Optimizing Cyclic Steam Oil Production With Genetic Algorithms

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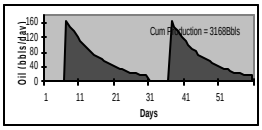
Cyclic Steaming Process

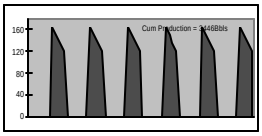
- Trying to produce heavy, viscous oil from diatomite – like trying to get roofing tar out of a brick
- Need to inject steam to:
  - fracture the rock
  - reduce the viscosity of the oil
- We do this using a cyclic process:
  - Inject steam for 3-4 days
  - Let it soak in for 2-3 days
  - Produce oil for ~30 days (production declines exponentially with time)
  - Repeat

- **Optimization Opportunity**

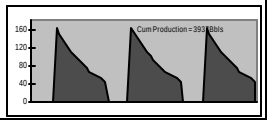
◆Maximize cycle time (inject steam less frequently) because there is no production during steam and soak periods



◆Minimize cycle time (inject steam more frequently) because oil production is highest immediately after returning the well to production, then declines rapidly



◆There is an **optimum cycle length (OCL)** for every well that results in maximum productivity



- **This is a formidable optimization problem**

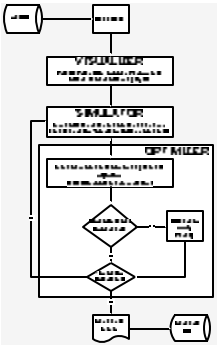
- Large number of wells
- Multiple objectives – Production, Profit, Steam efficiency
- Multiple constraints –
  - Steam availability
  - Steam loop balancing
  - Facility constraints
- Special situations
  - Steam generator maintenance
  - Well shutdowns due to maintenance
  - Communicating / Gassy wells
- A S**cheduling tool** would be very helpful

Cyclic Steam Optimization Project

- **Objective**
  - Develop a tool to optimize the steam injection schedule to increase oil production and decrease steam-oil ratio
- **Project Challenges**
  - Complex combinatorial problem
  - Pockets of feasible space
  - Data quality is not very good
  - Well performance models are not readily available
  - Work process will change significantly
  - Operators must buy into the new tool & work process

- **Scheduler has 3 components**

- **Visualizer** – Reconciles data & predicts future performance for individual well
- **Simulator** – Simulates field-wide performance for a given steaming sequence
- **Optimizer** – Uses Genetic Algorithm to optimize steaming sequence



- **Why is GA suitable for this problem**
  - **Optimize over a long period of time**
  - **Discrete / integer variables**
  - **Pockets of feasible space**
  - **Computation time not an issue**
  - **Some constraints can't be expressed in a mathematical form**
  - **Multiple solutions are preferred by the user**

- **GA Features**
  - **Chromosomes**
    - **Enumerated chromosomes**
    - **Literal representation**
    - **Sequential representation – Preferred**
    - **Sequence length – Heuristic based**
  - **Seeding Algorithm based on Optimum Cycle Length**
  - **User defined operators – insert, delete, swap**
  - **User controlled termination criteria**
  - **Inclusion of both hard & soft constraints**

- **Closed loop test**

- **Conducted during July – November 2001**
- **One gauge setting - 21 wells**
- **Similar constraints as the whole field**
- **Objective was to maximize oil production over next 60 days**
- **Compared the performance against pre-selected baselines**

- **Closed loop test proved the feasibility**

  - Production during closed-loop test increased by 4 - 18% (depending on which baseline you used for comparison)
  - Steam injection also increased by 11 - 41% (was this fair?)
  - The field operators & engineers made the new work process a success
  - Project is economically viable and technologically feasible

- **Challenges / Strategies for scale up**

- **Risk mitigation – Phased development**
- **Retain performance – Heuristics, New GA operators**
- **Robust optimization – Breeding pool**
- **Evaluating the success of the project - ?**
- **Project management – Constant tracking and communication**

- **Project economics are very attractive**

Project Economics

- **NPV (@10%) = $5.8MM**
- **DPI (@10%) = 5.25**
- **Payout = 9 months**
- **Total Investment = $1.4MM**

- **Lessons Learned**
  - **GA can be effectively used for production optimization**
  - **Technology implementation is as much about right people as it is about right technology**
  - **External peer review resulted in selecting software that is better suited for field-wide implementation**
  - **Design of a pilot for a complex facility is not an easy task but very critical**
  - **Measurement accuracy / frequency very important for optimization**

- **Questions?**