GPRS Technical Report

# Loops for Multisegment Well Model in GPRS

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### Anna Semenova

### Department of Energy Resources Engineering

### Stanford University

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# 1. Introduction

Modeling loops is an important extension of multi-segmented well model in the GPRS. It might be useful for modeling surface facilities, cross-flow between tubing and unpacked annulus through valves, complicated well trajectories, and etc.

This report describes the implementation of looped flowpath in the GPRS. Examples and comparisons with the ECLIPCE reservoir simulator are given at the end of the report.

# 2. Looped flowpath implementation

The muti-segmented well (MSWell) model in the GPRS in general does not allow looped topology, however it is possible to add a loop by introducing an additional segment and linking it to a one physically coincident with it. This way the original MSWell model needs minimum modifications. It is described the same way as a well without loops, except for the linked segments.

The looped flowpath implementation in GPRS is very similar to the one in ECLIPSE [1]:

1. First a multi-segmented well should be specified, one or more nodes of which should be made physically coincident. For example, in Fig. 1 nodes 13 and 27 are the same, they have exactly the same size and depth.
2. Then additional connections are specified to link these segments. For example, in Fig. 1 there is only one loop linking segments 13 and 27. The input file for GPRS it would look as follows

|  |
| --- |
| # --- linked segments (WSEGLINK) --------  number\_of\_linked\_connections 1  #1st\_segment 2nd\_segment   1. 27 |

1. Equations for the first linked segment of the connection remain unchanged, while all equations except for the pressure equation in the second linked segment are replaced with equality equations. The volume associated with the second liked segment then is treated as an additional volume of the first linked segment.

For example, equations for segment 27 in Fig. 1 in case of black oil model are:

, (1)

where *RP* is pressure loss equation, *Pi* is pressure in segment *i*, *αg,i* and *αw,i* are gas and water holdups in segment *i* correspondingly.

Equations for segment 13 in this case remain unchanged, but the volume *V* of the segment 13 is calculated as

(2)

where *Vi* is the volume of segment *i*.

There are some requirements of the current looped flowpath implementation:

1. The second linked segment must be always at the end of a branch.
2. The second linked segment should not have any connections with a reservoir.

# 4. Examples

Figure 1 shows a vertical well with one loop. Here segments 13 and 27 are coincident. The only one connection with the reservoir is in segment 15. Some of the properties for this case are: segments length and depth change are 40 ft, diameter is 0.15 ft, well index *WI* is 9705 md·ft, constant wellhead pressure is 4700 psi, fluid is two-phase black oil (oil and gas), initial oil saturation in the reservoir is equal to 1.0, wellbore model is drift-flux [2,3].

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| Figure 1. Vertical well trajectory with a loop,  where segments 13 and 27 are linked and physically coincident |

Results of the GPRS simulation shown in Figs. 2-3 are compared with ECLIPSE results for the same case. Gas and oil flow rates (Fig. 2), as well as pressure and gas holdup profiles after 50 days of production (Fig. 3) are very similar for both simulators.

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| Figure 2 Oil and gas rate comparison |

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| Figure 3. Pressure and gas holdup comparison after 50 days of production |

Another example is for a horizontal well. The trajectory of the well is the same as in Fig. 1. Properties are also the same except the wellhead pressure, which is equal to 2500 psi.

Results of the simulation and comparison with Eclipse are shown in Figs. 4-5, where all curves are in a good agreement.

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| Figure 4. Oil and gas rate comparison |

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| Figure 5. Pressure and gas holdup comparison after 50 days of production |

The last example deals with three-phase flow in an inclined well. It is shown in Fig. 6, The angle of inclination is 60° from vertical. Some of the data are taken from case 3: segments length is 40 ft, depth change is 20 ft, diameter is 0.15 ft, two perforations are located in segment 15 and 29, well indexes *WI* for them correspondingly are 970.5 and 97.05 md·ft, constant wellhead pressure is 1500 psi, fluid is three-phase black oil (gas, oil and water), initial oil and water saturations in the reservoir are both equal to 0.5, wellbore model is drift-flux [2,3].

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| Figure 6. Inclined well trajectory (60° from vertical) with a loop,  where segments 13 and 30 are linked and physically coincident |

The results for the last case are shown in Figs. 7-8. Comparison with Eclipse is satisfactory, small differences might be due to differences in model parameters or model implementation.

# 5. Summary

1. The looped flowpath capability was implemented in MSWell model of GPRS.

2. The model was verified against Eclipse for two-phase and three-phase black oil cases and wells with different inclinations varying from vertical to horizontal.

3. Overall results look good, and comparison with Eclipse is satisfactory.

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| Figure 7. Water, oil, and gas rate comparison |

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| Figure 8. Pressure and holdups (gas, oil, and water) comparison after 50 days of production |

# References

1. Schlumberger: “ECLIPSE Technical Description”, Version 2010.2
2. Shi H., Holmes J.A., Durlofsky L.J, Aziz K., Diaz L.R., Alkaya B. and Oddie G. Drift-flux Modeling of Two-Phase Flow in Wellbores. SPE J. 10(1): 24-33, March 2005.
3. Shi H., Holmes J.A., Diaz L.R., Durlofsky L.J and Aziz K. Drift-flux Parameters for Three-Phase Steady-State Flow in Wellbores. SPE J. 10(2): 130-137, June 2005.

# A. Example of GPRS input file for a well with a loop

|  |
| --- |
| number\_of\_segments 28  # No.of Branch Outlet Length Depth Diam Rough  # Seg Num Seg Change Change  # 0 default homogeneous segment  1 0 0 0.1 0 0.15 0.001  2 0 1 40 40 0.15 0.001  3 0 2 40 40 0.15 0.001  4 0 3 40 40 0.15 0.001  5 0 4 40 40 0.15 0.001  6 0 5 40 40 0.15 0.001  7 0 6 40 40 0.15 0.001  8 0 7 40 40 0.15 0.001  9 0 8 40 40 0.15 0.001  10 0 9 40 40 0.15 0.001  11 0 10 40 40 0.15 0.001  12 0 11 40 40 0.15 0.001  13 0 12 40 40 0.15 0.001  14 0 13 40 40 0.15 0.001  15 0 14 40 40 0.15 0.001  16 0 1 40 40 0.15 0.001  17 0 16 40 40 0.15 0.001  18 0 17 40 40 0.15 0.001  19 0 18 40 40 0.15 0.001  20 0 19 40 40 0.15 0.001  21 0 20 40 40 0.15 0.001  22 0 21 40 40 0.15 0.001  23 0 22 40 40 0.15 0.001  24 0 23 40 40 0.15 0.001  25 0 24 40 40 0.15 0.001  26 0 25 40 40 0.15 0.001  27 1 26 40 40 0.15 0.001  # --- linked segments (WSEGLINK) --------  number\_of\_linked\_connections 1  #1st\_segment 2nd\_segment  13 27    END |