Conference Paper

An Analysis of the Effect of Plunger Barrel Performance of High Pressure Pumps and Fuel Against the Main Engine Injector Performance

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Abstract

This study aimed to analyze the magnitude of the performance correlation value of a plunger barrel of high pressure pump (X_1) and fuel (Y_1) in the main engine injector performance (Y). This study applied SPSS (Statistical Package for the Social Sciences) analysis which produces quantitative data to describe the object under the study. The data were collected through a questionnaire by using a Likert scale approach. The results showed that the X_1 coefficient on variable Y was moderate but the correlation value of X_2 to Y was low. The correlation value of the influence of variables X_1 and X_2 together on the variable Y was also low. This variable can be used as an analysis in assessing the performance of the main engine injector in commercial vessels.

Keywords: Influence, SPSS, plunger barrel performance of high pressure pump, fuel, injector performance, main engine.

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1. Introduction

At present, diesel engines with a power of up to 10 kW (one and two cylinders) are widely used. The maximum plunger speed can be increased proportionally in order to increase the HPFP shaft speed (High Pressure Fuel Pump). In a 4-stroke Diesel Engine, the HPFP shaft rotates with a speed two times less than that of the crankshaft. By using HPFP shaft equalization and crankshaft speed, it is possible to increase the speed of the plunger twice faster. However, the fuel pressure provided by HPFP will not be 2 times greater due to its compressibility and the fuel leakage (throttling) in the HPFP cavity. Thus, a predictable increase in pressure in the system is around 1.45-1.5 times (Salykin et al., 2017).

There are some requirements for high pressure fuel for injection. Firstly, the injected fuel must have enough pressure to penetrate the mass of the solid combustion chamber. Secondly, there should be high rotation speeds. Thirdly, the amount of time available for fuel injection is very low, and high pressure is needed to break the fuel into a fine mist (Heywood, 1988).

There are three components that can decrease the power of the main engine, namely the plunger barrel, high pressure pump, fuel, and main engine injector. These three components play very important roles in supporting the process of fading and burning of the diesel motors. If one of the components does not work properly, it will affect the temperature of the exhaust gas. When the temperature is high, the power in the main engine will decrease. Therefore, maintenance or new replacement must be carried out on damaged components. Moreover, maintenance or replacement is also needed when the working hours of the parts exceeds the provisions written on the manual book (8000-1200 hours for the plunger barrel and 2000-3000 hours for the injector). If the plunger barrel does not work properly but is not replaced immediately, it will decrease the pressure of the fuel injected from 320 bar to 290 bar. When it happens, the quality of the fuel will be low because it contains a lot of water and other impurities which also leads to the low performance of the injector. The fuel cannot be completely uprooted because the fuel nozzle is clogged due to either the fuel's poor quality or exceeding working hours. Thus, new spare parts are needed.

This research was aimed to analyse: (1) the effect of high pressure barrel pump plunger performance on main engine performance, (2) the effect of fuel on main engine performance, and (3) the performance of plunger barrel high pressure pump and fuel on the main engine injector.

2. Literature Review

The injection pump is a pump house made of cast aluminum (or cast iron). The camshaft or pump shaft is supported by two tapered roller bearings and driven by a motor through a gear chain. Pump elements consisting of plunger and cylinder (barrel) are regarded as the most important parts. These plungers and cylinders are applied by high-precision finishing and are placed in very small tolerances in order to allow the pump element remain in a very high pressure without any leakage (Arifin, 2011).

Fuel is obtained by distillation or breakdown of petroleum or crude oil. Crude oil is a dark brown liquid which is a combination of a large number of mixtures. The main chemical elements which compose this whole mixture are hydrogen and carbon.

Therefore, this mixture is called hydrocarbon. The amount of hydrogen in the mixture varies from 11 to 15 weight percent while the rest is carbon (Maleev, 1995).

In the first development stage of diesel motors, coal powder is used as fuel. However, since it does not work well and is considered as impractical, coal is no longer used. Thus, until now, liquid fuel is a type of fuel that is widely used (Arismunandar, 2002).

In the fuel system of the main engine on board, there is a fuel system component which includes fuel tank, filter, purifier, fuel pump, injection pump and nozzle (Instruction Manual, 2005).

3. Methods

In this research, quantitative approach was applied. Quantitative research is a type of research whose findings can be obtained by using statistical procedures or measurement (Sujarweni, 2015). The population consisted of 77 students of the 8^{th} semester student of Semarang Merchant Marine Polytechnic (SMPP). Slovin formula was applied to obtain the research sample with a 95% confidence level (Sujarweni, 2015). Sixty seven students in total were selected as the sample of this study.

SPSS (Statistical Package for the Social Science) Version 17.0 was used to analyze the data. Some tests, including (1) the indicator validity test; (2) reliability test; (3) classical assumption test consisting of multicollinearity test, heteroscedasticity, test and normality test; (4) multiple regression analysis; (5) T-test hypothesis test; and (6) the test to find out the coefficient of determination (R^2) were carried out (Dwi Piyatno, 2009).

In this research, there were two independent variables and one dependent variable. Five indicators were used in the first, second independent variables and dependent variable.

4. Results and Discussions

A correlation values between item scores with total scores was found, and it was then compared to the r table value. R table was determined at the significance of 0.05 with the 2-sided test and the number of data (n) = 67, so the r table was 0.242. Based on the analysis, the correlation for the item X_2 independent variable on item X_2 was less than 0.242. It can be concluded that they were not significantly correlated with the total score (invalid). Therefore, it must be issued or repaired. On the other hand, the other items reached more than 0.242 which can be concluded that the instrument was valid.

TABLE 1: Indicators of independent and dependent variables.

Type indicator	Indicator	Scale
Independent variable X_1 (Plunger barrel)	1. The ability to inject fuel into the injector 2. Good material quality (not easy to apply) 3. Potency for high fuel expansion (119°C-133°C) 4. The ability to supply fuel continuously well 5. Plunger barrel replacement which meets the standard working hours (8000–12000 hours)	Likert (1-5)
Independent variable X_2 (Fuel)	1. Good ignition quality according to CCAI standards (Calculated Carbon Aromaticity Index 800 - 880) 2. SG value, corresponding viscosity and flash point value (SG: 0.971 gr/ml; viscosity: 12 cst at 1250C) 3. Minimum water content 4. Metal content according to rules (sodium: 100 mg/kg; vanadium: 600 mg/kg; aluminum: 80 mg / kg) 5. 5.0% sulfur content	Likert (1-5)
Dependent variable Y (Injector)	1. Ability to fade at 320 bar 2. Conformity of exhaust gas temperature of each cylinder with the information in the manual book (400°C) 3. Good condition of fuel nozzle tip 4. Replacement of fuel nozzle tip which meets the standard working hours (2000-3000 hours) 5. Conformity of maximum pressure with the standardized rules (1350 bar)	Likert (1-5)

Based on the results obtained from the reliability testing of research instruments, variable $X_1$and X_2 obtained coefficient value > 0.60. It can be concluded that the instrument was declared as reliable. Moreover, the dependent variable Y on items Y_4 and Y_5 obtained coefficient value < 0.60 which can be concluded that the instrument is not reliable.

Multicollinearity test is aimed to determine whether there is an intercorrelation (strong relationship) between the independent variables. A good regression model is characterized by no intercorrelation between independent variables (no symptoms of multicollinearity). One of the most accurate ways to detect the presence or absence of multicollinearity symptoms is by looking at the tolerance value. If the tolerance value is greater than 0.10, it means that there is no multicollinearity. It can also be found out by looking at the VIF value; if the VIF value is smaller than 10.0, it means there is no multicollinearity.

Based on the data above, it can be concluded that the regression model did not occur in multicollinearity symptoms; the variable VIF of the plunger barrel and fuel was less than 10.00.

The purpose of heteroscedasticity test is to determine whether there is residual variance inequality in the regression model found in one observation to another observation. The basis for decision making can be seen with Scatter plot image patterns.

Table 2: Results of independent and dependent variable Bivariate Pearson analysis.

Item	Item -total Correlation	R table	Note
	Plunger Barrel		
X_1	0.530**	0.242	Valid
X_2	0.609**	0.242	Valid
X_3	0.630**	0.242	Valid
X_4	0.500**	0.242	Valid
X_5	0.497**	0.242	Valid
Item	Item -total Correlation	R table	Note
	Fuel		
X_1	0.530**	0.242	Valid
X_2	0.210	0.242	Invalid
X_3	0.488**	0.242	Valid
X_4	0.641**	0.242	Valid
X5	0.606**	0.242	Valid
Item	Item -total Correlation	R table	Note
	Injector		
Y_1	0.680**	0.242	Valid
Y_2	0.608**	0.242	Valid
Y_3	0.683**	0.242	Valid
Y_4	0.557**	0.242	Valid
Y_5	0.559**	0.242	Valid

It is regarded as unstable heteroscedastic regression if the data points spread above and below or at around number 0. Moreover, the spread of data points should not form a wavy pattern, becoming narrow and widen again. The spread of data points is not patterned.

Based on Table 7, it can be seen that the regression constant was 5.301. The variable regraft coefficient was high pressure pump plunger barrel (X_1) of 0.423 whereas the variable fuel regression coefficient (X_2) was 0.344. Thus, the regression equation could possibly composed: $Y = a + b_1X_1 + b_2X_2$, $Y=5.301+0.423X_1+0.344X_2$ (Ghozali in Sujarweni, 2005).

The explanation of the multiple regression equation is as follows. If a = 5.301, it means that the injector performance is 5,301 (the variable plunger barrel (X_1) and fuel (X_2)). The number showed that there was no change (constant). Moreover, if it was written b_1 = 0.423, it means that if the high pressure barrel pump plunger variable increased 1 unit and the fuel variable was constant, the injector performance variable would also increase by 0.423. On the other hand, b_2 = 0.344 means that if the fuel variable increased

Table 3: The results of the independent and dependent variable reliability testing.

Item	Cronbach Alfa	Coefficient Value	Note
Plunger Barrel			
X_1	0.747	0.60	Reliable
X_2	0.749	0.60	Reliable
X_3	0.752	0.60	Reliable
X_4	0.759	0.60	Reliable
X_5	0.743	0.60	Reliable

Item	Cronbach Alfa	Coefficient Value	Note
Fuel			
X_1	0.758	0.60	Reliable
X_2	0.767	0.60	Reliable
X_3	0.759	0.60	Reliable
X_4	0.750	0.60	Reliable
X_5	0.743	0.60	Reliable

Item	*Cronbach Alfa*	Coefficient Value	Note
Injector			
Y_1	0.680	0.60	Reliable
Y_2	0.603	0.60	Reliable
Y_3	0.683	0.60	Reliable
Y_4	0.557	0.60	Unreliable
Y_5	0.557	0.60	Unreliable

Table 4: Multicollinearity test results.

Model	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
	B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1 (Constant)		2.898		1.829	0.072		
Plunger barrel	0.423	0.112	0.421	3.786	0.000	0.796	1.257
Fuel	0.344	o.144	0.265	2.384	0.020	0.796	1.257

1 unit and the barrel plunger variable was constant, the injector performance variable would increase by 0.344.

Based on the regression equation, it is shown that the variable plunger barrel high pressure pump and fuel positively influenced the performance of the Main Engine injector.

According to Sujarweni (2015), if the significance value is <0.05, or t count is > t table, there is an effect of variable X on Y. However, if the significance value is > 0.05,

Table 5: Heteroscedasticity test results.

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
1 (Constant)	4.191	1.638		2.559	0.013
Plunger Barrel	-0.123	0.063	-0.259	-1.949	0.056
Fuel	-0.014	0.082	-0.023	-0.113	0.863

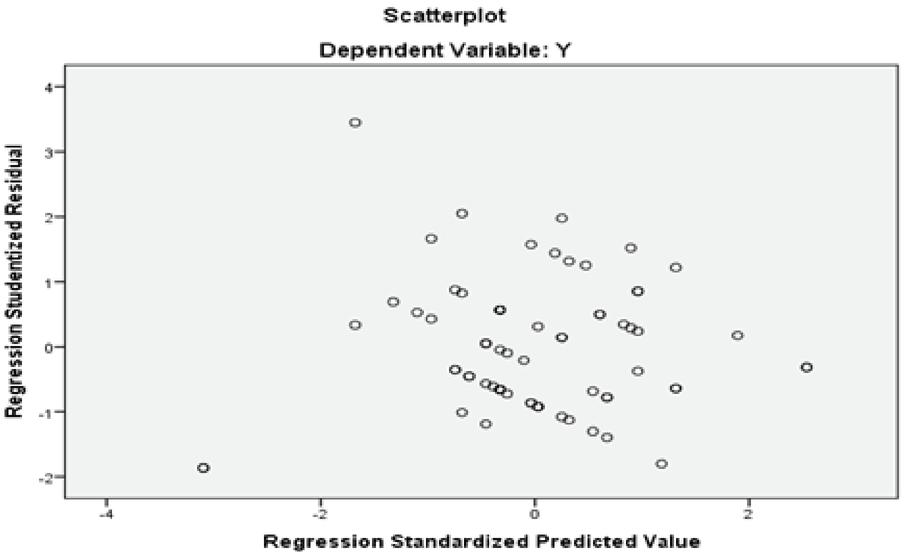

Figure 1: Scatter Plot between variables.

Table 6: Normality test results.

One-Sample Kolmogorov-Smirnov Test		
		Unstandardized Residual
N		0.69
Normal Parameters[a,b]	*Mean*	0.0000000
	Std. Deviation	1.79685806
Most Extreme Differences	*Absolute*	0.091
	Positive	0,090
	Negative	-0.091
Test Statistic		0.091
Asymp. Sig. (2-tailed)		0.200[c,d]
a. *Test distribution is Normal.*		
b. *Calculated from data.*		
c. *Lilliefors Significance Correction.*		
d. *This is a lower bound of the true significance.*		

or t count is <t table, there is no effect of variable X on variable Y with formula t table

Table 7: Results of the independent variable normality test (X_2) with the dependent variable (Y).

Coefficients[a]						
		Unstandardized Coefficients		Standardized Coefficients		
	Model	B	Std. Error	Beta	t	Sig.
1	(Constant)	5.301	2.898		1.829	0.072
	Plunger barrel (x_1)	0.423	0.112	0.421	3.786	0.000
	Fuel (x_2)	0.344	0.144	0.265	2.384	0.020
a. *Dependent Variable*: injector performance						

= t (a / 2; nk-1) = t (0.025; 66) = 0.242, where n = number of samples, k = number of variables X (2 variables), a = level of trust, testing hypotheses h_1, h_2, and h_3 with t test.

On the first hypothesis (H_1) testing, it is known that the significance value for influencing X_1 to Y is 0.000 <0.05 and the value of t counts is 3.786 > t table 0.242. Based on the finding, it can be concluded that H_1 is accepted. It means there is an influence of X_1 on Y. On the second hypothesis (H_2) testing, it is known that the significance value to influence X_2 to Y is 0.020 <0.05 and the value of t counts is 2.384> t table is 0.242. Thus, based on the finding, it can be concluded that H_2 is accepted. It means that there is an influence of X_2on Y. On the third hypothesis (H_3) testing, it is known the significance value to influence X_1 and X_2which is simultaneously to Y is X_1 equal to 0.000 < 0.05. The value of t counts is 3.786 > t table 0.242 whereas X_2 is 0.020 <0.05. The value of t counts is 2.384 > t table 0.242 and Y equal to 0.000 <0.05. Based on the finding, it can be concluded that H_3 is accepted and it means that there is an influence of X_1 and X_2 simultaneously on Y.

Based on the table, it is seen that the value of R square (R^2) reached 0.349. This indicates that the contribution of the variable independent of the high pressure barrel pump plunger (X_1) and the fuel variable (X_2) to the dependent variable injector performance was 34.9% and 65.1% remaining.

The finding can be interpreted that the high pressure barrel pump plunger variable (X_1) and fuel variable (X_2) affected the injector performance dependent variable (Y) to (0.349 x 100) = 34.9% and 65.1% remaining.

5. Conclusion

The performance of the barrel high pressure pump plunger affected positively to the performance of the main engine injector for about 42.1% and B_1 (regression coefficient

Table 8: Hypothesis test results t.

Model		Sum of Squares	D_f	Mean Square	F	Sig.
1	Regression	96.776	2	48.388	17.705	0.000[b]
	Residual	180.383	66	2.733		
	Total	277.159	68			
a. DependentVariable: injector performance						
b. Predictors: (Constant), Fuel, Plunger barrel						

Coefficients[a]				
Unstandardized Coefficients		Standardized Coefficients		
B	Std. Error	Beta	t	Sig.
5.301	2.898		1.829	0.072
0.423	0.112	0.421	3.786	0.000
0.344	0.144	0.265	2.384	0.020
a. *Dependent Variable*: injector performance				

Table 9: Test results of the coefficient of determination (R^2).

Model	*R*	*R Square*	*Adjusted R Square*	*Std. Error of the Estimate*
1	0.591[a]	0.349	0.329	1.653
a. Predictors: *(Constant),* fuel, plunger_barrel				

value X_1) of 0.421. Thus, it is found that the effect of the high pressure plunger barrel pump performance on the Main Engine injector performance was medium.

Fuel performance had a positive effect on the performance of the main engine injector by 26.5% and B_2 (regression coefficient X_2) reached 0.265. The effect of fuel performance on the performance of the Main Engine injector was low.

B_3 (regression coefficient value X_1 and X_2) showed that the magnitude of the coefficient of determination shown by the R Square Adjuster value reached 0.329. It means that the high pressure barrel pump plunger variable (X_1) and fuel free variable (X_2) could possibly affect dependent variable injector performance (Y) by 32.9% (0.329 x 100) and 67.1% (100- 32.9) was remaining. Thus, the performance of the plunger barrel pumps high pressure and fuel against the performance of the main engine injector was low.

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