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Experimental investigation of compact heat exchanger using with different blends

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Abstract:

This experimental investigation focuses on evaluating the thermal performance of a compact heat exchanger using various blends of GOETZE, MFC, and Castrol oils mixed with water. The study explores the effect of different oil blend concentrations on heat transfer at temperatures of 60°C and 80°C with varying mass flow rates. The nano-fluid mixtures are sonicated to achieve uniform nanoparticle dispersion, which enhances the thermal conductivity and improves overall heat transfer properties. The results show that 10% and 12% oil concentrations in the GOETZE, MFC, and Castrol blends provide the highest thermal efficiency. Furthermore, temperature gradients in the heat exchanger are validated through experimental analysis to ensure accurate representation of the heat transfer behavior. This research identifies the optimal oil blend concentrations that significantly enhance thermal performance and improve heat transfer efficiency.

Keywords: Compact heat exchanger, nano-fluid mixtures, thermal performance

1. Introduction

A heat exchanger is the equipment built to efficiently transfer heat from one medium to another without actually mixing the two. The two media may be separated one and another by a solid conducting structure to prevent mixing the two. It is widely used in appliances such as air conditioning, refrigeration, power plants, chemical plants, space heating, natural gas processing, petrochemical plants, petroleum refineries and sewage treatment. The ultimate example of a heat exchanger is found in an internal combustion engine in which a fluid known as engine coolant flows through radiator coils and air flows which past the coils cools the coolant and heats the incoming air. Heat exchangers are devices that facilitate the exchange of heat between two fluids that are at different temperatures while keeping them from mixing with each other.

Objectives:

1. To Evaluate the performance of a compact heat exchanger using different blends of GOETZE, MFC, and Castrol oils mixed with water.
2. To Examine the impact of varying oil blend concentrations on heat transfer at 60°C and 80°C, under different mass flow rates.

3. To Ensure uniform dispersion of nanoparticles in nano-fluid mixtures through sonication to enhance the thermal properties.
4. To Identify optimal blend concentrations for GOETZE, MFC, and Castrol oils that maximize heat transfer efficiency and thermal performance

2.Literature Review

The performance of compact heat exchangers has been extensively studied, particularly in the context of using different coolant blends and the incorporation of nano-particles to enhance thermal efficiency. Compact heat exchangers (CHEs) are critical in improving heat transfer performance while reducing size and weight, as noted by Kays and London (2016). The choice of coolant plays a pivotal role, with research by Saidur et al. (2018) highlighting the enhanced thermal conductivity of oil-water mixtures such as GOETZE, MFC, and Castrol oils. The addition of nano-particles, introduced by Choi (1995), further improves heat transfer by increasing the thermal conductivity of base fluids. Studies by Kherbeet et al. (2017) and Khan et al. (2021) showed that nano-fluids, especially when sonicated for uniform dispersion, lead to more consistent and efficient heat transfer, particularly under low-flow conditions. The influence of temperature and coolant concentrations on heat transfer has been explored by Mehdizadeh et al. (2017) and Yadav and Rajput (2019), with findings suggesting that 8-10% oil concentrations yield optimal thermal performance without excessively increasing pressure drop. However, pressure drop remains a critical factor in performance, with Alam et al. (2018) highlighting that higher oil concentrations can lead to increased viscosity and flow resistance. Experimental investigations have consistently identified the optimal blend concentrations typically between 8-12%—as those providing the best balance between thermal efficiency and manageable pressure drop, as seen in the work of Ali et al. (2020). Overall, the literature emphasizes the significance of selecting appropriate coolant blends, incorporating nano-particles, and ensuring uniform dispersion for achieving optimal heat transfer in compact heat exchangers.

3.Methodology

The work is divided into two distinct case studies: the first focuses on evaluating the performance of standard coolant blends, while the second explores the impact of adding nanoparticles to those blends. Both case studies are designed to provide a comprehensive understanding of the coolant blends' thermal behavior under various conditions. Each test is conducted under controlled temperature and pressure drop conditions, ensuring consistency across experiments. The duration of each test is set at 10 minutes, allowing sufficient time for the system to stabilize and for accurate data to be collected for further analysis.

Case Study 1:

The objective of this study is to evaluate the performance of coolant-water blends with 8% and 10% coolant concentrations. The blends are prepared by adding 8% and 10% of the selected coolants to water, ensuring uniform mixing. The testing is conducted under two temperature conditions: 60°C and 80°C, to assess the thermal performance under different operating temperatures. During the tests, both temperature transfer and pressure drops are measured, with a focus on identifying the stagnation point of heat transfer for each blend. Each test run is conducted for 600 seconds (10 minutes), providing sufficient time for the temperature transfer to stabilize before measurements are recorded. This approach ensures a comprehensive evaluation of the coolant blends' performance under varying conditions.

Case Study 2:

The objective of this case study is to examine the effect of adding 2% nanoparticles to each coolant-water blend used in Case Study 1. The coolant blends are prepared by initially adding 8% and 10% of coolant to water, followed by the addition of 2% nanoparticles to each blend, creating nano-fluid mixtures. These nano-fluid blends are then tested under the same temperature conditions (60°C and 80°C) and pressure drop conditions as in Case Study 1. The testing is conducted under two pressure drop conditions: no pressure drop and a 50% pressure drop on the coolant input side. Each test run lasts for 10 minutes, allowing sufficient time for the temperature transfer to stabilize before final measurements are taken.

Preparation of Nano Coolant Blends:

The preparation of nano coolant blends involves the careful dispersion of nanoparticles into base fluids to ensure proper mixing, stability, and improved thermal conductivity. The following procedure was followed for the preparation:

1. **Measure Nanoparticles**: Accurately measure the required amount of nanoparticles to achieve a 2% concentration by volume.
2. **Add Nanoparticles**: Add the nanoparticles to the MFC base fluid.
3. **Magnetic Stirring**: Use a magnetic stirrer for 20–30 minutes to ensure even dispersion of nanoparticles in the base fluid.
4. **Sonication**: Sonicate the mixture for 1–2 hours using an ultrasonic processor to break down any agglomerates and enhance nanoparticle dispersion.
5. **Visual Inspection**: Visually inspect or test the sample for sedimentation to ensure sufficient suspension stability.

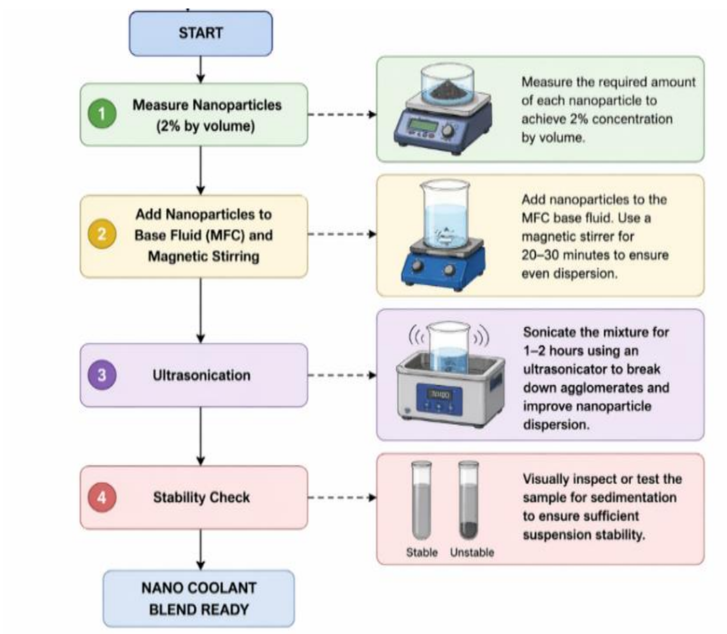

Figure 1: Preparation of Nano Coolant Blends

Figure 2: Experimental setup

Table 1: Blend properties of water blends with coolants

Parameter	GOETZE BLEND		MFC BLEND		CASTROL BLEND	
	10%	12%	10%	12%	10%	12%
Density (kg/m^3)	861	872	1028	1087	1040	1065
Boiling point (^{0}c)	138	148	135	145	112	123
Melting point (^{0}c)	84	84	80	80	104	104
Thermal conductivity (W/m^{0}c)	8.233	8.336	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

Table 2: Blend properties of water blends with coolants with 2% Nano addition

Parameter	GOETZE BLEND		MFC BLEND		CASTROL BLEND	
	10%	12%	10%	12%	10%	12%
Density (kg/m^3)	870	878	1040	1814	1040	1065
Boiling point (^{0}c)	120	121	135	145	112	123
Melting point (^{0}c)	70	70	70	70	104	104
Thermal conductivity (W/m^{0}c)	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

4. Results and discussions

GOETZE, MFC, and CASTROL coolants with optimized to at temperatures of 60^0 degrees Celsius and 80^0 degrees Celsius, respectively. Water is first heated to 60^0 degrees Celsius in a hot tank. The next step is to begin the T1, T2, T3, and T4 processes for each temperature, the flow is carried out in one of two ways: completely floe or half-sectional. After we start the process, we use X1, and when we finish, we use X2, which is the final flow reading. For a total of 10 minutes, the process is repeated with readings being obtained every minute.

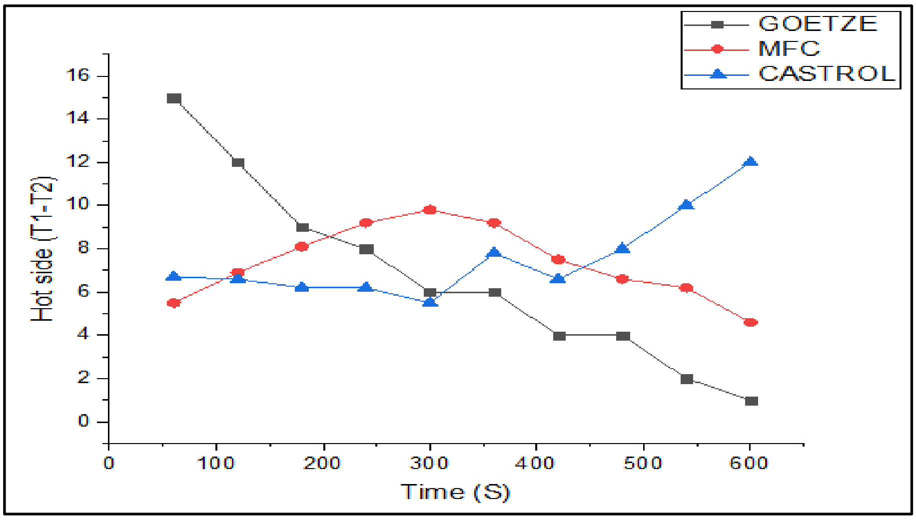

Figure 3: Water with a mixture of 10% Different coolant blends at 60^0c (complete flow) Hot side (T1-T2)

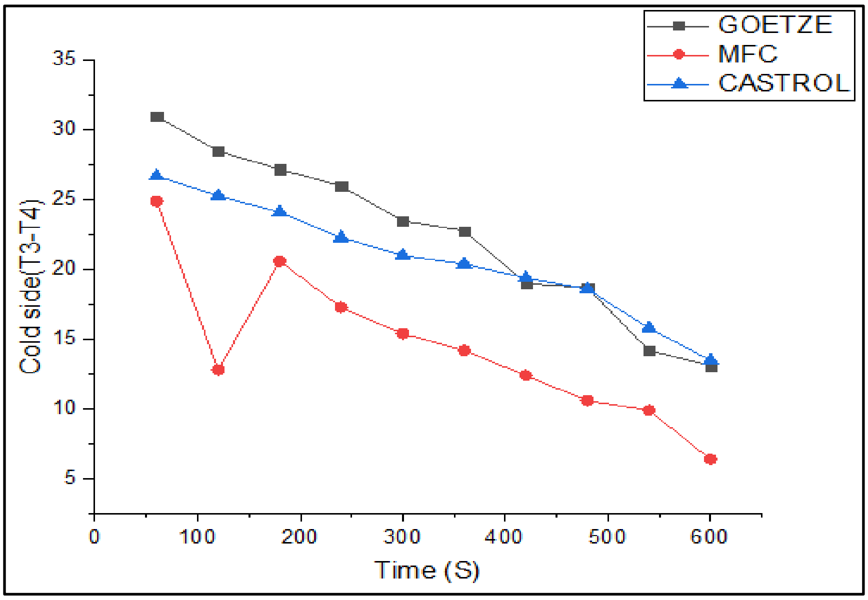

Figure 4: Water with a mixture of 10% Different coolant blends at 60^0c (complete flow) Hot side (T1-T2)

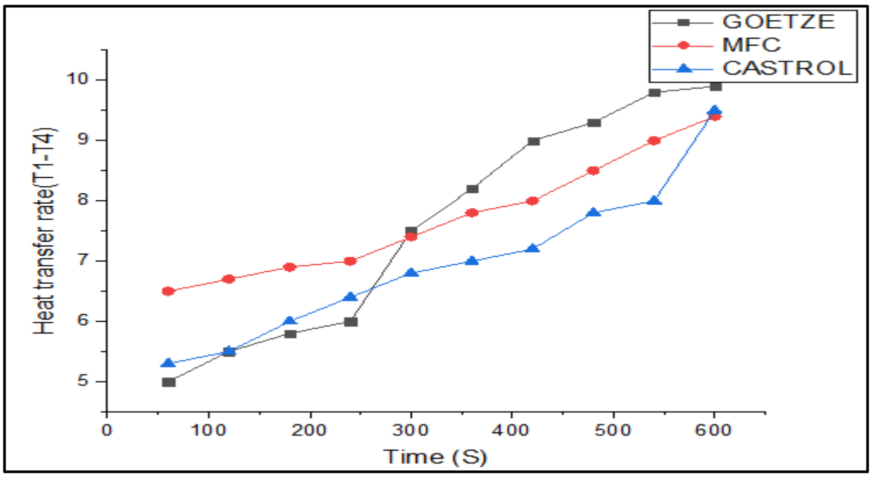

Figure 5: Water with a mixture of 10% Different coolant blends at 60^{0}c (complete flow) Heat transfer rate(T1-T4)

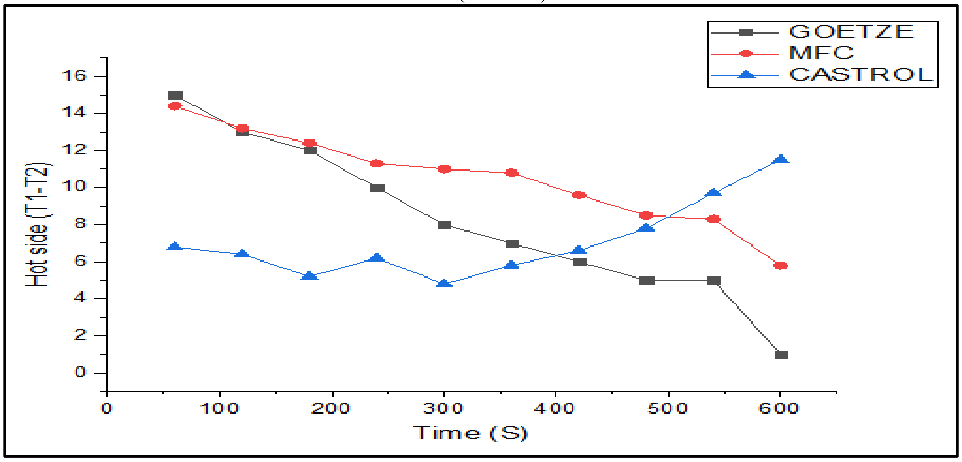

Figure 6: Water with a mixture of 10% Different coolant blends at 60^{0}c (Half flow) Hot side (T1-T2)

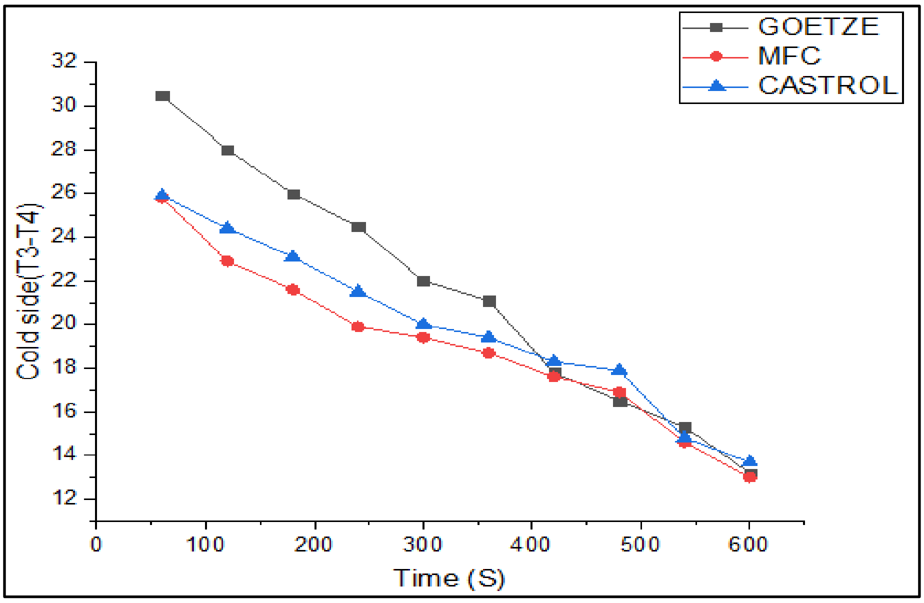

Figure 7: Water with a mixture of 10% Different coolant blends at 60^{0}c (Half flow) Cold side(T3-T4)

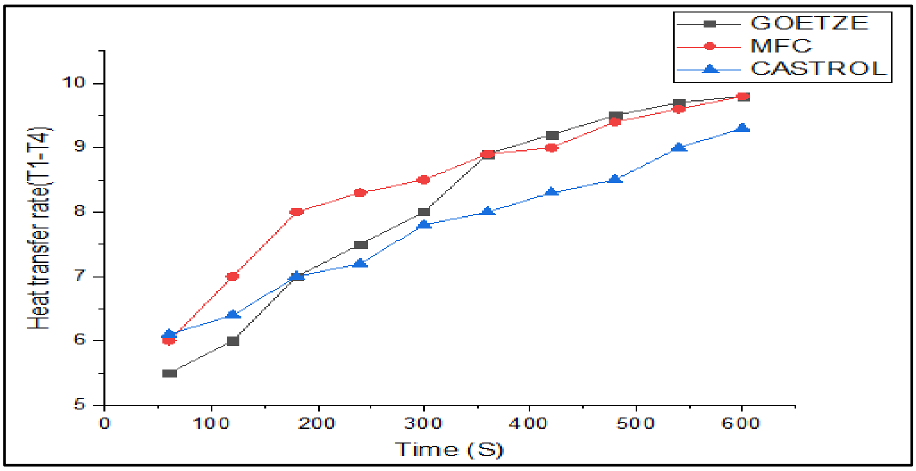

Figure 8: Water with a mixture of 10% Different coolant blends at 60^{0}c (Half flow) Heat transfer rate(T1-T4)

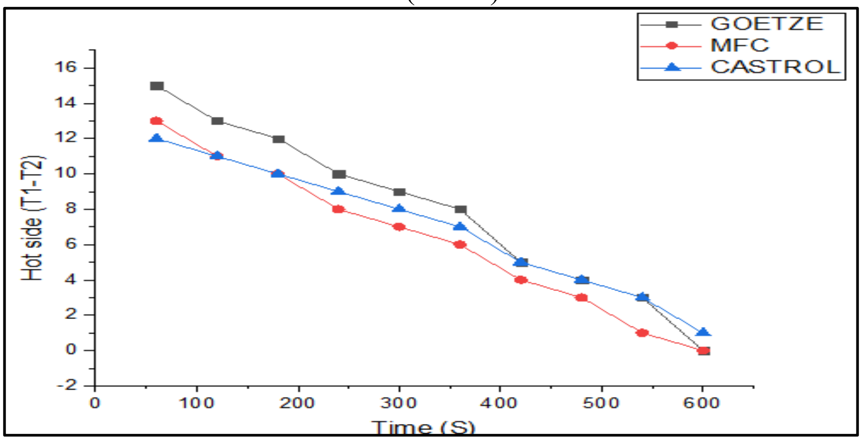

Figure 9: Water with a mixture of 10% Different coolant blend at 80^{0}c (complete flow) Hot side (T1-T2)

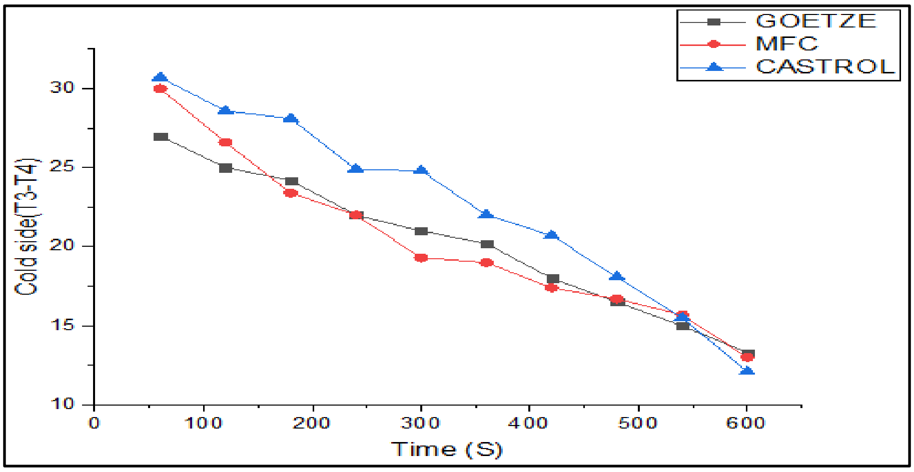

Figure 10: Water with a mixture of 10% Different coolant blend at 80^{0}c (complete flow) Cold side (T3-T4)

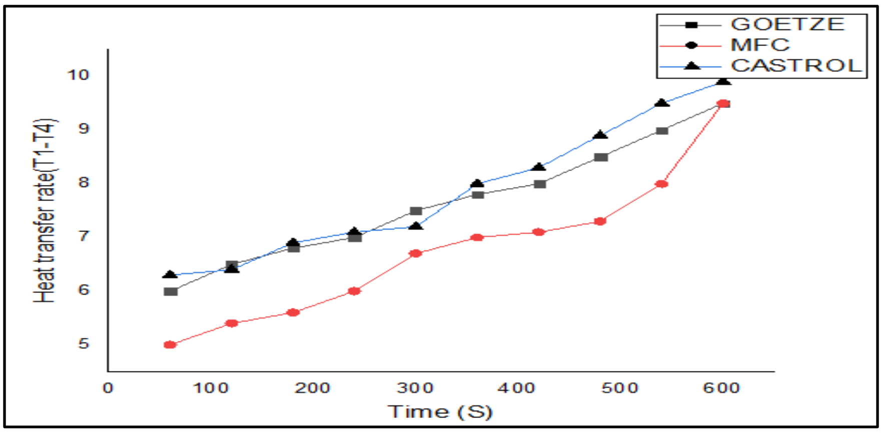

Figure 11: Water with a mixture of 10% Different coolant blend at 80^{0}c (complete flow) Heat transfer rate(T1-T4)

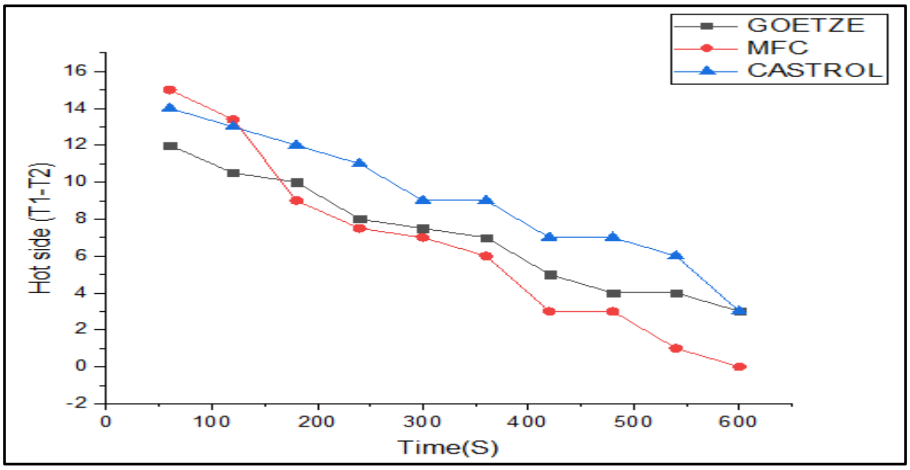

Figure 12: Water with a mixture of 10% different coolant blend at 80^{0}c (Half flow) Hot side (T1-T2)

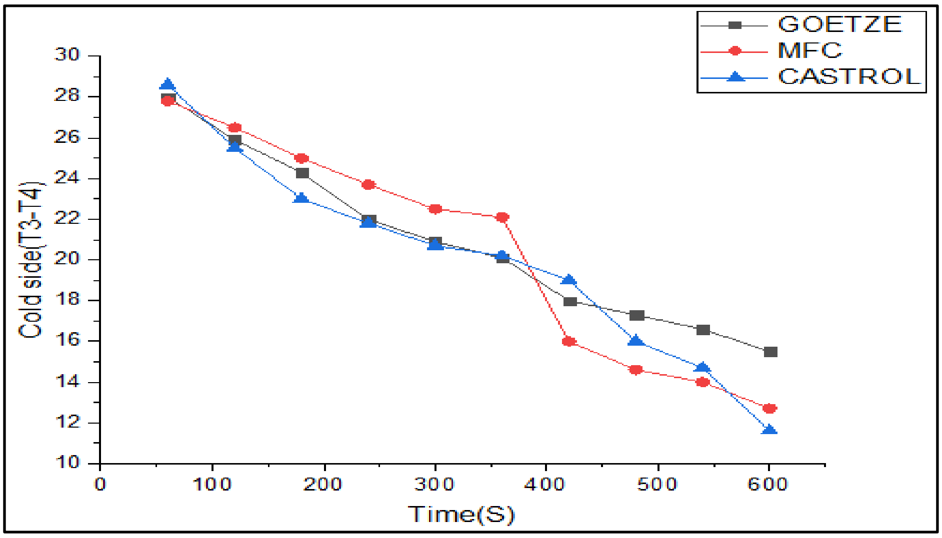

Figure 13: Water with a mixture of 10% different coolant blend at 80^{0}c (Half flow) Cold side(T3-T4)

Conclusions

In conclusions to Increasing the proportion of GOETZE in the blend improves heat transfer rate and overall heat transfer coefficient.

- The 12% MFC blend at 60°C showed the highest temperature variance, indicating superior thermal efficiency.
- GOETZE blends performed better in terms of temperature difference at both 60°C and 80°C.
- 10% and 12% GOETZE blends provided the best thermal performance at both 60°C and 80°C.
- GOETZE blends consistently showed higher temperature variance, indicating better heat transfer efficiency.
- The 12% GOETZE blend consistently demonstrated the best heat transfer rate, making it the most effective coolant for enhancing heat exchanger performance.

Future scope:

1. Further investigation can explore the impact of different nanoparticle types and concentrations on the heat transfer efficiency of compact heat exchangers.
2. Future studies could also examine long-term stability and performance of nano-fluid blends under varying operational conditions, including higher temperatures and pressures.

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