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Elementary Analysis Of Organic Fluids For Rankine Cycle Power Generation

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Abstract

The properties of the organic working fluids are estimated by using specific correlations, equations are programmed on the computer for different types of organic fluids. A systematic method is proposed for selection of optimal working fluid(s) considering the cycle operating conditions and thermo-physical properties. The importance of ORC system recommended for low boiling point temperature is used as working fluid. Dry fluids have highest thermal efficiency when compared to wet fluids like R227ea, RC318, R600, R114, R600a, R245fa, and R123 etc. The Second-law analysis is used for organic Rankine cycle (ORC) to convert waste energy to power from low-grade heat sources.

Key words: organic fluids, classification, thermodynamic properties working fluids.

1.0 Introduction

a good working fluid should exhibit low toxicity, good material compatibility and fluid stability limits [12], and low flammability, corrosion, and fouling characteristics. Refrigerants are good candidates for ORC applications because of their low-toxicity characteristics. A good working fluid should have low toxicity, good material compatibility and fluid stability limits and low flammability, corrosion, and fouling characteristics. Refrigerants are good candidates for ORC applications because of their low-toxicity character. Dry and isentropic fluids are better working fluid s for an ORC because they do not condensate after the fluid goes through the tur-bine **[1]**.

2.0 Classification of organic working fluids

Depending on the slope of the saturation vapour curve on a T-s curve working fluids can be classified in to Dry, Wet and isentropic fluids .

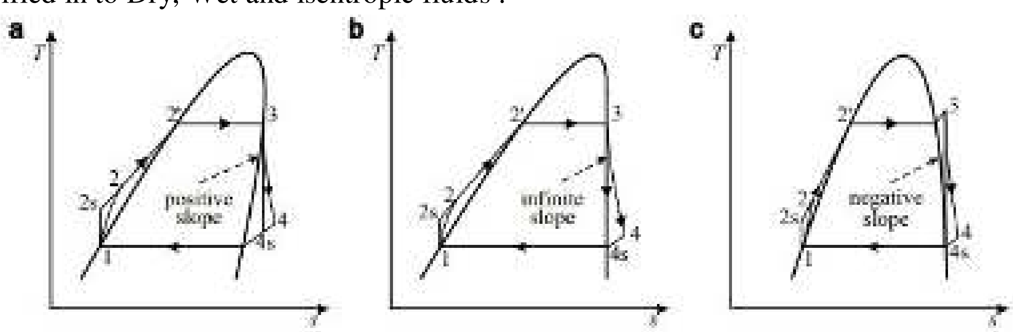

Figure 2. Temperature – entropy diagram of ORC: (a) dry fluid; (b) isentropic fluid; (c) wet fluid

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A working fluid can be classified as dry, isentropic, or wet fluid depending on the slope of the saturation vapour curve on a T-s diagram. Vapour saturation curve of wet fluid (e.g., water) has a negative slope, resulting in a two-phase mixture upon isentropic expansion. A dry fluid (e.g., n-pentane) has a positive slope, while an isentropic (e.g., R245fa) has an infinitely large slope, the fact that the vapour saturation line on a T-s diagram is vertical for these fluids.

- Dry fluids are high molecular mass organic fluids exhibiting positive slope on the T-s diagram.
- Wet fluids are low molecular mass organic fluids exhibiting negative slopes on the T-s diagram. Isentropic fluids are generally of medium molecular mass, exhibiting infinite or nearly vertical on the T-s diagram.

Wet fluids normally require superheating attributed the presence of hydrogen bond in the molecules of some organic working fluids like water, ammonia, and ethanol, as a probable cause of some fluids being wet as a result of larger vaporizing enthalpies which is considered inappropriate for ORC systems **[2]**. Many of the fluids suitable for use in ORC can have harmful effects on the environment or human health. Chlorofluorocarbons (CFC's) have good thermodynamic properties, are thermally stable, and non-toxic. Hydrocarbons such as pentane or toluene have good thermodynamic properties but are also toxic, and extremely flammable. For this study dry fluids have highest thermal efficiency compared with wet fluids and dry fluids like R123 with the values of 53.94 % and 49.7% and R600a with the values of 52.02% and 48.24% for the lowest and highest pump inlet temperatures, have the maximum and minimum amounts. For isentropic fluids, it is 54.85% and 50.35% for R141b and 49.78% and 46.31% for R134a. For wet fluids, R152a with the values of 50.28% and 46.66% has the highest value, and R143a has the lowest values with the values of 47.91% and 44.68% **[3].**

Table: Thermodynamic properties and its analysis of working fluids

Working fluid	**Fluid type**	**Molecular mass\ [gmol]**	**T[K]**	**P[MPa]**
R227ea	dry	170.03	375.8	3.00
RC318	dry	200.03	388.2	2.78
R600a	dry	58.12	407.7	3.63
R114	dry	170.92	418.7	3.26
R600	dry	58.12	427.0	3.80
R245fa	dry	134.05	456.7	3.65
R245ca	dry	134.05	477.4	3.93
R123	dry	152.93	456.7	3.66
R141b	Isentropic	116.95	477.4	4.21
R113	dry	187.38	487.1	3.39
R125	wet	102.02	339.1	3.62
R143a	wet	84.04	345.7	3.78
R32	wet	52.02	351.1	4.99

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R22	wet	89.47	389.1	4.99
R290	wet	44.10	369.7	4.25
R134a	wet	102.03	374.1	4.06
R12	wet	120.91	385.0	4.14
R152a	wet	66.05	386.3	4.52
R142b	wet	100.5	410.1	4.06

In this study the thermodynamic, environmental and safety aspects, rather than the economics of the system. working fluid for used in ORC cycles is a crucial point, because depending on the application, the source and the heat level to use, the fluid must have optimal thermodynamic properties at lowest temperatures and pressures and also satisfy several criteria such as being economical, nontoxic, non-flammable, environmentally friendly, allow a high utilization of the available energy from the heat source.

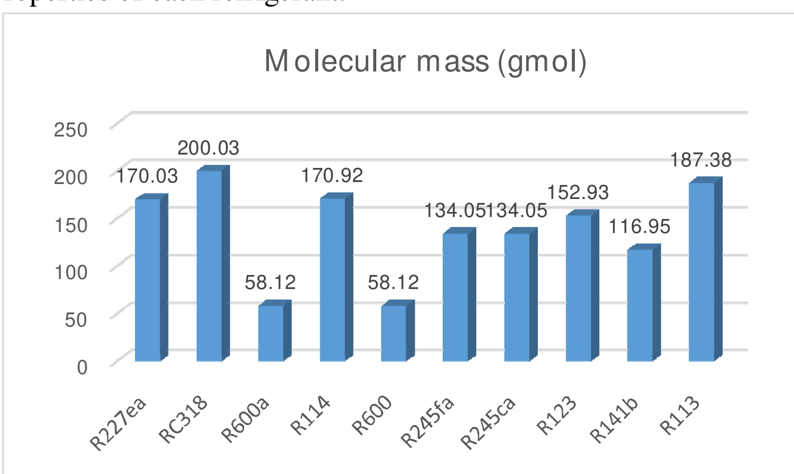
ORC's can be operated on low temperature heat sources with low to moderate evaporation pressure, and still achieve a better performance than a steam cycle. It require bigger feed pumps, because of a higher mass flow, which has a higher impact on the net electric power.

(i) Saturated liquid density.
(ii) Saturation pressure (i.e. the vapour pressure when in contact with its own liquid).
(iii) Pressure-specific volume-temperature behaviour of the vapour.
(iv) Constant volume specific heat of the refrigerant's ideal gas i.e. that of the refrigerant vapour as p →0 **[3].**

3.0 Methodology & Results:

Assessment of the thermodynamic properties

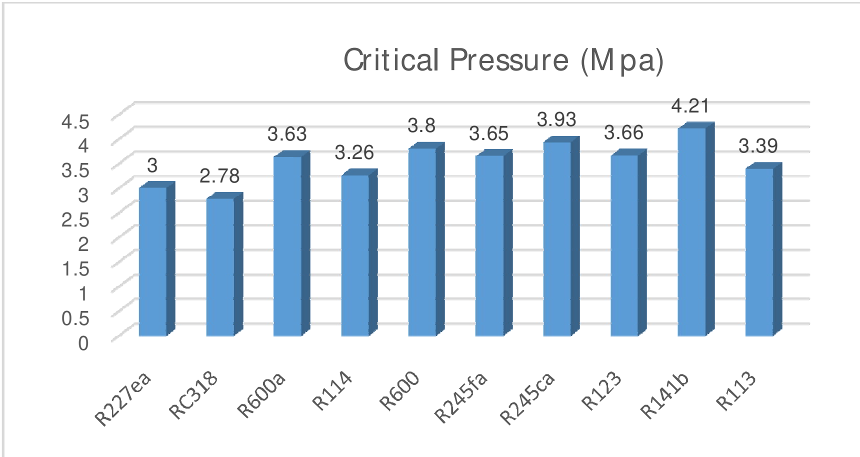
Specific correlations and equations have been selected, or developed, for refrigerants R-I1, R-12, R-13, R-14, R-21, R-22, R-23, R-I13, R-I14, R-115, R-500, R-502 and R-C318. General computer sub-routines have been composed for the VAX 11/780 digital computer, in order to evaluate the properties of each refrigerant.



Dry fluids →

Graph: Dry fluids Vs Molecular mass

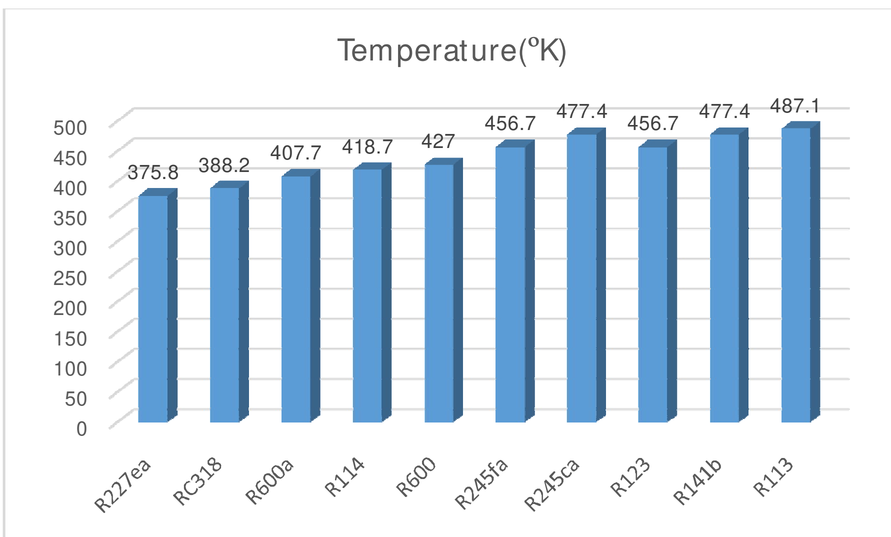
. The reason is the lower temperature at the turbine inlet temperature. However, the maximum amount is for R141b, which is an isentropic one. For the Studied dry fluids, R123 with the values of 53.94 % and 49.7% and R600a with the values of 52.02% and 48.24% for the lowest and highest pump inlet temperatures, have the maximum and minimum amounts



Dry fluids →

Graph: Dry fluids Vs Pressure

In this graph the pressure of the R141b is increased by 4.21 when compared to other working fluids .Increasing evaporator pressure leads to the decrease in the mass flow rate of the ORC and the evaporator heat as well as the increase in inlet enthalpy of the ORC turbine.



Dry fluids →

Graph: Dry fluids Vs temperature

The dry fluids R600a, R245ca, R141b and, R113, showed a decrease of efficiency with the increase in inlet temperature to the turbine.R141b is the isentropic.

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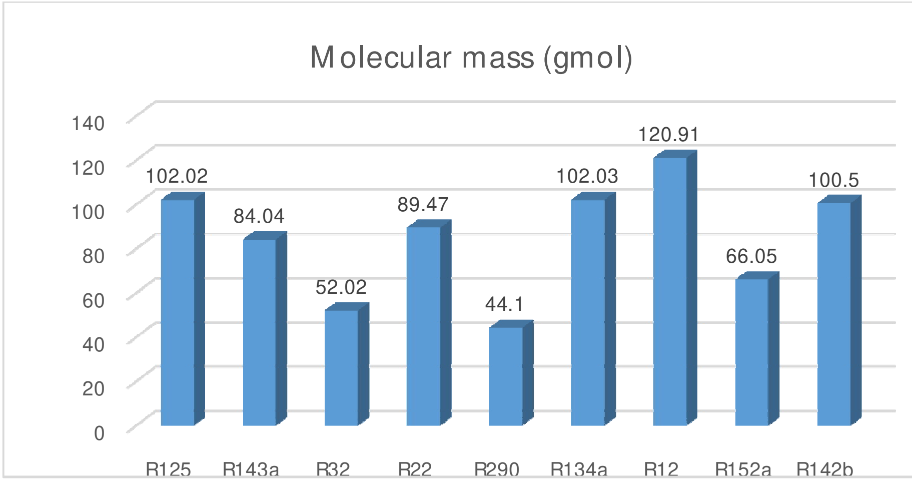
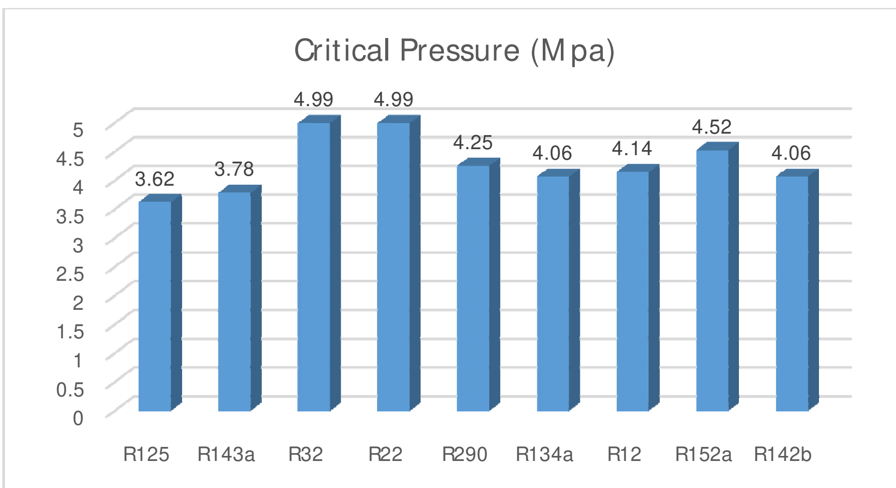


Wet fluids

Graph: Wet fluid Vs Molecular mass

Working fluids with low molecular weight (90 kg/Mol) are suitable for low power output plants using single-stage turbines. The flow rate of working fluid depending on molecular mass.



Wet fluids

Graph: Wet fluid Vs pressure

R32, R22 are have high operating pressure at inlet of turbine for better performance temperature and Wet fluids have the lowest thermal efficiencies.

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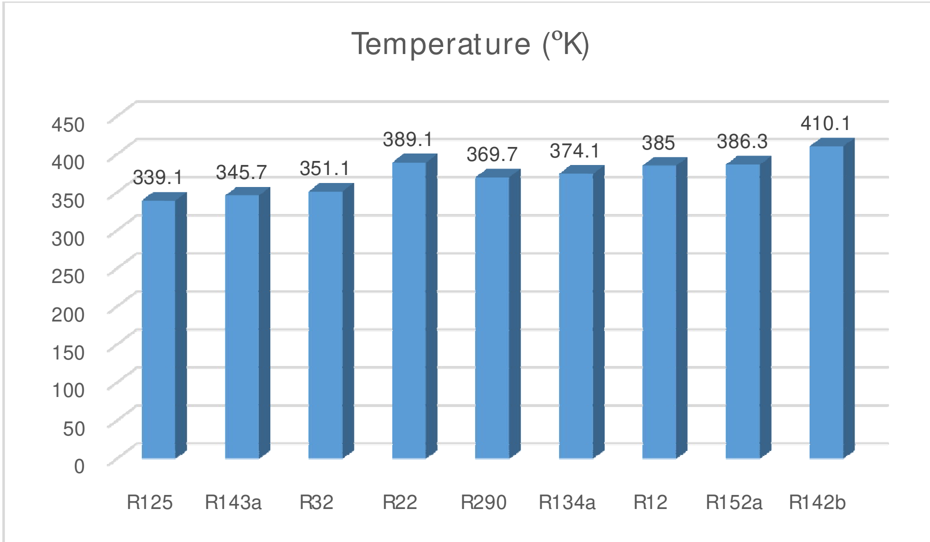

Wet fluids →

Graph: Wet Fluid Vs Temperature

In wet fluids the thermal efficiency is very low when compared with other working fluids because of the lower critical temperature at inlet of the turbine.

From all graphs the results shows that dry fluids have the highest values of thermal efficiency compared with other fluids, and the wet fluids have the lowest amounts because of the lower temperature at the inlet of the turbine. However, the thermal efficiency for R141b is maximum which an isentropic one is. The results show that R123, R141b and R152a have the maximum amounts of thermal efficiencies in dry, isentropic and wet working fluids.

- At the optimum point, R141b in isentropic fluids, R123 in dry fluids andR717 in wet fluids have the highest thermal efficiency values.
- Increase in evaporator pressure, first increases the thermal efficiency and then reduces it and causes an optimum pressure in which thermal efficiency is maximum.

4.0 Conclusion:

The thermophysical properties, environmental impact, safety and stability as well as its availability and cost, play a critical role in the selection of the working fluid in these cycles. According to research carried out in this work, it can be concluded that using organic working fluids in Rankine cycles, relatively good efficiencies are obtained recovering and/or using heats of low/medium temperature to convert them into electricity.to evaluate the thermal properties of fluids halocarbon compounds R-11, R-113 and R-114, are the most suitable organic working fluids for the majority of operational Rankine-cycle engines utilising low grade heat sources. The net power of R125 increases basically with the evaporation temperature from 298 K to 338 K.

5.0 Future scope

Due to peculiar thermodynamic behaviours at low temperatures, organic fluids--as the working media in Rankine-cycle with superior characteristics to make them suitable for extracting mechanical work from low-grade heat sources. Commonly used refrigerants--halogenated hydrocarbons R-11, R-113 and R-114--are the most attractive organic working fluids and they are available for different applications.

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References

1. P J Mago, L M Chamra, C Somayaji et.al, (2007), “Performance analysis of different working fluids for use in organic Rankine cycles”, Journal of Power and Energy, ISSN: 0957-6509, (e) ISSN: 2041-2967, Vol No: 221 Issue No: 3, PP: 255-263.
2. Babatunde, A. Fakeye, ein t .al (2019), “A Review of Working Fluids for Organic Rankine Cycle (ORC) Applications”, IOP Conference Series: Materials Science and Engineering, ISSN: 1757, Issue: 413. , Vol No: 1, PP: 1-12.
3. Amin Habibzadeh, Mohammad Mehdi Rashidi, et.al,(2016), “Thermodynamic Analysis Of Different Working Fluids Used In Organic Rankine Cycle For Recovering Waste Heat From GT-MHR”, Journal of Engineering Science and Technology, ISSN: 1823-4690, Vol No: 11 , Issue No: 1 ,PP: 121 – 135.
4. O. Badr, P. W. O'Callaghan and S. D, Probert et.al (1985), “Thermodynamic and Thermophysical Properties of Organic Working Fluids for Rankine-cycle Engines”, Applied Energy, ISSN: 0306-2619, Vol No: 19, Issue No: 1, PP: 1-40.