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The Development of an Aftermarket Intercooler Spray for Turbocharged Vehicles using Water

Muhammad Izzat Nor Ma'arof[1*], Sathurshan Suresh[1], Shaheerthana Suresh[1], Yuli Panca Asmara[1], Girma Tadesse Chala[2]

[1]Faculty of Engineering and Quantity Surveying (FEQS), INTI International University, Persiaran Perdana BBN, Putra Nilai, 71800 Nilai, Negeri Sembilan, Malaysia
[2]International College of Engineering and Management, P.O. Box 2511, C.P.O Seeb 111, Muscat, Oman.

[*]**Email**: muhammadIzzat.maarof@newinti.edu.my

Abstract

An intercooler is a type of heat exchanger used to cool the air which has been compressed by turbocharger. The temperature at the intercooler increases as more compressed hot air enters from the turbocharger. Factors such as engine heat and weather condition hinder the efficiency and power output. The objective of this study was to design and develop an intercooler cooling system operating autonomously. This system senses temperature changes at the intercooler and spray water or any diluted solution with varying enthalpy of vaporization and thermal capacity over the intercooler when the outlet temperature is high. The system developed was powered by Arduino Uno microcontroller that gathers data from the temperature sensor and triggers the spraying mechanism when required automatically. The results show that spray cooling had significant impact as the efficiency improved from 56.52% to an outstanding efficiency of 89.70% by spraying tap water. Even the lowest possible efficiency of an intercooler with the combination of spray mechanism was 87.69% using distilled water, which was over 50% more efficient than the ordinary intercooler without the spray cooling unit. Conclusively, this newly designed portable plug-and-play intercooler spray unit would be beneficial in increasing the performance of the intercooler by improving the heat exchange capacity of the unit. For future studies, other types of solutions could be investigated as the intercooler spray.

Keywords

Engine Downsizing, Forced Induction, Turbocharging, Intercooler, Automation

Introduction

Various manufactures in the automotive industry meet the emission requirement through downsizing. However, downsized engines should be able to be comparable to their larger counterparts, the specific performance output must be increased by a ratio which is equivalent to the reduction of engine size. The path to achieve high specific output the engine speeds must be

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increased and/or by increasing intake boosting. This raises the induced dose of air and fuel mixture, thus improves the performance of the downsized engine to match the performance to its larger counterpart. In 2012 Ford focus replaced their 1.6 Liter engine with their new downsized Ecoboost three-cylinder 1Liter engine producing the same power because of the new emission rules ("Ford Focus 1.0 Ecoboost review", 2019). Since the 2011 BMW started using Two liter four cylinder turbocharged engine N20 engine replacing their Three Liter six cylinder engines such as N52 and N53 engines (Revolvy, 2019).

The draw back with forced induction is when air is compressed, the air gets hotter according to ideal gas law. On top of this the temperature in the engine bay and the temperature outdoor affects the temperature of the air that enters the air intake. Hotter air is less dense and less effective for through combustion in the combustion chamber, therefore, the hot air coming from the compressor is passed through a heat exchanger known as an Intercooler. At the intercooler, heat is transferred to the surrounding by convection with the help of intercooler fins and the temperature of the air inside is reduced. The air leaving the intercooler is colder and denser, in other words it has more oxygen molecules per unit volume for thorough combustion (Bilen K., 1998). Therefore, combustion could be further improved.

In that period majority of the studies focused on diesel engine and in the 1990s there were a lot of both theoretical and experimental studies on force induction on with the use of intercooling on diesel engines (İbrim, 1989; Bayrakçı, 1998; Arslan, 2006) and spark ignition engine (Döngeloğlu, 1994; Atlay, 1997) as well for their characteristics in performance, the studies mainly suggested that forced induction increases the power output while maintaining low fuel consumption. Furthermore, hotter air also influences the turbocharger where it naturally raises the operation temperature inside the turbo (Canli, 2010; Lee, 2009). Most of all the intercooler is used to cool down the air from hot air intake but during warmer weather the efficiency of the intercooler reduces as it is also exposed to high temperatures. As intercooler the only device in the whole induction system which helps heat exchange and its heat exchangeability is easily altered by weather outside. To reduce the heat stroke on both the turbo and the intercooler a simple cooling mechanism on the intercooler. This would vastly help in overcoming these problems faced during rough warm weather which is faced in countries with equatorial climate such as Malaysia.

The purpose of this study was to improve the intercooler's heat exchange efficiency by promoting evaporative cooling through spraying water. By improving the efficiency of the intercooler through this process, the effective cooling of the intercooler unit is improved, through which more oxygen molecules are sent to the intake of the engine for more through and effective combustion not precisely defined by Graham (2006).

Methodology

In the developing process of a portable plug-and-play intercooler spray unit, the first stage carried out was the development of the first prototype in form of a test rig for safety purposes. Through this testing various parameters were changed, and their effects were studied. At the end of the testing stage, with the help of collected data, the analysis was done to find out the optimum working and design parameters. In identifying the list of critical parameters i.e. controls and variables involved in designing portable plug-and-play intercooler spray unit for automobile, intensive literature review was conducted.

In this experiment, the controlled variables were kept constant and the independent variables were changed. The reading of the dependent variable (outlet temperature at the intercooler) were measured after the use of spraying mechanism with the change of each independent variables. The outlet temperature was chosen because it is the most important temperature in the intercooler/heat exchanger which is directly linked to the efficiency of the whole unit. The dependent variable, outlet temperature was measured by a feedback system which sprays a fluid automatically for the set spray time just when the temperature reaches an assigned value. After spraying the lowest temperature at the intercooler outlet was measured and temperature drop before and after spraying at the intercooler outlet was calculated. The lowest temperature was taken over the temperature after a certain period of time as this project focused mainly on the maximum effect of the spraying mechanism and not the rate at which the cooling process happened. By using outlet temperature of the intercooler as the dependent variable to calculate the temperature drop, the efficiency of the Intercooler before and after the spray cooling process were found.

The system works by sensing the temperature at the intercooler exit by the temperature sensor, where if the temperature reaches above a certain temperature the relay turns on which starts the pump and sprays water onto the intercooler which lowers the temperature. The temperature was analyzed by the sensing element throughout and if the temperature does not drop, the loop continues and sprays until the temperature reaches below the designated value. The independent variables were varied, and the dependent variable was measured, which was used to study the effect of these parameters in spray cooling. Figure 1 shows the schematic diagram of the experimental setup.

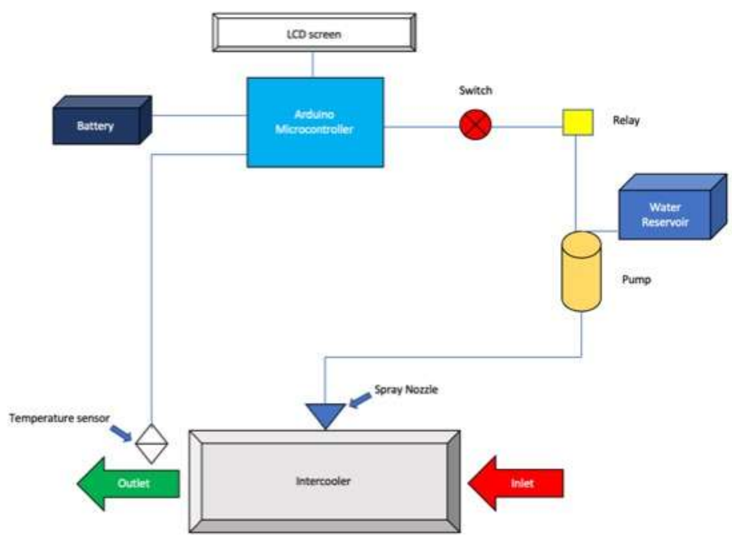

Figure 1. Schematic diagram of the system

The collected data for the dependent variable, outlet temperature, and calculation was done to find out the efficiency to be compared with the efficiency of the intercooler without the intercooler spray unit, which was found to be 56.52%.

Results and Discussion

The spray cooling unit was mounted, and data was gathered for the dependent variable (Outlet temperature) through the control of independent variables such as Type of fluid and number of pumps through which the total pressure was altered. The value for the Lowest Outlet temperature is taken as this study involves the maximum effect of the independent variable on the spray cooling unit.

Table 1. Experimental data for Tap water

Number of Pumps	Inlet Temp. (°C)	Outlet Temp. (°C)	Temp. Drop (°C)	Average Temp. Drop (°C)	Efficiency (%)
	151	39.4	111.6		
1	151	39.7	111.3	111.60	88.22
	151	39.1	111.9		
	151	38.5	112.5		
2	151	38.2	112.8	112.60	89.01
	151	38.1	112.9		
	151	37.5	113.5		
3	151	37.8	113.2	113.47	89.70
	151	37.3	113.7		

Table 2. Experimental data for Distilled water

Number of Pumps	Inlet Temp. (°C)	Outlet Temp. (°C)	Temp. Drop (°C)	Average Temp. Drop (°C)	Efficiency (%)
	151	40.1	110.9	110.93	
1	151	39.8	111.2		87.69
	151	40.3	110.7		
	151	39.2	111.8		88.22
2	151	39.3	111.7	111.60	
	151	39.7	111.3		
	151	38.5	112.5		
3	151	38.1	112.9	112.80	89.17
	151	38	113		

Based on the results obtained in Tables 1 and 2, the overall data collected could have uncertainties as temperature readings were recorded using both Sensor and Mercury Thermometer. There could have been instrumental error from the readings obtained through the Mercury Thermometer, however the error would be very small at approximately 0.1˚C. The overall idea of minimizing heat soak through spray cooling had a vast impact as the efficiency improved from 56.52% to an outstanding efficiency of 89.70% by spraying tap water. Even the lowest possible efficiency of an intercooler with the combination of spray mechanism was 87.69% using distilled water, which was over 50% more efficient than the ordinary intercooler without the spray cooling unit.

In the case of tap water, the only independent variable was pressure generated by the pump, where the temperature drop increased with the increasing amount of pressure created by the pump based on the number of pumps in the system, which lead to an efficiency of 89.70%. On the other hand, distilled water with peak efficiency of 89.17% followed the same trend where, the temperature drop increased with increasing amount of pressure created by the additional pumps. In the case of tap and distilled water the temperature drops, and efficiency increased proportionally to the amount of pressure generated. This is because, as the pressure was increased the evaporative cooling process happened more frequently. As more tiny droplets of water molecules were sprayed over a wide area of the intercooler through high pressure, the tiny molecules covering large surface area gained enough energy from the heated surface to evaporate through absorbing the heat energy from the heated intercooler (Horacek, 2005; Pais, 1992).

Conclusions

The aim of this study was to design and develop an intercooler cooling system which is designed to operate autonomously. This system senses temperature changes at the intercooler and spray water or any diluted solution with varying enthalpy of vaporization and thermal capacity over the intercooler when the outlet temperature is high. The results shown that spray cooling had a vast impact as the efficiency improved from 56.52% to an outstanding efficiency of 89.70% by spraying tap water. Even the lowest possible efficiency of an intercooler with the combination of spray mechanism was 87.69% using distilled water, which was over 50% more efficient than the ordinary intercooler without the spray cooling unit. Conclusively, the idea of spray cooling to improve the heat exchange capacity of the intercooler through evaporative cooling shows a positive effect as the efficiency had a drastic improvement and this could be also used in bigger scale heat exchanger, such as the ones used in engineering industries.

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