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Experimental Comparison of Heat Transfer in a Down Flow Louvered Fin Auto Radiator using Water, Water and Ethylene Glycol Mixture & Water, Ethylene Glycol and Sugarcane Juice Mixture as Coolants

Swagath. V. Mohan
Department of Mechanical Engineering
MA College of Engineering, Kothamangalam

Prof. Jacob Kuriakose
Department of Mechanical Engineering
MA College of Engineering, Kothamangalam

Nidhin A R
Department of Mechanical Engineering
MA College of Engineering, Kothamangalam

Binu Varghese
Department of Mechanical Engineering
MA College of Engineering, Kothamangalam

Feizal Fidus
Department of Mechanical Engineering
MA College of Engineering, Kothamangalam

Abstract

This study is focused on searching for alternative coolants to improve overall performance of the radiator. To enhance the cooling rate, increasing the surface area by addition of fins was the earliest approach but this approach of increasing heat transfer already reached its limit. Water and water mixed with anti-freezing agents such as ethylene glycol (EG) and propylene glycol (PG) are the traditional coolants for automotive radiator. Recently nano fluid have been proposed as coolant for automotive radiator. However, operation and long term stability are major challenges for nano fluid. Hence, the search for alternative coolant is not ending. Sugar cane juice, which has very similar freezing and boiling points with water, may be used as an alternative coolant. A study is conducted using sugar cane juice, ethylene glycol and water as coolants, CFD as well as experimental analysis is also done.
Keywords- CFD, Ethylene Glycol (EG), Sugarcane Juice

I. INTRODUCTION

Radiators are heat exchangers used for cooling internal combustion engines, mainly in automobiles. The overall aim of this study is to increase the performance of the automotive radiator. This study is focused on the searching of alternative heat transfer fluids for overall performance improvement. In the present study, performance analyses of louvered fin and flat tube automotive radiator using various coolants

1) Water
2) Ethylene Glycol
3) Sugar-Cane Juice

Rashmi Rekha SAHOO, Pradyumna GHOSH, Jahar SARKAR [1] did screening of various coolants (water, ethylene glycol, propylene glycol, brines, and Nano fluid and sugarcane juice) for louvered fin automotive radiator on different energetic and exergetic performance parameters. Effects on radiator size, weight and cost as well as engine efficiency and fuel consumption were discussed as well. And they found Sugarcane juice yields better heat transfer and pressure drop characteristics at higher temperature. Sugarcane juice is slightly better in terms of both heat transfer pumping power than water and nano fluid, whereas significantly better than EG and PG.

Datta N. Mehtre, Sandeep S. Kore [2] experimentally studied the thermal performance of car radiator using Al_2O_3–nano fluid in temperature ranges from (40-75°C) under different fractions of nanoparticles from 0.5, 1, and 1.5% by volume. In their study, the heat transfer with water based nano-fluids was experimentally compared to that of pure water as coolant in an automobile radiator. Liquid flow rate in the range of 50 lph to 200 lph and air velocityin the range of 3.8 m/s to 6.2 m/s were chosen respectively. The fluid inlet temperature was varied from 40°C to 75°C to find the optimum inlet condition. Results demonstrate that increasing coolant flow rate can improve the heat transfer performance. Also increasing the air flow rate improves the heat transfer rate. The rate of heat transfer enhancement was found19% to 42% in comparison with pure water.

D. Bohne, S. Fischer, and E. Obermeier [3] measured thermal conductivity, density, and viscosity of ethylene glycol - water mixtures. The measurements have been performed in the temperature range from - 20°C to 1 8 0 T for thermal conductivity, from -10°C to 150°C for density, and from - 10°C to 100°C for viscosity.

G.N. Tiwari, Sanjeev & mar, Om Prakash [4] the study of heat and mass transfer during natural convection heating for preparation of Jaggery was carried out for the open and closed conditions. An indoor experiment was conducted for simulation of developed thermal model for heat and mass transfer for maximum evaporation. Evaporated water was condensed at the inner surface for the closed system as fresh water. The effect of different rates of heating (varying voltage) and heat capacity of sugar cane juice on heat and mass transfer were also carried out. It was observed that the evaporative heat transfer coefficient depends significantly on the rate of heating and heat capacity.

S.N. Sridhara, S.R. Shankapal and V. Umesh Babu [5], the flow behaviour and temperature profile prediction in the radiator tubes are very useful information and is of great importance to the designer. The geometry of the finned-tube heat exchanger is an intricate one and there are no analytical optimization schemes available to optimize their design, while experimental trial and error is far too time-consuming. In their study a tube fin arrangement of an existing radiator was analysed for evaluating the fluid flow and heat transfer characteristics. The overall pressure, temperature and mass flow rate distribution of the coolant and air in and around the single tube-fin arrangement with 32 fins were evaluated. The fluid flow simulation was conducted using commercial software FLUENT 6.1. The pressure and temperature distribution along the tube length and tube width were presented and analysed.

Zailer Astolfi-Filho, Eduardo Basílio de Oliveira, Jane Sélia dos Reis Coimbra, Javier Telis-Romero Sugarcane (Saccharum sp.) [6] In their work, determined friction factors (f) and Nusselt number (Nu) for sugarcane juice in different steps of its processing (untreated sugarcane juice, clarified sugarcane juice and mixed sugarcane juice). For both laminar and turbulent flows, the empirical models for f fitted well ($r2 \geq 0.9$) with the experimental values obtained by pressure drop measurements.. This finding indicates the suitability of such analogy in this case, allowing good estimations of heat transfer coefficients from frictions factors, or vice versa, for sugarcane juices in turbulent flow conditions.

Sang Hyuk Lee, Nahmkeon Hur and Seongwon Kang [7] An efficient method to predict the heat transfer performance of a louver fin radiator in an automotive power system. A numerical method to efficiently predict heat transfer phenomena of a louver fin radiator was presented – multi-scale semi microscopic heat exchange (SHE) method. Numerical models for the heat transfer rate and flow friction derived from the microscopic analysis are then used for simulations of the full radiator model in semi microscopic analysis. In the semi microscopic analysis, conjugate heat transfer is analysed for the domain with the radiator whose louver fin area is replaced by a porous media. The results with the proposed method show a good agreement with the experimental data. The proposed method can be used to predict flow and heat transfer characteristics of a realistic louver fin radiator with a reduced cost and sufficient accuracy.

II. EXPERIMENTAL DETAILS

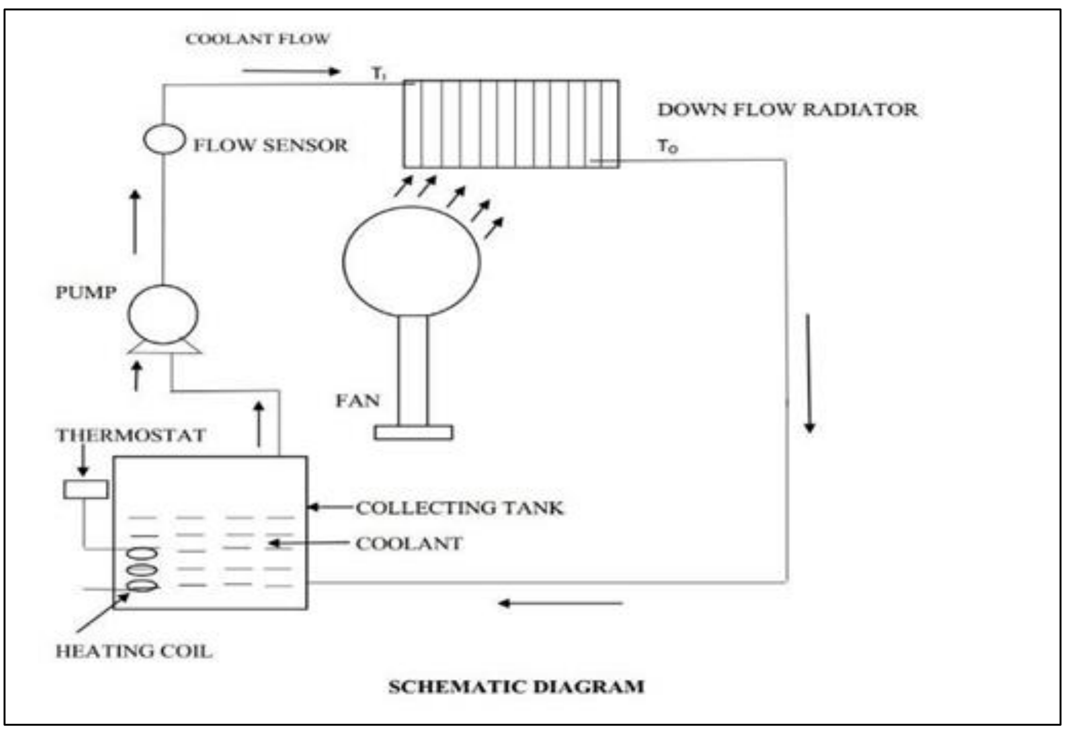

Fig. 1: Schematic Representation of Exp. Test Rig

Fig. 2: Experimental Test Rig

This experimental setup includes a reservoir in the form of plastic tank, electrical heater, a centrifugal pump, a flow meter sensor, flow control valve, fan, thermostat,infra-red thermometer for temperature measurement, wind gauge meter and heat exchanger (automobile radiator). The fluid flows through nylon tubes (1 inch) by a centrifugal pump (2500rpm) from the tank to the radiator. The total volume of the circulating fluid is (4 litres) and constant in all the experimental steps. An electrical heater (1500W) is placed inside a plastic storage tank which represent the engine. The heater is used to heat the working fluid. A voltage regular (0-240 V) is provided to maintain inlet fluid temperature from 40 ºC to70ºC. A flow meter sensor and a ball valve is used to measure and control the flow rate of the fluid. An infra-red thermometer is used for recording the inlet and outlet fluid temperatures.

III. RADIATOR SPECIFICATIONS

Table 1: Radiator Specifications

Make	*Delphi Tata Ace Radiator*
Radiator Size	*340mm*365mm*24mm*
Radiator Fan	*Axial Fan With 3 Speeds*
Radiator Capacity	*1 Litre*
Type	*Down Flow*
Coolant Inlet & Outlet Pipe Dia.	*2.48 Cm*
Total Core Tubes	*34*
No. Of Fin Columns	*35*
No. Of Fins In A Column	*73*
Coolant Volume Taken	*4 Litres*
Core Tube Effective Area	*347480mm^2*
Fin Effective Area	*947394mm^2*

IV. COOLANT MIXTURE

A. WATER

Total volume of coolant taken is 4 litres. Using of water alone as a coolant is obsolete. When water is used as coolant we have to regularly check the coolant level and refill it .The bad side of using water alone as coolant is it results in corrosion.

B. WATER+EG

Total volume of coolant taken is 4 litres. Water + Ethylene glycol (EG) is currently used as coolant in auto radiators worldwide. In this experiment 50% Water+50% EG mixture is used.EG when added to water improves its boiling point as well as freezing point. At the same time EG also acts as a corrosion inhibitor. As per data available from paper published by D. Bohne, S. Fischer, and E. Obermeier [3] density, specific-heat and thermal-conductivity of Water + EG mixture are 1045 Kg/m^3, 3560 J/KgK and 0.375 W/mK respectively.

C. WATER+EG+SUGARCANE JUICE

Total volume of coolant taken is 4 litres in which 50% is Ethylene glycol (EG), 25% is Water and remaining 25% is Sugarcane juice. Water + EG + Sugarcane juice is entirely a new coolant mixture. As per data available from paper published by Zailer Astolfi-Filho, Luis A. Minim, Javier Telis-Romero, Vale ´ria P. R. Minim, and Vania R. N. Telis [7] density, specific-heat and thermal-conductivity of Water + EG + Sugarcane juice mixture are 1170 Kg/m^3, 3712 J/KgK and 0.486 W/mK respectively.

V. EXPERIMENTAL DATA ANALYSIS

From heat conducted = heat convected
Heat transfer rate Q is calculated by

$$Q=m * c * (T_{in} - T_{out}) \qquad (1)$$

m = density * V
V = (LPH/3600) * 0.001
M-mass flow rate of coolant Kg/s
V-volume flow rate (m^3/s).

VI. BOUNDARY CONDITIONS

- Air inlet temperature - 300K
- Coolant inlet temperature - 323K & 333K
- Mass flow rate of water - 0.217 Kg/s,0.383 Kg/s & 0.55 Kg/s
- Mass flow rate of water+EG - 0.226 Kg/s,0.4 Kg/s & 0.574 Kg/s
- Mass flow rate of water+EG+UCSJ - 0.253 Kg/s,0.448 Kg/s & 0.643 Kg/s
- Coolant used - Water, Water + EG.Water+EG+UCSJ
- Air inlet velocity - 3.3m/s,4.3m/s & 5.3m/s

VII. EXPERIMENTAL READINGS

A. SET NO. 1

Table 2: Experimental readings of Water at 50 degree Celsius

Sl. No.	Coolant	Air velocity (m/s)	Mass flow rate (Kg/s)	Inlet tube temp. (^0C)	Outlet tube temp. (^0C)	Inlet fin temp. (^0C)	Tube wall temp. (^0C)	Heat transfer rate (kW)
1	WATER	3.3	0.217	50	46.8	30	46	2.90
2			0.383	50	47.1	30	46.7	4.64
3			0.550	50	48	30	47.2	4.59
1	WATER		0.217	50	45.8	30	45	3.80

2		4.3	0.383	50	46.5	30	45.6	5.60
3			0.550	50	47	30	46	6.89
1	WATER	5.3	0.217	50	44.8	30	43.7	4.71
2			0.383	50	45	30	44	8
3			0.550	50	45.8	30	44.8	9.65

Table 3: Experimental readings of Water + EG at 50 degree Celsius

Sl. No.	Coolant	Air velocity (m/s)	Mass flow rate (Kg/s)	Inlet tube temp. (^{0}C)	Outlet tube temp. (^{0}C)	Inlet fin temp. (^{0}C)	Tube wall temp. (^{0}C)	Heat transfer rate (kW)
1	EG + WATER	3.3	0.226	50	45	30	44	4.02
2			0.4	50	46	30	44.8	5.69
3			0.574	50	46.8	30	45.3	6.53
1	EG + WATER	4.3	0.226	50	44.1	30	43.5	4.74
2			0.4	50	44.9	30	43.9	7.26
3			0.574	50	45.8	30	44.5	8.58
1	EG + WATER	5.3	0.226	50	43.2	30	42.2	5.47
2			0.3	50	44	30	43	8.54
3			0.574	50	44.9	30	43.9	10.42

Table: 4 Experimental readings of Water+EG+Sugarcane juice at 50 degree Celsius

Sl. No.	Coolant	Air velocity (m/s)	Mass flow rate (Kg/s)	Inlet tube temp. (^{0}C)	Outlet tube temp. (^{0}C)	Inlet fin temp. (^{0}C)	Tube Wall temp. (^{0}C)	Heat transfer rate (kW)
1	EG + WATER + SUGARCANE JUICE	3.3	0.253	50	43.8	30	42.8	5.82
2			0.448	50	44.5	30	43.5	9.14
3			0.643	50	45.4	30	44.1	10.97
1	EG + WATER + SUGARCANE JUICE	4.3	0.253	50	43	30	41.9	6.57
2			0.448	50	43.9	30	42.9	10.14
3			0.643	50	44.6	30	43.6	12.88
1	EG + WATER + SUGARCANE JUICE	5.3	0.253	50	42.1	30	40.9	7.41
2			0.448	50	43	30	42	11.64
3			0.643	50	43.9	30	42.8	14.55

B. SET NO.2

Table 5: Experimental readings of Water at 60 degree Celsius

Sl. No.	Coolant	Air velocity (m/s)	Mass flow rate (Kg/s)	Inlet tube temp. (^0C)	Outlet tube temp. (^0C)	Inlet fin temp. (^0C)	Tube wall temp. (^0C)	Heat transfer rate (kW)
1	WATER	3.3	0.217	60	56.5	30	55.2	3.17
2			0.383	60	57	30	56	4.80
3			0.550	60	57.5	30	56.9	5.74
1	WATER	4.3	0.217	60	55	30	53	4.53
2			0.383	60	56	30	54.1	6.40
3			0.550	60	56.8	30	56	7.35
1	WATER	5.3	0.217	60	53.8	30	51.9	5.62
2			0.383	60	54.9	30	53.2	8.16
3			0.550	60	55.5	30	54.6	10.34

Table 6: Experimental readings of Water + EG at 60 degree Celsius

Sl. No.	Coolant	Air velocity (m/s)	Mass flow rate (Kg/s)	Inlet tube temp. (^0C)	Outlet tube temp. (^0C)	Inlet fin temp. (^0C)	Tube wall temp. (^0C)	Heat transfer rate (kW)
1	EG + WATER	3.3	0.226	60	55	30	53	4.02
2			0.4	60	55.8	30	54.9	5.98
3			0.574	60	56.3	30	55.8	7.56
1	EG + WATER	4.3	0.226	60	53.6	30	52.1	5.14
2			0.4	60	54.2	30	53	8.25
3			0.574	60	55.1	30	54.5	10.01
1	EG + WATER	5.3	0.226	60	51.3	30	50.6	6.99
2			0.4	60	53	30	51.9	9.96
3			0.574	60	54.3	30	53	11.64

Table 7: Experimental readings of Water+EG+Sugarcane juice at 60 degree Celsius

Sl. No.	Coolant	Air velocity (m/s)	Mass flow rate (Kg/s)	Inlet tube temp. (^0C)	Outlet tube temp. (^0C)	Inlet fin temp. (^0C)	Tube wall temp. (^0C)	Heat transfer rate (kW)
1	EG + WATER + SUGARCANE JUICE	3.3	0.253	60	53	30	51	6.57
2			0.448	60	53.9	30	51.9	10.144
3			0.643	60	55	30	54.2	11.93

1	EG + WATER + SUGARCANE JUICE	4.3	0.253	60	52.1	30	50.7	7.41
2			0.448	60	52.9	30	51.9	11.80
3			0.643	60	53.6	30	52.7	15.27
1	EG + WATER + SUGARCANE JUICE	5.3	0.253	60	51	30	49.2	8.45
2			0.448	60	51.7	30	50.4	13.80
3			0.643	60	52.5	30	51	17.90

VIII. RESULTS AND DISCUSSION

A. At Temperature 50

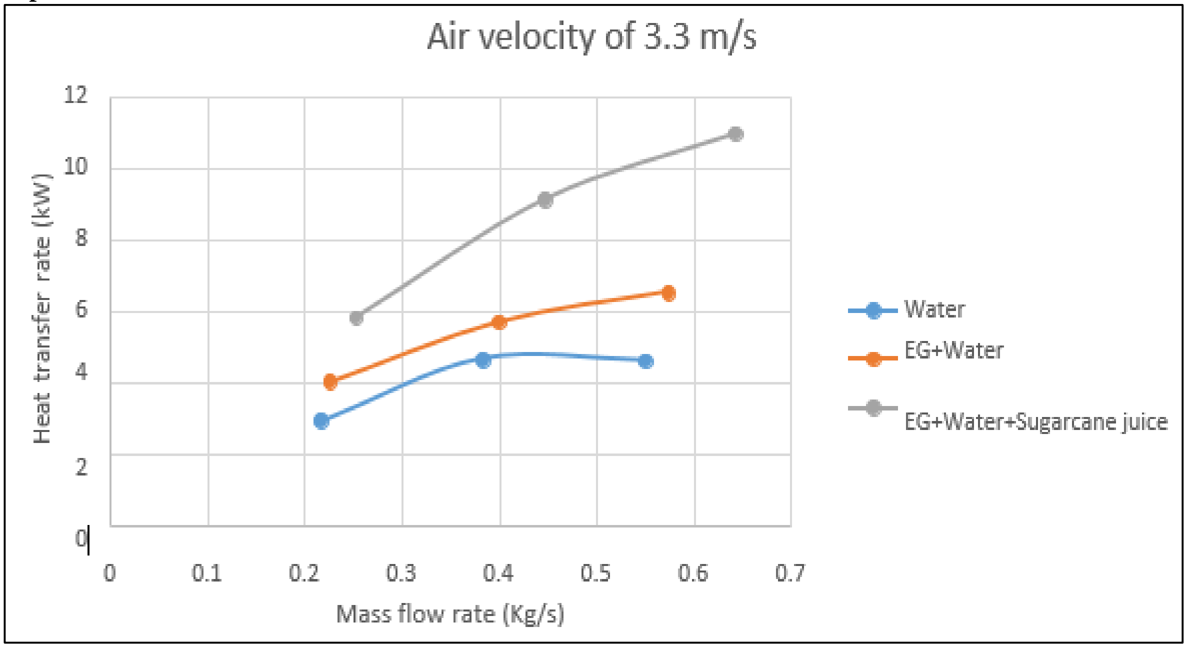

Fig. 3: Variation of heat transfer rate for different mass flow rate at air velocity of 3.3 m/sec

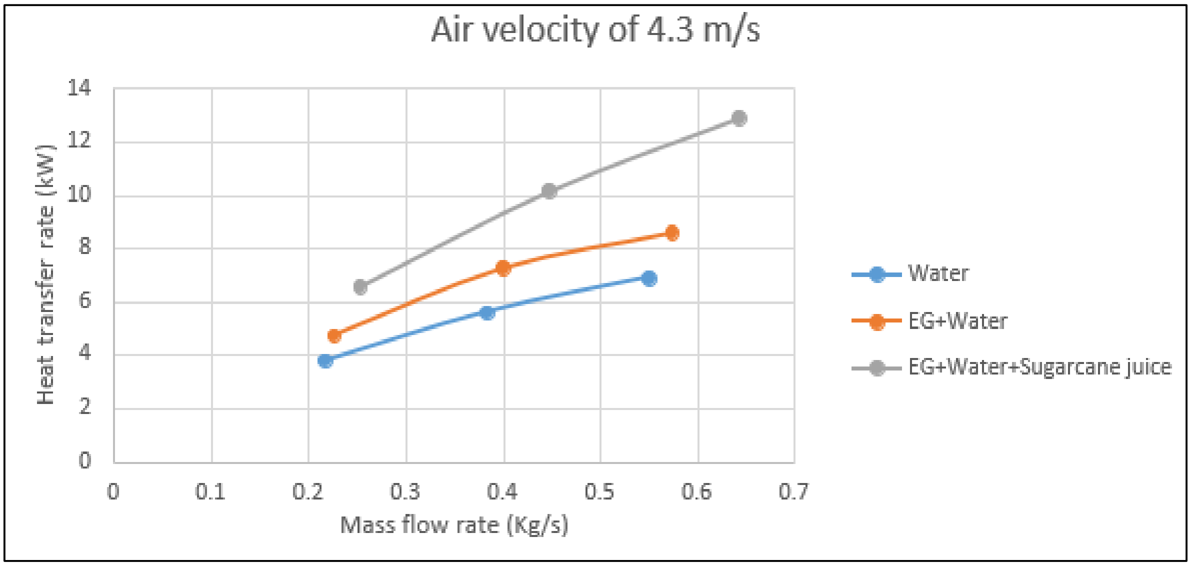

Fig. 4: Variation of heat transfer rate for different mass flow rate at air velocity of 4.3 m/sec

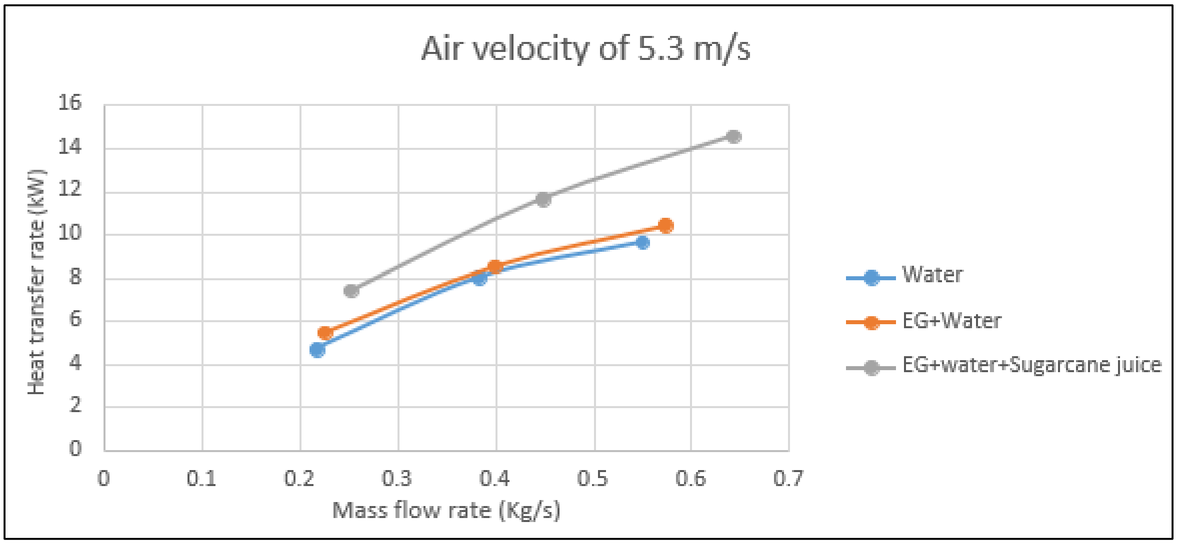

Fig. 5: Variation of heat transfer rate for different mass flow rate at air velocity of 5.3 m/sec

B. At Temperature 60

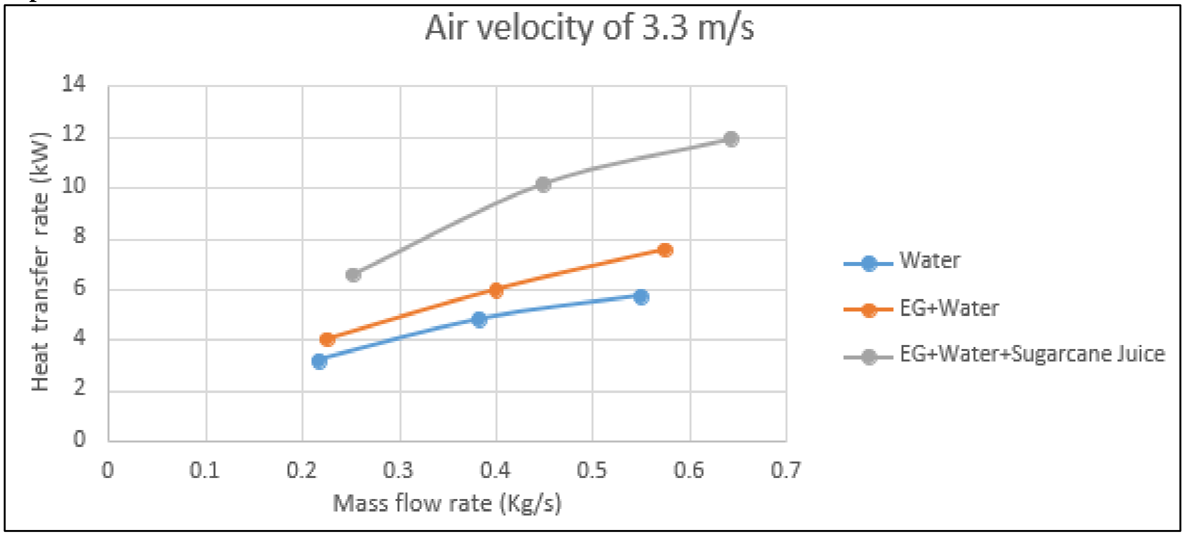

Fig. 6: Variation of heat transfer rate for different mass flow rate at air velocity of 3.3 m/sec

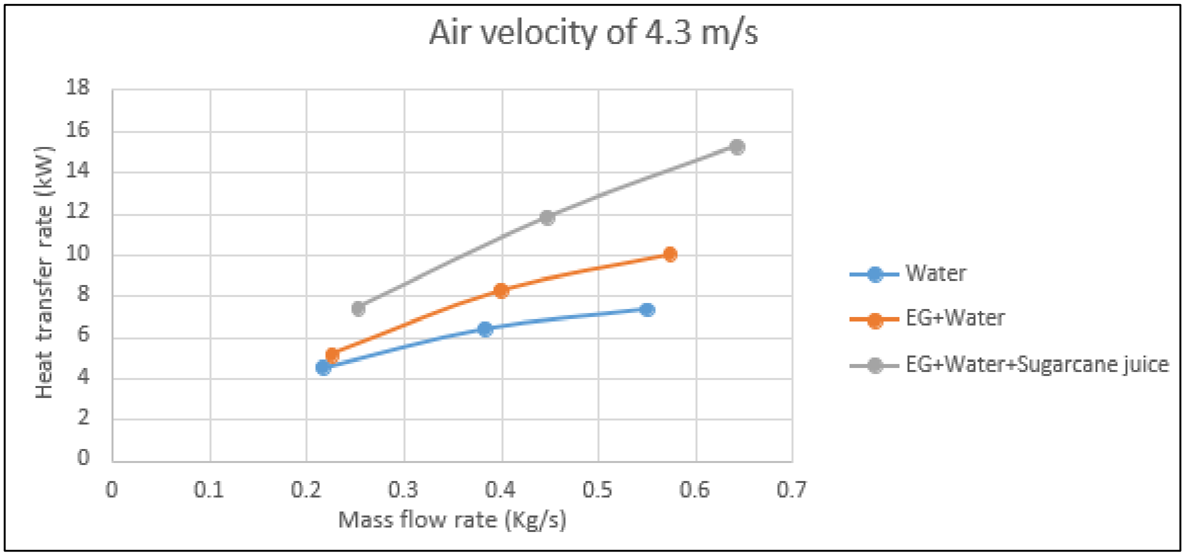

Fig. 7: Variation of heat transfer rate for different mass flow rate at air velocity of 4.3 m/sec

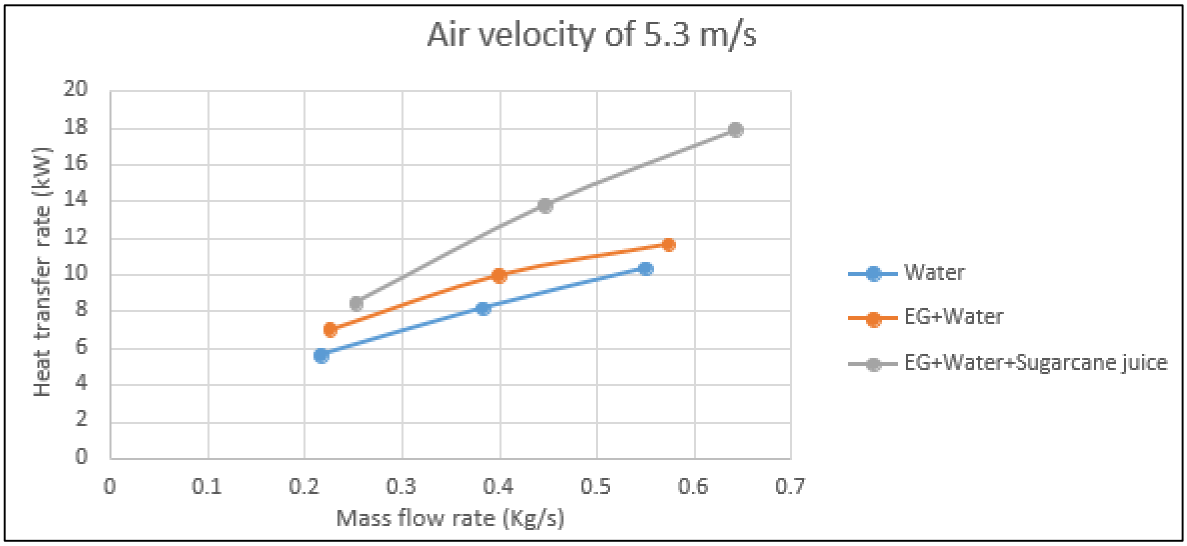

Fig. 8: Variation of heat transfer rate for different mass flow rate at air velocity of 5.3 m/sec

Automobile radiator while using Water, Water+EG & Water+EG+Sugarcane juice as coolants. The results shows that, the highest heat transfer rate is experienced while using Water+EG+Sugarcane juice as coolant and lower heat transfer rate while using water as coolant.

Water is used as coolant with mass flow rates 0.217 Kg/s, 0.383 Kg/s and 0.55 Kg/s, Water+EG is used as coolant with mass flow rates 0.226 Kg/s,0.4 Kg/s & 0.574 Kg/s and Water+EG+Sugarcane juice is used as coolant with mass flow rates 0.253 Kg/s,0.448 Kg/s & 0.653 Kg/s. For each mass flow rate of coolants, experiments are conducted for three different air velocities of 3.3m/s,4.3m/s & 5.3m/s. For the three different coolant mixtures.

- Water
- Water+EG
- Water+EG+Sugarcane juice

Experiment is conducted at two different temperatures of 50 degree Celsius and 60 degree Celsius. And the above graphs clearly shows the highest heat transfer rate is experienced while using Water+EG+Sugarcane juice as coolant and lower heat transfer rate while using water as coolant.

IX. Conclusions

This experimental work was conducted to investigate the heat transfer rate of automobile radiator while using Water, Water+EG & Water+EG+Sugarcane juice as coolants. The results shows that, the highest heat transfer rate is experienced while using Water+EG+Sugarcane juice as coolant and lower heat transfer rate while using water as coolant.

- Sugarcane juice yields better heat transfer rate than Water+EG & Water as coolants.
- Only long term stability is an issue. To solve this issue intense researches is to done on sugarcane juice properties, mixture preparation etc.

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