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THE INFLUENCE OF BIODIESEL BLENDS (UP TO B-20) FOR PARTS OF DIESEL ENGINE FUEL SYSTEM BY IMMERSION TEST

KOMPATIBILITAS KOMPONEN SISTEM BAHAN BAKAR MESIN DIESEL TERHADAP B-20 MELALUI UJI PERENDAMAN

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ABSTRAK

Pemerintah Indonesia akan menerapkan kebijakan kewajiban penggunaan campuran Bahan Bakar Minyak jenis Minyak Solar dan Biodiesel dengan persentase minimum 20% (B-20) dimulai pada tahun 2016. Dari sudut pandang teknis, masalah kompatibilitas komponen menjadi salah satu perhatian industri otomotif. Karakteristik biodiesel sebagai pelarut dikhawatirkan akan menjadikannya bereaksi dengan komponen sistem bahan bakar kendaraan mesin diesel, terutama elastomer. Penelitian ini bertujuan untuk mengidentifikasi material penyusun komponen sistem bahan bakar, meliputi komponen logam dan non logam, dengan kompatibilitas yang baik terhadap B-20. Identifikasi material penyusun komponen non logam dilakukan dengan uji FTIR dan DSC,dan uji XRD dan XRF untuk komponen logam. Uji perendaman selama 2500 jam dilakukan untuk membandingkan pengaruh 5 (lima) campuran bahan bakar (B-0, B-5, B-10, B-15 dan B-20) terhadap perubahan sifat fisika komponen logam dan non logam sistem bahan bakar kendaraan mesin diesel. Sifat fisika yang diamati adalah berat spesimen komponen uji. Hasil yang diperoleh menunjukkan bahwa perubahan berat komponen logam diperoleh pada rentang 0.007% hingga 0.595%. Perubahan berat yang lebih besar diperoleh pada komponen non logam antara 0.001% to 13.85%. Perubahan berat yang lebih rendah terlihat pada komponen logam jenis material CuO, Al_2O_3 dan SiO, sedang untuk komponen non logam perubahan terendah diperoleh dari polimer jenis fluoroviton A. Pengamatan terhadap komposisi bahan bakar sebelum dan sesudah uji perendaman komponen dengan FTIR menunjukkan tidak ada perubahan yang signifikan dan efek dari sifat pelarut bahan bakar campuran ini dapat diabaikan.

Kata Kunci: kompatibilitas, logam, non logam, biodiesel, material

ABSTRACT

The Government of Indonesia will implement the mandatory policy on the use of Diesel Fuel and Biodiesel mixture with minimum 20% volume of biodiesel (B-20) start from 2016. From technical point of view, compatibility issue becomes one of the problems to be considered by automotive industries. The concern relate with solvent characteristic of biodiesel, which cause the biodiesel and its blends react with the parts of fuel system, especially the elastomers. This work is aimed to identify the material constructed the fuel system parts, including metal and non-metal parts, which has good compatibility to biodiesel blends up to B-20. Identification of the parts material was done by FTIR and DSC for non-metal parts and by XRD and XRF for metal parts. The immersion test is used to compare the effect of five biodiesel-diesel fuel blends (B-0, B-5, B-10, B-15, and B-20) to the physical change of metal and non-metal parts of diesel fuel system in *a 2500 hours test period. The physical change being checked is the weight of the parts. The result obtained that for immersed metal parts, the change of weight occurred in the range of 0.007% to 0.595%. The higher weight change obtained by non-metal parts in the range of 0.001% to 13.85%. The lowest change was shown by metal parts consists of an alloy of CuO, Al_2O_3 and SiO, whether for non-metal parts was shown by a polymer type of Fluoroviton A. Through FTIR analysis we also observed that fuels composition before and after immersed with the tested parts were not change significantly means that effect of solvent characteristic of biodiesel in the fuel mixture is negligible.*

Keywords: compatibility; metal; non-metal; biodiesel; material

I. INTRODUCTION

Application of the mixture of diesel fuel and biodiesel known as B-XX (where XX represent percent volume of biodiesel) for transportation sector now become a common policy taken by countries to solve their dependence on fossil fuel. Combined with another benefits such as carbon emission reduction, cleaner gas emission, increasing added value of some non-productive plants, and decreasing of fossil fuel imports, the use of biodiesel to substitute diesel fuel will be accelerated to the contents of 20% from national demand start from 2016 by Government of Indonesia (DEMR No/2014). The policy of using the mixture of diesel fuel and biodiesel becomes a mandatory since end of 2013 by implementing B-10. Now, in the next 2 years the content of biodiesel usage will be doubled to B-20.

Currently, the usage of biodiesel mixture for automotive still limited to low percentage in the countries worldwide. In ASEAN countries, Malaysia has just implement B-10, Thailand reached B-7 and Philippines use B-5. From the automobile makers point of view, the recommended blending for diesel vehicles even lower which only B-5, as stated in the document of World Wide Fuel Charter (WWFC) 2012 edition. It is because some limitation that the producers of automobile considered biodiesel will affect engine performance in some ways. Biodiesel is observed to provide slightly lower power and torque, and higher fuel consumption (Demirbas 2007). Distinction between diesel fuel and biodiesel that being attributed to their difference in chemical nature may becomes the root cause in the technical problems. Besides the major fatty ester components, minor constituents of biodiesel include intermediary mono-and di-glycerides and residual triglycerides resulting from the transesterification reaction, methanol, free fatty acids, sterols etc (Knothe 2010). Due to its unsaturated molecules and compositional effects, it is oxidative and causes enhanced corrosion and material degradation (Jain & Sharma 2010). (Fazal *et al.* 2010) concluded on their paper that auto-oxidation, higroscopic nature, higher electrical conductivity, polarity and solvency properties of biodiesel cause enhanced corrosion of metal and degradation of polimers.

In relation with non-metal parts compatibility, (Bessee & Fey 1997) investigated the effect of methyl soy ester and diesel blends on the tensile strength, elongation, hardness, and swelling of several common elastomers. They showed that nitrile rubber, nylon 6/6, and high density polypropylene exhibited changes in physical properties while Teflon ®, Viton® 401-C and Viton® GFLT were unaffected. Another study by (Haseeb et al. 2011) conduct a static immersion test for 500 hours of three different elastomer materials; nitrile rubber (NBR), polychlorophrene, and fluoro-viton A in B-0 (diesel fuel), B-10 (blend sof 10% vol. palm biodiesel and diesel fuel) and B-100 (biodiesel). At the end of immersion, degradation behavior of the tested materials was characterized by measuring changes in mass, volume, hardness, tensile strength and elongation. On the conclusion, from these three materials they assure consumer confidence on using fluoro-viton for biodiesel use. They explained that less dissolving elastomer has less possibility to exhibit swelling or cracking. This reveals that it is important to find such a material having low solubility in biodiesel or its blends.

Another research focusing on material compatibility to biodiesel and its blends work on metal part compatibility. Copper, mild carbon steel, aluminium and stainless steel are four important metals widely used in diesel engines. (Enzhu Hu *et al.* 2012) immersed four metal strips: copper, carbon steel, aluminium and stainless steel for two months in B-0 and B-100 from rapeseed methyl ester (RME).

Characterization of the metal surface were done using scanning electron microscopy with energy dispersive X-Ray analysis (SEM/EDS) and an X-Ray photoelectron spectroscopy (XPS). After the study they conclude that corrosion effects of biodiesel on copper and carbon steel are more severe than those on aluminium and stainless steel. Another experiment was done by (Fazal *et al.* 2010) where copper, aluminium, and 316 stainless steel were immersed in diesel and palm biodiesel for 600 hours and 1200 hours. They found that biodiesel is more corrosive for copper and aluminium and that copper acts as strong catalyst to oxidize palm biodiesel. The differences between research results exist because they conduct different test conditions and also different fuels.

From the published papers focusing on material compatibility to biodiesel, the materials used are specific sheet or strips prepared for the immersion test, not from the existing fuel system of a vehicle. A research by (Reza Sukaraharja *et al.* 2011) conduct an immersion test using specimen from existing fuel system parts, both for metal and non-metal parts, on a diesel (B-0) and B-10 exhibit a swelling behavior for some non-metal parts. It is not identified on that research the type of the material that being swollen or corroded more than the others.

In order to provide useful information for automotive industries and identification of the current existing parts material having better compatibilities to blends of diesel fuel and biodiesel up to 20% volume (B-20), we conduct an immersion test of the current fuel system parts. The difference between this work and other available work on compatibility to biodiesel is we use the current parts inside fuel system of diesel vehicles in Indonesia and identify the constituent components of the parts to select the more compatible materials than others to B-20. For both metal and non-metal parts, we cut the specimen into a particular size in order to facilitate each specimen to be immersed in tested fuels inside 1 litre HDPE bottle. By doing this work we expect to provide recommendation for the government, industries and also public consumers about the materials compatible to B-20.

II. METHODOLOGY

Before immersion test, fuel samples to be tested were prepared by blending diesel fuel and biodiesel. Five fuels consist of pure diesel fuel (B-0) and the blends B-5, B-10, B-15 and B-20 are used as tested fuels. Some physical and chemical parameters of the tested fuels were compared to the diesel fuel specification in Indonesia. The fuel system part specimens from 3 types of diesel vehicles marketed in Indonesia, two from the conventional diesel engine and one from the common rail vehicle were prepared for the immersion test. Both metal and non-metal parts were cut into a particular size in order to facilitate each specimen to be immersed in tested fuels inside 1 litre HDPE bottle. The measurements of the specimen weight were taken before the immersion. Elemental analysis was conducted using Fourier Transform Infrared Spectroscopy (FTIR) and Differential Scanning Calorimetry (DSC) to identify material elements of non-metal specimens and X-Ray Diffraction (XRD) and X-Ray Fluorescence (XRF) to identify material elements of metal specimens. The weight of each specimens were observed before immersed and 2500 hours at the end of the immersion test. Before taking the weight data, the remain tested fuels that attached on the surface of the test specimens were dissolved by using acetone for 2-3 minutes then put it on a dry cloth to dry it. Soon after the specimen dry then the weight data was taken directly.

III. RESULTS AND DISCUSSION

The following results were presented: the physical and chemical properties of the tested fuels, elemental analysis of the material constructed the test specimens and the weight change of the immersed specimens during 2500 hours of test period.

A. Physical and chemical analysis of the tested fuels

All of the tested fuels are checked for its physical and chemical properties in order to ensure its quality referring to the diesel fuel specification in Indonesia (called *Minyak Solar 48* specification). Table 1 below shows us the result of all fuel quality testing

From Table 1, all of the tested fuels fulfill the specification of *Minyak Solar 48*, except for the limit of FAME content. This is understandable that in this study the FAME content for the fuels are varied to understand the effect of biodiesel content to material degradation during immersion test. The compliance between the results and the specification ensure us that the tested fuels are having good quality.

Table 1
Physical and chemical properties of the tested fuels

No	Fuel Properties	Unit	B-0	B-5	B-10	B-15	B-20	Limit value refer to Indonesian spec.	Test Method
1	Cetane Number	-	48,5	48,7	50,2	50,7	52,5	Min. 48	ASTM D 613
2	CCI		45,8	50,0	48,07	49,09	49,23	Min. 45	ASTM D 4737
3	Specific gravity @15°C	kg/m³	850	851	852	854	855	815 - 860	ASTM D 4052
4	Kinematic Viscosity @40°C	mm²/s	3,13	3,28	3,28	3,30	3,40	2,0 – 4,5	ASTM D 445
5	Sulphur Content	% m/m	0,100	0,112	0,106	0,100	0,094	Max. 0,35	ASTM D 4294
6	Distillation T_{90}	°C	365,5	356,0	350,0	348,5	346,5	Max. 370	ASTM D 86
7	Flash Point	°C	68	68	70	71	73	Min. 52	ASTM D 93
9	Carbon Residue	%	nil	nil	nil	nil	Nil	Max. 0,1	ASTM D 4530
10	FAME Content	% v/v	0	5,20	10,20	15,30	20,60	Min. 10	ASTM D 7806
11	Copper Strip Corrosion	Merit	1a	1a	1a	1a	1ª	Max. Class 1	ASTM D 130
12	Sediment Content	%	nil	nil	nil	nil	Nil	Max. 0,01	ASTM D 473
13	Visual Appearance	-	Clear & bright	Clear & bright	Clear & bright	Clear & bright	Clear & bright	Clear & bright	-
14	Lubricity	Micron	301	296	285	276	261	Max. 460	ASTM D 6079

Table 2
Result of XRD and XRF for elemental analysis of metal parts

Parts Name									
Fuel Pump		Injection Pump 1		Injection Pump 2		Fuel Injection Pump 1		Fuel Injection Pump 2	
Element	%	Element	%	Element	%	Element	%	Element	%
Fe_2O_3	87.69	Fe_2O_3	85.93	Fe_2O_3	87.04	CuO	93.16	CuO	83.31
ZnO	5.31	Al_2O_3	4.51	Al_2O_3	4.95	Al_2O_3	2.78	Al_2O_3	7.00
Al_2O_3	2.60	ZnO	2.75	CuO	2.63	SiO_2	1.58	SiO_2	4.05
CuO	1.32	SiO_2	2.02	SiO_2	1.56	P_2O_5	0.34	ZnO	1.62
SiO_2	1.13	MnO	1.37	ZnO	1.47	Fe_2O_3	0.34	SnO_2	0.79

B. Elemental analysis of metal and non-metal parts

Different test are conducted to identify the elements constructing the test specimens that are grouped to; the metal parts using XRD and XRF analysis whether the non-metal parts using FTIR and DSC analysis. Table 2 shows us the result of elemental analysis for metal parts and Table 3 shows the result of non-metal parts.

From Table 2 we can observe that for parts in pump section, material constructing the parts mainly consist of ferrous alloy in majority or more than 80% in mass concentration. Other constituents belong to zinc alloy and aluminum alloy. For fuel injection pump parts, the materials dominated by copper alloy followed by aluminum alloy as the constituent.

The result of FTIR and DSC for identification of polymer type constructing the non-metal parts reveals that common polymer used in the fuel system parts belong to Nitrile Butadiene Rubber (NBR) groups, and other polymer identified is the group of Fluorocarbon type V (Viton A). By identifying the elements for the test specimens, we can observe the type of material that is suitable for biodiesel blends up to 20% use.

C. Dimension change during Immersion Test

From previous study done in Lemigas by Sukaraharja, we noted that the effect of biodiesel use to polymeric materials in fuel

Table 3
Result of FTIR and DSC for elemental analysis of non-metal parts

Parts Name	Polymer	Plasticizer
Fuel Injection Pump 1	Fluorocarbon rubber (Viton	-
Fuel Pump	Poly (butadiene-co-acrylonitrile)- NBR	plasticizer
Fuel Injection Pump 2	Poly (butadiene-co-acrylonitrile)- NBR	Phtalate esther

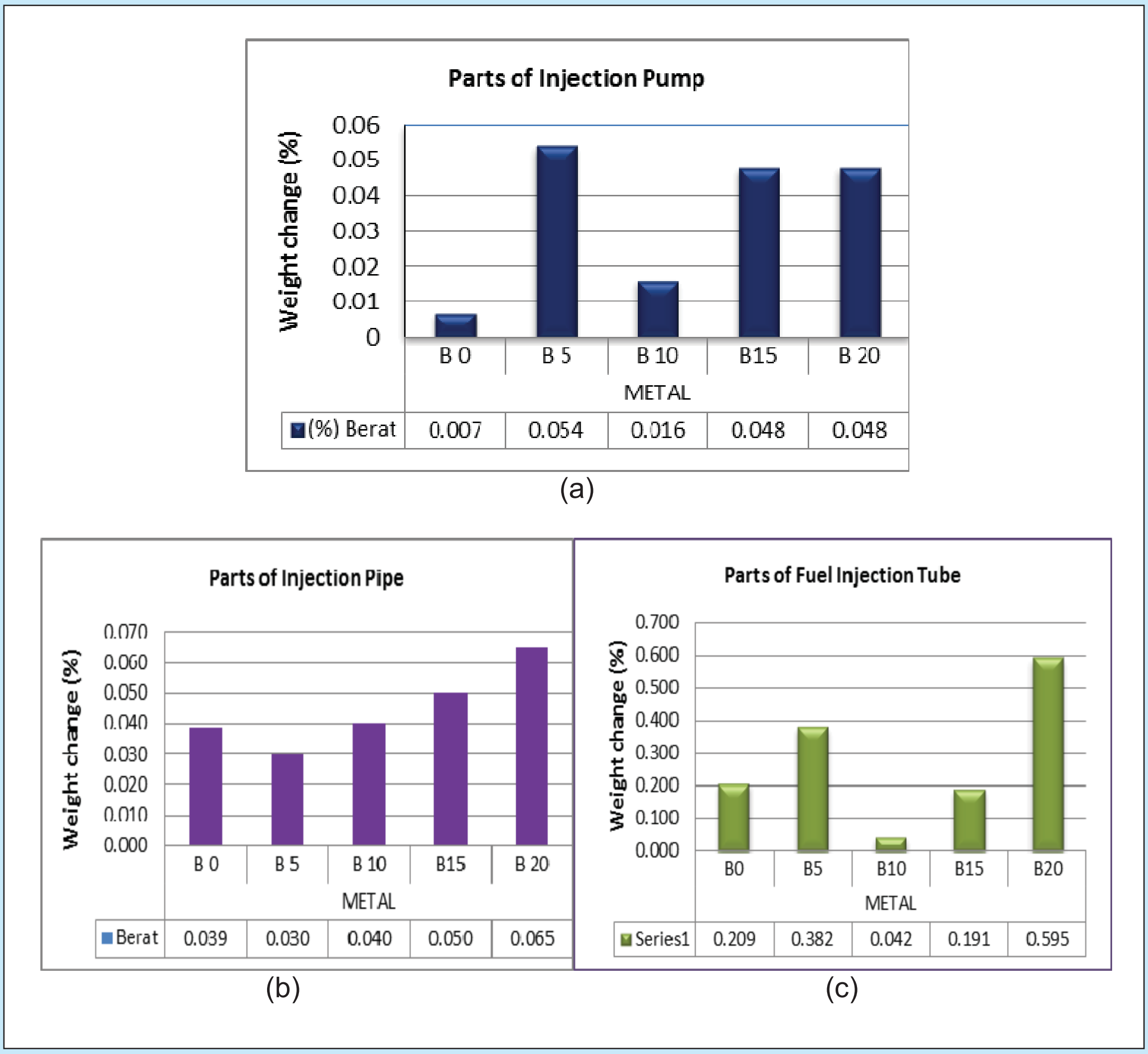

Figure 1
Weight change of metal parts : (a) parts of injection pump, (b) parts of injection pipe, (c) parts of fuel injection tube

line system is observed from the weight increasing of the test specimen (Reza Sukaraharja *et al.* 2011). Graph of weight change as presented in Figure 1 (a), (b), and (c) shows us that after 2500 hours being immersed in the tested fuels, the change of the metal specimens weight ranging from 0.007% for the parts of injection pump immersed in B-0 to 0.595% for parts of fuel injection tube immersed in B-20. The positive values of the result show that the weight of all test specimens increased. Deeper observation over these 3 figures reveals that weight change happened in all tested fuels including B-0 or the diesel fuel. Further observation focusing on the change of parts immersed in B-20 as our goals is finding the most compatible material for B-20. The lowest change of the metal parts immersed in B-20 is belong to parts of injection pump with the change only 0.048%. Tracing back to Table 2, it is observed that parts of fuel injection pump are constructed from the alloy of CuO and Al_2O_3 and other elements in smaller concentration. This observation lead us to choose the more compatible parts in contact with B-20 is made from the alloy of CuO, Al_2O_3 and SiO.

Figure 2 shows the weight change of non-metal parts during 2500 hours of immersion test. Similar with the result show on Figure 1, the positive value in Figure 2 indicate weight increasing of the test specimens. Higher weight change of the non-metal

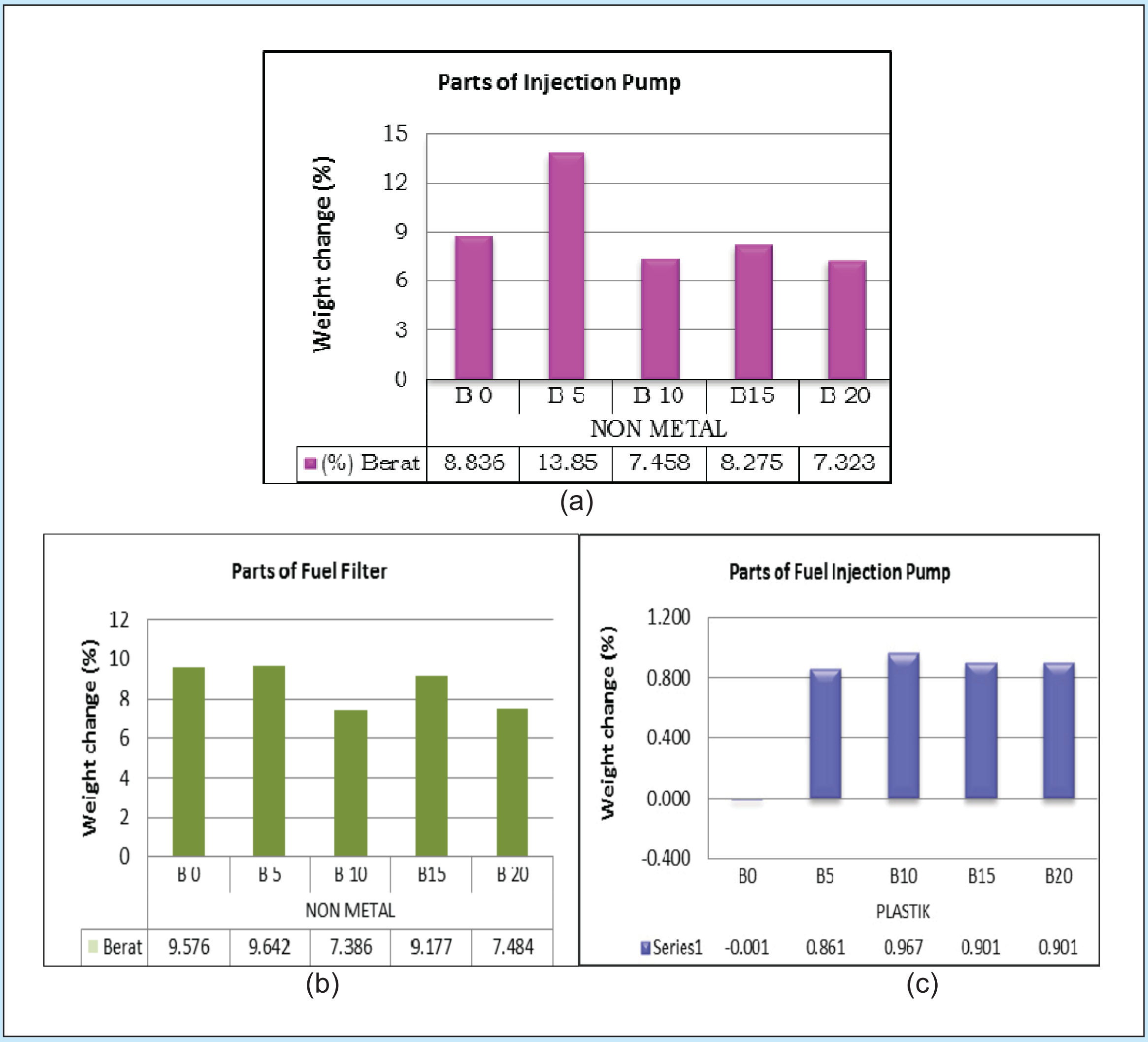

Figure 2
Weight change of non-metal parts : (a) parts of injection pump, (b) parts of fuel filter, (c) parts of fuel injection pump

parts compared to the metal parts can be observed from Figure 2, where the range of weight change is from 0.001% for parts of fuel injection pump immersed in B-0 to 13.85% for parts of injection pump immersed in B-5. The effect of biodiesel blends to non-metal parts is higher than metal because swelling phenomenon occur in non-metal parts. Swelling occur because the interaction between biodiesel and polymer constructing the non-metal parts caused absorption of the biodiesel liquid take part into the polymer bodies. This liquid absorption increasing the volume and also affected the weight of the non-metal parts immersed in biodiesel blends. The weight change occured for all tested fuels, even in B-0 swelling also occured. Focusing our observation to B-20, we could find the lowest weight change is belong to parts of fuel injection pump. Tracing back to Table 3, we can find that there are 2 types of fuel injection pump parts used in this research. From the identification number of related part, we conclude that the part with lowest change is the one constructed from Fluorocarbon rubber (Viton A).

IV. CONCLUSION

Evaluation on the results of present work focusing on the identification of current fuel system parts that having better compatibility to B-20 lead us to conclude the following points:

1. Higher compatibility in the matter of weight change to the application of B-20 is shown by metal parts of injection pump constructed from alloy of CuO, Al_2O_3 and SiO.
2. For non-metal parts, higher compatibility in the matter of weight change on the application of B-20 is shown by parts of fuel injection pump made from Fluorocarbon rubber (Viton A).

REFERENCES

Bessee G.B., Fey J.P., 1997, Society of Automotive Engineering technical paper no 971690.

Decree of Minister of Energy and Mineral Resources Republic of Indonesia No. 20, 2014.

Demirbas A., 2007, “Progress and recent trends in biofuels”, Prog Energy Combust Sci. 33:1-18.

Fazal M.A., Haseeb A.S.M.A., Masjuki H.H., 2011, “Biodiesel Feasibility Study: An evaluation of material compatibility; performance; esmission and engine durability”, Renewable and Sustainable Energy Reviews. 15: 1314-1324.

Fazal M.A., Haseeb A.S.M.A., Masjuki H.H., 2010, “Comparative corrosive characteristics of petroleum diesel and palm biodiesel for automotive materials”, Fuel Processing Technology. 2010; 91: 1308-1315.

Haseeb A.S.M.A., Jun T.S., Fazal M.A., Masjuki H.H., 2011, “Degradation of physical properties of different elastomers upon exposure to palm biodiesel”, Energy. 36: 1814-1819.

Hu E., Xu Y., Hu X., Pan L., Jiang S., 2012, “Corrosion behaviors of metals in biodiesel from rapeseed oil and methanol”, Renewable Energy. 2012; 37: 371-378.

Jain S., Sharma M.P., 2010, “Stability of biodiesel and its blends : review”, Renewable and Sustainable Energy Reviews, 14: 667-678.

Knothe G., 2010, “Biodiesel and renewable diesel : a comparison”, Prog Energy Combust Sci. 2010; 36: 364-373.

Reza Sukaraharja et al., 2011, ”Final reports of study on biodiesel effects on hardness and dimension change of diesel engine non-metal parts”, a research project report prepared for LEMIGAS.