

Quick Setup

Koko Simulator for CHEARS Users

By Focus Simulation Inc.

Step 1. Run a CHEARS deck as it is

Users can launch the Koko simulator via the Koko client, a graphical user interface. The Koko simulator runs a CHEARS deck as it is. Acceptable CHEARS keywords and new Koko simulator keywords are summarized at the end of this document.

The Koko simulator will place the output files in the same directory as that of input file. The output files have the same name as the input file, but with different file type. For example, given an input file of test.deck, we will have the following output files: test.lst (like a CHEARS fort.6 file), test.dbg (like a CHEARS fort.99 file), test.sim (like a CHEARS fort.17 file), test.sum (like a CHEARS fort.7 file), test.ohist (cumulative well production/injection in a history file format), test.nnc (non-neighboring connection information), test.orftxt (calculated RFT pressures), test.rst6 (a restart output file).

Occasionally, the automatic memory allocation of Koko may not be sufficient. Koko will output the required memory in test.lst. The following line can be added in the Problem Description Section of the data set to manually allocate the array dimension:

```
ARRAYDIMENSION NRT NIT NCT ND
```

NRT is the dimension for the real array, NIT for the integer array, NCT for the character array, and ND for the number of data to be optimized. If automatic allocation is to be used for certain dimensions, then substitute the dimension with # such as follows:

```
ARRAYDIMENSION # NIT NCT #
```

Step 2. Conduct approximation runs of the original CHEARS deck

Add the following lines in the Problem Description Section of the original CHEARS deck. Then launch Koko simulator.

```
AUTOCOARSEN 0.5 0.5 0.5 IMPLICIT 1  
NORMSATENDPT  
MODELSIZE NX NY NZ 2
```

The first line states that the coarsening will reduce the model size by 0.5 in x, y, and z dimensions. The coarsened grids will use an implicit formulation and it will have only one level of coarsening. The actual model size of this run will be approximately 0.5*0.5*0.5 of the original model size.

The second line- NORMSATENDPT is required for a coarsened model. It is a good practice to use a single rock region, although this is not a requirement. With a single rock region, users can still adjust saturation end points and relative permeability at these end points to mimic multiple rock regions.

If the results of the coarsened model deviate significantly from those of the original model, it implies the coarsened model is inadequate. In this respect, Koko is useful for *studying grid sensitivity*.

The last item of the third line sets the number of grids to 2. This is because one level coarsening will introduce one additional grid. The number will have to be increased further if multi-level coarsening is used or RETAINWELLGRID is used. RETAINWELLGRID is described later.

Step 3. Conduct an optimization run of the coarsened CHEARS deck

3a) Add the following lines in the Problem Description Section of the CHEARS deck.

```
ANALYTICALDERIV
CHAOTICSEARCH 40 1 40 2.0
OPTMMAXITN 5
RFTTXTFILE
```

The first line states that the analytical derivative is to be used. When the analytical derivative is used, the types of properties that can be optimized will be limited. Currently, these properties are porosity, permeability, pore volume, transmissibility, initial gas/oil contact, initial water/oil contact, initial solution gas oil ratio, skin factor, and PI multiplier.

The second line states that a chaotic search is used with a maximum of 40 iterations. The random seed is 1. The number of iterations per cycle is 40. (That is only one cycle will be used in this case.) Parallel chaotic searches always require one cycle. The initial temperature (not reservoir temperature) for chaotic search is 2.0.

The third line states a gradient search with a maximum number of 5 iterations will immediately follow the chaotic search. The minimum located by the chaotic search will be used as the initial guess for the gradient search.

The last line states that RFT pressure data that are stored in a .rfttxt file.

3b) Add the Optimization Parameter Section.

The Optimization Parameter section is after the Output Specification Section and before the Fluid Property Section. In principle, any real number can be optimized. However, if analytical derivative is activated, only properties that are eligible for analytical derivative can be included in the gradient search. An example of the Optimization Parameter Section is shown next.

```
*****
* Example of Optimization Parameter Section *
*****
*
```

```
*
* First Specify the Parameters
* Parameter 1 will have an initial guess
* of 0.1, a minimum value of 0.01, a maximum
* value of 0.95, and a perturbation size of 0.01.
* (Perturbation size is used to calculate the
* sensitivity coefficients via a numerical
* derivative. If analytical derivative
* is activated, the value is redundant. )
* Parameter 2 and Parameter 3
* are similarly defined.
*
```

```
PAR#1 0.1 0.01 0.95 0.01
PAR#2 1.0 -10.0 10.0 0.01
PAR#3 1.0 0.001 100.0 0.01
```

```
*
* The chaotic search needs to use
* MAPSEARCH to define map points.
* Since we have three parameters,
* we require a three-dimensional map.
* The following line defines the number of
* division(or cells) along each dimension to be
* 5, 4, and 5.
*
```

```
MAPSEARCH
5 4 5
```

```
*
* At every visit to a map point in a chaotic
* search, one can conduct a gradient search.
* The following line specifies
* 1 iteration for the gradient search with
* the map point as the initial guess.
*
```

```
MAPSEARCHMAXITN 1
```

```
*
* The following line explicitly defines
* the parameters to be included in a gradient
* search. The first and second parameters are
* included, but the third parameter are not.
* This is useful to exclude parameters that
* are not eligible for analytical derivative.
*
```

```
NEWTONACTIVITY
1 1 0
```

3c) Specify which property to be optimized and what type of data to be fitted to. Then, launch Koko. The field data should be in the test.hist file and/or test.rfttxt. The results of the optimization are summarized in the test.csv, test.olst, and test.orfttxt files. The

test.csv file can be plotted via Excel or any software that accepts a .csv file.

The following is an example:

```
*
* Porosity in WINDOW 1 3 1 4 1 2 and
* LAYER 3 are assigned to be PAR#1
*
POROSITY
WINDOW 1 3 1 4 1 2 = PAR#1
LAYER 3 = PAR#1
*
* First, set XPERM of LAYER 2 to 10
* Next, the power of X PERM
* in LAYER 2 is raised to the power of
* PAR#2. .
*
X PERM
LAYER 2 = 10.0
LAYER 2 @ PAR#2
*
* the SWIR multiplier is set to Parameter 3
*
SWIR
ALL * PAR#3
TIME 0.0
*
* Starting from time 0.0, water and gas rates
* of well W1 are fitted to with a weighting
* factor of 1.0
* RFT pressures of well W1 are fitted with a
* weighting factor of 0.5
DATAOPTM W1 CUMWATP CUMGASP 1.0
DATAOPTM W1 RFTMINP 0.5
TIME 365.0
*
* Starting from TIME 365.0
* Water rate of well W2 is added to the data
* pool to be fitted to with a weighting factor of
* 0.5
*
DATAOPTM W2 CUMWATP 0.5
*
* We did not include all well information
*
```

Step 4. Improve simulation results surrounding the wells during optimization

Add the following lines to the Problem Description Section of the optimized CHEARS deck. Launch the optimization run.

```
RETAINWELLGRID 1
MODELSIZE NX NY NZ NGRIDS
```

The first line instructs Koko to retain one ring of fine grid blocks surrounding wells during grid coarsening.

The second line increases the number of grids to NGRIDS in MODELSIZE card. NGRIDS is usually equal to the number level of coarsening + the number of wells + 1.

Note: in the absence of RETAINWELLGRID and FOCUSGRID (to be introduced next), Koko will only simulate the coarsest level of grid.

Step 5. Improve simulation results in one particular area of interest during optimization

Add the following line to Problem Description Section of the optimized CHEARS deck. Launch Koko.

```
FOCUSGRID 1 10 1 10 1 3 6
```

This instructs Koko to retain 6 rings of fine grid blocks surrounding wells for all wells in the window of 1 10 1 10 1 3. This overrides the number of rings defined in RETAINWELLGRID. However, if the number of rings is less than that defined in RETAINWELLGRID, the latter is used.

Step 6. Optimize well PI via a restart file

Add the following lines to the beginning of the Recurrent Data Section. Set up the restart file just like CHEARS and launch Koko.

```
DATAOPTM W1 MINBHP 1.0
DATAOPTM W2 MINBHP 1.0
WELLPIOPTM W1 / PAR#1
WELLPIOPTM W2 / PAR#2
```

The first two lines instruct Koko to fit to minimum bottom hole pressures of wells W1

and W2. The third and fourth lines instruct Koko to optimize on the divider of the well PI for these wells. Only divider of well PI can be optimized. Optimization of well PI cannot be mixed with optimization of other properties.

Optimization of well PI is generally considered to be the last stage in a history matching. Well PI is fitted to the bottom hole pressures towards the end of production history. Usually a few

time steps before the end of production history are required. Thus, users can use a restart file for such an optimization.

Restart file can also be used for optimization of basic or cell properties. However, this use can only be justified if excluding the earlier production data does not significantly affect the results.

List of Implemented CHEARS keywords

ALL	APIGRAVITY	ASSIGN	BININTCOEF	
BUBBLEP	BURDEN	BURDENAREA	CELLS	
COMPINIT	COMPONENTS	COPY	CRITPERM	
DATE	DATUMPRES	DEPTH	DEPTHVAR	
DEPTHVARLIQ	DEPTHVARVAP	DX	DXA	
DY	DYA	DZ	ENTHALPY	
EOSPARMS	EQUILCMP	EQUILIBRIUM	EQUILREG	
EQUILRSRL	FAULT-XDIR	FAULT-YDIR	FAULTDEF	
FLUIDCOMP	FORMULATION	FRACTURE	GASCMP	
GASFVF	GASPROP	GASSAT	GASVISC	
GRAPHFREQ	GRAPHINITIAL	GRAPHRECUR	GRIDBASIC	
GRIDDEF	GRIDEND	GRIDFORM	GRIDSIZE	
GRIDWINDOW	GROSS	HEATCP	HEATCPVOL	
HIST	INJECTOR	INJGASCOMP	INJGASCOMP	
JFUNCTION	JFUNCTOILGAS	JFUNCTWATOIL	KRREGION	
KVALUES	LAYER	MAPFREQ	MAPORIENT	
MAPSINITIAL	MAPSRECUR	MAXBHPINJ	MAXGAS	
MAXGASINJ	MAXLIQ	MAXNNC	MAXOIL	
MAXOILINJ	MAXSEPS	MAXSTMINJ	MAXTABL	
MAXVOL	MAXVOLINJ	MAXWAT	MAXWATINJ	
MAXWELL	MINBHP	MIXINGPARM	MODELSIZE	
NCOMPONENTS	NEGTRANS	NET	NFAULTS	
NHISTPI	NNC	NNCGRID	NOECHO	
NORMOILGASPERM	NORMSATENDPT	NORMWATOILPERM	NRCONVPARM	
NRCONVTOL	NREGIONS	OILDEN	OILGASPERM	
OILGASPOWER	OILPROP	OILSAT	OILVISC	
PARACHOR	PINCHOUT	POREVOLUME		
POROSITY	PRESS	PRODUCER	PVTREGION	
RCOMPRESS	REGION	REMAINCOARSE	RESOILMISC	
RESTART	RESTARTFREQ	RESTEMP	RSRLINIT	
SATEQ1	SEPDEF	SEPSTAGE	SEPSTAGE	
SGC	SHUTIN	SIMULATOR	SOLVENTPROP	
SORG	SORW	START	STDPRESTEMP	
STMQUALITY	STOP	SWIR	TDEPTH	
TEMP	THREEPHASEPERM	TIME	TITLE	
TRANSMOD	TSLIM	TSPARM	TSSET	
UNDERSATEQ1	VOIDAGE	WATEROILPERM	WATEROILPOWER	
WATERPROP	WATERSAT	WATPROP	WELLBORE	

WELLCOMP	WELLDEF	WELLFREQ	WELLIMIT
WELLNAME	WELLSEP	WINDOW	XDIVISIONS
XHCOND	XHTRANS	XPERM	XTRANS
XYPLOT	XYPLOTREQ	YDIVISIONS	YHCOND
YHTRANS	YPERM	YTRANS	ZDIVISIONS
ZHCOND	ZHTRANS	ZPERM	ZTRANS

New Koko Keywords

ANALYTICALDERIV	ARRAYDIMENSION	AUTOCOARSEN	AUTOCOARSENREST
CHAOTICSEARCH	DATAOPTM	FINEGRIDNAME	FOCUSCOMP
FOCUSGRID	GRIDDEFKOARSEN	GRIDFORMKOARSEN	MAPSEARCH
MAPSEARCHMAXITN	MIXEDFLUID	NEWTONACTIVITY	OPTMMAXITN
PAR#	PARALLELCHAOTIC	PINTERPOLATION	RETAINKOARSE
RETAINFINE	RETAINLGR	RETAINWELLGRID	RFTTXTFILE
VARIABLE1	WELLPIOPTM	XKOARSEN	XKRGCW
XKROCW	XKRWRO	YKOARSEN	ZKOARSEN

For questions and suggestions, please contact support@focussimulation.com.