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Distinguished Lecturer Program
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Diamond – A Driller’s Best Friend

Terry Matthias

Society of Petroleum Engineers
Distinguished Lecturer Program
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Overview

Copper Nickel

Cobalt

Tungsten Carbide

Natural Diamond

Synthetic Diamond

PDC

Natural Diamond Bits

PDC Bits

Performance
Early Use of Diamond

- Mists of Time
  - Adornment
  - Stoneworkers
  - Talisman (Lucky Charm)
- From 1000 A.D.
  - Cleave & later polish diamonds

[Images of diamond and jewelry]
What is diamond?

• 1700’s New science of chemistry
  – Break down materials with fire – couldn’t with diamond

• 1772 Antoine Laurent Lavoisier
  – Magnifying glass to burn diamond

• 1797 Smithson Tennant
  – Diamond = Graphite
Early attempts to make diamond

- 1772 – 1870  Temperature
  - Attempts to grow diamond crystals by evaporation of carbon rich solutions

- 1870 Diamonds found South Africa

- 1870 – 1910  Temperature and Pressure
  - Iron tubes, electric arcs, explosives, high velocities

All Failed
Structure

- 1912 Crystallography

Graphite

Diamond
High Pressure

- Percy Bridgman

<table>
<thead>
<tr>
<th>Year</th>
<th>Pressure (atm)</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900</td>
<td>2,500</td>
<td>Cell leakage</td>
</tr>
<tr>
<td>1905</td>
<td>7,000</td>
<td>Screw press</td>
</tr>
<tr>
<td>1910</td>
<td>20,000</td>
<td>Hydraulic press</td>
</tr>
<tr>
<td>1935</td>
<td>50,000</td>
<td>Opposed tapered steel anvils</td>
</tr>
<tr>
<td>1940</td>
<td>70,000</td>
<td>Opposed tapered carbide anvils</td>
</tr>
</tbody>
</table>

Courtesy Wikipedia
High Pressure Carbide

Cobalt Cemented Tungsten Carbide
1938

Thermodynamics predicts

Phase Diagram

High Pressure & High Temperature

Early 1940’s GE & Norton engage Bridgman

High pressure & high temperature tests to establish conditions diamond not destroyed

Conclusion

$>1,000 ^\circ C \& >50,000 \text{ atm}$

to make diamond

10
Natural Diamond Bits

• Diamond retention
  – Cannot wet
  – Mechanically lock
Synthetic Diamond

- 1951
  - Project Superpressure at General Electric

- 1954
  - 16th December First diamond made
    - Repeated 20 times in next 2 weeks
Man-Made® Diamond

1957 – 1977
Synthetic Diamond Grit
- Improving control of process for shape & properties
- Averaged a new product every year
- Grinding, sawing, drilling, lapping & polishing non ferrous materials

® GE registered trademark
PCD

• Large single diamond crystals cleave

• Carbonado
  – Grains of diamond, diamond-to-diamond bonded together, a natural polycrystalline diamond

• 1973 Compax® φ8mm x 3.5mm
  – GE mix cobalt & fine diamond
  – Press at 60,000 atm & 1400°C

©GE registered trademark
First PDC Bits

- 1974 - 1\textsuperscript{st} Bit runs
  - USA
  - Isle of Wight, England
Cutter & Bit Development

1973
1976
1978
1979
1980
1982
1986
PDC Development for Drill Bits

Compromise Between

Hardness & Durability

Hard – Wear resistant but brittle

Durable – Tough but soft
PDC Development for Drill Bits

• Micron diamond size
  – Mono modal - Single size of diamond
    • Diamond bonds/unit volume
  – Multi modal - Mix of 2, 3 or 4 sizes
    • Diamond bonds/unit volume
    &
    • Diamond volume
PDC Development for Drill Bits

- Diameters

- Polished diamond faces
PDC Development for Drill Bits

- Diamond layer thickness
  - From $\frac{1}{2}$ mm to 2-4mm
- Chamfered/Bevelled Edge
- Internal stresses - Interfaces
  - Flat to shaped – Claw, Star, Iris etc.

Bit Design
Thermal Stability

Removal of catalyst from surface of PCD

- **1\textsuperscript{st} Generation (SPE 79797)**
  - +40% footage
  - +40% rate of penetration

- **2\textsuperscript{nd} Generation (SPE 102067)**
  - +43% footage
  - +26% rate of penetration
Drill Bit Market

Source: Spears

![Drill Bit Market Bar Chart](#)
The Future for PDC and PDC Bits

• Diamond Sizes
  – Sub-micron  250nm – 1000nm
  – Nano        1nm – 250nm

• Diamond Mixes
  – Mono or multi modal sub-micron and/or nano
  – Multimodal with micron
The Future for PDC and PDC Bits

• Challenges of Catalyst Removal
  – Islands
  – Dissolved

• Future Direction
  – Deeper
  – Smaller pathways
  – Implications on time to leach
The Future for PDC and PDC Bits

• Other catalysts
  – Rare earth elements
• Catalyst free
The Future for PDC and PDC Bits

• Pressing Equipment
  – Higher pressures and/or temperatures
  – Pressing volume
  – Cycle time

Implications for PDC costs
Conclusions

• PDC is a very reliable, high performance cutting tool.
• Thermally stable PDC was the biggest drilling cost reducer
• The PDC bit is now the predominant drilling product.
• With your help
  – New generations of PDC for even higher bit performance
Your Feedback is Important

Enter your section in the DL Evaluation Contest by completing the evaluation form for this presentation:

Click on: Section Evaluation

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