

GLOBAL JOURNAL

OF RESEARCHES IN ENGINEERING : A MECHANICAL AND MECHANICS ENGINEERING

DISCOVERING THOUGHTS AND INVENTING FUTURE



HIGHLIGHTS

Reforming and Compression Ratio

Piping of an Ethylene Compressor

Determination of Flux Consumption

Operation Fuelled with Ethanol

Assembly Line

Volume 12

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Theoretical Investigation Over the Effects of EGR, Fuel Reforming and Compression Ratio on the HCCI Engine Operation Fuelled with Ethanol

By Alireza Rahbari, Ahmad Afsari, Bamdad Barari & Iman Rostamsowlat

Iran University of Science and Technology, Tehran, IRAN

Abstract - HCCI engines have great potentials in high efficiency with ultra-low NO and particulates emissions and high flexibility in using various fuels. They operate on the basis of auto-ignition and therefore the fuel chemical kinetic is the main ignition controller. Thus initiation of combustion is a determining parameter in the prediction of combustion behavior. The main focus of the present study is to comprehensively investigate the impact of exhaust gas recirculation, fuel reforming and compression ratio on the combustion behavior of HCCI engines using ethanol as fuel. Results show that the increase of EGR delays the ignition timing, slows down the combustion reaction rate and reduces the temperature and pressure in cylinder. Also associating with the effect of exhaust gas fuel reforming, it is shown that hydrogen in the form of reformed gas helps in lowering the intake temperature required for stable HCCI operation. Also, the addition of hydrogen advances the start of combustion in the cylinder. Consequently, it is elucidated that increasing the compression ratio results in advancing the ignition timing, decreasing the burn duration and increasing the temperature and pressure. It is worth noting that the obtained results from the present model have the great compatibility with experimental data.

Keywords : *HCCI Engine, Ethanol, Exhaust Gas Recirculation, Fuel Reforming, Compression Ratio.*

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Theoretical Investigation Over the Effects of EGR, Fuel Reforming and Compression Ratio on the HCCI Engine Operation Fuelled with Ethanol

Alireza Rahbari ^α, Ahmad Afsari ^σ, Bamdad Barari ^ρ & Iman Rostamsowlat ^ω

Abstract - HCCI engines have great potentials in high efficiency with ultra-low NO and particulates emissions and high flexibility in using various fuels. They operate on the basis of auto-ignition and therefore the fuel chemical kinetic is the main ignition controller. Thus initiation of combustion is a determining parameter in the prediction of combustion behavior. The main focus of the present study is to comprehensively investigate the impact of exhaust gas recirculation, fuel reforming and compression ratio on the combustion behavior of HCCI engines using ethanol as fuel. Results show that the increase of EGR delays the ignition timing, slows down the combustion reaction rate and reduces the temperature and pressure in cylinder. Also associating with the effect of exhaust gas fuel reforming, it is shown that hydrogen in the form of reformed gas helps in lowering the intake temperature required for stable HCCI operation. Also, the addition of hydrogen advances the start of combustion in the cylinder. Consequently, it is elucidated that increasing the compression ratio results in advancing the ignition timing, decreasing the burn duration and increasing the temperature and pressure. It is worth noting that the obtained results from the present model have the great compatibility with experimental data.

Keywords : HCCI Engine, Ethanol, Exhaust Gas Recirculation, Fuel Reforming, Compression Ratio.

1. INTRODUCTION

Homogenous charge compression ignition (HCCI) engines are being actively developed worldwide as they can have efficiencies close to that of diesel engines, with low levels of oxides of nitrogen (NO_x) and particulate matter (PM) emissions.¹ In addition, HCCI engines have been shown to operate with a range of fuels including ethanol.² Research on alternative renewable fuels has become very important worldwide due to concerns about the effects of fossil fuel usage on global warming.³ Ethanol is a renewable fuel when it is produced from non-petroleum based

products.⁴ Megaritis *et al.*,⁵ investigated the effect of water blending on bioethanol HCCI combustion with forced induction and residual gas trapping. Rahbari and Mozafari,⁶ used two step reaction mechanisms in order to model HCCI engines using ethanol as a fuel and also the performance prediction and in-cylinder heat transfer were calculated.

Controlling the combustion phenomenon in HCCI engines is one of the most challenging and demanding issues and the important factors in controlling the combustion phenomenon of HCCI engine are the ignition timing and operating range which is limited to low load because of knocking and misfiring. Several control techniques have been proposed by researchers to control the combustion phase of HCCI engines such as inlet air heating, supercharging, equivalence ratio, EGR, fuel reforming and compression ratio. These techniques depend on engine or fuel types and operating conditions. Associating with these controlling strategies, Martinez-Frias *et al.*,⁷ elaborated the ignition timing control system that involved varying the intake temperature of an HCCI engine. Their control system consisted of an exhaust-fresh charge heat exchanger, a supercharger, an EGR addition valve, and an intercooler. Chen and Milovanovic,⁸ studied the effect of EGR on the combustion of HCCI engine fuelled with methane. It was found that the thermal energy contained in the EGR is essential for the combustion initiation.

Then, Dec,⁹ used Chemkin to explore the bulk generation of CO and HC at low loads and to identify the physical mechanisms by which EGR influenced the energy release rate. Yap *et al.*,¹⁰ investigated the application of bioethanol HCCI operation on a gasoline type engine, in conjunction with residual gas trapping. Then he explored two different approaches to achieve HCCI with bioethanol namely, trapping of internal residual gas and intake temperature heating with a high compression ratio.¹¹ Kim and Lee,¹² recently investigated partial HCCI combustion as a control mechanism for HCCI combustion. Cooled EGR was introduced for the suppression of advanced auto-ignition of the premixed fuel. The results showed that a simultaneous decrease of NO_x and soot was obtained by increasing the premixed ratio. Dubreuil *et al.*,¹³

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studied the effect of the addition of variable initial NO concentration. A detailed kinetic model was performed to rationalize the results. Experiments were also performed using a HCCI engine to characterize the effect of EGR rates with NO addition.

Megaritis *et al.*,¹⁴ investigated the Effect of inlet valve timing and water blending on bioethanol HCCI combustion with forced induction and residual gas trapping which resulted in a greatly extended engine load range compared to normal aspiration operation.¹⁵ In the recent study, Rahbari,¹⁶ studied the effect of EGR on HCCI combustion characteristics such as ignition timing, burn duration, temperature, pressure and NOx emission containing ethanol as fuel. In addition, Jothi *et al.*,¹⁷ experimentally investigate the effect of EGR on a 100% Liquefied Petroleum Gas (i.e., LPG) fueled HCCI engine throughout the load spectrum.

Fuel reforming refers to the dissociation of the hydrocarbon fuel into CO and H₂ and the effect of this phenomenon is less studied by the researchers.¹⁸ The addition of hydrogen to the main hydrocarbon fuel is reported to be beneficial in terms of brake power, thermal efficiency and reduction of HC, CO, CO₂ and particulates in.¹⁹ Another important parameter is the use of different engine exhaust gas temperatures and compositions due to different engine conditions requires adjustments of the reactant flows in the reforming process, so that both maximum hydrogen production and process efficiency can be achieved.²⁰

Hosseini and Checkel,²¹ performed a series of experimental studies using reformer gas blending to control ignition timing with three base fuels: n-Heptane, isooctane, and natural gas. It was found that, reformer gas blending could provide combustion timing control despite the wide range of reformer gas composition. Rahbari *et al.*,²² studied the role of fuel reforming on the combustion characteristics of the HCCI engines fuelled with ethanol. Tsolakis *et al.*,²³ documented the application of exhaust gas fuel reforming of two alternative fuels, biodiesel and bioethanol. The benefits of exhaust gas fuel reforming were demonstrated by adding simulated reformed gas to HCCI engine fuelled by bioethanol.

Another key parameter in controlling the HCCI engines is the role of compression ratio. In relation to the importance of the controlling factors, the comprehensive investigation is recently done by Machrafi and Cavadiasa,²⁴ over the effects of the inlet temperature, the equivalence ratio and the compression ratio on the pressure, the heat release and the ignition delays. These three parameters appeared to decrease the ignition delays, with the inlet temperature having the least influence and the compression ratio the most.

In this research after following the comprehensive study on the HCCI engines fuelled with ethanol with the emphasis on the role of EGR, fuel reforming and compression ratio on the combustion

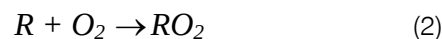
characteristics. Therefore, this study is followed by a computational model using a mechanism containing ethanol reactions and the governing equations consist of conservation of mass, conservation of energy, conservation of species and heat transfer phenomena are simultaneously solved. This theoretical model declares the effects of these parameters on the in-cylinder pressure and temperature, ignition timing and burn duration. The result obtained from the model has been compared with the experimental data published in the literature and the comparison showed a reasonable compatibility.

II. CHEMICAL KINETICS OF AUTO-IGNITION

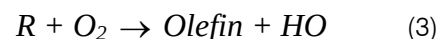
In general, the chemical reaction of fuel and air is initiated by:²⁵



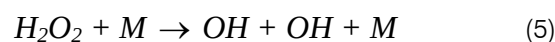
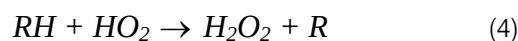
Auto-ignition of hydrocarbons occurs when chain branching processes become significant. At lower temperatures, reaction (2) produces chain branching precursors which can be decomposed by the temperature above 800K.²⁶



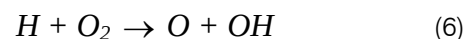
A highly exothermic cycle is initiated by (2) to produce H₂O and an alkylperoxide. The low temperature reactions are terminated when the reaction (3) becomes competitive as temperature rises.



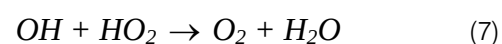
At intermediate temperature 900-1100K, chain branching occurs by:



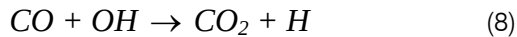
When temperature is reaching up to 1000K, the slightly exothermic reaction (4) is more dominant, thus the temperature and the concentration of H₂O₂ increases steadily. When temperature reaches 1000-1050K, reaction (5) catches up and the concentration of OH increases rapidly. Most OH will react with the fuel molecules, producing water and heat, thus increasing the temperature of the mixture. When the temperature is greater than 1100K, the high temperature chain branching reaction (6) dominates.



In this stage, OROOH and Olefin decompose to HO and CO. Finally, H₂O is formed by:



And CO is converted to CO₂ through:

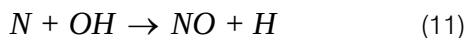
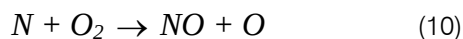
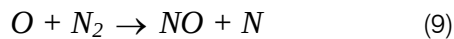


Where (7) and (8) are highly exothermic and release most of the energy.²⁷ In an HCCI engine, auto-ignition first occurs at local in-homogeneities which overcome their threshold energies to the chain branching reactions faster due to specific heat differences. This is very similar to the knocking phenomenon in SI engines.

It is recognized in all studies that HCCI combustion can't be initiated at atmospheric temperature, i.e. preheating of the engine mixture is necessary in addition to the temperature rise from compression. The energy released will quickly bring the remainder of the mixture to ignite and gives a very rapid heat release rate.

III. NO FORMATION

The thermal NO route is the major constituent to the NO_x emission and can be described by three elementary reactions, called the extended Zeldovich mechanism:



Reaction (9) has very high activation energy. The triple bond of the N₂ molecule is strong, thus the reaction rate is slow unless the temperature is high.

IV. EFFECT OF EGR

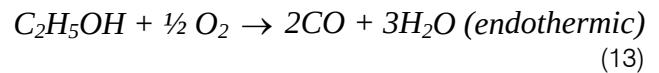
EGR is one of the most important HCCI combustion control mechanisms affecting the auto-ignition timing. In this section, the effects of internal EGR are considered as HCCI combustion controller. EGR is defined as:

$$EGR = \frac{m_e}{m_e + m_f + m_i} \quad (12)$$

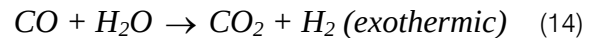
Where m_e is the mass of exhaust gas in one cycle, m_i and m_f are the mass of intake air and fuel respectively in the same cycle. At different engine operating conditions, the amount of EGR was regulated through the EVC timing, which is Exhaust Valve Close timing. The mass of exhaust gas in every cycle was calculated by using the ideal gas law, and the mass of the intake air was measured by the mass flow meter, also the fuel mass was calculated in combined with the intake air mass and Lambda which was get by the oxygen sensor.

V. FUEL REFORMING

Fuel reforming can be used to dissociate hydrocarbons and alcohols into CO and H₂.²⁸ Ethanol, the fuel used in this study, can be reformed into 2 moles of CO and 3 moles of H₂ through the reaction:



Reaction (13) can be further converted to more H₂ and CO₂ through:



Hydrogen has the advantages of relatively wide flammability limits and a higher burning velocity than most hydrocarbons, thus it is often studied as an additive to extend the operating limit of engines.²⁹ Although more hydrogen means a higher heating value of the fuel, further conversion of CO into extra H₂ is found to be unfavorable, because the formation of extra CO₂ will increase the heat capacity and decrease the combustion promotion by hydrogen.

The study by Shudo and Ono,³⁰ found that CO and H₂ in dimethyl ether (DME) are able to increase IMEP and the indicated efficiency. Also, CO and H₂ have lower cetane number and less low temperature reactions compared to DME, therefore decreasing the ratio of DME to CO and H₂ can be used to retard the ignition timing by reducing the low temperature heat release.³¹ When ignition is retarded using H₂, A comparison between the effects of H₂ and CO found that both are equally effective in increasing IMEP, but H₂ is more effective in retarding the ignition timing. In addition, CO is more effective in lowering the unburned HC emissions than H₂ at higher equivalence ratios, because ignition with CO addition is less retarded, so the peak temperature occurs closer to TDC and therefore is higher. In addition, the use of reformed gas to complement the fuel helps to avoid the need for dual fuel storage onboard.

Fuel reforming can be carried out on-board by a catalytic reactor; higher thermal efficiency can be resulted because the endothermic reaction promotes waste heat recovery from the engine exhaust gas. In-cylinder fuel reforming, which makes use of negative valve overlap and direct fuel injection, is a newly researched technique. This technique injects fuel into the in-cylinder residual gas during the negative valve overlap interval. When the fresh intake charge and the trapped exhaust gas are compressed together, the energy supplied by the piston and also the water in the exhaust gas can be used to perform a steam reforming on the intake fuel. This technique has the potential of reducing fuel consumption by optimizing the split ratio between the fuel injected during negative valve overlap and in the take stroke.³²

In this research, in order to simulate the fuel ethanol/air mixture with fuel reforming rate is described reforming effect, the reforming product CO/ H₂- by:

$$(1-y)C_2H_5OH + \frac{3}{\phi} \left[\frac{1}{2}(1-y) \right] O_2 + 2yCO + 3yH_2 + 3/\phi 3.76N_2 \quad (15)$$

Where y is defined as the fraction of ethanol converted into carbon monoxide and hydrogen (e.i. fuel reforming rate). Thus, the role of different fuel reforming rate is obtained by adding the H₂ and CO concentration at the start of the cycle and changing the quantity of y. It is worth noting that equivalence ratio refers to the ethanol/air mixtures before they are mixed with exhaust gas or converted into reforming products.

VI. THEORETICAL EQUATION

In order to define any thermodynamic state within the cylinder, two independent properties and the mixture composition should be known. The general equations governing conservation of mass, species, and energy will be developed for a variable volume reactor, shown in Figure (1). It is assumed that the working fluid behaves as an ideal gas.

a) Conservation of Mass

The rate mass change within any control volume is:

$$m = \sum_{k=1}^K m_k = cte \Rightarrow \frac{dm}{dt} = 0 \quad (16)$$

b) Conservation of Species

Equations tracking the evolution of species within the combustion chamber will be developed on a mass basis corresponding to the definition in Eq. (17).

$$Y_k = \frac{m_k}{m} \quad (17)$$

It must be said that mixing and stratification are important and can be used for controlling HCCI, but in this research, these effects are ignored for simplicity. As a result the rate of heat release is solely depended on the chemical kinetic reaction rates. To model the combustion process of HCCI engine, it is necessary to describe the heat release via a suitable chemical mechanism and a well-matched, stiff chemical kinetic solver. The model includes the effects of heat transfer, for different engine configurations. The rates of creation/destruction of chemical species are modelled using mass-action kinetics and the specific reaction rate constants strongly depend on the temperature. An elementary reaction that involves 'K' chemical species in 'I' reactions can be represented in the form of:

$$\sum_{k=1}^K \nu'_{ki} \chi_k \Leftrightarrow \sum_{k=1}^K \nu''_{ki} \chi_k \quad (18)$$

$$\omega_k = \sum_{i=1}^I \nu_{ki} q_i \quad (19)$$

$$\nu_{ki} = \nu''_{ki} - \nu'_{ki} \quad (20)$$

$$q_i = k_{fi} \prod_{k=1}^K [X_k]^{\nu'_{ki}} - k_{ri} \prod_{k=1}^K [X_k]^{\nu''_{ki}} \quad (21)$$

Where ν_{ki} , χ_k , $\dot{\omega}_k$, q_i , k_{fi} and k_{ri} are the stoichiometric coefficients, the chemical symbol for the k th species, the production rate of the k th species, the rate of progress variable for the i th reaction, the forward and reverse rate constants of the i th reaction respectively. The forward and reverse rate constants of the i th reaction rate could be expressed as:

$$k_{fi} = A_i T^{\beta_i} \exp\left(\frac{-E_i}{R_c T}\right) \quad (22)$$

$$k_{ri} = \frac{k_{fi}}{K_{ci}} \quad (23)$$

$$K_{ci} = K_{pi} \left(\frac{P_{atm}}{RT} \right)^{\sum_{k=1}^K \nu_{ki}} \quad (24)$$

$$K_{pi} = \exp\left(\frac{\Delta S_i^\circ}{R} - \frac{\Delta H_i^\circ}{RT} \right) \quad (25)$$

Where A_i , β_i , E_i and K_{pi} are the pre-exponential factor, temperature exponent, activation energy and the equilibrium constants respectively. The mass conservation equation is employed:

$$\frac{dy_k}{dt} = \frac{\dot{\omega}_k W_k}{\rho} \quad (26)$$

c) Thermodynamic Property Treatment

The working fluid composition in the cylinder is constantly changing. Once at any time the composition is determined, mixture properties can be calculated. This method simply considers thermodynamic properties of the mixture containing residual gas,

exhaust gas recirculation, unburned gaseous fuel and air. For thermodynamic properties such as constant pressure specific heat, enthalpy and entropy, the NASA curve fits in the following forms are used:

$$\frac{C_{pk}^{\circ}}{R} = \sum_{n=1}^5 a_{nk} T^{n-1} \quad (27)$$

$$\frac{h_k^{\circ}}{RT} = a_{1k} + \sum_{n=1}^5 \frac{a_{n,k}}{n} T_k^{n-1} + \frac{a_{6k}}{T_k} \quad (28)$$

$$\frac{S_k^{\circ}}{R} = a_{1k} \ln T_k + \sum_{n=1}^4 \frac{a_{n+1,k}}{n} T_k^n + a_{7k} \quad (29)$$

d) Conservation of Energy

The generalized energy equation for a thermodynamic control volume may be written as:

$$\dot{T} = \sum_{k=1}^N \frac{\omega_k h_k \bar{W}_k}{\rho \bar{C}_p} - \frac{\dot{Q}_{wall}}{\bar{C}_p m} - \frac{1}{\rho \bar{C}_p} \frac{dp}{dt} \quad (30)$$

The ideal gas law can be written as:

$$PV = nR_u T \quad (31)$$

These equations can be solved using Dvode subroutine.

e) Heat Transfer

Heat transfer from in-cylinder contents to surrounding surfaces is modelled by Woschni correlation.³³ In this model, in-cylinder gas velocity and convective heat transfer coefficient are as:

$$\omega = [(C_{11} + C_{12} \frac{V_{swirl}}{\bar{S}_p})] \bar{S}_p + C_2 \frac{V_d T_i}{P_i V_i} (P - P_m) \quad (32)$$

$$h = 3.25 T^{-0.53} B^{-0.2} P^{0.78} \omega^{0.78} \quad (33)$$

In which B is assumed to be cylinder bore. Thus the heat transfer correlation is obtained as:

$$Q_{wall} = hA(T - T_{wall}) \quad (34)$$

VII. RESULTS AND DISCUSSION

For the purpose of finding the accuracy of the present model, the predicted values of in-cylinder pressure for ethanol are compared with the experimental obtained results.³⁴ The specifications of the engine used in the experiments and test conditions are presented in Table 1.

a) Cylinder Pressure

Variations of pressure with crank angle are shown in Figures (2) and (3) for $\phi=0.287$ and $\phi=0.334$ respectively. As seen, the maximum predicted pressures

for the present model are about 71.48 bar and 78.123, fairly comparable with corresponding experimental values of 72 bar and 78.7 bar. It must be said that in the present model 386 reactions are considered in order to simulate these engine so that the trend and peak pressures of predicted results are more compatible in comparison with the theoretical predicted model.³⁵ In order to investigate the effects of important parameters on HCCI engine performance, the engine specification used for this part is shown in Table 2.

b) Cylinder Temperature

Variation of temperature with crank angle is shown in Figure (4) for $\phi=0.287$ and $\phi=0.334$. As observed, the maximum anticipated temperatures for the present model are about 1882 K and 2026 K for $\phi=0.287$ and $\phi=0.334$, respectively. As perceived, the ignition process is started earlier for $\phi=0.287$ in comparison with $\phi=0.334$ and also the expected maximum temperature is higher for $\phi=0.334$ compared with $\phi=0.287$.

c) Mole Fraction

The species mole fractions as a function of CAD are analyzed for different equivalence ratios. Figures (5) and (6) show that at the maximum in-cylinder temperature, the concentrations of ethanol and oxygen sharply decrease but the concentrations of CO and H₂ increase. Then because of equation (33), the CO is converted to CO₂ thus concentration of CO₂ increases.

d) The Effect of EGR Rate on In-Cylinder Pressure and Temperature

Figures (7) and (8) show the variation of pressure and temperature with the EGR rate. The intake charge temperature is maintained at 430K and the equivalence ratio is assumed to be 0.6. Figure (7) shows that the peak pressure decreases with increase in EGR rates, which indicates that pressure is affected by the reduction in the chemical energy content in the engine charge. As seen in Figure (8), the peak temperature starts to decrease rapidly with higher EGR rates where more unreactive molecules are available due to increase in EGR rate. As observed, the increase of EGR delays the ignition timing and slows down the combustion reaction rate.

e) The Effect of Fuel Reforming Rate on In-Cylinder Pressure and Temperature

Figures (9) and (10) show the variation of pressure and temperature with the fuel reforming rate respectively where the inlet temperature is maintained at 421K and the equivalence ratio is considered 0.6 for all cases. As seen in Figure (9), while shooting up the fuel reforming rate increases the in-cylinder pressure when the fuel reforming rate reaches to 27%, there is a considerable decrease in the pressure behavior above this percentage which implies that the variation of pressure is directly proportional to the ignition timing. This matter elucidates that when ignition occurs after top dead center, raising the fuel reforming rate culminates to

increase in peak pressure on contrary to the case in which ignition happens before the top dead center.

As seen in Figure (10), increasing the fuel reforming rate to H_2 , CO causes to have a remarkable raise in the temperature trend. It must be said that the engine performance is acceptable only for the case in which fuel reforming rate is under 27% due to the fact that the knock phenomena occurs in the range above this value.

f) The Effect of Compression ratio on In-Cylinder Pressure and Temperature

Figures (11) and (12) illustrate the variation of pressure and temperature for different values of compression ratio. As observed, by increasing the compression ratio, the initiation of ignition is retarded and burn duration is decreased and therefore the in-cylinder heat release and chemical reaction rates are enhanced and as a result the maximum pressure and temperature goes up. It is worth noting that the combustion process does not occur for the compression ratio equal and lower than 14 and also at compression ratios higher than 17, the auto-ignition phenomenon occurs.

VIII. CONCLUSION

In this research, a single-zone thermodynamic model is used to predict and analyze the combustion of HCCI engines fuelled with ethanol. For this purpose, a mechanism containing the important reactions of ethanol is employed. Control of combustion phenomenon, ignition timing and burn duration are the main issues of these engines and the exhaust gas recirculation (EGR), fuel reforming and compression ratio are the attempts in order to achieve the acceptable operation of these engines. The aim of this study is to investigate the performance of HCCI engines using these controlling methods.

From this analysis, the predicted pressures have been compared with both experimental and theoretical results and they show a good agreement with the published data. In addition, the in-cylinder mole fraction at different equivalence ratios shows that the concentrations of ethanol and oxygen sharply decrease but the concentrations of CO and H_2 increase and because the CO is converted to CO_2 thus the concentration of CO_2 increases. The effect of EGR rate on the engine specification indicate that the ignition timing and burn duration increase and the in-cylinder pressure and temperature decrease as a result of increasing the EGR rate.

As elucidated in this research, ignition timing advances and burn duration shortens when the fuel reforming rate enhances and above 27% of reforming rate, higher amount of heat release may lead to knocking in the cylinder. Furthermore, it is shown that higher amount of fuel reforming rate results in increasing

the peak temperature. The peak pressure is dominated by the location of ignition timing which implies that the increase in the fuel reforming rate under 27% causes the enhancement in the pressure profile because the initiation of ignition is after TDC, but above this percentage, the pressure profile declines because the initiation of ignition is before TDC. Consequently, increasing the compression ratio results in advancing the ignition timing, decreasing the burn duration and increasing the in-cylinder pressure and temperature.

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Table 1 : Engine specifications

Displaced Volume	1600 cm ³
Bore	120.65 mm
Stroke	140 mm
Connecting Road Length	260 mm
Inlet Temperature (K)	383
Comp. Ratio	18
Engine Speed	1000 RPM
ϕ	A=0.278 , B=0.334
Exhaust Valve Opening	39° BBDC
Exhaust Valve Closing	10° BTDC
Inlet Valve Opening	5° ATDC
Inlet Valve Closing	13° ABDC

Table 2 : Engine specifications

Displaced Volume	587.622 cm ³
Bore	72 mm
Ratio of the Connecting Road length to Crank Radius	3.59
Inlet Temperature (K)	415 to 460 K
Engine Speed	1000 RPM
ϕ	0.2 to 0.6
EGR Rate (%)	10 to 50
Reforming Rate (%)	0 to 100
Compression Ratio	14 to 19

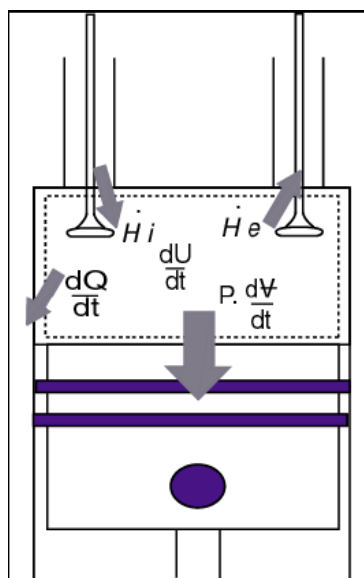


Figure 1 : Schematic view of control volume interaction with surrounding

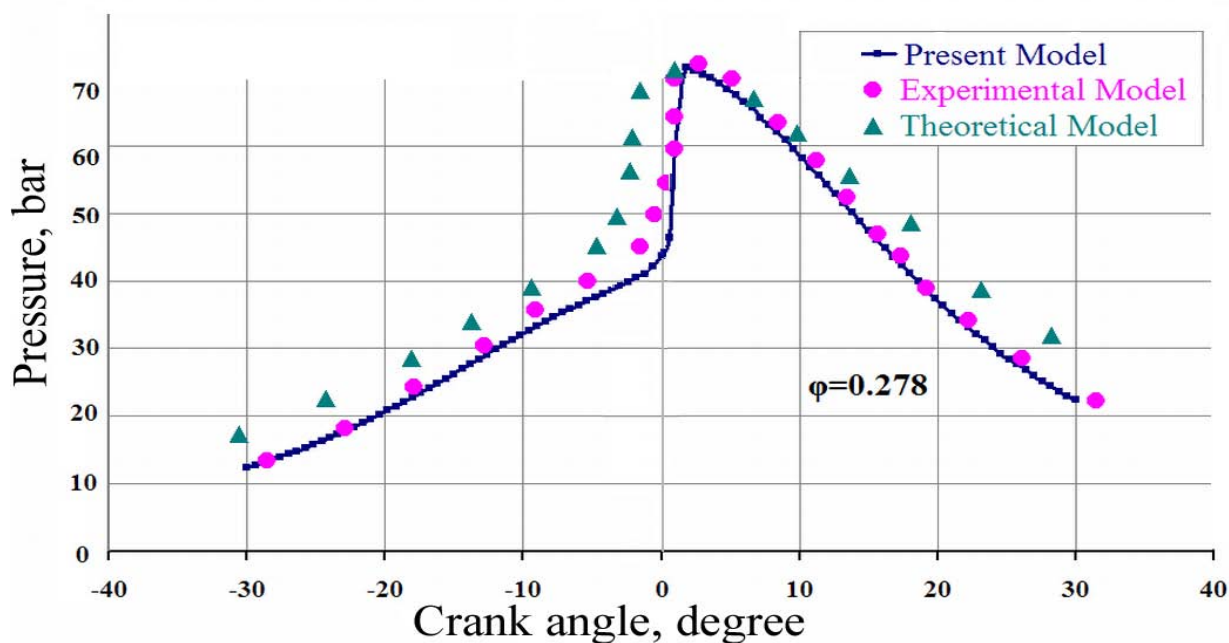


Figure 2 : Variation of predicted, experimental and theoretical values of pressure with crank angle for $\phi = 0.278$

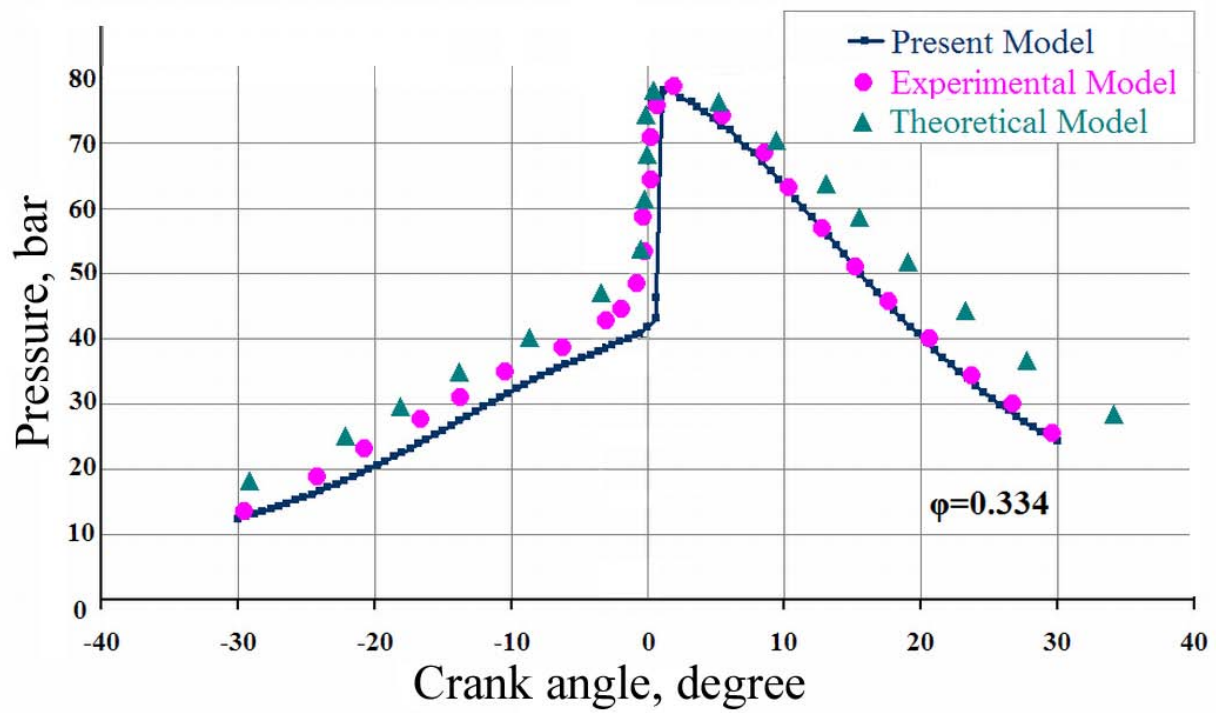


Figure 3 : Variation of predicted, experimental and theoretical values of pressure with crank angle for $\varphi = 0.334$

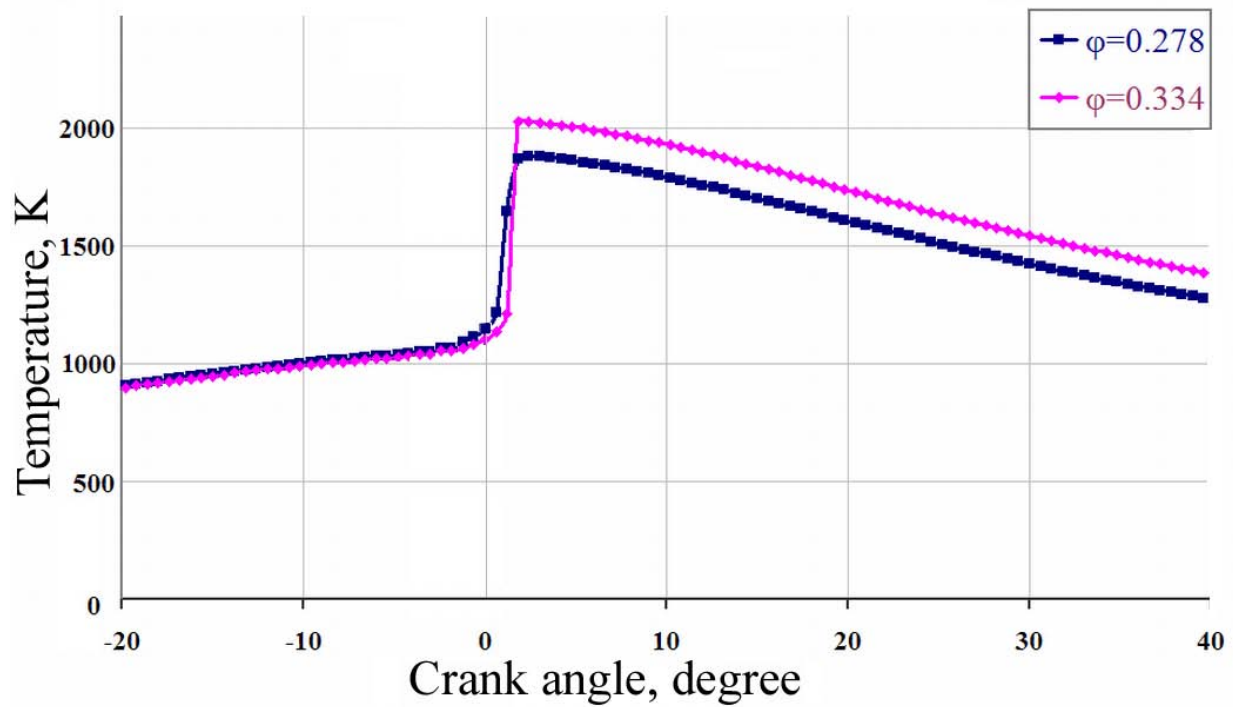


Figure 4 : Variation of temperature with crank angle for $\varphi = 0.278$ and $\varphi = 0.334$

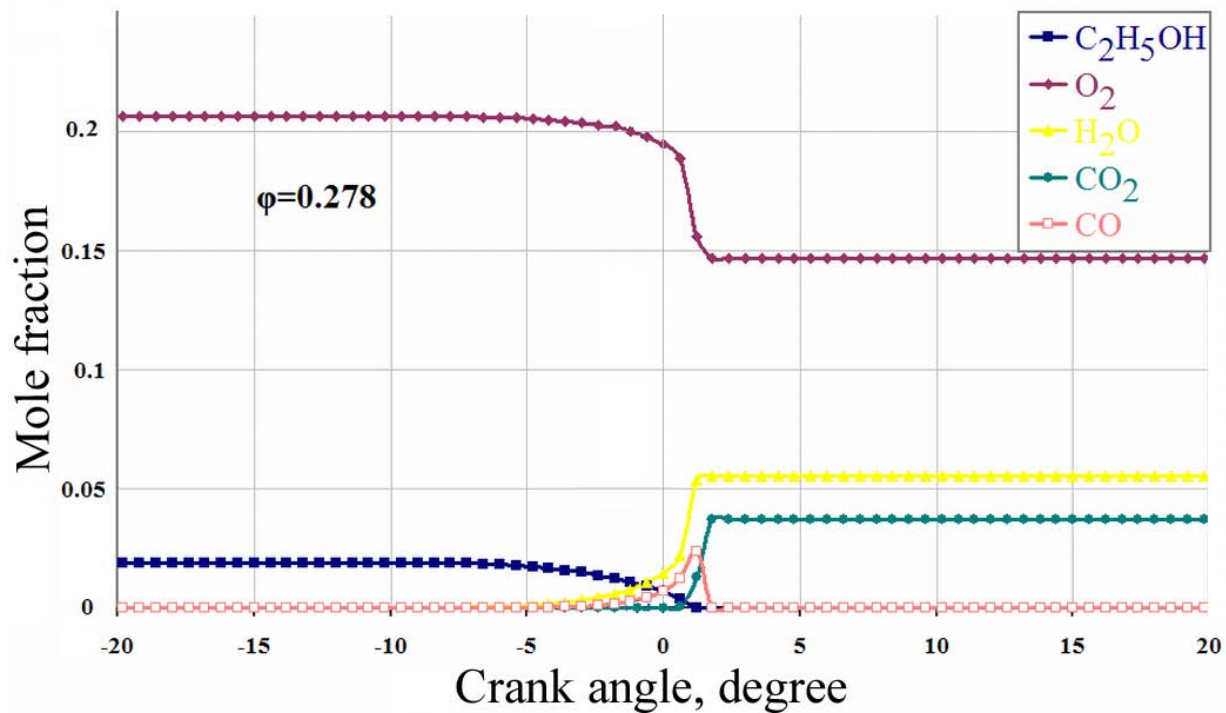


Figure 5 : Variation of in-cylinder mole fraction with crank angle for $\phi = 0.278$

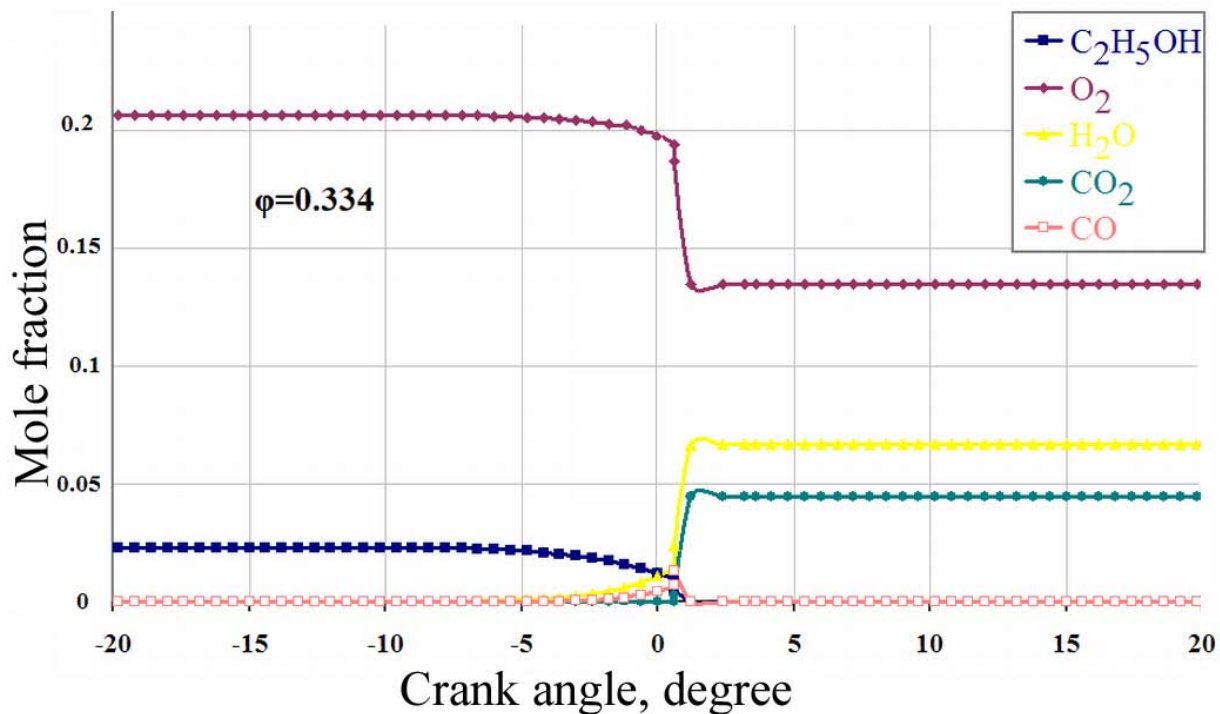


Figure 6 : Variation of in-cylinder mole fraction with crank angle for $\phi = 0.334$

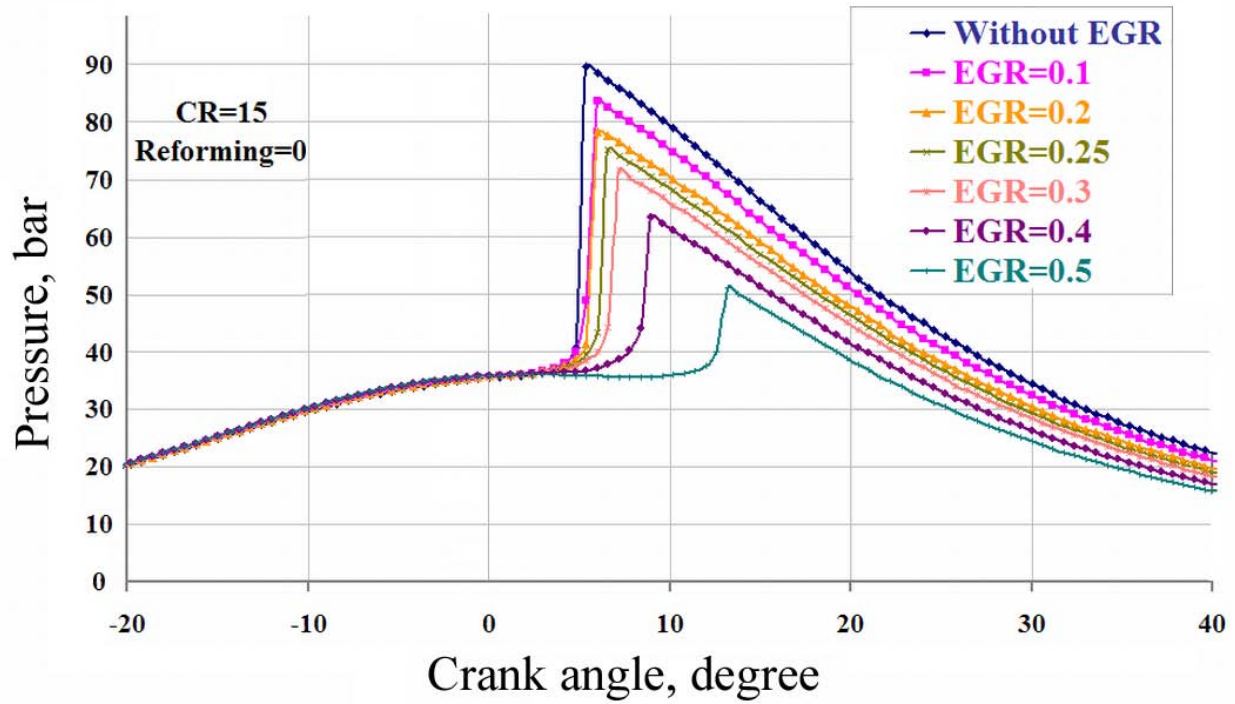


Figure 7 : Variation of pressure with crank angle for different EGR rate

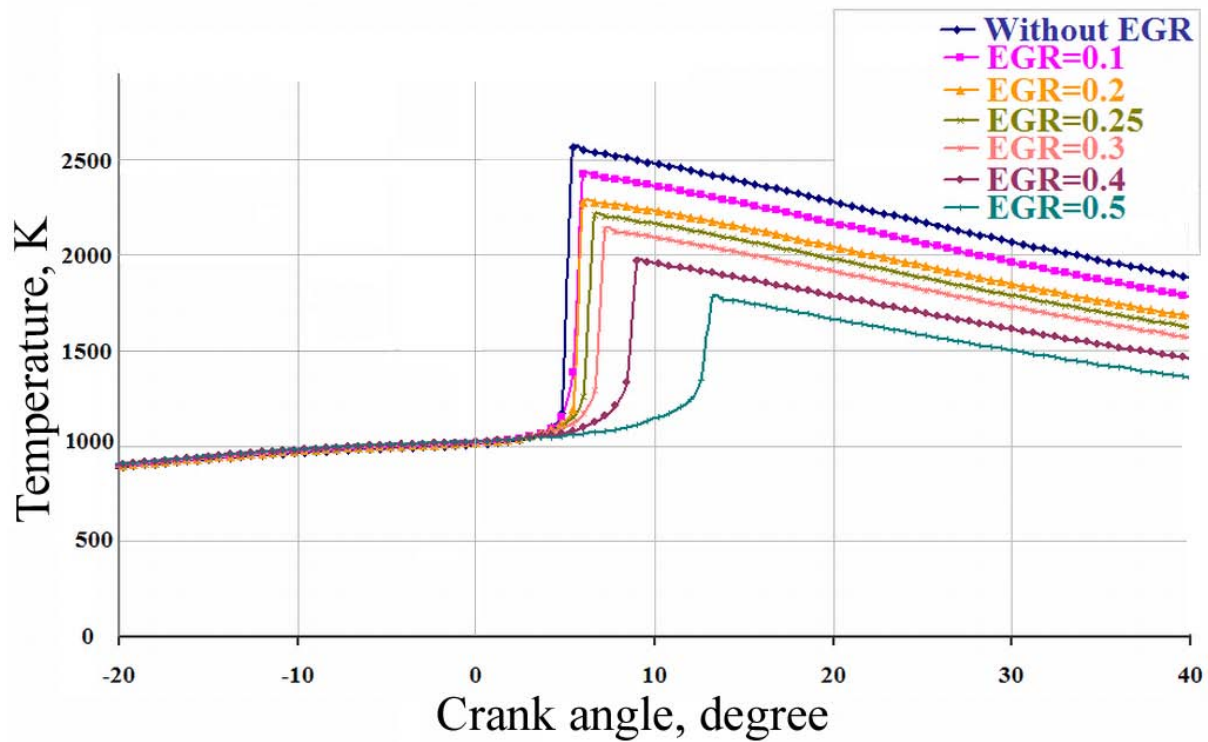


Figure 8 : Variation of temperature with crank angle for different EGR rate

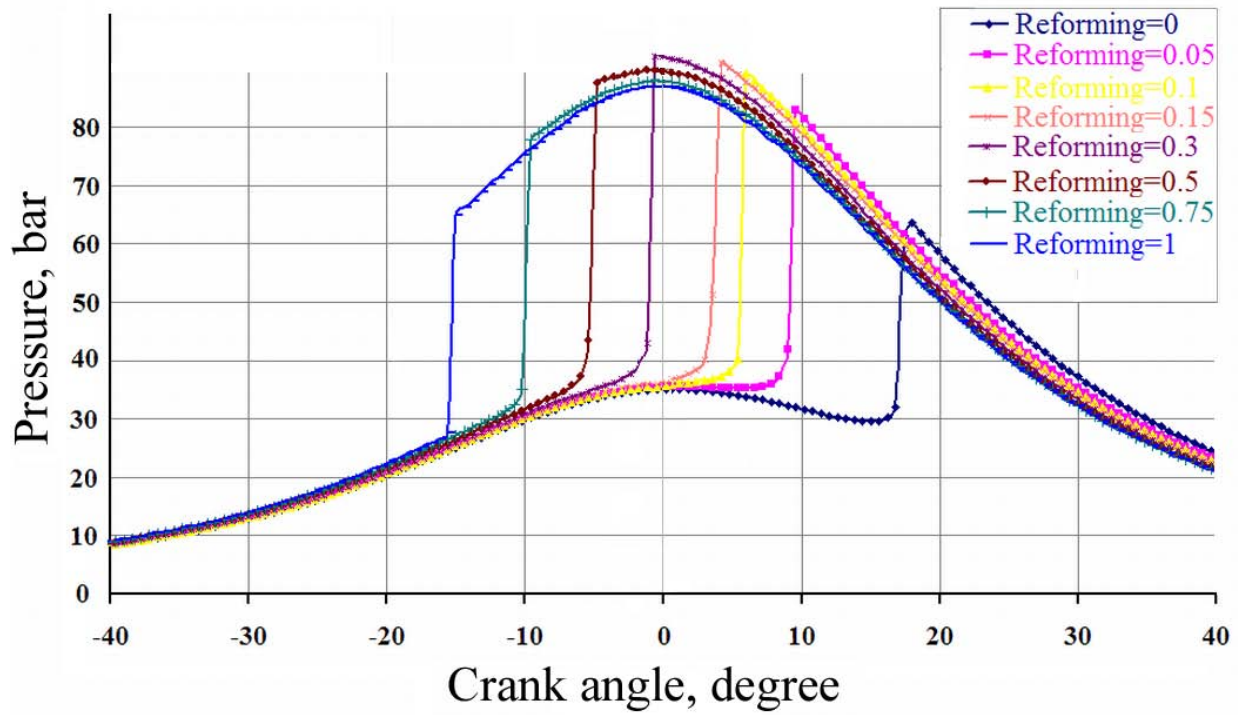


Figure 9 : Variation of pressure with crank angle for different fuel reforming rate

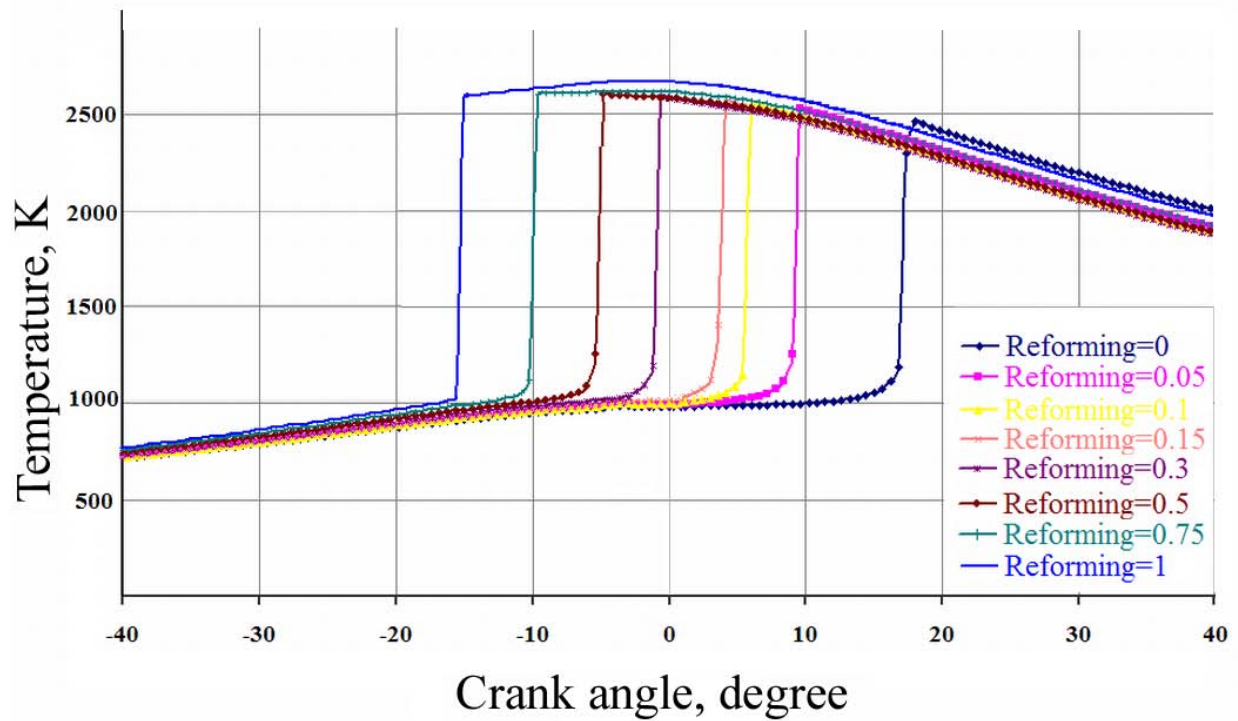


Figure 10 : Variation of temperature with crank angle for different fuel reforming rate

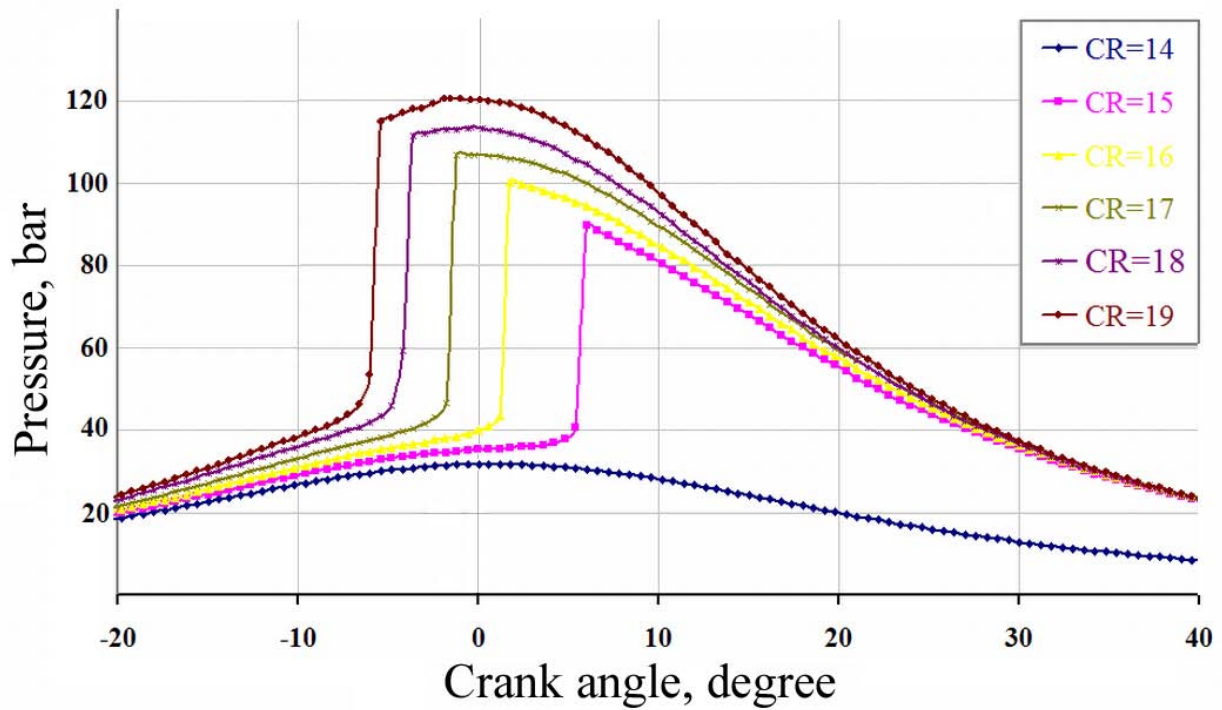


Figure 11 : Variation of pressure with crank angle for different compression ratio

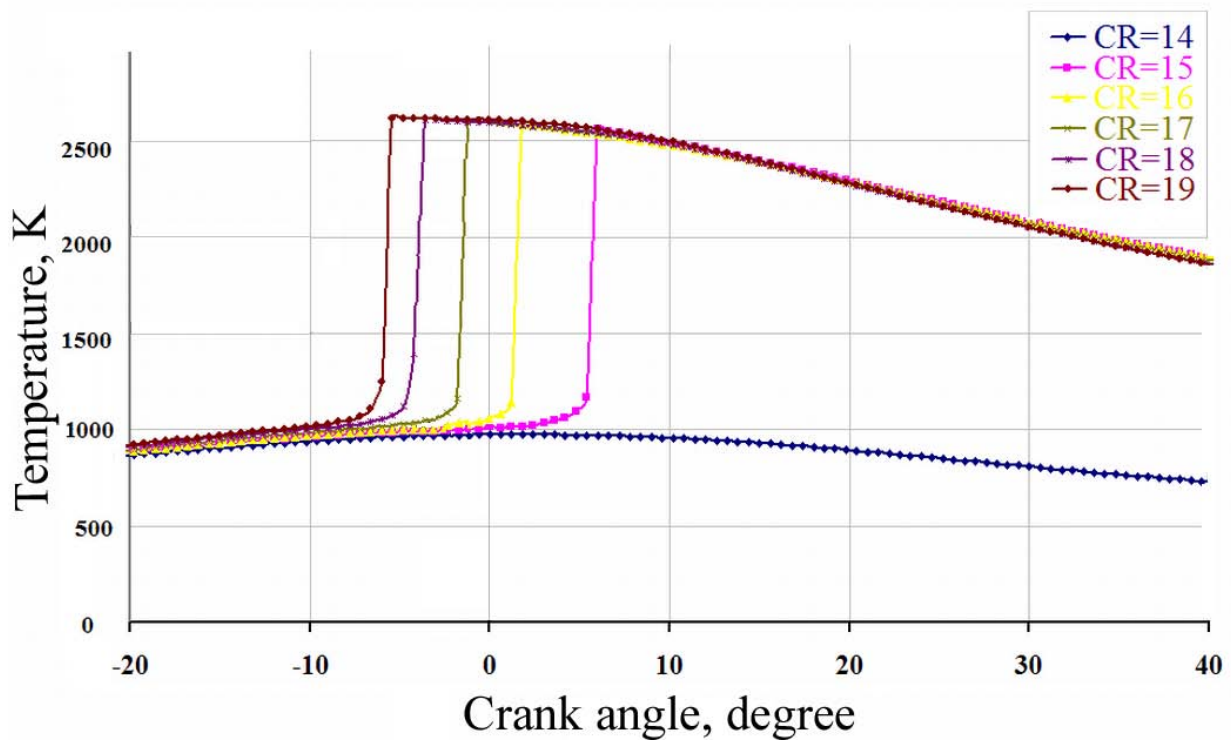


Figure 12 : Variation of temperature with crank angle for different compression ratio

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Failure Analysis of a Weld Neck Flange of the Discharge Piping of an Ethylene Compressor in a Petrochemical Complex

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Abstract - Failure Investigation was carried out on a fractured Weld neck flange of an 8" discharge pipeline of an ethylene compressor in a Petrochemical complex. The Investigation was carried out with the aim of determining the root cause of the failure. In the course of this investigation, Metallurgical techniques including micrography and fractography as well as stress analysis of the piping were carried out on the failed part. The root cause of the failure was identified as vibration induced fatigue enhanced by the non-homogeneity of the microstructure of the flange due to incorrect normalizing practice after forging. Remedial measures to prevent a reoccurrence were proffered.

Keywords : Metallography, Fractography, Failure, Analysis, Striation, Fatigue, transgranular.

GJRE-A Classification : FOR Code: 091406



Strictly as per the compliance and regulations of:



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Keyword : Metallography, Fractography, Failure, Analysis, Striation, Fatigue, transgranular.

I. INTRODUCTION

The 8" piping that branches out from the main discharge piping of an Ethylene compressor, failed after thirteen years of service life. The pipe carries ethylene gas at approximately 27k/cm² at 75-80°C. The failure took place on the upstream side of a pressure safety valve (PSV) in the discharge piping of an ethylene compressor around the HAZ between the 4" weld neck flange and the weldment of the 4" to 8" reducer. The reducer was completely snapped (fractured) off from the weld-neck flange. This was attributed to process upset. Photograph of the failure weldneck flange is presented in figure 1. This paper presents the failure analysis carried out with the aim of finding the root cause.

II. SCOPE OF REPORT

The scope of this report covers the failure analysis of the fractured HAZ between the 4" weld neck flange and weldment of 4" to 8" reducer of the pressure safety valve. The material used is therefore limited to the sample from the fractured 4" class 300 flange.

The scope of the failure analysis includes:

- Complete metallographic analysis of failed pieces with scanning electron microscopy (SEM), and spectrometric analysis of material and weldment.
- Mechanical Testing include; hardness testing and Tensile strength determination.
- Combining piping stress analysis at fracture point
- Root cause determination and recommendations to avoid reoccurrence of failure.

III. METALLURGICAL STUDY OF FAILURE

a) Spectrometric Analysis

The Chemical analysis of the nipple was carried out using an optical emission spectrometer which gave the composition presented in Table 1.

Table 1 : Chemical composition of Weld neck flange samples

C	Cr	Ni	Si	Mn	S	P	Cu
0.276	0.092	0.033	0.30	1.28	0.06	0.017	0.149

This conforms to ASTM A350 LF2

b) Metallographic Analysis

The fractured weld-neck flange of the pressure safety valve was prepared for metallography in accordance with ASTM E3, methods of preparation of

metallographic specimen. The three samples were then observed under metallurgical microscope and the resulting micrographs are presented in figures 2 and 3.

i. Discussion of Micrographs

The micrograph of the fractured weld-neck flange of the pressure safety valve presented in figure 2, shows coarse grain microstructure and the presence of widmanstatten ferrite. The metallographic examination

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revealed that the microstructure and grain size vary considerably with the maximum and minimum ASTM grain size numbers being 3 and 6 respectively. The grain sizes of the samples were determined in consonance with the requirement of ASTM E 112. The un-etched specimen presented in figure 3 shows a number of porosities.

c) SEM Analysis

Sample from the weld neck flange of pressure safety valve, was subjected to SEM fractography using JEOL JSM-6390LV scanning electron microscope. In the course of the SEM fractography, several shots were taken at different points on each of the mounted samples at magnification of x300, x500 and x700. The resultant fractographs are presented in figures 4, 5 and 6.

i. Discussion of SEM Fractographs

The SEM fractograph of the weld neck flange of pressure safety valve presented in figure 4 shows the three-dimensional nature of the various grains which is typical of (brittle) intergranular fracture as opined in Davis(1998). The figure also shows various cleavages which is typical of (brittle) transgranular fracture. The fatigue striations revealed by this fractograph are

characteristic of fatigue failure. Another very prominent revelation of the SEM fractograph of figure 4 is the presence of a continuous threadlike rod of inclusion which is a very likely point of crack initiation. The fractograph in figure 5 shows clearly the transgranular fracture in a cleavage. Figure 6 fractograph of this sample shows mainly transgranular and intergranular and intergranular failure nodes. It could therefore be inferred that the failure of this sample was catastrophic and was to a largely extent by brittle mode. The inclusion and blow holes in figure 3 as well as the dark particles in this micrograph are a pointer to manufacturing flaws in the flange.

IV. MECHANICAL TEST

a) Microhardness Test

The sample from fractured weldment, flange of pressure safety valve was subjected to microhardness test using Leco microhardness tester LM 700AP, applying a load of 50gf in a dwell time of 15 seconds. The test was carried out in accordance with ASTM standard E92, standard test method for Vickers hardness of metallic materials and ASTM E384, standard test for microhardness of materials. The result of the test is presented in table 2.

Table 2 : Microhardness Tests Result of pressure safety valve of weld neck flange

VHN	VHN	VHN	Average (VHN)	Deviation	Range	Converted to BHN
168.3	134.8	137.7	146.9	18.5	33.5	143

i. Discussion

The high value of the deviation in the hardness of the three points tested, shows inhomogeneity in the microstructure of the flange.

b) Tensile Strength of materials

The tensile strength = $K \times BHN$ Mpa [Rao (1998)]

Where $k = 3.296$ for alloy steel and 3.342 for plain carbon steel.

For the flange, Tensile strength = $3.296 \times 143 = 471.33$ Mpa.

Mean diameter $D_m = 4.25$ in

Operating Temperature = $75 - 80^\circ\text{C}$ ($167 - 176^\circ\text{F}$)

Material of pipe = ASTM A 350 LF2

Designation: Similar to API 5L GR B

Operating pressure = $27 \text{ kg/cm}^2 = 385.354 \text{ psi}$

The maximum allowable pressure is determined in accordance with ANSI/ASME B31.8 standard for Gas Transmission and Distribution system by the equation.

$$P = (2 St/D) \times F \times E \times T \quad 5.1$$

Where, P = Design pressure, (psi)

S = Specified minimum yield strength (psi)

t = Nominal wall thickness (in)

D = Nominal outside diameter (in)

F = Design factor

E = Longitudinal joint factor

T = Temperature de-rating factor.

$S = 35,000 \text{ psi}$ [ANSI/ASME Code B31-8-2003, Appendix D]

V. STRESS ANALYSIS OF FAILED WELD NECK FLANGE

a) Determination of the maximum allowable pressure (Design pressure)

Data:

Nominal outside diameter, $D = 4.5$ in

Nominal inside diameter, $d = 4$ in

$t = 0.25\text{in}$

$D = 4.5\text{in}$

$F = 0.72$ [ANSI/ASME Code B 31-8-2003 Table 841.1A]

$E = 1.00$ [ANSI/ASME Code B 31-8-2003 Table 841.1B]

$T = 1.00$ [ANSI/ASME Code B 31-8-2003 Table 841.1C]

Therefore Design pressure,

$$P = (2 \times 35,000 \times 0.25 \div 4.5) \times 0.72 \times 1.00 \times 1.00 \\ = 2800\text{Psi} = 197.26\text{kg/cm}^2$$

b) Determination of the collapsing pressure of pipe

The collapsing pipe pressure is determined, taking into consideration the effect of lateral contraction by the DNV equation.

$$P_c = \frac{2E_y}{1-\lambda^2} \left[\frac{t}{D_m} \right]^3 \quad 5.2$$

[Antaki (2005)]

Where P_c = minimum net collapsing pipe pressure (psi)

E_y = modulus of elasticity = 28×10^6 psi

t = pipe thickness = 0.25in

D_m = Mean diameter of pipe = 4.25in

λ = Poisson ration = 0.29

Therefore, collapsing pipe pressure,

$$P_c = \frac{2 \times 28 \times 10^6}{1-(0.29)^2} \left[\frac{0.25}{4.25} \right]^3 = 12,445\text{psi} = 878.75\text{Kg/cm}^2$$

c) Determination of Maximum allowable net external pressure for pipe with eccentricity (1% out-of-roundness)

$$P_e^2 - \left[2S \left(\frac{t}{D} \right) + \left(1 + 0.03 \left(\frac{D}{t} \right) P_c \right) \right] P_e + 2S \left(\frac{t}{D} \right) P_c = 0 \quad 5.3$$

[Yong Bai and Qiang Bai (2005)]

Where P_e = maximum allowable net external pressure

P_c = critical value of collapsing pressure

S = yield stress allowable stress value.

= 25,200 psi [ANSI/ASME code B31-4-2006, Table 402.3.1(a)]

$$P_e^2 - \left[2 \times 25,200 \left(\frac{0.25}{4.25} \right) + 12,445 \left(1 + 0.03 \left(\frac{4.25}{0.25} \right) \right) \right] P_e + 2 \times 25,200 \left(\frac{0.25}{4.25} \right) \times 12,445 = 0$$

$$P_e^2 - 21756.7P_e + 36895764.71 = 0$$

$$P_e = 1,853.8\text{psi} = 130.6\text{Kg/cm}^2$$

d) Hoop Stress (S_h) Analysis

$$S_h = (P_e - P_i) (D - t) / 2t \quad 5.4$$

$$= (1,853.8 - 385.35) (4.5 - 0.25) / 2 \times 0.25$$

$$= 12,481.825\text{psi}$$

Hoop stress criterion of ABS (2000) according to Yong Bai and Qiang Bai (2005) is given by

$$S_h \leq F \times S \times T = 0.72 \times 35000 \times 1 = 25,200$$

The hoop stress for the pipe is therefore appropriate since it is less than the value obtained from the criterion.

VI. CONCLUSION / ROOT CAUSE OF FAILURE

From the analysis carried out, the following conclusions may be drawn;

1. The three samples provided failed by catastrophic brittle fracture, the cracks being intergranular and transgranular.
2. The failure mode is therefore brittle fracture and the mechanism is fatigue.
3. The cleavage like flakes (crack) observed in the

SEM fractographs are attributed to stresses produced by localized transformation and decreased solubility of hydrogen during cooling after hot working (forging). Hydrogen in excess of 5ppm plays an important role in this phenomenon and can be prevented by vacuum degassing treatment.

4. The pipe stresses are appropriate.
5. Failure of the 4" weldneck flange of pressure safety valve was a result of vibration induced fatigue enhanced by the weakened microstructure of the flangedue to incorrect normalizing practice after forging and hydrogen embrittlement.

VII. RECOMMENDATIONS

1. The flange used for replacing the failed one should be sourced from vendors that can guarantee the use of vacuum degassing after forging as this has been found to reduce hydrogen to less than 3ppm in forgings which ultimately preclude the possibility of hydrogen embrittlement.
2. The flange used for replacing the new one should be subjected to normalizing heat treatment at 910°C for 30minutes as research work carried out by Belgian Welding Institute for a material of similar composition revealed that

the aforementioned normalizing practice yielded fine grain and fairly homogeneous microstructure with ASTM grain size number 8 to 9 and little variation in the flange hardness.

VIII. ACKNOWLEDGEMENT

The author is grateful to Engineering Materials Development Institute Akure, Nigeria and the University of Legon, Ghana for providing the equipment used for this work.

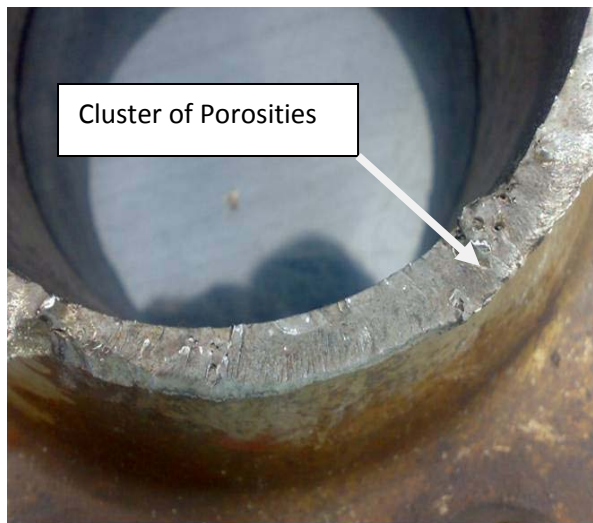


Fig 1 : Failed PSV Weld neck flange showing porosities

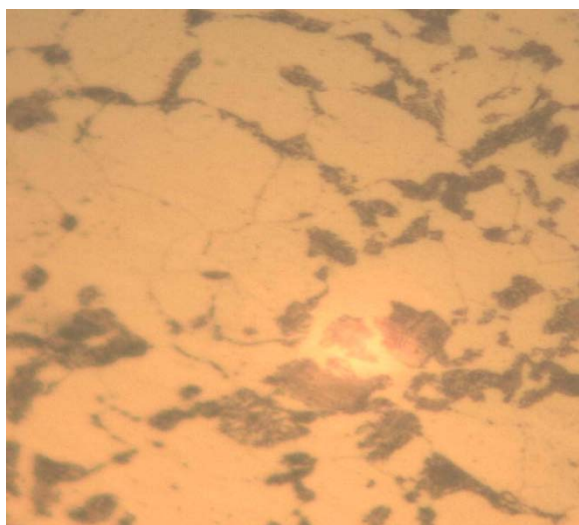


Fig 2 : Micrograph of weldneck flange of PSV, 2% nital etched x 800

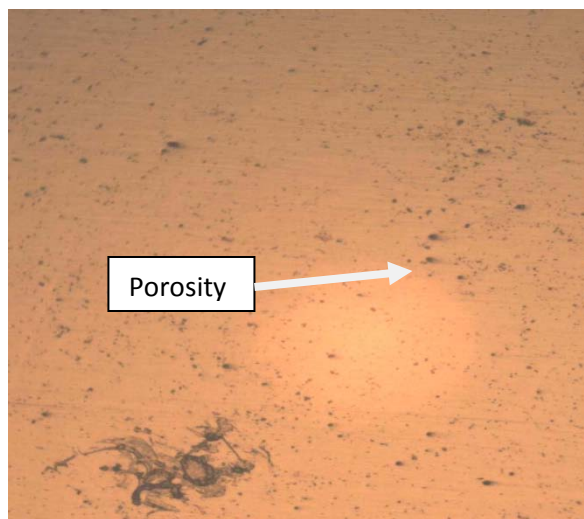


Fig 3 : Micrograph of weldneck flange of PSV, unetched x100 showing porosities

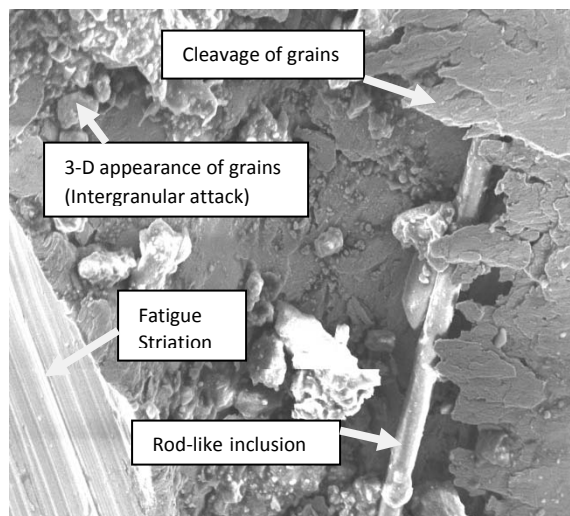


Fig 4 : Fractograph of failed weldneck flange of PSV x500

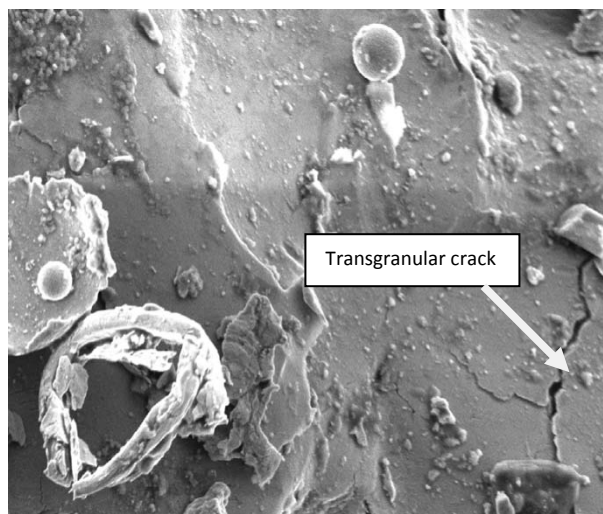


Fig 5 : SEM Fractograph of failed flange of PSV x700

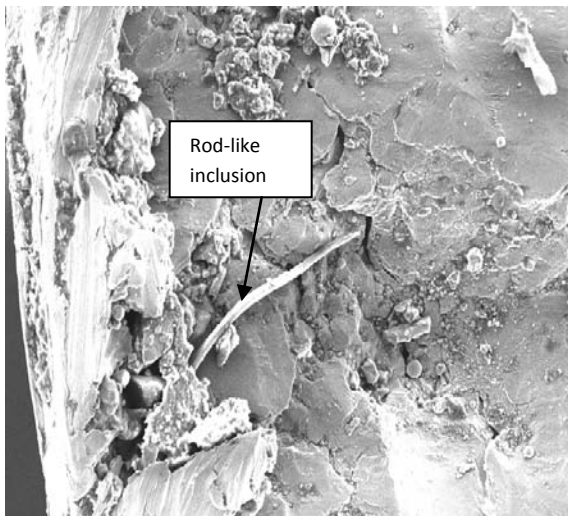


*Fig 6 : SEM Fractograph of failed flange of
PSV x300*

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Determination of Flux Consumption in Submerged arc Welding by the Effect of Welding Parameters by Using R.S.M Techniques

By Krishankant, Sandeep Jindal & Shashi Kant Shekhar

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Abstract - Purpose : Submerged arc welding (SAW) is a common arc welding process where the total welding cost includes the cost of the flux consumed during welding, SAW is preferable more its inherent qualities like easy control of process variables, high quality, deep penetration, smooth finish. Flux used in submerged arc welding contributes a major part towards welding cost. In the present work, the effect of operating voltage, welding current, welding speed and basicity index on flux consumption has been studied. Flux consumption for each bead was weighed. Although the physical and chemical properties of SAW fluxes have been studied widely, very little attention has been paid to the factors that affect its consumption. Design/Methodology and Technique : The experiment was designed based on a five level factorial central composite rotatable design with full replication . The experimental calculations and results graph was conducted as per the design matrix using Design Expert Software. The response surface methodology (RSM) is a set of techniques that encompasses (i) the designing of a set of experiments for adequate and reliable measurement of the true mean response of interest; (ii) the determining of mathematical model with best fits; (iii) finding the optimum set of experimental factors that produces maximum or minimum value of response; and (iv) representing the direct and interactive effects of process variables on the bead parameters through two dimensional and three dimensional graphs.

Keywords : R.S.M , Process Parameters, Submerged arc welding, H.S.L.A Material, Design Expert.

GJRE-A Classification : FOR Code: 290305



Strictly as per the compliance and regulations of:



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Krishankant^a, Sandeep Jindal^o & Shashi Kant Shekhar^p

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Design/Methodology and Technique : The experiment was designed based on a five level factorial central composite rotatable design with full replication . The experimental calculations and results graph was conducted as per the design matrix using Design Expert Software. The response surface methodology (RSM) is a set of techniques that encompasses (i) the designing of a set of experiments for adequate and reliable measurement of the true mean response of interest; (ii) the determining of mathematical model with best fits; (iii) finding the optimum set of experimental factors that produces maximum or minimum value of response; and (iv) representing the direct and interactive effects of process variables on the bead parameters through two dimensional and three dimensional graphs.

Keywords : R.S.M , Process Parameters, Submerged arc welding, H.S.L.A Material, Design Expert.

1. INTRODUCTION

Response surface methodology (RSM) is a technique to determine and represent the cause and effect relationship between true mean responses and input control variables influencing the responses as a two or three dimensional hyper surface [2]. The accuracy and effectiveness of an experimental program depends on careful planning and execution of the experimental procedures. In Submerged arc welding (SAW) of various wall thickness, a common problem

faced in industry is the selection of suitable values for the process parameters to the required flux consumption, bead geometry and quality, especially the bead penetration, reinforcement, bead width and dilution [1]. In submerged arc welding (SAW), the total welding cost includes the cost of the flux consumed . In the present work, the effect of operating voltage, welding current, welding speed and nozzle to plate distance on flux consumption has been studied. Flux consumption for each bead was weighed [8]. Response surface methodology was applied to derive mathematical models to predict and control the flux consumption within the range of the parameters. It was found that flux consumption increases with the increase in operating voltage, decreases with the increase in nozzle to plate distance and welding speed. This paper deals with the application of RSM in developing mathematical models and plotting contour graphs relating important input process parameters namely the open-circuit Current (C), Voltage (V), Welding speed (S) and the nozzle-to-plate distance (D) in the SAW ,through the development of a computer program find out the effect of parameters on flux consumption.[1].

During SAW process only that portion of the flux that is actually melted is consumed. The unused portion of the flux is separated from the slag and reused. The consumption of the flux is dependent upon the flux melting. The heat needed to melt the flux comes from three sources:[1]: i. Conduction from the molten metal, ii . Radiation from the arc, iii. Resistance heating of the slag. The conduction from molten metal would depend upon the weld metal temperature and weld metal-flux contact area. This contact area is dependent upon the bead shape, hence welding parameters. Although the physical and chemical properties of SAW fluxes have been studied widely, very little attention has been paid to the factors that affect its consumption. In a different work it has been shown that the flux consumption generally increases with increasing welding current reaches a maximum and then starts decreasing again. Although several authors have stated that the flux consumption can be influenced by physical properties such as density and particle size, no systematic information is presently available [4].

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II. EXPERIMENTAL PROCEDURE

The experiment was designed based on a designing the experiments based on Box-Behnken Design (BBD) using state ease 6.0 version of design of experiment. The experiment was conducted as per the design matrix using TORNANDO SAW M-800 equipment at Mullana University Mullana India. Welding was done bead on material plate of Mild Steel. The size of each specimen was 200*150 mm of thickness 10 mm. ESAB SA1 (E8) copper coated wire of 4 mm diameter electrode, granular flux was used for welding. Two transverse specimens were cut from each weldment and standard metallographic procedures were adopted. The bead profiles were drawn using a reflective type profile projector. The bead profile parameters were measured using an accurate digital planimeter [8]. Before starting welding on plate weighted the flux and again weight the flux after complete bead on the plate. That the way how calculated the flux consumption for each bead when the parameters selected accordingly Table 1.

III. PLAN OF INVESTIGATIONS

The research work was planned to be carried out in the following steps [4] :

1. Identifying the process parameters.
2. Finding the upper and lower limits of the control variables, viz. open-circuit voltage (V), Current (C), welding speed (S), and nozzle-to-plate distance (D)
3. Developing of the design matrix
4. Conducting the experiments as per the design matrix.
5. Checking the adequacy of the models developed;
6. Analysis of results & Conclusions.

a) Identification of the process parameters

The following independently controllable process parameters were identified to carry out the experiments: open-circuit Voltage (V); Current (C); Welding speed (S); and Nozzle-to-plate distance (D) [1].

b) Finding the limits of the process variables

Trial runs were carried out by varying one of the process parameters whilst keeping the rest of them at constant values. The working range was decided upon by inspecting the bead for smooth appearance and the absence of any visible defects. The upper limit of a factor was coded as +2 and the lower limit as -2, the coded values being calculated from the following relationship [1]:

$$Xi = \frac{2[2X_{-}(X_{max} + X_{min})]}{(X_{max} - X_{min})}$$

where X_i is the required coded value of a variable X ; and X is any value of the variable from X_{min} to X_{max} . The selected process parameters with their limits, units and notations are given in Table 1.

Parameters	Units	Limits				
		-2	-1	0	+1	+2
Current (C)	Amp	300	350	400	450	500
Voltage (V)	Volts	26	28	30	32	34
Welding Speed (S)	M/Hr	21	24	27	30	33
N.P. Distance (D)	MM	16	18	20	22	24

c) Developing the design matrix

The selected design matrix, is a design consisting of 29 sets of coded conditions. It comprises a full replication of [2]. All welding parameters at the intermediate level points and the combinations of each of the welding variables at either its lowest (+2) level or highest (-2) level with the other three variables at the intermediate levels constitute the star points. Thus the 31 experimental runs allowed the estimation of the linear, quadratic and two-way interactive effects of the process parameters.

d) Conducting the experiment as per the design matrix

The experiments were conducted as per the design matrix at random, to avoid the possibility of systematic errors infiltrating the system.

e) Development of mathematical models

The response function representing any of the weld bead dimensions can be expressed as [3].

$Y = f(V, C, S, D)$. The relationship selected being a second degree response surface expressed as follows:

$$Y = b_0 + b_1V + b_2C + b_3S + b_4D + b_{11}V^2 + b_{22}C^2 + b_{33}S^2 + b_{44}D^2 + b_{12}VC + b_{13}VS + b_{14}VD + b_{23}CS + b_{24}CD + b_{34}SD$$

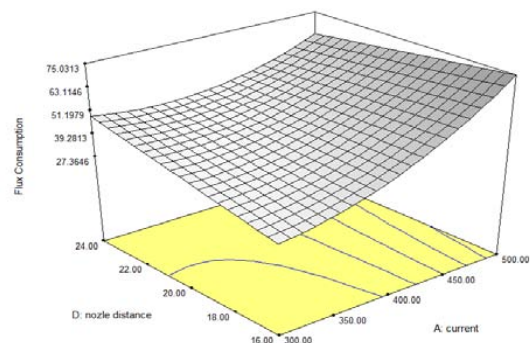
	Experiment	Process Parameters				Responses Factors
Standard	Run	Current	Voltage	Welding Speed	Nozzle to Plate Distance	Flux Consumption
Limits	Numbers	(Amperes)	(Volts)	(M/hr)	(M.M)	(Gms)
1	11	300	26	27	20	33.0
2	26	500	26	27	20	78.0
3	17	300	34	27	20	45.0
4	19	500	34	27	20	60.0
5	9	400	30	21	16	30.0
6	23	400	30	33	16	39.0
7	6	400	30	21	24	40.0
8	7	400	30	33	24	45.0
9	28	300	30	27	16	30.0
10	3	500	30	27	16	75.0
11	25	300	30	27	24	48.0
12	20	500	30	27	24	60.0
13	27	400	26	21	20	38.0
14	12	400	34	21	20	32.0
15	8	400	26	33	20	40.0
16	2	400	34	33	20	40.0
17	15	300	30	21	20	35.0
18	4	500	30	21	20	50.0
19	18	300	30	33	20	23.0
20	14	500	30	33	20	78.0
21	5	400	26	27	16	48.0
22	24	400	34	27	16	40.0
23	1	400	26	27	24	50.0
24	16	400	34	27	24	47.0
25	21	400	30	27	20	42.0
26	29	400	30	27	20	43.0
27	10	400	30	27	20	44.0
28	13	400	30	27	20	48.0
29	22	400	30	27	20	40.0

IV. RESULTS AND DISCUSSION

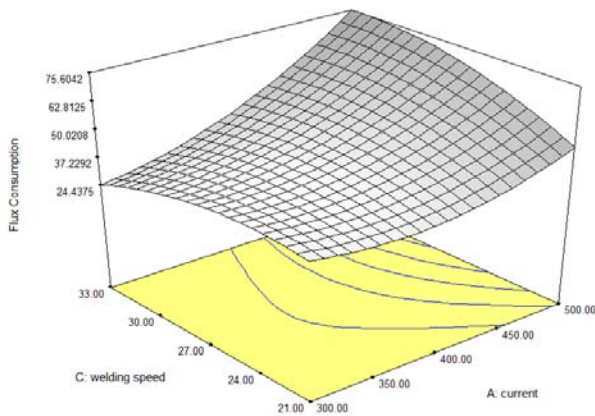
The analysis of variance (ANOVA) was applied to study the effect of input parameters on the flux consumption [4]. It revealed that the quadratic model is the best suggested model. In addition to this, the goodness of fit of the fitted quadratic model was also evaluated through 'lack of fit test'[8]. The "Prob > F" for all these tests was found in excess of 0.001, implying that the lack of fit is insignificant. So, for further analysis this model was used.

Interaction effects :- The difference in effect of one variable when a second variable is changed from one level to another is known as interaction effect and study of interaction effects of process variables on bead dimensions is interesting and very useful for understanding the process behavior. In this study, the

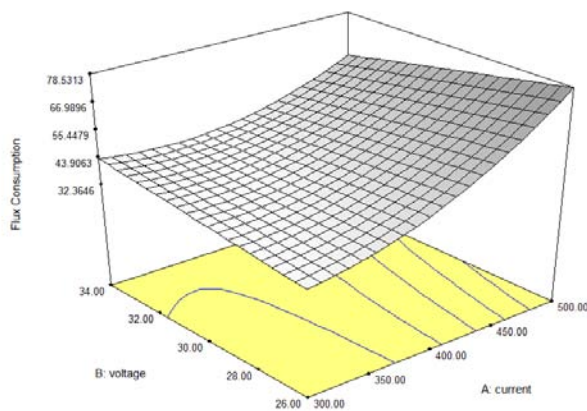
effect of welding current, arc voltage, welding speed and distance between tip of nozzle & work piece on the flux consumption.



3D surface graphs for the Flux Consumption between nozzle to plate distance and current



3D surface graphs for the Flux Consumption between welding speed and current



3D surface graphs for the Flux Consumption between voltage and current.

V. CONCLUSIONS

On the basis of present study the following conclusions can be drawn:

1. RSM can be used effectively in analyzing the cause and the effect of process parameters on response. The RSM is also used to draw contour graphs for various responses to show the interaction effects of different process parameters.
2. Flux consumption increased with the increase in open circuit voltage and very small increases with increases in current.
3. Welding speed has negative effect on flux consumption.
4. Flux consumption also small decreases with the increase in nozzle to plate distance.

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MedhAMshaShOdhini - An Efficient Bilingual Search Engine Tool for Telugu Language

By Dr.K.V.N.Sunitha

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Abstract - Search engine technology has become quite popular to help users seek information available on the web. The success of a searching system is determined by the quality and efficiency of the search results. There may be very good items on the search topic in other language, but, search engine will generally retrieve items of only one language. Most of these search engines use pattern search which is not efficient. In this paper we present a tool that addresses this problem. Here we discuss the work carried out in developing an efficient tool that retrieves all the items of the database relevant to search term, not just the term matching. This tool retrieves all the synonym matches from both languages. 'MedhAMshashOdhini', meaning, the one which searches exactly what your brain wants to search for, retrieves the documents in both Telugu and English languages. This tool gives the flexibility of searching based on the context, based on the semantics in two different languages. Main claim of the paper is the efficient architecture of thesaurus and the procedure used in retrieving the relevant documents in both languages based on the context.

Keywords : MedhAMshashOdhini, Telugu dictionary, Foreign key, EngTelMap, context resolution, reverse mapping.

GJRE-A Classification : FOR Code: 080704



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I. INTRODUCTION

The growth of the Web leads to high popularity of the online search services. The success of a searching system is determined by the quality and efficiency of the search results. Most users have been trained to become accustomed to the traditional search interface where a user submits a query to an input textbox. It is not easy for Web users to specify their search intentions by term combination. Sometimes a user can not generate a query correctly even though the user is clear about what to search.. The vastness of knowledge available on the WWW is the cause of our ever-increasing vulnerability to "not the best" knowledge available. As the number of indexable pages on the Web exceeds, it becomes more and more difficult for search engines to keep an up-to-date and comprehensive search index, resulting in low precision and low recall rates. Users often find it difficult to search for useful and high-quality information on the Web using general-purpose search engines, especially when searching for information on a specific topic or in a language other than English[1]. Many domain specific or language specific search engines have been built to facilitate more efficient searching in different areas. But for Indian

languages, it is still not much advanced. For Telugu language, perhaps, there is no efficient search engine that is based on thesaurus.

Telugu has a vast and rich culture and literature dating back to many centuries[2]. Yet there is no widely available electronic thesaurus till date. However bilingual dictionaries are available. For NLP applications, Thesaurus is to be constructed from these dictionaries. The existing searching system gives results only for the search term given and it doesn't provide any specific meanings for the given word depending upon the context.

In this paper, we present our work in designing and implementing a software tool that addresses this problem. We will focus on the architectural design of the tool. The rest of the paper is organized as follows. Section 2 reviews related work in search engine development. Section 3 discusses our research objective. In Section 4, we present our proposed system, called "medhAMshashOdhini," that we have developed to help users create specialized search engines in different domains and languages. Section 5 presents sample results.

II. STATE OF THE ART

There are many free software tools that provide all of the components of a search engine. Although these toolkits provide integrated environments for users to build their own domain-specific search engines, most of these tools only work for English documents and are not able to process non-English documents, especially for non-alphabetical languages. Only a few of them, such as GreenStone, support multilingual collection building. As a result, most of these tools cannot be used to create digital library for non-English collections. Another problem is that many of these tools do not provide enough technical details, and their components and building steps are tightly coupled. As a result, users often find it difficult to customize the tools or reuse the intermediate results in other applications (such as document classification) even if they have strong technical skills. For example, in Alkaline, all the intermediate results of the spidering and indexing processes are hidden from users. In addition, most of these tools store the spidering results (Web pages) and indexing results (indexed terms and the document-term relationships) in binary format or other proprietary formats, often due to performance issues. This has made it very difficult, if not impossible, for users to use

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the results from a search tool for other purposes or in other applications.

The popular search engine, Google, uses the random walk algorithm, which ranks the documents according to the link structure, coupled with the local query specific score to give the final rank to the page[4].

Search engines like oingo.com, excite.com and simpli.com also provide meaning based searching. Launched in October 1999, Oingo has already introduced three fully functional products: DirectSearch, DomainSense and AdSense. DirectSearch, a meaning-based search technology, uses the company's ontology to provide more precise and effective search results. DomainSense, Oingo's meaning-based domain name suggestion technology, currently increases domain name sales for leading registrars around the world. AdSense serves the most highly targeted advertisements on the Internet; effectively targeting advertisements based on search meanings rather than keywords[3].

Step in the direction of meaning based searching was taken by a project of Chinese Academy of Sciences. This project [4], accomplished in 1998, worked on simplified Chinese and English. This project provided the flexibility of adding Traditional Chinese (Big5) and Traditional Chinese (EUC) in the future. Its established system consisted of two subsystems: Organization based subsystem and Web page based subsystem. Organization based subsystem was developed specially for users to find whether a certain organization in China had its own website and some detailed information about that organization. The web page based subsystem was developed for users for searching information in the web documents.

III. MEDHAMSHASHODHINI

'MedhAMshashOdhini', meaning, the one which searches exactly what your brain wants to search for, retrieves the documents in both Telugu and English languages. This tool gives the flexibility of searching based on the context, based on the semantics in two different languages. Different ways of searching provided by medhAMshashOdhini is described as below.

a) *Synonym based Searching*

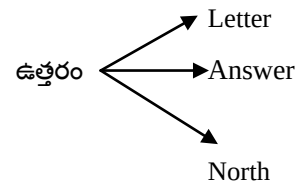
There is no controlled vocabulary or list of standardized terms or descriptors for the Web. Because there is no controlled vocabulary, the use of synonyms and variations of keywords to describe the search query is very important.

b) *Context based Searching*

If the word has different meanings, depending upon the context all the different meanings will be displayed.

c) *Cross linear Searching*

For a given term in Telugu we can retrieve words in English. Searching is possible for both the languages i.e searching is possible from English–Telugu as well as from Telugu–English.



The objectives of this work are :

- Manual Construction of Telugu Thesaurus
- Efficient creation and manipulation of the database for the thesaurus.
- Creating transliterable input control so that user can give input in both Telugu and English.
- Using database for context resolution
- Fetching the results using the URL from web server
- Performing web content mining for retrieving the links
- Displaying list of Websites that matches the given search criteria

IV. ARCHITECTURE OF MEDHAMSHASHODHINI

a) *Thesaurus Building*

In the proposed system we use relational database(tables) to store and retrieve large amounts of data. Here we consider two schemas, one for generic context and another for specific context. Each context will in turn have two tables. General context contains two tables: GenWordsEng(table for English words), GenWordsTel(table for Telugu words). Specific context contains two tables: EngSp(Specific context table for English words), TelSp(Specific context table for Telugu words).

i. *GenWordsEng Table*

This table contains all the English words. The table 'GenWordsEng', shown in Table 1, has two attributes: 'Word' and 'Id'. 'Id' is the primary key, which uniquely identifies the words in the table. 'Word' attribute is also unique, which doesn't allow having duplicate copies of word in the table. For each word in the table a unique id is assigned so that, using the id, words can be retrieved from other table. Both will act as the candidate keys. 'Id' of GenWordsTel acts as foreign key for GenWordsEng table. This foreign key is used in EngTelMap as discussed in section 4.4

Word	Id
Letter	1
Rent	2
Hundred	3
Tax	4
Gold	5
Hand	6
answer	7
do	8
reply	9
.....	

Table 1 : English words general context – GenWordsEng

ii. *GenWordsTel Table*

This table contains all Telugu words and its corresponding English word Id. Just like GenWordsEng table, it also has two attributes 'Word' and 'Id' with a difference that in this table, only the attribute 'Word' is unique and hence is the primary key. Id stores the value of GenWordsEng Id. So it may be duplicated. For example, consider word 'Gold'. It's Id in GenWordsEng is 5. All its semantically equivalent words of Telugu will have the same value, i.e. 5, in their Id field as shown in Table 2.

Word	Id
ఉత్తరం	1
లేఖ	1
జవాబు	7
స్వర్ణం	5
బంగారం	5
పైడి	5
పసిడి	5
కనకం	5
పుత్తడి	5
...	...

Table 2 : General Context Telugu table - GenWordsTel

b) *Mapping for General Context*

Mapping is the main module that retrieves semantically equivalent words from Telugu if the search term is in English and vice versa. As stated above, id of GenWordsEng table is the foreign key of GenWordsTel table. For example, if the search term is 'Gold' whose id is '5' in GenWordsEng, the tool searches for value '5' in Id column of GenWordsTel and retrieves all the rows of id '5' to get the respective synonyms for English word in GenWordsEng. Thus, by this mapping we can get multiple synonyms for given English word as shown in Fig.2

Gold = రం (sva-rNM), బంగారం (baM-gA-rM), పైడి (pai-Di),
పసిడి (pa-si-di), కనకం (ka-na-kM), పుత్తడి (pu-tta-Di)

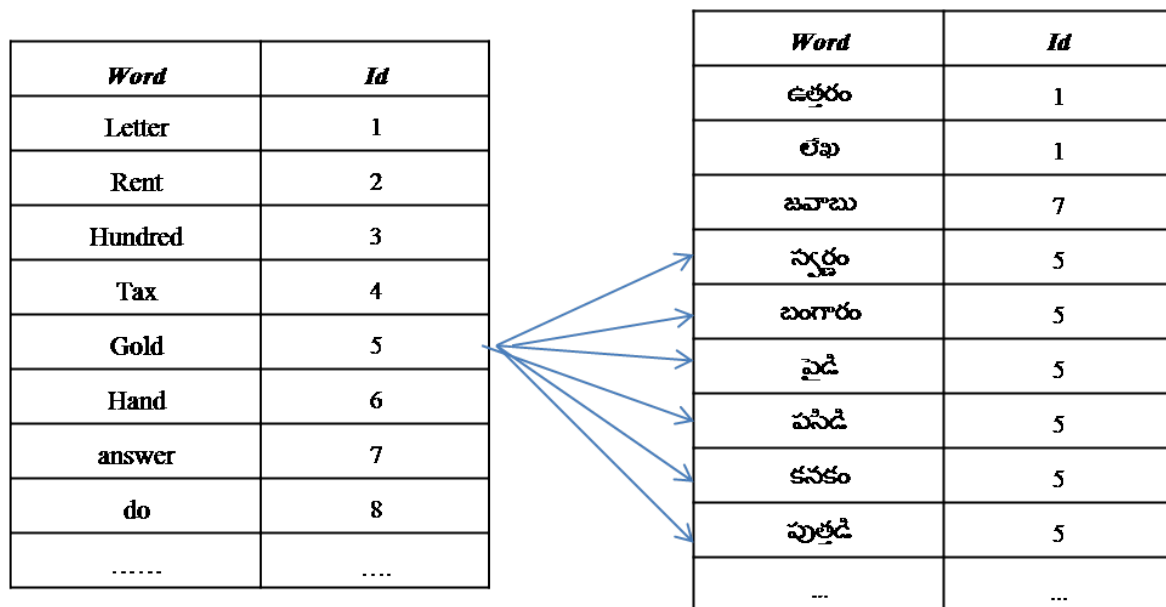


Fig 2 : Mapping word with its synonyms

Word	Id
Letter	1
Rent	2
Hundred	3
Tax	4
Gold	5
Hand	6
answer	7
do	8
.....	

Word	Id
ఉత్తరం	1
లేఖ	1
జవాబు	7
స్వర్ణం	5
బంగారం	5
పైడి	5
పసిడి	5
కనకం	5
పుత్తడి	5
...	...

Fig 3 : Reverse mapping

Fig 3 shows reverse mapping, in which we can get English synonym for given Telugu word. So, if you give any of the above mentioned Telugu word, it will map to the English word 'Gold' with the help of Id field.

స్వర్ణం, బంగారం, పైడి, పసిడి, కనకం, పుత్తడి = Gold

In fig.4, we can observe, mapping within the table, which gives multiple Telugu synonyms for given Telugu word. Given a word in Telugu, get the corresponding Id of it and then scan the whole table for that Id in Id column and extract all the words having that Id. Then the result set contains all the synonyms for the given word.

Word	Id
ఉత్తరం	1
లేఖ	1
జవాబు	7
స్వర్ణం	5
బంగారం	5
పైడి	5
పసిడి	5
కనకం	5
పుత్తడి	5
...	...

Fig 4 : Mapping in the same table

For example, consider the word 'స్వర్ణం', Id of it is '5', searching the whole table for Id 5, we get the words like: బంగారం, పైడి, పసిడి, కనకం, పుత్తడి. Thus in this kind of mapping we can get English/Telugu synonyms for given words of same language.

c) Specific Context Tables and Mapping

These tables are designed for user specific match. A word may be having many meanings. Depending on the user choice, it will search only for those user selected meanings instead of all semantically related words.

i. EngSpTable

As shown in Table 3, EngSp table contains four attributes: Id, Eword, Eid, Tid. 'Id' is the primary key which uniquely identifies the word in the table. 'Eword' is the English word which is the unique key avoiding duplicate copies. 'Eid' and 'Tid' are the ids of the English and Telugu synonyms of the word in the same table and the other table. 'Eid's are the Id's of English words in the same table. 'Tid's are the Telugu word id's in table 'TelSp'. Using these two columns id's we get synonyms for the given word.

Id	Word	Eid	Tid
1	reply	7	1,3
2	add	3,4	10
3	join	2,4	10
4	combine	2,3	10
5	Gold	---	5

6	reason	8	11
7	answer	1	1,3
8	excuse	6	11
9	north	---	1
10	grow	---	12
...	...	...	...

Table 3 : Specific context English table (EngSp)

ii. *TelSp*

Table 4 is 'TelSp' table which has Telugu words with its corresponding Ids. This table contains four attributes: 'Id', 'Tword', 'Eid', 'Tid'. 'Id' is the primary key which uniquely identifies the Telugu word in the table. 'Tword' is the Telugu word which is unique, avoiding duplicate entries of the same word. 'Eid' and 'Tid' are the Ids of the English and Telugu synonyms of the word in the same table and other table. 'Eid's are the ids of English words in the EngSp table. 'Tid's are the Telugu word ids in the same table. Using these two columns we get synonyms for the given word.

Id	Word	Tid	Eid
1	ఉత్తరం	2,3	1,7,9
2	లేఖ	1	1
3	జవాబు	1	7

Id	Word	Eid	Tid
1	reply	7	1,3
2	add	3,4	10
3	join	2,4	10
4	combine	2,3	10
5	Gold	—	5
6	reason	8	11
7	answer	1	1,3
8	excuse	6	11
9	north	—	1
....			

4	స్వర్గం	5,6,7,8,9	5
5	బంగారం	4,6,7,8,9	5
6	పైడి	4,5,7,8,9	5
7	పసిడి	4,5,6,8,9	5
8	కనకం	4,5,6,7,9	5
9	పుత్తడి	4,5,6,7,8	5
10	కూడు	---	2,3,4
11	సాకు	12,13	6,8
12	పెంచు	11	10
13	కారణం	11	6

Table 4 : Specific context Telugu table (TelSp)

d) *EngTelMap - Mapping*

This mapping is done when the given term is in English, and has many meanings; we need to search for a specific meaning. Fig.5 shows the EngTel Mapping. From the figure we can observe the mapping between the two tables in specific context. Given an English word get the Tids of the word. Now scan the 'Id' column of 'TelSp' using the Tid's we got previously, as shown in the figure. So, for example, for the English word 'reply', Tids are:1,3. So, get the words from TelSp table with ids 1 and 3. The resulting set of words is list of synonyms of the word 'reply'.

reply: ఉత్తరం, జవాబు. This illustrates forward mapping from English to Telugu.

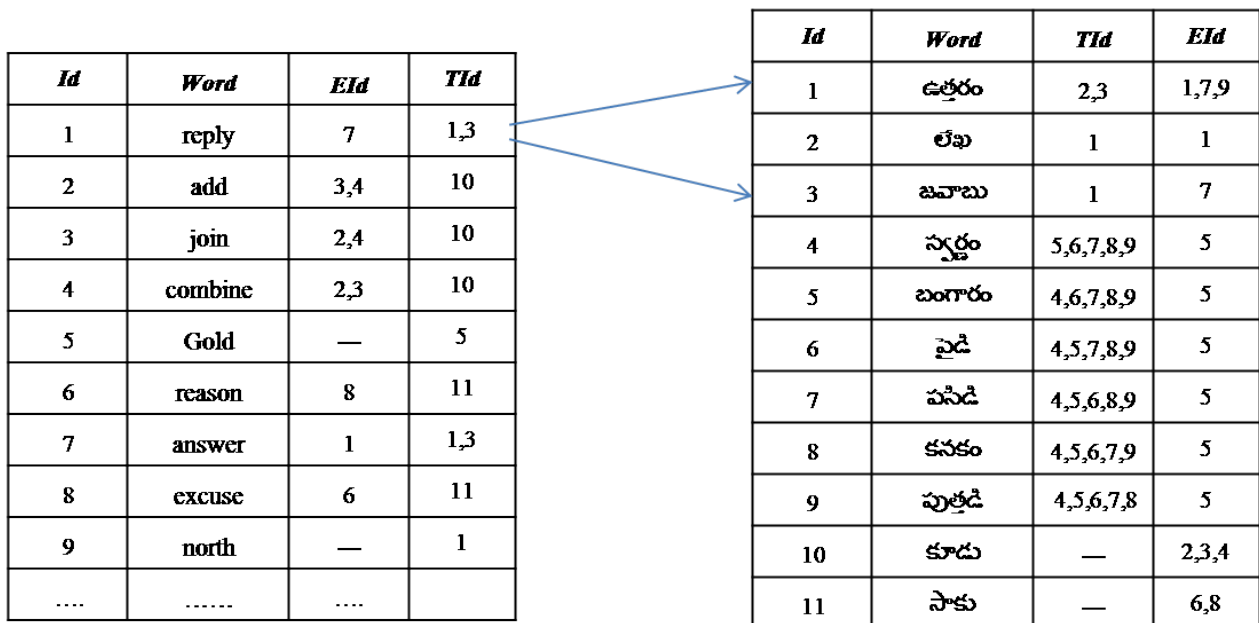


Fig 5 : EngTelMap

<i>Id</i>	<i>Word</i>	<i>EId</i>	<i>TId</i>
1	reply	7	1,3
2	add	3,4	10
3	join	2,4	10
4	combine	2,3	10
5	Gold	—	5
6	reason	8	11
7	answer	1	1,3
8	excuse	6	11
9	north	—	1
....			

<i>Id</i>	<i>Word</i>	<i>TId</i>	<i>EId</i>
1	ఉత్తరం	2,3	1,7,9
2	లేఖ	1	1
3	జవాబు	1	7
4	స్వర్ణం	5,6,7,8,9	5
5	బంగారం	4,6,7,8,9	5
6	పైడి	4,5,7,8,9	5
7	పసిడి	4,5,6,8,9	5
8	కనకం	4,5,6,7,9	5
9	పుల్లడి	4,5,6,7,8	5
10	కూడు	—	2,3,4
11	పాకు	—	6,8

Fig 6 : TelEngMap

The figure 6 shows how the backward mapping goes from Telugu table to English table in specific context. Given a Telugu word, first get the Eid of the corresponding Tword from 'Eid' column. Scan the EngSp table for the retrieved ids previously, and extract the respective English words from EngSp table, then the resulting set contains all the English synonyms for the given Telugu word. In Fig 7, we can see the mapping within the table, where we can get the multiple Telugu synonyms in various context for given Telugu word. Given a Telugu word, we get the Tid of the corresponding word and scan the same table for the retrieved id. The result set contains the set of Telugu words which resembles meanings for given word in various contexts.

For eg:word: పాకు = పెంచు, కారణం

<i>Id</i>	<i>Word</i>	<i>TId</i>	<i>EId</i>
1	ఉత్తరం	2,3	1,7,9
2	లేఖ	1	1
3	జవాబు	1	7
4	స్వర్ణం	5,6,7,8,9	5
5	బంగారం	4,6,7,8,9	5
6	పైడి	4,5,7,8,9	5
7	పసిడి	4,5,6,8,9	5
8	కనకం	4,5,6,7,9	5
9	పుల్లడి	4,5,6,7,8	5
10	కూడు	—	2,3,4
11	పాకు	12,13	6,8
12	పెంచు	11	10
13	కారణం	11	6

Fig 7 : Mapping in the same table

IX. CONCLUSION

The overall quality of web searching system is determined not only by the prowess of its searching algorithm, but also by the caliber of its corpus, both in terms of comprehensiveness (e.g. coverage of topics,

language, etc.) and refinement (e.g. freshness, avoidance of redundancy, etc.). The relative corpus size estimates competitive marketing advantage and bragging rights in the context of the web searching.

We have collected 700 Telugu words with their respective synonyms in general context and 25 Telugu words with different synonyms and semantically related words in specific context. In all the corpus has 1,020 words stored in a very efficient manner.

Manual procedures of thesaurus building can be a bottleneck of our proposed approach. In our future work we are going to address the problem by making use of automated lexical acquisition. The automatically constructed thesaurus can also be taken as a starting point for developing a better searching system. In the present system we have developed tools for searching Telugu and English words. This can be extended to other languages so that the user can perform multilingual searching at one go.

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Complete support for both authors and co-author is provided.

4. MANUSCRIPT'S CATEGORY

Based on potential and nature, the manuscript can be categorized under the following heads:

Original research paper: Such papers are reports of high-level significant original research work.

Review papers: These are concise, significant but helpful and decisive topics for young researchers.

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Research letters: The letters are small and concise comments on previously published matters.

5. STRUCTURE AND FORMAT OF MANUSCRIPT

The recommended size of original research paper is less than seven thousand words, review papers fewer than seven thousands words also. Preparation of research paper or how to write research paper, are major hurdle, while writing manuscript. The research articles and research letters should be fewer than three thousand words, the structure original research paper; sometime review paper should be as follows:

Papers: These are reports of significant research (typically less than 7000 words equivalent, including tables, figures, references), and comprise:

- (a) Title should be relevant and commensurate with the theme of the paper.
- (b) A brief Summary, "Abstract" (less than 150 words) containing the major results and conclusions.
- (c) Up to ten keywords, that precisely identifies the paper's subject, purpose, and focus.
- (d) An Introduction, giving necessary background excluding subheadings; objectives must be clearly declared.
- (e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition; sources of information must be given and numerical methods must be specified by reference, unless non-standard.
- (f) Results should be presented concisely, by well-designed tables and/or figures; the same data may not be used in both; suitable statistical data should be given. All data must be obtained with attention to numerical detail in the planning stage. As reproduced design has been recognized to be important to experiments for a considerable time, the Editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned un-refereed;
- (g) Discussion should cover the implications and consequences, not just recapitulating the results; conclusions should be summarizing.
- (h) Brief Acknowledgements.
- (i) References in the proper form.

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It is vital, that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

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Acknowledgements: Please make these as concise as possible.

References

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