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Economic Evaluation for Enhanced Oil Recovery Using Deterministic-Stochastic Particle Swarm Optimization (PSO)

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Abstract
The utilization of CO_2 gas from the oil and gas fields or industry for the purposes of Enhanced Oil Recovery has a dual purpose which to increase reserves and also to help deal with the greenhouse effect. The objective is to analyze economic uncertainty in decision making based on stochastic method analysis with the objective function of Net Present Value (NPV).

This research was conducted by two methods, deterministic and stochastic method. In this field development, producers were converted to injector and the economic parameter such as Net Present Value (NPV), Internal Rate of Return (IRR), and Pay Out Time (POT) are feasible to be applied in the field. Then the analysis of the optimal cases is applied to Field X both technically and economically with the stochastic method. This study applied stochastic method Particle Swarm Optimization (PSO) with objective function Net Present Value (NPV) and limit parameters for the number of injection wells and CO_2 injection volume. There are scenarios using different parameter of stochastic method Particle Swarm Optimization (PSO): Inertia Weight and Learning Factor. The changes in the main parameters of Particle Swarm Optimization (PSO) method (Inertia Weight and Learning Factor) indicate that Inertia Weight is the most influential for the simulation.

Keywords: Enhanced Oil Recovery, CO_2, NPV, Particle Swarm Optimization

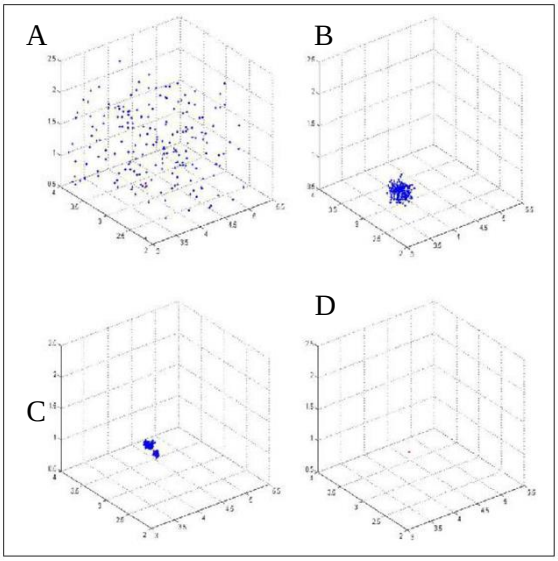
Introduction

The increase in carbon dioxide is a potential greenhouse gas effect that can generate heat on earth. The increasing concentration of carbon dioxide in the atmosphere can cause global warming which has an impact on an unstable climate that will eventually cause natural disasters in various regions in the world. The utilization of CO_2 gas from the oil and gas fields or industry for the purposes of Enhanced Oil Recovery has a dual purpose which to increase reserves and also to help deal with greenhouse effect.

One of the method to increase oil production is by implementing Enhanced Oil Recovery (EOR) method using CO_2 injection into the reservoir through injection wells so that it can produce oil that can not be produced using the primary or secondary recovery methods. In Indonesia, one of the sources of CO_2 can come from natural gas fields which have high content of CO_2 concentration, such as East Natuna Gas Field, which have more than 72% mole of CO_2 (Muslim et al., 2013).

However, the method that has been used so far is by trial and error all the possibilities, such as a combination of the location of the well, the number of injection wells, and the required injection rate. This takes quite a long time. In this research, a field development optimization study was conducted using stochastic method which can process simulations with various possibilities and the results are more varied. So with this stochastic method, it is expected that the calculation time in optimizing field development can be faster.

Particle Swarm Optimization (PSO) was first introduced by Dr. Eberhart and Dr. Kennedy in 1995 with the purpose of continuously optimizing non-linear functions, the Particle Swarm Optimization (PSO) algorithm is a population-based optimization technique inspired by the social behavior of the movement of birds or fish (bird flocking or fish schooling).



The population movement visualization is shown in Figure 1 starting from Figures A to D where the distribution of particles is seen in finding the best position or value. From the explanation above, it can be said that the PSO algorithm combines local search methods with global search methods (Rosita et al., 2012).

Figure 1: Population Movement Visualization of Particle Swarm Optimization (PSO)

Particle Swarm Optimization is a method that memorizes the previous best solution, has the potential to be more effective than other optimization algorithms because it can find the optimal solution faster. However, PSO does not always give better results because it tends to be more exploitative (Sanghyun, 2018).

Data and Method

The deterministic method optimization study is carried out by directly analyzing the results of optimization using software for technically and economically using production sharing contract. Before the Enhanced Oil Recovery method is applied, an in-depth study must be carried out to find out how the optimum CO_2 injection is suitable for use. The data that are used in this study are shown in Table 1.

Table 1. Data Parameter

Parameter	Value
Project life	20 years
Oil price	US$ 60/bbl
Capital cost	13.3 MMUSD/year
Operating cost	0.22 MMUSD/year

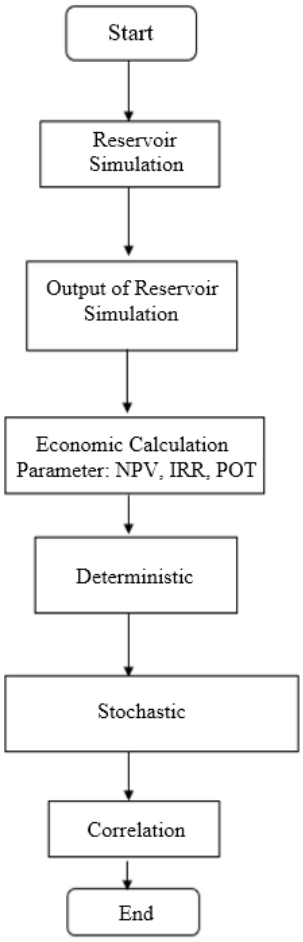


Figure 2: Evaluation Flowchart

This research is carried out data processing flow as shown in Figure 2. In conducting reservoir simulation, limits have been determined for each production and injection well,

such as the number of infill wells, number of injection wells, oil production rate, bottom hole pressure, and CO_2 gas injection rate in each development case.

After reservoir simulation several output parameters are used for the next correlation with stochastic method:

- Oil production cummulative
- Production rate
- Recovery Factor
- CO_2 injection rate
- Recovery Factor

From the output of the reservoir simulation, economic evaluation is conducted to get economic parameter as indicator whether the field development case is feasible or not. The economic parameters are:

- Net Present Value (NPV)
- Internal Rate of Return (IRR)
- Pay Out Time (POT)

The Particle Swarm Optimization of Net Present Value (NPV) objective function method begins with an initialization algorithm consisting of a constant and particle movement. Clerc and Kennedy (2002) suggest the Particle Swarm Optimization (PSO) control parameter value which inertia weight = 0.7298, learning factor C1 and C2 = 1.49618. r1 and r2 are random numbers between 0 and 1.

This study uses Design of Experiment (DoE) to determine the level of influence of several parameters in the simulation. The method used is Plackett-Burman method, which is this method can reduce the number of simulations that must be carried out in finding the level of influence of several parameters to be searched for the level of influence on the calculation time of the objective function.

The inertia weight value that used is in two levels, 0.4 for low and 0.9 for high value. Meanwhile the learning factor parameter uses minimum value of 1 and 1.8 for maximum value.

Table 2 shows the pair of inertia weight and learning factor as input for Design of Experiment to analyze the parameters that affect the search for the objective function NPV.

Table 2. Input Parameter for Design of Experiment

Parameter	Low	High
Inertia Weight	0,4	0,9
Learning Factor	1	1.8

Results and Discussion

After the simulation of objective function (Net Present Value) in stochastic method Particle Swarm Optimization has been done, the results of Net Present Value (NPV) is compared to the number of experiment. And the optimum Net Present Value is 5 MMUSD which the data distribution

is more homogeneous than the other part in the graph as shown in Figure 3.

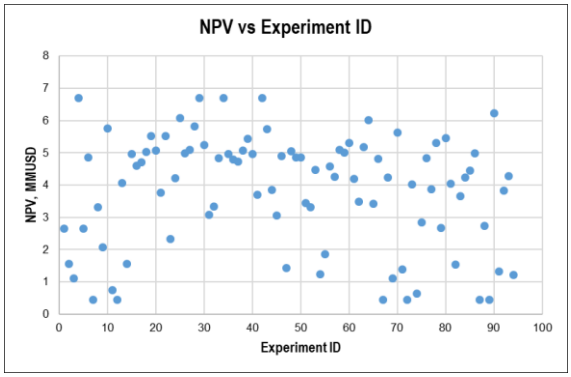


Figure 3: Graphic of Objective Function Net Present Value to the number of experiment stochastic method

Figure 4 shows a Pareto Chart resulting from the simulation based on pairs of the parameter of Particle Swarm Optmization. The chart shows that the inertia weight parameter is the main effect or the parameter that has the most influence on the results compared to the learning factor parameter, because the inertia weight plot is far to the right of the Plackett-Burman coefficient.

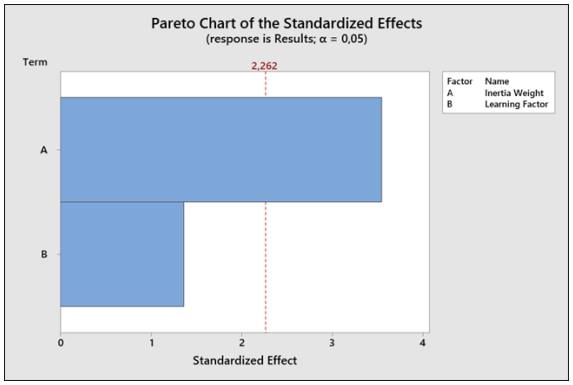


Figure 4: Design of Experiment Analysis Result

Conclusion

Optimization of field development using stochastic method Particle Swarm Optimization (PSO) provides more accurate results in determining the field development plan on economic parameter objective function compared to the method that has been carried out so far, trial error with various possibilities. Based on the results of the analysis in determining the combination of inertia weight and learning factor parameter data using the Plackett-Burman Design of Experiment (DoE) method, inertia weight is the most influential parameter in simulation of objective function value compared to learning factor parameter.

In addition, it will be better to calculate CO_2 produced into the economic calculation so that the results are more accurate and can utilize the CO_2 produced on the other side to save the costs.

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