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Turbo Intercooler Cooling System

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ABSTRACT : *An intercooler is an additional component fixed to a turbo charger to improve its performance and efficiency. It is similar to a radiator whereas a radiator cools the engine but a turbo intercooler cools the air which is fed into the engine. As the turbocharger engine running in long range, more hot air are compressed by turbo entered into intercooler. The temperature of intercooler at certain time will increase due to hot air entered, temperature engine and weather condition. Turbo Intercooler Cooling System are design operated automatically to detect the temperature increase at intercooler. When temperatures are increased, motor will trigger and sprinkler will spray water through intercooler. The system generally embedded in front of intercooler and generated by a control panel which are require 12 v power supply can directly attach from battery and tap on the circuit on which it convert to 5v by the circuit before connect to the controller. The system is powered by the Arduino Uno as the main controller on which being program to control automatically. The control panel also can operate in manually which a manual switch are attached to give choices to the user whether to choose auto or manual operating mode.*

KEYWORDS : *Intercooler, Ideal gas law, Fuel energy, turbo, cooling system*

I. INTRODUCTION

Intercoolers have been increasingly used in internal combustion engines with supercharging since 1990s because of their positive effect on engine power and fuel consumption. An intercooler is any mechanical device used to cool a fluid, including liquids or gases, between stages of a multi-stage heating process, typically a heat exchanger that removes waste heat in a gas compressor. The intercooler is placed somewhere in the path of air that flows from the turbo/supercharger to the motor. An intercooler is needed because of the physics of air described in the Ideal Gas Law, that is PV= nRT. Explaining the ideal gas law as basic because pressure and temperature are directly proportional, as it create more pressure with turbo or supercharger, which produce more heat as well. Hot air is less dense and therefore contains less molecules of oxygen per unit volume. This means less air for the motor in a given stroke and therefore less power produced. Hot air also causes a higher cylinder temperature and therefore can aid in pre-detonation of the combustion cycle causing detonation.[1]. Intercoolers increase the efficiency of the induction system by reducing induction air heat created by the supercharger or turbocharger and promoting more thorough combustion. This removes the heat of compression (i.e., the temperature rise) that occurs in any gas when its pressure is raised or its unit mass per unit volume (density) is increased. The purpose of this project is to enhance the development of an automatic turbo intercooler cooling system in reducing air heat created by turbocharger which hot air passing through intercooler and enter the intake system. By reducing the intercooler temperature, hot air flow passes through intercooler will be more cooled before its enter intake engine. When air is cold so it has more oxygen, good density and volume which will increase performance engine. When hot air entered from turbine flow through intercooler, the hot air temperature will reduce because of the fins at intercooler will absorb the hot air through it. After operated for a while, the temperature of intercooler will raise because hot air flow through continuously non stop. Hot air have low density, volume and minimal oxygen content which will reducing the performance when enter intake of engine. These will reduce the turbo engine performance. The automated turbo intercooler cooling system will operates when Arduino UNO microcontroller received signal from heat sensor which mounted at intercooler. When temperature increase at some value, water tank motor will on to spray the intercooler using nozzle mounted at side of intercooler.

From the previous project, there are some development needs to enhance a manually operated for turbo intercooler cooling system have been design. User have to push the button by itself if want to reduce the temperature of intercooler. Other than that, intercooler is counting up to the air flow through it to reduce heat and temperature. Some of user does not alert when the temperature of intercooler raise. This will reduce the performance of turbo engine because hot air enter intake of engine.The main objective of this project is to study and investigate temperature rise of intercooler at turbo. Other than that, to develop and design an automatic controller circuit to reduce temperature of intercooler. Last but not least, to install and testing the efficiency and accuracy of turbo intercooler cooling system. The scope of this project is to measure the intercooler temperature before and after installing Turbo Intercooler Cooling System. The data will be compare and get the final result and plot a graph. For this project, turbo engine L200s injection 660cc were used to measure and collect data for result.This project only for turbo engine only and mainly use water ($H2O$) as a medium to reduce heat efficiency

II. LITERATURE REVIEWS

Several studies have been made by previous researchers on turbo intercooler. Automotive engine cooling system takes care of excess heat produced during engine operation. It regulates engine surface temperature for engine optimum efficiency. Recent advancement in engine for power forced engine cooling system to develop new strategies to improve its performance efficiency. Also to reduce fuel consumption along with controlling engine emission to mitigate environmental pollution norms. Studies for turbocharging systems are also included in this range. One of the most important problems faced in turbocharging systems is that air density is decreasing while compressing air. Also air with high temperature causes preignition and detonation at spark ignited engines. Various methods have been developed to cool down charge air which is heated during turbocharging process. One of these methods is to use a compact heat exchangers called as intercoolers to cool charging air. The purpose of an intercooler is to cool the charge air after it has been heated during turbocharging. As the air is cooled, it becomes denser, and denser air makes for better combustion to produce more power. Additionally, the denser air helps reduce the chances of knock.Turbo intercooler is a heat exchanger. Heat exchangers are two or more fluids that don't physically touch each other but a transfer heat or energy takes place between them. Turbo Regals made in 1986/87, Turbo TAs, GMC Syclones and Typhoons all came with intercoolers to cool down the hot compressed air coming from the turbocharger. Turbo Regals and Turbo TAs use outside air as the cooling media; Syclones and Typhoons use water. Turbo Regals made in 1985 and before did not have intercoolers as original equipment[2]. There are certain problems in automotive applications that cause environmental effect, cost and comfort problems. Therefore, internal combustion engines are required to have not only a high specific power output but also to release less pollutant emissions. For these reasons, current light and medium duty engines are being highly turbocharged because of having negative environmental effects of internal combustion engines.Various new or improved vehicle engine technologies are being exploited to reduce C02 emission by improving vehicle fuel economy. Among many technical innovations and improvements in these vehicles, engine downsizing (reduction in displacement volume and/or the number of cylinders) is one of the most effective methods to reduce fuel consumption, i.e. CO_2 emission [3]. These equations are good for any heat transfer problem, such as radiators and a/c condensers, not just intercoolers(1)
The first equation describes the overall heat transfer that occurs.

$$Q = U \times A \times DTlm \qquad (1)$$

Q is the amount of energy that is transferred.
U is called the heat transfer coefficient. It is a measure of how well the exchanger transfers heat. The bigger the number, the better the transfer.
A is the heat transfer area, or the surface area of the intercooler tubes and fins that is exposed to the outside air.
DTlm is called the log mean temperature difference. It is an indication of the "driving force", or the overall average difference in temperature between the hot and cold fluids.

It's helpful to understand that, during operation, internal combustion engines convert the energy of fuel into mechanical work and heat. Approximately one-third of the fuel energy goes into the mechanical work of the moving vehicle, one-third into exhaust heat, and one-third into heat transferred by the engine cooling system to the ambient air.

Fig.1. Fuel energy distribution

This means that heat load to the cooling system at rated power (Usually expressed in BTUs per minute) is approximately equal to the rated power of the engine expressed in BTUs per minute (HP X 42.4 = BTU/minute). From this we can see that if an engine is modified to increase its horsepower, the load to the cooling system will also increase. In fact, the heat load to the cooling system will increase by about the same percentage as the increase in engine horsepower. So, if we increase the engine horsepower by 20 percent, we can expect an increase of about 20 percent in the heat load to the cooling system[4]. There are various case studies about supercharging and intercooling configurations in newly developed internal combustion engines such as Homogenous Charge Compression Ignition Engines, Lean Burn Engines and Hydrogen Fueled Engines. 50 % specific fuel consumption decrease and 147 kW effective power output were obtained from a supercharged intercooled Lean Burn Spark Ignition Engine while the exhaust gas emission values obtained proper to Euro 6 emission regulations [5]. Some research had done by comparing turbocharger engine n/a with and without intercooler and natural aspirated engine. It shows that adding intercooler will increase the performance engine[1]. Fig.2. Shows the power output of engine.

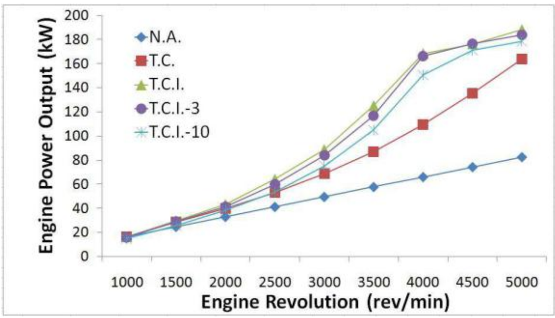

Fig. 2. Power output values of the engine due to supercharging, N.A. - Naturally aspirated engine, T.C. - Engine with turbocharger and without intercooler, T.C.I. - Engine with turbocharger and intercooler, T.C.I.-3 - Engine with turbocharger and intercooler and 3 percent pressure drop,T.C.I.-10 - Engine with turbocharger and intercooler and 10 percent pressure drop

When power output values are considered, it can be seen that the intercooling process starts to affect after a certain revolution value of the engine. This delay effect occurs because of low temperature of charge air and low temperature difference between ambient air and compressed charge air. In another words, if supercharging system cannot make a significant difference between charge air and ambient air temperatures, adding an intercooler to the supercharging system would decrease performance because of its pressure drop effect. One more important clue comes from the figure is that increasing charge air mass flow rate too much with an intercooler at high rpm may cause a low working efficiency of the compressor. That is, it can be said that if an intercooler would be used, supercharging system elements should be selected according to it. It can also be observed from the figure that ideal intercooler massively affect power output whether with pressure drop or not[6].

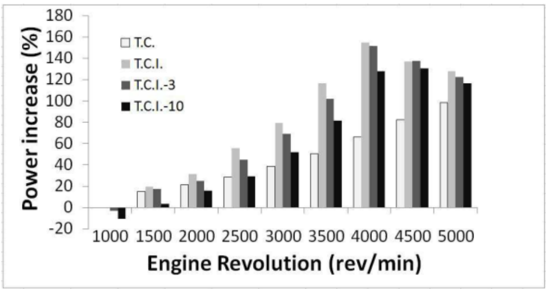

Fig. 3. Power increase percentage of the engine due to supercharging system, T.C. - Engine with turbocharger and without intercooler, T.C.I. - Engine with turbocharger and intercooler, T.C.I.-3 - Engine with turbocharger and intercooler and 3 percent pressure drop, T.C.I.-10 - Engine with turbocharger and intercooler and 10 percent pressure drop

As seen in Fig. 3, power output can be increased 154% by ideal intercooler while single turbocharger without intercooler can only increase 65% engine power output. These numbers emphasize the importance of charge with cooled air. As percentages are further evaluated, pressure drop value of 3% slightly affects power output for a narrow revolution interval while there are no significant power differences in upper revolution values. It should be stated that 3% power drop value was selected due to the experimental data results given in the literature [7]. There can be a question that why ideal intercooler effect and ideal intercooler effect with 3 %

pressure drop are approximately equal at high rpm. The answer is that the efficiency of compressor decreases sharply after a mass flow rate threshold, it cannot provide sufficient air to increase power

III. METHODOLOGY

A flowchart has been design as operating system of Turbo Intercooler Cooling System. The step will go for start when auto switch been trigger. Micro-controller and LCD will display the actual temperature at intercooler. Temperature sensor LM 35 being use to measure temperature. The highest temperature being set at 36 Celsius. If temperature increases more than 36 Celsius, relay will trigger on the motor tank. The motor tank will pump water to spray intercooler until sensor read and temperature reduce below 36 Celsius. If temperature reduce, relay will cut off, if not it will spray until temperature reduced.

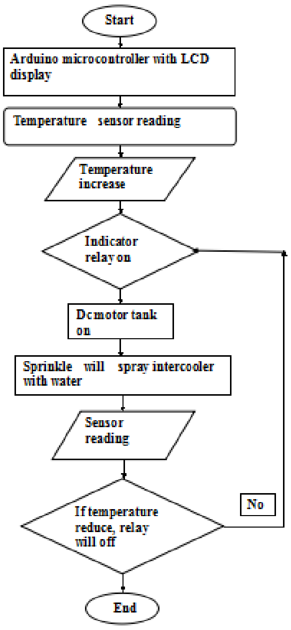

Fig.4. Flow Chart of experiment

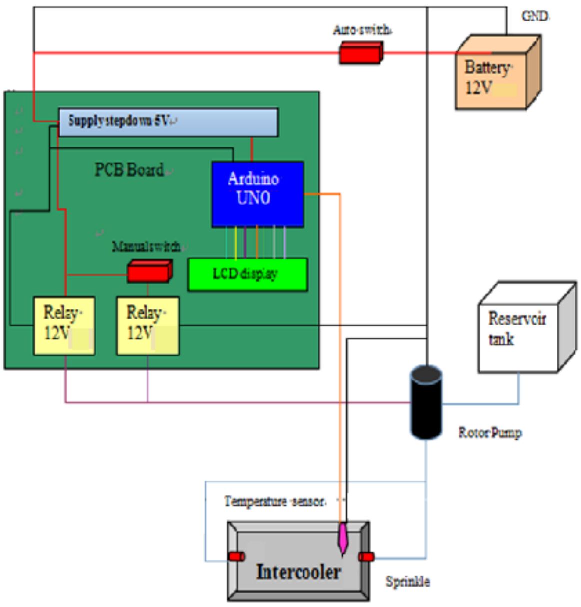

Fig.5. Turbo intercooler cooling system block diagram

A block diagram is design as an illustration of Turbo Intercooler Cooling System to clarify main component of the system, hardware needed and connection of electrical wiring. The main components are controller, battery 12v, dc motor, tank reservoir and intercooler. For controller, Arduino Uno act as main controller with lcd display as output source. Others, temperature sensor lm35 act as input, two sets of switch and relay needed. A circuit diagram are design to fulfill the requirement of develop Turbo Intercooler Cooling System. It is an electrical wiring to supply voltage needed for controller, relay and dc motor to achieve output required.

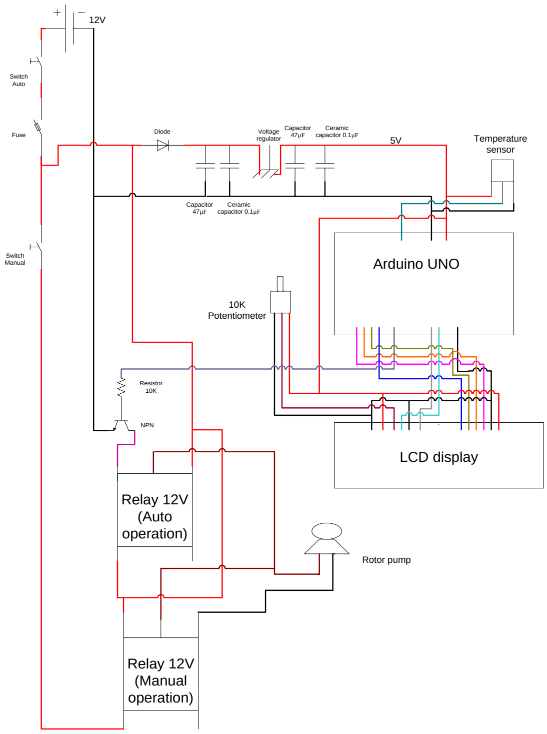

Fig.6. Turbo intercooler cooling system circuit diagram

IV. RESULT AND DISCUSSION

To achieve the main objective, Turbo Intercooler Cooling System are install into turbo car. Perodua Kancil year 2003 fitted with Daihatsu L200s turbo with capacity engine 659cc are chosen because it is small and compact turbo car and easy to measure and collect data. These turbo car are fitted with 15 inch rim with front suspension are adjustable(Tein) and rear are stock absorber. Lastly, ron95 are used as fuel system for this engine.

TABLE 1
Vehicle Specification

Car manufacture		Perodua
Model		Kancil
Year		2003
Engine		Daihatsu L200s turbo
Engine capacity (cc)		659
Tyre		ATR 50/15/160
Suspension	(Front)	Adjustable (Tein)
	(Rear)	Oem (Kancil)
Petrol		RON 95

Installing Turbo Intercooler Cooling System at vehicle need to be more careful and safety for prevention in future. All tubes and wiring are needed to be covered, tighten, and place it far from moving parts especially belting to prevent damage and danger while engine running. Fig.7. are the full view of successful installation. Front bumper are not included for a clear view.

Fig.7. Installing hardware on turbocharger vehicle (full view)

The intercooler are mount with two sprinkler spray at the side of intercooler as highlighted in square box. One T slot are used to distribute water from tank(highlight in diamond box).

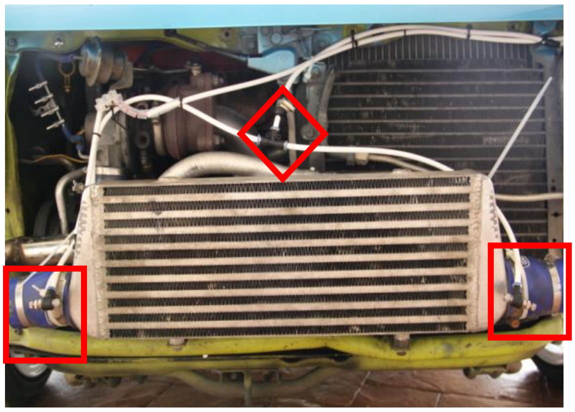

Fig.8. Front view of intercooler

Temperature sensor are placed at the right side of intercooler(as shows in red box) where the inlet air pressure come from turbo pass through intercooler. This is the ideal position to place the temperature

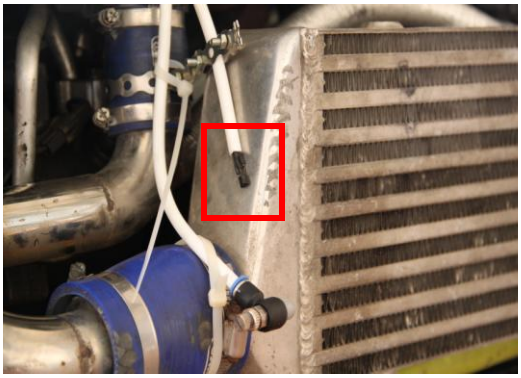

Fig.9. Temperature sensor location

In operating Turbo Intercooler Cooling System, 12v battery are required to generate supply. A control box fitted with micro-controller inside act as controller to control the operating system and a reservoir tank with dc motor is used to store and distribute water.

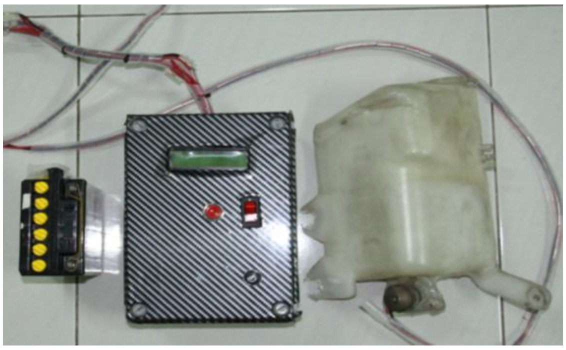

Fig.10. Control box, water tank and battery of turbo intercooler cooling system

For collecting data, the data being collected are before and after installing Turbo Intercooler Cooling system. The parameters to measure are in minute for time and Celsius for temperature. The data shows before installing turbo intercooler cooling system the intercooler temperature increase between 2 to 3 Celsius each 10 minute. After installing turbo intercooler cooling system, when temperature increases above 36 Celsius, sprinkler will spray water through intercooler and the temperature reduces. When temperature reduces, more cool air will produce which mean it will increase the engine performance.

TABLE 2
Result of Turbo Intercooler Cooling System

Turbo Intercooler Cooling System (X)		Turbo Intercooler Cooling System (√) Temperature set at 36 C to turn on TICS	
Time Engine Running (Minute)	Temperature Intercooler (Celsius)	Time Engine Running (Minute)	Temperature Intercooler (Celsius)
10	36	10	32
20	38	20	33
30	41	30	34
40	44	40	35
50	47	50	34
60	49	60	35

To compare and get the final result, a graph are plotted using data collected temperature vs time. From the data plotted, it can be conclude that while running turbo engine for a long distance, temperature of intercooler will increase and hot air will entered intake which will reduce performance of engine. It is important to keep the temperature of intercooler lower as it can which will produce more cool air and increase the performance of engine

E. TICS plot

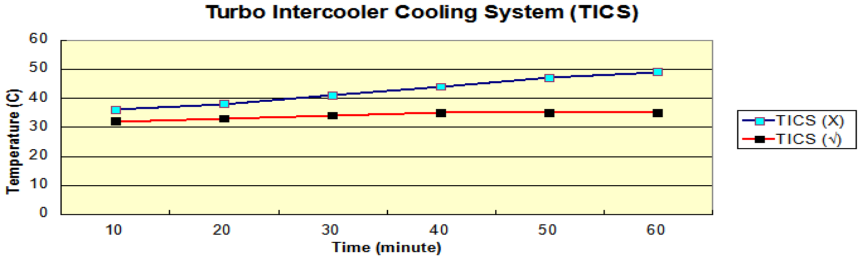

Fig.11. Temperature vs Time plot graph

This system are operated in auto mode when switch are turn on and the temperature are set at 36 Celsius. A temperature sensor LM35 are mount at side of intercooler to measure the intercooler temperature. If temperature of intercooler increased above 36 Celsius, controller will send a signal to relay to on the motor and sprinkler will spray water onto intercooler to reduce the temperature of intercooler. Water are used as medium. From the data have been collected during testing, the temperature of intercooler are decreasing after installing turbo intercooler cooling system. Theoretically, as the air is cooled, it becomes denser, and denser air makes for better combustion to produce more power. Additionally, the denser air helps reduce the chances of knock By keeping the temperature of intercooler below 36 C, it will prevent hot air which has low density entered intake and the engine being less power. There are several factor that affecting the intercooler temperature. The factors that occur are the increases of engine temperature, weather temperature increase, hot air flow from turbo, size of intercooler, distance travel and air flow through intercooler. These factors will result the engine performance drop and fuel consumption will increase.It is important to remove heat produce from engine to avoid power loss and increase uses of fuel consumption. This will increase engine performance and keep engine in a good condition. Even though intercooler is heat exchanger, at certain condition it will produce a higher temperature. By installing Turbo Intercooler Cooling System, it will help to reduce temperature and produce more cool air flow through intake.

V. CONCLUSION

In conclusion, this project is successful following the objective that enhances the turbo intercooler cooling system. A prototype of turbo intercooler cooling system was design with the use of temperature sensor, controller and a direct current motor. The function of this project is totally run well and smoothly towards measuring intercooler temperature. Once temperature sensor sense heat, the temperature will increase. Temperature is set at 36 Celsius as the maximum level to control ideal intercooler temperature . If temperature increase above 36 Celsius, controller will trigger dc motor and pump water to spray intercooler as an effort in reducing to ideal intercooler temperature. As temperature reduced, more oxygen with high density and volume produce. This project only focused in reducing intercooler temperature. For the recommendation, the size of water tank should be in large capacity with ability to store water in high volume. From observation, a high speed motor is needed to increase the pressure pump. With high pressure pump from motor, water can be spray equally through intercooler surface. Others, a variable sprinkler which spray in small molecule of water. Using this sprinkler will distribute water to entire surface of intercooler. Lastly, install more temperature sensor for accurate measurement in future.

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