Research Article

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MATLAB simulation investigation for optimum work net and optimum efficiency of combined cycle (Intercooled) power plant using different fuels with supplementary heat from HRSG

Abstract

In this paper, MATLAB simulation investigation for optimum Work net and optimum efficiency of combined cycle (Intercooled) power plant using different fuels with supplementary heat from HRSG are presented. The HRSG structures (steam pressure, maximum temperature and mass flow rate) are designed system composed by HRSG and steam turbine (ST). The analysis procedure is followed for finding both optimums Worknet and optimum efficiency. A fraction of hot gases heat from combustion chamber is bypassed to HRSG. Exit heat from gas turbine also passed through the HRSG. The simulation is carried out for different fuels (Nepthalene, CNG, LNG and Kerosene), air fuel ratios (50, 55 and 60) for different pressure ratios. The simulation codes are made in MATLAB. The evaluation shows that use of HRSG is particularly convenient in the perspective of efficiency increase it can be a valid technical solution aiming to up gradation of existing combined cycle power plants. The significance of this kind of investigation gives advantages of combine power plant that utilizes the waste energy for generation of steam to run the steam turbines. This leads to increase in power output in thermal efficiency. The performance of combined cycle depends upon the number of parameters like pressure ratios, types of fuel used, component efficiency, turbine exhaust temperature, degree of supplementary heating and condition of steam generation. It is noticed that fraction hot gases bypassed from combustion chamber to HRSG certainly give sufficient heat energy to generate steam at required pressure and temperature to obtain the optimum Worknet and optimum efficiency significantly.

Keywords: combined cycle power plants, supplementary heating, HRSG, intercooled

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Introduction

The available literature on subject combined cycle is as: Seyedan et al.,[1] department of mechanical engineering IIT Delhi published technical paper in July 1996. In this paper optimization of waste heat recovery boiler of a combined cycle was studied. The optimum design results in reduction of total weight of power plant about 25 % at reduced cost. The computer simulation strategy was adopted for optimization of weights heat recovery boiler. TS Kim & STRO.,[2] turbo & power machinery research centre, Seoul, South Korea published a technical paper in 2000 on power augmentation of combined cycle plant using cold energy of liquefied natural gas. They analyzed combined cycle power plant based on the 1350^0 Celsius class gas turbine where inlet air is cooled by the cold energy released by LNG as performed and relative power augmentation was examined in term of ambient temperature and humidity significantly. Zwebek et al.,[3] Sue et al.,[4] and A Franco et al.[5] contribution is notable. In this context, numerous approaches are there such as Valdés et al.,[6] Cihan et al.,[7] Bassily.,[8] Sanjay Y, Singh O, Prasad BN.[9] Butcher and Reddy.,[10] T. Srinivas.,[11] investigated the heat recovery steam generator (HRSG), plays a key role on performance of combined cycle (CC Mohagheghi M and Shayegan J.,[12] investigated the thermodynamic optimization using genetic algorithm. Isam H and Aljundi.,[13] studied the energy and exergy analysis of a steam power plant in Jordan. Godoy et al.[14] investigated the optimal thermodynamic solutions for combined cycle. Kotowicz J and Bartela L.,[15] studied the optimal values of the design variables of a combined cycle plant. Woudstra et al.,[16] investigated the 800 MW combined cycle power plant. For high performance, better conditions for compressor, HRSG sections, steam reheater and deaerator are developed by Franco A.[17] The analysis is based on minimizing total exergy losses in order to optimize the performance of the HRSG-steam turbine system presented by MM Rahman and TK Ibrahim.[18] Optimisation of the combined cycle power plants for Worknet and efficiency, based on the supplement heat used for HRSG for different fuels (Nepthalene, CNG, LNG and Kerosene), different air fuel ratios (50, 55 and 60) and different pressure ratios, using C++ and MATLAB codes simulation is studied by by Rajesh et al.[19]

MATLAB simulation study for optimum work net and optimum efficiency of combination of gas turbine and steam turbine cycle (Intercooled) using different fuels with supplementary heat from HRSG is not investigated to the best of author's knowledge.

Gas turbine cycle

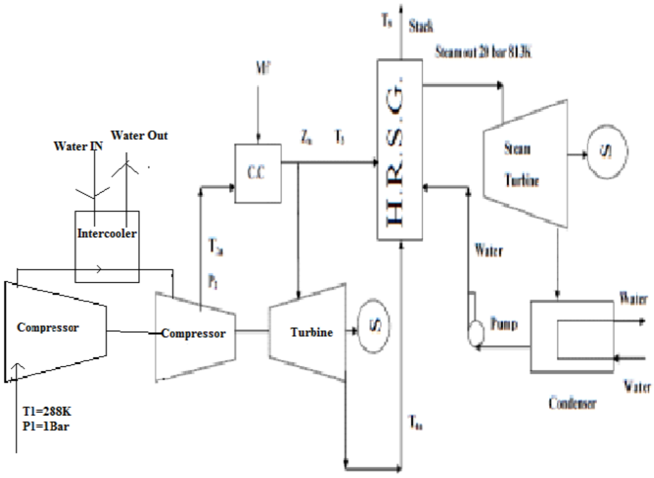

Figure 1 Schematic for an open gas-turbine intercooled cycle.

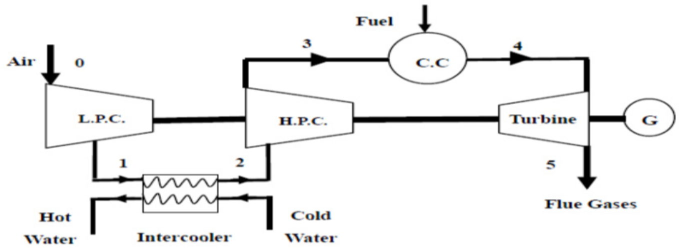

Figure 2 Schematic for an open gas-turbine intercooled.

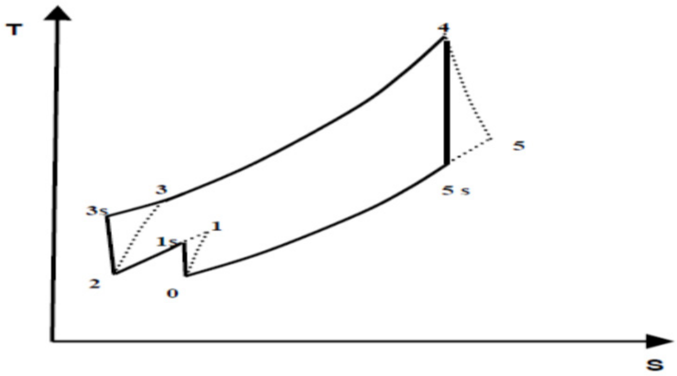

Figure 3 T-S diagram of intercooled gas-turbine cycle.

Combined cycle analysis

$Worknet_3 = Work_{net1} + Work_{net2}$ (1)

$Efficiency_3 = Efficiency_1 + Efficiency_2$ (2)

Assumptions

All assumptions made for present study are mentioned in earlier published research article Rajesh et al.[19]

Investigation with intercooler and without supplementary heating

For gas turbine work & efficiency

$T_3 = T_1$ (3)

$T_5 = (m_a \times lcv) + (m_a \times C_{pa} \times T_{4a}) / (m_a + m_f) \times C_{pg}$ (4)

$W_T = (m_a + m_f) \times C_{pg} \times (T_5 - T_{6a})$, (5)

$W_{C1} = m_a \times C_{pg} \times (T_{2a} - T_1)$, (6)

$Wc_2 = m_a \times C_{pa} \times (T_{4a} - T_3)$ (7)

$Work_1 = W_T - W_{C1} - W_{C2}$ (8)

$Work_{net} = Work_1 / (m_a + m_f)$, (9)

$Efficiency_1 = Work_1 / (m_f \times l.c.v)$ (10)

For steam turbine work & efficiency steam is generated at 20 bar 813 K

$m_w = (m_a + m_f) \times C_{pg} \times (T_{6a} - T_9) / (h_1 - h_{f3})$, (11)

If ($T_{6a} > 813$ & $T_3 < 1400$), (12)

$Work_2 = m_w (h_1 - h_2)$ (13)

$Worknet_2 = Work_2 / (m_a \times m_f)$, (14)

$Efficiency_2 = Work_2 / (m_f \times l.c.v)$ (15)

Now

$Work_3 = Work_{net1} + Work_{net2}$, (16)

$Efficiency_3 = Efficiency_1 + Efficiency_2$, (17)

$Work_2 = m_w \times (h_1 - h_2)$ (18)

$Work_{net2} = Work_2 / (m_f \times l.c.v)$, (19)

Now

$Work_3$ = Worknet1+ Worknet2 (20)

$Efficiency_3 = Efficiency_1 + Efficiency_2$ (21)

Investigation with intercooler and with supplementary heating

Gas turbine work and efficiency

$W_T = Z \times (m_a + m_f) \times C_{pg} \times (T_5 - T_{6a})$ (22)

Where $Z = 1 - Z_a$ (23)

$W_{C1} = m_a \times C_{pa} \times (T_{2a} - T_1)$, (24)

$Wc_2 = m_a \times C_{pa} \times (T_{4a} - T_3)$ (25)

$Wc = Wc_1 + Wc_2$ (26)

$Work_1 = W_T - W_C$ (27)

$Work_{net1} = Work_1 / (m_a + m_f)$, (28)

$Efficiency_1 = Work_1 / (m_f \times l.c.v)$ (29)

Steam turbine work and efficiency

$T_x = (T_{6a} x\, Z + T_5 x\, Z_a)$ (30)

If ($T_x > 813$ & $T_5 < 1400$),

Steam is generated at 20 bar 813 K then

$$m_w = \frac{Z_a \times (m_a + m_f) \times C_{pg} \times T_5 + Z \times (m_a + m_f) \times C_{pg} \times T_{6a} - (m_a + m_f) \times C_{pg} \times T_9}{(h_1 - h_{f3})} \quad (31)$$

Results and discussion

The analysis procedure is followed for finding both optimum Worknet and efficiency. A fraction of hot gases heat from combustion chamber is bypassed to HRSG. Exit heat from gas turbine also passed through the HRSG. The simulation is carried out for different fuels with air fuel ratios for different pressure ratios. The simulation codes are made in MATLAB.

The significance of combine power plant is that it utilizes the waste energy for generation of steam to run the steam turbines. The above mentioned codes in words format with reheat without supplementary heating and with reheat with supplementary heating are converted in MATLAB codes for simulation. Tables 1–8 present the optimum Worknet and optimum efficiency at air fuel ratio =50 for four kinds of fuels i.e. Nepthalene, CNG, LNG and Kerosene. Tables 9–16 present the optimum Worknet and optimum efficiency at air fuel ratio =55 for four kind s of fuels i.e. Nepthalene, CNG, LNG and Kerosene. Tables 17–24 present the optimum Worknet and optimum efficiency at air fuel ratio =60 for four kind s of fuels i.e. Nepthalene, CNG, LNG and Kerosene. Similarly, Figures 4–6 present the comparative optimum Worknet, and optimum efficiency for air fuel ratio=50, 55 and 60 respectively.

Table 1 presents the results for Naphthalene fuel having lcv = 43963.5 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=50. Worknet1, worknet2 and worknet3 is investigated with fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0).At pr ratio=20 optimum Worknet is 290.6497.

Table 1 Naphthalene fuel having lcv = 43963.5 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=50. Worknet1, worknet2 and worknet3 is investigated with compressor intercooling and with fraction bypass heat from combustion chamber

Pr	za= 0.1 to 0.5 (Fraction bypassed at from CC)			Pr	za=0.0 (without bypass)		
	Worknet 1	Worknet 2	Worknet 3		Worknet 1	Worknet 2	Worknet 3
4	124.8429	156.1174	280.9603	4	192.6094	0	192.6094
6	101.5969	155.7809	257.3778	6	228.6059	0	228.6059
8	249.2855	0	249.2855	8	249.2855	0	249.2855
10	249.2855	0	249.2855	10	249.2855	0	249.2855
12	272.0152	0	272.0152	12	272.0152	0	272.0152
14	278.7788	0	278.7788	14	278.7788	0	278.7788
16	283.8319	0	283.8319	16	283.8319	0	283.8319
18	287.6811	0	287.6811	18	287.6811	0	287.6811
20	290.6497	0	290.6497	20	290.6497	0	290.6497

Table 2 presents the results for Naphthalene fuel having lcv = 43963.5 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=50. Efficiency1, Efficiency2 and Efficiency3 is investigated with fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0). At pr ratio=20 optimum Efficiency is 0.3372.

Table 2 Naphthalene fuel having lcv = 43963.5 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=50. Efficiency1, Efficiency2 and Efficiency3 is investigated with compressor intercooling and fraction bypass heat from combustion

Pr	Za= 0.1 to 0.5 (Fraction bypass heat from CC)			Pr	Za=0.0 (without bypass)		
	Efficiency 1	Efficiency 2	Efficiency 3		Efficiency 1	Efficiency 2	Efficiency 3
4	0.1448	0.1811	0.3259	4	0.2234	0	0.2234
6	0.1179	0.1807	0.2986	6	0.2652	0	0.2652
8	0.2892	0	0.2892	8	0.2892	0	0.2892
10	0.3047	0	0.3047	10	0.3047	0	0.3047
12	0.3156	0	0.3156	12	0.3156	0	0.3156
14	0.3234	0	0.3234	14	0.3234	0	0.3234
16	0.3293	0	0.3293	16	0.3293	0	0.3293
18	0.3337	0	0.3337	18	0.3337	0	0.3337
20	0.3372	0	0.3372	20	0.3372	0	0.3372

Table 3 presents the results for CNG fuel having lcv = 46900 KJ/Kg, pressure ratio 4 to 16 for air fuel ratio=50. Worknet1, worknet2 and worknet3 is investigated with fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0). At pr ratio=4 optimum Worknet is 332.3103.

Table 3 CNG fuel having lcv = 46900 KJ/Kg, pressure ratio 4 to 16 for air fuel ratio=50. Worknet1, worknet2 and worknet3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber

Pr	Za= 0.1 to 0.5 (Fraction bypass heat from CC)			Pr	Za=0.0 (without bypass)		
	Worknet 1	Worknet 2	Worknet 3		Worknet 1	Worknet 2	Worknet 3
4	173.1313	159.179	332.3103	4	208.6151	0	208.6151
6	159.6199	155.6344	315.2543	6	248.2142	0	248.2142
8	120.5645	162.5436	283.1082	8	271.2084	0	271.2084

Table 3 Continued.....

10	286.2882	0	286.2882	10	286.2882	0	286.2882
12	296.8935	0	296.8935	12	296.8935	0	296.8935
14	304.6938	0	304.6938	14	304.6938	0	304.6938
16	310.6089	0	310.6089	16	310.6089	0	310.6089
18	315.1915	0	315.1915	18	315.1915	0	315.1915
20	318.7957	0	318.7957	20	318.7957	0	318.7957

Table 4 presents the results for CNG fuel having lcv = 46900 KJ/Kg, pressure ratio 4 to 16 for air fuel ratio=50. Efficiency1, Efficiency2 and Efficiency3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0). At pr ratio=4 optimum Efficiency is 0.3614.

Table 4 CNG fuel having lcv = 46900 KJ/Kg, pressure ratio 4 to 16 for air fuel ratio=50. Efficiency1, Efficiency2 and Efficiency3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber

Pr	Za= 0.1 to 0.5 (Fraction bypass heat from CC)			Pr	Za=0.0 (without bypass)		
	Efficiency 1	Efficiency 2	Efficiency 3		Efficiency 1	Efficiency 2	Efficiency 3
4	0.1883	0.1731	0.3614	4	0.2269	0	0.2269
6	0.1736	0.1692	0.3428	6	0.2699	0	0.2699
8	0.1311	0.1768	0.3079	8	0.2949	0	0.2949
10	0.3113	0	0.3113	10	0.3113	0	0.3113
12	0.3228	0	0.3228	12	0.3228	0	0.3228
14	0.3313	0	0.3313	14	0.3313	0	0.3313
16	0.3378	0	0.3378	16	0.3378	0	0.3378
18	0.3427	0	0.3427	18	0.3427	0	0.3427
20	0.3467	0	0.3467	20	0.3467	0	0.3467

Table 5 presents the results for LNG fuel having lcv = 49400 KJ/Kg, pressure ratio 4 to 12 for air fuel ratio=50. Worknet1, worknet2 and worknet3 is investigated with fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0). At pr ratio=4 Optimum Worknet is 381.3907.

Table 5 LNG fuel having lcv = 49400 KJ/Kg, pressure ratio 4 to 12 for air fuel ratio=50. Worknet1, worknet2 and worknet3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber

Pr	Za= 0.1 to 0.5 (Fraction bypass heat from CC)			Pr	Za=0.0 (without bypass)		
	Worknet 1	Worknet 2	Worknet 3		Worknet 1	Worknet 2	Worknet 3
4	222.2417	159.1491	381.3907	4	222.2417	159.1491	381.3907
6	218.9414	152.2393	371.1807	6	264.9079	0	264.9079
8	185.7105	157.2291	342.9395	8	289.8725	0	289.8725
10	306.373	0	306.373	10	306.373	0	306.373
12	318.0737	0	318.0737	12	318.0737	0	318.0737
14	326.7567	0	326.7567	14	326.7567	0	326.7567
16	333.4056	0	333.4056	16	333.4056	0	333.4056
18	338.6126	0	338.6126	18	338.6126	0	338.6126
20	342.7578	0	342.7578	20	342.7578	0	342.7578

Table 6 presents the results for LNG fuel having lcv = 49400 KJ/Kg, pressure ratio 4 to 12 for air fuel ratio=50. Efficiency1, Efficiency2 and Efficiency3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0). At pr ratio=4 Optimum Efficiency is 0.3937.

Table 6 LNG fuel having lcv = 49400 KJ/Kg, pressure ratio 4 to 12 for air fuel ratio=50. Efficiency1, Efficiency2 and Efficiency3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber

Pr	Za= 0.1 to 0.5 (Fraction bypass heat from CC)			Pr	Za=0.0 (without bypass)		
	Efficiency 1	Efficiency 2	Efficiency 3		Efficiency 1	Efficiency 2	Efficiency 3
4	0.2294	0.1643	0.3937	4	0.2294	0.1643	0.3937
6	0.226	0.1572	0.3832	6	0.2735	0	0.2735
8	0.1917	0.1623	0.354	8	0.2993	0	0.2993
10	0.3163	0	0.3163	10	0.3163	0	0.3163
12	0.3284	0	0.3284	12	0.3284	0	0.3284
14	0.3373	0	0.3373	14	0.3373	0	0.3373
16	0.3442	0	0.3442	16	0.3442	0	0.3442
18	0.3496	0	0.3496	18	0.3496	0	0.3496
20	0.3539	0	0.3539	20	0.3539	0	0.3539

Citation: Kumar R. MATLAB simulation investigation for optimum work net and optimum efficiency of combined cycle (Intercooled) power plant using different fuels with supplementary heat from HRSG. *Aeron Aero Open Access J*. 2025;9(4):205–217. DOI: 10.15406/aaoaj.2025.09.00239

Table 7 presents the results for Kerosene fuel having lcv = 43000 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=50. Worknet1, worknet2 and worknet3 is investigated with fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0). At pr ratio=20 Optimum Worknet is 281.4147.

Table 7 Kerosene fuel having lcv = 43000 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=50.Worknet1, worknet2 and worknet3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber

Pr	Za= 0.1 to 0.5 (Fraction bypass heat from CC)			Pr	Za=0.0 (without bypass)		
	Worknet 1	Worknet 2	Worknet 3		Worknet 1	Worknet 2	Worknet 3
4	87.2834	162.2694	249.5528	4	187.3578	0	187.3578
6	222.1721	0	222.1721	6	222.1721	0	222.1721
8	242.0924	0	242.0924	8	242.0924	0	242.0924
10	254.9559	0	254.9559	10	254.9559	0	254.9559
12	263.8523	0	263.8523	12	263.8523	0	263.8523
14	270.2757	0	270.2757	14	270.2757	0	270.2757
16	275.0461	0	275.0461	16	275.0461	0	275.0461
18	278.6546	0	278.6546	18	278.6546	0	278.6546
20	281.4147	0	281.4147	20	281.4147	0	281.4147

Table 8 presents the results for Kerosene fuel having lcv = 43000 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=50. Efficiency1, Efficiency2 and Efficiency3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0). At pr ratio=20 Optimum Efficiency is 0.3338.

Table 8 Kerosene fuel having lcv = 43000 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=50. Efficiency1, Efficiency2 and Efficiency3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber

Pr	Za= 0.1 to 0.5 (Fraction bypass heat from CC)			Pr	Za=0.0 (without bypass)		
	Efficiency 1	Efficiency 2	Efficiency 3		Efficiency 1	Efficiency 2	Efficiency 3
4	0.1035	0.1925	0.296	4	0.2222	0	0.2222
6	0.2635	0	0.2635	6	0.2635	0	0.2635
8	0.2871	0	0.2871	8	0.2871	0	0.2871
10	0.3024	0	0.3024	10	0.3024	0	0.3024
12	0.3129	0	0.3129	12	0.3129	0	0.3129
14	0.3206	0	0.3206	14	0.3206	0	0.3206
16	0.3262	0	0.3262	16	0.3262	0	0.3262
18	0.3305	0	0.3305	18	0.3305	0	0.3305
20	0.3338	0	0.3338	20	0.3338	0	0.3338

Table 9 Presents the results for CNG fuel having lcv = 46900 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=55.Worknet1, worknet2 and worknet3 is investigated with fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0). At pr ratio=20 Optimum Worknet is 278.4256.

Table 9 CNG fuel having lcv = 46900 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=55.Worknet1, worknet2 and worknet3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber

Pr	Za= 0.1 to 0.5 (Fraction bypass heat from CC)			Pr	Za=0.0 (without bypass)		
	Worknet 1	Worknet 2	Worknet 3		Worknet 1	Worknet 2	Worknet 3
4	86.0494	160.9422	246.9916	4	185.7067	0	185.7067
6	220.1364	0	220.1364	6	220.1364	0	220.1364
8	239.8051	0	239.8051	8	239.8051	0	239.8051
10	252.4845	0	252.4845	10	252.4845	0	252.4845
12	261.2372	0	261.2372	12	261.2372	0	261.2372
14	267.5435	0	267.5435	14	267.5435	0	267.5435
16	272.2155	0	272.2155	16	272.2155	0	272.2155
18	275.7394	0	275.7394	18	275.7394	0	275.7394
20	278.4256	0	278.4256	20	278.4256	0	278.4256

Table 10 presents the results for CNG fuel having lcv = 46900 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=55. Efficiency1, Efficiency2 and Efficiency3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0). At pr ratio=20 Optimum Efficiency is 0.3324.

Table 10 CNG fuel having lcv = 46900 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=55. Efficiency1, Efficiency2 and Efficiency3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber

Pr	Za= 0.1 to 0.5 (Fraction bypass heat from CC)			Pr	Za=0.0 (without bypass)		
	Efficiency 1	Efficiency 2	Efficiency 3		Efficiency 1	Efficiency 2	Efficiency 3
4	0.1027	0.1922	0.2949	4	0.2217	0	0.2217
6	0.2628	0	0.2628	6	0.2628	0	0.2628
8	0.2863	0	0.2863	8	0.2863	0	0.2863
10	0.3015	0	0.3015	10	0.3015	0	0.3015
12	0.3119	0	0.3119	12	0.3119	0	0.3119
14	0.3195	0	0.3195	14	0.3195	0	0.3195
16	0.325	0	0.325	16	0.325	0	0.325
18	0.3292	0	0.3292	18	0.3292	0	0.3292
20	0.3324	0	0.3324	20	0.3324	0	0.3324

Table 11 presents the results for Naphthalene fuel having lcv = 43963.5 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=55.Worknet1, worknet2 and worknet3 is investigated with fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0). At pr ratio=20 Optimum Worknet is 252.7927.

Table 11 Naphthalene fuel having lcv = 43963.5 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=55.Worknet1, worknet2 and worknet3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber

Pr	Za= 0.1 to 0.5 (Fraction bypass heat from CC)			Pr	Za=0.0 (without bypass)		
	Worknet 1	Worknet 2	Worknet 3		Worknet 1	Worknet 2	Worknet 3
4	44.0843	157.4909	201.5752	4	171.1301	0	171.1301
6	202.2787	0	202.2787	6	202.2787	0	202.2787
8	219.8396	0	219.8396	8	219.8396	0	219.8396
10	230.9993	0	230.9993	10	230.9993	0	230.9993
12	238.5802	0	238.5802	12	238.5802	0	238.5802
14	243.9423	0	243.9423	14	243.9423	0	243.9423
16	247.8293	0	247.8293	16	247.8293	0	247.8293
18	250.6853	0	250.6853	18	250.6853	0	250.6853
20	252.7927	0	252.7927	20	252.7927	0	252.7927

Table 12 presents the results for Naphthalene fuel having lcv = 43963.5 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=55. Efficiency1, Efficiency2 and Efficiency3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0). At pr ratio=20 Optimum Efficiency is 0.3220.

Table 12 Naphthalene fuel having lcv = 43963.5 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=55. Efficiency1, Efficiency2 and Efficiency3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber

Pr	Za= 0.1 to 0.5 (Fraction bypass heat from CC)			Pr	Za=0.0 (without bypass)		
	Efficiency 1	Efficiency 2	Efficiency 3		Efficiency 1	Efficiency 2	Efficiency 3
4	0.0562	0.2006	0.2568	4	0.218	0	0.218
6	0.2577	0	0.2577	6	0.2577	0	0.2577
8	0.28	0	0.28	8	0.28	0	0.28
10	0.2942	0	0.2942	10	0.2942	0	0.2942
12	0.3039	0	0.3039	12	0.3039	0	0.3039
14	0.3107	0	0.3107	14	0.3107	0	0.3107
16	0.3157	0	0.3157	16	0.3157	0	0.3157
18	0.3193	0	0.3193	18	0.3193	0	0.3193
20	0.322	0	0.322	20	0.322	0	0.322

Table 13 presents the results for Kerosene fuel having lcv = 43000 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=55.Worknet1, worknet2 and worknet3 is investigated with fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0). At pr ratio=20 Optimum Worknet is 244.3823.

Table 13 Kerosene fuel having lcv = 43000 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=55.Worknet1, worknet2 and worknet3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber

Pr	Za= 0.1 to 0.5 (Fraction bypass heat from CC)			Pr	Za=0.0 (without bypass)		
	Worknet 1	Worknet 2	Worknet 3		Worknet 1	Worknet 2	Worknet 3
4	41.2146	152.7665	193.9811	4	166.3473	0	166.3473
6	196.4195	0	196.4195	6	196.4195	0	196.4195
8	213.2887	0	213.2887	8	213.2887	0	213.2887
10	223.9497	0	223.9497	10	223.9497	0	223.9497
12	231.1462	0	231.1462	12	231.1462	0	231.1462
14	236.1984	0	236.1984	14	236.1984	0	236.1984
16	239.8279	0	239.8279	16	239.8279	0	239.8279
18	242.4647	0	242.4647	18	242.4647	0	242.4647
20	244.3823	0	244.3823	20	244.3823	0	244.3823

Table 14 presents the results for Kerosene fuel having lcv = 43000 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=55. Efficiency1, Efficiency2 and Efficiency3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0). At pr ratio=20 Optimum Efficiency is 0.3183.

Table 14 Kerosene fuel having lcv = 43000 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=55. Efficiency1, Efficiency2 and Efficiency3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber

Pr	Za= 0.1 to 0.5 (Fraction bypass heat from CC)			Pr	Za=0.0 (without bypass)		
	Efficiency 1	Efficiency 2	Efficiency 3		Efficiency 1	Efficiency 2	Efficiency 3
4	0.0537	0.199	0.2526	4	0.2166	0	0.2166
6	0.2558	0	0.2558	6	0.2558	0	0.2558
8	0.2778	0	0.2778	8	0.2778	0	0.2778
10	0.2917	0	0.2917	10	0.2917	0	0.2917
12	0.301	0	0.301	12	0.301	0	0.301
14	0.3076	0	0.3076	14	0.3076	0	0.3076
16	0.3123	0	0.3123	16	0.3123	0	0.3123
18	0.3158	0	0.3158	18	0.3158	0	0.3158
20	0.3183	0	0.3183	20	0.3183	0	0.3183

Table 15 presents the results for LNG fuel having lcv = 49400 KJ/Kg, pressure ratio 4 to 18 for air fuel ratio=55.Worknet1, worknet2 and worknet3 is investigated with fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0). At pr ratio=20 Optimum Worknet is 300.2483.

Table 15 LNG fuel having lcv = 49400 KJ/Kg, pressure ratio 4 to 18 for air fuel ratio=55.Worknet1, worknet2 and worknet3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber

Pr	Za= 0.1 to 0.5 (Fraction bypass heat from CC)			Pr	Za=0.0 (without bypass)		
	Worknet 1	Worknet 2	Worknet 3		Worknet 1	Worknet 2	Worknet 3
4	129.1964	161.4352	290.6316	4	198.1166	0	198.1166
6	106.2061	161.0001	267.2063	6	235.3395	0	235.3395
8	110.3568	153.6598	264.0166	8	256.8027	0	256.8027
10	270.776	0	270.776	10	270.776	0	270.776
12	280.5264	0	280.5264	12	280.5264	0	280.5264
14	287.6365	0	287.6365	14	287.6365	0	287.6365
16	292.9767	0	292.9767	16	292.9767	0	292.9767
18	297.0693	0	297.0693	18	297.0693	0	297.0693
20	300.2483	0	300.2483	20	300.2483	0	300.2483

Table 16 presents the results for LNG fuel having lcv = 49400 KJ/Kg, pressure ratio 4 to 18 for air fuel ratio=55. Efficiency1, Efficiency2 and Efficiency3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0). At pr ratio=20 Optimum Efficiency is 0.3404.

Table 16 LNG fuel having lcv = 49400 KJ/Kg, pressure ratio 4 to 18 for air fuel ratio=55. Efficiency1, Efficiency2 and Efficiency3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber

Pr	Za= 0.1 to 0.5 (Fraction bypass heat from CC)			Pr	Za=0.0 (without bypass)		
	Efficiency 1	Efficiency 2	Efficiency 3		Efficiency 1	Efficiency 2	Efficiency 3
4	0.1465	0.183	0.3295	4	0.2246	0	0.2246
6	0.1204	0.1825	0.3029	6	0.2668	0	0.2668
8	0.1251	0.1742	0.2993	8	0.2911	0	0.2911
10	0.307	0	0.307	10	0.307	0	0.307
12	0.318	0	0.318	12	0.318	0	0.318
14	0.3261	0	0.3261	14	0.3261	0	0.3261
16	0.3321	0	0.3321	16	0.3321	0	0.3321
18	0.3368	0	0.3368	18	0.3368	0	0.3368
20	0.3404	0	0.3404	20	0.3404	0	0.3404

Table 17 presents the results for Naphthalene fuel having lcv = 43963.5 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=60.Worknet1, worknet2 and worknet3 is investigated with fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0). At pr ratio=20 Optimum Worknet is 221.1418.

Table 17 Naphthalene fuel having lcv = 43963.5 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=60.Worknet1, worknet2 and worknet3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber

Pr	Za= 0.1 to 0.5 (Fraction bypass heat from CC)			Pr	Za=0.0 (without bypass)		
	Worknet 1	Worknet 2	Worknet 3		Worknet 1	Worknet 2	Worknet 3
4	153.172	0	153.172	4	153.172	0	153.172
6	180.2676	0	180.2676	6	180.2676	0	180.2676
8	195.2209	0	195.2209	8	195.2209	0	195.2209
10	204.4983	0	204.4983	10	204.4983	0	204.4983
12	210.6264	0	210.6264	12	210.6264	0	210.6264
14	214.8167	0	214.8167	14	214.8167	0	214.8167
16	217.7287	0	217.7287	16	217.7287	0	217.7287
18	219.7543	0	219.7543	18	219.7543	0	219.7543
20	221.1418	0	221.1418	20	221.1418	0	221.1418

Table 18 presents the results for Naphthalene fuel having lcv = 43963.5 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=60. Efficiency1, Efficiency2 and Efficiency3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0). At pr ratio=20 Optimum Efficiency is 0.3068.

Table 18 Naphthalene fuel having lcv = 43963.5 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=60. Efficiency1, Efficiency2 and Efficiency3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber

Pr	Za= 0.1 to 0.5 (Fraction bypass heat from CC)			Pr	Za=0.0 (without bypass)		
	Efficiency 1	Efficiency 2	Efficiency 3		Efficiency 1	Efficiency 2	Efficiency 3
4	0.2125	0	0.2125	4	0.2125	0	0.2125
6	0.2501	0	0.2501	6	0.2501	0	0.2501
8	0.2709	0	0.2709	8	0.2709	0	0.2709
10	0.2922	0	0.2922	10	0.2922	0	0.2922
12	0.2922	0	0.2922	12	0.2922	0	0.2922
14	0.2981	0	0.2981	14	0.2981	0	0.2981
16	0.3021	0	0.3021	16	0.3021	0	0.3021
18	0.3049	0	0.3049	18	0.3049	0	0.3049
20	0.3068	0	0.3068	20	0.3068	0	0.3068

Table 19 presents the results for Kerosene fuel having lcv = 43000 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=60.Worknet1, worknet2 and worknet3 is investigated with fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0). At pr ratio=20 Optimum Worknet is 213.4207.

Table 19 Kerosene fuel having lcv = 43000 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=60.Worknet1, worknet2 and worknet3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber

Pr	Za= 0.1 to 0.5 (Fraction bypass heat from CC)			Pr	Za=0.0 (without bypass)		
	Worknet 1	Worknet 2	Worknet 3		Worknet 1	Worknet 2	Worknet 3
4	148.7813	0	148.7813	4	148.7813	0	148.7813
6	174.8885	0	174.8885	6	174.8885	0	174.8885
8	189.2069	0	189.2069	8	189.2069	0	189.2069
10	198.0266	0	198.0266	10	198.0266	0	198.0266
12	203.8017	0	203.8017	12	203.8017	0	203.8017
14	207.7076	0	207.7076	14	207.7076	0	207.7076
16	210.3832	0	210.3832	16	210.3832	0	210.3832
18	212.2076	0	212.2076	18	212.2076	0	212.2076
20	213.4207	0	213.4207	20	213.4207	0	213.4207

Table 20 presents the results for Kerosene fuel having lcv = 43000 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=60. Efficiency1, Efficiency2 and Efficiency3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0). At pr ratio=20 Optimum Efficiency is 0.3028.

Table 20 Kerosene fuel having lcv = 43000 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=60. Efficiency1, Efficiency2 and Efficiency3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber

Pr	Za= 0.1 to 0.5 (Fraction bypass heat from CC)			Pr	Za=0.0 (without bypass)		
	Efficiency 1	Efficiency 2	Efficiency 3		Efficiency 1	Efficiency 2	Efficiency 3
4	0.2111	0	0.2111	4	0.2111	0	0.2111
6	0.2481	0	0.2481	6	0.2481	0	0.2481
8	0.2684	0	0.2684	8	0.2684	0	0.2684
10	0.2809	0	0.2809	10	0.2809	0	0.2809
12	0.2891	0	0.2891	12	0.2891	0	0.2891
14	0.2947	0	0.2947	14	0.2947	0	0.2947
16	0.2985	0	0.2985	16	0.2985	0	0.2985
18	0.301	0	0.301	18	0.301	0	0.301
20	0.3028	0	0.3028	20	0.3028	0	0.3028

Table 21 presents the results for CNG fuel having lcv = 46900 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=60.Worknet1, worknet2 and worknet3 is investigated with fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0). At pr ratio=20 Optimum Worknet is 244.6736.

Table 21 CNG fuel having lcv = 46900 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=60.Worknet1, worknet2 and worknet3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber

Pr	Za= 0.1 to 0.5 (Fraction bypass heat from CC)			Pr	Za=0.0 (without bypass)		
	Worknet 1	Worknet 2	Worknet 3		Worknet 1	Worknet 2	Worknet 3
4	41.2512	153.1861	194.4373	4	166.5538	0	166.5538
6	196.6614	0	196.6614	6	196.6614	0	196.6614
8	213.5498	0	213.5498	8	213.5498	0	213.5498
10	224.2224	0	224.2224	10	224.2224	0	224.2224
12	231.4263	0	231.4263	12	231.4263	0	231.4263
14	236.4834	0	236.4834	14	236.4834	0	236.4834
16	240.116	0	240.116	16	240.116	0	240.116
18	242.7549	0	242.7549	18	242.7549	0	242.7549
20	244.6736	0	244.6736	20	244.6736	0	244.6736

Table 22 presents the results for CNG fuel having lcv = 46900 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=60 Efficiency1, Efficiency2 and Efficiency3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0).. At pr ratio=20 Optimum Efficiency is 0.3182.

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Table 22 CNG fuel having lcv = 46900 KJ/Kg, pressure ratio 4 to 20 for air fuel ratio=60 Efficiency1, Efficiency2 and Efficiency3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber

Pr	Za= 0.1 to 0.5 (Fraction bypass heat from CC)			Pr	Za=0.0 (without bypass)		
	Efficiency 1	Efficiency 2	Efficiency 3		Efficiency 1	Efficiency 2	Efficiency 3
4	0.0537	0.1992	0.2529	4	0.2166	0	0.2166
6	0.2558	0	0.2558	6	0.2558	0	0.2558
8	0.2778	0	0.2778	8	0.2778	0	0.2778
10	0.2916	0	0.2916	10	0.2916	0	0.2916
12	0.301	0	0.301	12	0.301	0	0.301
14	0.3076	0	0.3076	14	0.3076	0	0.3076
16	0.3123	0	0.3123	16	0.3123	0	0.3123
18	0.3157	0	0.3157	18	0.3157	0	0.3157
20	0.3182	0	0.3182	20	0.3182	0	0.3182

Table 23 presents the results for LNG fuel having lcv = 49400 KJ/Kg, pressure ratio 4 to 18 for air fuel ratio=60.Worknet1, worknet2 and worknet3 is investigated with fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0). At pr ratio=20 Optimum Worknet is 264.7076.

Table 23 LNG fuel having lcv = 49400 KJ/Kg, pressure ratio 4 to 18 for air fuel ratio=60.Worknet1, worknet2 and worknet3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber

Pr	Za= 0.1 to 0.5 (Fraction bypass heat from CC)			Pr	Za=0.0 (without bypass)		
	Worknet 1	Worknet 2	Worknet 3		Worknet 1	Worknet 2	Worknet 3
4	80.5517	153.7408	234.2925	4	177.9465	0	177.9465
6	210.6184	0	210.6184	6	210.6184	0	210.6184
8	229.1542	0	229.1542	8	229.1542	0	229.1542
10	241.0146	0	241.0146	10	241.0146	0	241.0146
12	249.1343	0	249.1343	12	249.1343	0	249.1343
14	254.9294	0	254.9294	14	254.9294	0	254.9294
16	259.1755	0	259.1755	16	259.1755	0	259.1755
18	262.3364	0	262.3364	18	262.3364	0	262.3364
20	264.7076	0	264.7076	20	264.7076	0	264.7076

Table 24 presents the results for LNG fuel having lcv = 49400 KJ/Kg, pressure ratio 4 to 18 for air fuel ratio=60. Efficiency1, Efficiency2 and Efficiency3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber (za=0.1 to 0.5) and without bypass (za=0.0). At pr ratio=20 Optimum Efficiency is 0.3269.

Table 24 LNG fuel having lcv = 49400 KJ/Kg, pressure ratio 4 to 18 for air fuel ratio=60. Efficiency1, Efficiency2 and Efficiency3 is investigated with compressor intercooling and fraction bypass heat from combustion chamber

Pr	Za= 0.1 to 0.5 (Fraction bypass heat from CC)			Pr	Za=0.0 (without bypass)		
	Efficiency 1	Efficiency 2	Efficiency 3		Efficiency 1	Efficiency 2	Efficiency 3
4	0.0995	0.1898	0.2893	4	0.2197	0	0.2197
6	0.2601	0	0.2601	6	0.2601	0	0.2601
8	0.283	0	0.283	8	0.283	0	0.283
10	0.2976	0	0.2976	10	0.2976	0	0.2976
12	0.3076	0	0.3076	12	0.3076	0	0.3076
14	0.3148	0	0.3148	14	0.3148	0	0.3148
16	0.32	0	0.32	16	0.32	0	0.32
18	0.3239	0	0.3239	18	0.3239	0	0.3239
20	0.3269	0	0.3269	20	0.3269	0	0.3269

Figure 4 shows the optimum Work output and optimum efficiency for Air fuel ratio=50, fraction bypass heat from combustion chamber for different pressure ratios and different Fuels. Optimum Work output is 381.3907 for LNG at pressure ratio=4, optimum Work output is 332.3103 for CNG at pressure ratio=4, optimum Work output is 290.6497 at pressure ratio=20 for Nepthelene and Optimum Work output is 281.4147 at pressure ratio=20 for Kerosene fuel used. Optimum efficiency is 0.3937 for LNG at pressure ratio= 4, optimum efficiency is 0.3614 for CNG at pressure ratio= 4, optimum efficiency is 0.3372 for Nepthelene at pressure ratio= 20 and optimum efficiency is 0.3338 at pressure ratio=20 for Kerosene fuel used in present study. Here it can be noticed that LNG fuel at pressure ratio=4 gives highest workout put and efficiency.

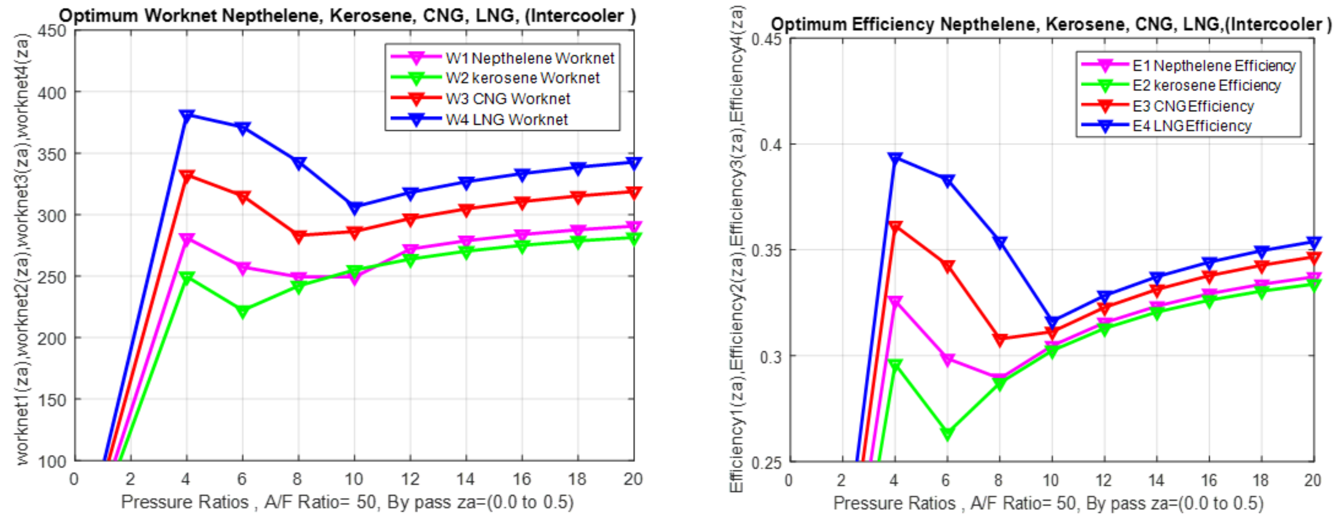


Figure 4 Optimum Work output and optimum efficiency for Air fuel ratio=50, fraction bypass heat from combustion chamber for different pressure ratios with compressor intercooling and different fuels.

Figure 5 shows the optimum Work output and optimum efficiency for Air fuel ratio=55, fraction bypass heat from combustion chamber for different pressure ratios and different fuels. Optimum Work output is 300.2483 for LNG at pressure ratio=20, optimum Work output is 278.4256 for CNG at pressure ratio=20, optimum Work output is 252.7927 at pressure ratio=20 for Naphthalene and optimum Work output is 244.3823 at pressure ratio=20 for Kerosene fuel used. Optimum efficiency 0.3404for LNG at pressure ratio= 20, optimum efficiency is 0.3324 for CNG at pressure ratio= 20, optimum efficiency is 0.3220 for Naphthalene at pressure ratio= 20 and optimum efficiency is 0.3183 at pressure ratio=20 for Kerosene fuel used in present study. Here it can be noticed that LNG fuel at pressure ratio=20 gives highest workout put and efficiency.

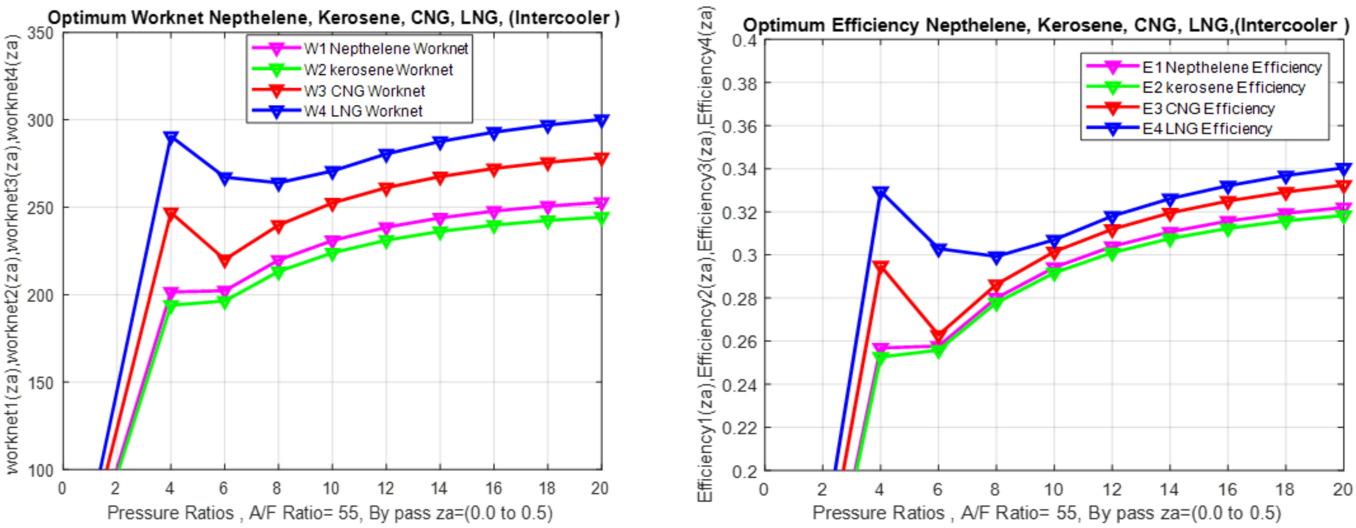
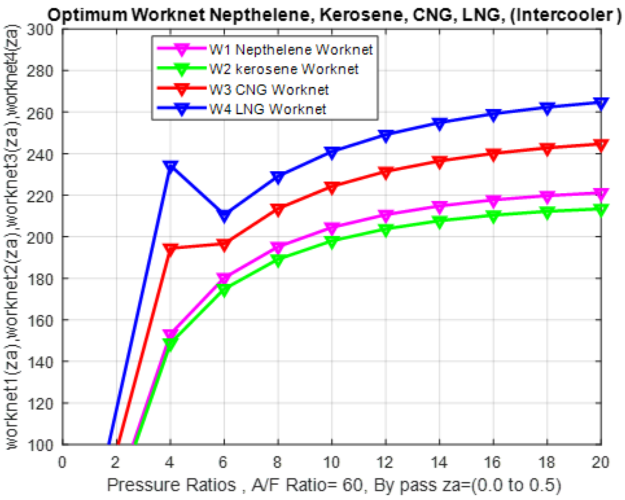


Figure 5 Optimum Work output and optimum efficiency for Air fuel ratio=55, fraction bypass heat from combustion chamber for different pressure ratios with compressor intercooling and different fuels.

Figure 6 shows the optimum Work output and optimum efficiency for Air fuel ratio=60, fraction bypass heat from combustion chamber for different pressure ratios and different fuels. Optimum Work output is 264.7076 for LNG at pressure ratio=20, optimum Work output is 244.6736 for CNG at pressure ratio=20, optimum Work output is 221.1418 at pressure ratio=20 for Naphthalene and optimum Work output is 213.4207 at pressure ratio=20 for Kerosene fuel used. Optimum efficiency is 0.3269for LNG at pressure ratio= 20, optimum efficiency is 0.3182 for CNG at pressure ratio= 20, optimum efficiency is 0.3068 for Naphthalene at pressure ratio= 20 and optimum efficiency 0.3028 at pressure ratio=20 for Kerosene fuel used in present study. Here it can be noticed that LNG fuel at pressure ratio=20 gives highest workout put and efficiency.[20,21]



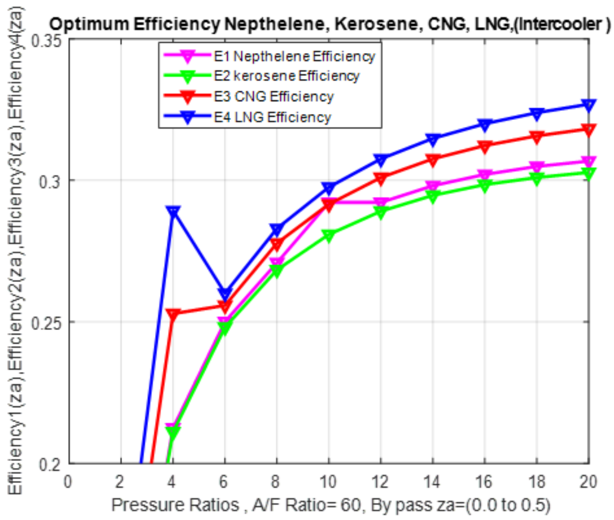


Figure 6 Optimum Work output and optimum efficiency for Air fuel ratio=60, fraction bypass heat from combustion chamber for different pressure ratios with compressor intercooling and different fuels.

Findings and conclusion

The following points are concluded on the basis of this research:

a) The performance of combined cycle depends upon the number of parameters like pressure ratios, types of fuel used, degree of supplementary heating and condition of steam generation.

b) LNG fuel with lower pressure ratios 4 and higher pressure ratio 20 is more efficient in terms of optimum Work output and optimum efficiency when operated with air fuel ratios 50 compared to Naphthalene, Kerosene and CNG fuels. The kerosene fuel has lowest optimum Work output and Optimum efficiency among different fuels studied.

c) For different fuels and pressure ratios studied LNG fuel at air fuel ratio 55, optimum Work output is 300.2483 for LNG at pressure ratio=20 and optimum Efficiency 0.3404 at same pressure ratio. The kerosene fuel has lowest optimum Work output and optimum efficiency among different fuels studied. Optimum Work output is 264.7076 for LNG at pressure ratio=20 and optimum efficiency is 0.3269 at same pressure ratio. The kerosene fuel has lowest optimum Work output and optimum efficiency among different fuels studied.

d) At studied pressure ratios LNG and CNG fuels are better options among studied fuels for getting optimum Worknet and optimum efficiency at air fuel ratio=50 and Kerosene fuel give lower optimum Worknet and optimum efficiency. These are simulation results give a guidelines to optimize power plants practically. Further some more fuels can be studied for future needs.

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Conflict of interest

Author has no conflicts of interest.

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