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Heat Transfer Enhancement of Nano Al_2O_3 Mixed with Regular Coolant Blends in Compact Heat Exchanger

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ABSTRACT

Heat transfer enhancement is showing a relatively positive effect on compact heat exchanger performance in automobile applications. Heat transfer enhancement helps to increase the thermal efficiency of the heat exchanger, allowing it to transfer more heat in less time. This helps to reduce the fuel consumption of the vehicle and increase its efficiency. Present researches focus on the enhancement of high-performance heat exchangers in heavy cargo vehicles in the automobile sector. Compact heat exchangers having low space occupancy and high performance coolant blends need to be studied for heat transfer applications. The work is a case study of blends comparison with and without Nano addition to check the variation after adding 1% Al_2O_3 to locally available coolants like TFC Anti-freeze coolant, MFC, Castrol. The experiments were run at 60℃ and 80℃ and 1.765, 3.53 bar pressure taken as full flow and pressure drop conditions. The Sonication process was also explained to evaluate the thermal properties of coolant blends before and after NANO-addition. The addition of NANO-Al_2O_3 with MFC gave good results when compared with the others.

1. INTRODUCTION

Heat exchangers are the most necessary equipment used in automobiles, the pharma industries, and heat-absorbing and transferring applications. There are many types of heat exchangers that are available, such as shell and tube, fin tube, coil based Etc. Compact heat exchangers are better than others. CHE has common occupation space with more surface area [1]. CHE applications are known to be less space-consuming with a high heat transfer rate, such as radiators in heavy vehicles. Composites are known to be effective for heat transfer applications. The present study also explores composite plates and fins in CHE fabrication [2]. The current research also focuses on conventional water blends and NANO addition to check heat exchanger performance. Blends are added at different ratios to water to evaluate the most effective thermal properties as an approach. A test rig has been made to check the experimental analysis of all coolant blends.

Heat dissipation is probably one of the most important considerations in engine design. Internal combustion engines create enough heat to destroy themselves. Without an efficient cooling system, we wouldn't be able to do what we do today. The original radiators were simple networks of round copper dissipation. Generally, thermal fluids have poor thermophysical properties due to their inherent characteristics. As a promising solution to increase thermal energy system efficiency, Nano fluids with a stable design, enhanced heat transfer and a lower pressure drop are suggested. The effectiveness of compact heat exchangers can be enhanced by using promising new thermal fluids called "Nano fluids" for heat transfer and fluid flow.

The present research focused on the experimentation of Nano Al_2O_3 mixed with conventional coolants to improve the performance of heat exchanger by increasing heat transfer rate.

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The present research focused on the experimentation of Nano Al_2O_3 mixed with conventional coolants to improve the performance of heat exchanger by increasing heat transfer rate.

2. LITERATURE REVIEW

Kim and No [3] investigated a new PCHE model's thermal-hydraulic performance using various airfoil shape fins. It was found that the new PCHE model had the same heat transfer performance and a pressure drop that was only within as large as that of the standard zigzag channel PCHE. PCHE has a low porosity of about 0.4-0.55 compared to a typical PFHE porosity range of 0.6-0.75. In comparison to traditional shell-and-and-tube heat exchangers with the same thermal duty and pressure drop, PCHEs have a volume that is 4–6 times smaller and weighs about half as much because of their compact design. In the study of Manente and Fortuna [4], a conventional internal combustion engine radiator heat transfer and pressure loss can be predicted with mathematical modeling. According to the findings, different materials, such as copper, brass, aluminum, carbon steel and stainless steel had varying effects on the building of fins and tubes. This was done by assuming that the bonding effectiveness between tubes and fins was 100 percent. Various fin and tube material combinations were tested during normal radiator operation to see how well they performed. Two different authors, two different pieces of work, performed experiments for water and airflows, respectively, in a tube-in-tube heat exchanger under iso thermal heating conditions to study the turbulent heat transfer and pressure drop characteristics of straight and helically finned tubes [5].

However, Yang et al. [6] found that in addition to physical features, the style of flow (laminar or turbulent) within the heat-exchanging equipment has a significant impact on a Nano fluid's performance. In helical coils and parallel surfaces, Saeed and Kim [7] analyzed at the flow of Al_2O_3 Nano fluid. There was a significant improvement in heat transfer efficiency with increasing particle concentration for Reynolds numbers ranging from 250 to 1000. However, they found that the base fluid had a negative impact on wall shear stress. Hu et al. [8] suggested from using nanoparticles in two-phase CHE, according to the study. Particles begin to collect in rather big clusters near the tube exit once the boiling process begins because of regionalized evaporation. Once this clustering occurs, the coolant cannot get into the cooling system, and the complete cooling system fails due to catastrophic cooling system failure. Bennett and Chen [9] investigated at heat transfer and pressure drop data for straight and spiral finned tubes with fin heights ranging from 0.77 to 3.3 mm when using water as the working fluid. In terms of hydraulic diameter, the Reynolds number ranged from about 1500 to 50000. There had been an earlier laminar-to-turbulent transition, the researchers determined.

When it came to friction factor, their results showed that the smooth tube correlations could also be applied for the rugged region's tested finned tubes [10]. For sustainable growth, it is critical to produce, convert, and consume energy correctly. There are many industrial applications for heat transfer, including power generation plants, automobiles, aerospace, and chemical industries. A number of challenges emerged in this field, like improving energy efficiency and reliability for devices, as well as miniaturization (lower sizes) and cost reduction. In heat transfer applications, compact heat exchangers (CHXs) provide better thermal performance, are smaller, require less thermal fluid amount and have lower production costs. Heat transfer intensification is needed, however, when conventional thermal fluids flow through CHX minichannels for cooling/heating [11]. By dispersing metallic/non-metallic nanoparticles into conventional thermal fluids, Nano fluids have been studied by many researchers since then for applications such as cooling engine devices, managing vehicle thermal energy, renewable energy technology [12], microelectromechanical systems, medical devices, cooling energy systems, and so forth for a number of thermal applications, it was found that Nano fluids can be operated successfully with CHXs. Nonetheless, using Nano fluids may cause some problems such as corrosion in the walls of the channels, nanoparticle sedimentation and increased pressure drop by Sarafraz et al. [13]. This requires further careful investigations into the flows of Nano fluids for each nanoparticle type. So far, several studies have been conducted focusing on the heat transfer behaviours of Nano fluids flowing through several CHX types. Shell and tube heat exchangers are extensively used in numerous applications in the industrial sector, including electricity plants and oil production [14]. According to researchers in this field, Nano fluids, when flowed in the tube side of a compact shell and tube HX (inner diameter of the tube Din-tube, 8.1 mm), can improve thermal performance. Yang et al. [15] conducted an experimental investigation. On horizontal shell and tube HX working with two types of nano fluids (Al_2O_3/water and TiO_2/water). It is under turbulent flow conditions that no fluids flow through the tube (5.1 mm in diameter). The results indicated a significant enhancement in HTC up to 20% for Al_2O_3 Nano fluid and up to 24% for TiO_2 Nano fluid compared with base fluid at the same Peclet number. Also, Albadr [16] investigated the thermal performance of shell and tube HX with a tube of 2.4 mm diameter, moving Al_2O_3 Nano fluids under turbulent flow. With increasing particle concentration, thermal performance showed a significant improvement. Another study by Barzegarian et al. [17], a shell and tube HX with a 5 mm inner diameter was used to contain Al_2O_3 Nano fluid at several particle concentrations. When particle concentration was increased to 0.3 vol%, a significant increase in heat transfer (Nu) was observed. Munimathan et al. [18] conducted a study on heat transfer rates using Al_2O_3/water nanofluids at concentrations of 0.25%, 0.1%, and compared these with deionized water in microchannel heat conductors. In the study of Nakhchi and Esfahani [19], the combined effects of CuO-water nanofluids and perforated louvered strip vortex generators with various geometries on the turbulent flow characteristics inside circular tubes were numerically investigated. In the study of Zhang et al. [20], the chevron angle was identified as the most important geometrical parameter for chevron corrugation plate heat exchangers, according to the data. The pressure drop and heat transfer in single-phase systems increase as the chevron angle rises. The research of Kapustenko et al. [21] investigates heat transfer and pressure losses during different types of vapor condensation occurring in plate heat exchanger (PHE) channels. It specifically focuses on the local process parameters within small zoned areas of the channels and analyzes how these parameters are distributed across the channel field, taking into account the geometry of the grooves. Albadr et al. [22] analyzed are the heat transfer and flow properties of a water-based nanofluid containing varying volume concentrations of Al_2O_3 (0.2-2%) that flows counter to a horizontal shell-and-tube heat exchanger under turbulent conditions.

3. METHODOLOGY AND MATERIALS

The present work is divided into two case studies. There was an addition of 8 and 10% of coolants to water primarily. These blends are tested when the temperatures and pressure drop up to the stagnated level of transfer at approximately 600 seconds. A second case study adds coolant to water at 8 and 10% with1% Nano addition to each percentage.

Properties evaluation: Thermal properties are evaluated for the performance study of coolant blend with experimental heat transfer data. Conventional coolants taken as primary blending with water and properties are evaluated for the first case of experiment to check the heat transfer rate after blending to water. The results were shown in the Table 1.

Table 1. Blend properties of water blends with coolants

Parameter	TFC Blend		MFC Blend		Castrol Blend	
	8%	10%	8%	10%	8%	10%
Density (kg/m^3)	861	872	1028	1087	1040	1065
Boiling point (℃)	120	121	135	145	112	123
Melting point (℃)	70	70	70	70	104	104
Thermal conductivity (W/m℃)	5.231	5.346	6.431	6.682	6.328	6.628
Specific heat (Kj/Kg/K)	0.689	0.72	0.692	0.764	0.521	0.552

3.1 Preparation of blends

Blends are primarily prepared with 8 and 10% of TFC Anti-freeze coolant, MFC, Castrol added to the distilled water at room temperature to check the concentration. The addition of NANO Al_2O_3 particles of 1% to this blend sonicated for further properties evaluation. Nano coolant sonication equipment process has been shown in the Figure 1. The process explained below:

Figure 1. The ultrasonic both vibrator and spectrometer for sonication

All the chemical compounds used in our experiments were analytic and were used directly without further washing. Our experimental procedure has been as follows:

Stability and operational performance of Nano fluids are the major obstacles to be overcome. Thermo-physical qualities must be maintained throughout time, which necessitates nano fluid stability. Stability of nano-fluids is being improved, as is understanding of nano-fluid behaviour as part of the supply chain required to commercialise these cutting-edge fluids. Nano fluid investigations, comprising production, stability evaluative mechanisms and sweetening techniques and Nano fluid thermodynamic properties will be described in this context. There is now a strong correlation between particle dispersion uniformity and the preparation process performed. If two similar Nano fluids made in different methods have different thermophysical properties, it could have a major impact on both. The thermo - physical properties features and the tendency to aggregate could hardly be more dissimilar.

1. The distilled water (100 mL) was dissolved at room temperature and stirred by ultrasound during 10-minute sonication in some quantity of aluminium, isopropyl alcohol and PEG6000.

2. Nitric acid in an adequate volume was processed with 1.5 weight percent KH-560 for 30 minutes at 65℃ with magnetic stirring. Once the pH of the Alooh gel was reduced to 9, ammonia was added and the Al_2O_3 precursor was produced.

3. After washing with alcohol, the Al_2O_3 precursor was placed in the autoclave three times, and reaction conditions were set at 220℃, 3.6 Mpa pressure, and 2.5 hours, resulting in modified Nano particles.

4. The situ-modified methodology completes the surface preparation and adjustment for nanoparticles Al_2O_3 immediately.

Table 2. Blend properties of water blends with coolants with 1% NANO Al_2O_3 addition

Parameter	TFC Blend		MFC Blend		Castrol Blend	
	8%	10%	8%	10%	8%	10%
Density (kg/m^3)	870	878	1040	1814	1040	1065
Boiling point (℃)	120	121	135	145	112	123
Melting point (℃)	70	70	70	70	104	104
Thermal conductivity (W/m℃)	5.231	5.346	6.431	6.682	6.328	6.628
Specific heat (Kj/Kg/K)	0.689	0.72	0.692	0.764	0.521	0.552

5. The sonication did for 45 days to check the increased viscous values, thermal properties tested for Nano blends. Properties of blends shown in Table 2 after sonication with conventional coolants for the improvement of HTR.

4. EXPERIMENTAL WORK AND RESULTS

The blend properties in the two cases are characterized for further research. Coolants are tested at 600℃ and 800℃ for no pressure drop conditions and 50% pressure drop on the coolant input side. Each test runs a span of 10 minutes, that the temperature transfer gets stabilized.

Coolant blends tested for the parameters mentioned earlier of methodology to check the heat transfer difference in cold and hot side to check the coolant's performance and designed heat ex-changer performance. Experimental work has been carried out at two temperature inputs of 60 and 80 degrees with a time interval of 60 seconds, up to 10 minutes working time taken to stabilize the exact quantity of heat carried out. The temperature difference has been taken for all three blends with Nano addition. Sonication process of nano particles with blends gives a good particle distribution in the conventional coolant. The density of the coolant blend varied at minute level when the sonication done for a long time up to even distribution of particles. Experimentation done for counter flow direction for with and without Nano addition. The experimental setup to test the Nano coolant in compact heat exchanger with equipment details shown in the Figure 2.

Figure 2. The test-rig setup of compact heat exchanger

The results obtained for comparison of 60℃ hot side for 8% blend given in the Table 3.

Table 3. Comparative results of 60℃ hot side for 8% blend

S. No.	Time (S)	MFC	TFC	Castrol
1	60	9.8	1.1	9.3
2	120	12.44	20.2	8.7
3	180	11.44	15.2	7.2
4	240	12.42	12.3	7.9
5	300	12.65	11	8.2
6	360	14.75	9	7.7
7	420	15.77	9.1	7.5
8	480	17.8	8.4	7.3
9	540	18.72	7.8	6.2
10	600	19.32	8.2	8.2

Comparisons made with three blends and the coolant TFC having initial rise and sudden fall with the increase of cycle time when it comes to stability, Castrol shows the consistency. Still, not much variation found on the hot liquid input side means the coolant-carrying capacity from the initial stage is quite convenient. Compared to these two at no pressure drop and at 60℃, a gradual increase in the heat absorption was found in MFC as shown in Figure 3. The full flow of the coolant substance without any disturbance with maximum capacity has been shown in Figure 3.

The comparative results at 60℃, cold side 8% coolant blend are given in the Table 4. The results showing that 8% MFC given better results compare with other coolants. The results comparison plot shown in the Figure 4.

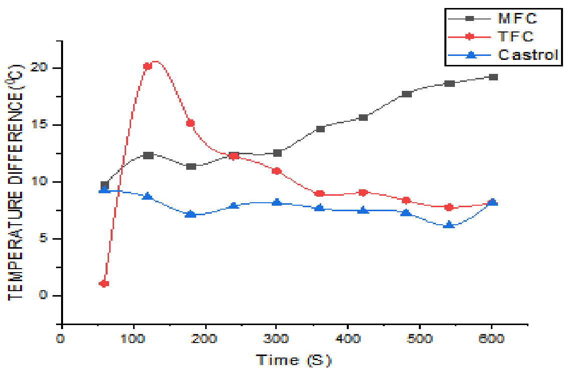

Figure 3. Time vs temperature difference without pressure drop hot side at 60℃

Table 4. Comparative results of 60℃ cold side for 8% blend

S. No.	Time S sec	MFC	TFC	Castrol
1	60	18.28	8.6	10.2
2	120	19.48	18	9.9
3	180	14.72	15.5	8.7
4	240	12.73	13.1	7.8
5	300	14.65	11.9	7.9
6	360	12.46	10.9	7.4
7	420	11.05	10.2	7.6
8	480	11.56	10	7.2
9	540	10.35	9.7	6.9
10	600	11.54	9.8	7.1

The comparison of the above graph (Figure 4) clearly shows the difference in the heat absorption rate of Castrol coolant blend after Nano addition also significantly less when compared with MFC and TFC. At the stabilized time, the cold side difference is more negligible, but the absorbing capacity of MFC is better than the other two.

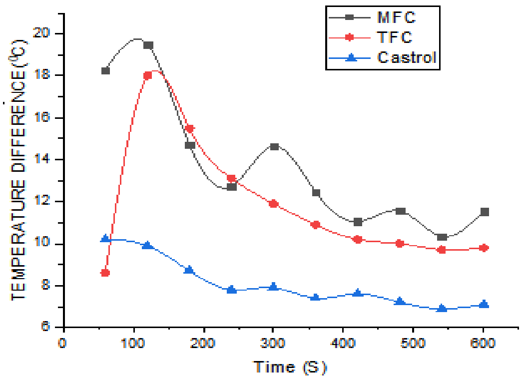

Figure 4. Time vs temperature difference without pressure drop cold side at 60℃

The comparative results at 60℃ hot side for 8% coolant blend are given in the Table 5. The results showing that 8% MFC given better results at 50% pressure drop also compare with other coolants. The results comparison plot shown in the Figure 5.

In the pressure drop condition, MFC shows a significant difference while the Castrol and TFC have their consistency of not much variation in absorbing capacity. Graphical comparison of the above coolants showing clear temperature difference even in the pressure drop condition at the hot side; and relevant cold side should be noted within the consideration of coolant evaporation. The input pressure for the coolant to reduce mass flow rate a volve attached to the coolant input side to test the half capacity of tank level when coolant level at low condition.

Table 5. Comparative results of 60℃ with 50% pressure drop hot side for 8% blend

S. No.	Time S sec	MFC	TFC	Castrol
1	60	6.8	0.5	6.9
2	120	9.4	10.5	7
3	180	11.18	9.8	7
4	240	11.75	9.2	7
5	300	13.65	8.9	6.7
6	360	13.75	8.6	6.6
7	420	16.77	8.2	5.6
8	480	17.79	8	6.3
9	540	18.15	7.9	6.4
10	600	19.32	7.6	6.3

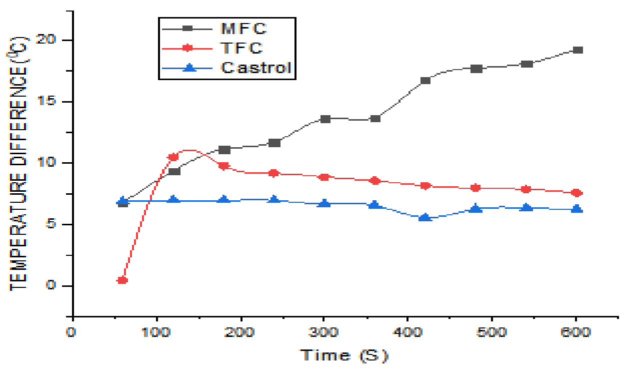

Figure 5. Time vs temperature difference with pressure drop hot side at 60℃

The comparative results at 60°C cold side 8% coolant blend are given in the Table 6. The results showing that 8% MFC given better results at 50% pressure drop also compare with other coolants. The results comparison plot shown in the Figure 6.

Table 6. Comparative results of 60°C with 50% pressure drop cold side for 8% blend

S. No.	Time S sec	MFC	TFC	Castrol
1	60	14.7	8.5	6.8
2	120	17.16	11.8	7.2
3	180	18.06	10.8	6.8
4	240	19.85	10.1	6.6
5	300	21.85	10	7
6	360	22.8	9.9	6.7
7	420	23.35	9.9	6.9
8	480	25.1	9.7	6.5
9	540	25.1	9.5	6.5
10	600	16.73	9.2	6.2

As observed from the comparison at graph 3, graph four also followed concerning MFC has given significant variation at the above temperature of 60°C in pressure drop condition. Castrol made an equal variation, and TFC was consistent, but the difference in heat-absorbing capacity is low.

The comparative results at 80°C, hot side 8% coolant blend are given in the Table 7. The results showing that 8% MFC given better results compare with other coolants. The results comparison plot show in the Figure 7.

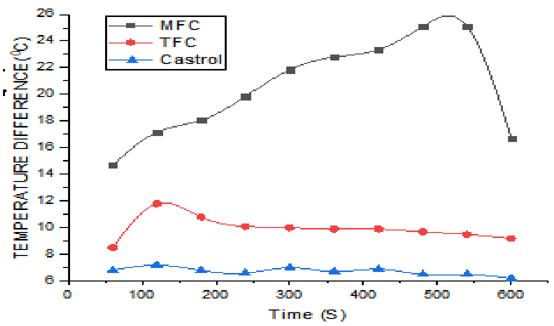

Figure 6. Time vs temperature difference with pressure drop cold side at 60°C

Table 7. Comparative results of 800°C hot side for 8% blend

S. No.	Time S sec	MFC	TFC	Castrol
1	60	21	1.2	21.4
2	120	24.89	18.1	17.1
3	180	24.88	16.2	14.2
4	240	22.79	13.7	12.5
5	300	22.64	12.6	11.1
6	360	22.22	11.7	11.1
7	420	22.72	10.9	9.9
8	480	23.11	11.1	10
9	540	23.11	10.1	9.1
10	600	22.88	10.3	9.1

The temperature raised to 80 degrees in the second case means the input of the hot side increases to check the performance of Nano coolant with the above three blends. At increased temperatures, heat absorption capacity also increased in all the coolants. In the perception of consistency, all the coolants are good at Nano addition, but MFC given more variation in heat-absorbing capacity, the difference rate is more than 20 degrees.

The comparative results at 80°C, cold side 8% coolant blend are given in the Table 8. The results showing that 8% MFC given better results compare with other coolants. The results comparison plot show in the Figure 8.

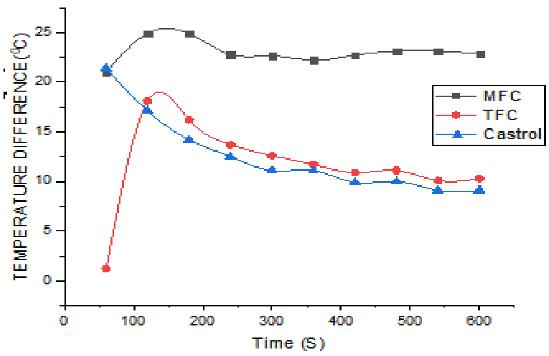

Figure 7. Time vs temperature difference with no pressure drop hot side at 80°C

A notable difference in heat transfer was observed on the cold side with increasing temperature in all Nano coolant blends. TFC is a bit higher than Castrol, but variation between these two is very low, compare to this, MFC increases its heat absorption rate with time which is not found in another two blends. Found an approximate variation of 20% with MFC to other Nano blends.

Table 8. Comparative results of 80°C cold side for 8% blend

S. No.	Time S sec	MFC	TFC	Castrol
1	60	27.8	7.4	18.2
2	120	27.57	16.5	14.7
3	180	28.18	15.6	12.6
4	240	28.19	13.7	10.8
5	300	28.62	13	10.2
6	360	29.17	12.2	9.6
7	420	29.89	11.6	9.2
8	480	30.14	11.7	9.1
9	540	31.27	11.5	8.9
10	600	32.06	11.2	8.7

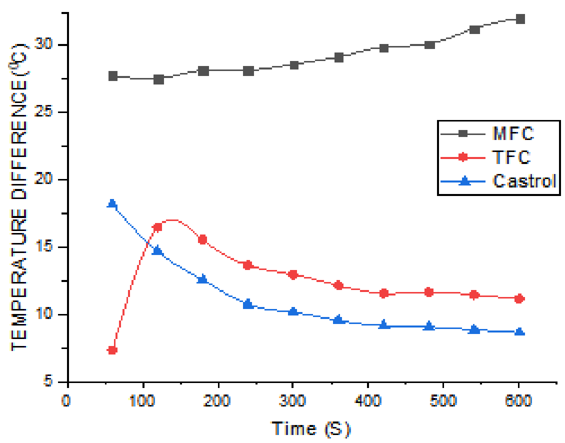

Figure 8. Time vs temperature difference with no pressure drop cold side at 80°C

The comparative results at 80°C hot side 8% coolant blend are given in the Table 9. The results showing that 8% MFC given better results at 50% pressure drop also compare with other coolants. The results comparison plot shown in the Figure 9.

Table 9. Comparative results of 80°C with 50% pressure drop hot side for 8% blend

S. No.	Time S sec	MFC	TFC	Castrol
1	60	26.9	1.4	12.8
2	120	25.3	23.3	14.9
3	180	24.2	17.4	12.5
4	240	23.1	15.4	11.2
5	300	22.1	12.7	11.2
6	360	22	11.4	10.3
7	420	20.9	10.3	10.1
8	480	21.1	10.2	9.4
9	540	20.3	10.2	10.5
10	600	20.7	10	9.6

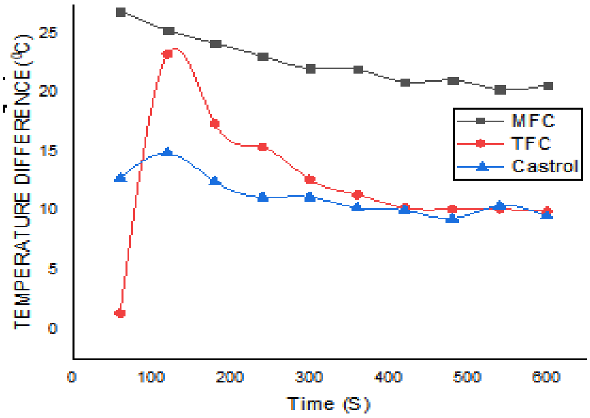

Figure 9. Time vs temperature difference with pressure drop hot side with at 80°C

A differed condition observed with the comparison of the above graph the pressure drop affected the blend at high temperature. MFC noted good result along with time its noted that heat took capacity decreasing at pressure drop, variation of 10% between normal and pressure drop conditions are observed.

The comparative results at 80°C cold side 8% coolant blend are given in the Table 10. The results showing that 8% MFC given better results at 50% pressure drop also compare with other coolants. The results comparison plot shown in the Figure 10.

Table 10. Comparative results of 80°C with 50% pressure drop cold side for 8% blend

S. No.	Time S sec	MFC	TFC	Castrol
1	60	24.7	1.6	8.2
2	120	22.9	20.8	14.7
3	180	21.8	17.1	12.6
4	240	21.5	15	10.2
5	300	20.4	12.3	9.6
6	360	20.6	12.3	9.2
7	420	20.1	11.6	9.2
8	480	20	11.3	9.1
9	540	19.4	11.2	8.9
10	600	19.3	11	8.7

Cold side is also relatively similar to the hot side at higher temperature and pressure drop graph 8 comparatively similar to hot side a clear difference of 10-12% observed between MFC and other coolant blends.

The comparative results at 60°C hot side 10% coolant blend with Nano addition are given in the Table 11. The results showing that 10% MFC given better results at no pressure drop also compare with other coolants. The results comparison plot shown in the Figure 11.

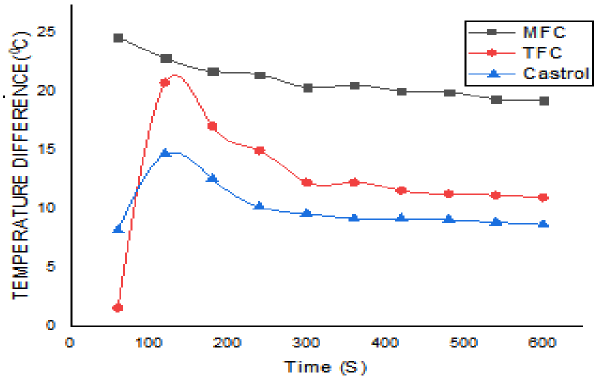

Figure 10. Time vs temperature difference with pressure drop cold side with at 80°C

Table 11. Comparative results of 60°C hot side for 10% blend with NANO

S. No.	Time S sec	MFC	TFC	Castrol
1	60	10.2	1.4	9.7
2	120	12.44	20.3	8.7
3	180	11.44	17.2	7.9
4	240	12.42	15.3	7.11
5	300	12.65	3.2	8.22
6	360	14.75	9.2	7.12
7	420	15.77	9.4	7.52
8	480	17.81	8.8	7.3
9	540	18.88	7.9	6.2
10	600	20.33	8.5	8.2

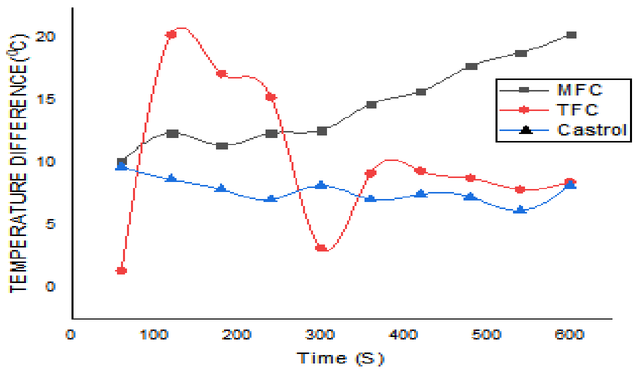

Figure 11. Time vs temperature difference with no pressure drop hot side with at 60°C

From the comparative analysis, after increasing to10% blend addition with 1% Nano Al_2O_3. The results are pretty increased in the temperature difference value of input and output as properties deviated with coolant. A 5-8% raise in differential values compared to the previous experiment of 8% blend.

The comparative results at 60°C cold side 10% coolant blend with Nano addition are given in the Table 12. The results showing that 10% MFC given better results at no pressure drop also compare with other coolants. The results comparison plot shown in the Figure 12.

Table 12. Comparative results of 60°C cold side 10% blend with NANO

S. No	Time S sec	MFC	TFC	Castrol
1	60	18.30	9.62	10.11
2	120	20.52	20.5	9.11
3	180	14.88	18.5	12.4
4	240	12.75	19.12	11.8
5	300	14.68	12.92	10.7
6	360	11.49	13.98	8.9
7	420	12.15	15.25	8.74
8	480	12.62	12.45	8.17
9	540	12.37	10.78	9.14
10	600	12.58	10.82	7.19

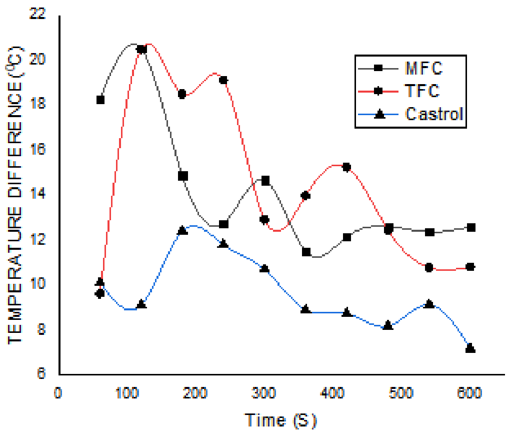

Figure 12. Time vs temperature difference with no pressure drop cold side with at 60°C

At cold side comparison, the blends increased their capacity to absorb heat when coming to stable absorption, except MFC other blends are not much preferable at the cold end. Slight differences are observed in all the combinations compare with the 8% blend.

The comparative results at 60°C hot side 10% coolant blend with Nano addition are given in the Table 13. The results showing that 10% MFC given better results at 50% pressure drop also compare with other coolants. The results comparison plot shown in the Figure 13.

Table 13. Comparative results of 60°C with 50% pressure drop hot side 10% blend with NANO

S. No.	Time S sec	MFC	TFC	Castrol
1	60	7.12	1.0	8.9
2	120	10.4	12.52	9.8
3	180	12.18	10.8	9.15
4	240	12.75	10.22	9.14
5	300	13.65	9.9	8.75
6	360	12.75	9.62	8.6
7	420	18.77	9.22	8.6
8	480	19.79	8.22	7.3
9	540	20.15	8.92	7.4
10	600	19.88	8.62	6.3

Much difference varied in the hot side with MFC at an initial temperature of constant input 60°C; minimal deviations were found in the other two coolant blends.

The comparative results at 60°C cold side 10% coolant blend with Nano addition are given in the Table 14. The results showing that 10% MFC given better results at 50% pressure drop also compare with other coolants. The results comparison plot shown in the Figure 14.

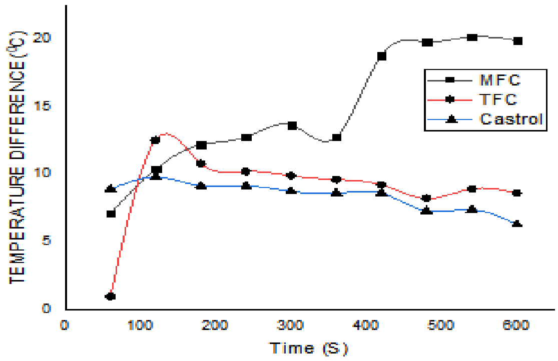

Figure 13. Time vs temperature difference with pressure drop hot side at 60°C

Table 14. Comparative results of 60°C with 50% pressure drop cold side 10% blend with NANO

S. No.	Time S sec	MFC	TFC	Castrol
1	60	16.72	10.51	14.8
2	120	19.18	12.8	8.28
3	180	20.06	14.8	10.8
4	240	21.85	14.1	9.65
5	300	22.85	15	7.82
6	360	25.82	12.9	10.7
7	420	25.35	12.9	12.9
8	480	28.1	12.7	10.5
9	540	28.1	12.5	9.52
10	600	20.02	12.2	8.22

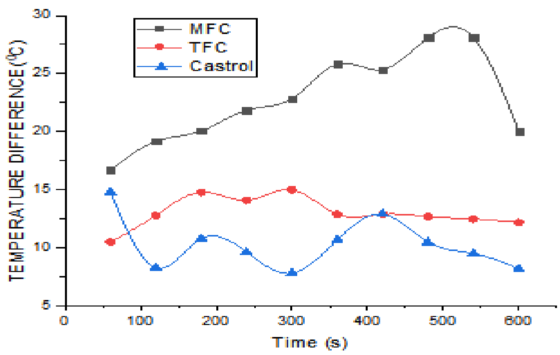

Figure 14. Time vs temperature difference with pressure drop cold side with at 60°C

Cold side with pressure drop, the evaporation of the blend becomes slow after 2% addition to the coolant blend of 8%. Castrol 10% is also consistent in addition to the extra coolant. MFC and TFC blend evaporation is also less.

The comparative results at 80°C hot side 10% coolant blend with Nano addition are given in the Table 15. The results showing that 10% MFC given better results at no pressure drop also compare with other coolants. The results comparison plot shown in the Figure 15.

MFC has given a better result of 15% compared with the other coolant blends; the observed effects of Castrol are also similar to TFC at high temperatures.

The comparative results at 80°C, cold side 10% coolant blend with Nano addition are given in the Table 16. The results showing that 10% MFC given better results at no pressure drop also compare with other coolants. The results comparison plot shown in the Figure 16.

Table 15. Comparative results of 80°C hot side 10% blend with NANO

S. No.	Time S sec	MFC	TFC	Castrol
1	60	27.82	10.2	20.2
2	120	27.58	18.52	18.7
3	180	28.19	16.61	16.6
4	240	28.19	14.7	11.8
5	300	28.65	14.7	17.2
6	360	29.17	14.22	10.6
7	420	29.89	10.61	11.2
8	480	30.14	10.71	8.1
9	540	31.27	10.51	9.9
10	600	32.06	10.21	10.7

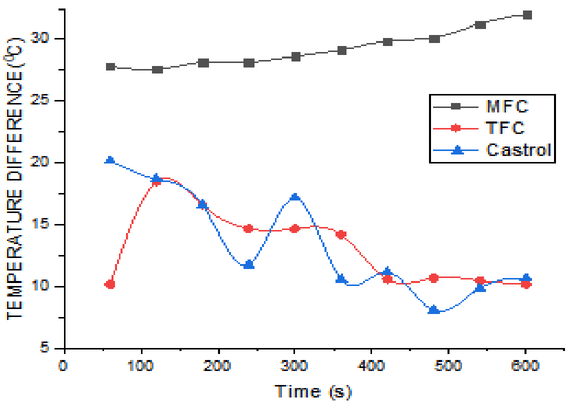

Figure 15. Time vs temperature difference with no pressure drop hot side with at 80°C

Table 16. Comparative results of 80°C cold side 10% blend with NANO

S. No.	Time S sec	MFC	TFC	Castrol
1	60	25.22	2.28	21.47
2	120	24.89	20.1	17.17
3	180	24.88	18.2	14.24
4	240	23.79	14.7	12.55
5	300	21.67	12.6	11.15
6	360	21.22	11.7	11.12
7	420	21.70	12.9	9.91
8	480	23.11	10.1	10.22
9	540	23.11	11.1	9.15
10	600	25.80	12.3	9.55

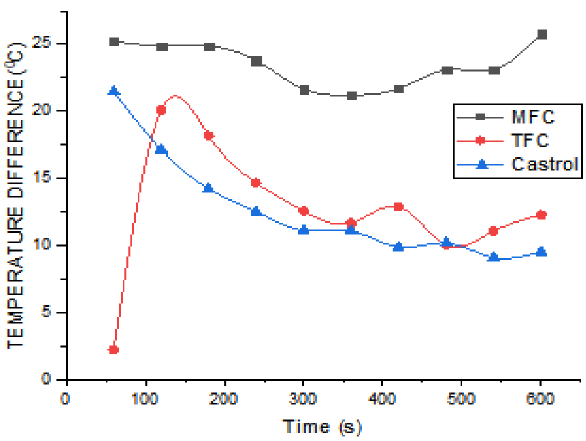

Figure 16. Time vs temperature difference with no pressure drop cold side with at 80°C

MFC noted good result along with time it's noted that heat took capacity without pressure drop, variation of 15% between other coolants are observed.

The comparative results at 80°C hot side 10% coolant blend with Nano addition are given in the Table 17. The results showing that 10% MFC given better results at 50% pressure drop also compare with other coolants. The results comparison plot shown in the Figure 17.

Table 17. Comparative results of 80°C with 50% pressure drop hot side

S. No	Time S sec	MFC	TFC	Castrol
1	60	28.92	2.42	12.82
2	120	28.32	23.3	14.92
3	180	25.21	17.4	12.55
4	240	24.15	15.4	11.25
5	300	23.15	13.7	11.2
6	360	23.55	12.4	12.34
7	420	20.98	11.35	12.18
8	480	21.15	11.22	11.4
9	540	20.32	10.24	12.5
10	600	20.78	10.55	10.8

MFC noted good result along with time it's noted that heat took capacity decreasing at pressure drop, variation of 10% between normal and pressure drop conditions are observed. Even though the results obtained are better than 8% addition, the uniqueness observed is like another temperature with MFC compared with other coolants.

The comparative results at 80°C cold side 10% coolant blend with Nano addition are given in the Table 18. The results showing that 10% MFC given better results at 50% pressure drop also compare with other coolants. The results comparison plot shown in the Figure 18.

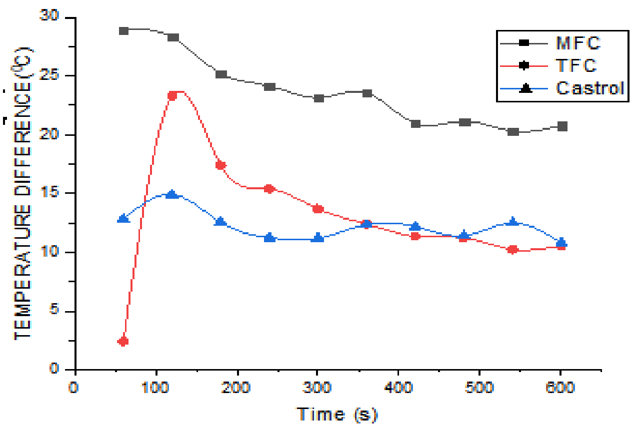

Figure 17. Time vs temperature difference with pressure drop hot side with at 80°C

Table 18. Comparative results of 80°C with 50% pressure drop cold side

S. No.	Time S sec	MFC	TFC	Castrol
1	60	28.7	3.68	12.22
2	120	25.9	18.25	18.74
3	180	22.8	19.1	16.61
4	240	28.5	15.3	18.21
5	300	24.4	13.32	11.61
6	360	22.6	12.32	10.21
7	420	20.18	12.6	10.21
8	480	20.8	12.32	10.12
9	540	19.4	14.2	10.92
10	600	19.32	11.25	9.72

A variation of 25°C was found at the cold side with coolant increment in blend in MFC. The other two are similar to the before blend percentage. Slight variations are observed.

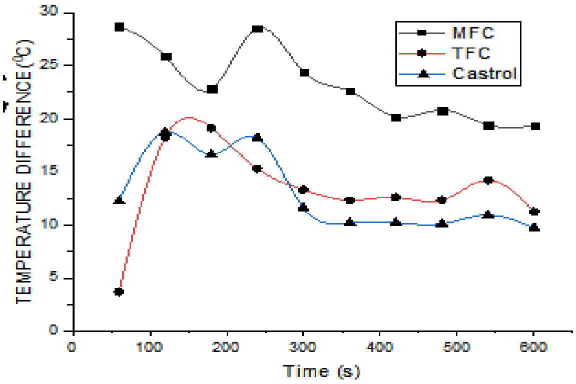

Figure 18. Time vs temperature difference with pressure drop cold side with at 80°C

5. CONCLUSIONS

Blending of coolants with NANO addition gives positive results. Comparison of three blends made in experiment MFC with a 10% maximum temperature variation from hot to cold observed to be more than 25%. This is likely because the addition of the NANO particles helps to reduce the heat capacity of the coolant, allowing it to absorb more heat when it's cold and release more heat when it's hot. This allows the coolant to maintain a constant temperature, resulting in more energy-efficient cooling. In comparison with TFC and Castrol blends, MFC gave better results. The two results of 2nd and 3rd blends produced similar results of variation, with an approximate difference of 15% was observed when compared with MFC. This is likely due to the fact that MFC has a higher viscosity than TFC and Castrol blends, allowing it to provide better lubrication and protection. Additionally, MFC has a higher boiling point, which helps it to resist corrosion and oxidation better than TFC and Castrol blends. A cross flow analysis obtained fruitful results with selected blends; the Q value achieved was 22.14 with the specific heat load absorbed and the calculated heat transfer of the CHE with MFC coolant. This indicates that the CHE was efficiently cooled with the MFC coolant and that the Q value was significantly higher than the cross flow without the MFC coolant. This suggests that MFC coolant is an effective cooling agent for the CHE and could be used to improve the performance of other CHEs. To ensure proper validation, an experimental investigation of the same condition and Nano fluid should be conducted along with the numerical approach. This is because an experimental approach can provide direct measurements and data that can be used to compare with the numerical results. Additionally, the experimental data can provide a deeper understanding of the physical phenomena involved in the Nano fluid system, which can help refine the numerical model. It is also important to avoid generalizations about Nano fluids because expecting a specific behaviour can result in misunderstandings. This is because there are so many variables that can affect the behaviour of Nano fluids, such as the type of nanomaterials, the concentration and size of the particles, and the temperature. By conducting an experimental investigation, it is possible to gain a better understanding of the behaviour of Nano fluids and to make more accurate predictions.

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