



SOME RECENT RESULTS OF AUTOMATED DRILLING AND TORSIONAL VIBRATION ACTIVE DAMPING R&D AIMED AT MATURE DRILLING SYSTEMS RETROFITTING



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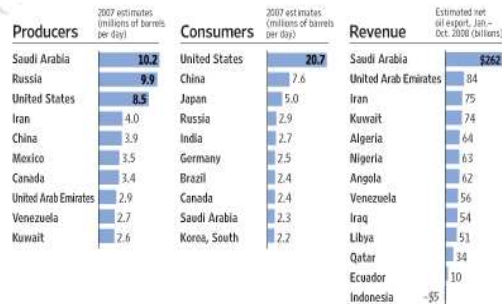
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MOTIVATION



Fueling Up

A look at key oil statistics, including proved reserves, the top 10 producers and consumers, and oil revenues of OPEC countries.



Source: U.S. Energy Information Administration

- 2.116 oil/gas drilling rigs operational worldwide (8/17)
- rental cost may exceed 60k \$/d.
- large oil exports revenues

Sector	Market size [EUR bn]	Growth	Description
Industrial machinery	284	339 (5%)	<ul style="list-style-type: none"> • Metalworking machinery • Engines
Oil and gas equipment	228	287 (6%)	<ul style="list-style-type: none"> • Drilling rigs and equipment • Supplies and services to drilling and completing wells
Consumer electronics	210	250 (4%)	<ul style="list-style-type: none"> • Audio-visual equipment • Games consoles
Cleantech	198	240-290 (5-10%)	
Machinery	154	203 (7%)	<ul style="list-style-type: none"> • Agricultural equipment • Mining equipment • Construction equipment
Heavy electrical equipment	76	91 (5%)	<ul style="list-style-type: none"> • Power-generating equipment • Other heavy electrical machinery

Legend: ■ Market size in 2011 ■ Market size in 2015

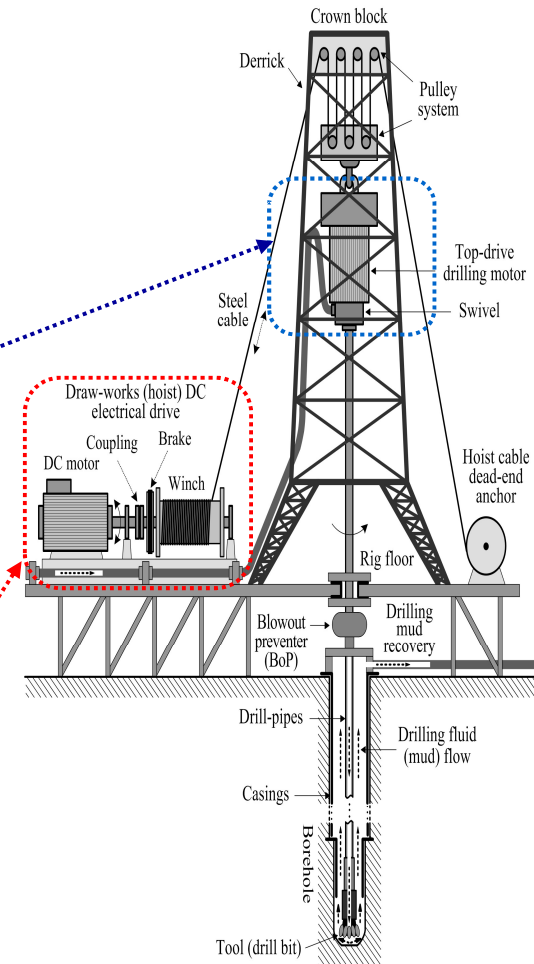
- equipment market share : 2nd largest (287 bn. EUR in 2015.)

RETROFITTING R&D IN OIL DRILLING

- SERVICE COMPANIES WITH MATURE DRILLING EQUIPMENT NEED TO BE COMPETITIVE
- RETROFITTING TO PROLONG EQUIPMENT USEFUL SERVICE LIFE
- FRACTION OF THE COST OF THE BRAND NEW DRILLING RIG

Rotary drilling drive affected by drill-string torsional vibrations ⇒ Active Damping!

Manually-operated hoist winch mechanical brake for tool descent ⇒ Automatic Drilling!

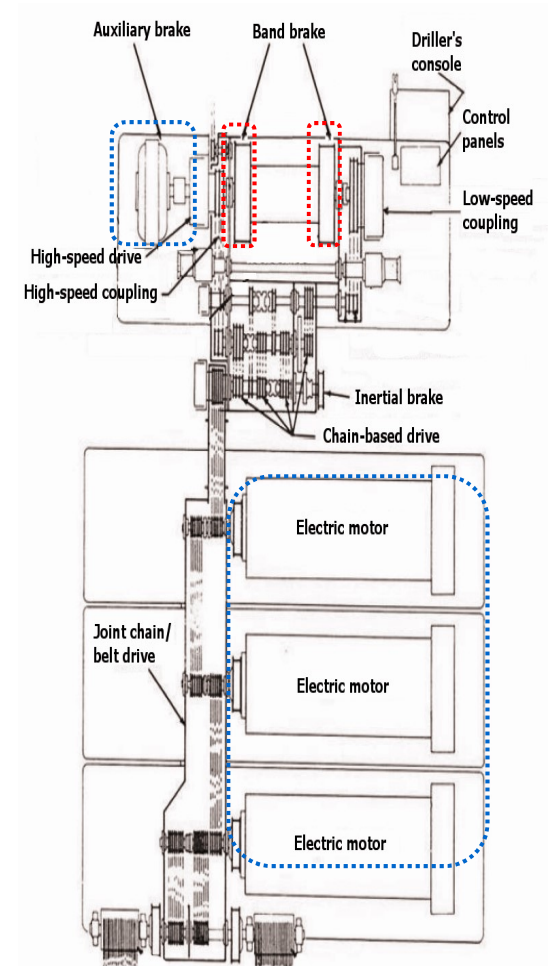


DRILLING RIG RETROFITTING LEADING PRODUCTS (AND RELATED R&D EFFORTS)

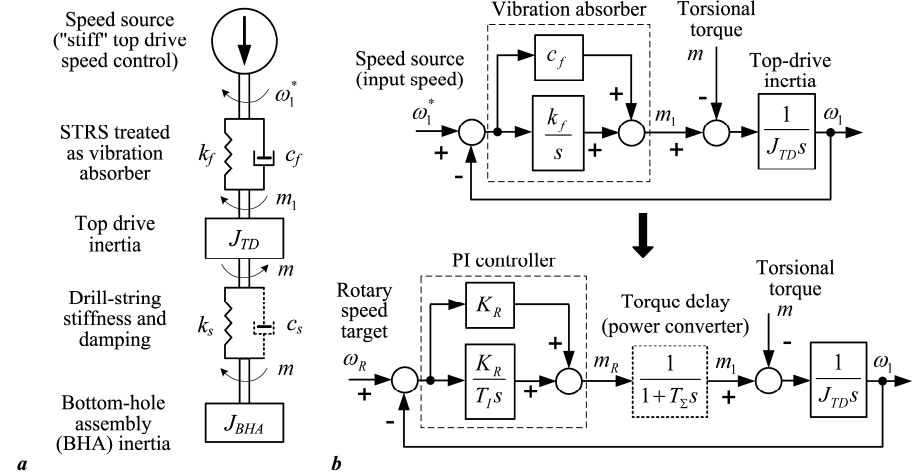
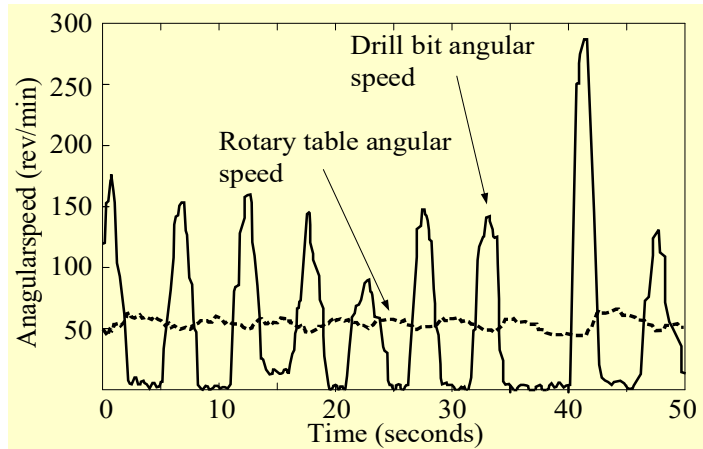
Producer	Origin country	Automatic drilling systems	Torsional vibration active damping
Bentec	Germany 	Available	Available
National Oilwell Varco	TX, USA 	Available	Available
Canrig	TX, USA 	Available	Available
Shell Global Solutions Int.	Netherlands 	-	Available (principal licensor)
ElectroProject	Netherlands 	-	Available
Pason	Canada 	Available	-
Rigserv	TX, USA 	Available	-
Lidan	Sweden 	Available	-
 HEL B	Croatia 	Available	Available

AUTOMATIC DRILLING SYSTEMS

- TRADITIONAL SOLUTION: MANUAL BRAKE CONTROL!
- LARGE TOOL WOB AND ROP VARIATIONS (QUALITY OF DRILLED BOREHOLE).
- SIMPLEST SOLUTION:
 - position control brake mechanism
- MORE ADVANCED:
 - draw-works electric motors
 - auxiliary (eddy-current) brake



TORSIONAL VIBRATION DAMPING

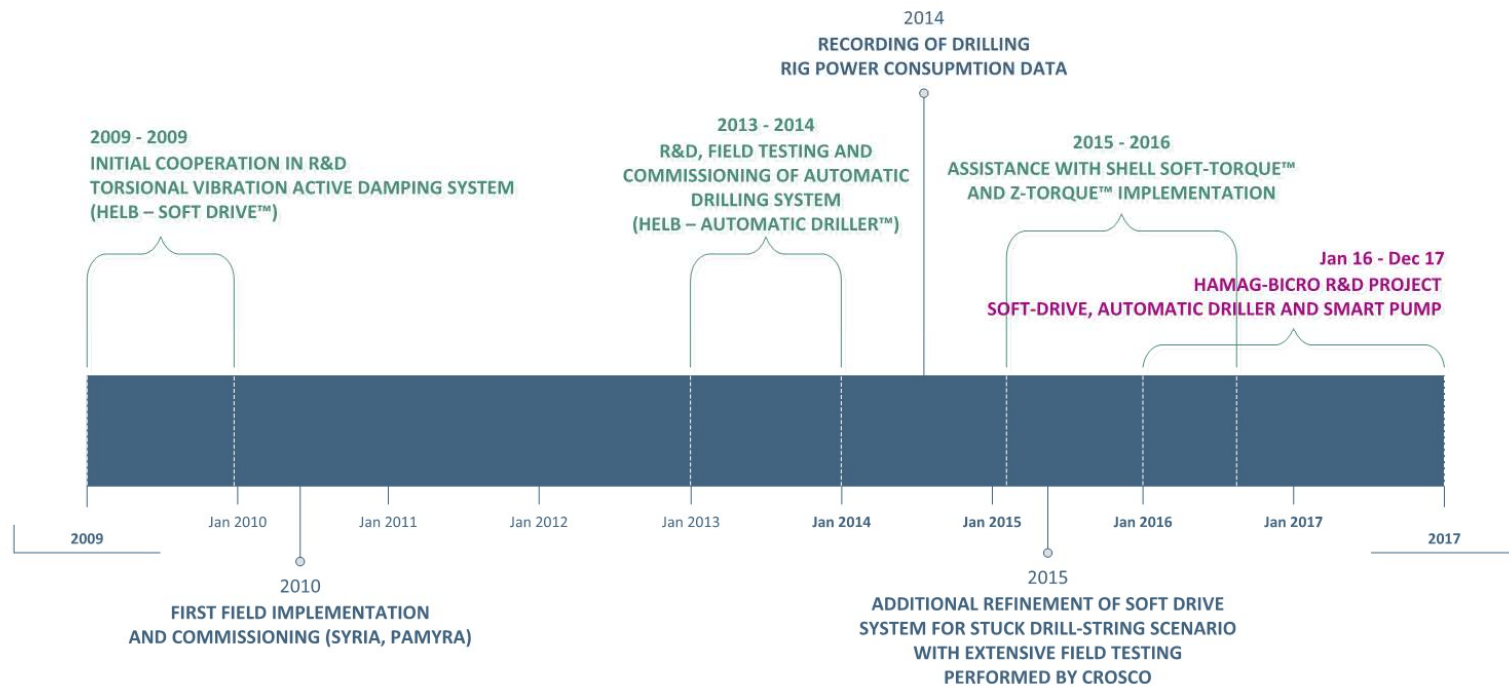


- Stiff drill-string speed controller
 → high-magnitude torsional vibrations!

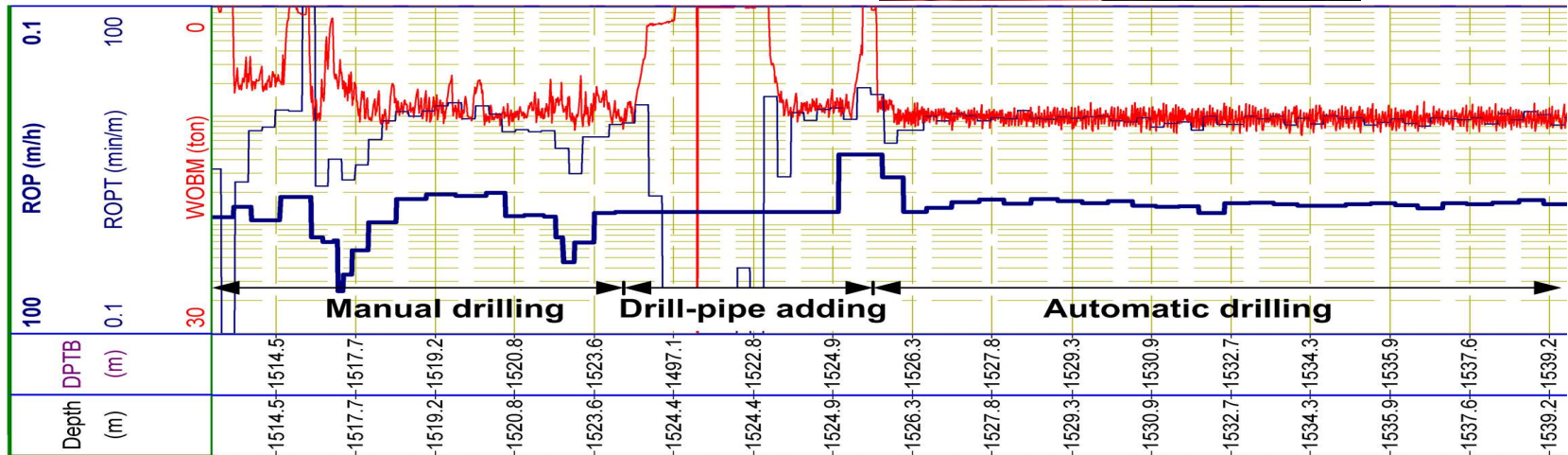
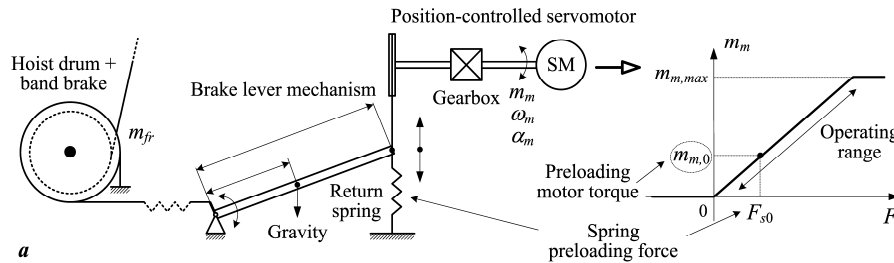
- Solution: controller re-tuned to act as vibration absorber → active damping

Shell licenses such a solution as Soft Torque Rotary System™ (STRS)

COOPERATION BETWEEN THE UNIVESITY OF ZAGREB AND OIL DRILLING SECTOR



AUTOMATIC DRILLING SYSTEMS



- Simplest solution: brake lever actuator with servo-capabilities (Automatic Driller)

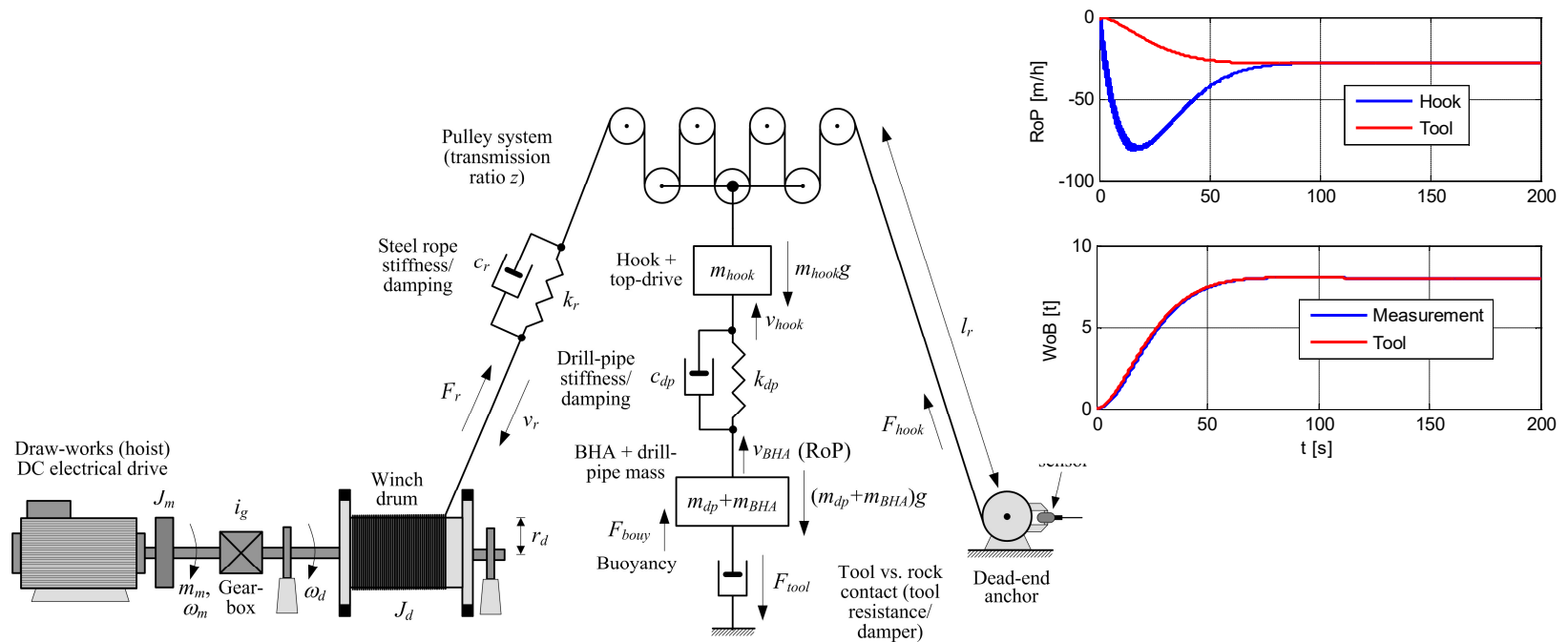
- Drilling quality improvement in terms of WoB/RoP performance!

AUTOMATIC DRILLING SYSTEMS

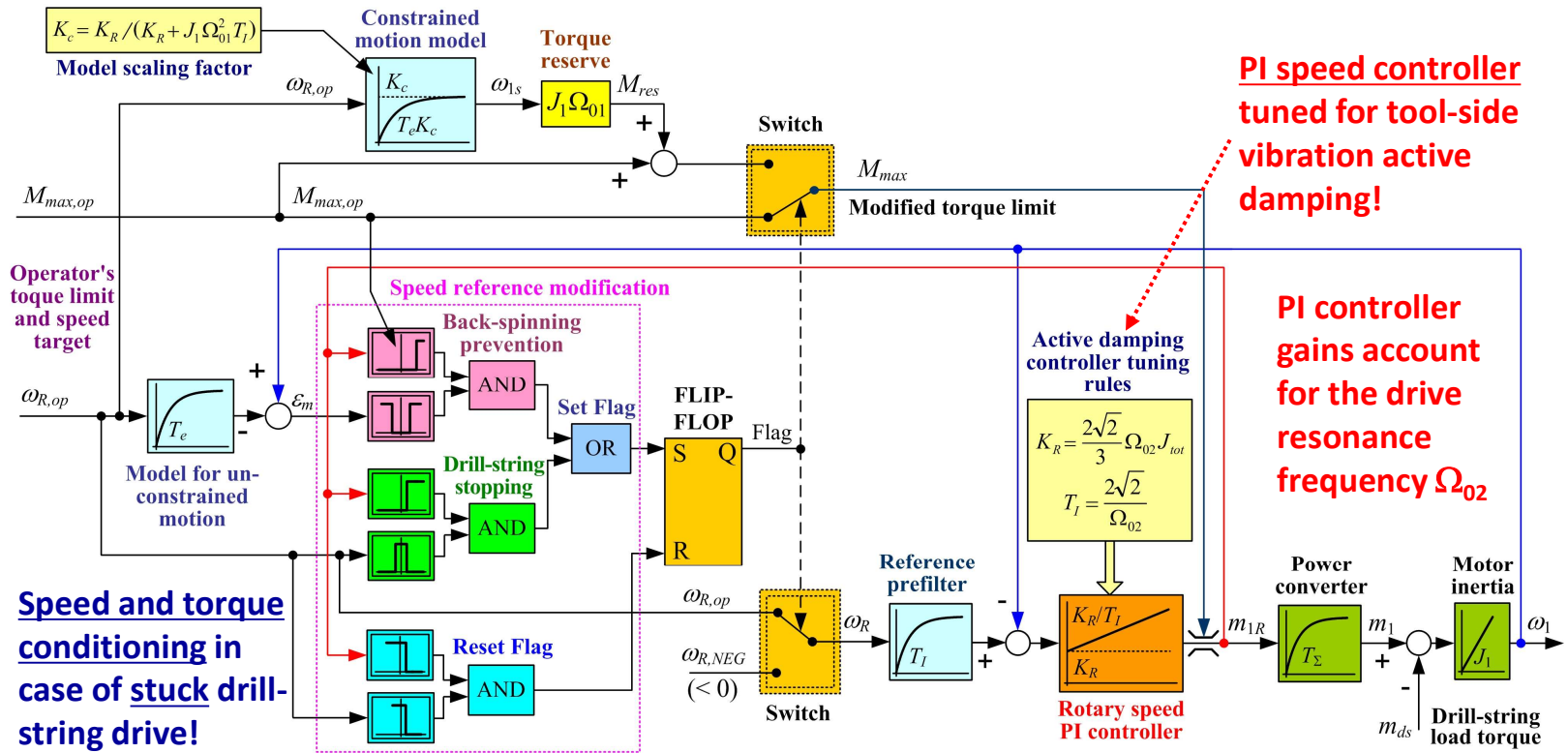
- Draw-works drive equipped with servo-capabilities: increased WoB/RoP control precision!
- 1st step: comprehensive draw-works models need to be derived!

- Simulation results:

- WoB pulsations are notably suppressed!
- High consistence of tool penetration (RoP)!

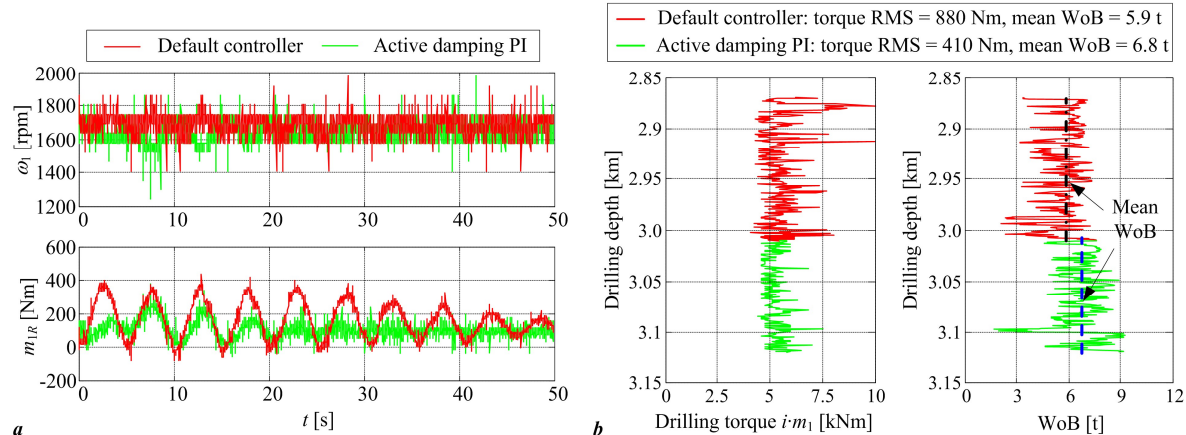


TORSIONAL VIBRATION DAMPING

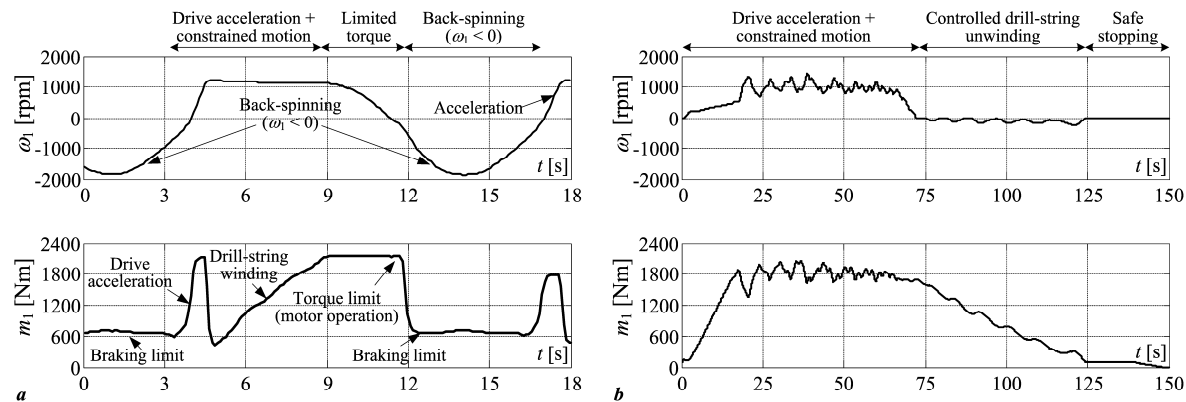


- SOFT DRIVE IS BASED ON WELL-KNOWN PROPORTIONAL-INTEGRAL (PI) SPEED CONTROLLER, TUNED W.R.T. DRILL-STRING DRIVE RESONANCE FREQUENCY
- OPERATOR'S SPEED TARGET AND TORQUE LIMIT ARE CONDITIONED IN THE CASE OF STUCK DRILL-STRING → SAFE DRILL-STRING UNWINDING

TORSIONAL VIBRATION DAMPING



COMPARISON OF DEFAULT (“STIFF”) AND SOFT DRIVE PI CONTROLLER (A) AND COMPARISON IN TERMS OF TORQUE VARIATIONS (B) IN THE FIELD.



STUCK DRILL-STRING BEHAVIOR WITHOUT (A) AND WITH BACK-SPINNING PREVENTION (B).

MAIN FEATURES:

- Drilling torque perturbations reduced by 50%
- WoB could be increased by 20%
- Consequently, RoP and drilling productivity are increased
- Hazardous back-spinning is prevented
- Benefit of dedicated speed and torque conditioning scheme

CONCLUSION

- GREAT POTENTIAL FOR MODERNIZATION THROUGH RETROFITTING OF THE EXISTING (& STILL QUITE USEFUL) MATURE DRILLING EQUIPMENT
- LOCAL ENTERPRISES HAVE MANAGED TO KEEP UP WITH GLOBAL TRENDS BY DEVELOPING THEIR OWN PROPRIETARY SOLUTIONS, AND ALSO BY MASTERING KEY COMMERCIAL TECHNOLOGIES
- THE COOPERATION WITH UNIVERSITY - A KEY FACTOR IN TIMELY FIELDING OF STATE-OF-THE-ART RETROFITTING DESIGNS AND PERFORMING INNOVATIVE RESEARCH
- RETROFITTING UPGRADES HAVE SHOWN SIGNIFICANT POTENTIAL FOR IMPROVING THE QUALITY OF THE DRILLING PROCESS IN TERMS OF TORSIONAL VIBRATION DAMPING AND CONSISTENCY OF WOB/ROP PERFORMANCE



THANK YOU!

QUESTIONS?

