TESTING SPEED LIMITER INTEGRATED FATIGUE ANALYZER AND ITS EFFECT ON FUEL EFFICIENCY AND REDUCTION IN GREENHOUSE GAS EMISSION ON TRUCK ENGINE WITH 17 TON

Hadi Pranoto[1,2], A.M. Leman[2], Yudhi Gunardi[1], Triyanto Pangaribowo[1]

[1] *Faculty of Engineering, Universitas Mercubuana, Jakarta, Indonesia*
[2] *Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia (UTHM), Malaysia*
Email: hd.pranoto@gmail.com,

ABSTRACT

The Speed Limiter Integrated Fatigue Analyzer-SLIFA test on a 17-ton capacity truck engine was conducted to find out how much fuel efficiency can be saved after the SLIFA-installed on truck, fuel is the dominant factor in the transportation business and its cost is number 1 that should be efficient, the purpose of this test is to investigate whether the use of SLIFA can have a positive effect on fuel consumption when the truck operates. Another positive impact of fuel savings is to reduce greenhouse emissions. the methods for this test is dynamic testing which is done by pairing a flow meter device connected to the fuel supply to the fuel injection pump. The emission test using an exhaust emission opacity tester device to determine the level of smoke thickness which is found by the residue of combustion. The truck is run on Jakarta-Bekasi-Bandung route with full load of 17 tons. Total distance is 100 km and the average speed in the urban road is 60 km / h on the highway 70 to 100 km / h with maximum engine speed of 3200 rpm, the result of the test done when the truck is not in install the SLIFA tool get the value of fuel efficiency used fuel ratio A + B + C / Total ratio = 1: 3.43 km / l with the calculation rate of supply rate 20 Lph (53 gph) return rate 10 lph (2.2gph) total value rate based on digital fuel mater readings is 0.46 gph or 0.12 lph, then after installing SLIFA on the truck the fuel total ratio 1:4.02 km/l. For emission test result before installing SLIFA at 22 and after installing SLIFA at 16.6. This reducing of gas emission and fuel consumption are about 28.14 % and 32.53% respectively after SLIFA installation on truck engine. With this significant result, SLIFA could be valuable consideration to enhance performance of fuel consumption and reduce gas emission

Keyword: - *speed limiter, fuel consumption, gas emission, safety device speed limiter, SLIFA.*

1. INTRODUCTION

SLIFA is created to resolve the increasing number of fatalities accident on urban system transportation. The police survey is mentioned in 2010 that 31.234 people are dead at road accident. In the Chart-1, it is showed almost 20% and 17%, overspeed and fatigue as factor of accident respectively. Additional information explains besides motor cycle, bus and truck has significant probability of risk in the fatalities [1-2]. Therefore, it is very needed to solve that problems to improve safety driving and reduce truck accident [3]. SLIFA works on vehicle to limit the speed by cutting off the fuel supply when the speed and fatigue at certain condition. Some of regulations arrange the speed that is allowed for vehicle and it is adapted by government. These regulations are mentioned in the following [4-6]:

- The minimum and maximum speed in highway 60 km/h and 100 km/h respectively.
- The maximum speed in urban area is 80 km/h.
- The highest speed in central of urban are 50 km/h.
- The maximum speed in settlement place 30 km/h.

SLIFA has been proven to minimalize the potential number of fatalities by limiting the speed [7-8]. The other cause of overspeed is led the increasing of fuel consumption.

The amount of fuel consumption depends on some conditions such as the power of vehicle that is needed on field, configuration of vehicle [9] and including overspeed. The amount of fuel consumption on vehicle has relationship with the gas emission to the environment. If the truck is overspeed, more increase of fuel consumption and more gas emission is emitted to the environment. According to European commission in 2001 speed limiter were introduce to improve safety and reduce environmental effect. In the chart-2, it is showed the successful of speed limiter to the improvement of fuel efficiency based on survey from 84 respondence [10].

There are some points to draw the problem in urban system transportation such as: safety engineering system, fuel consumption and the issue of environment. So that in responding of these points this investigation has been conducted to answer the problem. The investigation of safety engineering system on vehicle has been developed by researcher [11-12] and the development of image processing that could be included in development of the safety engineering system has been investigated [13].

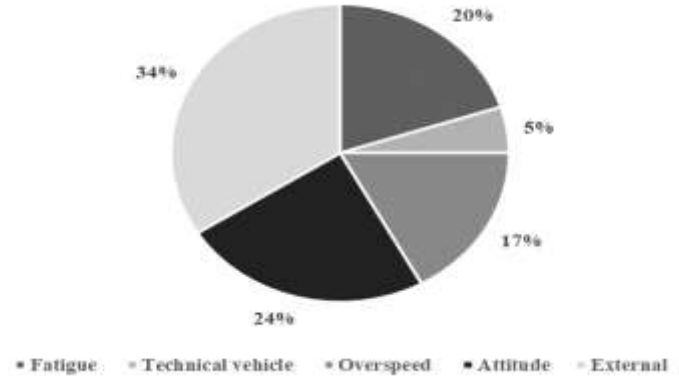

Chart -1: Factors of Accident

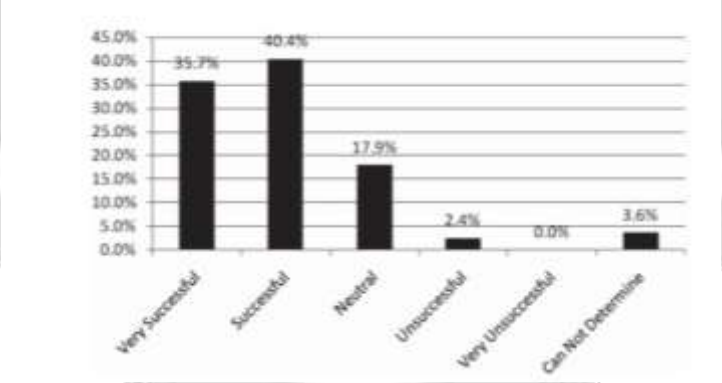

Chart-2: Success of Speed Limiters in Increasing Fuel Economy

2. METHODOLOGY

The methodology generally is divided into five steps and described in the Fig-1. First step is vehicle preparation. This step is very important before running test and involving checking condition of truck before running the fuel and emission test. Second step is inspection test. This test has purpose to make sure condition before test is in right condition. Such as route, weather, driver and fuel condition are being inspected in this step. Instrument preparation is included apparatus installation and inspection to measure fuel and emission condition before and after using SLIFA. Test procedure is divided into two steps there are fuel and emission test. This procedure was explained carefully to the driver in order to avoid vague result or fault test procedure. Test procedure was conducted on truck with and without SLIFA-installed. The truck run on Jakarta-Bekasi-Bandung route and the distance about 100 km. The average speed on urban road 60 km/h and on highway 70 to 100 km/h. Data for fuel consumption and gas emission will be recorded during the test.

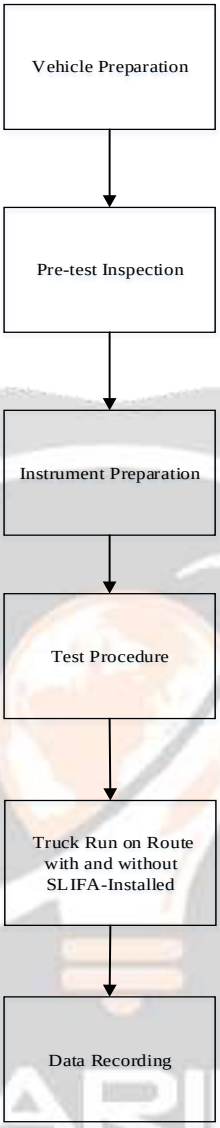

Fig-1: Diagram Schematic of The Test

2.1 Fuel Consumption Test

Fuel consumption analysis on truck will be performed and analyzed by digital flow meter. It is conducted in travel distance of 100 km with maximum speed of 70 km/h with maximum rotation frequency of 3200 rpm. The comparison between truck at condition with and without SLIFA installation will be performed in order to investigate the effect of SLIFA on fuel consumption.

Digital flow meter will be installed in high pressure flexible pipe at fuel injection pump to monitor fuel flow during the test. Digital flow meter monitoring system is shown in the Fig-2.

Fig-2: Digital Flow Meter

These steps are describing on tool preparation and standard operation procedure:

1. Prepare the truck sure it is in good condition, with attention and priority to the safety first
2. Tool preparation.
3. Open the cabin set, preparation to install digital flow meter and the others of apparatus.
4. In the fuel filter there are two pipes. Remove the connecting pipe between the fuel filter to the injection pump
5. Remove the pipe connecting the fuel filter to the injection pump and Remove the injection pump return hose to the fuel tank
6. Prepare sensor-supply
7. Prepare one-way valve
8. Install sensor on hose of the fuel and install one-way valve
9. Install supply sensor in the chassis and tighten
10. Install hose that is one way to filter on, and then plug the hose next to the injection pump
11. Install sensor to chassis and then tighten bolt
12. On the sensor there are two hose connectors, plug the first hose to put out the pipe material from the injection pump, and then install the hose from the fuel tank to the connector fuel meter
13. Install fuel meter display then install the bracket to the front of the dashboard for easy reading
14. At the top there is a fuel meter connector holes, three pairs of the cable with the provisions of the gray cable to the white line sensor fuel supply
15. Install the printer cable at the bottom of the fuel meter to a printer that has been available
16. Once all the wires in pairs of, then connect the gray cable to the white combination supply fuel sensor
17. Install the gray cable to the return sensor
18. Check leakage of any connection to fuel
19. Start the engine and the vehicle as the road route that has been set on the unit and fuel meter

The accuracy of reading the fuel flow in the combination of supply-return flow, can be determined by using the following formula:

$$(.5 \text{ x Supply Rate[gph]}) + (.5 \times \text{Return Rate[gph]}) \div 8 = \text{Fuel consumption} \quad 1$$

But there is equation that could be used to calculate fuel consumption:

$$B = \frac{\rho \; x \; 1000 \; x \; 716.2 \; x \; 0.93 \; x \; 0.12 \; x \; \pi}{144 \; x \; \{0.01 \; x \; L \; + (0.0035 \; x \; 4.5 \; x \; V)\}} \quad 2$$

B= fuel consumption (km/l)
L=Loading of the truck (kg)
V=Speed of the truck(km/h)
ρ= Specific gravity of fuel
in this paper the calculation of fuel consumption will use equation 1.

2.2 Exhaust Emission Analysis

Exhaust emission analysis will be performed on truck with and without installation of SLIFA. The purpose is to investigate if it will increase or decrease the gas emission after installation SLIFA. This test will be performed on diesel engine of truck. Engine temperature is maintained in below 82^0 C. This process will be carried out in various rotation frequency of 1200, 2000, 3000 and 3500 rpm with 3 times repetition. The procedure will be mentioned in the following and the specification of tool could be seen in the Fig-3.

1. Prepare the vehicle and make sure the vehicle is in good condition, with due regard to safety first.
2. Prepare test equipment emission tester/ opacity meter
3. Turn on key and starting the engine with the condition stationer 700 rpm until 15 minutes and check position gouge temperature engine and oil
4. Turn on special tools emission tester/opacity meter and then wait 5 minutes so that the emission tester can achieve temperature standard and calibration test
5. Connect to the probe from exhaust emission opacity meter to the exhaust pipe the engine
6. Increase the rpm engine: step one 700 rpm, step two 1000 rpm, step three 2000 rpm and step four 3000 rpm
7. Check the reading exhaust emission opacity every rpm to determined, and print out data through pc already in connect to the emission tester tools

Repeat the test until it gets the correct one and then compare the data between the installed SLIFA with not installed

Fig-3: Exhaust Emission Opacity Tester

3. RESULT

This subsection will discuss about the result of performance test on fuel consumption and gas emission with and without SLIFA-installed. Generally, the result from the test was concluded that SLIFA has significant value in increasing efficiency of fuel and reduce the impact of gas emission. The result will be specifically described in the next subsection.

3.1 Effect of SLIFA On Fuel Consumption

The advantages of SLIFA on trucks engine is regarding to engine performance and fuel consumption. SLIFA is fulfil the requirement of truck. Therefore, SLIFA didn't decelerate the engine performance. It indirectly increases fuel consumption efficiency which investigated during truck operation. Engine performance and fuel consumption analysis were analyzed by 4 stroke-diesel-engine 6 cycle.

3.1.3 Fuel Consumption Analysis Before Installed By SLIFA

Fuel consumption analysis on diesel trucks engine before SLIFA implementation intend to know beginning data of fuel consumption and then tested directly using digital fuel test meter as shown in Fig-2. The test resulted the standard of fuel consumption before SLIFA implemented. The test performed by drive the truck with route A:

Jakarta-Cikampek highway, Tam Krawang to Tam Cibitung, route B: Tam Cibitung to Tam Krawang and route C: Tam Karawang to Bandung. Total distance of this test was 143 Km with 31,620 kgs total load. Fuel consumption test performed show that fuel consumption ratio is 1:2.3 km/l and more clearly is tabulated in Table-1. The result of fuel consumption rate before speed limiter implementation described in Chart-3 and the average ratio could be calculated as it is:

$$\frac{Used\ Fuel\ Ratio\ Route\ A + B + C + D}{Total\ Ratio} = 1:3.43\ l/km$$

From the result of perception and examination of roadway of HINO SG 260 tractor we conclude as follows: the used of fuel consumption before installation SLIFA depended by condition of road, vehicle operation, the duration journey and payload.

Table-1: Fuel Testing Before Installation of SLIFA

Total Used Fuel Consumption Before Installation SLIFA

Weight of vehicle+Body (Kg)	Route	Total Distance (Km)			Fuel Consumption value (L)	Ratio (l/km)
		Start	Finish	Distance		
20.94	A	118,728	118.778	59.9	14.873	1:4.0
31.62	B	118.778	118.823	34.6	11.802	1:2.9
20.94	C	118.823	118.856	33.6	9.651	1:3.5
30.72	D	118.856	118.931	74.8	22.941	1:3.3

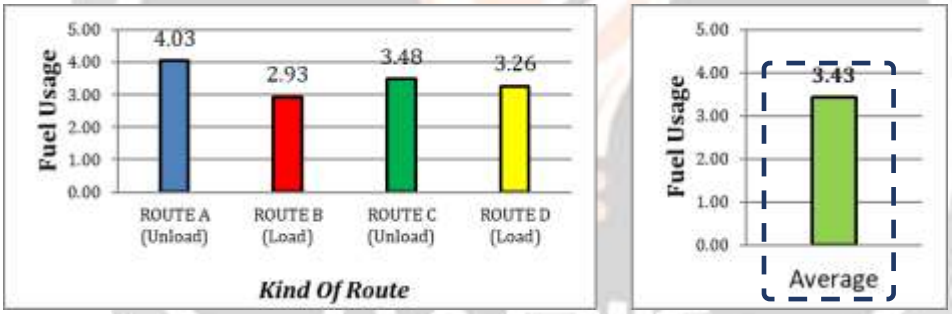

Chart-3: Fuel Usage Before Installation SLIFA

Fuel consumption static analysis by digital fuel flow meter
Supply Rate = 20 Lph (5.3 gph) Return Rate = 10 Lph (2.2 gph) Burn Rate = 10 Lph (2.2 gph)
[(0.5×5.3 gph) + (0.5 × 2.2 gph)] ÷ 8 = (2.6 + 1.1) ÷ 8 = 3.7 ÷ 8 = 0.46 gph or 0.12 Lph

3.1.4 Fuel Consumption Analysis After Installed By SLIFA

The next step will do the test with same condition but with SLIFA (Speed limiter integrated fatigue analyzer) implemented on the engine tested. The result shows a significant increase of fuel consumption. Fuel ratio before SLIFA test were performed to trucks engine. The result shows that top speed performed by driver up to 133 km/h when truck uninstalled by speed limiter. Meanwhile, when speed limiter is installed to the truck, top speed locked at 70 km/h even though the driver wants to speed up. It means that fuel cut-off system is very effective to lock the speed at 70 km/h and it shown the improvement up to 65% and then for the bus, after the installation speed limiter the highest and average speed of 136 km/h and 123.5 km/h is observed by truck speed prior to use speed limiter. After speed limiter applied in the bus, the approved maximum speed is 90 km/h.

Table-2: Fuel Testing After Installation of SLIFA

Total Used Fuel Consumption After Installation SLIFA

Weight of vehicle+Body (Kg)	Route	Total Distance (Km)			Fuel Consumption value (L)	Ratio (L/Km)
		Start	Finish	Distance		
20.94	A	118,728	118.778	59.9	12.873	1:4.65
31.62	B	118.778	118.823	34.6	9.802	1:3.47
20.94	C	118.823	118.856	33.6	7.651	1:4.39
30.72	D	118.856	118.931	74.8	20.941	1:3.57

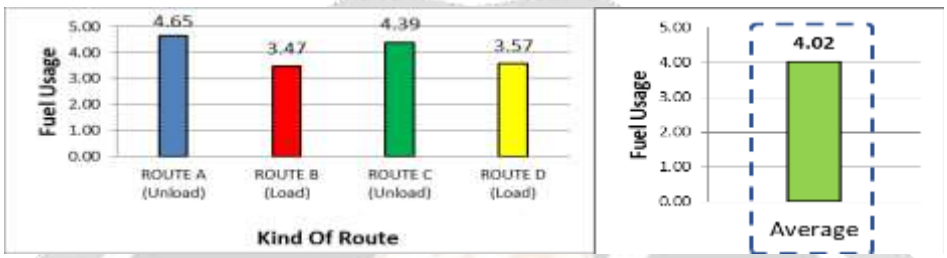

Chart-4: Fuel Usage After Installation SLIFA

Those data approve that the speed limiter can reduce 83% from the top speed before speed limiter applied. Fuel ratio after SLIFA implemented is 1: 4.2 km/l and more clearly is tabulated in Table-2. The improvement of the tool implementation reaches 81 % after SLIFA implemented. The result test after SLIFA implemented in the Chart-4 and it shows fuel usage after SLIFA implementation. It shows the effect of SLIFA installation on engine diesel directly increase the efficiency of fuel at 28.14%. From chart-4 the analysis calculation of average can be used as it is:

$$\frac{Used\ Fuel\ Ratio\ Route\ A + B + C + D}{Total\ Ratio} = 1{:}4.02\ l/km$$

Fuel consumption static analysis by digital fuel flow meter
Supply Rate = 60 Lph (16 gph) Return Rate = 30 Lph (8 gph) Burn Rate = 30 Lph (8 gph)
$[(0.5 \times 16\ gph) + (0.5 \times 8\ gph)] \div 8 = (8 + 4) \div 8 = 12 \div 8 =$ 1.5 gph.

3.2 The Effect of SLIFA on Environment

Environment impact of SLIFA implementation is air pollution resulted by the rest of engine combustion. The data acquisition was performed when trucks are in accelerated condition with minimum 20 km/h speed and maximum 70 km/h. Percentage opacity index value obtained by 3x tests to know the effectiveness of SLIFA implementation on the engine and compared with engine with no SLIFA implemented. Table-1 and Table-2 show decreasing value of percentage opacity index after SLIFA implemented.

3.2.1 Emission Testing Before Installation of SLIFA

It shows the percentage decrease in opacity index value before the engine installation the SLIFA. The average results of tests on the engine emission trucks before installation the SLIFA achieves 22% as shown in the Table-3.

Table-3: Emission testing before installation of SLIFA

ENGINE TYPE	SPEED (KM/H)	RPM	BEFORE EMISSION TESTING (%)		
			1	2	3
TRUCK SG 500	20	1300	21	17	17
	50	2000	22	18	19
	55	2500	23	25	20
	60	3000	23	22	22
	70	3500	19	28	34
Average (%) before install SLIFA emission testing			22		

3.2.2 Emission Testing After Installation of SLIFA

It shows the percentage decrease in opacity index value before the engine installation the SLIFA. The average results of tests on the engine emission trucks after installation the SLIFA achieves 16.6 % as shown in Table-4.

Table-4: Emission Testing After Installation Of SLIFA

ENGINE TYPE	SPEED (KM/H)	RPM	AFTER EMISSION TESTING (%)		
			1	2	3
TRUCK SG 500	20	1300	16	9	14
	50	2000	13	14	14
	55	2500	21	18	17
	60	3000	16	16	15
	70	3500	20	22	24
Average (%) before install SLIFA emission testing			16.6		

the comparison shows emission testing before and after SLIFA installation that the emission of gas is decreasing about 32.53% as the effect SLIFA installation.

3.3 Relationship Fuel Consumption and Gas Emission

After investigate the effect of SLIFA on fuel consumption and gas emission, there is a relationship between fuel consumption and gas emission. The relation between fuel consumption and gas emission is described like this, if speed is accelerated then the efficiency of fuel consumption will decrease and gas emission will increase. This relation will be shown clearly in the Chart-5.

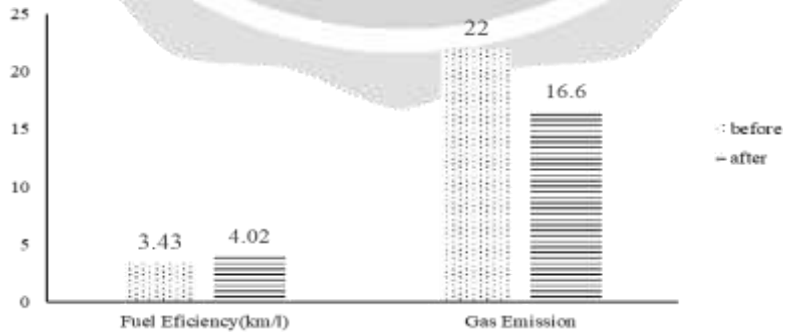

Chart-5: Relation of Fuel Efficiency and Gas Emission

4. CONCLUSIONS

From the results it could be concluded the effect of SLIFA to gas emission and the efficiency of fuel has a positive feedback. It could be seen when the truck testing on the route without SLIFA installation. Driver could speed up the truck and then as effect the fuel consumption and gas emission will increase. Of course, with the speed of the vehicle is accelerated the possibility of the fatalities accident is increased.

As mentioned earlier that the problem of urban transportation system there are high possibilities of accident, fuel consumption and the impact of gas emission. The relationship of gas emission and fuel consumption is directly related to the speed. When SLIFA is installed the speed of vehicle could be limited at certain value. With this limitation the gas emission and fuel consumption could be maintained. The average ratio of efficiency of fuel consumption and gas emission are 3.43 and 22 respectively. Meanwhile, after SLIFA installation the average ratio of efficiency of fuel consumption is increased 4.02 and decreased at 16.6 for gas emission. So that with installation SLIFA, the gas emission could be decreased and the efficiency of fuel consumption could be increased. This result is must be considered that SLIFA could be installed on vehicle to resolve the problem of urban transportation system.

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