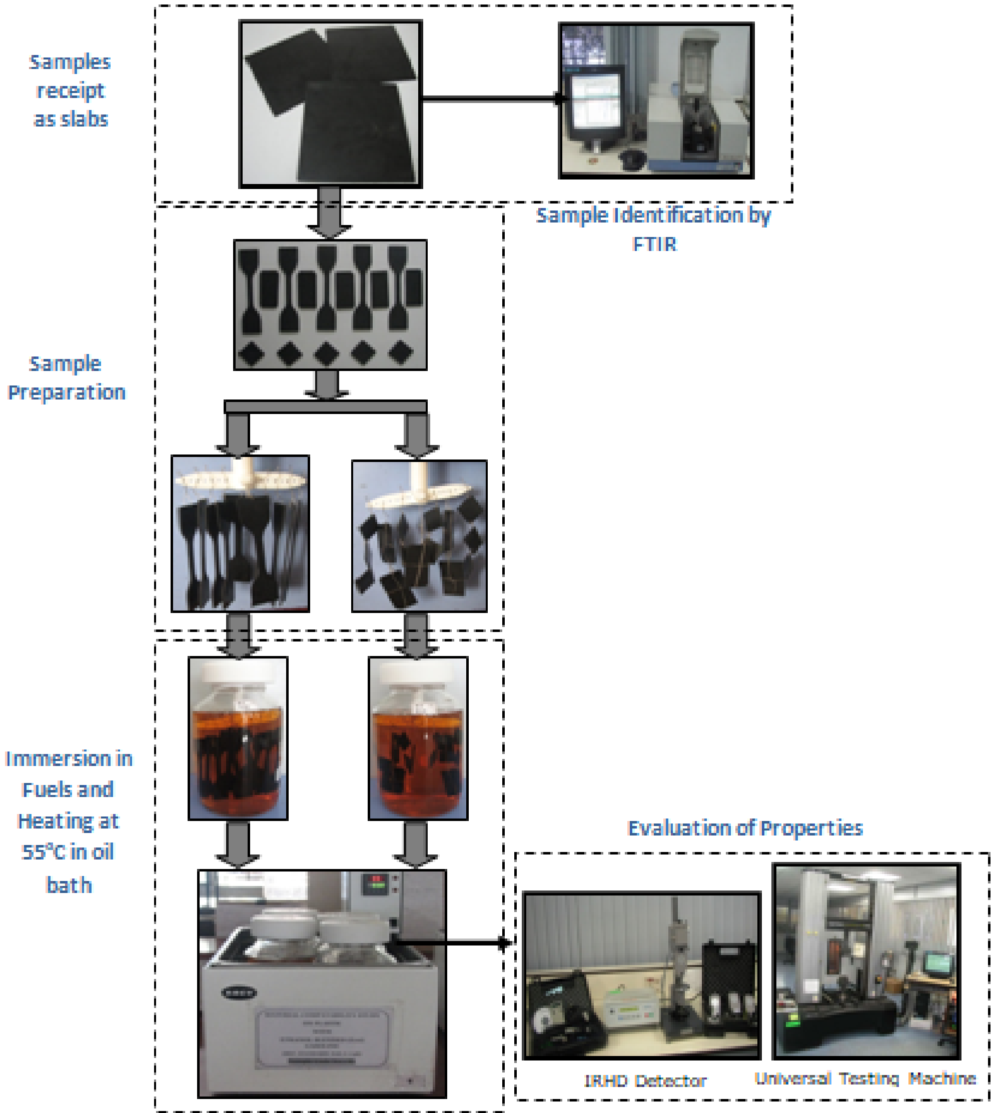


Fig. 2. Flow-chart for non-metals material compatibility study procedure.

TABLE 3
Materials selected for laboratory immersion testing.

Metals	Elastomers	Plastics
ο Aluminium JIS 5302	ο Fluoroelastomers (fluorocarbons)	ο Polyamide66 (PA-66)
ο Aluminium IS 733; Grade 64430	ο Styrene Butadiene Rubber (SBR)	ο Polyacetal
ο Copper 110	ο Polychloroprene Rubber	ο Polybutylene terephthalate (PBT)
ο Brass IS 319 Grade1	ο Hydrogenated Acrylonitrile-butadiene rubber	ο Polyamide (PA-12)
ο Stainless Steel 304	ο Polyvinyl chloride/Nitrile butadiene rubber blend (PVC/NBR)	
ο Zamak 5 (Zn Alloy)	ο Epichlorohydrin (CO/ECO)	
ο Terne Coating		
ο Aluminium 6061		

Test Conditions and Evaluation of Properties

Test sample pieces, prepared in shape and sizes specified in respective standards for property evaluation, were subjected to ageing in commercial gasoline and E20 fuels for specific duration and at a prescribed temperature. Details of test conditions and properties evaluated, pre and post immersion, for metals, elastomers and plastics are given in Table 4.

Three metals coupons of each material were subjected to ageing in respective fuels. One coupon was completely immersed in fuel, second coupon was half-immersed and half in vapour phase of fuel and third coupon was exposed to vapour phase only. This arrangement was carried out to evaluate the impact on metal exposed to different phases. In case of metals, visual appearance was observed throughout the duration of testing for change in colour, texture of surface, presence of pitting.

In case of elastomers and plastics, change in weight, volume, tensile strength, % elongation, impact strength (only for plastics) and hardness (only for elastomers) properties were evaluated pre and post immersion. Five test pieces of each materials were subjected to immersion testing in respective fuels. Average change in property along with standard deviation was considered for quality assurance purpose. Change in property pre and post immersion was calculated for assessment of impact of ageing in commercial gasoline (BS IV) as well as E20. Magnitude of change in the property after immersion in E20 is compared with the change observed after immersion in commercial gasoline and if the change is found to be similar, it was considered to be acceptable. Particularly in case of elastomers, two sets of samples were immersed in respective fuels. On one set of samples, measurement of properties was carried out immediately after they are removed at the end of immersion period. These samples are referred as wet-samples. Change in weight of wet-samples indicate absorption of fuel into the material. Another set of samples was dried till attainment of equilibrium weight, after removal from respective fuels. These samples are referred as dry-samples. Change in weight of dry-samples indicate amount of material leached out into the fuel.

TABLE 4

Test conditions for immersion study and properties evaluated.

		Metals	Elastomers	Plastics
Test Conditions	Fuel temperature	45 ± 2 °C	55 ± 2 °C	55 ± 2 °C
	Exposure duration	2016 hours (~12 weeks)	1008 hours (~6 weeks)	3024 hours (~18 weeks)
Properties evaluated	Appearance	√	√	√
	Weight change	√	√	√
	Corrosion Rate	√	--	--
	Volume/swell	--	√	√
	Tensile strength	--	√	√
	Elongation	--	√	√
	Hardness	--	√	--
	Impact strength	--	--	√

Periodic change in mass (after 1st, 3rd, 6th, and 12th week) was noted and corrosion rate in mm/year was calculated from the change in mass at the end of immersion duration (12 weeks). Corrosion rates of value less than 0.0025 mm/year, over a period of 20 years, are considered to be insignificant and hence any change in mass lesser than 0.0008g was considered insignificant.

Results and Discussion

Assessment of compatibility of materials with E20 fuel vis-à-vis commercial gasoline (BS IV), based on observed changes in properties pre and post immersion is presented in following sections.

Metals

Significant change in colour was not observed in any of the metals except for Copper 110 and Brass. Partially and completely immersed samples of Copper 110 showed significant colour change in both E20 and commercial gasoline. Change in colour of Brass sample coupons was observed in commercial gasoline. However, there was no evidence of pitting corrosion in both the fuels. Change in the appearance of metal samples in both the fuels is presented in Figure 3. Corrosion rate in mm/year calculated based on change in weight of samples after immersion is presented in Table 5. Corrosion rate in all metal samples were found to be insignificant in both the fuels.

Elastomers

In all elastomers, after immersion in both the fuels, change in gloss, texture, colour, cracking was not observed in wet as well as dry samples.

Change in properties of elastomers after immersion in both the fuels for wet and dry samples is presented in Figure 4A and Figure 4B.

Polychloroprene, SBR and HNBR have shown better performance in the properties after immersion in E20 as compared to commercial gasoline in wet samples. Fluorotelomer showed similar performance in both fuels. In Epicholohydrin and NBR/PVC blend, impact on the properties was higher for samples immersed in E20 compared to commercial gasoline. Highest change in weight (~65%) and volume (~83%) post immersion in commercial gasoline was observed in Polychloroprene, which in E20 was ~38% for weight change and ~31% for volume change. Highest change, for E20 immersed wet-samples, in weight and volume was observed in SBR>HNBR>Epichlorohydrin.

TABLE 5

Corrosion Rate in mm/year after immersion of Metals in E20 and Gasoline Fuel.

Sr No	Location / Metal	E20			Gasoline		
		Vapour exposed	Partially immersed	Fully immersed	Vapour exposed	Partially immersed	Fully immersed
1	M1 (Al JIS 5302)	-0.0002	0.0014	0.0002	-0.0001	0.0000	-0.0001
2	M2 (Al 6061)	0.0000	0.0001	0.0001	0.0000	-0.0001	-0.0001
3	M3 (Al IS 733)	0.0000	0.0001	0.0000	0.0001	0.0000	0.0000
4	M4 (Copper C110)	0.0000	0.0001	0.0002	-0.0001	0.0000	0.0001
5	M5 (Brass IS319)	0.0000	0.0001	0.0002	0.0000	0.0001	0.0001
6	M6 (SS 304)	0.0000	0.0000	0.0001	0.0001	0.0001	0.0002
7	M7 (ZAMAK 5)	0.0000	0.0000	0.0001	0.0000	0.0001	0.0000
8	M8 (Terne Coating)	0.0000	0.0000	0.0001	0.0000	0.0001	0.0000

Metals	Gasoline(F1)			Before Immersion	Ethanol blended Gasoline (20%) (F2)		
	Vapour Exposed	Partly Immersed	Fully Immersed		Vapour Exposed	Partly Immersed	Fully Immersed
M1 (Al JIS 5302)							
M2 (Al 6061)							
M3 (Al IS 733)							
M4 (Copper C110)							
M5 (Brass IS319)							
M6 (SS 304)							
M7 (ZAMAK 5)							
M8 (Terne Coating)							

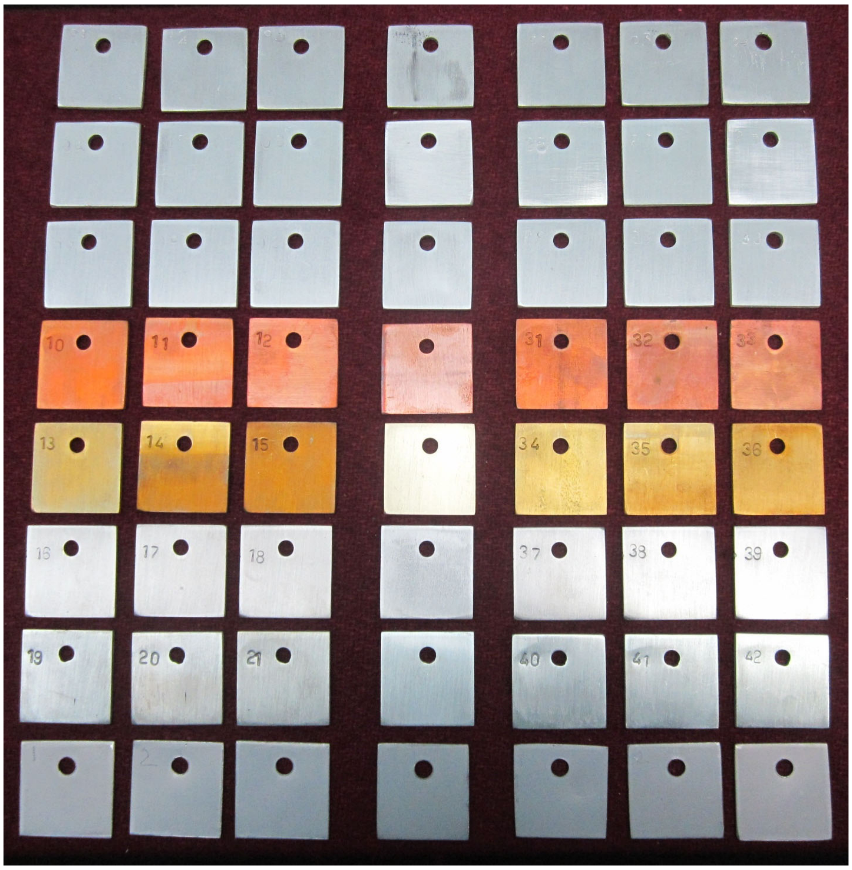


Fig. 3. Change in Metals before and after immersion in E20 and Gasoline.

All elastomers exhibited better or similar performance in E20 in terms of hardness change in wet-samples. However, for Epichlorohydrin change in hardness was ~9% compared to negligible change in commercial gasoline. Similarly, SBR showed ~20% hardness change in E20 as compared to ~13% change in commercial gasoline. Softening or hardening of elastomers can be considered to pose problem during operation. Hardening results in cracking due to flexibility loss and excessive softening results into damage due to material collapse under the condition of load.

In NBR-PVC(wet-samples), loss in tensile strength was more in E20 ~77% compared o ~66% in commercial gasoline. This was followed by Fluoroelastomer with ~57% in E20 and ~52% in commercial gasoline. Significant drop in elongation (wet-samples) was observed in NBR-PVC with ~59% in E20 against ~41% in commercial gasoline followed by Epichlorohydrin with ~58% and ~46% in E20 and commercial gasoline respectively. Disproportionate change in tensile strength can result in reduced ability of a material to take intended loads leading to failure of component. Similar, excessive increase in tensile strength can reduce flexibility due to reduced elongation and may pose problem.

In dry-samples, changes in all properties was found to be similar in both the fuels, except of SBR and Epichlorohydrin. In tensile properties, the impact of commercial gasoline was more on all elastomer (dry-samples) compared to E20. Change in elongation in case of dry-samples was similar in both the fuels.

Plastics

Significant discolouration was observed in polyamide-12 (PA-12) and Polyamide-66 (PA-066) samples after immersion on both the fuels (E20 and commercial gasoline) for 18 months. However, loss of gloss, texture, cracking of test pieces was not observed after immersion in E20 as well as commercial gasoline.

PA12, Polyacetal and Poly Butylene Terephthalate (PBT) exhibited similar change in properties post-immersion in both the fuels(Figure 5). However, decrease in tensile strength was more in E20 (~34%) than commercial gasoline (~20%) for PBT. Change in volume of PA66 was ~10% and ~2.5% post-immersion in E20 and commercial gasoline respectively. Impact of E20 fuel on properties like volume, weight and tensile strength change was found to be more on PA-66, while in case of change in % elongation and impact strength it was less as compared to commercial gasoline

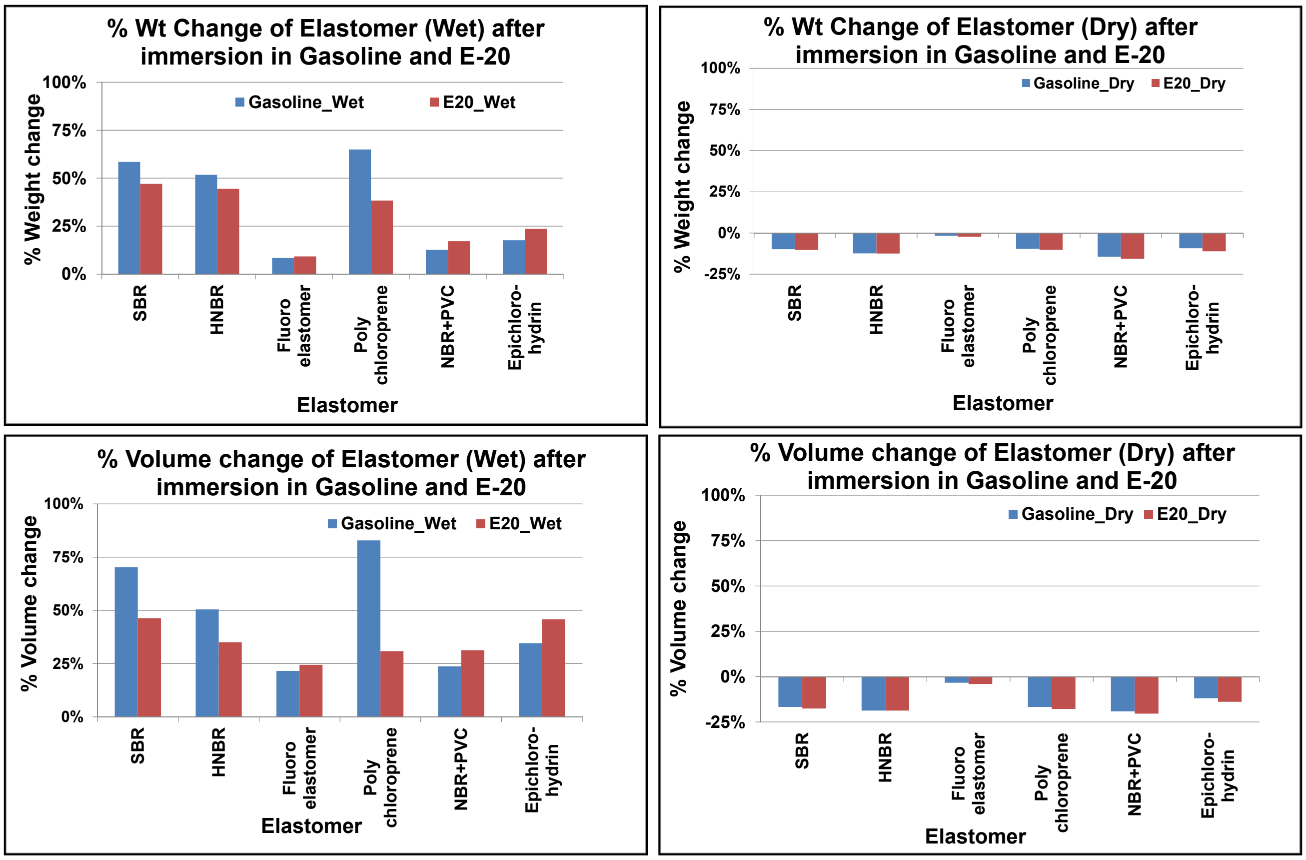
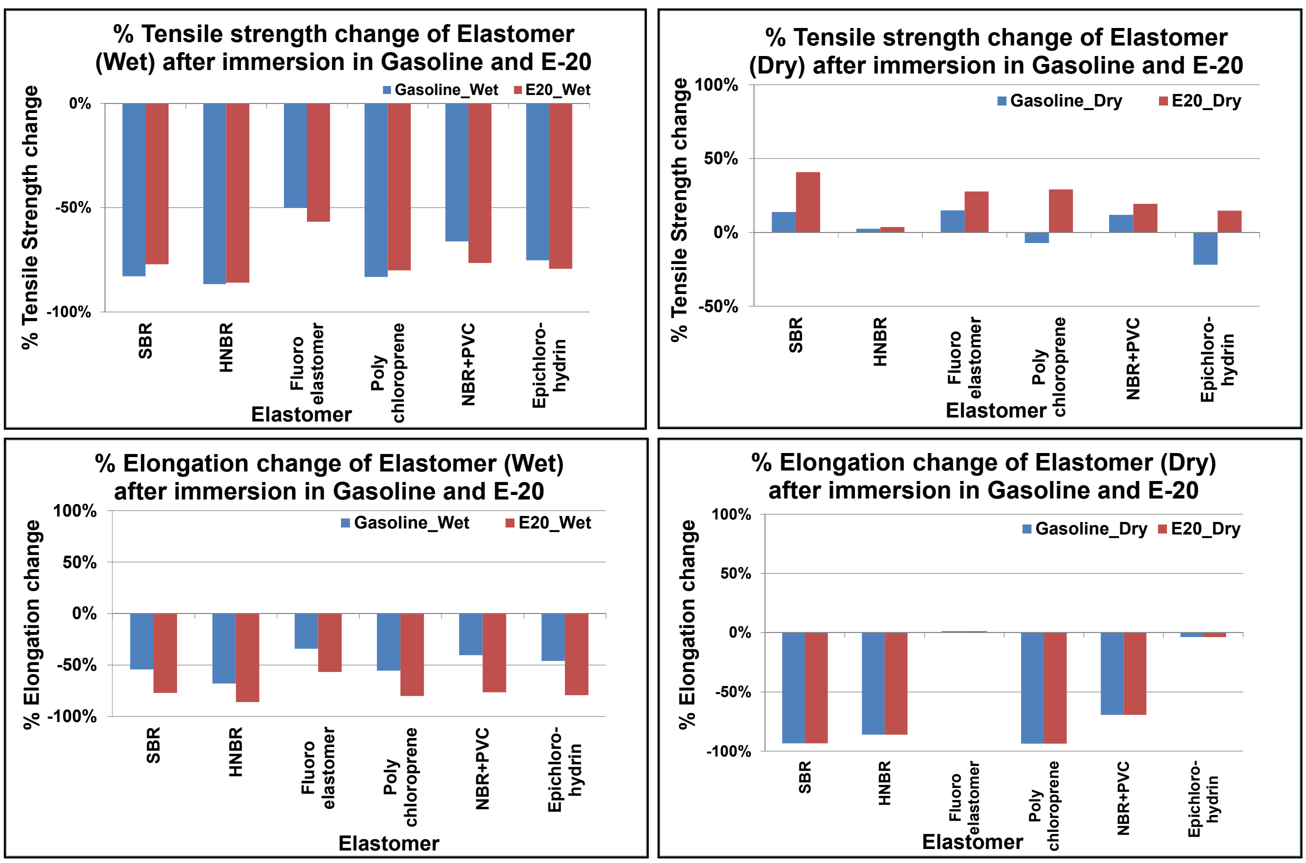


Fig. 4A. % Change in weight and volume of Elastomer after immersion in E20 and gasoline.



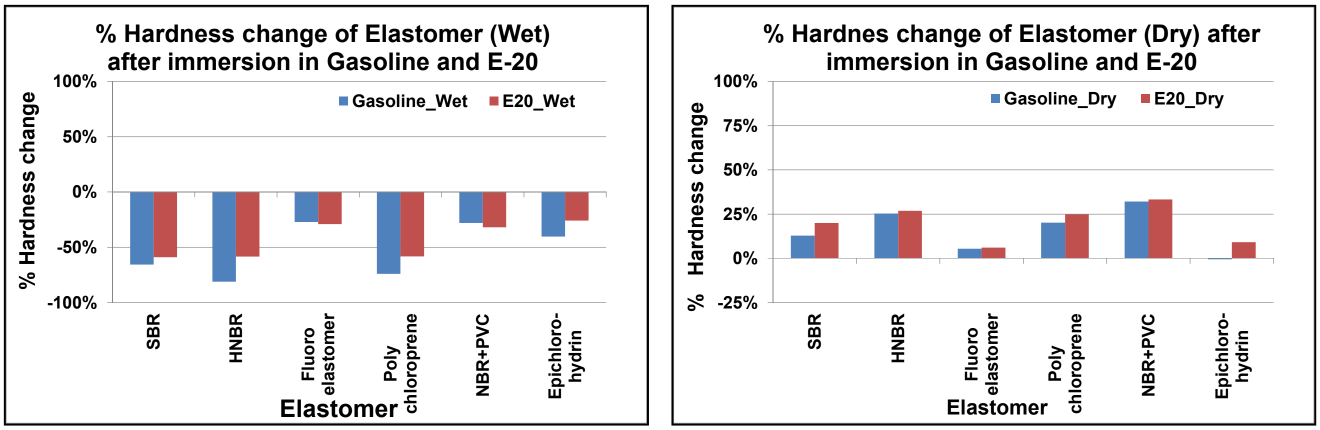


Fig. 4B. % Change in mechanical properties of Elastomer after immersion in E20 and gasoline.

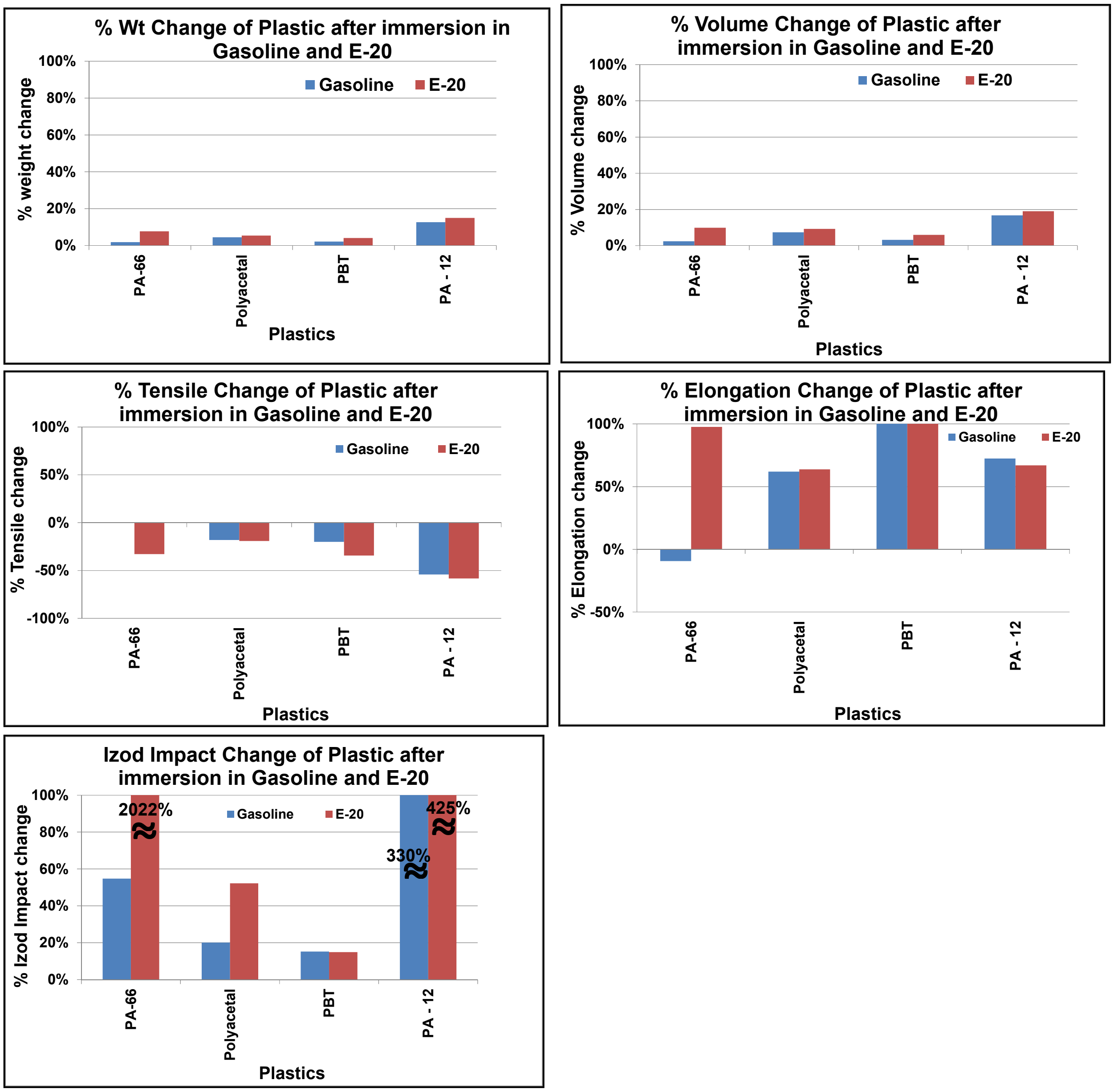


Fig.5. % Change in properties of Plastic after immersion in E20 and Gasoline.

Conclusions

Material compatibility study was conducted on 8 metals, 6 elastomers and 4 plastic materials, typically used in fuel-system components of vehicles, to evaluate impact of E20 fuel in comparison to commercial gasoline (BS IV) as a baseline fuel. Guidelines given in standard methods SAE J 1747 (metals) and SAE J 1748 (non-metals) were followed for conducting the laboratory immersion experiments. Testing was performed on multiple samples of each materials and results are statistically validated.

- All the metals tested have shown insignificant impact in terms of corrosion rates in both the fuels. There was no sign of pitting corrosion in any of the metals in both the fuels.
- Polychloroprene, SBR and HNBR were found be less impacted by E20 than commercial gasoline in most of the properties. Performance of Fluoroelastomer was found to be similar in both the fuels. Impact of E20 on properties of NBR-PVC and Epichlorohydrin was more as compared to commercial gasoline.
- PA12, PBT and Acetal exhibited similar changes in properties in both the fuels. Decrease in tensile strength of PA66 was more post-immersion in E20 as compared to insignificant drop in case of commercial gasoline. Also, change in volume of PA66 was more in E20 as compared to commercial gasoline.

A good amount of data is generated on the impact of E20 fuel on properties of various metals and non-metals used in fuel-system components. Material experts, design engineers can utilise this vital dataset to critically evaluate the same with due consideration to the significance of a property for intended application and service requirements of components in which the materials are used.

References

ACC. Plastics and Polymer Composites for Automotive Markets Technology Roadmap, American Chemistry Council, 2014.

Black, F. An overview of the technical implications of methanol and ethanol as highway motor vehicle fuels, SAE 912413,1991.

Dhaliwal, J. S., et al. Compatibility Studies on Elastomers and Polymers with Ethanol Blended Gasoline,Hindawi Publishing Corporation Journal of Fuels, Volume 2014, 2014.

DiCicco, D, E20 Durability Study Fuel System Components, CRC AVFL-15 Project Mid-Level Ethanol Blends Research Coordination Group, 2010.

Gailis, M andPirs V. Assessment of Compatibility of fuel supply system polymeric parts with bioethanol/gasoline blend E85, proceedings of the international scientific conference, Issue 14/2015, 2015.

Gajendra Babu M K and Subramanian K A. Alternative Transportation FUELS Utilization in combustion engines, CRC Press Taylor and Francis Group, 2013.

Goldemberg J. Sugarcane Ethanol: Strategies to a Successful Program in Brazil, University of São Paulo, Institute of Eletrotechnics and Energy, Advanced Biofuels and Bioproducts, 2013.

Jones B. et al. The Effects of E20 on Elastomers Used in Automotive Fuel System Components,SAE 2-22-2008, 2008.

Kameoka, Aet al. Effect of Alcohol Fuels on Fuel-Line Materials of Gasoline Vehicles, Japan Automobile Research Institute, presented at Power train & Fluid Systems Conference and Exhibition San Antonio, Texas USA,SAE 2005-01-3708, 2005.

MPCA. E20: The Feasibility of 20 Percent Ethanol Blends by Volume as a Motor Fuel:Executive Summary by Minnesota Pollution Control Agency, 2015.

Nihalani,I, et al. Compatibility of Elastomeric Materials with Gasohol. SAE 2004-28-0062, 2004.

Owen, K, and Coley, T. Automotive fuels handbook. United States: N. p., 1990.

Peason, RJ and Turner, JWG.Using alternative and renewable liquid fuels to improve the environmental performance of internal combustion engines: key challenges and blending technologies, University of Bath, UK, Woodhead Publishing Series in Energy: Number 57 Alternative Fuels and advanced vehicle technologies for improved environmental performance towards zero carbon transportation, 2014.

RamadhasA S. Alternative fuels for Transportation, CRC Press Taylor and Francis Group, 2010.

SAE International. Alternate Fuels Committee of the Engine Manufacturers Association, “A Technical Assessment of Alcohol Fuels”, SAE 820261, 1982.

SAE International. Compatibility Assessment of Plastic Infrastructure Materials with Test Fuels Representing E10 and iBu16, SAE 2015-01-0894, 2015.

Stradling R et al. Assessment of the impact of ethanol content in gasoline on fuel consumption, including a literature review up to 2006, Prepared for the CONCAWE Fuels Quality and Emissions Management Group, 2013.

SzeteiováK. Automotive materials plastics in automotive markets today - Institute of Production Technologies, Machine Technologies and Materials, Faculty of Material Science and Technology in Trnava, Slovak University of Technology Bratislava, 2010.

Thomas E W. Fluoroelastomer Compatibility with Bioalcohol Fuels, DuPont Performance Elastomers L.L.C.,SAE International, SAE 2009-01-0994, 2009.

ThummadetsakT. E10, E20, E30; Effects on Tailpipe Emissions, Vehicle Performance and Hot Weather Drivability, PTT Research & Technology Institute, 6’th Asian Petroleum Technology Symposium, 2008.

Wagner, TO etal. Practicality of alcohols as motor fuels, SAE 790429, 1979.

Address correspondence to Moqtik A. Bawase, *Environment Research Laboratory, Automotive Research Association of India, Survey No 102, Vetal Hill, off Paud Road, Kothrud, Pune-411038.*
Phone: 020 67621566
E-mail: bawase.erl@araiindia.com