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Multiple Linear Regression Theory Based Performance Optimization of Bakken And Eagle Ford Shale oil Reservoirs

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ABSTRACT: This paper presents the application of multiple linear regression modelling (MLR) to evaluate the performance of the Bakken shale oil and Eagle Ford gas condensate reservoirs in the United States.A critical review and analysis were made on the unconventional reservoirs and also on using CO_2 huff-n-puff, and flooding processes for enhanced oil recovery (EOR).A total of four models was taken for the analysis, such as the Bakken and Eagle Ford reservoirs with CO_2 huff-n-puff process and another two models with CO_2 Flooding. Injection pressure, injection rate, injection time, number of cycle, carbon dioxide soaking time, fracture half-length, fracture conductivity, fracture spacing, porosity, permeability, and initial reservoir pressure as taken as inputs and cumulative oil production, and oil recovery factor was taken as outputs. The reservoirs was designed for 30 years of oil production and this is considered as DMU and the Chi-Square test was used to validate the model for the goodness of fit. From the statistical results, it was investigated that the performance of the Eagle Ford reservoir in both scenarios of huff-n-puff and flooding were better than the Bakken reservoir model, even the χ^2test has validated the Eagle Ford gas condensate reservoir model as good.
Keywords: Energy Demand, CO_2 Injection,MLR, Chi-Square, SPSS.

I. INTRODUCTION

At this present time, the energy demand and climate change are the potential issues in the world. There is an urgency for the optimization of energy resources and reduction of carbon dioxide emissions. All over the world the Energy economists are in heated discussion and debate on the future of energy growth and demand. They predict the world population will rise thrice than today in the next two decades, as a result the demand for energy will be skyrocketing [4]. Due to this concern, the new energy resources need to be exploited. The Global and Russian Energy Outlook to 2040 suggests that, by 2040 the world oil demand will increase from the growing economies like India, and natural gas is the rapidly rising fossil fuel, which is growing at the rate of 1.6 % per year [2]. The development of horizontal wells and extended-reach wells have explored the remote complex subsurface for oil and gas recovery. The oil reserve might be located from a few meters from onshore and drilling can be executed from onshore (one location) to that offshore region (another location), thereby, leading to robust hydrocarbon production. Typically, this type of well is inclined to angle > 85° and it is characterized by build rate, short and medium radius horizontal wells.Increase in cumulative hydrocarbon production, reduction in the wellbore pressure drop, less fluid velocities, reduced water and gas coning, and lower formation damage and fines migration are the primary advantages of implementing wells in horizontal configuration.Like water flooding the CO_2 flooding is an EOR process in which the captured carbon dioxide is transported to oil field through the pipeline and injected into the reservoir to extract oil and gas. Its process is schematically presented in the figure 2. The recovery depends upon several factors. Injection pressure, time, mass, wellbore length and diameter, fracture properties, oil viscosity, mobility ratio, porosity, permeability, compressibility, reservoir pressure lithology etc. Both miscible and immiscible CO_2 flooding were successfully demonstrated in different oil and gas projects around the world. Mostly, many researchers analyzed the reservoir oil recovery rate by using miscible flooding, but some authors argue that, the performance of using immiscible CO_2 flooding is better than the miscible flooding [3].Hashemi et al. (2014), evaluated the miscible and immiscible carbon dioxide injection in an oil field in Iran. The authors used Eclipse reservoir simulation models to evaluate the miscible and immiscible CO_2 flooding in a fractured oil field and ten fluid components are grouped into pseudo-components to reduce to the simulation time. For making reservoir model as static a FloGrid software was used by the authors and ECLIPSE 300 was employed to miscible and immiscible CO_2-injection and several cases of natural depletion. The investigation exposed that oil recovery factor in the case of miscible CO_2 injection is more efficacious than other techniques [6].

Huang et al. (2003), developed an artificial neural network (ANN) model to predict the CO_2 flooding-minimum miscibility pressure (MMP). The reservoir fluid MMP CO_2 in the pure state is correlated with the molecular weight of reservoir temperature, C_5+ fraction and volatile concentrations (CH_4) and intermediate (C_2 –C_4) oil fractions. The impure form of CO_2 MMP factor, F_{imp}, is predicted by correlating the contaminant concentrations (C1, N_2, SO_2 and H_2S) in stream of CO_2 and their critical temperatures. The models were compared with predicted values in ANN with estimated MMP values and these values showed good agreement. Subsequently, authors suggesting that this ANN methodology is productive in determining the values of MMP [8].Song et al. (2014), conducted water alternating gas (WAG) carbon dioxide flooding sensitivity analysis for EOR in oil reservoirs with high cut. The authors simulated several heterogeneous 3D reservoir models to study the effects of reservoir types and efficiency of CO_2 flooding, and storage capacity. In order to optimize the operational parameters such as CO_2 injection rate, voidage displacement ratio, slug size of CO_2, and WAG ratio, they applied orthogonal array experimental design technique, nine, seven, and five spot patterns were employed in this study. The main results indicated that, five-sport pattern is the most suitable method for WAG flooding and the voidage displacement ratio is identified as the governing parameter. Oil price is selected to be the dominating economic parameter on WAG flooding with CO_2[25].

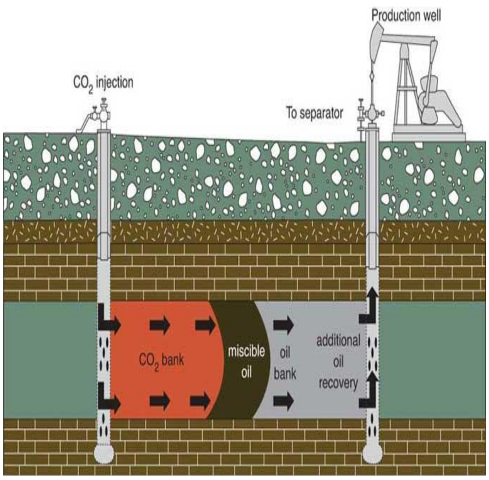

Fig.2: Schematic Diagram Indicating the Process of CO_2-EOR coupled with storage[12]

The CO_2 huff-n-puff process has been used in all types of reservoirs since in late 1980's. The schematic procedure of huff-n-puff process is shown in figure 3. It comprises of three steps such as carbon dioxide injection, soaking, and production. The first stage is injection, where CO_2 injected into the reservoir and the well will be shut-down for some time (very short period) for soaking this process is the second stage, and after soaking the well is opened for fluid recovery to the surface. The oil and gas recovery through huff-n-puff process is very effective in Eagle Ford gas condensate reservoir than CO_2 flooding due to decrease in oil saturation near wellbore, high drawdown pressure, and easily overcoming the problem of fluid transport [24]. The same impacts were also observed and reported in the Bakken tight oil reservoir [30].

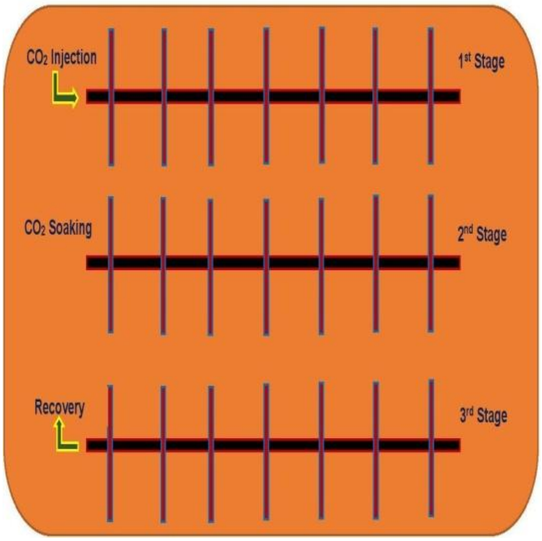

Fig.3: Huff-N-Puff Process with CO_2

Sanchez-Rivera et al. (2015), created a numerical model to optimize the process of Huff-and-Puff in the Bakken shale reservoir. Various Huff-n-Puff methods were studied by using CMG-GEM unconventional reservoir simulator: a compositional model. The author observed that starting Huff-n-Puff technique at an early phase in the well life reduces its effectiveness, and the lesser soaking time are preferable over longer waiting time. When natural fractures are present Bakken reservoir, then the CO_2 Huff-n-Puff is most influential [22].Sheng et al. (2015), investigated the potential of gas powered huff-n-puff process to proliferate oil production in an unconventional condensate reservoir. The authors have simulated Eagle Ford gas condensate reservoir and analyzed the optimum huff-n-puff procedure for 600 days. Other impacts such as gas composition, injection pressure, and initial water saturation were also investigated in this research.

The simulation results, suggest that either huff or puff process time should be about 900 days and the maximum gas injection pressure must be above upper dew-point pressure, hence the liquid dropout can be vaporized again [24]. Li et al. (2011), simulated and examined the carbon dioxide and viscosity aided steam huff-n-puff methodology for horizontal wells in a heavy oil reservoir. The CO_2 displacement efficiency and viscosity breaker assisted huff-n-puff process with steam flooding and injection pressure were analyzed in lab testing. The results demonstrated that, the carbon dioxide displacement efficiency and viscosity breaker steam flooding were 80.8%, this was higher than that of steam flooding which was 65.4%

Unconventional Fields

Unconventional reservoirs also known as shale are characterized by the fine grains in shale rocks and with respect to the depth of the reservoir (origin in source rock). Unlike conventional methods, this method needs new methods for commercial and effective hydrocarbon production. This type of reservoir become a subject of great interest among all oil and gas companies throughout the world are showing interest and investing in unconventional oil and gas reservoir exploration and production. As this became the new source of energy exploitation and generating a good profitable business. This project specifically deals with Bakken tight oil and Eagle Ford gas condensate reservoirs. The following figure 4 shows the America's major shale hydrocarbon geological formations.

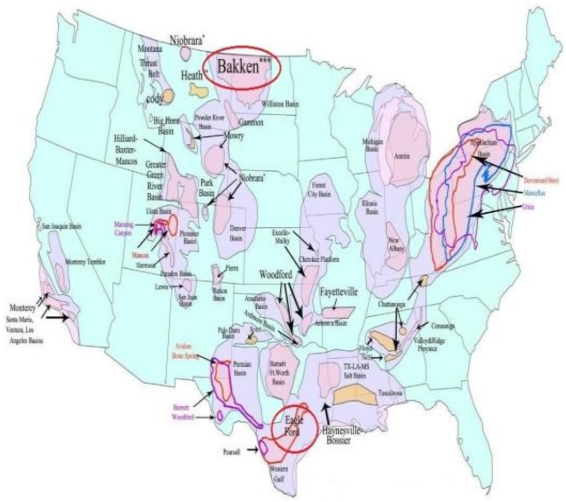

Fig.4: Major Unconventional-Shale Formations in United States, Bakken and Eagle formations are circled in red [27]

2.1 Bakken Shale Oil Field

The Bakken geological formation is a type of rock unit from the time of Late Devonian to Early Mississippian age covering about 520,000 km^2 of the Williston Basin subsurface, underlying regions of North Dakota, Montana, Manitoba and Saskatchewan. It is a sequence of interbedded sandstone, siltstone, and black shale in these areas and it is also one of the major deposits of shale oil and gas in Canada and USA.

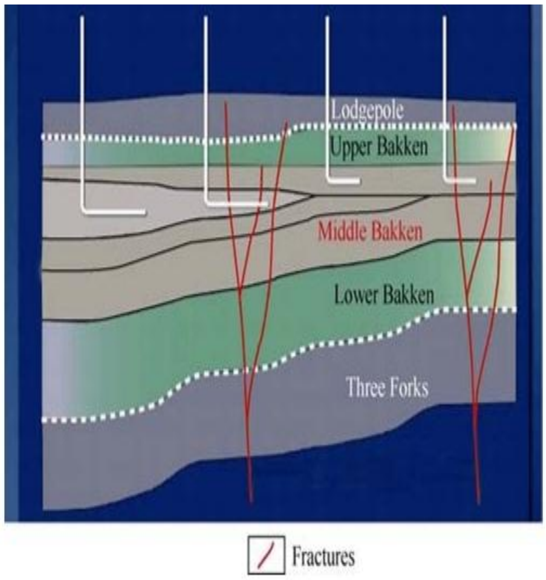

Fig.5: Bakken Tight Formation for Oil Production

The Bakken formation is mixed carbonate-clastic petroleum layers with low permeability and porosity and possess a complicated lithology, consisting of Upper, Middle and Lower Bakken Shales, Three Forks with fractures are shown in figure 5. The Middle Bakken and Three Forks are two main layers in the production of tight oil since they hold finest reservoir characteristics such oil saturation and porosity [10].Liang et al. (2013), investigated the production ability of single well and its influencing factors in the Bakken shale oil reservoir, Williston Basin. Liang employed orthogonal experiment design, gray correlative method, and information amount theory in designing and optimizing of a horizontal well (with fracturing). The results reveal that the parameters fracture length, permeability should be considered as primary influencing factors. These parameters assist in the optimization of oil production from a single well in Bakken [14].

McNally and Brandt (2015), briefly analyzed the prospects for the potential future oil recovery and production in Bakken formation at North America. The authors used least square curve fitting method on 5773 wells in the Bakken oil field.These wells were drilled from mid-2013 to 2015. Fitted each wells with decline and exponential models.

Individual well productivity, spacing, drilling rate were taken as important parameters. A typical well was modelled for 15 years of production with 270 mbbl per day (mean) or 221 mbbl per day (median). The major modelling result shows that enhancing ultimate recovery steadily declines over a period of years.As the author's study suggest that higher oil can be recovered at the initial stages of production [15].

Tran et al. (2011), analyzed the characteristics of three dissimilar types of shale oil production from Bakken reservoir. Decline curves of 146 well histories were analyzed by the author and classify the wells into Type I, II and II, which play a major role in the significant production of oil in Bakken [26]. Yu et al. (2015), analyzed the Bakken tight oil reservoir oil production with CO_2 injection. The author conducted a numerical simulation to model huff-n-puff CO_2 injection for oil production from Bakken reservoir. The Bakken reservoir was also modelled using with typical fracture properties. The impacts of fracture half-length, reservoir heterogeneity of carbon dioxide huff-n-puff process on the performance of the well, molecular diffusion, and number of cycles are analyzed deeply. The main results revealed that CO_2 diffusion plays a vital role in enhancing the oil recovery from shale or tight oil reservoirs. The author emphasized that the CO_2 Huff-n-Puff process is favorable for higher oil recovery factor in Bakken reservoir due to its geological properties [30].

2.2 Eagle Ford Gas Condensate Field

The Eagle ford group is a formation of sedimentary rock in the age of late cretaceous underlying from the southern US states of New Mexico to Texas, comprising of fossiliferous marine shale with organic rich-matter and figure 6 shows the map of Eagle Ford formation. The mineralogy of the Eagle Ford formation consists of calcite greater than 50%, moderate quantities of clays, kerogen, and quartz. This group encompasses a hydrocarbon fluids in wide spectrum ranging from low Gas-Oil-Ratio (GOR) black oils to volatile oils and lean, and rich condensates of gas [19]. It was estimated by US government agency Energy Information Administration (EIA) that, in this formation, there's 3.37 billion barrels of oil and 2.5 trillion cubic feet of gas.

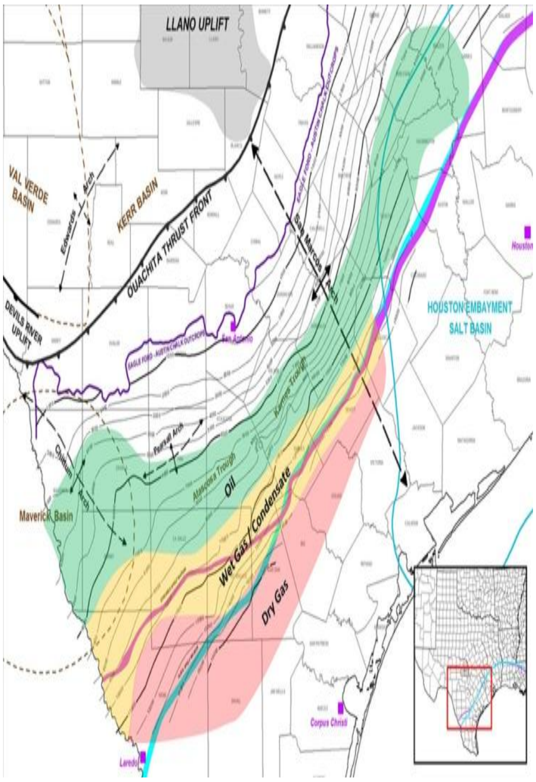

Fig.6: Eagle Ford Basin [18]

Gong et al. (2015), made an assessment of hydrocarbon resources in the Eagle Ford Shale reservoir. The authors employed Markov Chain Monte Carlo (MCMC) for getting probabilistic decline curve in order to forecast the resources and reserves [5].Mullen et al. (2010), critically analyzed the Eagle Ford shale development and its commercial production prospects. The authors compared the Eagle Ford with other shale reservoirs such as Barnett and Hynesville. They emphasized that Barnett and Hynesville fields have been producing since 1980 and 2005, but Eagle Ford has begun its production from 2009 onwards, they suggest that a more risk assessment should be made on Eagle Ford field for the energy company's economic benefits. A detailed study of this reservoir and drilling techniques is required. Finally, authors insisting to use pulsed-neutron log (PNL) and other well logs to determine the well's performance [17].Morsy et al. (2015), examined the Eagle Ford shale reservoir recovery, mechanical and physical factors. Also, they have examined the impacts of low concentration Hcl on the mineralogy of the Eagle ford shale reservoir. Core samples from Eagle Ford shale formations are taken for these physical properties evaluations. From the lab results, it was observed that the samples exposed 1, 2, and 3 wt% Hcl and mass were also observed in these samples.

These samples from the Eagle Ford geological formation exhibitedthe highest oil recovery factors in the range of 38% to 71% with an important decline in 25% to 82% of Young's modulus when exposed to Hcl solutions at 93 °C [16]. Robinson (2015), investigated the variability of hydrocarbon source rock within the Eagle Ford Shale and Austin Chalk. Author studied the geochemical analysis on these rocks to quantify the oil source rocks. He observed the results that both geological formation have the capability of generating liquid oil production.Specifically, Eagle Ford possess larger quantities of oil-prone kerogen, this reveals that Eagle Ford is a most important oil field for investment and development than the Austin Chalk formation[21].

II. METHODOLOGY

The methodology for this is presented in figure 7. The first step is to acquire input and output data for the both reservoir models using CO_2 huff-n-puff and flooding methods. Then modelling of multiple linear regression and statistical simulations. Tables 1, 2, 3 and 4 shows the input and output (highlighted in bold) values of Bakken and Eagle Ford reservoir models with CO_2 huff-n-puff and flooding techniques, and these values are obtained from the simulation results.The reservoir models were simulated using Eclipse and CMG-GEM reservoir software packages and the Eagle Ford and Bakken reservoir properties and other data are available in the literatures [24] and [30].But, the reservoir simulations modelling results were not presented in this paper and this paper emphasize only the applications of MLR modelling as part of sensitivity analysis.

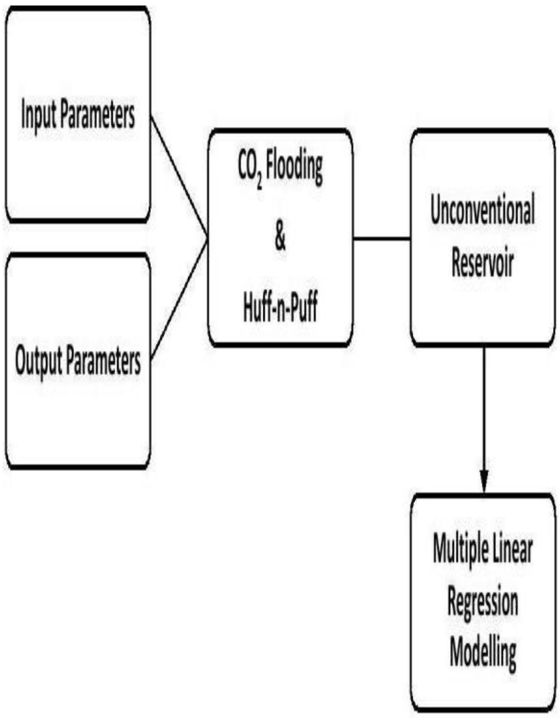

Fig.7: Unconventional Reservoir Performance Evaluation: MLR Process

Table 1: Input and Output (Bold) Data for Bakken Reservoir with CO_2 huff-n-puff Process

Year (DMU)	Injection Pressure (psi)	Injection Rate (MSCF/day)	Injection Time (Month)	Number of Cycle	CO_2 Soaking Time (Month)	Fracture Half-Length (ft)	Fracture Conductivity (md-ft)	Fracture Spacing (ft)	Prosity (Fraction)	Permeability (md)	Initial Reservoir Pressure (psi)	**Cumulative Oil Production (STB)**	**Oil Recovery Factor (%)**
1	0	0	0	0	1	340	1	50	0.04	0.00005	8000	**50**	**0.2**
2	2000	50	3	1	1	340	1	50	0.04	0.00005	8000	**65**	**3**
3	2000	50	3	1	1	340	1	50	0.04	0.00005	8000	**77**	**5**
4	2000	50	3	1	1	340	1	50	0.04	0.00005	8000	**89**	**8**
5	2000	50	3	1	1	340	1	50	0.04	0.00005	8000	**100**	**10**
6	2000	50	3	1	1	340	1	50	0.04	0.00005	8000	**116**	**12**
7	2000	50	3	1	1	340	1	50	0.04	0.00005	8000	**128**	**14**
8	2000	50	3	1	1	340	1	50	0.04	0.00005	8000	**137**	**15**
9	2000	50	3	1	1	340	1	50	0.04	0.00005	8000	**144**	**17**
10	2000	50	3	1	1	340	1	50	0.04	0.00005	8000	**155**	**18**
11	4000	100	6	2	3	340	1	50	0.04	0.00005	8000	**169**	**18.23**
12	4000	100	6	2	3	340	1	50	0.04	0.00005	8000	**173**	**18.35**
13	4000	100	6	2	3	340	1	50	0.04	0.00005	8000	**188**	**19**
14	4000	100	6	2	3	340	1	50	0.04	0.00005	8000	**196**	**19.01**
15	4000	100	6	2	3	340	1	50	0.04	0.00005	8000	**200**	**21**
16	4000	100	6	2	3	340	1	50	0.04	0.00005	8000	**262**	**21.68**
17	4000	100	6	2	3	340	1	50	0.04	0.00005	8000	**275**	**21.72**
18	4000	100	6	2	3	340	1	50	0.04	0.00005	8000	**284**	**22**
19	4000	100	6	2	3	340	1	50	0.04	0.00005	8000	**291**	**22.14**
20	4000	100	6	2	3	340	1	50	0.04	0.00005	8000	**300**	**23**
21	6000	500	9	3	5	340	1	50	0.04	0.00005	8000	**330**	**23.33**
22	6000	500	9	3	5	340	1	50	0.04	0.00005	8000	**347**	**23.45**
23	6000	500	9	3	5	340	1	50	0.04	0.00005	8000	**350**	**24**
24	6000	500	9	3	5	340	1	50	0.04	0.00005	8000	**356**	**24.82**
25	6000	500	9	3	5	340	1	50	0.04	0.00005	8000	**360**	**25**
26	6000	500	9	3	5	340	1	50	0.04	0.00005	8000	**366**	**25.32**
27	6000	500	9	3	5	340	1	50	0.04	0.00005	8000	**374**	**25.4**
28	6000	500	9	3	5	340	1	50	0.04	0.00005	8000	**378**	**26.64**
29	6000	500	9	3	5	340	1	50	0.04	0.00005	8000	**382**	**25.81**
30	6000	500	9	3	5	340	1	50	0.04	0.00005	8000	**385**	**26**

Table 2: Inputand Output (Bold) Data for Bakken Reservoir with CO_2 Flooding

Year (DMU)	Injection Pressure (psi)	Injection Rate (MSCF/day)	Fracture Half-Length (ft)	Fracture Conductivity (md-ft)	Fracture Spacing (ft)	Prosity (Fraction)	Permeability (md)	Initial Reservoir Pressure (psi)	Cumulative Oil Production (STB)	Oil Recovery Factor (%)
1	0	0	340	1	50	0.04	0.00005	8000	44	0.1
2	8000	200	340	1	50	0.04	0.00005	8000	61	0.2
3	8000	200	340	1	50	0.04	0.00005	8000	84	4
4	8000	200	340	1	50	0.04	0.00005	8000	106	5
5	8000	200	340	1	50	0.04	0.00005	8000	111	8
6	8000	200	340	1	50	0.04	0.00005	8000	116	12
7	8000	200	340	1	50	0.04	0.00005	8000	118	13.12
8	8000	200	340	1	50	0.04	0.00005	8000	119	15.32
9	8000	200	340	1	50	0.04	0.00005	8000	120	17
10	8000	200	340	1	50	0.04	0.00005	8000	124	17.56
11	8000	600	340	1	50	0.04	0.00005	8000	168	17.95
12	12000	600	340	1	50	0.04	0.00005	8000	173	18.03
13	12000	600	340	1	50	0.04	0.00005	8000	177	18
14	12000	600	340	1	50	0.04	0.00005	8000	181	19.14
15	12000	600	340	1	50	0.04	0.00005	8000	185	19.27
16	12000	600	340	1	50	0.04	0.00005	8000	230	19.35
17	12000	600	340	1	50	0.04	0.00005	8000	255	19.38
18	12000	600	340	1	50	0.04	0.00005	8000	285	19.42
19	12000	600	340	1	50	0.04	0.00005	8000	288	20
20	12000	800	340	1	50	0.04	0.00005	8000	290	20.09
21	15000	800	340	1	50	0.04	0.00005	8000	325	20.66
22	15000	800	340	1	50	0.04	0.00005	8000	332	20.7
23	15000	800	340	1	50	0.04	0.00005	8000	335	20.84
24	15000	800	340	1	50	0.04	0.00005	8000	338	20.86
25	15000	800	340	1	50	0.04	0.00005	8000	342	21
26	15000	800	340	1	50	0.04	0.00005	8000	345	21.16
27	15000	800	340	1	50	0.04	0.00005	8000	346	21.46
28	15000	800	340	1	50	0.04	0.00005	8000	350	21.53
29	15000	800	340	1	50	0.04	0.00005	8000	353	21.68
30	15000	800	340	1	50	0.04	0.00005	8000	358	22

Table 3: Inputand Output (Bold) Data for Eagle Ford Reservoir with CO_2 huff-n-puff Process

Year (DMU)	Injection Pressure (psi)	Injection Rate (MSCF/day)	Injection Time (Month)	Number of Cycle	CO_2 Soaking Time (Month)	Fracture Half-Length (ft)	Fracture Spacing (ft)	Prosity (Fraction)	Permeability (md)	Initial Reservoir Pressure (psi)	**Cumulative Oil Production (STB)**
1	0	0	0	0	1	250	45	0.09	0.00005	4000	**55**
2	500	50	3	1	1	250	45	0.09	0.00005	4000	**128**
3	500	50	3	1	1	250	45	0.09	0.00005	4000	**146**
4	500	50	3	1	1	250	45	0.09	0.00005	4000	**164**
5	500	50	3	1	1	250	45	0.09	0.00	4000	**170**

									005		
6	1000	50	3	1	1	250	45	0.09	0.00 005	4000	**175**
7	1000	120	3	1	1	250	45	0.09	0.00 005	4000	**184**
8	1000	120	3	1	1	250	45	0.09	0.00 005	4000	**196**
9	1000	120	3	1	1	250	45	0.09	0.00 005	4000	**204**
10	1000	120	3	1	1	250	45	0.09	0.00 005	4000	**224**
11	1000	120	3	1	1	250	45	0.09	0.00 005	4000	**229**
12	1000	120	3	1	1	250	45	0.09	0.00 005	4000	**247**
13	1000	120	3	1	1	250	45	0.09	0.00 005	4000	**260**
14	1000	120	3	1	1	250	45	0.09	0.00 005	4000	**269**
15	1000	120	3	1	1	250	45	0.09	0.00 005	4000	**275**
16	1000	295	6	2	3	250	45	0.09	0.00 005	4000	**290**
17	1500	295	6	2	3	250	45	0.09	0.00 005	4000	**307**
18	1500	295	6	2	3	250	45	0.09	0.00 005	4000	**320**
19	1500	295	6	2	3	250	45	0.09	0.00 005	4000	**322**
20	1500	295	6	2	3	250	45	0.09	0.00 005	4000	**328**
21	1500	295	6	2	3	250	45	0.09	0.00 005	4000	**336**
22	1500	295	6	2	3	250	45	0.09	0.00 005	4000	**345**
23	1500	295	6	2	3	250	45	0.09	0.00 005	4000	**352**
24	1500	295	6	2	3	250	45	0.09	0.00 005	4000	**361**
25	1500	295	6	2	5	250	45	0.09	0.00 005	4000	**367**
26	2500	530	9	3	5	250	45	0.09	0.00 005	4000	**370**
27	2500	530	9	3	5	250	45	0.09	0.00 005	4000	**380**
28	2500	530	9	3	5	250	45	0.09	0.00 005	4000	**385**
29	2500	530	9	3	5	250	45	0.09	0.00 005	4000	**396**
30	2500	530	9	3	5	250	45	0.09	0.00 005	4000	**400**

Table 4: Inputand Output Data (Bold) for Eagle Ford Reservoir with CO_2 Flooding

Year (DMU)	Injection Pressure (psi)	Injecti on Rate	Fracture Half-Length	Fract ure Spaci	Prosity (Fractio n)	Permeability (md)	Initial Reservoir Pressure	**Cumulativ e Oil Productio**

		(MSC F/day)	(ft)	ng (ft)			(psi)	**n (STB)**
1	0	0	250	45	0.09	0.00005	4000	**52**
2	500	50	250	45	0.09	0.00005	4000	**115**
3	500	50	250	45	0.09	0.00005	4000	**139**
4	500	50	250	45	0.09	0.00005	4000	**155**
5	500	50	250	45	0.09	0.00005	4000	**166**
6	1000	50	250	45	0.09	0.00005	4000	**170**
7	1000	120	250	45	0.09	0.00005	4000	**188**
8	1000	120	250	45	0.09	0.00005	4000	**194**
9	1000	120	250	45	0.09	0.00005	4000	**200**
10	1000	120	250	45	0.09	0.00005	4000	**216**
11	1000	120	250	45	0.09	0.00005	4000	**225**
12	1000	120	250	45	0.09	0.00005	4000	**244**
13	1000	120	250	45	0.09	0.00005	4000	**258**
14	1000	120	250	45	0.09	0.00005	4000	**264**
15	1000	120	250	45	0.09	0.00005	4000	**270**
16	1000	295	250	45	0.09	0.00005	4000	**386**
17	1500	295	250	45	0.09	0.00005	4000	**305**
18	1500	295	250	45	0.09	0.00005	4000	**318**
19	1500	295	250	45	0.09	0.00005	4000	**320**
20	1500	295	250	45	0.09	0.00005	4000	**325**
21	1500	295	250	45	0.09	0.00005	4000	**333**
22	1500	295	250	45	0.09	0.00005	4000	**341**
23	1500	295	250	45	0.09	0.00005	4000	**345**
24	1500	295	250	45	0.09	0.00005	4000	**348**
25	1500	295	250	45	0.09	0.00005	4000	**350**
26	2500	530	250	45	0.09	0.00005	4000	**353**
27	2500	530	250	45	0.09	0.00005	4000	**357**
28	2500	530	250	45	0.09	0.00005	4000	**368**
29	2500	530	250	45	0.09	0.00005	4000	**376**
30	2500	530	250	45	0.09	0.00005	4000	**384**

Deign of Experiment and Statistical Modelling are performed to establish a relationship between two or more variables. And also to determine their contribution to a particular goal or objective. Modelling are conducted by many researchers on a system by taking its input and output variables. For example, if we want to find the North Sea oil reservoir performance, we would consider the input affecting parameters like injection pressure, injection timing, injection fluid mass and output parameters like cumulative oil production and oil recovery factor. By modelling multiple regression or ANN (artificial neural network), we can find a relationship between variables and particular influencing variable contribution to the output. To our knowledge this is the first attempt to apply multiple regression modelling, and χ^2 Test in unconventional hydrocarbon reservoirs.

3.1 Regression Modelling with SPSS

The Multiple linear regression analysis is a statistical method for analyzing and establishing the relationship between two or more variables. The relationship between the variables are determined by the regression line slope termed as regression coefficient and clustering of points closed to this line indicates the strength of the model. It is apparent that, the Bakken and Eagle Ford reservoir are functions of its input parameters, which determines the expected and observed output. In this research project, the multiple linear regression analysis was conducted using SPSS (statistical package for social sciences) in version 22, a common statistical software tool. The software was simulated for the Bakken and Eagle Ford model with CO_2 huff-n-puff and flooding process, a total of four models were simulated. The general multiple regression equation is presented below [9].

$$Y = A_0+A_1X_1+A_2X_2+A_3X_3+\ldots\ldots\ldots\ldots+A_nX_n \quad (1)$$

Where,

Y = Estimated value corresponding to the dependent variable that is output.

A_0 = Intercept

X_1, X_2, X_3……..X_n = n independent (input) variable values
A_1, A_2, A_3……A_n = regression line (slope) associated with values of n input variables.

Amiri et al. (2015), applied multiple regression modelling method to evaluate the performance of energy consumption of commercial buildings across the United States of America. This model was created for workplace buildings with respect to cold, dry and warm, marine climate zones. The author's used DOE-2 a building simulation software for measuring the energy consumption and total of 17 key building key design variables was found. 150,000 in total, a computer simulation was performed by using Monte-Carlo simulations. This was done to develop a regression R statistical analysis program in accordance with 17 input parameters of annual energy consumption. The results indicated that, the models fitted close to the regression line for these climate regions, the value of R^2 was in the range from 0.95 to 0.98, and all other parameters showed almost a good agreement. Therefore, with a help of regression equation an energy consumption in corporate building can be obtained quickly [1].

Šebjan and Tominc. (2015), studied the usage of SPSS software package for students who are conducting statistical analysis. Also, investigating teachers support to this software package. The author's motive is to expand the technology acceptance model for SPSS by considering three factors, which includes teacher support, compatibility, and applications of statistics. Their study shows that, the SPSS plays a vital role in statistical analysis, teacher support added more weightage to this software package, and it helps economics students for their research [23].

3.2 Chi-Square test

The chi-square test was employed in this project to analyze the association between several input variables and also for model validation. The actual input and output values were compared with the observed values from the statistical software results, this non-parametric statistical tool χ^2test was designed on the hypothesis. Chi-square test consist of both T and F test, in this case we have used T or t test, is used to define whether there is a significant difference between the expected frequencies (actual data) and the observed frequencies (modelling data) in one or more categories. The equation (2) presents the standard formula for calculating the measure of the χ^2 test value [11].

$$\chi^2 = \sum_{i=1}^{n} \left(\frac{(O_i - E_i)^2}{E_i} \right)$$

Where,
O_i = Observed value
E_i = Expected value
n = Number of iterations used in the calculation

The χ^2 values are obtained for all the processes. The input and output values of both Bakken and Eagle ford reservoir scenarios were done with 5% significance level and SPSS (statistical package for social science) version 22 was used to carry out this study. This Chapter presents data envelopment analysis and multiple regression methods for CO_2 huff-n-puff process and flooding in Bakken shale oil and Eagle ford gas condensate reservoirs. The mathematical and equation modelling were successfully developed for both these statistical tools. The hysteresis modelling for carbon dioxide retention and the validation tool chi-square test was defined.

Xu et al. (2015), developed an algorithm and proposed a method to solve group decision making problems with obtaining a priority vector through chi-square method. Author's new developed model sheds a new light and way for executing and solving problems of group decision making with incomplete reciprocal preference relations [28].Usually, all statistical modelling and optimization techniques do not exactly emphasize the application and it only implies the role of modelling tool that is the main reason why we are unsuccessful in finding the relevant literature studies on SPSS and Chi-Square Test methods in tight oil and gas-condensate reservoirs.

IV. RESULTS AND DISCUSSIONS

4.1 Multiple Linear Regression Analysis with SPSS

The SPSS software tool has successfully provided the results for the multiple linear regression models, namely Bakken and Eagle Ford reservoirs using CO_2 huff-n-puff and flooding methods. Multiple inputs and output were taken for the analysis. Out of all input parametersthe regression model has considered for injection pressure, injection rate, CO_2 soaking time, and number of cycle due to variations of its values, while other parameters like fracture half-length, spacing, conductivity, porosity, permeability, and initial reservoir pressure were omitted for the analysis due constant values. Hence, this regression model can assist an oil and gas analyst to understand and quantify the relationships between several variables on the contribution to the output of oil production and recovery rate.

4.1.1 Bakken and Eagle Ford Reservoirs CO_2 EOR Huff-n-Puff Scenario

This section presents the regression model results for carbon dioxide huff-n-puff technique in the Bakken and Eagle Ford unconventional reservoirs. Tables 5 and 8, presents the model summary for Bakken and Eagle ford reservoir using CO_2 huff-n-puff technique. It the regression model predicts the value of R as .950 of 95% for Bakken and .920 or 92% for Eagle Ford, it is a proportion variance of dependent variables such as cumulative oil production and oil recovery rate, which the model predicts from the input that is the independent variable. The value of R-Square or R^2 Bakken and Eagle Ford are 0.903 and 0.847, it is the square of the correlation measure and shows the proportion of variance in the output variable or dependent variable. It is also called as the regression coefficient or the coefficient of determination, its values lies in the range between 0 and 1.Generally, in terms of engineering and technology field the R^2 above 0.7 indicates a good fit and in this case, it's a good fit [11].

Table 5: Regression Modelling Results for the Bakken Reservoir with CO_2 Huff-n-Puff

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.950[a]	.903	.892	37.1479

Table 6: ANOVA for the Bakken Reservoir with CO_2 Huff-n-Puff

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	332974.167	3	110991.389	80.430	.000[b]
	Residual	35879.200	26	1379.969		
	Total	368853.367	29			

Table 7: Coefficients Summary for the Bakken Reservoir with CO_2 Huff-n-Puff

Coefficients[a]					
	Unstandardized Coefficients		Standardized Coefficients		
Model	B	Std.Error	Beta	t	Sig.
1 (Constant)	20.433	23.083		.885	.384
Injection Pressure (psi)	.031	.019	.483	1.578	.127
Injection rate (MSCF/day)	.022	.083	.039	.259	.797
Carbon Dioxide Soaking Time (month)	29.567	23.083	.435	1.281	.212

Adjusted R square is beneficial in the measure of the model success which accounted for 95% and 92% variance in the output (dependent) variables. The Adjusted R square was found to be .892 and .829 in these unconventional reservoir models using CO_2 huff-n-puff method.The ANOVA table gives the significance of this model <0.005 as shown in tables 6 and 9, and the coefficient for dependent variables is presented in tables 7 and 10. The figures 8 and 10 shows the regression fit for CO_2 huff-n-puff process in the Bakken and Eagle Ford reservoir, where injection rate, injection pressure, carbon dioxide soaking time, and number of cycle are plotted on the X axis and unstandardized predicted value is plotted on the Y axis.

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It can be observed from the graph that, all points were closed to the 45° angle/direction (regression line), which indicates that this model is a better fit. The residual values were plotted for dependent variables as shown in figure 9 and 11, from the graph it can be spotted that, a huge variation between the dependent variables. The residual for cumulative oil production is higher than the oil recovery rate and the model directs that there is a significance difference between the observed and the expected values. On the whole, it can be inferred that this regression model was executed with a 5% error significance and 95% level of confidence and it can be determined that this CO_2 huff-n-puff process in the Bakken and Eagle reservoir is a better model

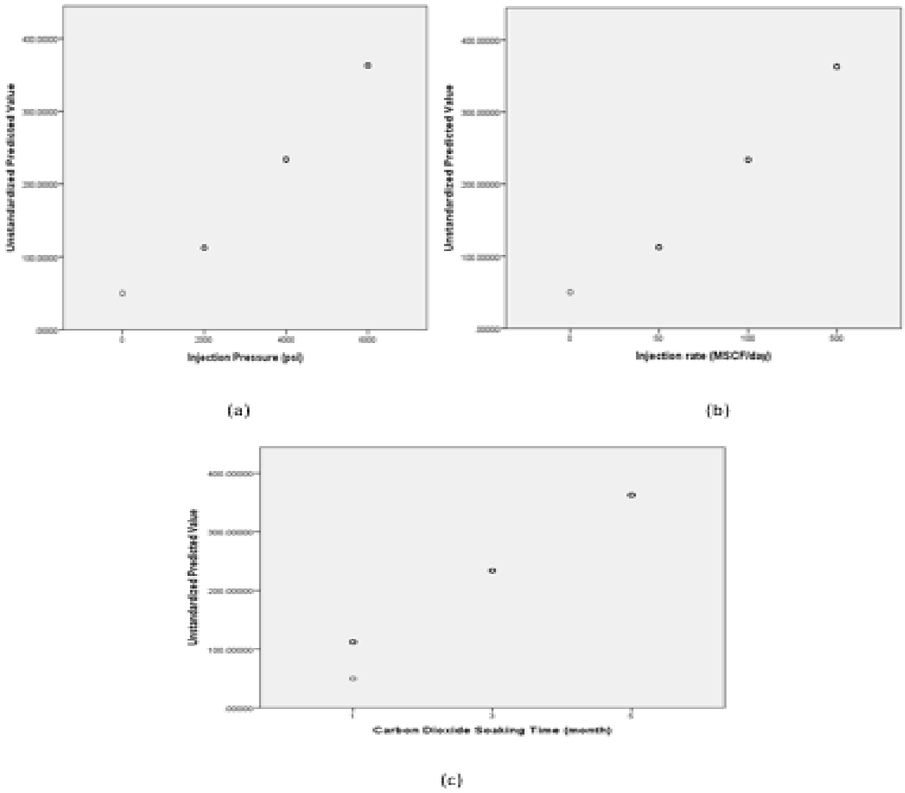


Fig.8: Regression Model Scatter Diagram for the Bakken Reservoir with CO_2 Huff-n-Puff, (a) Injection Pressure, (b) Injection Rate, and (c) Carbon Dioxide Soaking Time

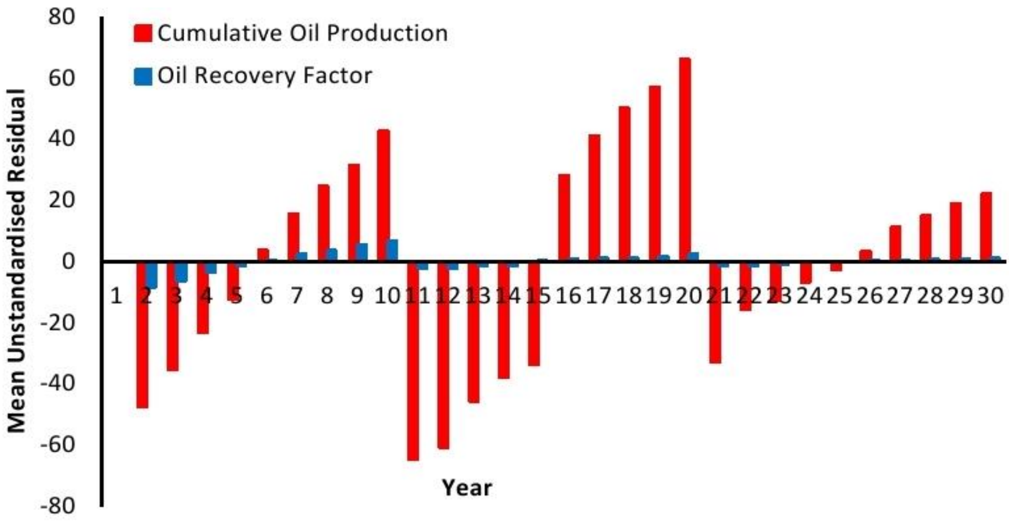


Fig.9: Regression Model Residuals for the Bakken Reservoir with CO_2 Huff-n-Puff

Table 8: Regression Modelling Results for Eagle Ford Reservoir with CO_2 Huff-n-Puff

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.920[a]	.847	.829	38.0614

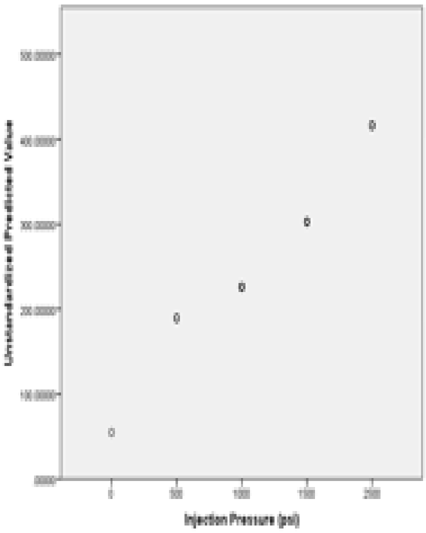
Table 9: ANOVA for Eagle Ford Reservoir with CO_2 Huff-n-Puff

Model	Sum of Squares	df	Mean Square	F	Sig.

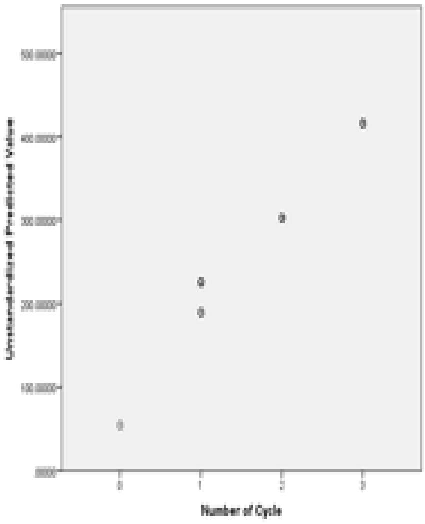
1	Regression	208632.655	3	69544.218	48.005	.000[b]
	Residual	37665.512	26	1448.674		
	Total	246298.167	29			

Table 10: Coefficients Summary for Eagle Ford Reservoir with CO_2 Huff-n-Puff

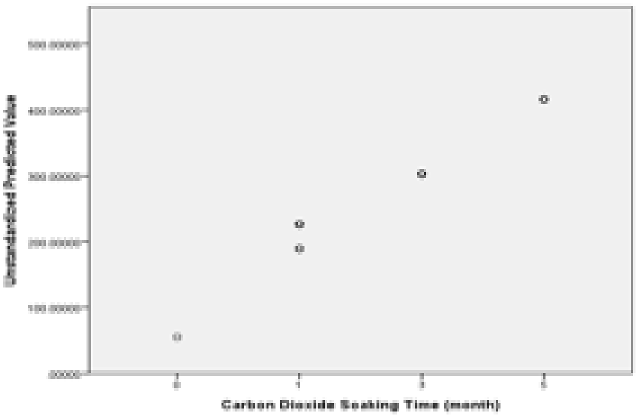
Coefficients[a]					
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std.Error	Beta		
1 (Constant)	55.000	38.061		1.445	.160
Injection Pressure (psi)	.074				
Number of Cycle Carbon	155.588	.040	.530	1.840	.077
Dioxide Soaking Time	-57.947				
(month)	-	87.527	1.365	1.778	.087
		41.898	-.979	-1.383	.178



(a)



(b)



(c)

Fig.10: Regression Model Scatter Diagram for Eagle Reservoir with CO_2 Huff-n-Puff, (a) Injection Pressure, (b) Number of Cycle, and (c) Carbon Dioxide Soaking Time

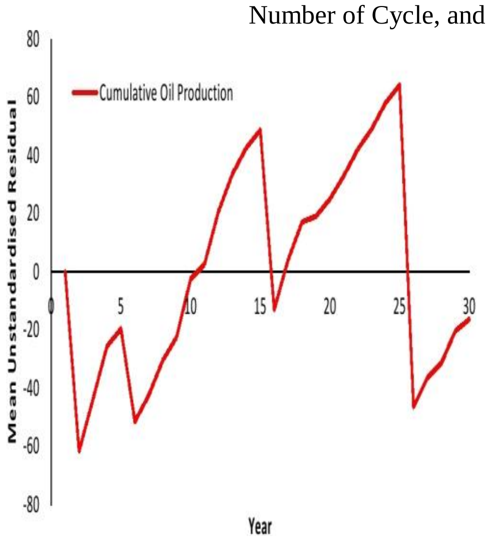


Fig.11: Regression Model Residuals for the Eagle Ford Reservoir with CO_2 Huff-n-Puff

4.1.2 Bakken and Eagle Ford Reservoirs CO_2 EOR Flooding Scenario

This section presents the Bakken and Eagle ford CO_2 EOR flooding regression model results. Like huff-n-puff process, nearly close results were observed for this carbon dioxide flooding scenario. It can be seen from tables 11 and 14 that, the R value for the Bakken model is .942 and .938 for Eagle Ford reservoir model. In the Bakken and Eagle ford regression models using CO_2 flooding process the R^2 and was noted to be .888 and .880. The adjusted R^2 are .879 and .872 for the Bakken and Eagle Ford models. All three regression values are so close for both shale oil and condensate oil regression models. The ANOVA (analysis of variance) and coefficient tables are presented in tables 12, 13, 15, and 16 which indicates the model significance with respect to their input and output variables.

Table 11: Regression Modelling Results for the Bakken Reservoir with CO_2 Flooding

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.942[a]	.888	.879	36.7766

Table 12: ANOVA for the Bakken Reservoir with CO_2 Flooding

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	288950.879	2	144475.439	106.819	.000[b]
	Residual	36518.088	27	1352.522		
	Total	325468.967	29			

Table 13: Coefficients Summary for the Bakken Reservoir with CO_2 Flooding

Coefficients[a]					
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std.Error	Beta		
1 (Constant)	-13.444	28.821		-.466	.645
Injection Pressure (psi)	.008	.005	.286	1.560	.130
Injection Rate (MSCF/day)	.267	.073	.669	3.644	.001

The figures 12 and 14 exhibits the regression fit for Bakken and Eagle ford models, the model predicts injection rate and injection pressures in both cases to be the major influencing factors which affect the oil production and oil recovery rate. Also, it was observed that, the injection pressure and injection rate independent variables are slightly deviated from the regression line or direction (45° angle). The multiple linear regression model suggests that, more improvements need to be made in these independent variables such as injection pressure and rate, in other words their values need to be changed for getting a better fit. The regression model residual was noted in the figures 13 and 15 for both reservoirs, like in CO_2 huff-n-puff process the cumulative oil production curve has larger variation than the oil recovery rate in CO_2 flooding scenario. Therefore, both models can be considered as a good model on the basis of R and R^2 values.

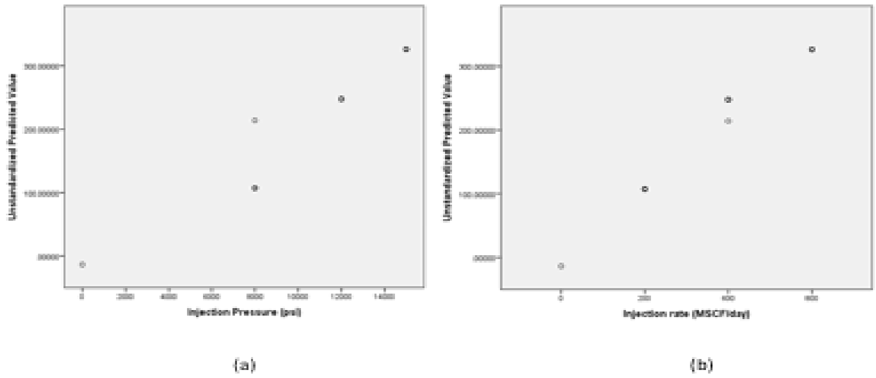


Fig.12: Regression Model Scatter Diagram for the Bakken Reservoir with CO_2 Flooding, (a) Injection Pressure, and (b) Injection Rate

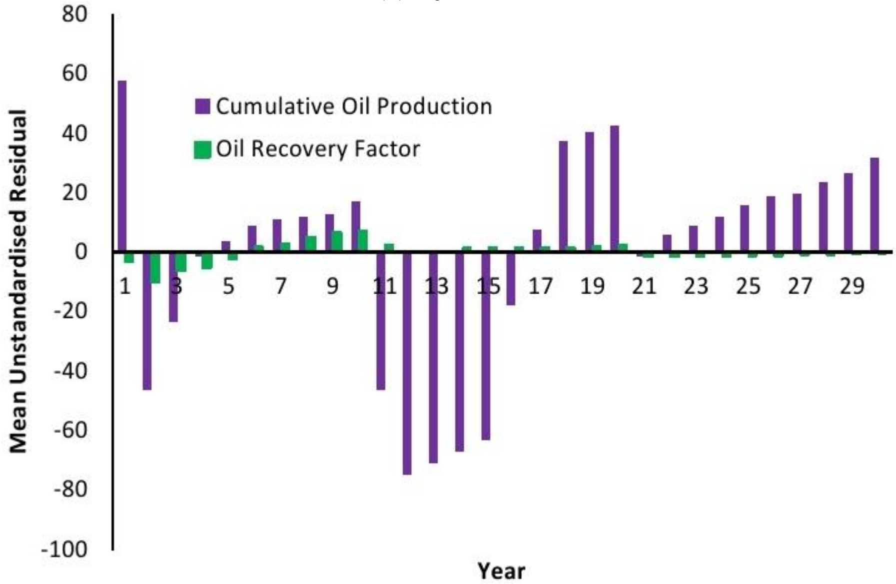


Fig.13: Regression Model Residuals for the Bakken Reservoir with CO_2 Flooding

Table 14: Regression Modelling Results for the Eagle Ford Reservoir with CO_2 Flooding

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.938[a]	.880	.872	31.9283

Table 15: ANOVA for the Eagle Ford Reservoir with CO_2 Flooding

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	202539.302	2	101239.651	99.341	.000[b]
	Residual	27524.198	27	1019.415		
	Total	230063.500	29			

Table 16: Coefficients for the Eagle Ford Reservoir with CO_2 Flooding

Coefficients[a]				
	Unstandardized Coefficients	Standardized Coefficients		

Model				t	Sig.
	B	Std.Error	Beta		
1 (Constant)	98.401	14.168		6.945	.000
Injection Pressure (psi)	.080	.014	.823	5.791	.000
Injection Rate (MSCF/day)	.066	.073	.128	.904	.374

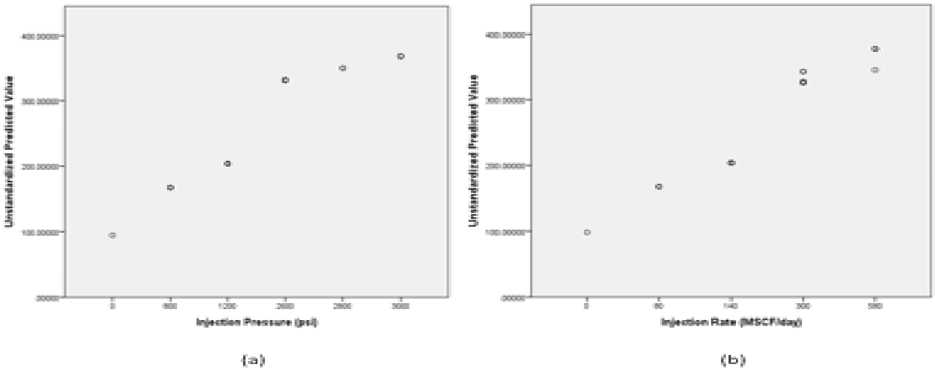


Fig.14: Regression Model Scatter Diagram for the Eagle Ford Reservoir with CO_2 Flooding, (a) Injection Pressure, and (b) Injection Rate

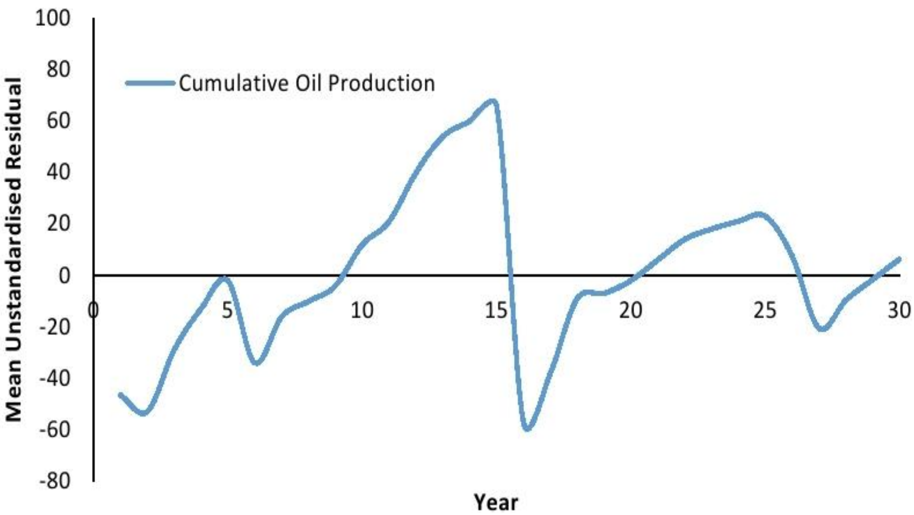


Fig.15: Regression Model Residuals for the Eagle Ford Reservoir with CO_2 Flooding

4.2Model Validation Using Chi-Square Test

After statistical modelling and analysis that concern model must be validated for accuracy. Generally, in SPSS software tool there are 5 model test can be performed for validation, they are Chi-square test, Runs Test, Wilcoxcon Signed Rank test, Kruskal-wallis test, and Mann-Whitney U test. In this paper, only Chi-square or χ^2 were used for validating the Bakken and Eagle Ford multiple regression models.

4.2.1 Bakken and Eagle Ford Reservoirs case of CO_2 EOR Huff-n-Puff Process

In this CO_2 huff-n-puff process in the Bakken and Eagle ford reservoir, the χ^2 was employed to validate this model and to investigate the real independent variables effect on its output. In the test of chi-square theory, there are two following cases [20],

Case 1: If an input value changes, then the output values will vary.

Case 2: If an input value changes, but the output values remains the same.

The R^2 values for the Bakken and Eagle Ford reservoir modelling in multiple linear regression are 0.903 and 0.847, which indicates the model is good and it can be seen from the table 17 that the significance value (Asymp. Sig) for injection pressure, injection rate, and carbon dioxide soaking time are observed to be 0.55, 0.55, and 1.000 for

Bakken, in which the test indicates that the CO_2 soaking time in puff period has least effect on the cumulative oil production and oil recovery rate since its values is equal to 1 while injection pressure and rate are lesser than 1. This scale is between 0 and 1, any value between 0.01 and 0.5 is a good model, and independent variables above 0.5 indicates not exactly a good model.

In Eagle Ford (in table 18) the input parameters injection pressure, number of cycle, and carbon soaking time have a vital impact on the cumulative condensate oil production from the shale formation, their Asymp. Sig. values are .035, .005, and .005. These both models fall under case 2 since their outputs cumulative oil production and oil recovery rate has 1.000 significance values. It suggests that, input variable data need to be generated in different ranges.

Table 17: Chi-Square Results for the Bakken Reservoir with CO_2 Huff-n-Puff

Test Statistics					
	Injection Pressure (psi)	Injection Rate (MSCF/day)	Carbon Dioxide Soaking Time (Month)	Cumulative Oil Production (STB)	Oil Recovery Factor (%)
Chi-Square	7.600[a]	7.600a	.000a	.000[b]	.000[b]
df	3	3	2	29	29
Asymp. Sig.	.055	.055	1.000	1.000	1.000

Table 18: Chi-Square Results for Eagle Ford Reservoir with CO_2 Huff-n-Puff

Test Statistics					
	Injection Pressure (psi)	Injection Rate (MSCF/day)	Carbon Dioxide Soaking Time (Month)	Cumulative Oil Production (STB)	Oil Recovery Factor (%)
Chi-Square	10.333[a]	12.933[a]	12.933[a]	.000[b]	.000[b]
df	4	3	2	29	29
Asymp. Sig.	.035	0.005	0.005	1.000	1.000

The Q-Q plots are presented in figures 16 and 17 for both the Bakken and Eagle ford reservoir models. The quantile-quantile (Q-Q) is a graphical method for establishing the two data models in a set which comes from a population within a common distribution and to check the normality of error and it gives a visual or a graphical comparison of observed value and expected theoretical value [9]. In the figure 16, it can be visualized that the observed values and expected chi-square values for both input and output parameters shows no proper correlation and thereby violating the assumption of normality. While in the Eagle Ford test in figure 17, all points were closely correlated in the Q-Q plot line, thus proved that this regression model is not spurious

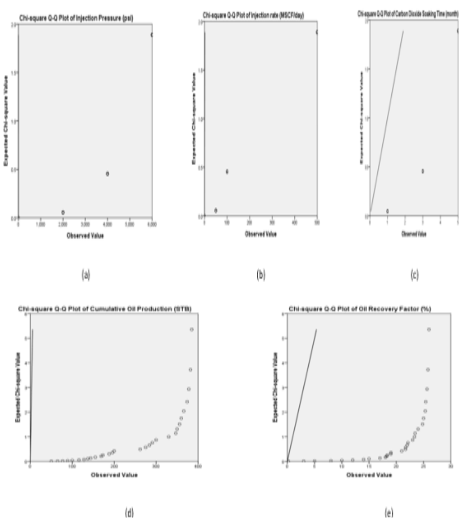


Fig.16 Chi-Square Test Q-Q plots for the Bakken Reservoir with CO_2 Huff-n-Puff, (a) Injection Pressure, (b), Injection Rate, (c) Carbon Dioxide Soaking Time, (d) Cumulative Oil Production, and (e) oil recovery factor.

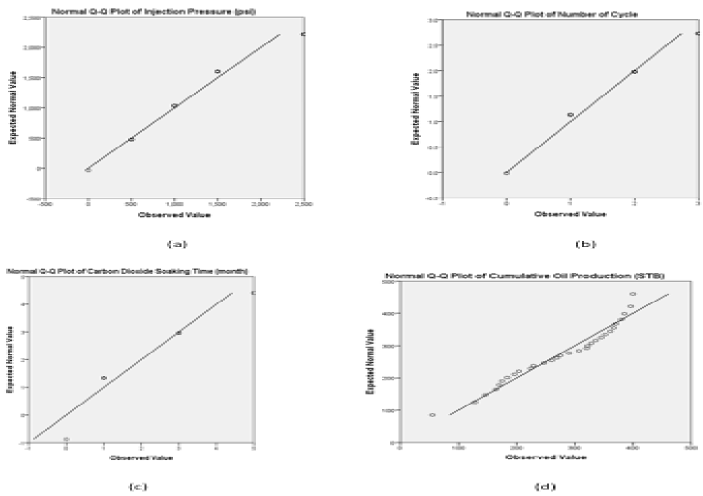


Fig.17: Chi-Square Test Q-Q plots for Eagle Ford Reservoir with CO_2 Huff-n-Puff, (a) Injection Pressure, (b) Number of Cycle, (c) Carbon Dioxide Soaking Time, and (d) Cumulative Oil Production.

4.2.2 Bakken and Eagle Ford Reservoirs case of CO_2 EOR Flooding

This portion presents the χ^2 test for the validation of multiple linear regression models for CO_2 EOR flooding in the Bakken tight oil and Eagle Ford gas condensate reservoirs. It was already known that, the R and R^2 values for the Bakken regression model are .942 and .888, whereas for the regression model R and R^2 values of Eagle Ford condensate reservoir model are .938 and .880. In both reservoir scenarios of multiple linear regression models the R and R-Square values are very close and indicating a good model. In this carbon dioxide flooding case, the injection pressure and injection rate were only found to be the main variables which contribute to the outcome (dependent variables). The significance values (table 19) in the CO_2 EOR flooding in the Bakken shale oil model were observed to be .055 (injection pressure) and .055 (injection rate). In Eagle Ford model (table 20) the injection pressure and rate values of significance (Asymp. Sig) was identified to be .018 and .035, which is better the Bakken CO_2-flooding process.

Table 19: Chi-Square Results for the Bakken Reservoir with CO_2 Flooding

Test Statistics				
	Injection Pressure (psi)	Injection Rate (MSCF/day)	Cumulative Oil Production (STB)	Oil Recovery Factor (%)
Chi-Square	7.600[a]	7.600[a]	.000[b]	.000[b]
df	3	3	29	29
Asymp. Sig.	.055	0.55	1.000	1.000

Table 20: Chi-Square Results for Eagle Ford Reservoir with CO_2 Flooding

Test Statistics			
	Injection Pressure (psi)	Injection Rate (MSCF/day)	Cumulative Oil Production (STB)
Chi-Square	13.600[a]	10.333[a]	.000[b]
df	5	4	29
Asymp. Sig.	.018	0.35	1.000

Figures 18 and 19 indicates the, normal Q-Q plots for the Bakken and Eagle ford models. It can be observed that, in both regression models all points are closer to the normal or regression line. The dependent variables such as cumulative oil production and oil recovery rate points are in light tailed shapes closer to the regression lines. The dependent variable cumulative oil production from condensate reservoir the Eagle Ford in figure 19 (c) has the best correlation since all points are closely clustered around the normal or regression line. So, based on the χ^2 test validation it can be concluded that, the oil production from the Eagle ford reservoir using CO_2-flooding is the best regression model. It was widely reported by many researchers that CO_2 flooding will always improve the oil and gas recovery from the condensate reservoirs [31].

Therefore, this paper has shown the multiple regression methodology for carbon dioxide huff-n-puff and flooding process in the Bakken and Eagle Ford unconventional reservoirs. The regression fit for both CO_2 huff-n-puff and flooding processes are presented in the scatter plot graphs and residual variation graph were revealed. Most importantly, the coefficient of regression 0.9 was obtained for this designed regression model and it was executed with confidence level and error significance of 95% and 5%. Therefore, the implication can be made that, this model is good and it has been validated by the Chi-Square test.

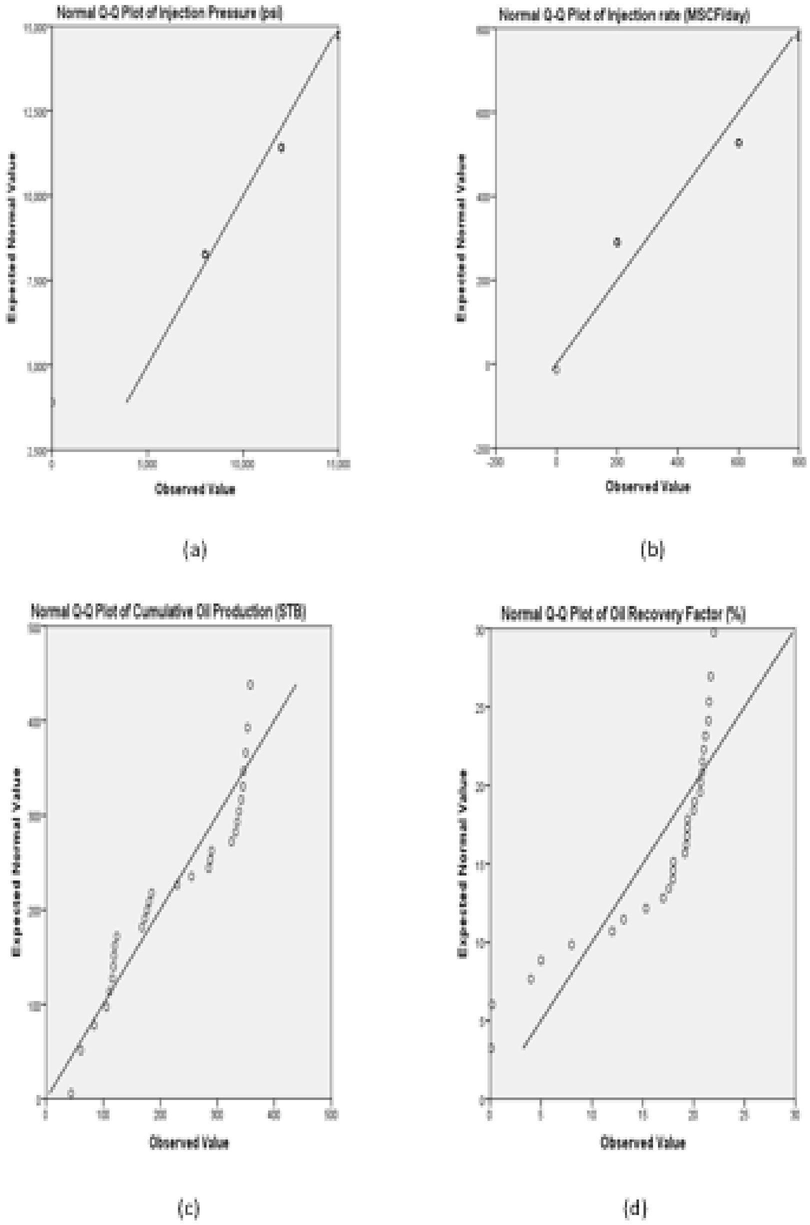


Fig.18: Chi-Square Test Q-Q plots for the Bakken Reservoir with CO_2 Flooding, (a) Injection Pressure, (b), Injection Rate, (c) Cumulative Oil Production, and (d) oil recovery factor.

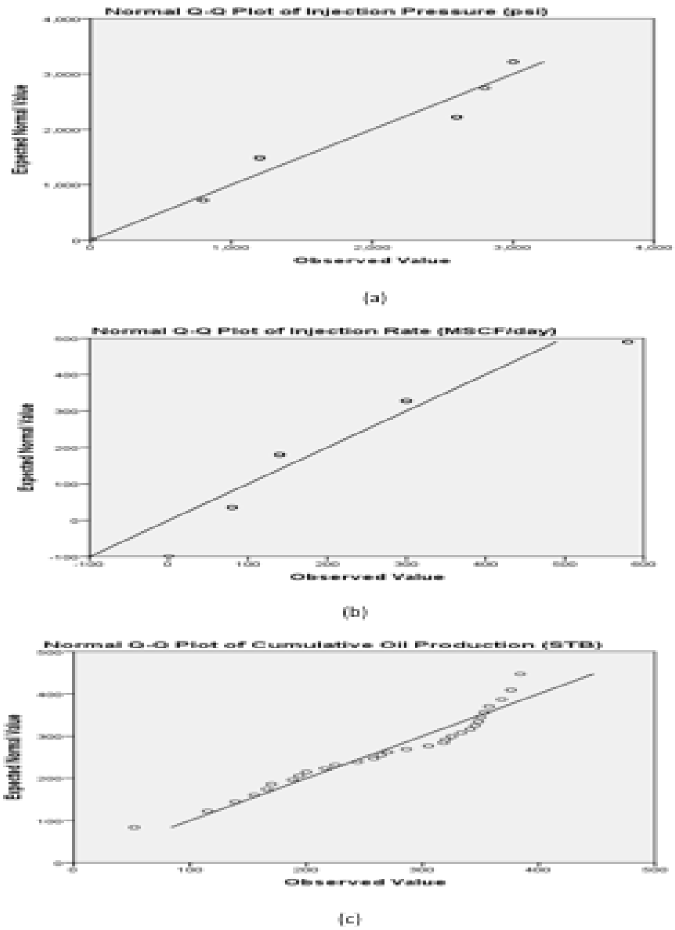


Fig.19: Chi-Square Test Q-Q plots for Eagle Ford Reservoir with CO_2 Flooding, (a) Injection Pressure, (b), Injection Rate, and (c) Cumulative Oil Production

4.4 Percentage of Contribution of Parameters for EOR Performance in Both Reservoirs

Figures 20 and 21, points out the input parameters percentage of contribution in Bakken and Eagle Ford reservoirs with CO_2 huff-n-puff and flooding process. The contribution percentage for input parameters were acquired from the Minitab statistical software version 16, this software platform is associated with the Six Sigma tool, which is used to measure the process improvement and for optimization. The input parameters in flooding and huff-n-puff processes are ranked in the ascending order on the basis of its contribution towards the output or response of cumulative oil recovery and oil recover factor.From the graphs, it can be observed and reckoned that the input parameters have great influence on output. Both graphs illustrate that, the input parameters for CO_2 flooding process is leading in the Bakken and Eagle Ford reservoirs, whose major contribution is injection pressure by 43.05% and 47.09%.Parameters porosity and permeability have good contribution to the output, their values for both huff-n-puff and flooding processes are similar. In Eagle Ford condensate reservoir the effect of fracture spacing, porosity, and permeability interaction have an impact in EOR [29]. Thus, it can be inferred that in both unconventional reservoirs and CO_2 injection scenarios, the injection pressure and injection rate parameters have the dominant effect on the EOR output and others have a moderate effect. It can be implicated that, the Eagle ford reservoir performance is quite better than the Bakken shale oil reservoir.

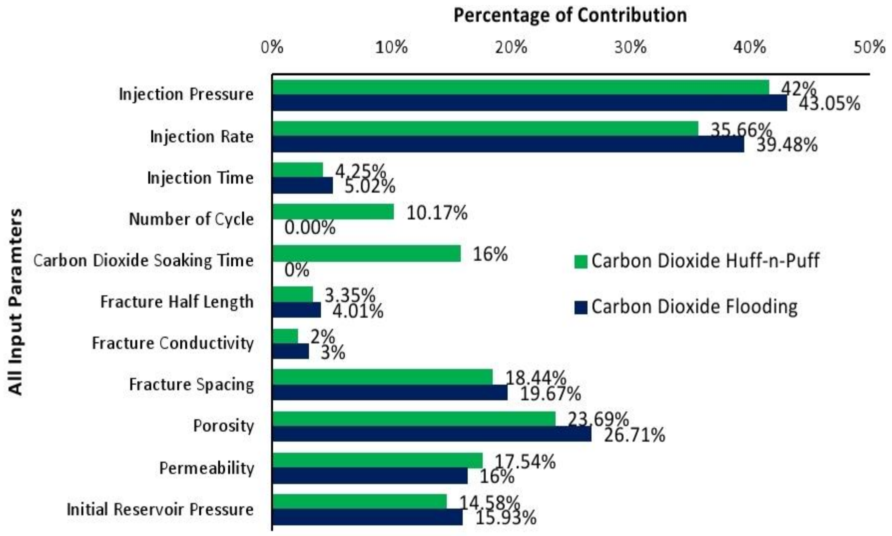


Fig.20: Influence of Input Parameters in Bakken Shale Oil Reservoir

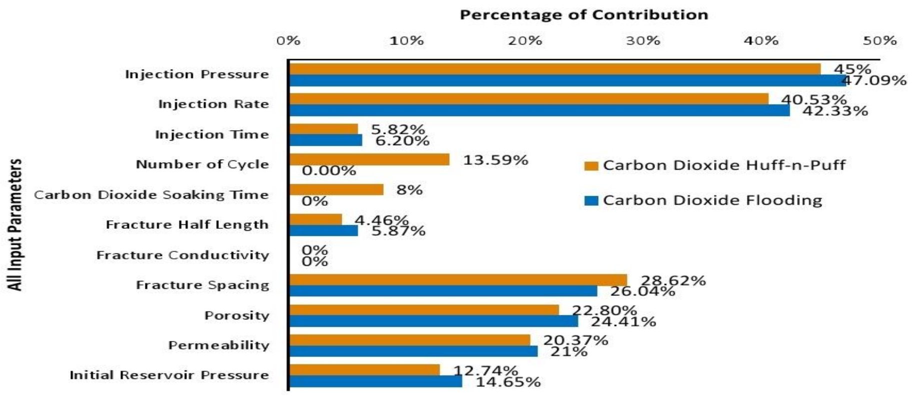


Fig.21: Influence of Input Parameters in Eagle Ford Gas Condensate Reservoir

This paper has shown the multiple regression methodology for carbon dioxide huff-n-puff and flooding process in the Bakken shale oil and Eagle Ford gas condensate unconventional reservoirs. The regression fit for both CO_2 huff-n-puff and flooding processes are presented in the scatter plot graphs and residual variation graph were revealed. Most importantly, the coefficient of regression 0.9 was obtained for this designed regression model and it was executed with confidence level and error significance of 95% and 5%. Therefore, the implication can be made that, this model is good and it has been validated by the Chi-Square test.

V. CONCLUSIONS

The energy demand, the Bakken and Eagle Ford unconventional reservoirs has been critically analyzed. Based on these criteria the need for statistical analysis was framed and this research adopted statistical toolmultiple linear regression for the performance analysis of these two unconventional reservoirs.Upon the evaluation of reservoir performance, the petroleum companies or governments can develop new policies and economic modelling.On the basis of reviews and statisticalmodelling in the Bakken, and Eagle Ford shale reservoirs, the following conclusions can be drawn:

1) A brief and critical reviews were made on the Bakken and Eagle Ford reservoirs with respect to its geology and oil production. The several literature reviews suggest that, both unconventional reservoir geologies are quite complex. Even reviews were made on the EOR simulations in the Bakken and Eagle Ford reservoirs and it was found that there is more oil can be recovered to surface through CO_2 injection, and the reservoir parameters such as porosity, permeability play a vital role in oil recovery.

2) The multiple linear regression model from SPSS statistical software tool indicates that the R and R^2 values are more than 0.7 for the Bakken and Eagle Ford models using CO_2 huff-n-puff and flooding processes. They are in the range between 0.8 and 0.9, which indicates that these

four models are good and close correlation in regression line was observed in all the four models. In the comparison, it was found that, the Eagle Ford reservoir model in both scenarios was better than the Bakken model.

3) The Chi-square test was performed using SPSS to validate these models and it was found that the Eagle Ford reservoir using CO_2 huff-n-puff and flooding models was investigated to be the best model. Whose significance values are .018 and .035 (flooding), and .035, 0.005, and .005 (huff-n-puff) for injection pressure, rate, number of cycle, and CO_2 soaking time.

4) The Q-Q plots, independent and dependent variables are closely correlated to the regression line. The percentage of contribution is gotten from Mini-Tab statistical and optimization software, it was inspected that, the input parameters injection pressure (42% and 45%) and injection rate (43.05% & 47%) was found to be the most influencing factor in oil production in the Bakken and Eagle Ford reservoirs.

5) On the whole, it can be implicated and concluded that the Eagle Ford models using CO_2 EOR huff-n-puff and flooding methods are good. These models are better than the Bakken shale oil models and more improvements are required to be made in these models. It this case, it is recommended to invest and optimize the oil production in the Eagle Ford gas condensate reservoir.

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