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Pressure analysis of the ideal intake manifold with the vibration parameters at the diesel engine

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Abstract. Using turbo as power booster still has left over one problem, namely, turbo lag. The turbo lag is still not resolved and Turbocharger technology development could not raise the engine's maximum torque. The purpose of this study was to analyze the ideal intake manifold pressure on several variations of engine rotation and some treatments of turbochargers with the vibration parameters and to examine the smallest vibrations when there was a change into the intake manifold for shorter engine acceleration and smoother engine sound due to the lower vibration. The results gotten from this study were from the intake air in the intake manifold showed a decrease in the vibration of 7-10% and experienced an average increase in volumetric efficiency of 26.63% compared with the engines without turbo and 18.32% when compared with the engine with turbo standard. This proved that the perfect combustion was at the smallest vibration. The smallest vibrations on the engine in the same rotation described the pressure conditions and the combustion chamber in the ideal conditions.

1. Introduction

A turbocharger is a component which is assembled on a motor vehicle that aims at increasing the power of the motor by adding more air density than the usual charging method. The turbocharger consists of a turbine and a compressor. The disposal loss is considerable. It, therefore, takes lots of the effort to reduce it. One of the ways of reducing the exhaust losses is to assemble a turbocharger in the exhaust. In this case, the exhaust gas is used to drive the gas turbine that drives the compressor. The compressor pumps the air into the cylinder to increase the pressure and the amount of the air put into the cylinder. Thus, the amount of fuel inserted into the cylinder can be multiplied so that the engine power can be enlarged. With the turbocharger, about 8 to 10% of the amount of fuel combustion heat can be saved [1].

However, the use of the turbo as a power booster still has left over one problem to date, namely, turbo lag. In general, turbo lag can be interpreted as a condition when the driver stepped on the gas pedal abruptly and the power generated instantly does not match as expected. This is because the turbines inside the turbo device take time to spin fast and move the compressor in producing enough air pressure to force it into the combustion chamber [2]. Moreover *wawan et al*, explained that the turbo lags make the characters of the turbo engines different and potentially dangerous [3]. There is a long time lag after the driver steps on the gas until the energies of the engine actually come out. This longer time occurs because the exhaust stream takes time to rotate the turbine that is driven up to reach the current flow. Once the gas is stepped on the exhaust current increases, the turbine slowly starts to spin but has not been able to make enough pressure because the blow-off valve is still open. When the

rotation increases then blow-off valve begins to close, then the turbo can increase the pressure gradually. This is different from the machine N/A (Naturally Aspirated) which directly gives effect power [4]. The unnatural character sometimes makes the rider startled. It feels like no power when the gas is stepped on especially the turbo engine normally has a lower compression ratio than the N/A engine [5]. But once the pressure accumulated, suddenly the energy becomes very large. Now turbo technology is growing. The use of a sequential double turbine up to variable turbine angle is designed (is made and used) to minimise the lag but still, its character cannot be natural N/A engine.

In the earlier description, the effort made to improve the engine performance is to make use of the turbocharger. The use of turbochargers on diesel motors is actually very common. However, this usage raises many problems. The problems are as follows as the problem of turbo lag has not been fully resolved. Then, The development of turbocharger and supercharger technology has not been able to raise the maximum torque near the idle round. Therefore, the researchers wished to examine the ideal pressure in the intake manifold space in some variations of rotation by using the vibration parameter as the ideal intake manifold pressure indicators. The smallest vibration of the engine in the same rotation describes the conditions of pressure and the mixture of the combustion chamber under the most ideal conditions [1]. The study is to refer to the limit issued by the Ministry of Environment No. 05 of 2006 [4].

2. Diesel engine characteristics

The previous reseacher [4] expnained that briefly elucidates that diesel engine is one form of the internal combustion motor besides to gasoline and gas turbine. Diesel engine or commonly called Compression Ignition engine is a motor ignition engine that has the concept of ignition caused by compression or suppression of mixture between fuel and oxygen in a motor engine under certain conditions. The concept is that when a fuel is mixed with oxygen, then at a certain temperature and pressure the fuel will ignite and generate power or heat.

The main characteristic of a diesel engine that distinguishes it from the other combustion engines lies in the method of fuel ignition. In a diesel engine, the fuel is injected into a cylinder containing high-pressure air. During the process of compressing the air in the engine cylinder, the air temperature increases, so when the fine fog-shaped fuel intersects with this hot air, then the fuel will ignite by itself without the help of another igniter. For this reason, the diesel engines are also called Compression Ignition Engines. Turbocharger is useful as it increases the volumetric efficiency of air entering the cylinder. This is done by pumping the air into the intake manifold using the rotor impeller / compressor (1) by utilising the exhaust gas stream that rotates the rotor turbine (2) [4]. The air generated by the exhaust gas is capable of diminishing the amount of light measured under normal conditions.

The pressure in the fluid can be defined as a force acting per unit area or: *P = F/A* [6, 7]. Pressure gauges and several other types of tools have been created to measure pressure, among which the simplest is the open-tube manometer. If a four-step engine can absorb the air at its suction condition as much as the volume of its piston steps for each suction step, then it is ideal. However, it does not happen in real life. The comparison between the actual amounts of the air exposed to the amount of the air expelled in the ideal condition is called volumetric efficiency [3].

As explained in [7] elucidates that the vibration is the insulated movement of the mechanical system and its dynamic conditions. Vibration can be a continuous recurrence of a clash or, in other words, can also be irregular or random movements. The usual vibration occurs when the machine or device is run by the motor. This has a mechanical effect. Vibration is an oscillation motion around a point caused by an air or mechanical vibration, such as a machine or other mechanical means. Therefore, the vibrations are mostly used to analyse the machines either from rotational or translational motions. Vibration has three parameters that can be used as a benchmark.

3. Research methodology

This research used the experimental method [8]. Defines experimental as a study which is intended to determine whether there is a result of a subject imposed on the subject. In other words, the experimental research attempts to examine the causal relationships by comparing one or more comparison groups that do not receive treatment. The locus of testing in this research was carried out in the workshop of the Department of Automotive Faculty of Engineering, State University of Padang. The Independent Variable (X) was the pressure of the ideal intake manifold. The dependent Variable (Y) was vibration. The object of this research was 4-stroke diesel (Toyota 2KD-FTV), the 4 cylinders with the capacity of 2494 cc. The instrument used in this research was Manometer U which was used to measure the airflow, vibrometer or knock sensor was used to detect the vibration in the engine whilst the Digital Storage Oscilloscope was made use of measuring the vibration detected vibrometer.
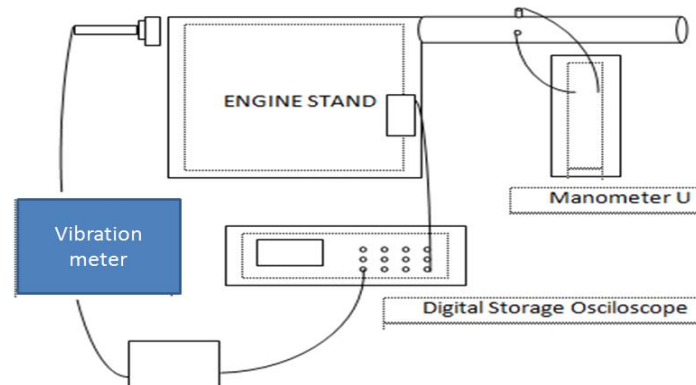

Figure 1. Experimental procedure

The experimental procedure in this study as depict in the Figure 1. Ahead of undertaking the test, preheat the engine until the operational condition. The test steps were as 1) Installing the auxiliary equipment on the test or test aids (U manometer with paralon pipes in the air intake into the intake manifold and oscilloscope with a series of vibration detectors or knock sensors), 2) The first test was to set the engine on idle rotation with engine condition not using the turbo. Then the vibration detection device was placed at the top of the engine. Test results could be read on U and oscilloscope manometer, 3) In addition to the idle rotation, this study was also varied with the speeds of 1000 rpm, 1500 rpm, 2000 rpm, 2500 rpm and 3000 rpm, 3) At each speed, a comparison was made when using the added turbo.

The data collection technique was by direct data retrieval on the machine tested by using Manometer U test, vibration detector and Digital Storage Oscilloscope. From the tests conducted, the researchers obtained the required data, which would be done processing, and analysis of the data obtained. Furthermore, the data collection tools were the tables that would be further processed to produce the percentages of the graph of rpm vs. flow rate, rpm vs. air pressure, rpm vs. peak-to-peak vibration, rpm vs volumetric efficiency. The required data were Rpm, high fluid on the pitot measuring instrument, peak-to-peak vibration, vibration time and time on 1 vibration wave. The data were taken on each variation of intake chamber pressure.

This research used descriptive analysis to observe directly the experimental results. Subsequently, the researchers concluded and determined the best results of the research. The data obtained from the first test were calculated to get the performance of the engine which includes torque, flow velocity, air pressure, vibration time and time device. Finally, the researchers analysed the results of the calculations performed in the form of the tables and graphs so that the conclusions could be drawn from the research.

3.1. Flow velocity

The flow velocity calculated in this study was the speed of air entering the combustion chamber through the intake manifold. The flow velocity (V) can be calculated as follows.

$$V = \frac{Q}{A} \tag{1}$$

Where Q is debet and A is the cross-sectional area.

3.2. Air Pressure

The air pressure was directly proportional to the flow velocity. The higher the speed of the air flow, the resulting pressure will also be higher and vice versa. The air pressure could be calculated as follows

$$\Delta p = \frac{1}{2} \rho H_2 Ogh(SGHg) \tag{2}$$

Prior to undertaking the test, theoretically, the researcher first calculated the air requirement required by the cylinder by calculating the Δh from each machine rotation level per minute (rpm) as benchmark setting of measuring the instrument which was used in data collection. In addition, the calculation of the Δh was also used to calculate the volumetric efficiency of the engine studied. The calculation of the Δh could be seen as follows

$$\Delta P 1_1 = \Delta P_2 \tag{3}$$

$$\frac{1}{2} \rho V^2 = \rho g h \tag{4}$$

$$h = \frac{\frac{1}{2} \rho(air)V^2}{\rho g} \tag{5}$$

The percentage of volumetric efficiency can be calculated by the following equation

$$\eta = \frac{h(manometer\,calculation)}{h(Manometer\,theoritis)}.100\% \tag{6}$$

4. Experimental results and discussion

The experimental results is shown in Table 1-3. The Figure 2 showed that the actual air supply comparison (incurred) on the 2KD-FTV diesel motor. Thus, the theoretical Δh on the graph indicated the need for the air to be met in order the machine's volumetric efficiency approached 100%. The Table 3 showed that the diesel motor with an added turbo had a higher speed when compared with the diesel engines without turbo and the diesel motors with the turbo. This was due to an added turbo and the turbo that increased the speed of the airflow that easily got into the intake manifold by forcing the atmospheric air into the cylinder during the suction step.

The working capacity of this turbo would work well on high rotation. The Table 2 showed that an added turbo diesel motor had a higher air pressure compared to the turbo diesel engine and the turbo diesel motor. This was caused by the added turbo and the turbo motor could increase the airflow rate which got into the intake manifold by forcing the atmospheric air into the cylinder during the suction step so that the air pressure would also increase. The Table 2 showed clearly that the actual (h actual) line was closer to the (h theoretical) to every variation of the engine spin. Accordingly, by using the additional turbo, the need for the air was met and the volumetric efficiency could approache100%. The additional turbo-rated diesel motor experienced the average increase of volumetric η was 26.63% when compared to a turbo diesel-powered motor. On the other hand, if the additional turbo diesel motor was compared to a standard turbo diesel engine the average increase of volumetric η was 18.32%.

Peak to peak vibration is the maximum amplitude. The Table 3 showed significant differences between the three variations of diesel motors. The diesel engines that used the additional turbo experienced a decrease in vibration by an average of 10.68% when compared to the diesel-powered

motors without turbo and when compared to the standard turbo or turbo diesel engine, it was found a decrease in vibration with an average of 7.93%.
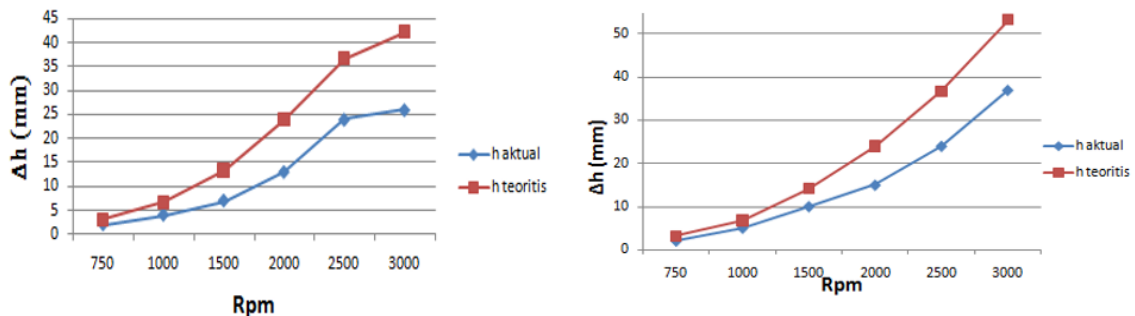
Table 1. Without turbo

rpm	h manometer u/velocity	Peak to peak vibration (m/s)
750	2	40
1090	4	28,6
1538	7	30,2
2054	13	33,6
2542	24	32,4
2727	26	41,2

Table 2. With turbo

rpm	h manometer u/velocity	Peak to peak vibration (m/s)
750	3	40,8
1090	5	25,4
1578	10	24
2054	15	31,6
2542	24	32,8
3061	37	35,2

Table 3. With additional turbo

rpm	h manometer u/velocity	Peak to peak vibration (m/s)
750	3	39,2
1111	5,5	23,6
1648	12,5	20,8
2238	22	15,8
2608	34	18,5
3000	49	24

(a) Preassure intake actual and teorities without turbo   (b) Preassure intake actual and teorities without turbo

Figure 2. pressure in intake manifold

5. Conclusion

The use of turbulence in the intake manifold at a 25-degree blade angle reduced power by 22% and torque by 9%. The use of turbulence in the intake manifold at a 40-degree blade angle increased the power by 12% and torque by 3%. The use of turbulence in the intake manifold at a 55-degree blade angle decreased the power by 9% and torque by 7%. This means that the uses of turbulent blade angles variations in the intake manifold significantly affected the power and torque of four-step motorcycles.

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