Effect of Variable Thermal Properties of Working Fluid on Performance of an IC Engine Cycle

Desai Rahulkumar Mohanbhai[1], Kiran D. Parmar [2]

[1] *P. G. Student, Mechanical Engineering Dept., Hansaba College of Engineering & Technology, Gujarat, India*

[2] *Assistant Professor, Mechanical Engineering Dept., Hansaba College of Engineering & Technology, Gujarat, India*

ABSTRACT

The performance of an air-standard Otto cycle with heat transfer loss and variable specific heats of working fluid is analyzed. The relations between the power output and the compression ratio, between the thermal efficiency and the compression ratio, as well as the optimal relation between power output and the efficiency of the cycle are derived by numerical simulations. Moreover, the effects of heat transfer loss and variable specific heats of working fluid on the cycle performance are analyzed. The effects of heat transfer loss and variable specific heats of working fluid on the cycle performance are obvious and they should be considered in practice cycle analysis. The results of this project may provide guidance for the design of practice internal combustion engines. Thermal distortions of engine components are to be studied. The Results may provide guidance for the Design of Practice Internal Combustion Engines.

KEYWORD: *Thermal Fluids Analysis, Effects of Heat Transfer Losses, IC Engine Cycle*

1. INTRODUCTION

Presently IC Engine are Designed based on Theoretical cycle and Actual efficiency of engine gets effected by various Irreversibility of system. The actual engine also has temperature dependent specific heats and Frictional losses which one to be accounted properly.

The actual deviate from Ideal IC Engine Cycle due to Temperature variation Frictional Losses and Irreversibility. The foam of work is to develop a reference study for future design of Actual IC engine. The Efficiency of IC Engine is optimized and Thermal Distribution of engine components are studied in this paper.

The effect of irreversibility introduced because of Temperature dependent specific heats and Friction losses on the efficiency of Otto cycle. Further, the optimization study of specific heat will result in achieving better efficiency of IC Engine performance. The effect of heat loss will be studied and applied for thermal distortion analysis of Piston.

2. METHODOLOGY

The proposed work will be solved as per major steps mentioned below:

A. Creation of 3D model in CAD software
B. Finite Element Analysis of Reference Problem as per base paper
C. Validation of base paper result with developing a Plots and Codes in Matlab software
D. Validation of output results with Experimental results of Paper
E. Optimization of Existing problem to increase the efficiency if Otto cycle
F. LMS_IMAGINE.LAB AMESIM 15 by SIEMENS software by creating a model also optimized model
G. Creating output results

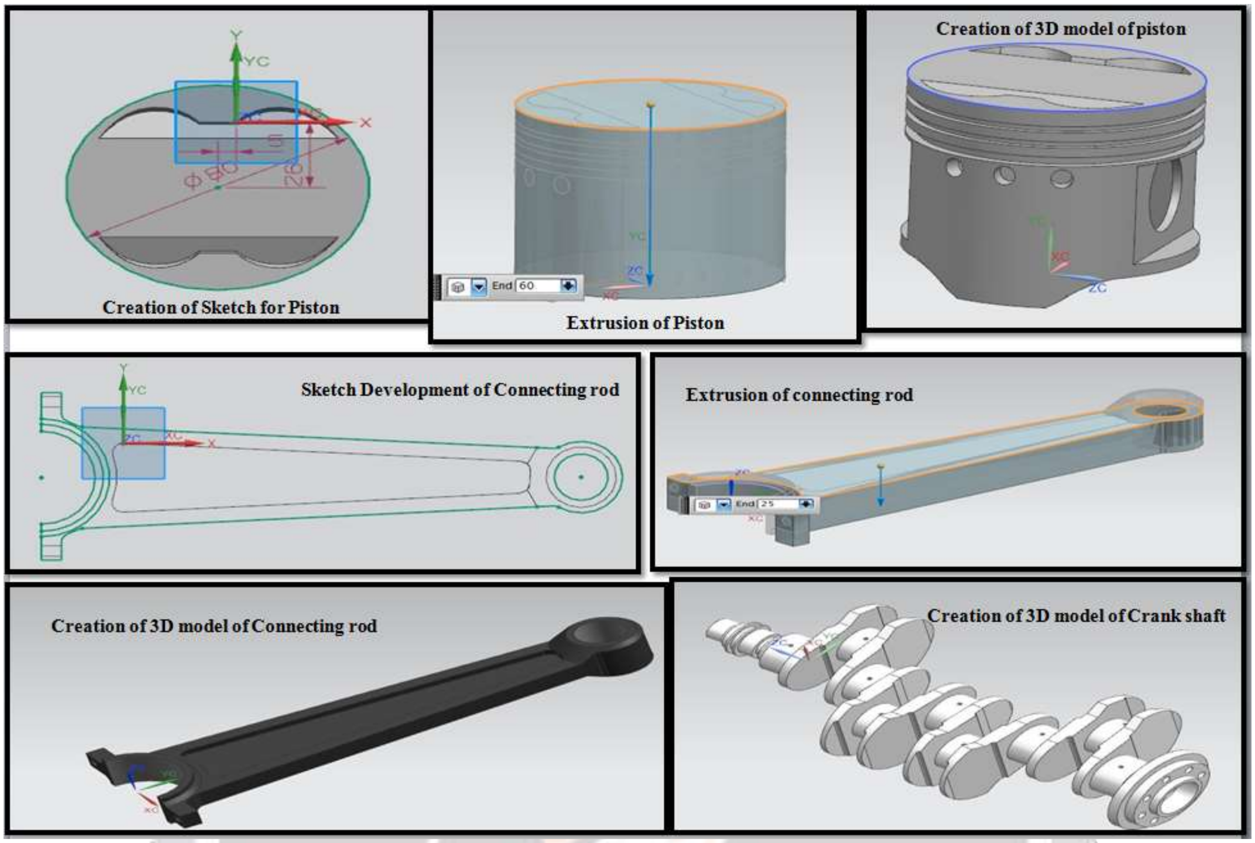

FIGURE 1: SHOWING 3D CREATION OF VARIOUS PARTS OF IC ENGINE

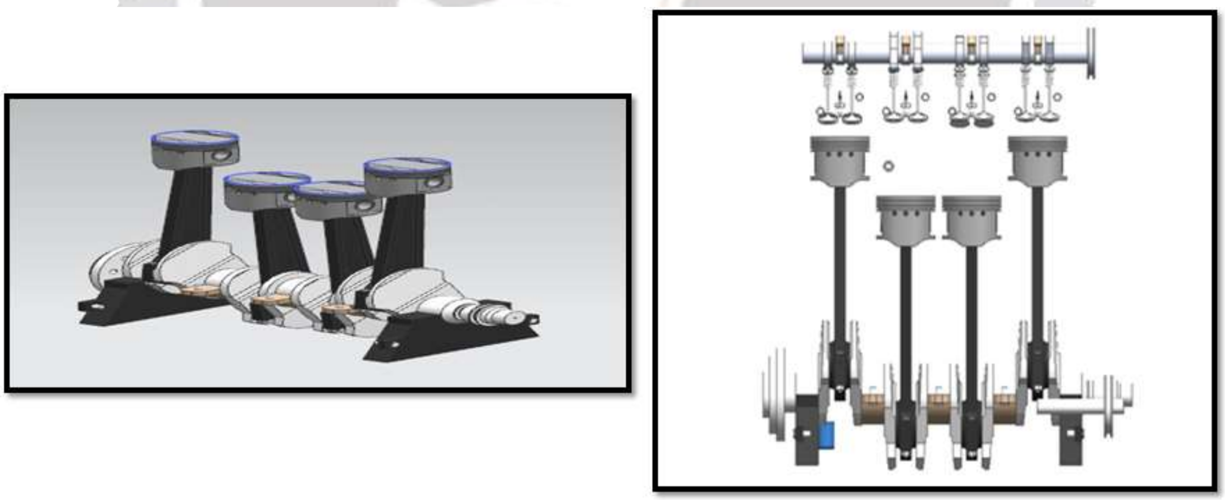

FIGURE 2: CREATION OF 3D MODEL OF PISTON, CONNECTING ROD, CRANK SHAFT ASSEMBLY

3. PLOTS AND DISCUSSION

According to ref. [1], the following parameters are used. A= 60000-70000 J/ mol * K, bv= 19.868-23.868 J/ mol *K, B= 20-30 J/mol *K, M= 1.57× 10^{-5} kmol, T_1= 350 K, k_1= 0.003844-0.009844 J/mol K^2. Taking equal heating and cooling times t1=t2=t/2=16.6 ms (t= 33.33 ms), the constant temperature rates K1 and K2 are estimated as:
K1= 8.128 × 10^{-6} s/K and K2= 18.67 × 10^{-6} s/K.

3.1 TEMPERATURES VERSUS COMPRESSION RATIO

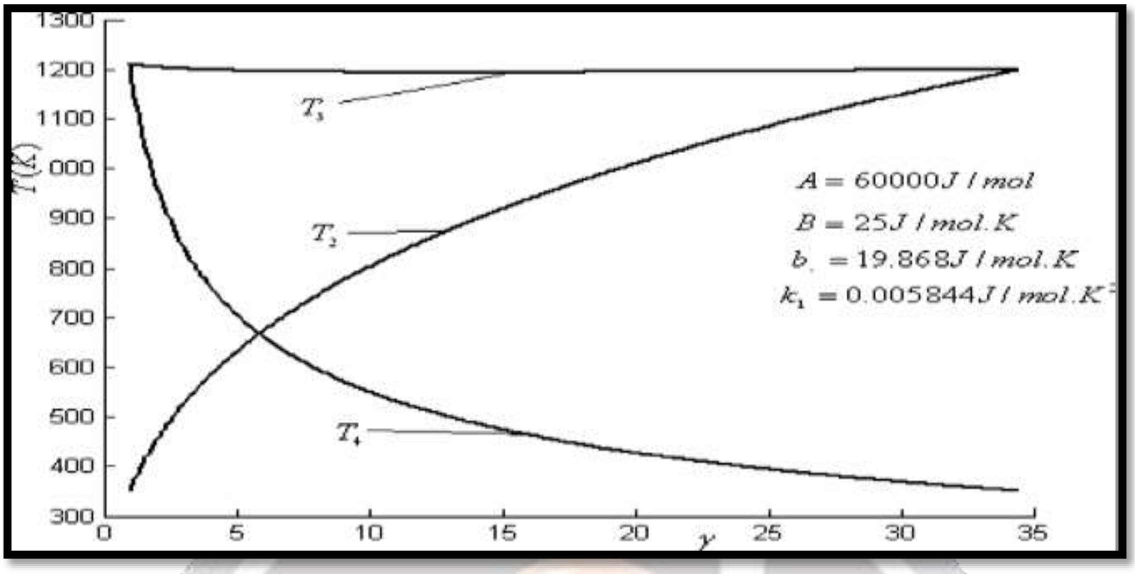

FIGURE 3: TEMPERATURES VERSUS COMPRESSION RATIO BY RP

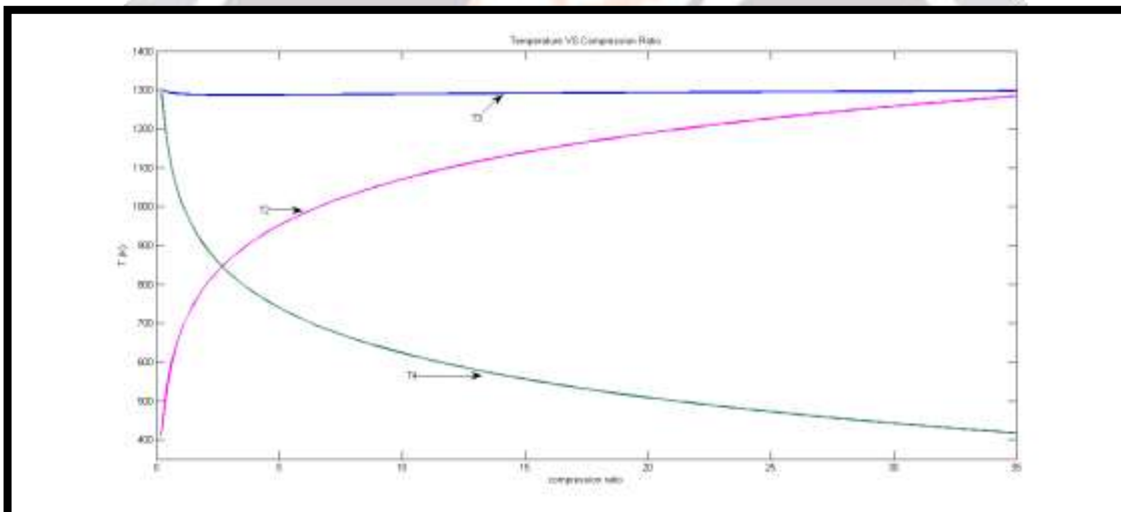

FIGURE 4: TEMPERATURES VERSUS COMPRESSION RATIO BY CODING

3.1.1 CONCLUSION

The variations in the temperatures T2, T3 and T4 with the compression ratio are shown in fig a, one can see that T3 and T4 decrease with the increase of compression ratio, and T2 increases with the increase of compression ratio. Also there are two special states: 1. With Gamma=1, and in this case T4=T3 and T2=T1 hold, 2. With Gamma=34.5, and in this case T4=T1 and T2=T3 hold. In this two special states, the power output of the cycle is zero.

3.2 POWER VERSUS COMPRESSION RATIO

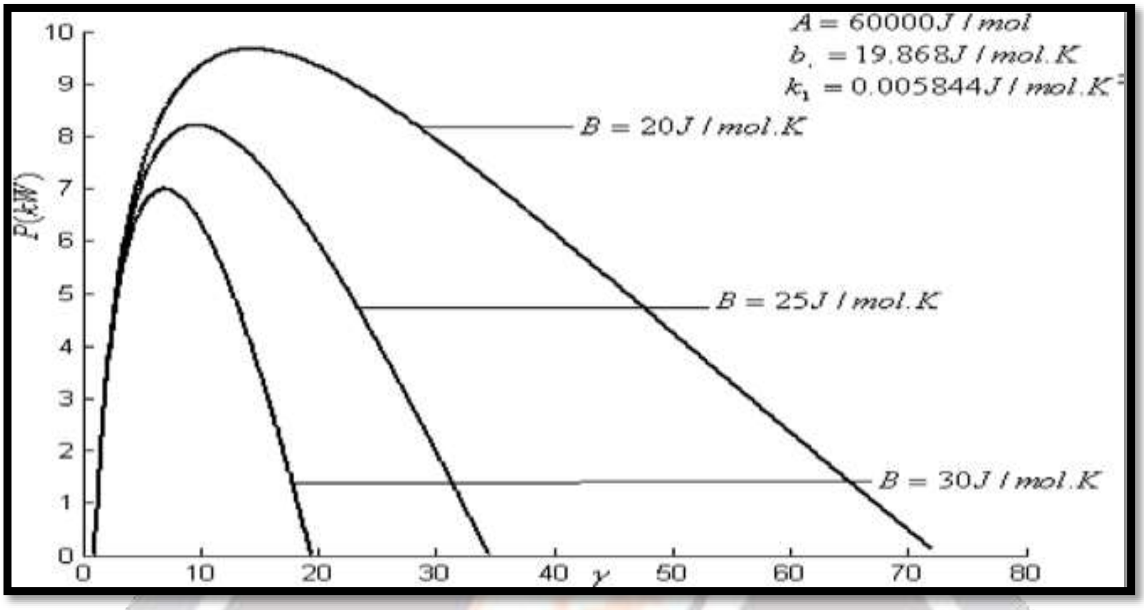

FIGURE 5: POWER VERSUS COMPRESSION RATIO (THE INFLUENCES OF B ON THE POWER BY RP

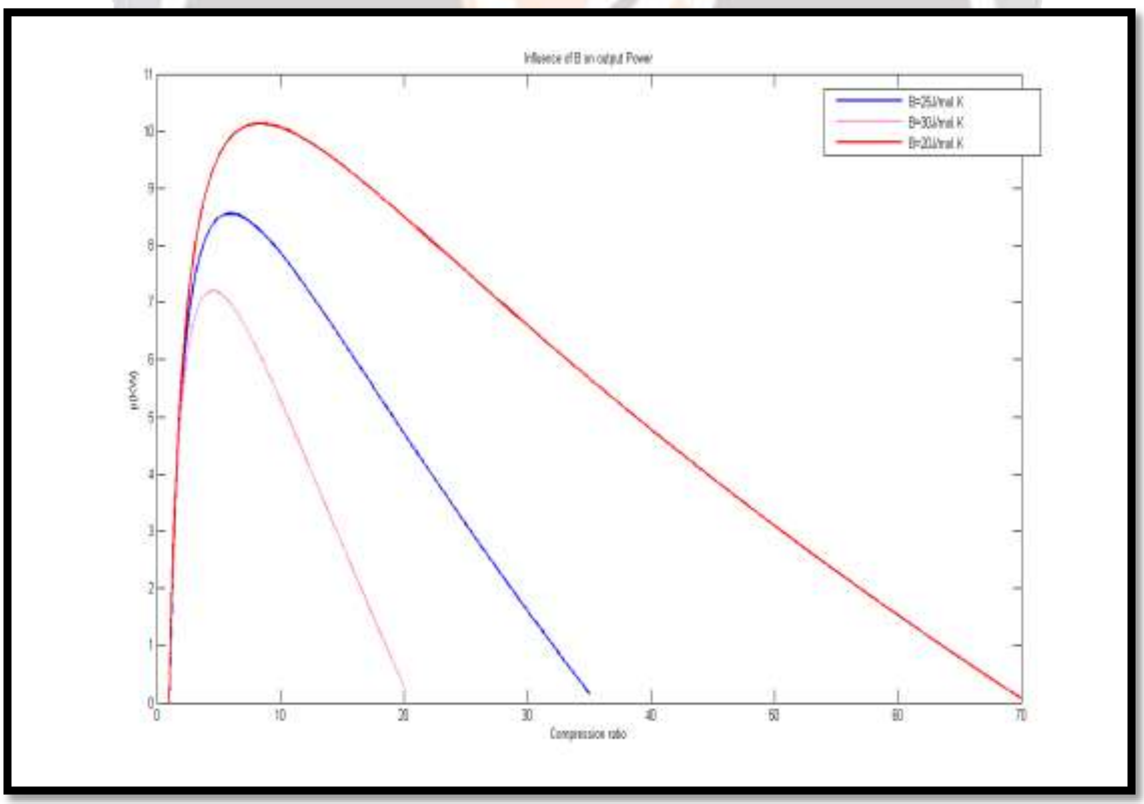

FIGURE 6: POWER VERSUS COMPRESSION RATIO BY CODING (THE INFLUENCES OF B THE POWER O/P)

3.3 POWER OUTPUT VERSUS EFFICIENCY

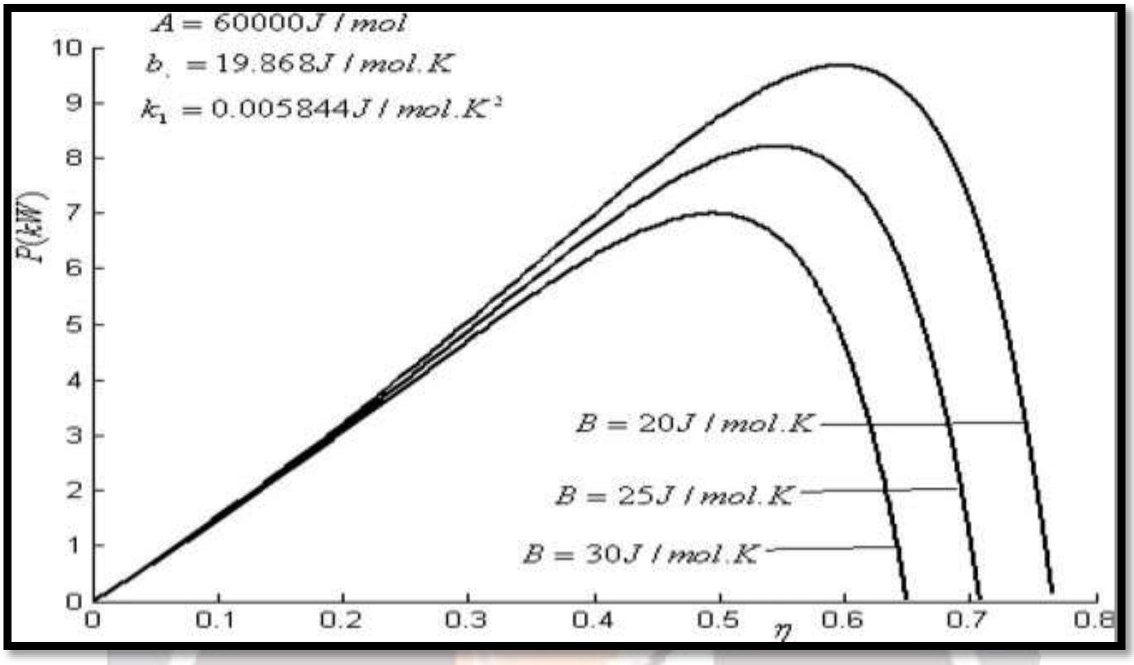

FIGURE 7: THE INFLUENCES OF B ON THE POWER O/P VERSUS EFFICIENCY CHARACTERISTIC BY RP

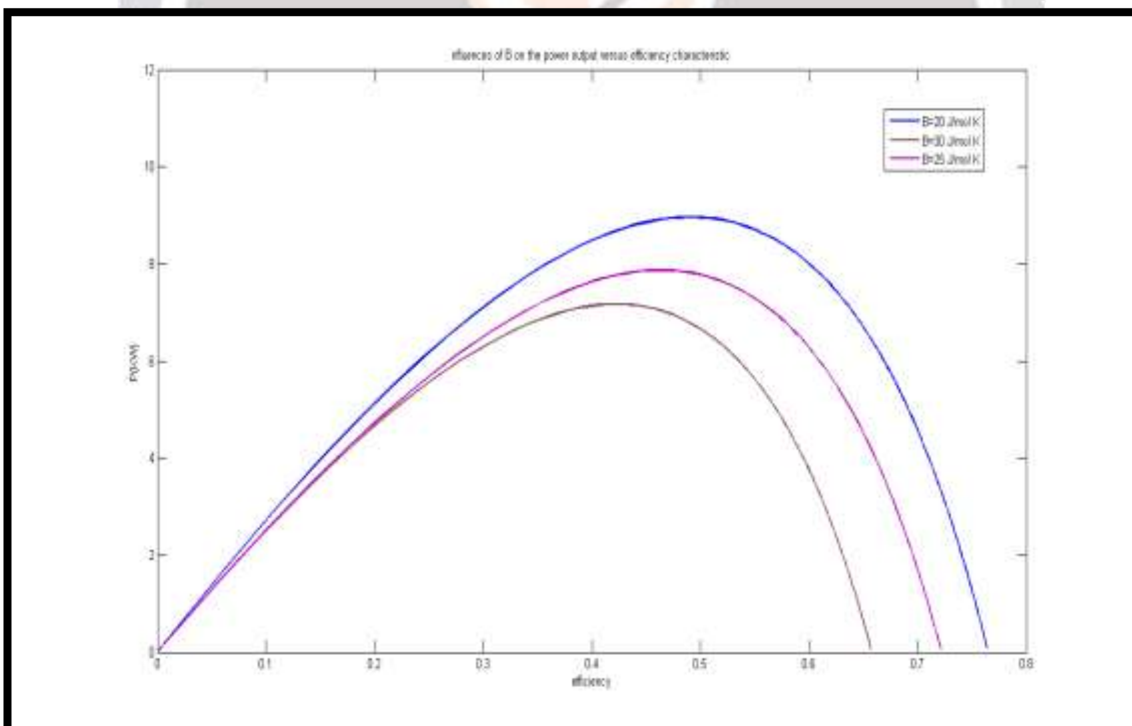

FIGURE 8: INFLUENCES OF B ON THE POWER O/P VERSUS EFFICIENCY CHARACTERISTIC BY CODING

3.4 POWER OUTPUT VERSUS COMPRESSION RATIO

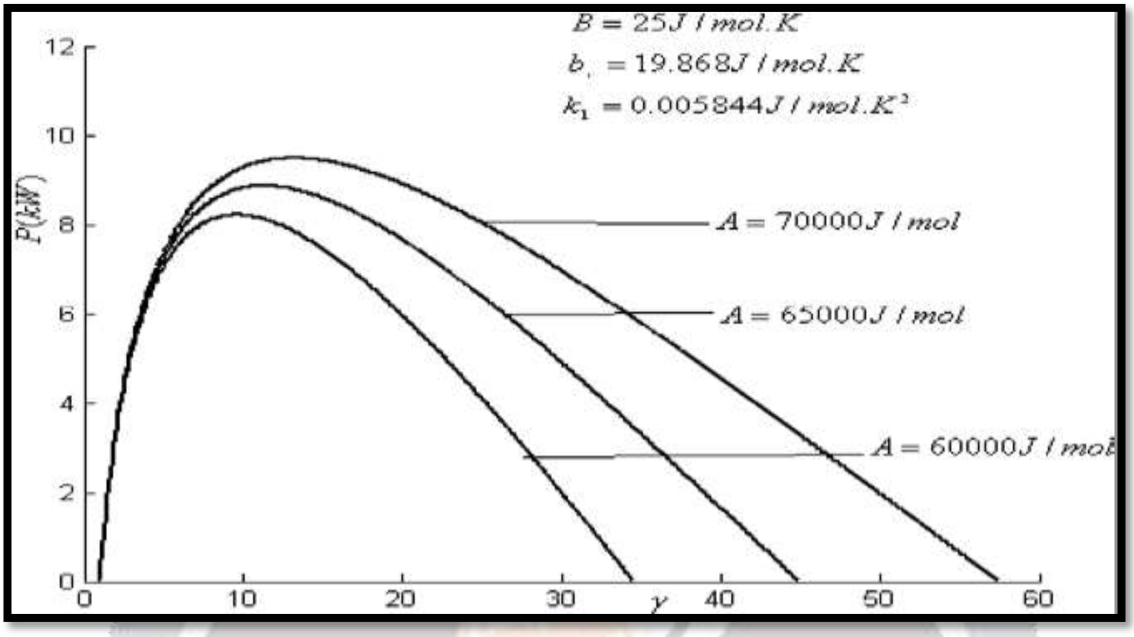

FIGURE 9: THE INFLUENCES OF A ON THE POWER OUTPUT VERSUS COMPRESSION RATIO BY RP

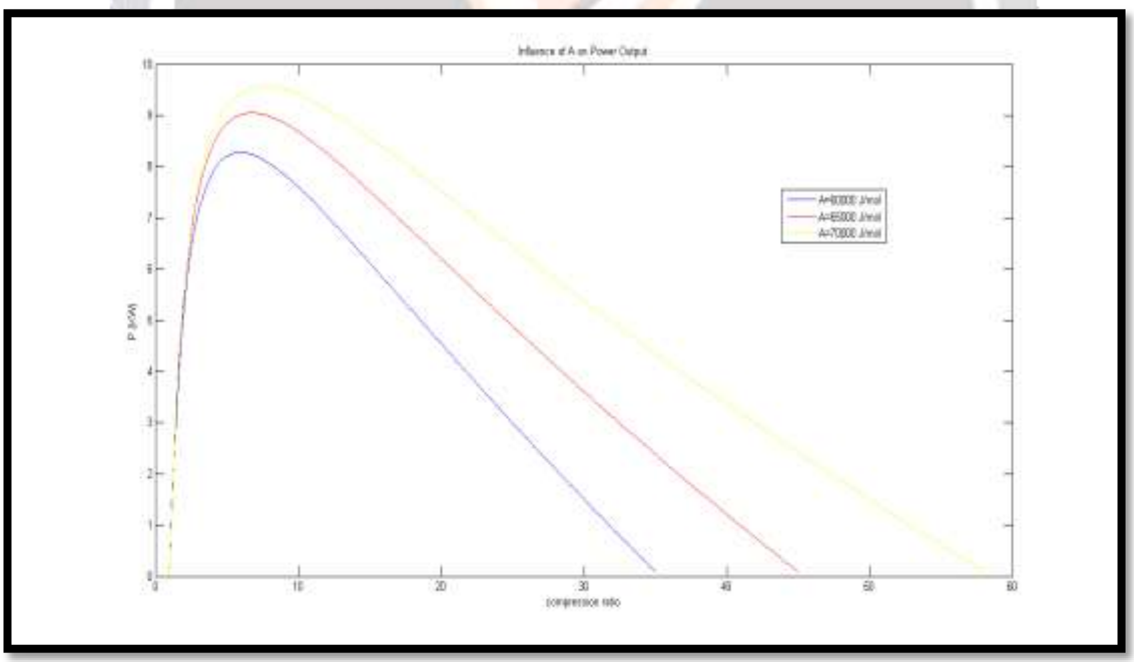

FIGURE 10: THE INFLUENCES OF A ON THE POWER OUTPUT VERSUS COMPRESSION RATIO BY CODING

3.5 POWER OUTPUT VERSUS EFFICIENCY

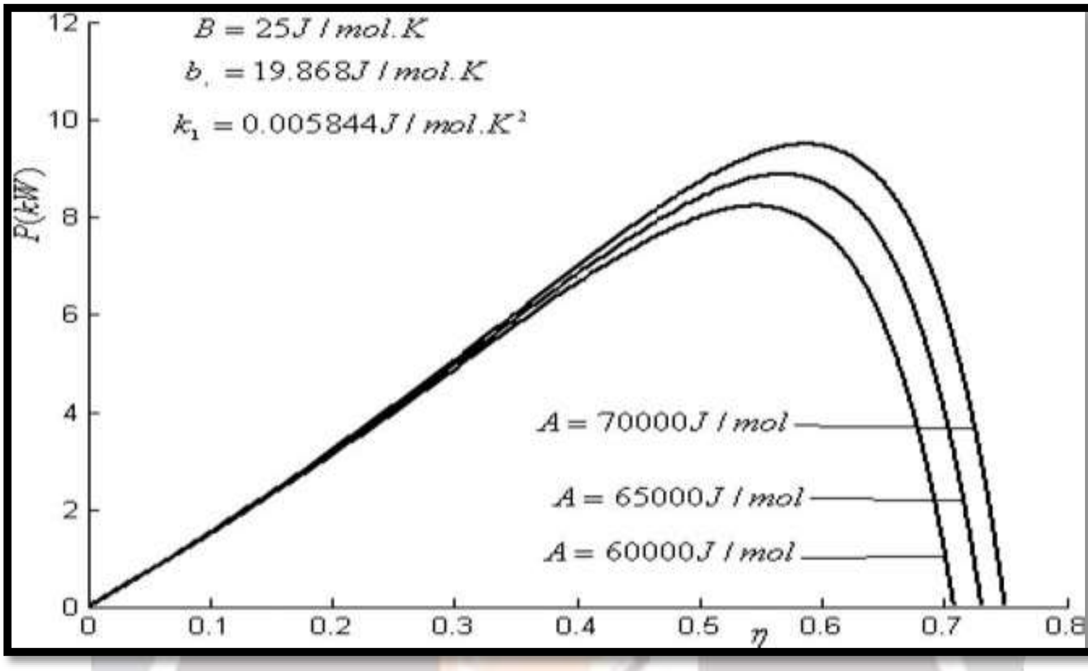

FIGURE 11: THE INFLUENCES OF THE POWER OUTPUT VERSUS EFFICIENCY CHARACTERISTIC BY RP

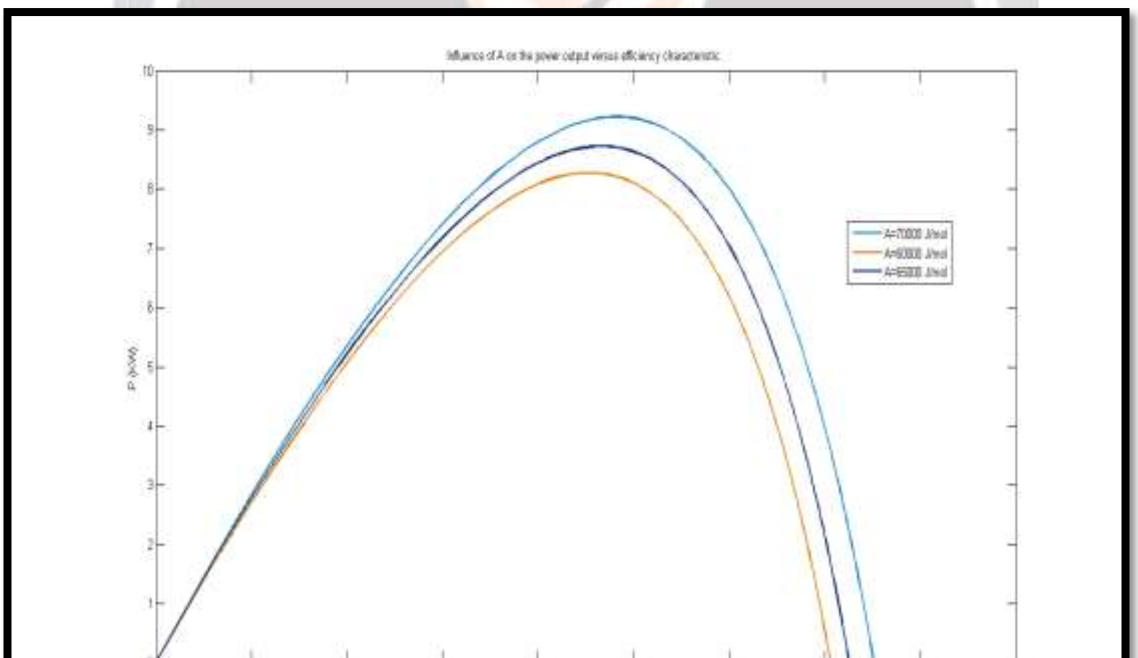

FIGURE 12: THE INFLUENCES OF A ON THE POWER O/P VERSUS EFFICIENCY CHARACTERISTIC BY RP

3.5.2 CONCLUSION

Figs. 5–12 show the effects of the heat transfer loss on the cycle performance. One can see that the power versus compression ratio characteristic and the power versus efficiency characteristic are parabolic-like curves. For any given γ , when the heat transfer loss increases, i.e., A decreases or B increases, the power output, the working range of the cycle, as well as the efficiency at the maximum power point will become smaller. If B increases by about 50%, the maximum power of the cycle decreases by about 28%,and the efficiency at the maximum power point decreases by about 20%. If A decreases by about 14%, the maximum power decreases by about 14%, and the efficiency at the maximum power point decreases about 8%.

3.6 POWER VERSUS COMPRESSION RATIO

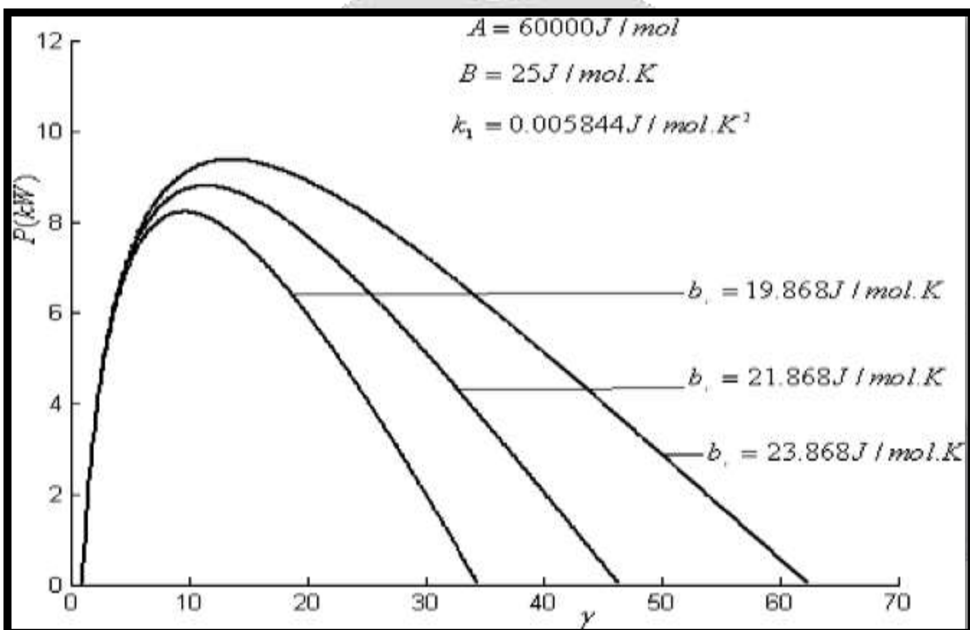

FIGURE 13: THE INFLUENCES OF BV ON THE POWER OUTPUT VERSUS COMPRESSION RATIO BY RP

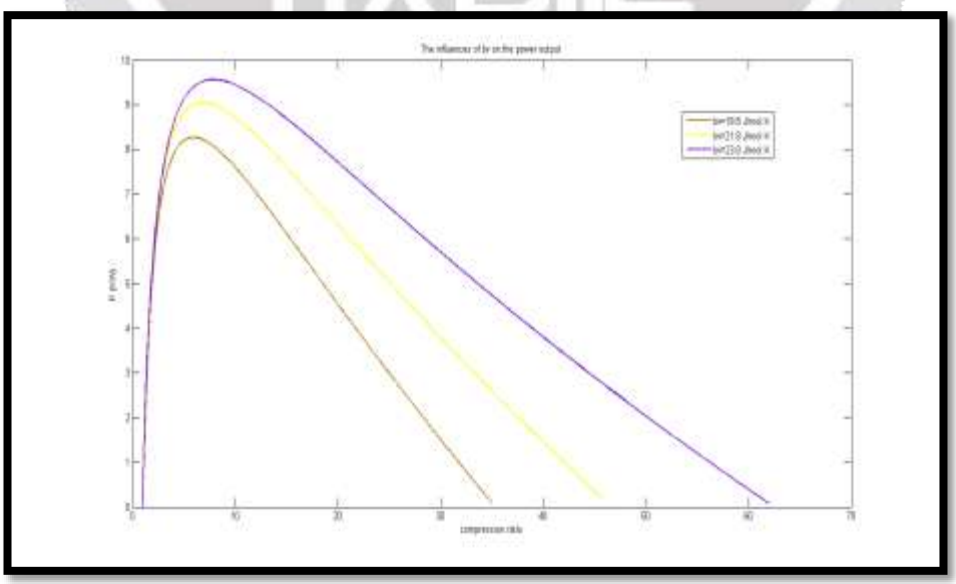

FIGURE 14: THE INFLUENCES OF BV ON THE POWER OUTPUT VERSUS COMPRESSION RATIO BY CODING

3.7 EFFICIENCY VERSUS COMPRESSION RATIO

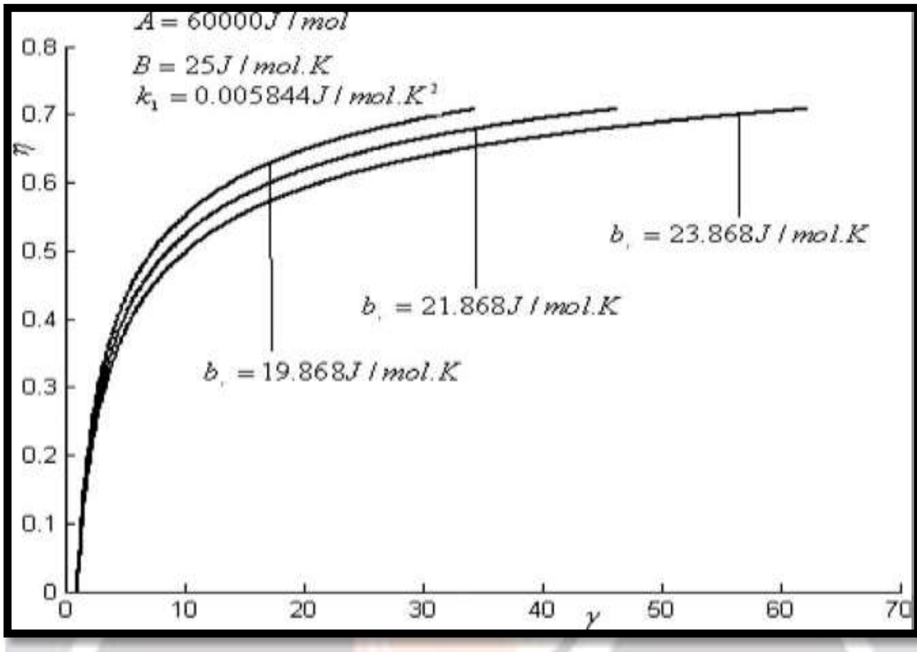

FIGURE 15: THE INFLUENCES OF BV ON THE EFFICIENCY VERSUS COMPRESSION RATIO BY RP

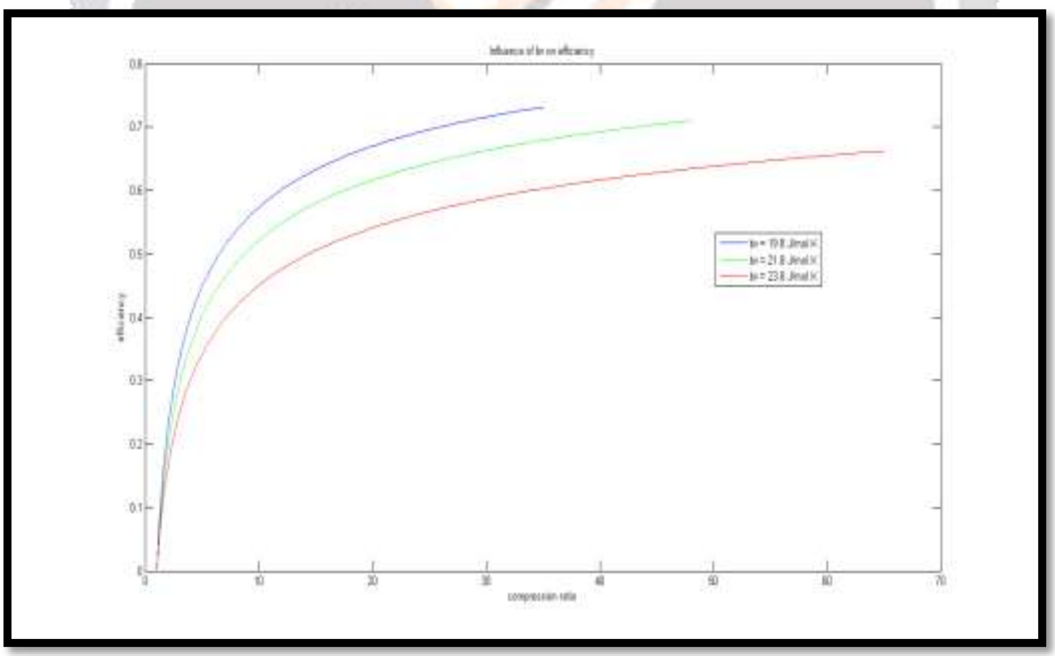

FIGURE 16: THE INFLUENCES OF BV ON THE EFFICIENCY VERSUS COMPRESSION RATIO BY CODING

3.8 POWER OUTPUT VERSUS COMPRESSION RATIO

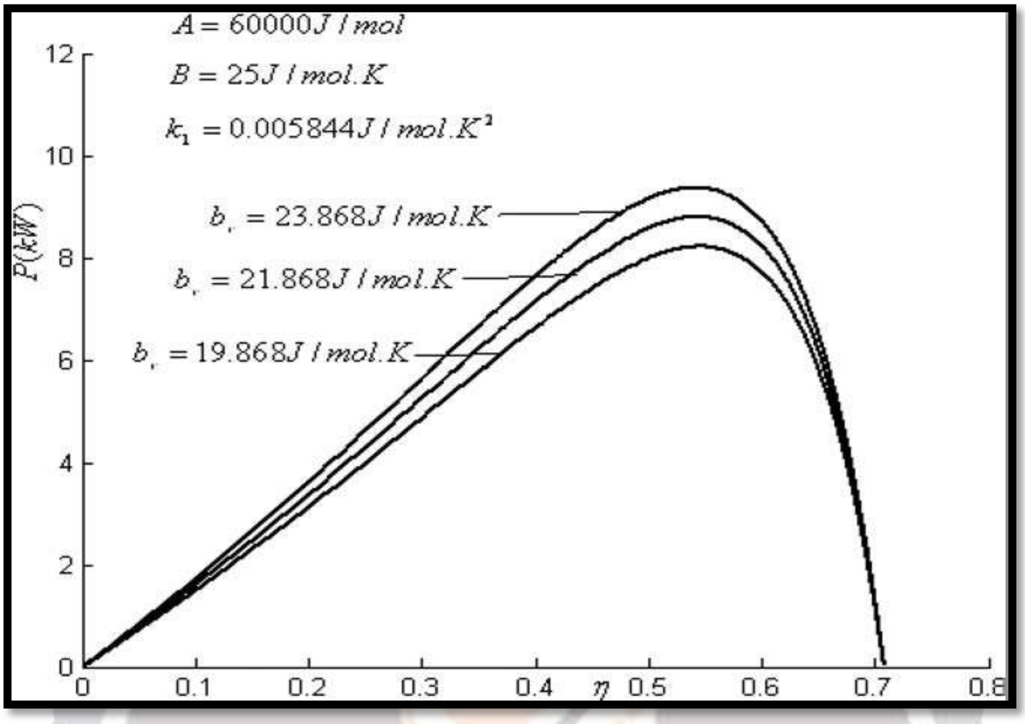

FIGURE 17: THE INFLUENCES OF BV ON THE POWER O/P VERSUS EFFICIENCY CHARACTERISTIC BY RP

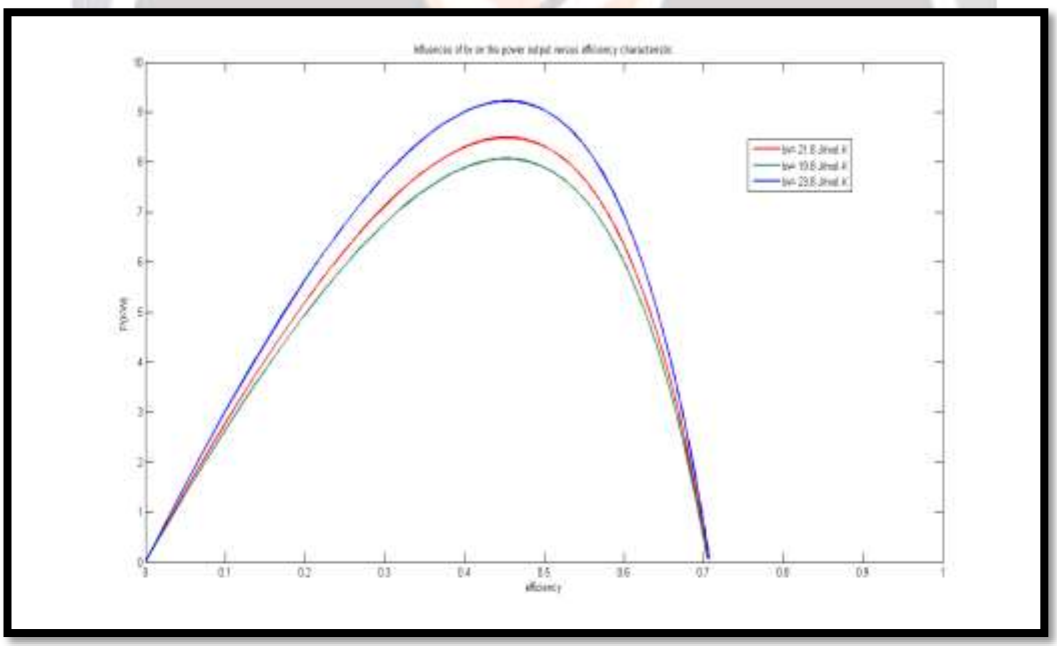

FIGURE 18: THE INFLUENCES OF BV ON THE POWER O/P VERSUS EFFICIENCY CHARACTERISTIC BY CODING

3.8.2 CONCLUSION

Figs. 13–18 reflects the effects of bv on the performance of the cycle.One can see that for any given γ , the power and the workingrange of the cycle decrease with the decrease of bv, whilethe efficiency increases with the decrease of bv. It also canbe found that the decrease of bv almost have no effects onthe efficiency at the maximum power point of the cycle. Ifbv decreases by about 17%, the maximum power decreases by about 14%.

3.9 POWER OUTPUT VERSUS COMPRESSION RATIO

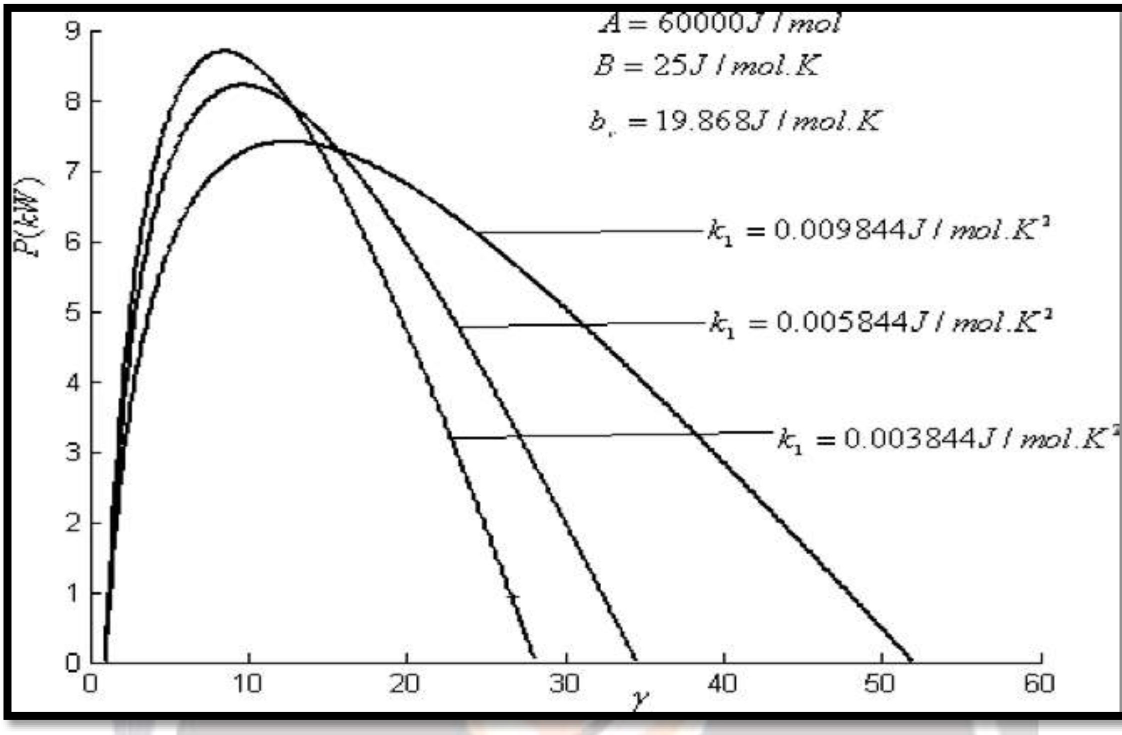

FIGURE 19: THE INFLUENCES OF K1 ON THE POWER OUTPUT VERSUS COMPRESSION RATIO BY RP

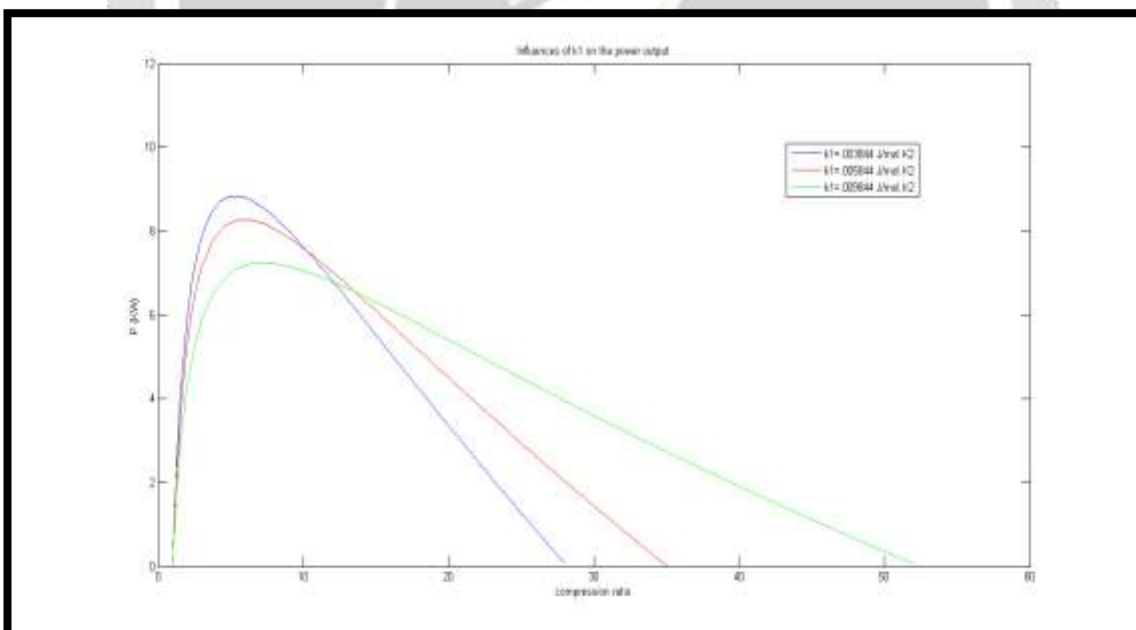

FIGURE 20: THE INFLUENCES OF K1 ON THE POWER OUTPUT VERSUS COMPRESSION RATIO BY CODING

3.10 EFFICIENCY VERSUS COMPRESSION RATIO

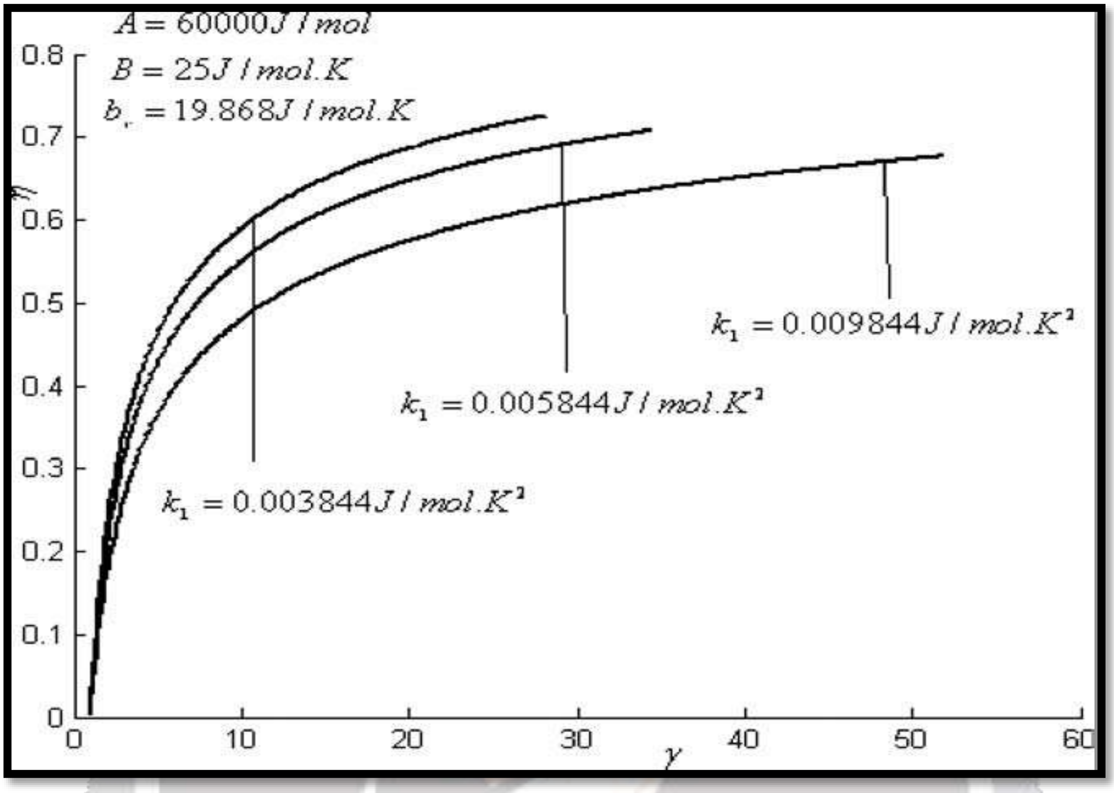

FIGURE 21: THE INFLUENCES OF K1 ON THE EFFICIENCY VERSUS COMPRESSION RATIO BY RP

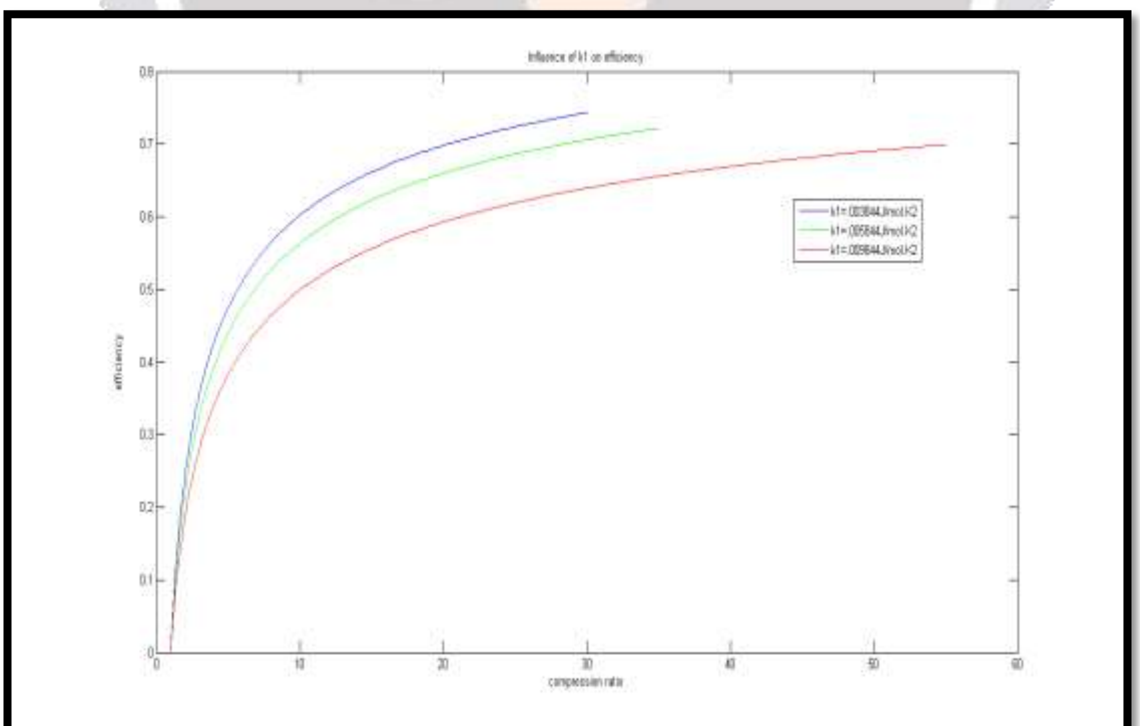

FIGURE 22: THE INFLUENCES OF K1 ON THE EFFICIENCY VERSUS COMPRESSION RATIO BY CODING

3.11 POWER OUTPUT VERSUS EFFICIENCY

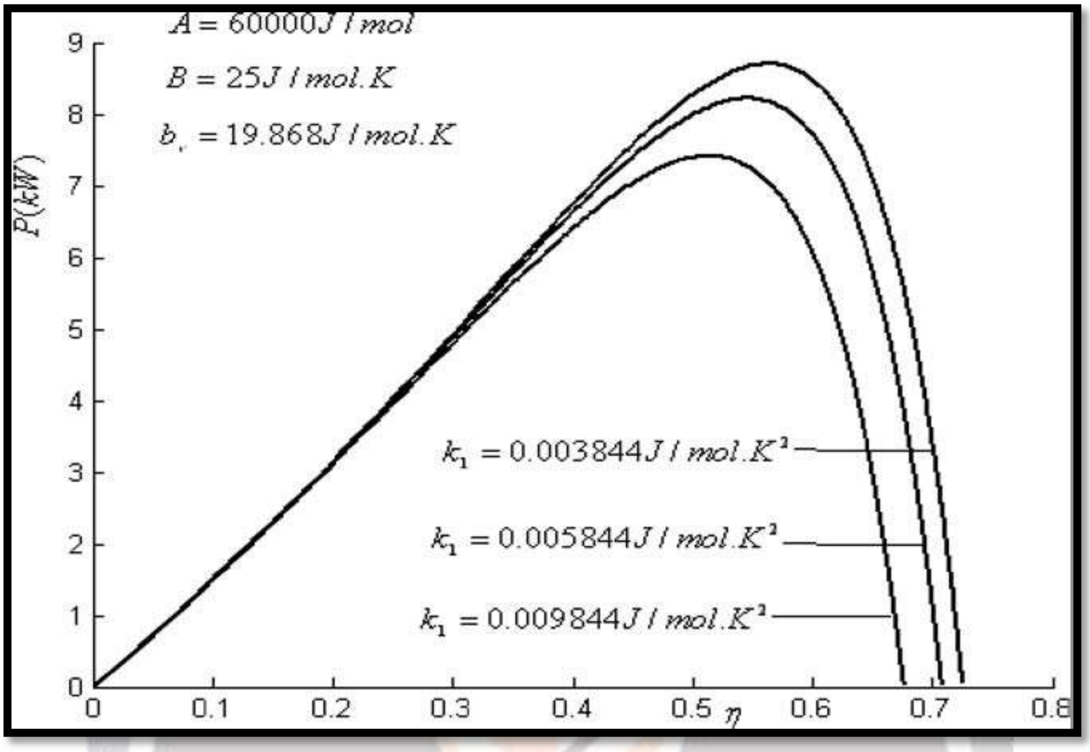

FIGURE 23: THE INFLUENCES OF K1 ON THE POWER O/P VERSUS EFFICIENCY CHARACTERISTIC BY RP

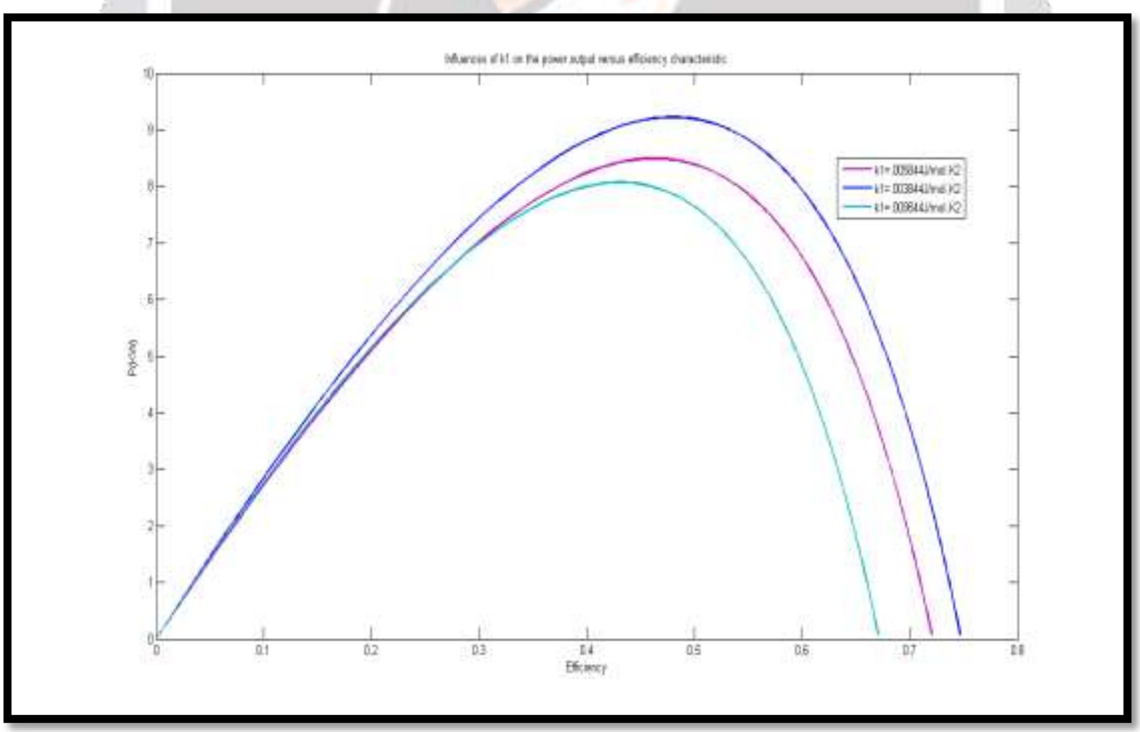

FIGURE 24: THE INFLUENCES OF K1 ON THE POWER O/P VERSUS EFFICIENCY CHARACTERISTIC BY CODING

3.12 POWER OUTPUT VERSUS COMPRESSION RATIO

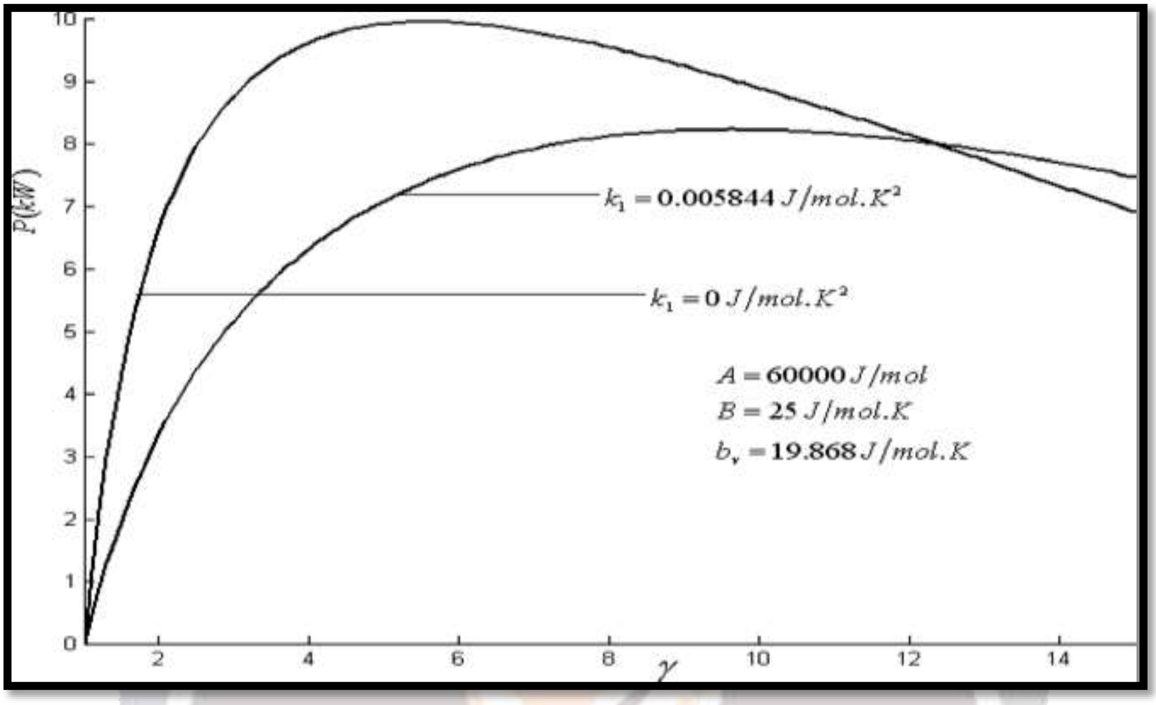

FIGURE 25: THE POWER OUTPUT VERSUS COMPRESSION RATIO WITH AND WITHOUT CONSIDERING VARIABLE SPECIFIC HEATS OF WORKING FLUID.

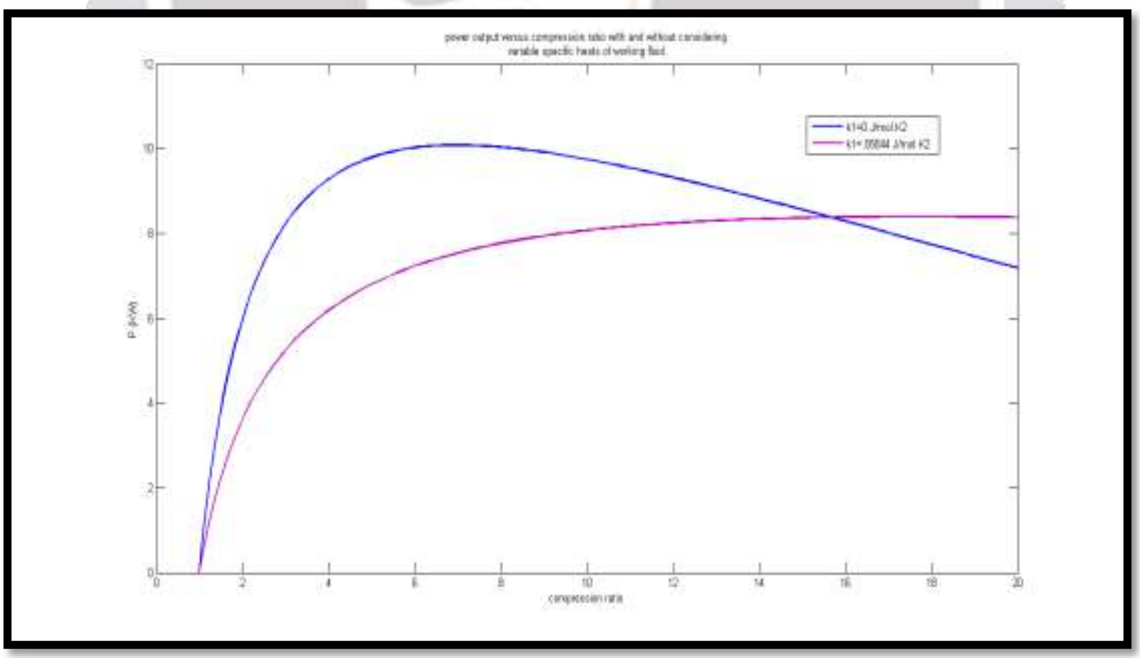

FIGURE 26: POWER OUTPUT VERSUS COMPRESSION RATIO BY CODING

3.12.2 CONCLUSION

Figs. 20-26 show the effects of k1 on the performance of the cycle. It can be found that the effects of k1 on the performance of the cycle is related to compression ratio γ . If γ is less than certain value, the decrease of k1 will make the power bigger, on the contrast, if γ exceeds certain value, the decease of k1 will make the power less. One also can see that the maximum power, and the efficiency at the maximum power point decrease with the decrease of k1. The maximum power increases by about 18% and the efficiency at the maximum power point increases by about 10% if k1increases by about 61%.In order to observe the practice meaning, one can compare the performance of the Otto cycle with constant molar specific heat and variable molar specific heat. Fig.26 shows the power output versus compression ratio characteristic with k1 = 0.005844 J•mol−1•K−2 and k1 = 0 J•mol−1•K−2.One can see that for the case of k1 = 0.005844 J•mol−1•K−2, the optimum compression ratio at maximum power output point is γ ≈ 11. This is consistent with the practical working compression ratio of SI engines, which are between 9.0and 11.5 in general.

4. MODEL FOR OPTIMIZATIONOF IC ENGINE

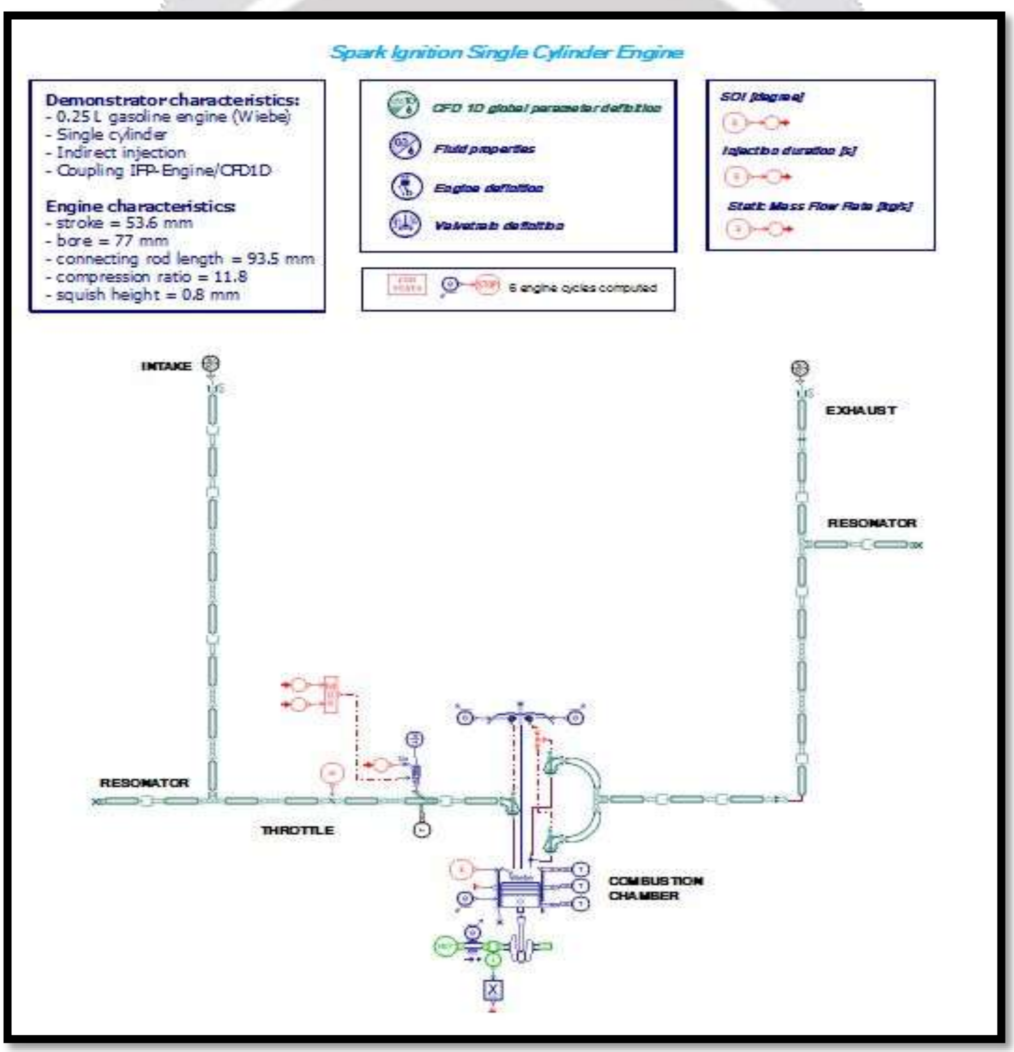

FIGURE 27: MODEL 1 BY SOFTWARE

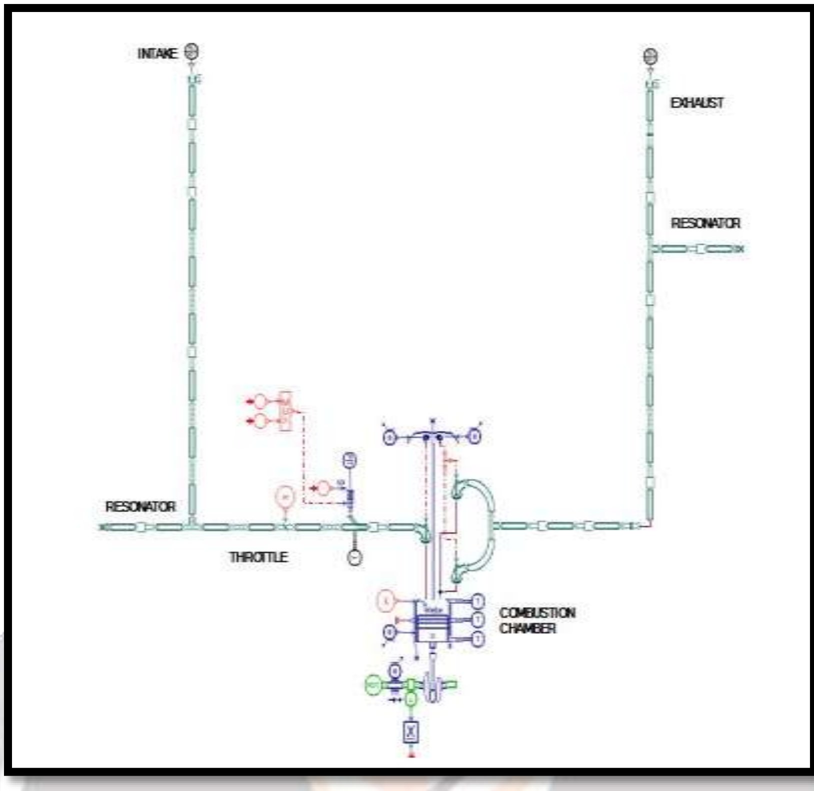

FIGURE 28: MODEL 2 BY SOFTWARE

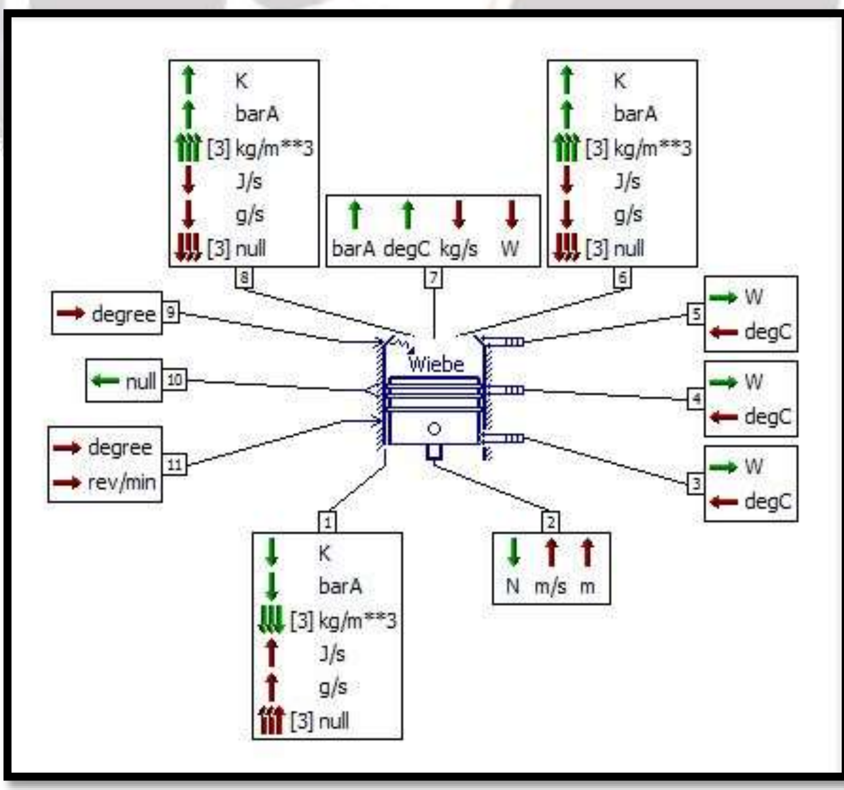

Figure 29: Model 3 by software

5. RESULTS AND DISCUSSION

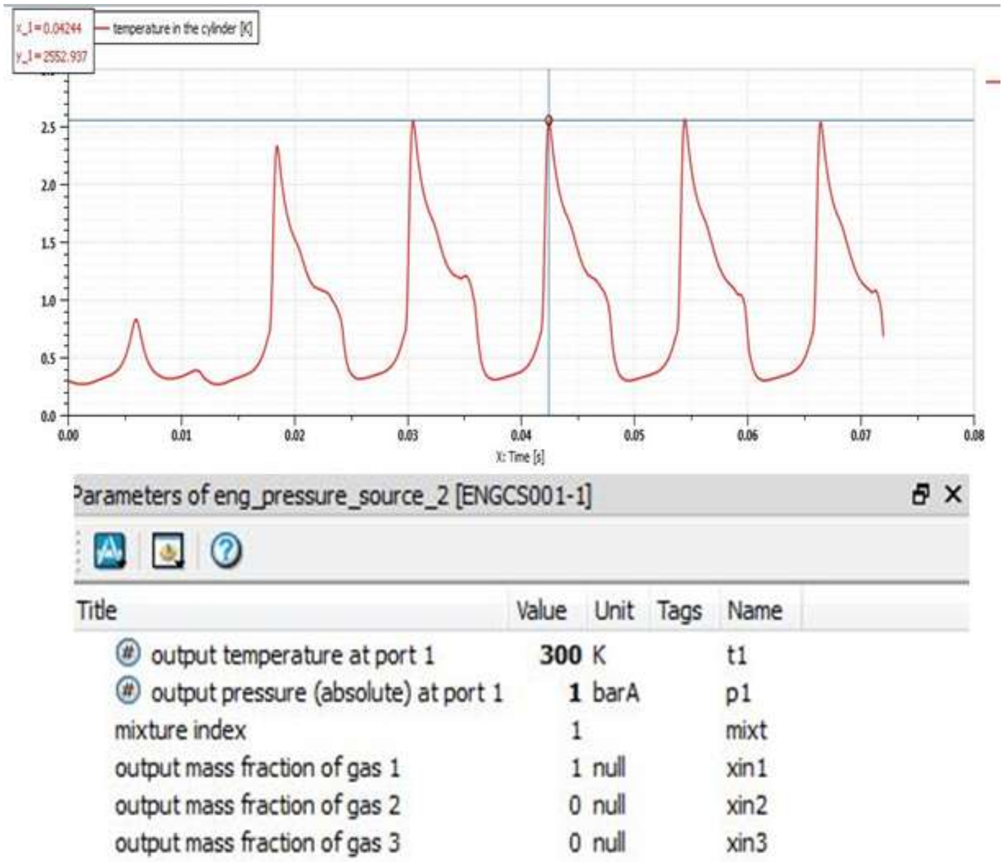

FIGURE 30: FOR INPUT TEMP 300K

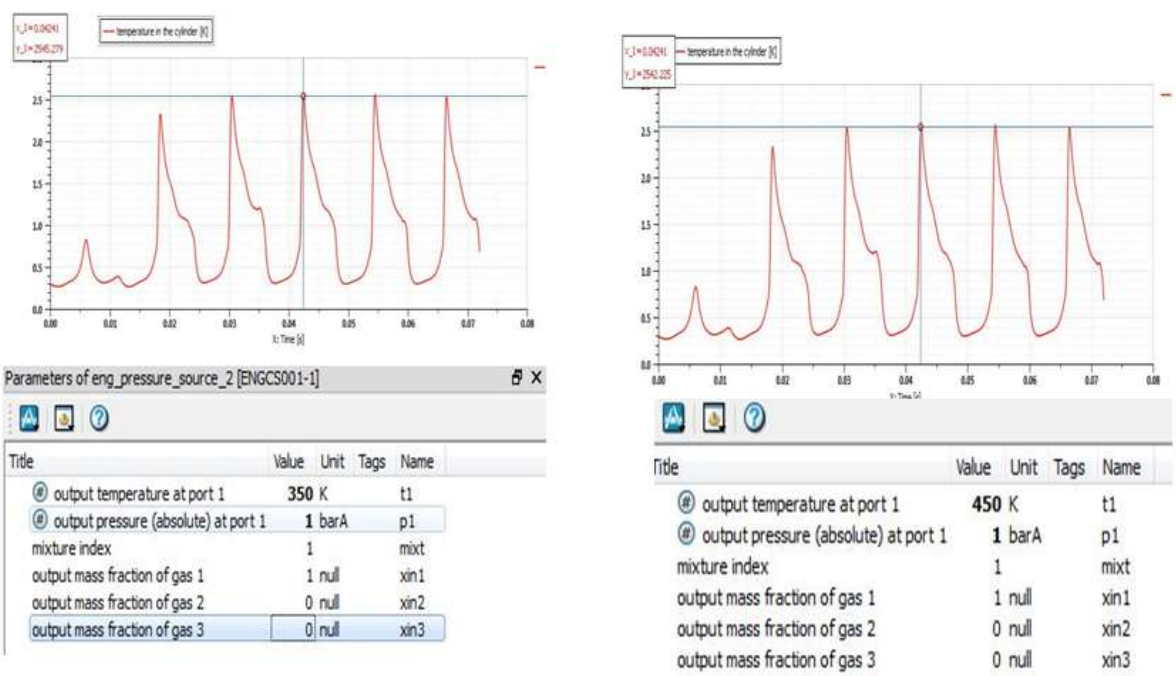

FIGURE 31: FOR INPUT TEMPERATURE OF 350 AND 400K

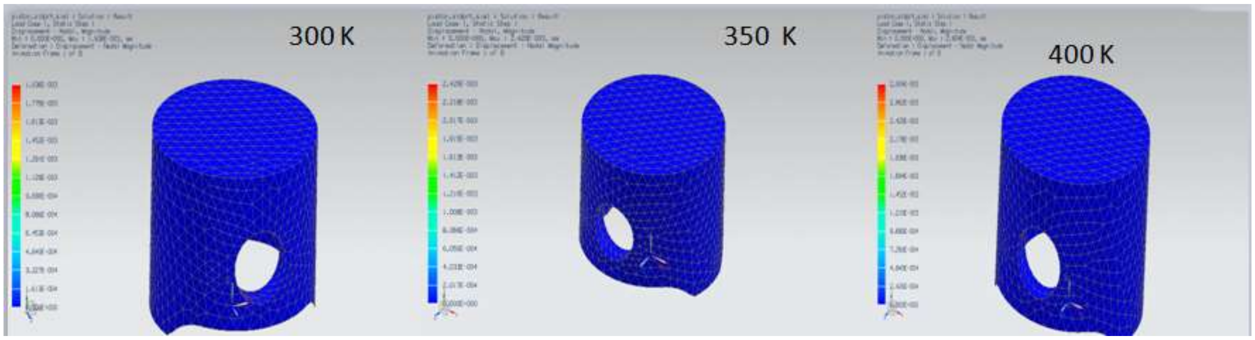

FIGURE 32: TEMPERATURE DISTORTION MODELS

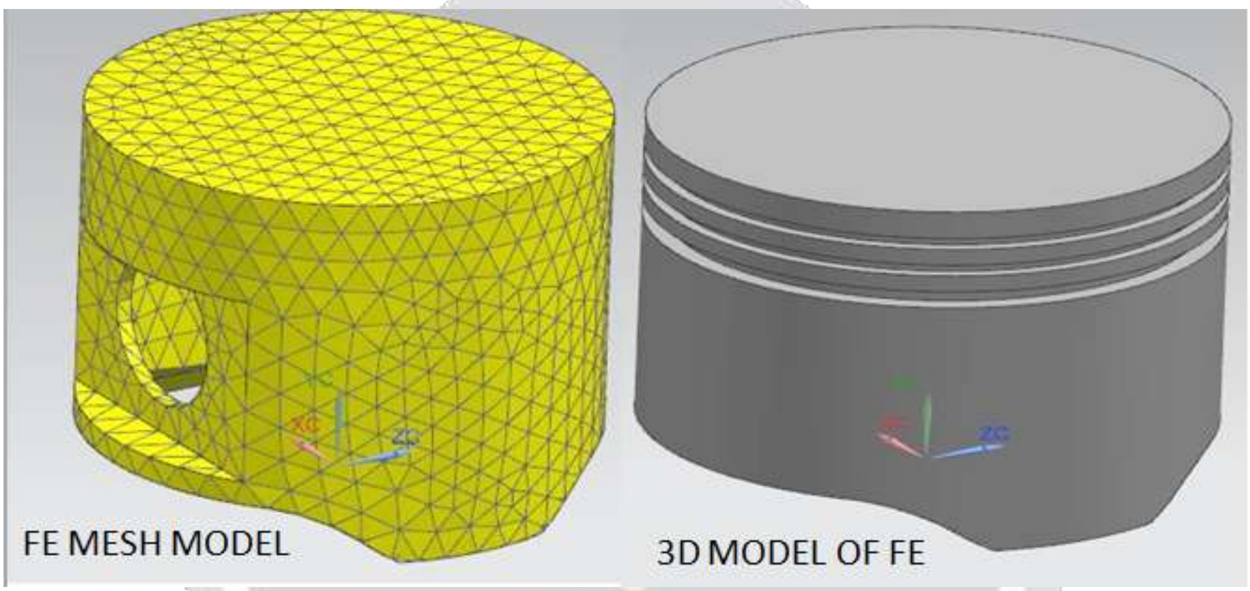

Figure 33: FE MESH MODEL AND 3D MODEL OF FE

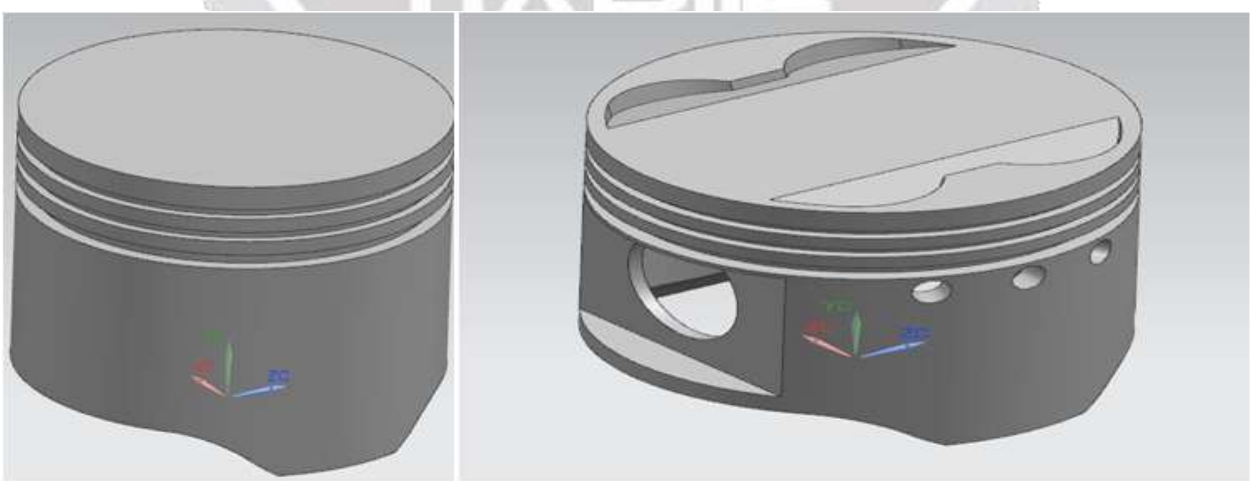

Figure 34: MESH SUMMARY AND PISTON MODEL

6. CONCLUSION

In the presented dissertation, an air standard Otto cycle has been studied for consideration of specific heats of working fluid varying with temperature. The effect of input to output temperature has been analyzed using software. The output temperature is being superimposed on a piston to study thermal distortions. The results indicated that by increasing input temperature of working fluid by 50K the put temperature varies by large amount. This further increases the thermal distortion of piston. The results show that the effects of the heat transfer loss and variable specific heats of working fluid on the cycle performance are obvious and they should be considered in practice cycle analysis. The results obtained in this paper may provide guidance in engine design and can be used as ready reference.

7. REFERENCES

[1]. Yanlin Ge et al. "Thermodynamic simulation of performance of an Otto cycle with heat transfer and variable specific heats of working fluid" International Journal of Thermal Sciences 44 (2005) 506–511.
[2]. Mohamad Hashemi Gahruei et al. "Mathematical Modelling and comparison of air standard Dual and Dual-Atkinson cycles with friction, heat transfer and variable specific-heats of the working fluid" Applied Mathematical Modelling 37 (2013) 7319–7329.
[3]. Lingen Chen et al. "Effects of heat transfer, friction and variable specific heats of working fluid on performance of an irreversible dual cycle" Energy Conversion and Management 47 (2006) 3224–3234.
[4]. V. Esfahanian et al. "Thermal analysis of an SI engine piston using different combustion boundary condition treatments" Applied Thermal Engineering 26 (2006) 277–287.
[5]. Yingru Zhao et al. "Optimum performance analysis of an irreversible Diesel heat engine affected by variable heat capacities of working fluid" Energy Conversion and Management 48 (2007) 2595–2603.
[6]. E. Abu-Nada et al. "Thermodynamic modelling of spark-ignition engine: Effect of temperature dependent specific heats" International Communications in Heat and Mass Transfer 33 (2006) 1264–1272.
[7]. Shuhn-Shyurng Hou et al. "Heat transfer effects on the performance of an air standard Dual cycle" Energy Conversion and Management 45 (2004) 3003–3015.
[8]. Yanlin Ge et al. "Finite-time thermodynamic modeling and analysis of an irreversible Otto-cycle" Applied Energy 85 (2008) 618–624.
[9]. Jiming Lin et al. "Finite-time thermodynamic modelling and analysis of an irreversible Miller cycle working on a four-stroke engine" International Communications in Heat and Mass Transfer 54 (2014) 54–59.
[10]. Yanlin Ge et al. "Finite-time thermodynamic modelling and analysis for anirreversible Dual cycle" Mathematical and Computer Modelling 50 (2009) 101108.
[11]. Zhijun Wu et al. "Thermal efficiency boundary analysis of an internal combustion Rankine cycle engine" Energy 94 (2016) 38e49.
[12]. Chao Wang et al. "Comparison of air-standard rectangular cycles with different specific heat models" Applied Thermal Engineering 109 (2016) 507–513.
[13]. T.M. Yunus khan et al. "Effects of engine variables and heat transfer on the performance of biodiesel fueled IC engines " Renewable and Sustainable Energy Reviews 44 (2015) 682–691
[14]. Rahim Ebrahimi et al. "effect of specific heat ratio on the power output and efficiency characteristics for a irreversible dual cycle" Journal of American science (2010) 6-2
[15]. Jerald A. Caton et al. "On the importance of specific heats as regards efficiency increases for highly dilute IC engines" Energy Conversion and Management 79 (2014) 146–160
[16]. Zhijun Wu et al. "Thermal efficiency boundary analysis of an internal combustion Rankine cycle engine" Energy 94 (2016) 38e49
[17]. R. Ebrahimi et al. "Effect of specific heat ratio on heat release analysis in a spark ignition engine" Scientia Iranica B (2011) 18 (6), 1231–1236
[18]. Bilge Albayrak Ceper et al. "Performance and emission characteristics of an IC engine under SI, SICAI and CAI combustion modes" Energy xxx (2016) 1e8
[19]. A Text Book of Thermal Engineering by author Domkundaval