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Evaluation of ThermophysicalPropertiesof aMixedRefrigerantby Varying the Volumetric CompositionsforIndustrial RefrigerationApplications

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Abstract

Duringthepast fewdecades,theconcept ofrefrigerantmixturefluidsisattracting moreres applicationfor coolingequipment's.Theconcept ofmixedrefrigerantha whilecomparedto thebasefluids.Itismainlyusedinindustrialaswellasdomesticrefrigerants,airconditionings andmanymore.Inthepresentstudy, tostudythethermophysicalpropertiessuchasdens analyzevariouspropertiesbyconsidering 10gms ofrefrigerantmixturesuch aspropanean compositions.Resultsare presentedforsimulations carriedoutatdifferentmassratioc respectto atemperaturerangeof300-350K andit isevaluatedthatvariationeffectc compositions ofarefrigerantmixture.Itisconcluded fromtheresultsthatasthetemperat mixedrefrigerantincreases.Similarly, viscosityincreaseswithanincreasein temperaturef different compositions. Moreover,asthepressureincreases from3N densityandviscosityincreased by 4.15%and 12.63%respectivelywhiletemperaturewask

Keywords:

Refrigerationmixture,
Coolants,
Heatexchangers;
Density;
Viscosity

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1. Introduction

Inpresentscenario, cooled fluidhavebecomepopularin both industrial andcommercialfields astoconventional applicationstopreservethefresh food.Toincreasetheenergyefficiencyvarious methodshavebeenadoptedfor freezers. Theconcept of refrigerationisderivedfromthe Latinwordre-and frigus,whichmeans'tocooldown'. Accordingthetechnologywhichremovestheheatfromthesurroundingwithsupplyofsomeliquidasfor

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theearly reportsin1756byWilliamCullenwasconductedanexperimentforthefirsttimeinhisuniversity [1]–[3]. Lateritwas developedbytheMichaelFaradayin1820byusingliquefiedammoniaandothergasesby usinghighpressureand low temperatures[1]–[3].Laterin1834JacobPerkinswhoclaimedpatentfortheVaporCompressionRefrigerationSystem [1]–[3].Researcheshaddevelopeditsthermophysicalproperties suchasspecificheat,density,thermalconductivity andspecificheat.Henceitisevidentfromtheopenliteraturesurvey,amixedrefrigerantsuchasPropane /ISO-butane (R290/R600a)attracts muchattentioninFreezercycle [4].Ingeneral,combinationofbothcarbonandhydrogenare known as hydrocarbonsuchas PropaneandISO-butanearehydrocarbonrefrigerantsareused toavoid Chlorofluorocarbons(CFCs)intheprocessofozonedepletionisacceptedwidely intheuniverse[5].Theusageofboth combinedHydrocarbons(HCs)suchaspropaneandISO-butanecombinationwhichshows majoradvantagessuchas highmiscibilitywith mineralorsyntheticoil,non-toxicity,etc.[6].Around180 yearsofrefrigeranthistorymaybe around50substanceshadmoreorlesswidelyusedfortheresearch.Duetosustainablereasonswithvary ingconditionsofapplications for the futuretrends andapplicationsafewnumberofnatural substance suchasammonia(NH_3), hydrocarbons(HCs) andcarbondioxide(CO_2),helium(He),hydrogen (H_2),water (H_2O)areused for theindustrial applicationsandmostoftheirediscardedduetovariousreasons[7].Inarefrigerantmixturepropanean dISO-butane (R290andR600a)zoetropemoreinsidethetubessupplyof lessliquid volatilecomponentthesaturationtemperature is decreased duetothereason pressureis compensated [8]. Mixed refrigerantsare highlyprecious duetoit'sa combination oftwodifferentrefrigerantsatdifferentcompositionsthermophysicalcomposedclassified purerefrigerantsandrefrigerants mixtureblends whicharefurtherareclassified based upon the propertyoffluids[9]Incomposedclassified purerefrigerantsandrefrigerants mixtureblends whicharefurtherareclassified based upon the propertyoffluids[9]Inthepresentwork,duetoaresearchgaphasanalyzedthatmanyresearchers conducted differentexperimentalresultsand simulation analysistocalculatethermophysicalpropertiessuch asspecificheat, viscosity, density andthermal conductivity.Inpresent context,a refrigerantmixturesuchas zoetropemixture combinationboth hydrocarbons (HCs)propane(R290)andISO-butane (R600a)arechosenforthe analysis atpressure of3MPatoapressureof7MPaandthetemperatureisvaryingfrom300-350Kin aVapourcompressionrefrigeration system(VCRS)andpropertiesofrefrigerantmixtureforthepresentworkisavailablefromresearchMet hodology(see Table 1). Themolecular weightof refrigerant mixtureistakenas 10gmsandrefrigerant mixtureis inthe massratio of10%-90%,20-80%, 30-70%,40-60%areconsidereddensityand viscosity varyingwithrespect totemperatureas plotted. Figure1representsschematicdiagramforanindustrialrefrigerationsystem.It mainlyconsists of four major componentssuch ascompressor,condenser,expansion valveandevaporator.Inthecompressorthevaporfromlow pressuregasadiabaticallycompressedtohighpressuregasthisisprocessisalsoknownas'Win'process [10]–[12]. Condenseristheprocesswhichcondensestheliquidfromhighpressuregas tohighpressureliquidin thisprocess the phasechangetakesplace andheatislossesoutsidethesystem(Q_{out})itisalsoreferstothelatentheatofvaporization [13]–[15].Expansion valveistheprocesswherenarrowpassage ofliquidfromhighpressuregasisconvertedto pressureliquidandvapor willbereleased.Intheexpansionvalve,neitherheatnorworkadded orrejectedfromthe systeminthisprocessisenthalpicprocesstakes(h_1=h_2)whichdealswiththepropertyofthesystem[13]–[15].Thefinal stageofthevaporcompression refrigerationsystemis(VCRS)evaporatorinwhichlowpressureliquidandvaporgasis convertedtolowpressure gaswheretheheatisaddedtothesystem(Q_{in}). Intheevaporatoraphasechangeprocess occurssimilartocondenseritis alsolatentheatofvaporization[11], [13], [15].

2. Materials andMethods

Yanetal[4]investigatedwithzeotropicrefrigerantmixturesuchasR290andR600afordomesticfreezerinaninternal autocascaderefrigeration cycle(IARC)performanceoftheseIARCa mathematical modelisusedtodevelopthe performance.Theresults arediscussedaboutthe pressureratioof compressor, COPperformance volumetric compressor.Richardson etal[5]investigatedtheperformanceofhydrogenandcarboninavaporcompression refrigerationsystemresultsarecalculatepropaneandISO-butanecanbeused forthebetterpurposeundersome operatingconditions.Yanetal[6]studyreportsusingzoetrope mixturesuchasR290andR600aforthemodified ejectorexpansioncycleinthisconventional ejectorexpansioncycleandthrottlingcycleiscarriedout.Resultsare presented that refrigeranteffectof COP, volumetricefficiencyetc.Lorentzen[7]naturalsubstancessuchasammonia (NH_3),propane(R290)andcarbondioxide(CO_2)areusedasconventionalfluidsthesefluidspresentshalocarbonsisan importantfactor.Theidealrefrigerationorheat pumpcycleforagivenpurposeisdefinedbytheboundaryconditions oftheapplicationandiscompletelyindependentoftherefrigerantsareusedtoenhancethethermodynamicandheat transfer properties.Mohanrajetal[8]performedanexperimentalwork,withsingleevaporatordomesticrefrigerator usinghydrocarbonsmixturewhich meana mixedrefrigerantof propane(R290)andISO-butane(R600a)itpresents that hydrocarbonshavelowerconsumptionofenergy. However, itleadstohighervalueofcoefficientofperformance (COP).Ardhapukaretal[9]inthepresentinvestigationtocalculatetheoverallheattransfercoefficients alongwiththe lengthofheatexchangers forvariousmixtureshasbeendeterminedfortheseexperimentaldataandempiricalco-relationshavebeendetermined. Dalkilicetal [16]inthisstudyexperimentalresults ofpressuredropcondensation wasdetermined bychoosingtwo refrigerantssuchas R600a1mlonghorizontalandsmoothwithinnerdiameter4mmadouterdia6mmandR134inavertical 0.5mmsmoothcoppertubewithinnerdiameter 8.1mmandouterand 9.52 mm.

3. Results and Discussion

3.1.Pressureeffectondensitywithrespecttotemperatureofa refrigerantmixtureatdifferentcompositions.

Inthepresentresults,fromFigure1toFigure4showninbelowthatthe effectofvariationinpressureatdifferentcomposition varies10%-90%,20%-80%,30%-70%,and40%-60% asdiscussedearlierdensityofrefrigerant mixturerefrigerant increases with anincreaseintemperature.

Figure1revealsthatdensity asafunctionoftemperatureatacompositionof10%-90%ofamixedrefrigerantR290 andR600a. Moreover,astheincreaseintemperaturedensityofa mixedrefrigerantisalsoincreases.

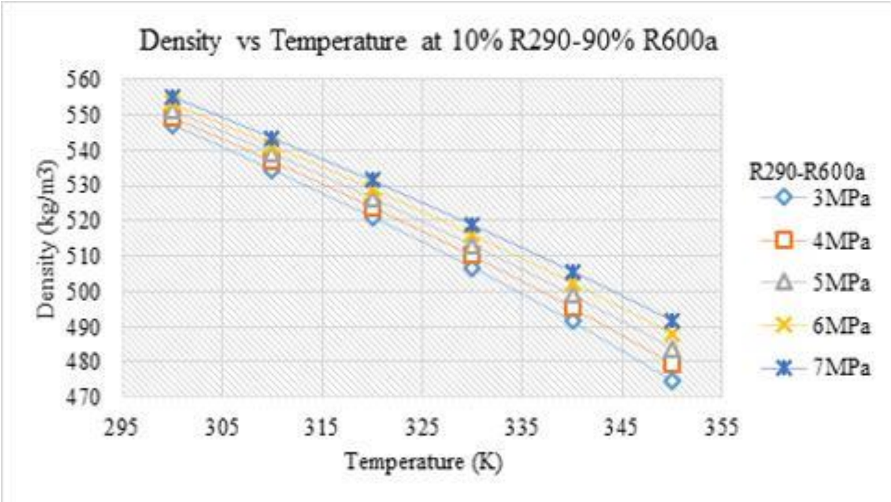

Figure1.Density vstemperatureat different compositions

Figure2representsthatdensityasafunctionoftemperatureatacompositionof20%-80%ofamixedrefrigerantR290andR600a.Moreover,astheincreaseintemperaturedensityofa mixedrefrigeransisalsoincreases.

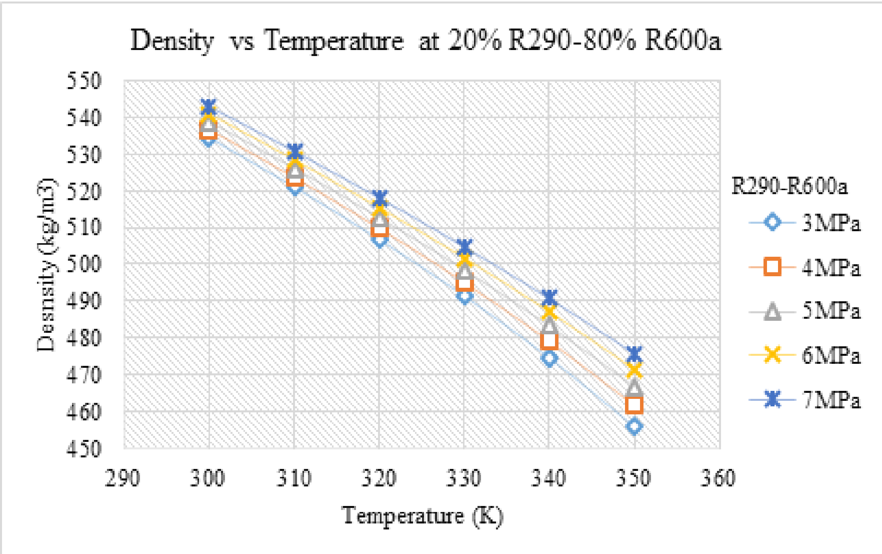

Figure2. Density vstemperatureat different compositions

Figure3showsthevariationofdensitywithrespecttotemperature atacompositionof30%-70%ofamixedrefrigerantR290 andR600a.Moreover,astheincreaseintemperature,densityofa mixedrefrigerantisalsoincreases.

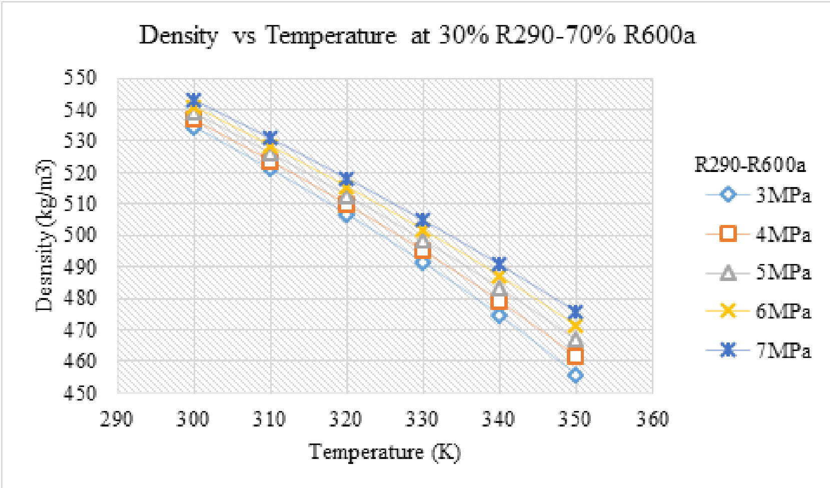

Figure3. Density vstemperatureat different compositions

Figure4showsthevariationofdensitywithrespecttotemperatureatacomposition of40%-60%ofamixedrefrigerantR290 andR600a.Moreover,astheincreaseintemperature,densityofa mixedrefrigerantisalsoincreases.

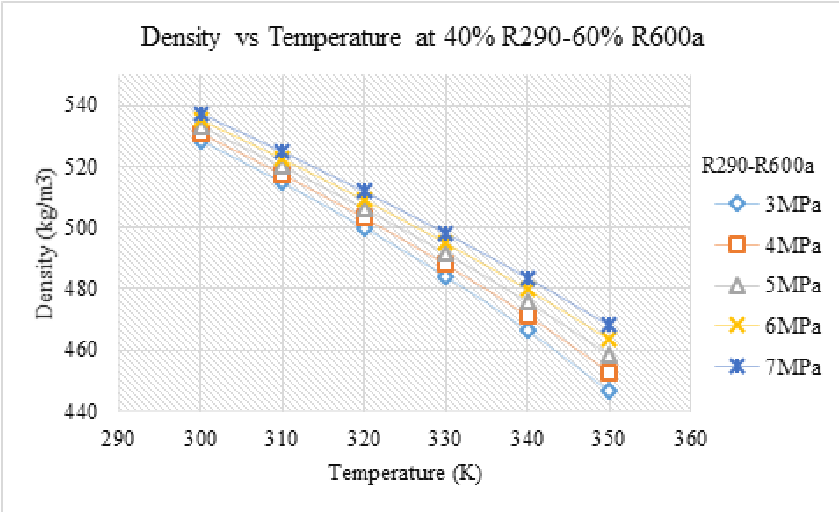

Figure 1.Density vstemperatureat different compositions

3.2.Effectofpressureonviscositywithrespecttotemperatureofa refrigerantmixtureatdifferentcompositions

InthisresultsfromFigure5toFigure8 showninbelowthattheeffectofvariationinpressureatdifferentcompositionvaries10%-90%,20%-80%,30%-70%,and 40%-60%asdiscussedearlierviscosityofrefrigerantmixturerefrigerantincreaseswithanincrease intemperature.

Figure 5 showsthevariationof viscositywith respecttotemperatureatacompositionof10%-90%of amixedrefrigerantR290 andR600a.Moreover,astheincreaseintemperaturedensityofa mixedrefrigerantisalsoincreases.

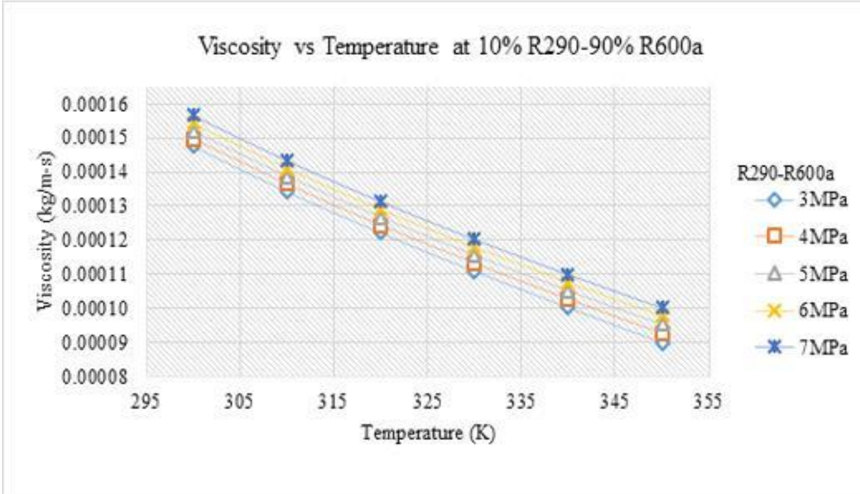

Figure 2.Viscosityvstemperatureat different compositions

Figure6representsthatviscosityasafunctionoftemperatureatacompositionof20%-80%ofamixedrefrigerantR290andR600a.Moreover,astheincreaseintemperaturedensityofa mixedrefrigerantisalsoincreases.

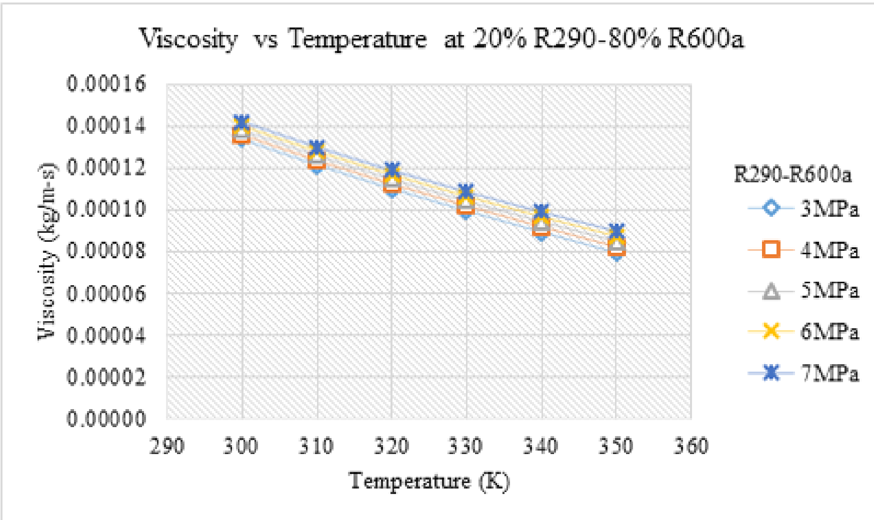

Figure6 viscosity vstemperatureat different compositions

Figure7showsthe variationviscosityof with respecttotemperatureatacompositionof 30%-70%of amixedrefrigerantR290 andR600a.Moreover,astheincreaseintemperaturedensityofa mixedrefrigerantisalsoincreases.

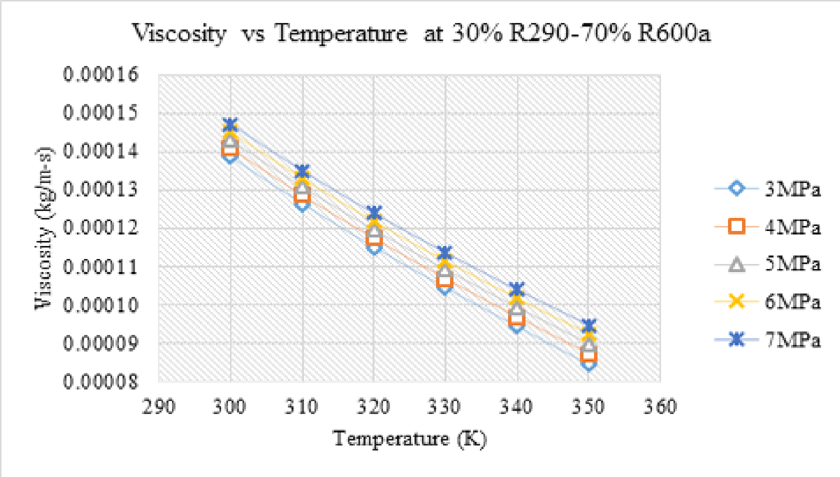

Figure7. viscosity vstemperatureat different compositions

Figure8representsthatviscosityasafunctionoftemperatureatacompositionof20%-80%ofamixedrefrigerantR290and R600a.Moreover,astheincreaseintemperaturedensityofa mixedrefrigerantisalsoincreases.

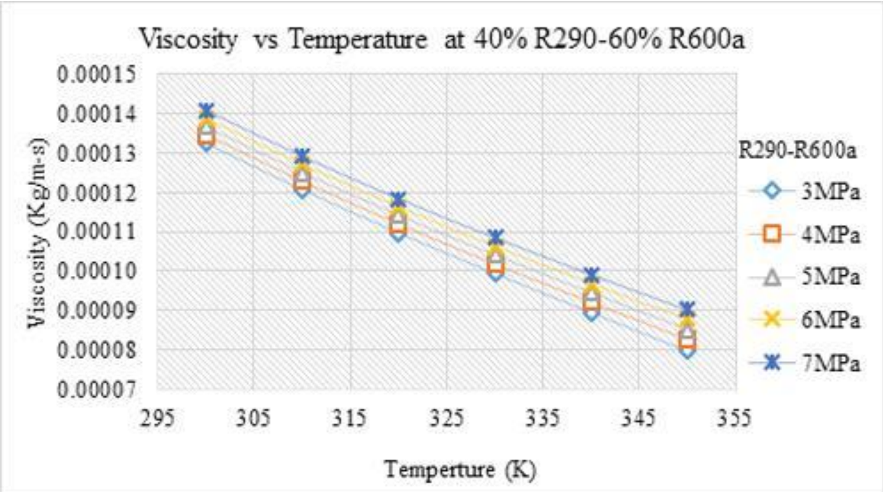

Figure8. viscosity vstemperatureat different compositions

4. Conclusion

Inthepresentresearchwork,investigationonpressureeffectatdifferentmixturerefrigerantsatdifferentcompositioniscarried. Itwasconcludedthatasthatastheincreaseindensityandviscosityareincreaseswithincreaseintemperatureof(300-350K). ThoughR-290(Propane)andR-600a(ISO-butane) arehighlyflammablegases,zeroozonedepletionpotentialandlessglobal warmingpotential.Itwasalsonoted that7MPabothdensityandviscosityincreasedby4.15%and12.63%respectivelywhiletemperature waskept constant at 350K.

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