CONVECTOR WATER EXCHANGE ANALYSIS IN FEROZA SERVICE CARS WITH DIFFERENT RUNNING VARIATIONS

Celcio Novian Primananda[1], F.A Widiharsa[1*], Agus Mulyono[2]
[1]Department of Mechanical Engineering, Faculty of Engineering, University of Merdeka Malang
[2]Department of IFV, Poltekad Malang
*Email *corresponding author:*fransiskus.widiharsa@unmer.ac.id

Abstract

The cooling system at work of a gasoline engine functions as a protective engine by absorbing heat. Engine heat is produced from combustion of fuel in the cylinder. The heat is something that is deliberately created to produce energy, but if left unchecked will cause excessive heat (over heating effect). Excessive heat is the cause of changing mechanical properties as well as the shape of the engine components. The purpose of the study was to determine the temperature of the cooling water on the convector / radiator on the convector / radiator on the ferroza official car that has been modified using a multi point injection system. This cooling system does work simultaneously with the combustion system, so as to produce engine work which is the output of the engine. The cooling system is a support system of engine work. The system is not the main system that is the basis of the engine to do work and effort, but both systems have a very vital function.

Keywords: *Convector Cooling Water, Heat Exchanger, Feroza Machine Using Multi Point Injection System.*

INTRODUCTION

Cooling plays an important role in the work process of a combustion motor. The use of a convector / radiator is considered the most efficient in reducing the heat generated. Therefore the use of liquid is very suitable for tropical climates. Convector / radiator is a type of heat exchanger using fluid as a heat exchanger. The function of the convector / radiator is to distribute the heat absorbed by the cooling water, absorb the heat from the combustion in the engine then the cooling water is cooled in the radiator with the surrounding air so that the surrounding air becomes hot.

The Feroza vehicle is one type of service vehicle owned by the Army that is still operational in supporting the main tasks of the Army ranks. However, this vehicle uses a lot of fuel consumption or is wasteful. One of the components that affects fuel consumption is the carburetor, because the mixture of air and fuel is less homogeneous so that the combustion that occurs in the combustion chamber is imperfect.

Previous research has not discussed the heat exchanger for the Feroza vehicle convector water which has been modified into a Multi Point Fuel Injection System, so the authors intend to analyze the Convector Water Heat Exchanger in the Ferroza Service Car with different rotation variations. So that it can increase and compare the heat transfer of convector water and increase the efficiency of fuel consumption.

METHODOLOGY

This research is an experimental study conducted at the Poltekad-Malang workshop which was conducted from February to June 2018. The following is a research flow diagram.

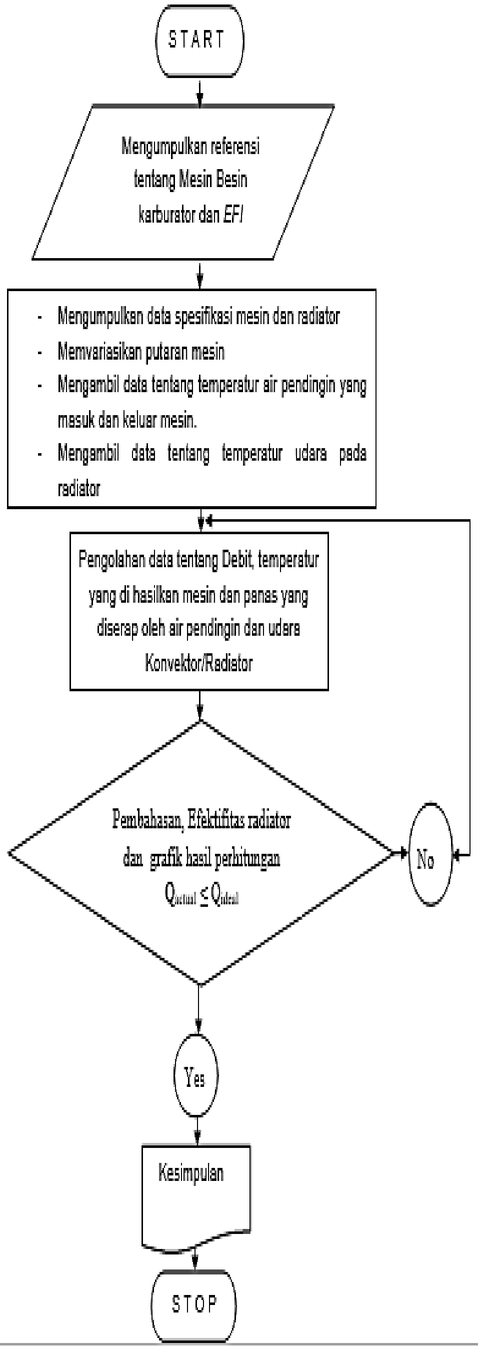


Figure 1. **Research Flowchart**

Research Variables

- Independent variables
  1. Engine rotation
- Dependent variables:
  1. Water discharge and flowing air
  2. Cooling water and air temperature
  3. The effectiveness of the cooling system. Water discharge and flowing air
  4. Cooling water and air temperature
  5. The effectiveness of the cooling system.

Tools and Materials

In the implementation of this research, the equipment used includes the Feroza official car engine using the multi-point injection system and the Feroza official car engine cooling system as well as measuring instruments in the Poltekad-Malang workshop.

1. Convector/Radiator.

   The radiator used is a conventional radiator in the vehicle. In this case, the cross-sectional area of the convector / radiator will be measured, which later the measurement data will be the initial data from the discussion.
2. Fan

   The fan used is the one already on the vehicle.
3. Machine.

   The machine used is a Feroza official car engine using a multi point injection system. Where the measurement data will be the initial data for the discussion.

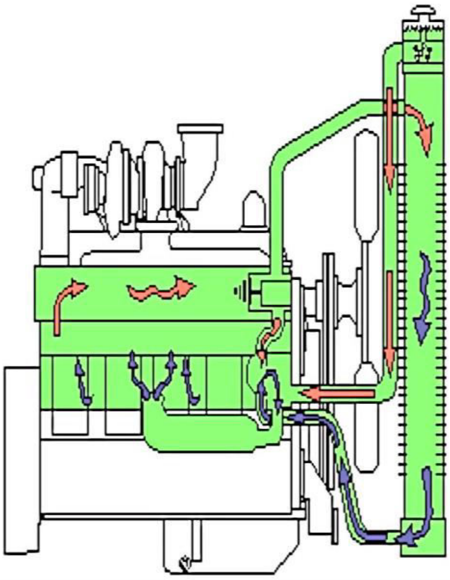
The machine used is a Feroza official car engine using a multi point injection system. Where the measurement data will be the initial data for the discussion.

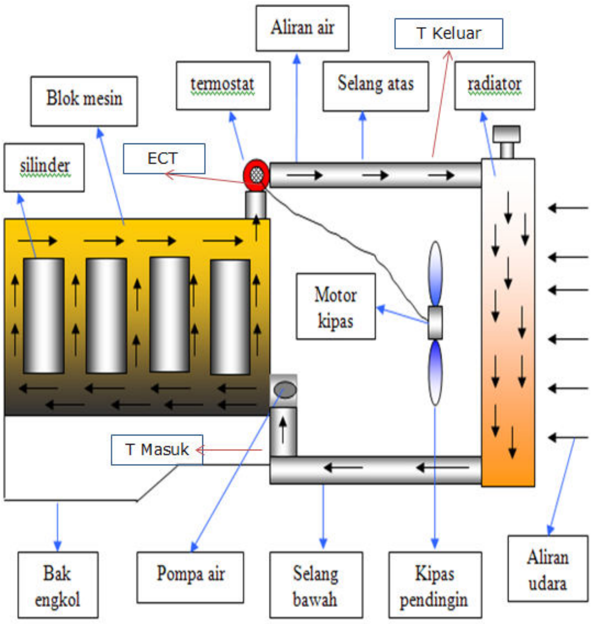
Type engine	: HD-C, fuel
Cylinder capacity	: 1589 cc
Number of valve	: 16. SOHC
Number of cylinder	: 4 seal, 4 takt.
Cooling system	: Water
Diameter x Takt	: 76,0 mm x 87,6 mm

Compression ratio : 9,5 : 1
Maximum power : 85,7 PS/6000 rpm
Maximum torque : 12,9 kgm/3600rpm

Figure 2. **Daihatsu Feroza**

Tool Work Diagram





DISCUSSION

At the time of data collection, it is done in a static way so that from the results of observations about the data released by the engine and varying the engine speed, the data results at 950 rpm stationary rotation with the initial water temperature Tin 30 °C and Tout 29.5 °C and at air temperature Tin 26.6 °C and Tout 29.6 °C as follows:

Table 1. **Table for Capturing Machine Temperature Data that can be cooled by cooling water.**

No	Putaran Mesin (rpm)	Debit air Q_{air} (m^3/s)	T In air (^0C)	T Out air (^0C)	Tm air (^0C)	Laju aliran masa air $\dot{m}_{air}$ (kg/s)	Kalor yang di lepas air Q (W)
1	**2**	**3**	**4**	**5**	**7**	**8**	**9**
1	1000	$8{,}01 \times 10^{-6}$	37,2	36,4	36,8	0,00794	26,55
2	1500	$1{,}13 \times 10^{-6}$	34,5	36,3	34,4	0,011206	9,36
3	2000	$1{,}93 \times 10^{-6}$	35,6	33,4	34,5	0,019175	176,25
4	2500	$2{,}41 \times 10^{-6}$	85,5	31,8	58,65	0,02389	5360,77
5	3000	$3{,}04 \times 10^{-6}$	112,8	32,7	72,75	0,030181	10101,64
6	3500	$3{,}91 \times 10^{-6}$	114,3	42,7	78,2	0,038781	11700,03

Table 2. **Air Temperature Data Retrieval which can cool water in the Convector/radiator.**

No	Putaran Mesin (rpm)	Debit udara Q_{udara} (m^3/s)	T In udara (^0C)	T Out udara (^0C)	Tm udara (^0C)	Laju aliran masa udara $\dot{m}_{udara}$ (kg/s)	Kalor yang di lepas udara Q (W)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	1000	2,35	26,6	29,6	28,1	2,76	8350,95
2	1500	3,05	26,1	29,7	27,9	3,58	12988,62
3	2000	3,55	25,7	29,8	27,75	4,16	17194,31
4	2500	4,06	25,9	30,2	28,05	4,76	20636,98
5	3000	4,56	26,3	36,9	31,6	5,28	56380,14
6	3500	5,37	27,7	42,4	34,85	6,15	93549,66

Table 3. **Effectiveness of Convectors/Radiators from water and air temperatures.**

No	Putaran Mesin (rpm)	Kapasitas kalor air (W/^{0}C)	Kapasitas kalor udara (W/^{0}C)	Q_{actual} (W)	Cmin (W/C)	Qideal (W)	Efektifitas (%)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	1000	33,19	2783,65	26,55	33,19	351,82	7,55%
2	1500	46,82	3607,95	9,36	46,82	393,29	2,38%
3	2000	80,11	4193,73	176,25	80,11	793,11	22,22%
4	2500	99,83	4799,30	5360,77	99,83	5949,76	90,10%
5	3000	126,11	5318,88	10101,64	126,11	10908,76	92,60%
6	3500	162,05	6195,34	11700,03	162,05	14098,37	82,99%

After taking data from the engine performance test using an engine speed of 1000 Rpm, the calculations are carried out as follows:

a. The discharge of cooling water in the car engine. (Q_{air})

$$Q_{air} = \frac{V_{air}}{t}\left(\frac{m^3}{s}\right)$$

Where :

Q_{air} = Water discharge (m^3/s)

V_{air} = Water volume (m^3)

T = Time (s)

Results of data retrieval:

V_{air} = 200 ml

= 0,0002 m^3

$$Q_{air} = \frac{V_{air}}{t}\left(m^3/s\right)$$

$$= \frac{0{,}0002\ m^3}{25{,}01\ s}$$

$$= 7{,}99 \times 10^{-6}\left(m^3/s\right)$$

b. The physical properties of water are that it has a high boiling point and heat of evaporation compared to fluids that have almost the same molecular weight. The physical properties of water are evaluated based on its mean water temperature.

$$T_{air} = \frac{T_{in}+T_{out}}{2}$$

Where.

T_{air} = Average water temperature (^{0}C)

T_{in} = In temperature (^{0}C)

T_{out} = Out temperature (^{0}C)

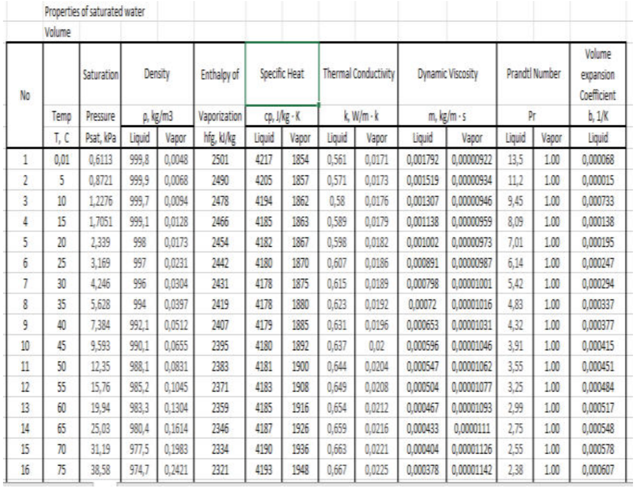
Thus the value of Tm_{air},

$$Tm_{air} = \frac{T_{in}+T_{out}}{2}$$

$$= \frac{37{,}2\ ℃ + 36{,}4\ ℃}{2}$$

$$= 36{,}8\ ℃$$

Table 4. **Thermo-physical properties of water.**



Properties of saturated water

Volume

No	Temp	Saturation Pressure	Density ρ, kg/m3		Enthalpy of Vaporization	Specific Heat cp, J/kg · K		Thermal Conductivity k, W/m · k		Dynamic Viscosity m, kg/m · s		Prandtl Number Pr		Volume expansion Coefficient b, 1/K
	T, C	Psat, kPa	Liquid	Vapor	hfg, kJ/kg	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid
1	0,01	0,6113	999,8	0,0048	2501	4217	1854	0,561	0,0171	0,001792	0,00000922	13,5	1.00	0,000068
2	5	0,8721	999,9	0,0068	2490	4205	1857	0,571	0,0173	0,001519	0,00000934	11,2	1.00	0,000015
3	10	1,2276	999,7	0,0094	2478	4194	1862	0,58	0,0176	0,001307	0,00000946	9,45	1.00	0,000733
4	15	1,7051	999,1	0,0128	2466	4185	1863	0,589	0,0179	0,001138	0,0000959	8,09	1.00	0,000138
5	20	2,339	998	0,0173	2454	4182	1867	0,598	0,0182	0,001002	0,00000973	7,01	1.00	0,000195
6	25	3,169	997	0,0231	2442	4180	1870	0,607	0,0186	0,000891	0,00000987	6,14	1.00	0,000247
7	30	4,246	996	0,0304	2431	4178	1875	0,615	0,0189	0,000798	0,00001001	5,42	1.00	0,000294
8	35	5,628	994	0,0397	2419	4178	1880	0,623	0,0192	0,00072	0,00001016	4,83	1.00	0,000337
9	40	7,384	992,1	0,0512	2407	4179	1885	0,631	0,0196	0,000653	0,00001031	4,32	1.00	0,000377
10	45	9,593	990,1	0,0655	2395	4180	1892	0,637	0,02	0,000596	0,00001046	3,91	1.00	0,000415
11	50	12,35	988,1	0,0831	2383	4181	1900	0,644	0,0204	0,000547	0,00001062	3,55	1.00	0,000451
12	55	15,76	985,2	0,1045	2371	4183	1908	0,649	0,0208	0,000504	0,00001077	3,25	1.00	0,000484
13	60	19,94	983,3	0,1304	2359	4185	1916	0,654	0,0212	0,000467	0,00001093	2,99	1.00	0,000517
14	65	25,03	980,4	0,1614	2346	4187	1926	0,659	0,0216	0,000433	0,0000111	2,75	1.00	0,000548
15	70	31,19	977,5	0,1983	2334	4190	1936	0,663	0,0221	0,000404	0,00001126	2,55	1.00	0,000578
16	75	38,58	974,7	0,2421	2321	4193	1948	0,667	0,0225	0,000378	0,00001142	2,38	1.00	0,000607

Water density:

$$\rho_{air\ @\ T\,=\,36{,}8\ ℃} = \frac{(36{,}8-35)}{(40-36{,}8)}(994-992{,}1)+992{,}1$$

$$= 993{,}31\ (kg/m^3)$$

Specific heat of water:

$$C_{p,air\ @T\,=\,36{,}8\ ℃} = \frac{(36{,}8-35)}{(40-36{,}8)}(4179-4178)+4178$$

$$= 4178{,}36\ (j/kg℃)$$

c. The mass flow rate of water can be found with the equation ($\dot{m}_{air}$) :

$$\dot{m}_{air} = \rho_{air} \cdot Q_{air}\ \ (kg/s)$$

Where:

$\dot{m}_{air}$. = Mass flow rate of water (kg/s)

ρ_{air}= Water density (kg/m^3)

Q_{air}= Water flow discharge (m^3/s)

Thus the value of $\dot{m}_{air}$,

$$\dot{m}_{air} = \rho_{air} \cdot Q_{air}\ \ (Kg/s)$$

$$= 993{,}31\ kg/m^3 \cdot 7{,}99 \times 10^{-6}\ m^3/s$$

$$=0{,}007943\ (kg/s)$$

d. The heat released by water ($\bar{Q}$). Heat can be identified by looking at the effect they have on an object, for example the temperature rises, its shape changes and its volume changes. Temperature is the degree of heat or coldness of an object, while heat is the amount of energy received by an object so that the object's temperature rises or changes shape, or the amount of energy that an object forces it to, so that the object's temperature drops or changes its form. Heat has two kinds of units, namely joules and calories by using the equation:

$\overline{Q} = \dot{m}.C_{p,air}(T_{h.in} - T_{h.out})$ (W)

Where:

$\overline{Q}$= Heat released (W)

$\dot{m}_{air}$= Mass flow rate (kg/s)

$C_{p.air}$= Water specific heat (J/Kg°C)

Thus the value of $\overline{Q}$,

$\overline{Q} = \dot{m}_{air} . C_{p\ air} . (T_{h,in} - T_{h,out})$ (W)

$= 0{,}007943 kg/s \cdot 4178{,}36 j/kg°C \cdot (37{,}2^0C - 36{,}4^0C)$(W)

= 26,55 (W)

e. The caloric capacity of water (liquid) is the amount of heat needed to raise the temperature of a certain substance (water) by one degree Celsius. To determine the heating capacity of water, the equation is used:

$C_{air} = \dot{m} \cdot C_p$ (W/°C)

Where :

C_{air}= Heat (W/°C)

$\dot{m}_{air}$= Mass flow rate (kg/s)

$C_{p.air}$= Specific heat of water (J/Kg°C)

Thus the value of C_{air},

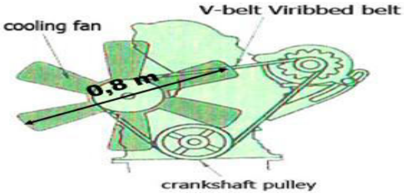
$C_{air} = \dot{m}_{air} . C_{p\ air}$ ($W/^0C$)

$=$ 0,007933 kg/s · 4179,01 j/kg°C

$=$ 33,19 ($W/^0C$)

f. The speed and cross-sectional area of the air flow are in accordance with the fan rotation and using a windspeed (mph) tool then converted to (m/s) at 1000 rpm (V_{udara}).

V_{udara}= 10,5 (mph)



= 4,69 (m/s)

Figure 9. Convector/radiator fan diameter

$A_{udara} = \frac{\pi}{4} \cdot D^2$ (m^2)

$= \frac{\pi}{4} . 0{,}8^2$ (m^2)

= 0,5026 (m^2)

g. Airflow discharge can be found by the equation (Q_{udara}).

$Q_{udara} = V_{udara} . A_{udara}$($m^3/s$)

=4,69 m/dtk · 0,5026 m^2

=2,359 (m^3/s)

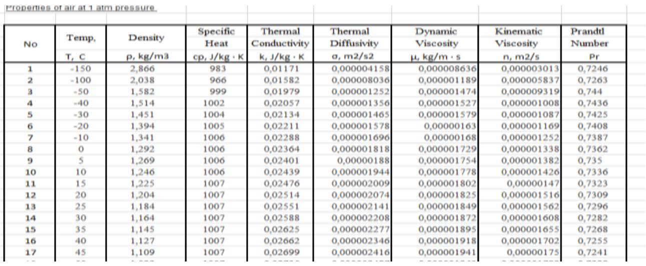
h. Air temperature is average (Tm_{udara})

$$Tm_{udara} = \frac{T_{in}+T_{out}}{2}$$

$$= \frac{26{,}6\ °C + 29{,}6\ °C}{2}$$

= 28,1 °C

Table 5. **Thermos physical properties of air**



Properties of air at 1 atm pressure

No	Temp, T, C	Density ρ, kg/m3	Specific Heat cp, J/kg · K	Thermal Conductivity k, J/kg · K	Thermal Diffusivity σ, m2/s2	Dynamic Viscosity μ, kg/m · s	Kinematic Viscosity n, m2/s	Prandtl Number Pr
1	-150	2,866	983	0,01171	0,000004158	0,000008636	0,000003013	0,7246
2	-100	2,038	966	0,01582	0,000008036	0,000001189	0,000005837	0,7263
3	-50	1,582	999	0,01979	0,000001252	0,000001474	0,000009319	0,744
4	-40	1,514	1002	0,02057	0,000001356	0,000001527	0,000001008	0,7436
5	-30	1,451	1004	0,02134	0,000001465	0,000001579	0,000001087	0,7425
6	-20	1,394	1005	0,02211	0,000001578	0,00000163	0,000001169	0,7408
7	-10	1,341	1006	0,02288	0,000001696	0,00000168	0,000001252	0,7387
8	0	1,292	1006	0,02364	0,000001818	0,000001729	0,000001338	0,7362
9	5	1,269	1006	0,02401	0,00000188	0,000001754	0,000001382	0,735
10	10	1,246	1006	0,02439	0,000001944	0,000001778	0,000001426	0,7336
11	15	1,225	1007	0,02476	0,000002009	0,000001802	0,00000147	0,7323
12	20	1,204	1007	0,02514	0,000002074	0,000001825	0,000001516	0,7309
13	25	1,184	1007	0,02551	0,000002141	0,000001849	0,000001562	0,7296
14	30	1,164	1007	0,02588	0,000002208	0,000001872	0,000001608	0,7282
15	35	1,145	1007	0,02625	0,000002277	0,000001895	0,000001655	0,7268
16	40	1,127	1007	0,02662	0,000002346	0,000001918	0,000001702	0,7255
17	45	1,109	1007	0,02699	0,000002416	0,000001941	0,00000175	0,7241

Air density:

$\rho_{udara\ @\ T = 28,1\ °C} = \frac{(28,1 - 25)}{(30 - 28,1)}(1{,}184 - 1{,}164) + 1{,}164$

= 1,1711 (kg/m^3)

Heat specific of air:

$C_{p\ udara\ @T = 28,1°C}$ = 1007(j/kg°C)

i. The mass flow rate of air can be found by the equation ($\dot{m}_{udara}$).

$\dot{m}_{udara} = \rho_{udara} \cdot Q_{udara}$ (Kg/s)

$= 1{,}1711 \text{ kg/m}^3 \cdot 2{,}359 \text{ m}^3/\text{s}$

$= 2{,}764$ (Kg/s)

j. The heat received by the air after cooling the water ($\bar{Q}$).

$\bar{Q} = \dot{m}_{udara} \cdot C_{p\ udara} \cdot (T_{h,in} - T_{h,out})$ (W)

$= 2{,}764 \text{ kg/s} \cdot 1007 \text{j/kg°C} \cdot (29{,}6^0\text{C} - 26{,}6^0\text{C})$ (W)

= 8350,95 (W)

k. Heat capacity of air (C_{udara}) is the amount of heat needed to raise the temperature of some substance (air) by one degree Celsius. To determine the heating capacity of air, the equation is used

$C_{udara} = \dot{m}_{udara} \cdot C_{p\ udara}$ (W)

$= 2{,}764 \text{ kg/s} \cdot 1007 \text{ j/kg°C}$

$= 2783{,}65$ (W/C)

Effectiveness of Thermal Convectors /Radiators.

a. Actual heat transfer (Q_{actual}) can be calculated from the energy released by cooling water received by the air received to exchange heat. Can be found out with the following equation:

$Q_{actual} = C_{air} \cdot (T_{hi} - T_{ho})$ (W)

$= 33{,}19 \text{ (W/°C)} \cdot (37{,}2 - 36{,}4)$

$= 26{,}55$ (W)

b. Minimal heat capacity (C_{min}).

Heat capacity of water = 33, 19 (W/°C)

Heat capacity of air = 2783,65 W/°C)

The smallest heat capacity = 33, 19 (W/°C)

$Q_{ideal} = C_{min} \cdot (T_{hi\ air} - T_{hi\ udara})$

$= 33{,}19 \text{ (W/°C)} \cdot (37{,}2 - 26{,}6)$

$= 351{,}82$ (W)

c. So the effectiveness of the Thermal Convector/Radiator to cool water is:

$$\varepsilon = \frac{Q_{aktual}}{Q_{ideal}}$$

$$= \frac{26{,}55 \text{ W}}{351{,}82 \text{ W}}$$

$$= 7{,}55\%$$

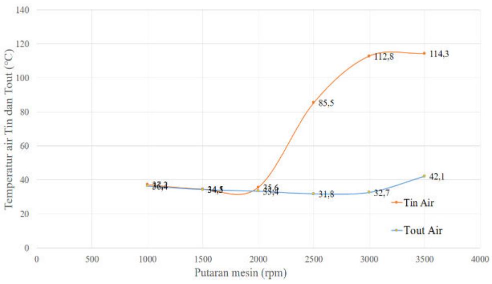


Figure 10. Graph of the Relationship between Water Temperature Entering the Convector / Radiator and the Exiting Water Temperature with Engine Speed

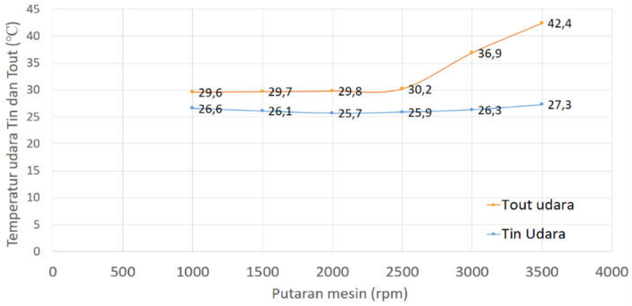


Figure 11. Graph of the Relationship of Air Intake Temperature in Convector / Radiator and Air Exit Temperature with Engine Speed

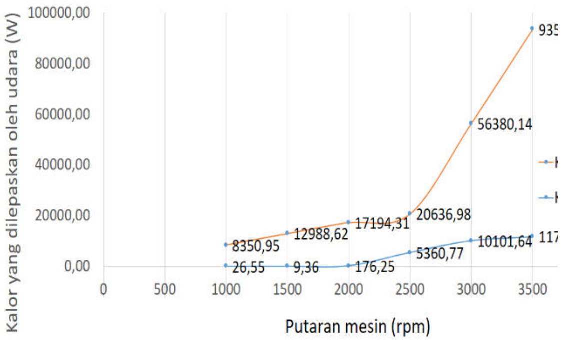


Figure 12. Graph of the Relationship of Heat Received by Air and Air by the convector/ radiator with engine speed

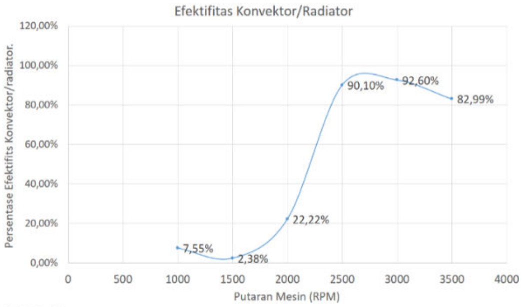


Figure 13. Graph of Convector / Radiator Effectiveness Relationship with Engine Speed

From the calculation results, it was found that the intake water temperature was 37.2 °C and the out water temperature was 36.4 °C. The temperature drop in the chilled water in the air-cooled convector / radiator, the temperature of the air entering the convector / radiator is 26.6 °C and the temperature of the air coming out is 29.6 °C. The increase in water temperature has not been too significant until the engine speed of 2500 rpm, from a water temperature of 85.5 °C then the water temperature rises to a temperature of 112.8 °C at 3000 rpm.The increase in water temperature occurs because the thermostat valve opens at the temperature inside the engine between 80 °C to 90 °C. There are other causes where the water temperature can get above 100 °C because the cooling water has not used a watercoolant so that it is not optimal so it is not optimal in absorbing engine heat from internal combustion.

CONCLUSION

From the analysis that has been carried out on the working temperature of the engine convector / radiator on the Feroza official car which has been modified into a multi point injection, several conclusions are obtained, including:

At 1000 to 2500 rotations the water is still rotating in the engine and has not experienced a significant increase in temperature. But at 3000 rpm the thermostat valve starts to open then the water enters the radiator so that the water experiences an increase in temperature to 112.8 0C then at 3500 engine speed it rises back to 114.3 0C . At the highest rotation of 3500 Rpm, the maximum capability of the convector/ radiator is obtained as follows:

1. Heat capacity of water: 162.05 (W / 0C)
2. Air heat capacity: 6195.34 (W / 0C)
3. Convector/radiator effectiveness: 82.99%

From the calculation of the value of the ability of the convector / radio to absorb water heat, the engine is less balanced with the value of heat generated when cooling in the engine, so that the energy balance can be met.

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