Technologies for mining in the deep sea

Stanislav Verichev
IHC Merwede B.V./MTI Holland B.V.

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DEEP SEA MINING
General Risk Analysis:
identification of the key risks followed by the development of prevention/mitigation strategies

![Risk Analysis Diagram]

**PROBLEMS** → **SOLUTIONS**
1. Geostatistical toolbox and SWORD
2. Hyperbaric cutting
3. Vertical hydraulic transport
4. Dynamics of the vertical transport system
5. Water hammer
6. Wear
7. Environmental impact
1. Geostatistical toolbox

core sampling → Kriging interpolation → geotechnical model of the area → 2D/3D maps → cutting forces and mining pattern
Key Features of the SWORD

• Sample sizes up to 4 inch.
• Operating depth up to 2500m.
• Ground penetration up to 50m.
• Target sample integrity > 95%.
• Remote operation from vessel-based control center.
• Combines conventional rotary drilling with sonic drilling capability which is typically up to 5 times faster than conventional sampling methods.
• Wire-line system for down hole tooling and CPT tests.
2. Hyperbaric cutting

ductile vs. brittle → cutting forces → experiments → modeling → optimal deep sea mining tool
3. Vertical hydraulic transport

*Fluidization tests at MTI Holland B.V.*

Marbles  Gravel  Rock blast gravel

Decreasing sphericity, increasing angularity
Shape and transport velocities
Experiments
Simulations

Concentration peak development
4. Dynamics of the vertical hydraulic transport system
Booster Stations (submersible dredge pumps)
Why correct modeling of dynamics is important?

- according to OREDA 2009, 16-24% of the total failures of the offshore oil production risers are fatigue-related failures;
- knowledge on maximal displacements and moments is critical for the design of joints and couplings;
- the model that accounts for all the aforementioned excitation sources has never been built and analyzed yet.
Internal and External Loads

VTS loading mechanisms

Dynamic loading
- Vessel motion, Waves
- Booster stations, Propulsion system
- Flow-induced instabilities
- Slurry flow

Static loading
- Dead weight, Hydrostatic pressure, Mean value of hydrostatic drag
- Vortex-Induced Vibration
- Ocean Currents
Dynamical Pressures as a Result of Inhomogeneous Slurry Flow
Example of the output
5. Water hammer

1. Valve closed - water still
2. Valve open - moving water
3. Valve closes - \textit{Water Hammer}
Mineral Mud System; Mixture (1600 [kg/m³])

- Blockage in 0.000001 [s]
- Blockage in 0.0001 [s]
- Blockage in 0.1 [s]
- Blockage in 1.0 [s]
- Blockage in 10 [s]

Pressure Drop [Bar]

Suction Mouth Blockage [%]
Subjects to be investigated for water hammer:

- Pump failure
- Bulk modulus mixture (under dynamic conditions)
- Model verification/validation
- Water hammer mitigation
- Other possible water hammer scenarios:
  - Breakage of a flexible hose
  - Startup & shutdown of the system
  - Valve failure
  - Free gas/gas hydrates handling, etc.
Abrasive wear at hyperbaric conditions
Wear rate vs. pressure. Low carbon steel m 1020 + emery stone, 1 h, N=1600, f=0.44 Hz, 2x0.7 kg
7. Environmental impact

JIP project

Project objectives

• To develop a framework to be used as a preliminary impact assessment of the mining activities in the deep sea

• To determine the uncertainties of the methodology and to determine the sensitivity of the assessment framework to these uncertainties
Location

MAR: Azores-Portugal EEZ
Location
Accurate grid of 4x4m cells

Positioned in a valley in MAR

Vents occur in a area of 300 by 700m on top of a vulcano

Depth ~1650m
Mining system

(Derived from “Nautilus” and “IHC’s” available data)

1. Soil conditions
SMS deposit scenario: Solid soil type “Solid Rock”.
This scenario implies working with small volumes and high slurry mixture concentrations.
Q&A
You have Questions
We have Answers