International Journal of Research and Innovation in Engineering Technology
Volume: 01 Issue: 09

ISSN: 2394 – 4854
Pages:10 – 17

IJRIET

ANALYSIS OF MIXTURES OF REFRIGERANT FOR VAPOUR COMPRESSION REFRIGERATION CYCLE USING MATLAB-SIMLINK

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Abstract

The goal of this work is to predict the performance of the compression cycle of different refrigerants. In compression refrigeration system, the refrigerant such as R22, R290 & R407C are considered as a refrigerant by mixing of these at a different mass fraction as 40%+30%+30%, 30%+40%+30%, 30%+30%+40%, 40%+20%+40%, 40%+40%+20% and 20%+40%+40% respectively. Experimental conditions for the condensing temperature were selected as 40,45&50 °C and evaporating temperature were selected 1,5 & 10°C. Various performance measures like COP, Volumetric Efficiency, Mass Flow Rate, Isentropic Compressor Work, Refrigeration Capacity, Compressor power, Compressor Outlet Temperature, Pressure Ratio & Overall Performance Index uses a several refrigerant mixture with the help of MATLAB-SIMLINK tool. Among these pure refrigerants and mixture of refrigerants group, R290 and 40%+40%+20% has a better COP

***Keywords**:* Refrigerants, COP, Volumetric Efficiency, Compressor power, MATLAB-SIMLINK

1. INTRODUCTION

Commercial chlorofluorocarbons (CFCs) are recognized for their severe harmful effects on the environment when they are released to the atmosphere. Specific concerns about their use of air conditioning and refrigeration equipment are related to their potential contribution to global warming and their depletion effect on the stratospheric ozone layer due to their chlorine chemical effect. Due to the fact that CFCs damage the ozone layer, environmental groups and the Montréal protocol call for halting CFC production.This alternative refrigerants must be found to replace the CFC Such alternative refrigerants should possess good thermodynamically and physical properties, comparable cost, low toxicity and low in flammability hydrocarbon offer acceptable refrigerants to the CFCs, since they possess good thermodynamically properties and they are universally available at low price. The absence of chlorine atoms from hydrocarbons results in zero ozone layer depletion potential is very low for

 ISSN: 2394 – 4854
Pages:10 – 17

hydrocarbons, owing to their higher latent heat of hydrocarbons compared with that of R-22.

2. NEED OF ALTERNATIVE REFRIGERANTS

CFC (chlorofluorocarbon) and HCFC (hydro chlorofluorocarbon) refrigerants as refrigerants in a vapor compression refrigeration system are known to be the principal cause of ozone depletion and production, global warming, and use of these refrigerants has hence been restricted [1]. As a result, a search for alternative refrigerants that fit the requirements in an air-conditioner or a heat pump has been underway. Refrigerant mixtures which are composed of HFC (hydro fluorocarbon) refrigerants having zero ODP (ozone depletion potential) are now being suggested as drop-in or midterm replacement. An air-conditioning system based on these new alternative refrigerants must be modified or redesigned because thermo physical properties of these alternative refrigerants differ from those of conventional refrigerants. In order to maintain or improve the performance of the cycle, the operating characteristics of individual components of the cycle should be redefined with these new alternative refrigerants. It has been reported that R407C is a close match to R22 with respect to energy efficiency.

3. MATHEMATICAL MODELING

The thermodynamic properties of the cyclic states can be determined from the equation of states of refrigerant. In calculating the values written with MATLAB-SIMLINK, the NIST routines were used to calculate these properties, which is an industry standard currently. When the property of each point is calculated, the equations for the cycle performance can be found based on the mass energy conservation.

MATLAB (matrix laboratory) is a numerical computing environment and fourth generation programming language. Developed in Maths Works, MATLAB allows Matrix manipulations, plotting of function and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java and Frotran. Although MATLAB is intended primarily for numerical computing, on optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing capabilities. An additional package, SIMLINK, adds graphical multi-domain simulation and Model-Based Design for dynamic and embedded systems.Simulink is a block library tool for modeling, simulating and analyzing dynamic systems with MATLAB Simulink is a graphical, "drag and drop" environment for building simple and complex signal and system dynamic simulations. It allows users to concentrate on the structure of the problem, rather than having to worry (too much) about a programming language.

The parameters of each signal and system block is configured by the user (right click on the block) Signals and systems are simulated over a particular time.

4. SIMLINK MODEL

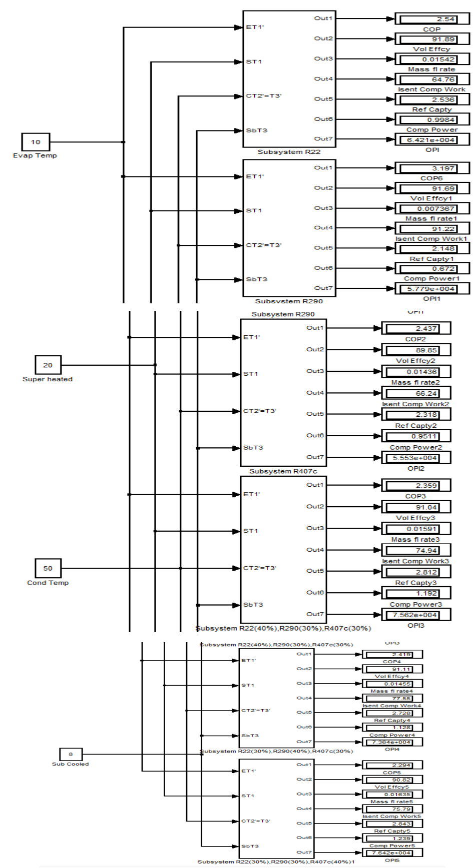


Figure: 1 Simlink Model of Various Refrigerants for Various Conditions

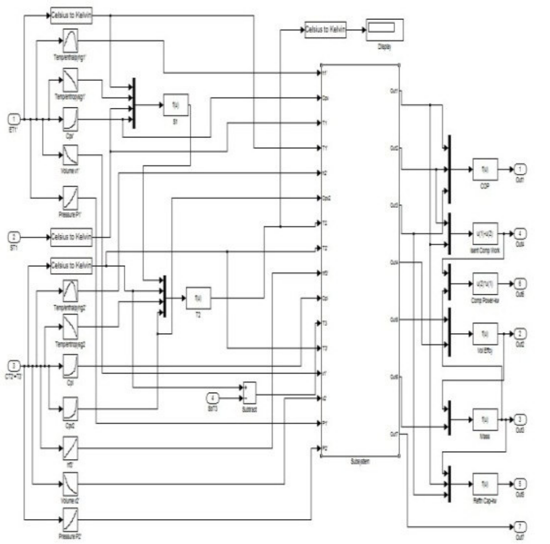


Figure: 2 Simlink Model of Subsystem 01

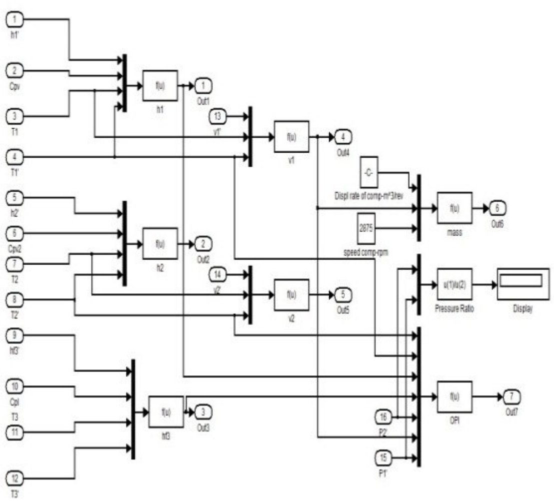


Figure: 3 Simlink Model of Subsystem 02

5. RESULTS AND DISCUSSIONS

Among the six mixtures ,two mixtures having good performance compare with other combination were selected based on thermodynamic cycle simulation evaluation as HCFC-22 alternates. The result compared with unmixed refrigerants R22,R290 and R407C and the six mixtures.It is inferred that R290 is the best performances refrigerants. But R290 is highly flammable .Therefore, it is suggested to use the mixture of refrigerant particularly R22-40%/R290-40%/R407C-20% in the place of practical applications. The simulation results are shown in the table 1 in support of the above content.

Ref & mixtures	Input Values				Output values								
	ET °C	SHT °C	SUBT °C	CT °C	COP	V.E	Mass Kg/sec	I. Comp Work kJ/kg	Ref Capt. kW	Comp Power kW	Comp O.T °C	PR	OPI kJ.°C/m³
R22					2.696	91.91	0.01171	64.51	2.036	0.7554	101.4	2.981	48080
R290					3.36	91.65	0.00568	92.07	1.76	0.5237	70.9	2.799	44370
R407C					2.643	89.9	0.01065	65.27	1.837	0.6952	86.3	3.231	40920
M1					2.62	91.3	0.0122	72.59	2.324	0.8868	81	2.816	58470
M2	1	11	8	40	2.687	91.36	0.0112	75.14	2.261	0.8415	78.6	2.798	57230
M3					2.566	91.13	0.01254	73.1	2.352	0.9165	80.2	2.823	59150
M4					2.502	90.94	0.01273	71.62	2.28	0.9115	84.4	2.908	55790
M5					2.737	91.49	0.0109	74.86	2.234	0.81625	79.4	2.793	56560
M6					2.637	91.21	0.01151	75.41	2.29	0.8683	77.8	2.803	57940
R22					2.339	90.15	0.01149	71.6	1.924	0.8224	109.4	3.362	46330
R290					2.995	89.88	0.00557	99.92	1.647	0.5574	76.1	3.136	42660
R407C					2.284	87.58	0.01038	72.1	1.709	0.7482	93	3.676	38740
M1					2.251	89.31	0.01195	80.35	2.161	0.9602	87	3.159	55900
M2	1	11	8	45	2.313	89.39	0.01096	82.88	2.101	0.9084	84.5	3.138	54680
M3					2.202	89.07	0.01226	8087	2.182	0.9911	84	3.168	56450
M4					2.149	88.84	0.01243	79.32	2.119	0.9863	90.5	3.271	53230
M5					2.361	89.59	0.01068	82.57	2.081	0.8814	85.4	3.131	54150
M6					2.262	89.19	0.01126	83.35	2.123	0.9385	83.7	3.145	55240

Table: 1 Parameters Values for ET=1 ^{0}C, SHT=11 ^{0}C, SUBT=8^{0}C,CT=40^{0}C& 45^{0}C

Ref & mixtures	Input Values				Output values								
	ET °C	SHT °C	SUBT °C	CT °C	COP	V.E	Mass Kg/sec	I. Comp Work kJ/kg	Ref Capt. kW	Comp Power kW	Comp O.T °C	PR	OPI kJ.°C/m³
R22					2.043	88.15	0.01123	78.8	1.808	0.885	116.7	3.772	44140
R290					2.604	87.88	0.00545	107.9	1.532	0.5885	81.3	3.502	40480
R407C					1.98	84.87	0.01006	79.13	1.576	0.7958	99.2	4.167	36220
M1					1.939	86.97	0.01164	88.36	1.993	1.028	92.4	3.533	52740
M2	1	11	8	50	1.99	87.09	0.01068	91.14	1.937	0.9732	90	3.508	51530
M3					1.89	86.83	0.01192	89.09	2.007	1.062	91.8	3.544	53130
M4					1.849	86.36	0.01209	87.38	1.953	1.056	95.9	3.667	50130
M5					2.038	87.36	0.01041	90.67	1.923	0.9439	91	3.499	51140
M6					1.941	86.8	0.01096	91.74	1.951	1.005	89.1	3.518	51940
R22					3.011	93.29	0.01346	58.29	2.362	0.784	96.79	2.626	56000
R290					3.716	93.08	0.00649	84.53	2.039	0.5486	69.7	2.484	51190
R407C					2.934	91.7	0.01243	59.51	2.171	0.74	83.5	2.818	48780
M1					2.89	92.78	0.014	66.65	2.697	0.9332	78.9	2.498	67580
M2	5	15	8	40	2.964	92.82	0.01282	69.05	2.623	0.885	76.8	2.485	66040
M3					2.829	92.64	0.01439	67.17	2.734	0.9663	78.2	2.503	68460
M4					2.77	92.5	0.01467	65.47	2.661	0.9604	81.9	2.568	65040
M5					3.023	92.93	0.01247	68.7	2.589	0.8564	73.5	2.481	65200
M6					2.904	92.7	0.01319	69.43	2.659	0.9155	76.1	2.489	66920

Table: 2 Parameters Values for ET=1 ^{0}C, SHT=11 ^{0}C, SUBT=8^{0}C, CT= 50^{0}C

Ref & mixtures	Input Values				Output values								
	ET °C	SHT °C	SUBT °C	CT °C	COP	V.E	Mass Kg/sec	I. Comp Work kJ/kg	Ref Capt. kW	Comp Power kW	Comp O.T °C	PR	OPI kJ.°C/m³
R22					2.59	91.73	0.01323	65.28	2.238	0.8639	104.9	2.96	54680
R290					3.249	91.5	0.00638	92.34	1.914	0.5891	75	2.783	49880
R407C					2.517	89.67	0.01216	66.28	2.028	0.8058	90.3	3.026	46810
M1					2.465	91.01	0.01373	74.35	2.517	1.021	85	2.802	65500
M2	5	15	8	45	2.534	91.07	0.01257	76.76	2.446	0.9652	82.7	2.786	63960
M3					2.411	90.81	0.0141	74.89	2.546	1.056	84.1	2.809	66220
M4					2.362	90.64	0.01437	73.11	2.482	1.051	88.1	2.888	62910
M5					2.589	91.23	0.01224	76.35	2.419	0.9343	83.5	2.781	63280
M6					2.475	90.9	0.01293	77.32	2.474	0.9997	82	2.792	64680
R22					2.246	89.95	0.01298	72.39	2.109	0.9393	112.4	3,326	52640
R290					2.849	89.71	0.00625	100.3	1.787	0.6272	80.2	3.108	47860
R407C					2.169	87.29	0.01184	73.25	1.88	0.867	96.6	3.635	44240
M1					2.111	88.93	0.01342	82.31	2.332	1.105	90.6	3.134	62470
M2	5	15	8	50	2.168	89.03	0.01229	84.96	2.264	1.044	88.4	3.115	60940
M3					2.057	88.65	0.01377	83.06	2.352	1.143	89.5	3.143	63020
M4					2.020	88.45	0.01403	81.11	2.298	1.138	93.7	3.238	59890
M5					2.222	89.26	0.01197	84.4	2.245	1.01	89.3	3.108	60420
M6					2.111	88.78	0.01263	85.65	2.284	1.082	87.5	3.123	61480

Table: 3 Parameters Values for ET=5^0C, SHT=15^0C, SUBT=8^0C,CT=45^0C&50^0C

Ref & mixtures	Input Values				Output values								
	ET °C	SHT °C	SUBT °C	CT °C	COP	V.E	Mass Kg/sec	I. Comp Work kJ/kg	Ref Capt. kW	Comp Power kW	Comp O.T °C	PR	OPI kJ.°C/m³
R22					3.487	94.78	0.0159	50.89	2.823	0.8094	91.32	2.252	65810
R290					4.234	94.61	0.00762	75.58	2.433	0.5745	68.3	2.151	59500
R407C					3.364	93.61	0.01496	52.66	2.65	0.7878	80.3	2.39	58960
M1					3.292	94.37	0.01649	59.42	3.227	0.9801	76.4	2.161	78750
M2	10	20	8	40	3.368	94.4	0.01507	61.78	3.136	0.9311	74.6	2.152	76820
M3					3.216	94.27	0.01697	60.04	3.277	1.019	75.8	2.165	79900
M4					3.164	94.17	0.01739	58.77	3.201	1.012	78.9	2.21	76540
M5					3.44	94.49	0.01405	61.34	3.091	0.8984	75.2	2.149	75760
M6					3.295	94.31	0.01552	62.24	3.183	0.9662	74.1	2.155	77940
R22					2.961	93.43	0.01568	57.76	2.681	0.9056	99.56	2.539	65620
R290					3.671	93.24	0.007492	83.34	2.292	0.6243	73.7	2.409	59240
R407C					2.854	91.88	0.0468	59.35	2.487	0.1713	87.1	2.719	57790
M1					2.778	92.84	0.01623	67.05	3.022	1.083	82.6	2.424	77980
M2	10	20	8	45	2.851	92.89	0.01483	69.41	2.935	1.029	86.7	2.413	76010
M3					2.712	92.69	0.01669	67.69	3.063	1.129	81.9	2.429	78970
M4					2.667	92.57	0.0171	65.73	2.998	1.124	85.3	2.486	75630
M5					2.917	93.61	0.01442	68.92	2.899	0.9936	81.3	2.409	75120
M6					2.78	92.75	0.01527	70.02	2.973	1.07	80.1	2.418	76970

Table: 4 Parameters Values for ET=10^0C, SHT=20^0C, SUBT=8^0C,CT=40^0C& 45^0C

Ref & Mixtures	Input Values				Output values								
	ET°C	SHT°C	SUBT°C	CT°C	COP	V.E	Mass Kg/sec	I. Comp Work kJ/kg	Ref Capt. kW	Comp Power kW	Comp O.T°C	PR	OPIkJ.°C/m³
R22					2.54	91.89	0.01542	64.76	2,536	0.9984	107.3	2.853	64210
R290					3.197	91.69	0.00736	91.22	2.148	0.672	79	2.61	57790
R407C					2.437	89.95	0.01436	66.24	2.318	0.9571	93.6	3.082	55530
M1					2.359	91.04	0.01591	74.94	2.812	1.192	88.4	2.711	75620
M2	10	20	8	50	2.419	91.11	0.01455	77.55	2.728	1.128	86.5	2.698	73640
M3					2.294	90.82	0.01635	75.79	2.843	1.239	87.5	2.178	76420
M4					2.26	90.69	0.01675	73.65	2.788	1.234	91.1	2.787	73210
M5					2.482	91.3	0.01415	76.9	2.701	1.088	87.2	2.692	72930
M6					2.352	90.93	0.01496	78.34	2.757	1.172	85.8	2.705	74400

Table: 5 Parameters Values for ET=10^0C, SHT=20^0C, SUBT=8^0C, CT=50^0C

M1(mixed refrigerant) →R22-40%/R290 30%/R407C-30%

M2 (mixed refrigerant) →R22-30%/R290-40%/R407C-30%

M3 (mixed refrigerant) →R22-30%/R290-30%/R407C-40%

M4 (mixed refrigerant) →R22-40%/R290-20%/R407C-40%

M5 (mixed refrigerant) →R22-40%/R290-40%/R407C-20%

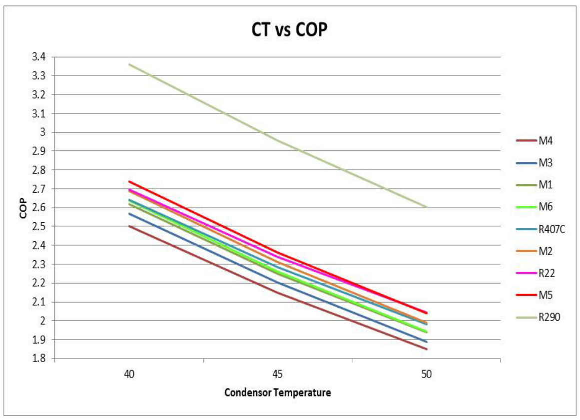
M6 (mixed refrigerant) →R22-20%/R290-40%/R407C-40%

6. GRAPH OF PARAMETERS

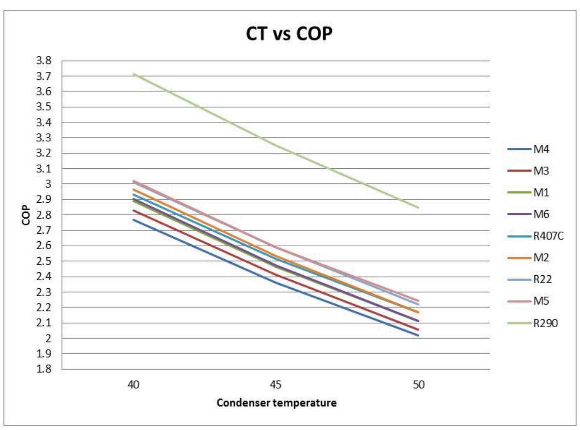
6.1 COP

The coefficient of performance variation for refrigerant mixture R22, R290 and R407 with six different mixtures are shown in fig 6.1 at the condenser temperature 40°C and evaporator temperature varied from 1°C to 10°C the refrigerant mixture increases the COP. When the evaporator temperature maintains constant at 1°C and condenser temperature varied from 40°C to 50°C the COP decreases.

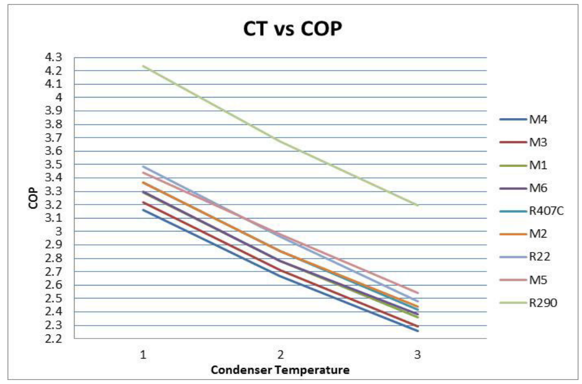
We have deduced that when the condenser temperature increases the COP value decreases, similarly when the evaporator temperature increases the cop value increases. From the three refrigerants and its combinations R 290 gives the highest cop. Among the combinations M5 gives the best COP.



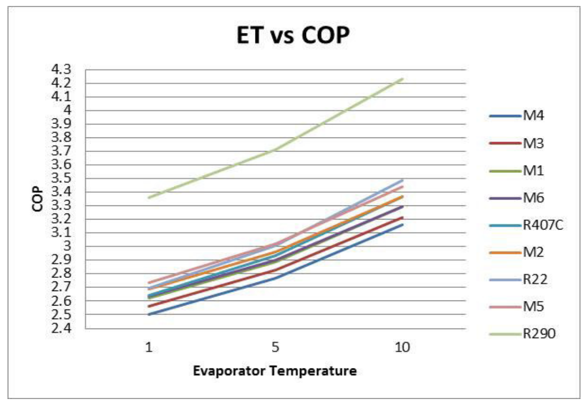
Graph 1 ET=1°C, SHT=11°C, SUBT=8°C, CT=40,45, 50°C



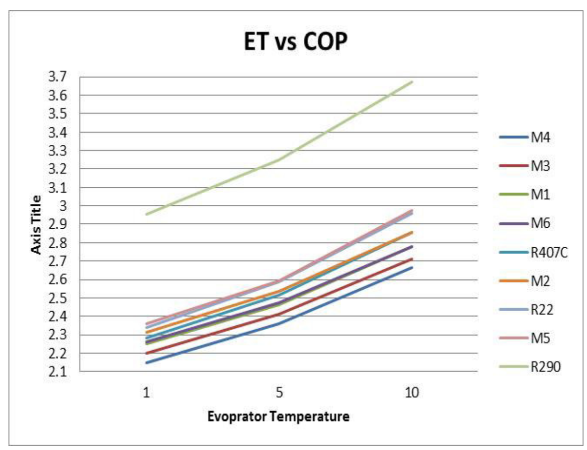
Graph 2 ET=5°C, SHT=15°C,SUBT=8°C, CT=40,45, 50°C



Graph 3 ET=10°C, SHT=20°C, SUBT=8°C, CT=40,45, 50°C

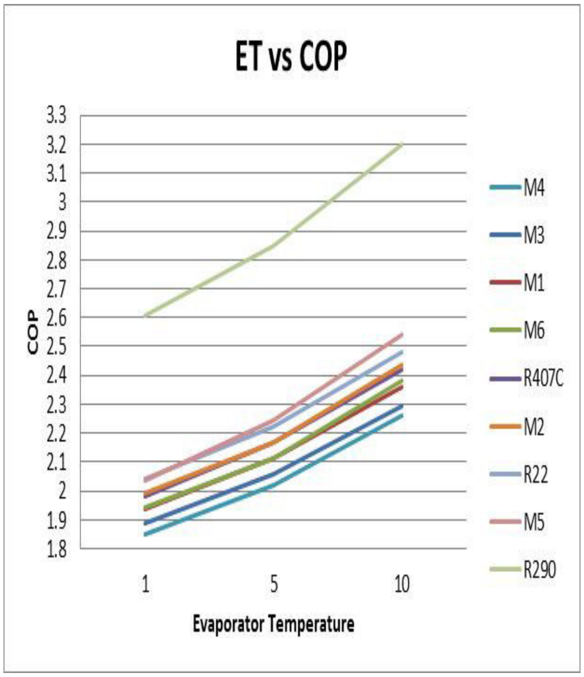


Graph 4 ET=1,5, 10°C, SHT=11,15,20°C, SUBT=8°C ,CT=40°C

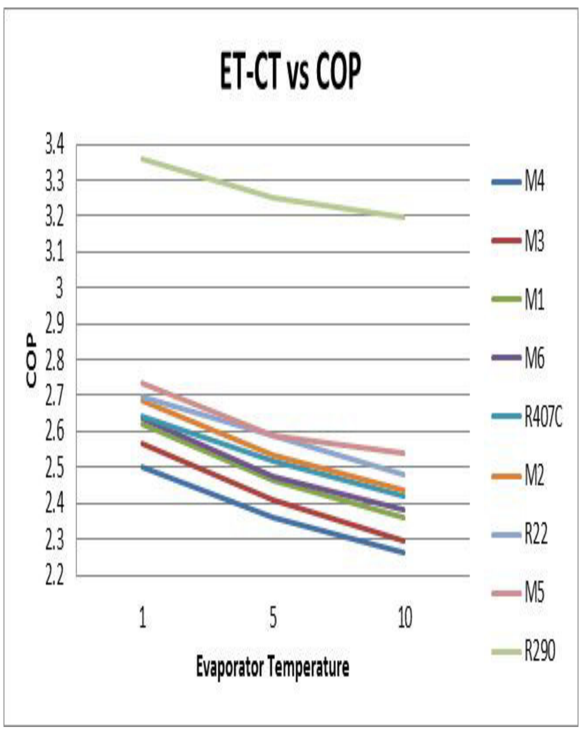


Graph 5 ET=1,5, 10°C,SHT=11,15,20°C, SUBT=8°C,CT=45°C

ISSN: 2394 – 4854
Pages:10 – 17



Graph 6 ET=1,5, 10°C,SHT=11,15,20°C,SUBT=8°C,CT=50°C

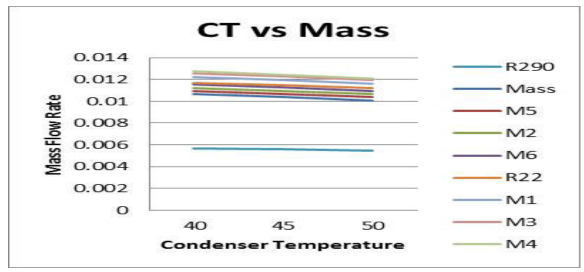


Graph 7 ET=1,5, 10°C,SHT=11,15,20°C,SUBT=8°C,CT=40,45, 50°C

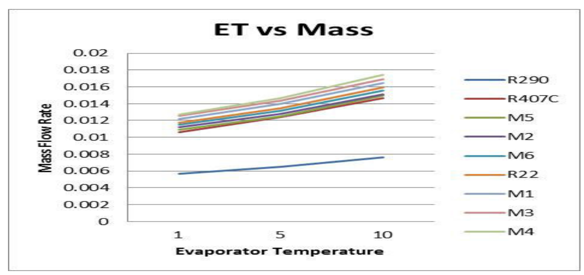
Graph 1,2,3,4,5,6,7. Compared COP and Condenser temp, Evaporator temperature for various conditions

6.2 Refrigeration Mass Flow Rate

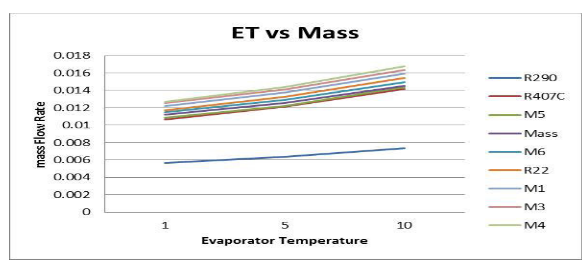
The mass flow rate variation for refrigerant mixture R22, R290 and R407C with six different mixtures are shown in fig 6.2 at the condenser temperature maintain at 40^0C and evaporator temperature varied from 1^0C to 10^0C the refrigerant mixture increases the mass flow rate. When the evaporator temperature maintains constant at 1^0C and condenser temperature varied from 40^0C to 50^0C the mass flow rate decreases in the range.



Graph 8 ET=1°C, SHT=11°C,SUBT=8°C,CT=40,45, 50°C



Graph 9.ET=1,5, 10°C,SHT=11,15,20°C,SUBT=8°C,CT=40°C

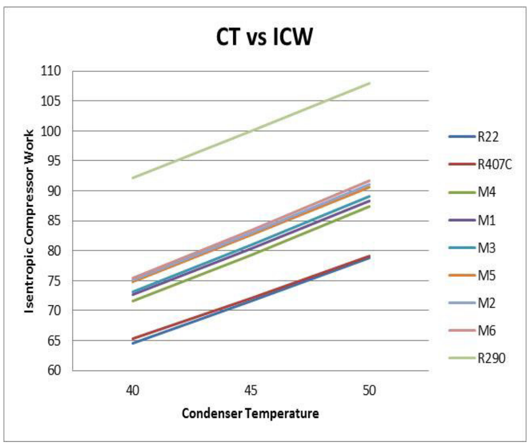


Graph 10 ET=1,5, 10°C,SHT=11,15,20°C,SUBT=8°C,CT=40,45, 50°C

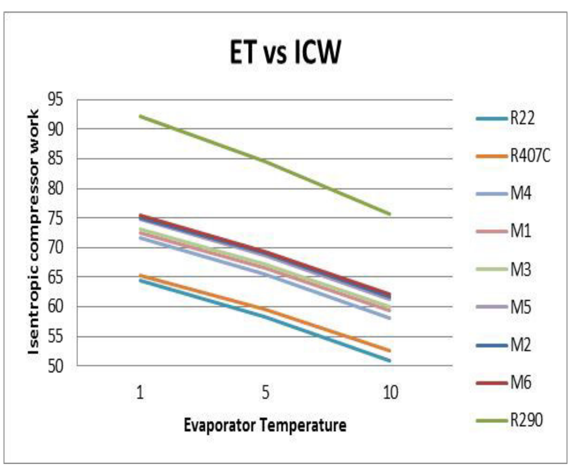
Graph.8,9,10. Compared Mass flow rate and Condenser temp, Evaporator temperature for various conditions.

6.3 Isentropic Compressor Work

The Isentropic compressor work variation for refrigerant mixture R22, R290 and R407C with six different mixtures are shown in fig 6.3 at the condenser temperature maintain at 40^0C and evaporator temperature varied from 1^0C to 10^0C the refrigerant mixture decrease the isentropic compressor work. When the evaporator temperature maintains constant at 1^0C and condenser temperature varied from 40^0C to 50^0C isentropic compressor work increase in the range.



Graph 11 ET=1°C, SHT=11°C, SUBT=8°C,CT=40,45, 50°C

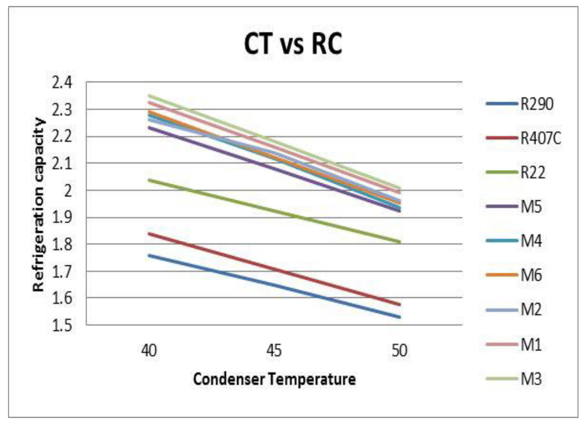


Graph 12 ET=1,5, 10°C, SHT=11,15,20°C,SUBT=8°C,CT=40°C

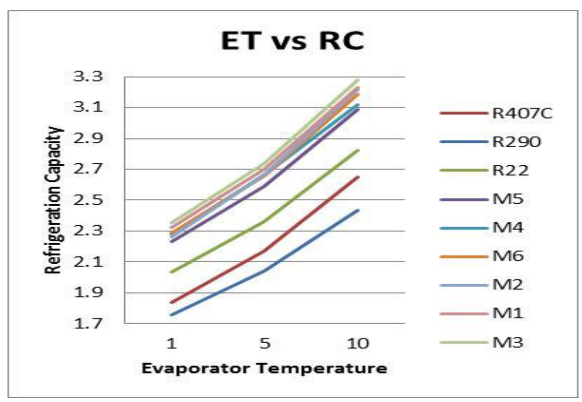
Graph 11,12. Compared Isentropic compressor work and Condenser temp, Evaporator temperature for various conditions.

6.4 Refrigeration Capacity

The Refrigeration Capacity variation for refrigerant mixture R22, R290 and R407C with six different mixtures are shown in fig 6.4 at the condenser temperature maintain at 40^0C and evaporator temperature varied from 1^0C to 10^0C the refrigerant mixture increases the Refrigeration Capacity. When the evaporator temperature maintains constant at 1^0C and condenser temperature varied from 40^0C to 50^0C Refrigeration Capacity decrease in the range.



Graph 13 ET=1°C, SHT=11°C, SUBT=8°C,CT=40,45, 50°C

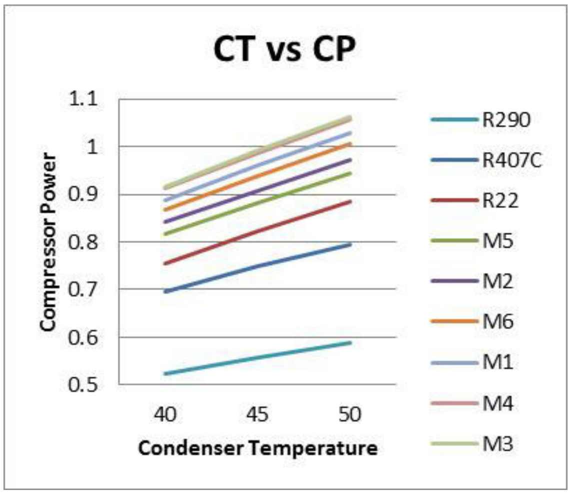


Graph 14 ET=1,5, 10°C,SHT=11,15,20°C,SUBT=8°C,CT=40°C

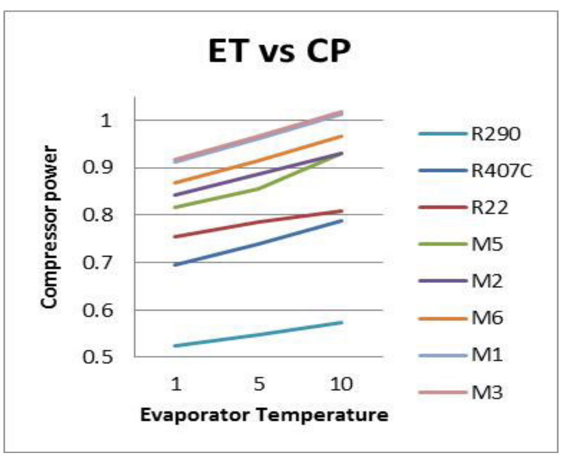
Graph 13,14. Compared refrigeration capacity and Condenser temp, Evaporator temperature for various conditions

6.5 Compressor Power

The Compressor Power variation for refrigerant mixture R22, R290 and R407C with six different mixtures are shown in fig 6.5 at the condenser temperature maintain at 40^0C and evaporator temperature varied from 1^0C to 10^0C the refrigerant mixture increases the Compressor Power. When the evaporator temperature maintains constant at 1^0C and condenser temperature varied from 40^0C to 50^0C Compressor Power increase in the range.



Graph 15 ET=1°C, SHT=11°C,SUBT=8°C,CT=40,45, 50°C



Graph 16 ET=1,5,10°C, SHT=11,15,20°C,SUBT=8°C,CT=40°C

Graph 15,16. Compared compressor power and Condenser temp, Evaporator temperature.

7. CONCLUSION

Mixed refrigerant is used in small window air conditioner, co-efficient of performance and mass flow rate are found to be increased. On the other hand the power consumed by a compressor is reduced. The simulation result shows that the use hydrocarbon refrigerant (R290) improves the performance of window air conditioners. Here we analyzed the several refrigerant mixture with the help of MATLAB-SIMLINK tool and we found that R290 and R22-40% / R290-40% / R407C-20% refrigerant mixtures gives better performance.The refrigerant data are calculated from REFPROP software. As R290 is flammable in nature, the mixture containing R22-40% / R290-40% / R407C-20% can be used in the domestic / practical applications. By using this alternate refrigerant mixture, we can reduce the GWP and also reduce the pollution of the environment.

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