Evaluation of two Commercial Flow Simulation Tools for Modeling of Subsea Carbon Dioxide Injection Systems

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Problem

The objective of the thesis is to conduct a comprehensive analysis of the simulation of CO2 injection systems, specifically comparing the performance of two software programs, OLGA and LedaFlow. The aim is to assess and evaluate the simulation capabilities of these programs in modeling the behavior of CO2 in injection cases and predicting the performance of CO2 under various operating conditions. The thesis intends to contribute to the development of more effective and efficient CO2 injection systems for Carbon Capture, Utilization, and Storage (CCUS) purposes.

Introduction

Carbon Capture, Utilization and Storage (CCUS) is considered to be one of the most promising factors to mitigate the effect of climate change caused by greenhouse gas emissions. One of the main approaches for CCUS is the injection of CO2 into subsurface formations such as saline aquifers and depleted oil and gas reservoirs. The process of CO2 injection includes the transportation of CO2 from the source to the injection site, and the subsequent injection into the formation. (1)

Due to the high complexity of CO2 injection, it is a process that requires careful monitoring and planning, to ensure the safety and effectiveness of the operation. Thus, utilizing simulation software allows for assessment and improved design of the injection system. Such simulations software are crucial tools for today's engineers as it allows for modeling of the behavior of CO2 in injection cases and predictions of the performance of CO2 under various operating conditions.

There are several such software programs used in the industry today, each one with its own advantages and limitations. Two being OLGA and LedaFlow, which are transient multiphase flow simulators, with OLGA being more commonly used in the industry. By comparing these two software programs, an evaluation of the performance of LedaFlow and OLGA in the simulation of CO2 injection systems can be made. (2)

Varying conditions will be simulated, and results compared, with the aim to provide a comprehensive analysis of the simulation of CO2 injection systems and to contribute to the development of more effective and efficient CO2 injection systems for CCUS purposes.

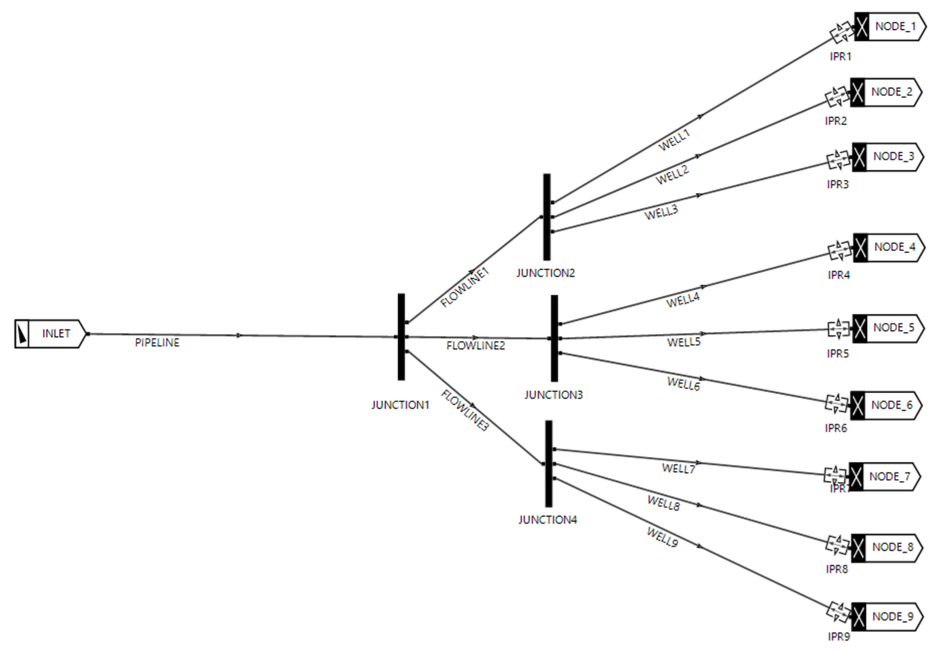

Figure 1. Schematic representation of the model

Transport of CO2 in pipelines

Transporting CO2 is crucial for effective Carbon Capture, Utilization, and Storage (CCUS). While tankers are commonly used, pipelines offer economic and convenient transport advantages. Despite the high initial investment cost, pipelines have lower running costs and can handle large volumes, making them a viable long-term choice.

Most CO2 transport pipelines are currently utilized for Enhanced Oil Recovery (EOR), establishing a direct link between CO2 sources and reservoirs. As CCUS demand rises, significant infrastructure expansion is necessary.

CO2 fluid state during pipeline transport is governed by temperature and pressure. Efficient transport requires a supercritical state, achieved within temperature ranges of 12-44 degrees Celsius and pressure ranges of 85-150 bar. However, temperature and pressure fluctuate along the pipeline. Flow state concerns emerge at the lower pressure range, while economic and risk factors limit the upper range. Seasonal ambient temperature fluctuations pose constraints at the lower temperature range, while booster outlet temperature and pipe material limits determine the upper range. Ideally, CO2 remains in the supercritical phase for maximum transport efficiency, but two-phase flow can occur at specific points if pressure and temperature drop below the critical point. (3)

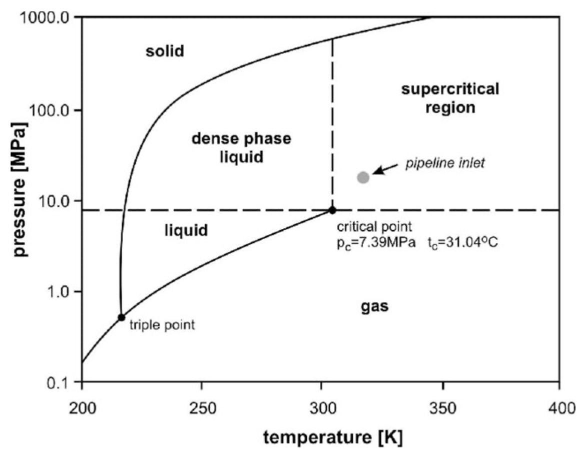

Figure 2. Phase envelope of CO2

Simulation parameters

Base Case

	Length	Diameter	Ambient temperature	Roughness
Pipeline	150 km	860 mm	4°C	0,045 mm
Flowline	1 km	360 mm	4°C	0,045 mm
Well	3 km (depth)	180 mm	7-95°C (gradient)	0,045 mm

Secondary Case

	Length	Diameter	Ambient temperature	Roughness
Pipeline	110 km	860 mm	4°C	0,045 mm
Flowline 1	20 km	360 mm	4°C	0,045 mm
Flowline 2	10 km	360 mm	4°C	0,045 mm
Flowline 3	5 km	360 mm	4°C	0,045 mm
Well	3 km (depth)	180 mm	7-95°C (gradient)	0,045 mm

Results

After assembly and verification of the network model in both LedaFlow and OLGA, comparison simulations were run. The intention of these tests was to assess the similarities and differences of the two simulation tools at a wide variety of conditions and parameters. This includes varying inlet pressures, mass flow rates, and injectivity index. Mass flow rates for 100 bar inlet simulations is shown in Figure 3.

100 bar		LedaFlow	OLGA	
Inlet		1173	1451	kg/s
Flowline 1		152	216	kg/s
Flowline 2		476	553	kg/s
Flowline 3		554	635	kg/s
Well 1		51	72	kg/s
Well 4		159	184	kg/s
Well 7		185	212	kg/s

Figure 3. Mass flow rates from LedaFlow and OLGA after stabilization

Deviation between LedaFlow and OLGA is shown in Figure 4 for the pipeline, flowlines 1, 2 and 3, and well 1, 4 and 7, respectively.

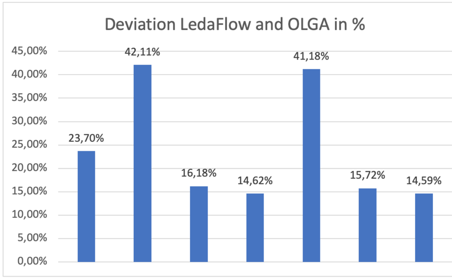

Figure 4. Deviation between LedaFlow and OLGA

Data for pressure profile was extracted for the same simulation run and plotted as pressure vs length. This plot is shown in Figure 5.

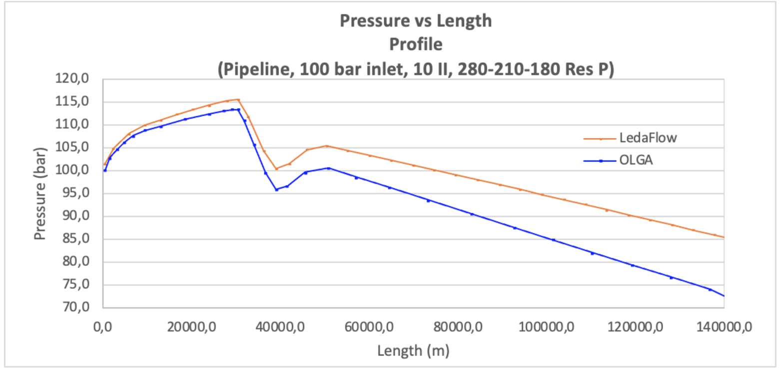

Figure 5. Pressure profile along the pipeline

Conclusion

This comparative analysis of LedaFlow and OLGA simulators for simulating CO2 injection systems provided valuable insights. Both simulators experienced initial instabilities, but eventually converged to consistent measurements. OLGA predicted higher mass flow rates, while LedaFlow showed higher pressure drops in wells. The analysis contributes to improving CO2 injection systems for CCUS, but further research is needed for validation.

References

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