Crude Oil Quality Association Meeting

TU Fluid Flow Research and Technology Development

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The University of Tulsa

October 26-27, 2011
Outline

- Relevance
- State of the Art
- Current Efforts
Relevance ...

Organic deposits → Hydrates & Ice → Mineral Deposits

Imposed Transients → Restrictors & Blockers

Steady State → Hydrodynamics

Natural Transients → Rheology

Flow Assurance

System Integrity

Sand Management

Others

Erosion Corrosion

Gellation

High Viscosity

Dispersions

Review of Multiphase Production & Transportation

- Until 1980’s
  - Designs Based on Empirically Developed Tools
    - Limited Applicability
    - Limited Success
  - Risk Aversive Culture
    - E.g. Separate Flow Lines to Avoid Multiphase Related Problems
Review ...

- Significant Progress Since Mid 1980’s
  - Better Understanding of Two-phase Flow
    - Mechanistic Steady State Models
      - TUFFP Unified Model
    - Transient Flow Models and Software
  - ± 20% or Less Average Uncertainty in Two-phase Flow Predictions
Gaps

- Two-phase Flow Gas-Liquid
  - Up-scaling (Size and Pressure)
  - CFD Modeling
    - Efforts Underway (Horizon and LEDA)
  - High Viscosity Oils
  - Steep Downward Flow
  - Slugging
  - Flow Control
    - Desired for Optimum Operation
Gaps …

- Two-Phase Oil-Water Flow
  - Water is Inevitable
  - Need to Have Good Knowledge of Flow Characteristics
    - Facility Design
    - Flow Assurance Support
      - Location of Water
    - Separation
  - Limited Understanding
Gaps …

- Two-Phase Oil-Water Flow …
  - Phase Distributions (Separated and Distributed)
  - Dispersion/Emulsion Characteristics
    - Viscosity
    - Phase Inversion
  - Chemistry (Effect of Natural Surfactants)
Gaps …

- Three-phase Gas-oil-water Flow
  - Still Unresolved Primarily Due to Complex Water Phase Interaction
  - Similar Problems Described in Oil-Water Flow, With Higher Degree of Complexity
Gaps …

- **Significant Uncertainty in Paraffin Deposition Predictions for Single Phase Flowing Conditions**
  - Turbulent Flow is Challenge
  - 100% Uncertainties are Common
  - Resulting in Conservative Measures

- **Very Limited Studies of Deposition Under Multiphase Flow Conditions**
Technology Development Platforms

- Consortia and JIPs
  - Tulsa University Fluid Flow Projects (TUFFP)
  - Tulsa University Paraffin Deposition Projects (TUPDP)
  - Tulsa University High Viscosity Oil Projects (TUHOP)
TUFFP

- Established in 1973
- Currently Supported by 15 Oil & Gas Companies and MMS
- $880,000 Operating Budget for 2011
- $55,000/year Membership Fee
TUFFP ...

Mission

- Investigate and Find Solutions for Many Multiphase Production and Transportation Problems Faced by Membership
- Develop Models and Software As Design Tools for Different Multiphase Flow Applications
## 2011 TUFFP Members

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TUFFP Deliverables

- Models and Software as Design Tools for Multiphase Flow Applications
- Research and Solutions on Many Multiphase Production and Transportation Problems
- Experimental Procedures, Analyses, and Data for the Membership in Conducting Their Own Studies and Practices
TUFFP Deliverables …

- Readily Available Expertise in Multiphase Flow Production and Transportation
- Access to TUFFP Facilities for Possible Contract Projects
- Platform to Exchange Information and Ideas on Multiphase Flow Practices
- Personnel Training Through Resident Education and Short Courses
TUFFP Research & Technology Development Contributions

- Development of First and Most Used Multiphase Flow Correlation for Hilly Terrain Pipelines
- Discovery of Severe Slugging Phenomenon, and Some of Elimination Techniques
- Pioneering of Comprehensive Mechanistic Modeling Approach
TUFFP Research & Technology
Development Contributions …

- Several Software as Design Tools Including
  - Beggs & Brill Correlation
  - Ansari Mechanistic Model
  - Xiao Mechanistic Model
  - Unified Mechanistic Model

- Developed Technology Currently Used in
  - Commercial Software Packages such as: Pipesim™, Pipephase™, PipeFlo™, PROSPER™, Pipesoft-2™, Perform™, etc.
  - In-house Simulators of Several Companies
Human Resource Development

★ Resident Education
  ➢ Over 80 TUFFP Alumni
    ▶ Prominent Positions in Many Companies and Universities

★ Training
  ➢ TUFFP Short Course
    ▶ In Tulsa or at Company Location
    ▶ Over 800 Individuals from 137 Different Companies
TUFFP ...

- Current TUFFP Research Projects
  - High Viscosity Multiphase Flow
  - Three-Phase Gas-Oil-Water Studies
    - Oil-water Flow Mechanistic Model Development
    - Three-phase Flow in Hilly-Terrain Pipelines
  - Droplet Homo-phase Studies
    - Entrainment Fraction Closure Relationship
TUFFP …

Current Studies …

- Low Liquid Loading in Large Diameter Pipes
- Multiphase Flow in an Annulus
- Transient Multiphase Flow in Pipes
- Up-scaling Studies
- Unified Mechanistic Thermo-Hydraulic Modeling of Multiphase Flows
TUFFP Facilities
TUPDP

- Tulsa University Paraffin Deposition Projects (TUPDP) Consortium Formed As Continuation of TU WAX JIP in 2001
- Three-year Revolving Business Plan
- Industry Participants (9)
  - BP, BHP Petroleum, Chevron, ConocoPhillips, ExxonMobil, Nalco, Petrobras, Total, Alyeska (In Process)
- Membership Fee is $60,000/year
TUPDP Objectives

- **Enhance Our Understanding of Paraffin Deposition in Single and Multiphase (Gas-Oil-Water) Flows**
  - Conduct Focused Experiments to Better Understand Various Aspects of Deposition Physics
  - Develop Models that Mimic the Right Physics
- **Enhance Paraffin Deposition Software**
Paraffin Deposition Review

★ Single Phase Flow Studies
  ➢ Experimental & Modeling
    ▶ Real Oils (South Pelto Oil, Garden Banks Condensate)
  ➢ Understanding of Many Paraffin Deposition Characteristics under Flowing Conditions

★ Two-Phase Flow Studies
  ➢ Experimental & Modeling
  ➢ First to Investigate and Develop Technology for Gas-Oil Paraffin Deposition
Accomplishments

🚀 Software Development (TUWAX)
- Wax Deposition Prediction Software
- Widely Used in Industry to Design Wax Management Programs
  - Utilized participants on several projects
    - E.g. Design of BP’s Baku-Ceyhan Pipeline
- Implemented in Pipesim Software for BP
Accomplishments

- $2 million in capital costs saved by ConocoPhillips by eliminating pig launcher
- One independent was destined for failure until Nalco showed them that their design needed to include a pig launcher and a better designed chemical treatment
Current Projects Descriptions

- Project-1: Turbulent Flow
- Project-2: Multiphase Flow
- Project-3: Field Verification and Upscaling
- Project-4: Gelled Re-start
- Project-5: Software Maintenance and Development
TUPDP Facilities

- Single-phase Facility
- Multiphase Facility
- Small Scale Facility
- Flow Assurance Lab
  - Bench Top Facility
  - Various Analytical Equipment
    - DSC
    - HTGC
    - Cold Finger

TUPDP Facilities
TUHOP

- Tulsa University High-Viscosity Oil Projects (TUHOP)
- $500,000/Year, All from Industry
- Experiments and Modeling of Various Multiphase Flow Combinations of High-Viscosity Oil, Water and Gas for Heavy Oil Production and Transportation