Coning exercise in Rubis

A ● Exercise objective

- How to set advanced gridding parameters to model coning in Rubis
- Application of such models in some reservoir situation

Coning is a phenomenon local to the near wellbore region and simulation must be concentrated around this area, possibly with a radial geometry grid structure, if one wishes to analyze it.

B ● Exercise 1: Grid optimization

B1 ● The reference case

We have initially a run that satisfy the real data match of water coning, however this run takes excessive time and we would like to obtain similar results within a reasonable timeframe. We name this dataset to be reference case.

B2 ● The exercise principle

We will try to find which fastest grid reproduces satisfactory results for coning.

For this exercise we start with the problem definition as stated below:

The problem is based on a near wellbore cylindrical model, with water coning issue. It contains a vertical well perforated above WOC (20ft above contact).

Starting from 1/1/2009, we make a run over 5 years.

The model has by default 10 layers, each being 5 ft thick. The reservoir bottom limit is at 6050 ft TVD. Constant pressure boundary around the model limits (presence of aquifer + big connected HC volume at virgin condition).

B3 ● Gridding parameters sensitivity study

The initial model is prepared ready to run:

01-cylindric_auto_starting_case.krp.

The automatic grids setting have been selected.
Go to browser and notice the difference compared to reference case.
We will now start to analyze different gridding parameters progressively.

B3.1 ● Well upscaling

Duplicate runs and try different well upscaling (Coarse-Rubis, Refined-Topaze, Very fine-Saphir, Coarse Rubis (=1 upscaling) direct) that should impact on water breakthrough time. Use the browser to compare different qw surface.

What can you conclude?

Name it to **02-cylindric_well_upscaling.krp**.

B3.2 ● Vertical layering

From precedent model with Topaze upscaling, uncheck automatic and define sublayering for each of the layers (Nz ratio per layer 1, 3 and 5). That should impact on water steady state production. Compare with browser and draw conclusion for acceptable level of error. Save another file under the name of 03-cylindric_Nz.krp.

B3.3 ● Areal layering

With the same logic, choose this time the Nx parameter (3, 12, 25). Compare and conclude. Save it under 04-cylindric_Nx.krp.

Conclusion:
Based on the following search, what are the settings that reproduce good results without sacrificing computing performance? We will be using this run to perform various analyses in a reasonable timeframe. Save it under the name of Cylindric_reference_final_result.krp. (Around 7000 cells). Is the run speed reasonable? Save it under 06-cylindric_reference.krp.

C ● Exercise 2: Reservoir parameters sensitivity

Now that we have a model for study, let us examine different reservoir configuration scenarios. We will use the optimized grid for study **(cylindric_reference.krp).**

Create several examples as indicated below:

C1 ● kh sensitivity

File **01 Cylindric_kh.krp.**
Keep kv constant at 150 mD and change kh 150, 200, 300 mD.
To do so, in the same file, duplicate runs and compare using browser.

C2 ● Kv/kr sensitivity

File **02 Cylindric_kv.krp.**
Kv/kr ratio (0.01, 0.1, 1). Kh at 150 mD.
Same as above.
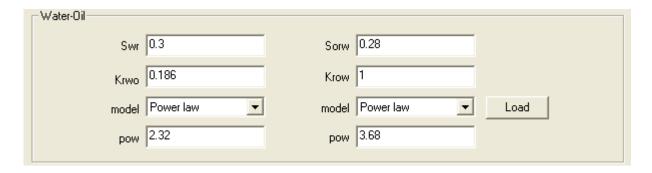
C3 • WOC sensitivity

File **03 Cylindric_WOC.krp.**
Water oil contact (relative difference compared to reference case: -5 ft, +5 ft).
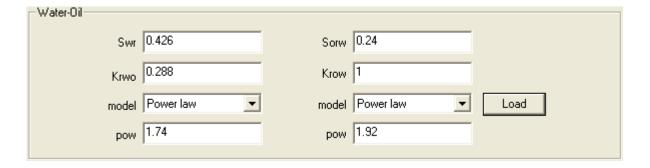
C4 • Kr sensitivity

File **04 Cylindric_kr.krp.**
Relative permeability try different dataset compared to initial reference case:

KrPc data set 1:

```
┌─Water-Oil──────────────────────────────────────────────────────────────┐
│                                                                          │
│      Swr  [0.3          ]          Sorw  [0.28         ]                  │
│                                                                          │
│     Krwo  [0.186        ]          Krow  [1            ]                  │
│                                                                          │
│    model  [Power law  ▼]          model  [Power law  ▼]   [ Load ]       │
│                                                                          │
│      pow  [2.32         ]           pow  [3.68         ]                  │
│                                                                          │
└──────────────────────────────────────────────────────────────────────────┘
```

KrPc data set 2:

```
┌─Water-Oil──────────────────────────────────────────────────────────────┐
│                                                                          │
│      Swr  [0.426        ]          Sorw  [0.24         ]                  │
│                                                                          │
│     Krwo  [0.288        ]          Krow  [1            ]                  │
│                                                                          │
│    model  [Power law  ▼]          model  [Power law  ▼]   [ Load ]       │
│                                                                          │
│      pow  [1.74         ]           pow  [1.92         ]                  │
│                                                                          │
└──────────────────────────────────────────────────────────────────────────┘
```

C5 • K contrast sensitivity

File **05 Cylindric_kcontrast.krp.**
The data is already input for this case. Use cylindric_kcontrast.krp.
Permeability is improving upwards: see in a cross-section the permeability, starting from 30 md to 150 md). Perform the run and compare with reference case.

D ● Exercise 3: Development scenarios

Consider a predefined model that we will use for analysis. This time we have a 3 phase model with both water and gas contacts.

The context of problem is: we have a producing flowline with limited Qliq capacity, but we also need to be careful not to produce too much gas because we have a limiting gas rate that can be handled as well.

Since there are gas and water contacts, we could maximize oil by avoiding water contact, but we may be exposed to too high gas rate then. We will have the opposite problem if we are too close to water contact.

D1 ● Building the initial case

We start with the reference case (50 ft formation thickness), vertical anisotropy, GOC at 6005 ft, WOC at 6045ft and 13 ft perforation in the middle. The simulation is run until end 2012. This starting case is provided and is **cylindric_3P_ref.krp.**

D2 ● Close to contacts

From this case, duplicate the run and move the 13 ft perforation to 5ft above water level, then 5ft below gas. Save as another file under **cylindric_3P_13ft.krp.** Zoom into the wellbore region to observe the coning effect over time.

D3 ● 20 ft perforation

Same case as precedent but with 20ft perforation, in all 3 positions save it under **cylindric_3P_20ft.krp.**

We can also start from the reference case and change the perforation.

D4 ● 5 ft perforation

Same as precedent with 5ft perforation, save in file **Cylindric_3p_5ft.krp.**

Because we are controlling through total liquid rate, the objective is to get maximum oil (meaning minimum water) while avoiding too much gas production. Double click on the results settings to get Qo max and Qgas max, and fill the numbers in the provided excel spreadsheet. A ranking has been done for each factor. Which configuration seems best?

For the sake of demonstration, in the "done exercise folder", there are also **cylindric_3P_hor200.krp and cylindric_3P_hor500.krp** for horizontal well case with 200 stb/d as target and 500 stb/d.

E ● Extra: Injector producer – gravity "tonguing"

It is a water oil system, with pair producer – injector.

A demonstration case where we will open up the whole layer, the upper part only or the lower part for comparison against injection.

Grid is optimized so that the "tonguing effect" is represented properly.

See: **rectangle_dietz.krp.**

This example demonstrates gravity tonguing effect between a injector producer pair.

See: **rectangle_DF_demo.krp.**

A dumpflood well. An inactive well is creating a path from lower reservoir to upper reservoir. Producer is open only in the upper part and injector only in the lower part. By making use of the path we can sweep upper layer with lower layer injection.

See: **nonuniform_water_front.krp**

Case with heterogeneous permeability (high permeable layer in the middle).
Saturation profile is affected by gravity and the distribution of flow speeds between the wells.