Research & Reviews: Journal of Engineering and Technology
ISSN: 2319-9873

Optimization of Helical Coil Heat Exchanger as a Waste Recovery System for Efficient Fuel Consumption

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Research Article

Received: 24/08/2016

Accepted: 26/09/2016

Published: 02/10/2016

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Keywords: Heat exchanger, Thermal expansion (fluid), Temperature difference, Heat exchanger effectiveness

ABSTRACT

By the year 2035, the demand for energy will be 50% more than the current demand in the market. The non-renewable resources of energy started depleting during the last decade. This depletion caused the price hike in the energy usage of every individual. This dry-up in energy resources gave the most impact on the fuel consumption for transportation. This research solely aims to recover heat losses in exhaust pipes. The heat obtained in the heat exchanger can be used as another source of heat. This heat exchanger technology leads to the improvement of the efficiency of the engine. Upon the retrieval of heat losses in the pipe, the fuel consumption by the engine was diminished. This occurrence of less fuel consumption induced less cost for every amount of fuel used. A heat exchanger was designed and simulated using Solid Works Software. A prototype was produced in line with the simulated design of the heat exchanger. A pilot test was done to compare the initial data gathered using the prototype and that of gathered using the simulation. The test was run five times, measuring values for different variables. The results of the research show that the variables have different relationships with other variables. The data gathered and p-values computed show the correlations between exit temperatures, pitch size, heat gain, and mass flow rate. The exit temperature is directly proportional to the heat gain and pitch size. On the contrary, the maximum heat gain is indirectly proportional to the effectiveness of the heat exchanger. The conclusion can be drawn that the analysis for the design helical coil heat exchanger and the results were found to be in good agreement with the experimental results. Furthermore, the effectiveness of the heat exchanger was proven to be directly proportional to the diesel fuel temperature. Following an in-depth multi-dimensional analysis of preliminary research results, it is recommended to consider for upgrade and invest further study regarding other parameters that might affect the recovery of heat losses.

INTRODUCTION

Heat is "energy transferred across boundary of the system due to difference in temperature between the systems and the surroundings of the system". As system does not contain heat, it contains energy, and heat is energy in transit or referred as "heat transfer" [1]. Temperature difference in any condition results from energy flow into a system or energy flow from a system to surroundings. The former leads to heating whereas latter leads to cooling of an object Newton's Law of Cooling states that the rate of change of the temperature of an object is proportional to the difference between its own temperature and the ambient temperature (i.e. the temperature of its surroundings) [2].

Engine efficiency is important in fuel consumption; the maximum efficiency of a modern engine is approximately 20% to 35% which means that 65% of the energy contained in the fuel is actually lost as heat 35% in exhaust gas and 30% through cooler or radiator of the engine [3]. Approximately half of the rejected heat or heat loss comes from exhaust gases that can be recovered and used as another source of heat to reheat the fuel that is consumed by the engine. Efficient combustion of the fuel in the engine can cause higher engine efficiency and lower fuel consumption. Recover the heat loss in exhaust pipe and use it as another

ISSN:2319-9873

source of heat to improve the efficiency of the engine is the main objective of this research [4] stated that "Combustion temperatures in cylinder of Engine can reach values of 2700 K and higher. Heat removed from engine cylinder is eventually rejected to the surroundings. Unfortunately, by keeping the engine from overheating with heat transfer to the surroundings, a large percentage of the energy generated within the engine is wasted, and the brake thermal efficiency of most engines is in the order of 30-40% [5]. The energy rejected by the engine through exhaust line is the one that can be recovered and used as another source of heat by means of heat exchanger. Heat exchanger is a device used to transfer or recover the waste heat from one source to another, the process of heat exchange between two fluids that are of different temperatures and separated by a solid wall occurs in many engineering applications [6]. There are different types of heat exchangers and the type of heat exchanger that this research will use as a reference for the design of heat exchanger for recovering the heat rejected are both Spiral and Counter flow heat exchangers. The Helical coil heat exchanger is a type of heat exchanger that transfers heat from one fluid to another without mixing the fluid by means of temperature difference of the fluid and the material used for the design of heat exchanger [7].

Helically coiled exchangers offer certain advantages. Higher film coefficients the rate at which heat is transferred through a wall from one fluid to another and more effective use of available pressure drop result in efficient and less-expensive designs [8]. True counter-current flow fully utilizes available LMTD (logarithmic mean temperature difference). Helical geometry permits handling of high temperatures and extreme temperature differentials without high induced stresses or costly expansion joints. High-pressure capability and the ability to fully clean the service-fluid flow area add to the exchanger's advantages [9].

Like all liquids, diesel fuel expands slightly in volume as its temperature increases. The coefficient of thermal expansion measures the rate of the expansion. A typical value of the coefficient of thermal expansion for diesel fuel is 0.00083 per degree Celsius (0.00046 per degree Fahrenheit). Using this value, 1.000 gallon of diesel fuel at -7 °C (20˚F) will expand to 1.037 gallons at 38˚C (100˚F). [1]

Experimental Procedure

The schematic diagram of the experiment set up is as shown in **Figure 1**. The experiment set up consists of a stainless shell in which helical coil copper tube is place through which exhaust gas flows from the engine. To ensure maximum heat transfer the copper helical coil is fully exposed in exhaust gas that came from the engine with a temperature maximum of 133 °C. The stainless shell is properly insulated so as to avoid the heat loss to the surrounding and to maximize the utilization of heat that comes from the exhaust gas [10].

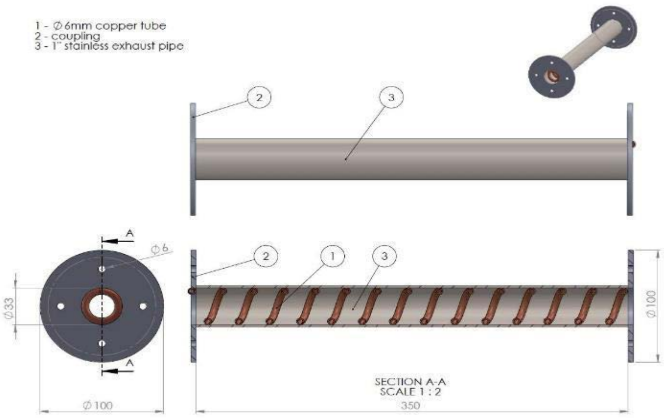

Figure 1. Design of helical coil heat exchanger.

On **Table 1** shows the standard parameters that will be used during experimentation process and simulation process. As shown in **Figure 2**, the relation between temperature increase and pitch of helical coil. As the pitch increases the temperature in the coil also increases.

Table 1. Operating parameter range of helical coil heat exchanger

Parameters	Measurement	
	Diesel Fuel	Exhaust Gas
Mass Flow Rate (kg/min)	0.002159	0.943017
Volume Flow Rate (m^3/sec)	2.54	0.943017
Initial Temperature °C	15.6	150
Outlet Temperature °C	31.93	133
Specific Heat	1.8	1

 ISSN:2319-9873

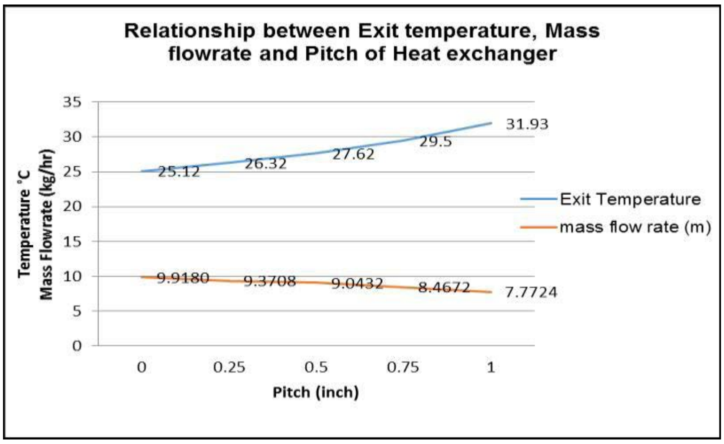

Figure 2. Relationship of temperature, mass flow rate and pitch.

The relation between temperature increase and pitch of helical coil. As the pitch increases the temperature in the coil also increases. Increase in pitch have a impact in increase of temperature because the exhaust gas with a initial temperature of 133°C pass through the gap (pitch) of the coil that carries heat that diesel fuel absorb. The increase in temperature absorbed by the fuel also has a impact to lessen the fuel consumption. Heat gain by the fuel also increases **(Figure 3)**. The data gathered using the simulation process and actual run of the heat exchanger are used to compute the mass flow rate of the engine to check if the heat exchanger is effective enough to minimize the fuel consumption. Also, it is indicated on **Table 2**. The relationship between mass flow and temperature outside of the fuel [11].

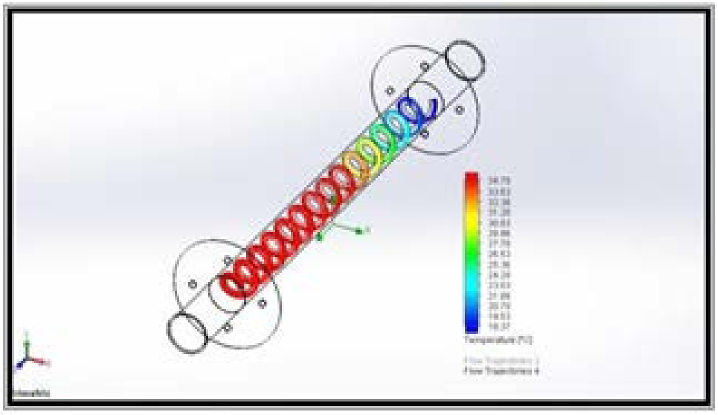

Figure 3. Simulation using solid works software.

Table 2. Dimension parameters for the design of heat exchanger.

Dimensional Parameters of Helical Coil	
Dimensional Parameters	Dimension
Outer Diameter of Exhaust Pipe	30 mm
Inner Diameter of Exhaust Pipe	27 mm
Thickness of Exhaust Pipe	1.5 mm
Outer Diameter of Coil	5 mm
Inner Diameter of Coil	4 mm
Thickness of Coil	0.5 mm

All of the data were treated using Anova Single Factor Test. The p-value has to be less than 0.05 to accept the assumptions mentioned earlier in this paper. With p-value less than 0.05, the data gathered for the test of relation between exit temperature and pitch of heat exchanger can prove the direct proportionality of the two parameters. The exit temperature gradually increases as the pitch size increases. On the other hand, the p-value for the exit temperature and heat gain was less than 0.05. Therefore, it can be said that the heat gain of the diesel fuel is larger if the exit temperature is significantly large as well. The same thing can be concluded in the relation between the average heat gain and the effectiveness of the heat exchanger [12]. The data computed show the inverse proportionality of the maximum heat gain and the effectiveness while the relation is directly proportional between the effectiveness and average heat gain **(Table 3 and 4).**

SUMMARY

GROUPS	Count	Sum	Average	Variance
0.0	4.0	2.5	0.6	0.1
25.1	4.0	115.4	28.8	5.9
0.0	4.0	0.0	0.0	0.0

ANOVA

SOURCE OF VARIATION	SS	df	MS	F	P- value	F crit
BETWEEN GROUPS	2171.1	2	1085.5	538.7	4.29E	4.2
	5		8	5	-10	6
WITHIN GROUPS	18.13	9	2.01			
TOTAL	2189.2	11				
	9	0				

Table 3: Tabulated computed data during experimental process.

Pitch (inch)	mass flow rate (Kg/min)	Temp. inside (diesel)	Temp. outside (diesel)	Specific Gravity	Exhaust Temp.
0	0.0028	15.6	25.12	0.8398	Input
0.25	0.0026	15.6	26.32	0.8284	
0.5	0.0025	15.6	27.62	0.8158	Exit
0.75	0.0024	15.6	29.5	0.8014	
1	0.0022	15.6	31.93	0.7849	
Note: Temperature is in °C					

Table 4: Computation of diesel index.

Actual Temperature	Correcting Factor	Specific Gravity	API	Aniline Point	Diesel Index
					Index
NA	NA	0.85	34.97	114.4	40
77.22	0.987949	0.8398	37	114.4	42.32
79.38	0.986437	0.8284	39.32	114.4	44.97
81.72	0.984799	0.8158	41.95	114.4	47.99
85.1	0.98243	0.8014	45.06	114.4	51.54
89.47	0.979368	0.7849	48.78	114.4	55.79
NOTE: temperature is in °F					

CONCLUSION

This paper presents a comparative analysis of optimization of coil design of helical coil heat exchanger. Heat exchangers' ability to reacquire and reuse waste heat from one source to another is a common knowledge in the industry. This paper made known the relative assay of optimization of the heat exchanger's helical coil design. This study has argued that modifying the helical coil heat exchanger offers advantages to the fuel consumption and emission of particulates. The various equations proved to be of great aid in determining the value of the constant parameters used in the research. The assessment of the design shows the expected results. Upon the alteration of the helical coil design by adding thermal insulator, the heat exchanger was able to collect the wasted heat and use them to better combust the fuel resulting to lessening the fuel consumption. The insulation of the helical coil gave way to the reduction of heat loss to the environment. Referring to the tabulated results, it can be established that the results attained from this study is in line with the initial design procedure. The design procedure and thermal evaluation of study under consideration is done and also has following conclusion.

The design procedure adopted gives sizing and rating analysis of the helical coil heat exchanger and results are found in good agreement with the experimental results. By increasing the pitch length of helical coil, the effectiveness, increase at constant length of the heat exchanger. When the temperature of diesel fuel increases, the effectiveness of the heat exchanger also increases *vice versa*. The various equations use different parameters for the analysis. The overall effect of these parameters on specific gravity, temperature/heat gain by the fuel and mass flow rate consumes in the engine. The analysis shows that, for high temperature gain by the fuel, the mass flow rate consumes less than the normal fuel intake of the engine. It indicates that helical coils are efficient are high with that parameter considered. The analysis also shows that, as tube pitch increases with constant coil diameter, the temperature gain also increases, which increases the efficiency of helical coil heat.

ISSN:2319-9873

REFERENCES

1. Merle P and Somerton. Craig Schaum's Outline of Thermodynamics for Engineers. 2nd edition.2006.
2. Perry RH and Green D. Perry's Chemical Engineers' Handbook, 7th edition, McGraw-Hill. 1997.
3. Incropera FP. Introduction to Heat Transfer. 5th edition, Wiley. 2007.
4. Patil RK, et al. Design of Helical-Coil Heat Exchanger. Chemical Engineering. 2000.
5. National Institute of technology Rourkela. Fuel consumption by Isidro Martinez. 2001.
6. Merle CP and Craig WS. Thermodynamic for Engineer's 2nd Edition. 2010.
7. Ajay C and Suryawanshi JG. Waste Heat Recovery from Exhaust Gases through I C Engine Using Thermoelectric Generator. Indian Journal of Applied Research. 2013;3:270-271.
8. U.S. Environmental protection agency EPA 400 F 92 007. Office of mobile sources fact sheet oms-5. 1994.
9. Ghobadi, et al. A review of Heat Transfer and Pressure Drop Correlation for Laminar Flow in Curve Circular Ducts. Heat Transfer Engineering. 2015;37:1-71.
10. Shokouhmand H. Experimental Investigation of shell and coiled tube heat exchangers using Wilson plots. International Communication in Heat and mass Transfer. 2008;35:84-92.
11. Theodore L. Heat transfer applications for the practicing engineer. Wiley, New Jersey. 2011.
12. Dai, et al. Human powered wireless charger for low-power mobile electronic device. IEEETransactions on Consumer Electronics. 2012;58:767-774.