Nov 14, 2018
Q4 IADC DEC Technology Forum
Houston, TX

Real-Time Health Monitoring of Top Drives Using Physics Based Models and New Sensor Technology

Pradeep Ashok

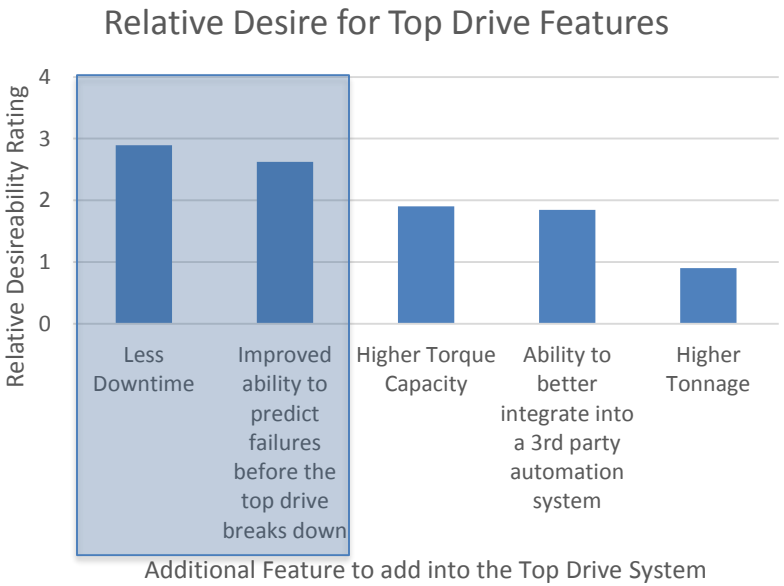
Introduction

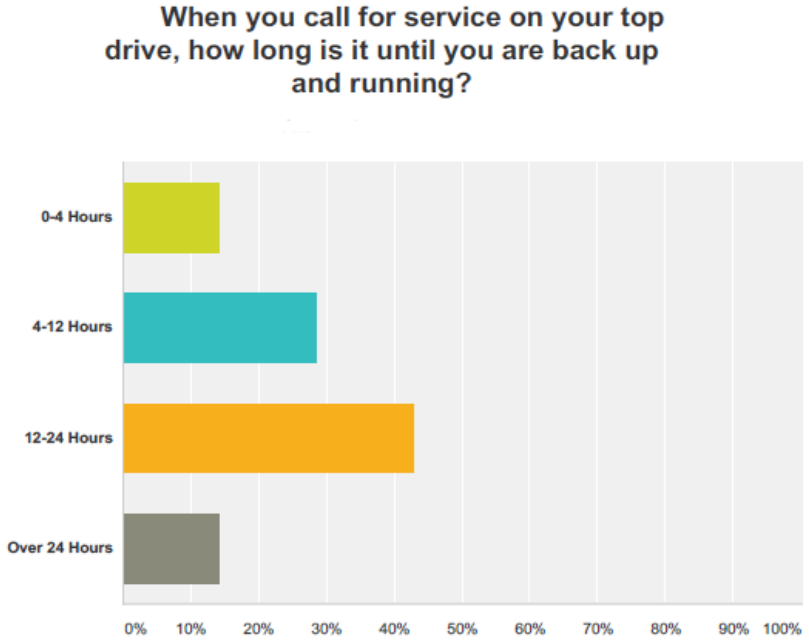
Top drive is a very important piece of equipment on a rig

Consequences of a top drive failure:

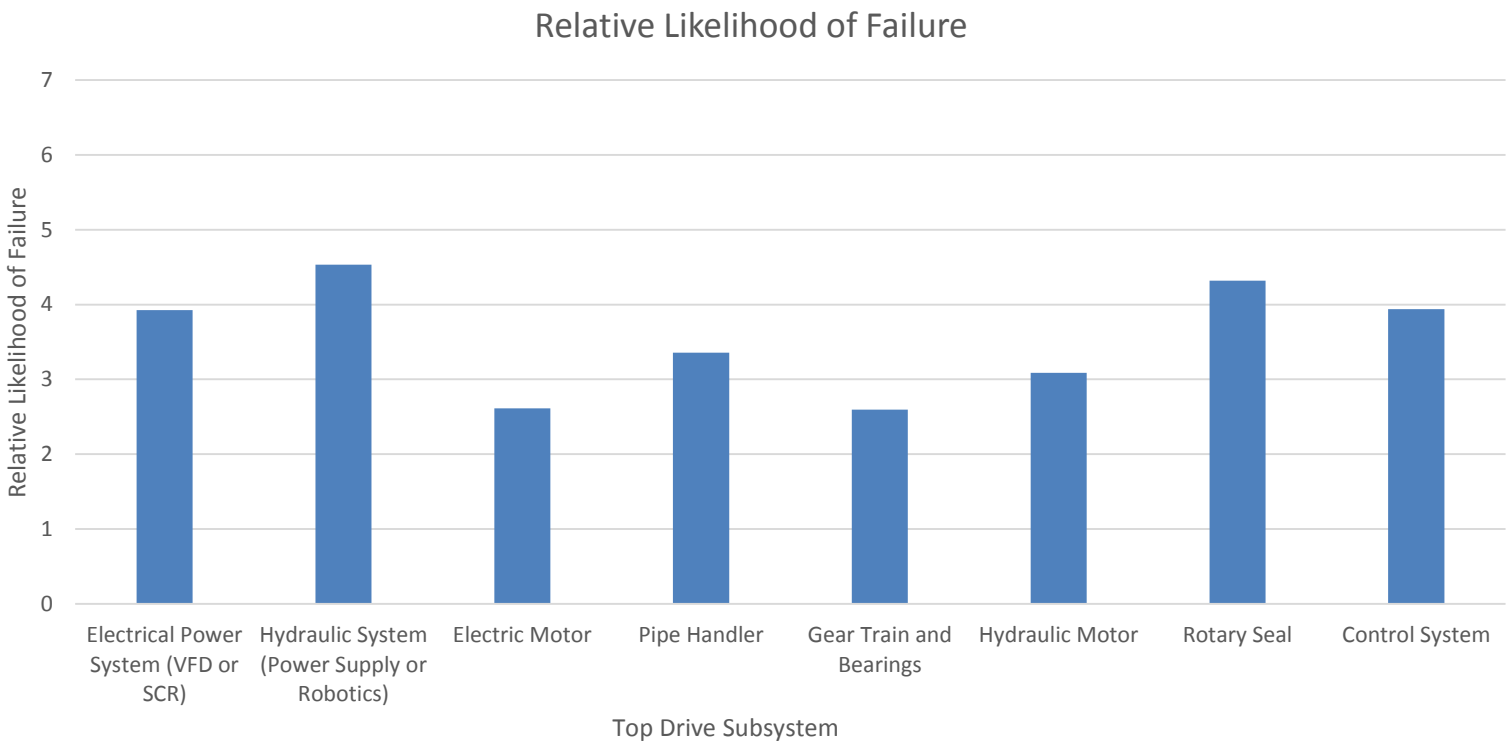
- All drilling efforts come to a halt
- Downtime to the operations
    - Rig rate must still be paid
- High repair costs
    - Availability of parts
    - Transportation of technician

Customer Survey

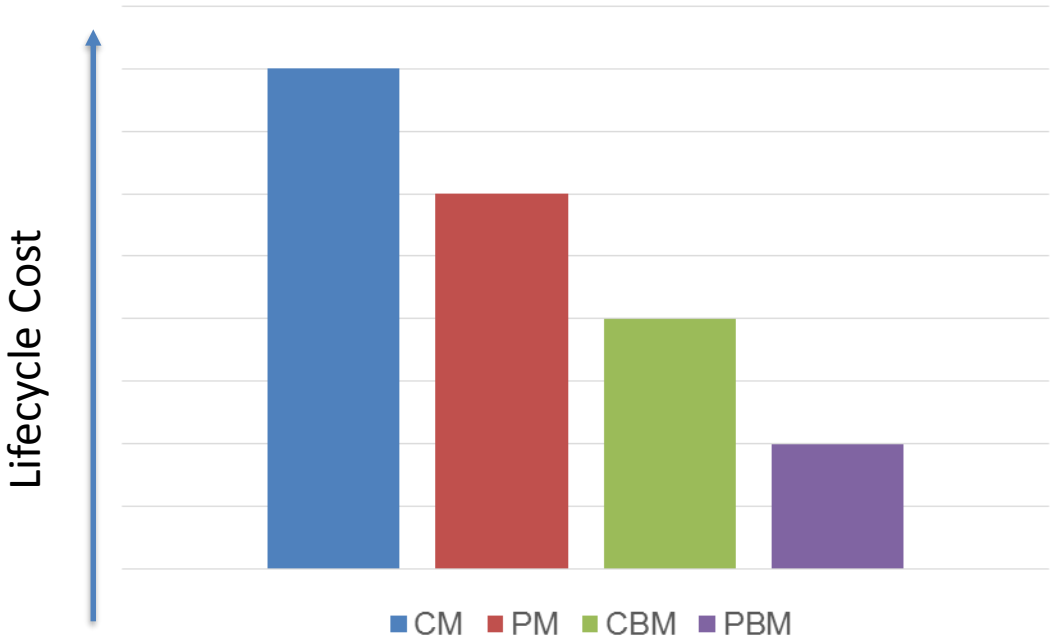




Different Problems on a Top Drive



Asset Management Strategy



CM – Corrective Maintenance, PM – Preventive Maintenance

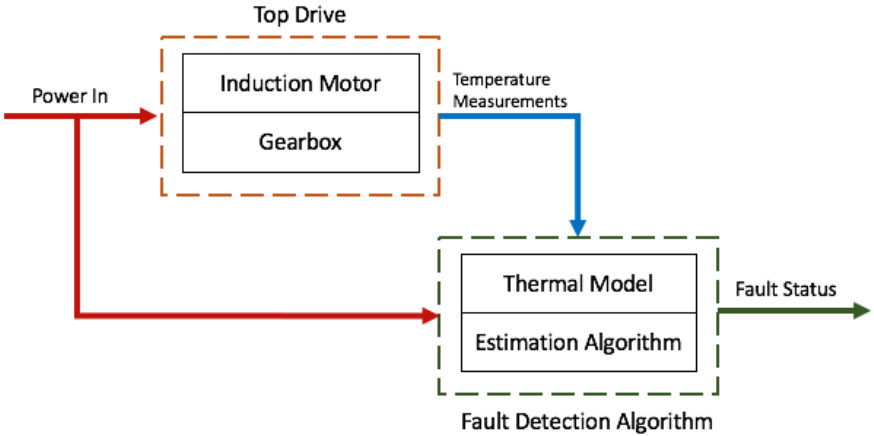
CBM – Condition-Based Maintenance, PBM – Performance-Based Maintenance

- Condition-based Maintenance vs. the traditional time-based preventative maintenance
- Real-time analysis to determine whether time-based preventative maintenance required

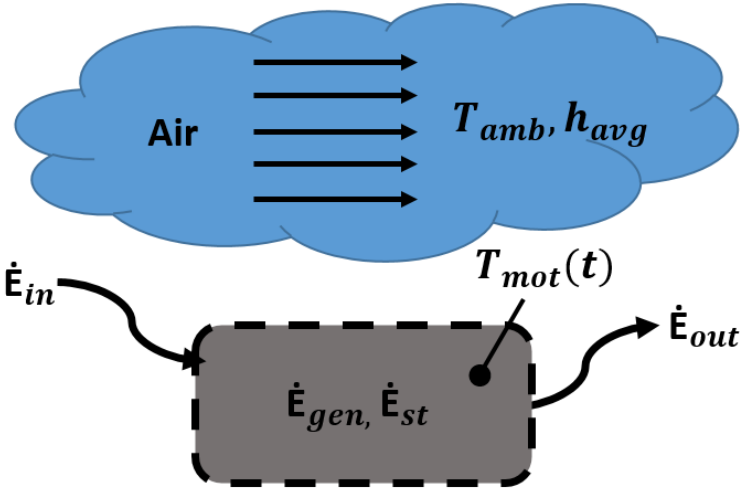
Thermal Modeling + Vibrations Monitoring + Oil Monitoring

Top Drive Thermal Monitoring

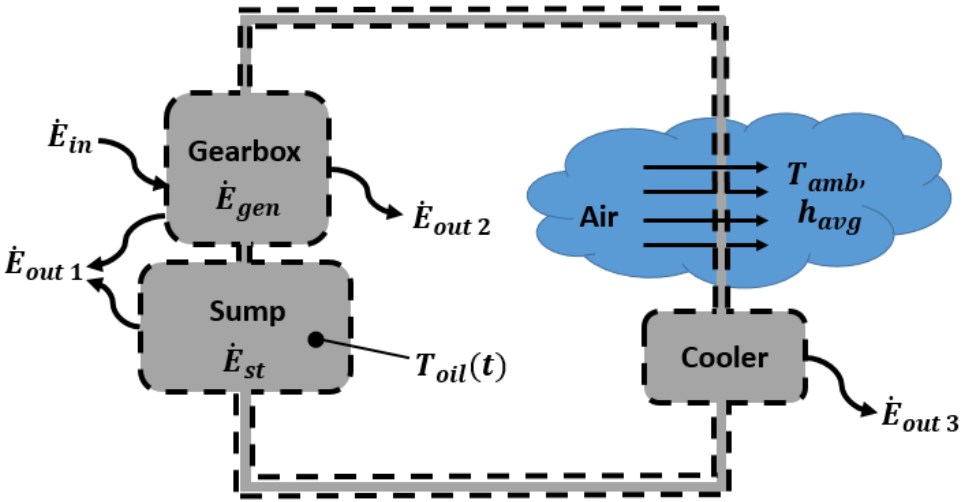
- Leverages temperature sensors already installed on most top drives :
  - Motor winding temperature sensors
  - Gearbox oil temperature sensors
- Estimation of model parameters from real-time temperature measurements
- Determine whether estimated parameters are “healthy”.



Physics Based Models



Electric Motor



Gearbox – Oil Sump

Induction Motor Thermal Model

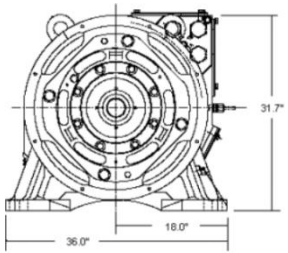
$$C_{rotor}\frac{dT_{rotor}}{dt} = P_{jr} - \frac{1}{R_1}(T_{rotor} - T_{case}) - \frac{1}{R_2}(T_{rotor} - T_{teeth})$$

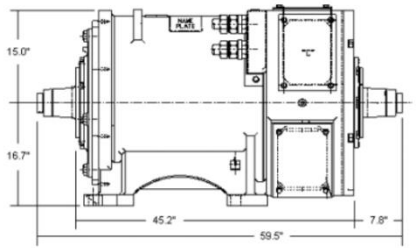
$$C_{teeth}\frac{dT_{teeth}}{dt} = \frac{1}{R_2}(T_{rotor} - T_{teeth}) + \frac{1}{R_3}\left(T_{st_{copper}} - T_{teeth}\right) - \frac{1}{R_4}\left(T_{teeth} - T_{st_{yoke}}\right)$$

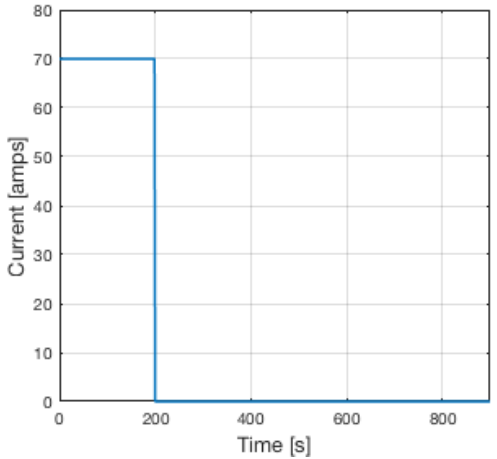
$$C_{st_{copper}}\frac{dT_{st_{copper}}}{dt} = P_{js} - \frac{1}{R_3}\left(T_{st_{copper}} - T_{teeth}\right) - \frac{1}{R_5}\left(T_{st_{copper}} - T_{case}\right)$$

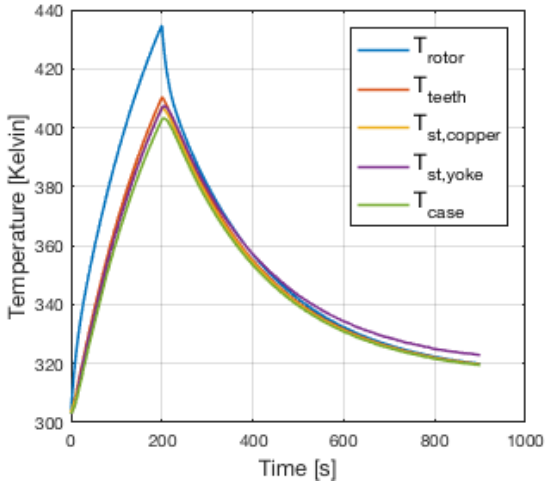
$$C_{st_{yoke}}\frac{dT_{st_{yoke}}}{dt} = P_{ir} + \frac{1}{R_4}\left(T_{teeth} - T_{st_{yoke}}\right) - \frac{1}{R_6}\left(T_{st_{yoke}} - T_{case}\right)$$

$$C_{case}\frac{dT_{case}}{dt} = \frac{1}{R_6}\left(T_{st_{yoke}} - T_{case}\right) + \frac{1}{R_5}\left(T_{st_{copper}} - T_{case}\right) + \frac{1}{R_1}(T_{rotor} - T_{case}) - \frac{1}{R_7}(T_{case} - T_{amb})$$







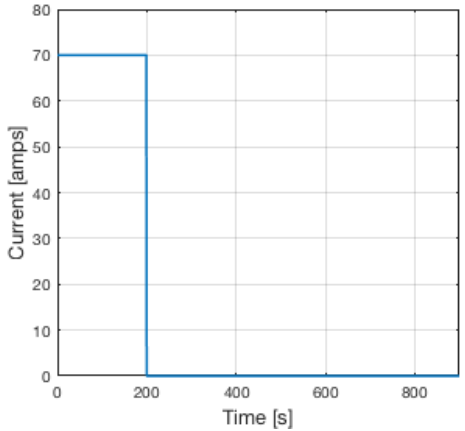


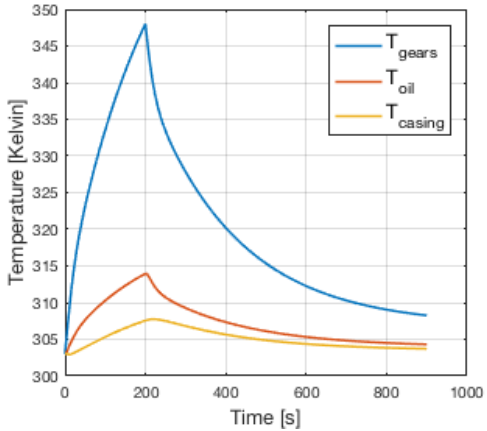
Gearbox – Oil Sump Thermal Model

$$C_{gears}\frac{dT_{gears}}{dt} = \frac{1}{R_8}(T_{rotor} - T_{gears}) + P_{gb} - \frac{1}{R_9}(T_{gears} - T_{oil})$$

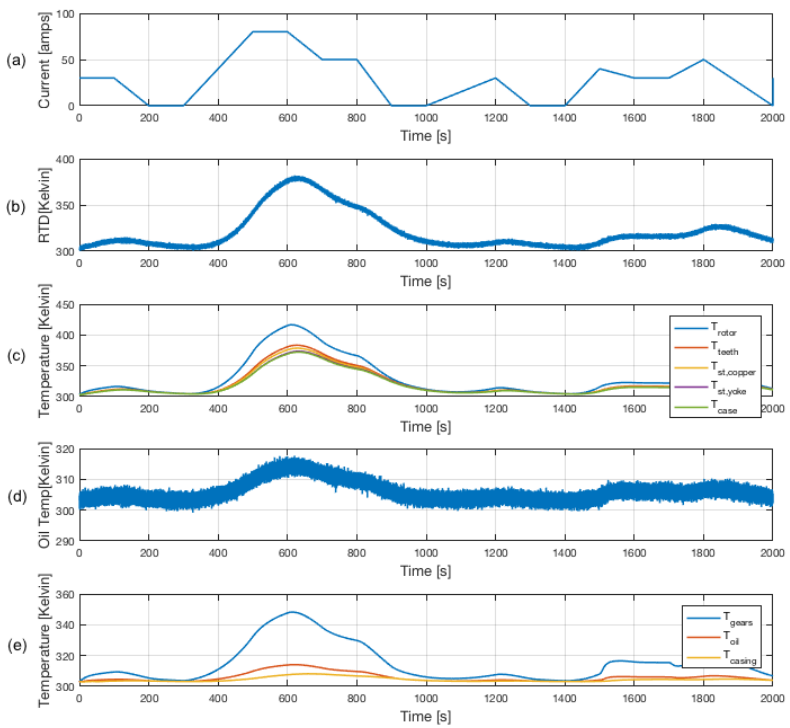
$$C_{oil}\frac{dT_{oil}}{dt} = \frac{1}{R_9}(T_{gears} - T_{oil}) - \frac{1}{R_{10}}(T_{oil} - T_{gearbox}) - P_{su}$$

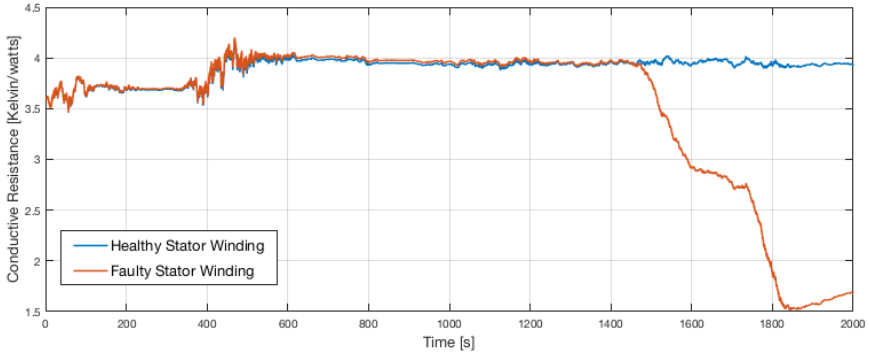
$$C_{gearbox}\frac{dT_{gearbox}}{dt} = \frac{1}{R_{10}}(T_{oil} - T_{geabox}) - \frac{1}{R_{11}}(T_{gearbox} - T_{amb})$$

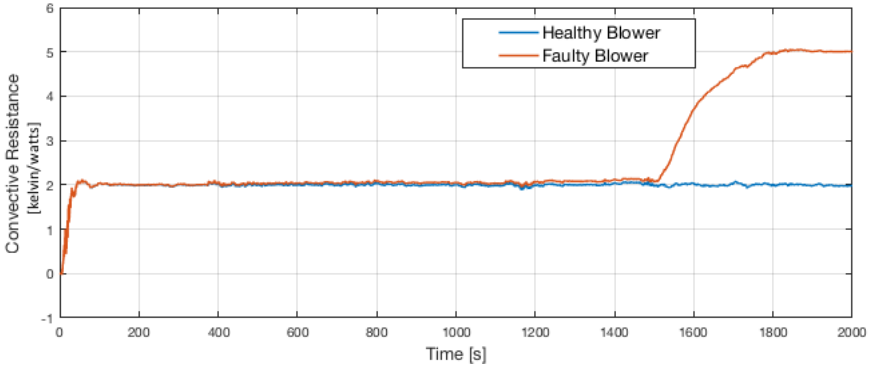




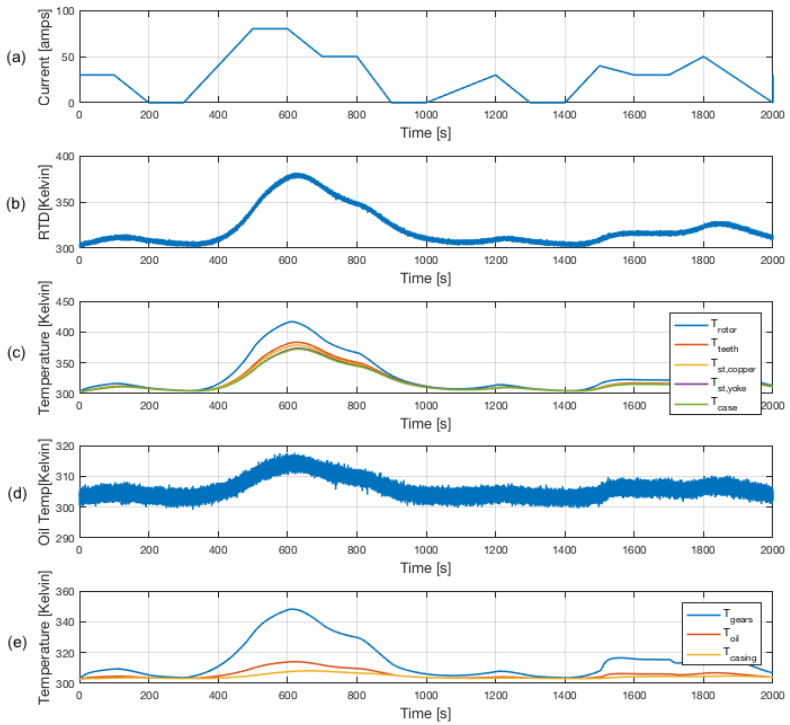
Results- Motor Faults

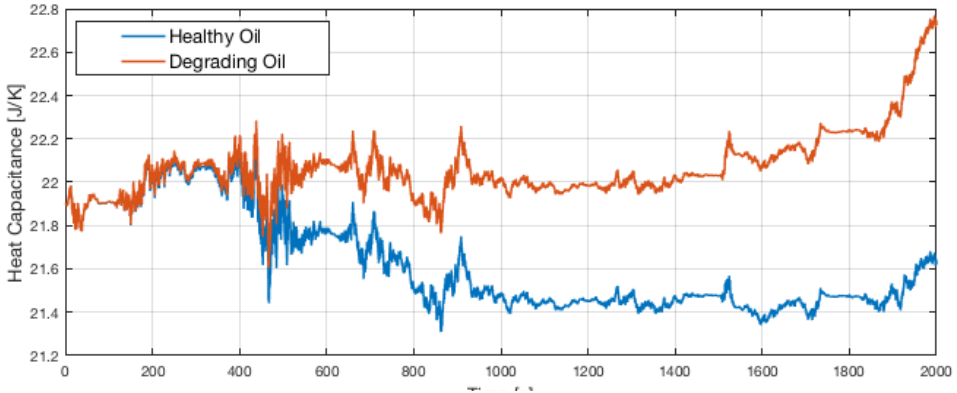


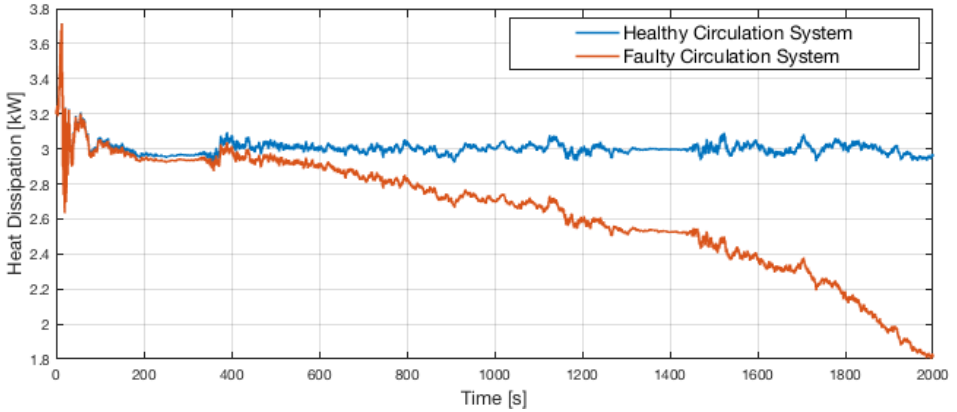




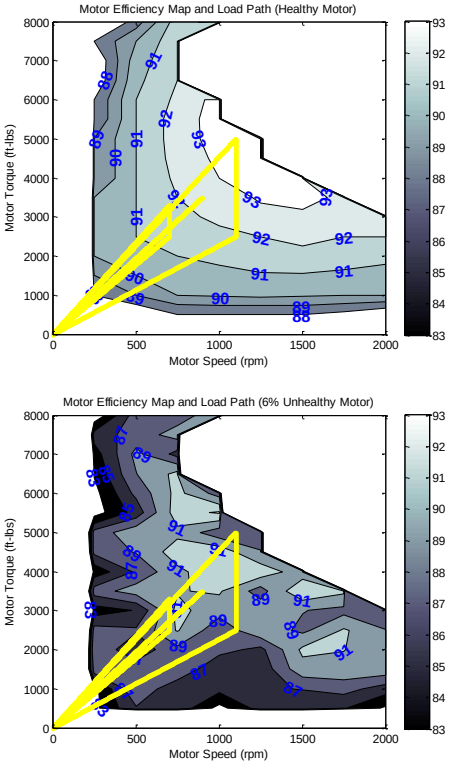
Results- Oil Degradation

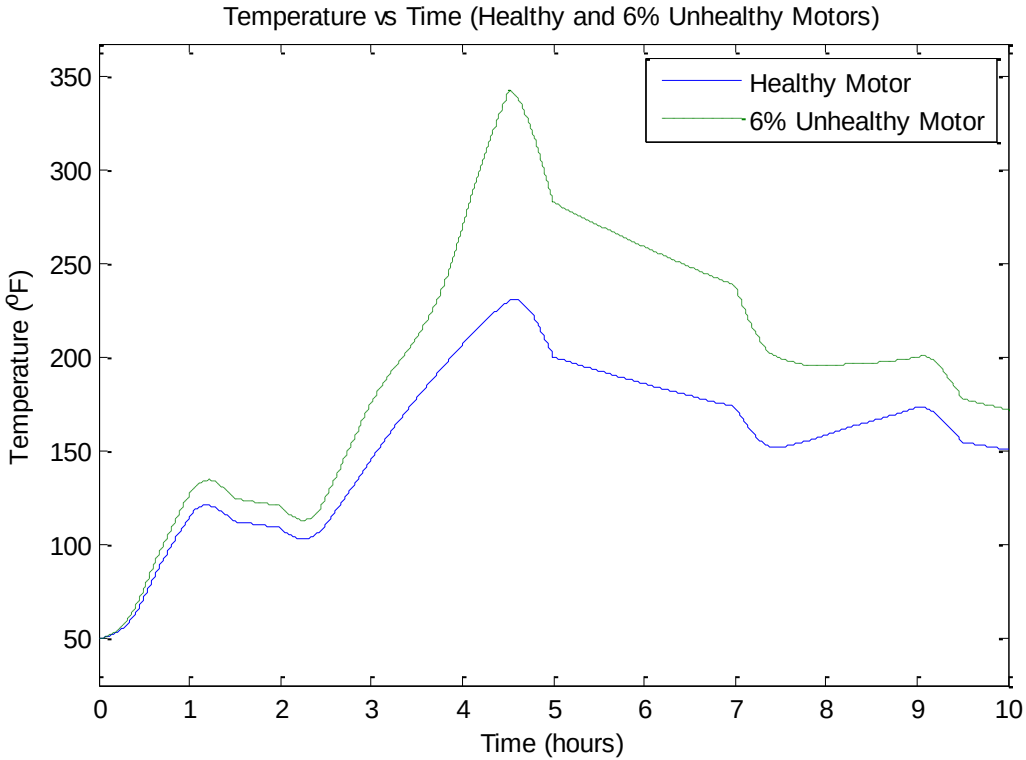






Performance Based Maintenance

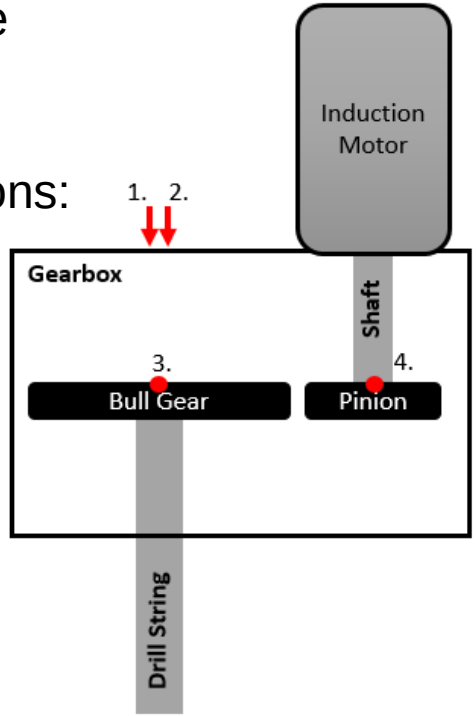




Top Drive Vibration Monitoring

- As a component or piece of a machine begins to fail, the vibrations emitted by that machine deviate from normal response.
- Various statistical measures to identify abnormal vibrations: RMS, crest factor, kurtosis factor
- Useful for bearing failures and gear failures

Number	Sensor Purpose	Sensitivity	Monitoring Time
1	High Shock Measurement	10 or 50 mV/g	Continuous
2	Thrust Bearing	100mV/g	Periodic
3	Gears (Bull and Pinion)	100mV/g	Periodic
4	Gears (Bull and Pinion)	100mV/g	Periodic



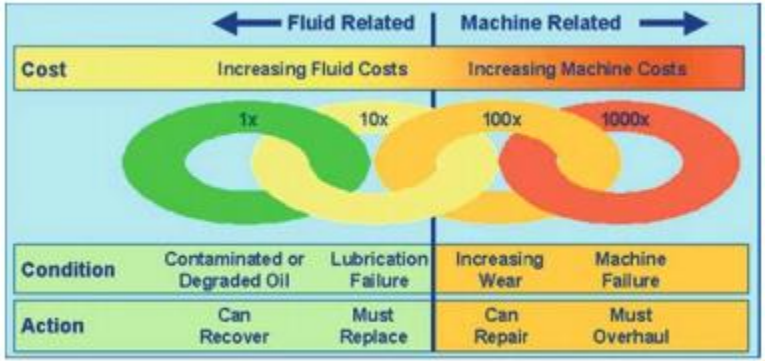
Top Drive Oil Monitoring

Goal is to:

- Optimize and extend oil drain intervals
- Forego catastrophic failures
- Reduce or eliminate unexpected downtime
- Extend the operating life of machinery

Sensors to use:

- Oil Quality Sensors
- Particle Count Sensors
- Wear Debris Sensors
- Fluid Properties Sensors
- Moisture and Humidity Sensors



Viscosity, Temperature, Dielectric Constant, Density and Conductance

Is There a Business Case for CBM ?

Average day rate for onshore drilling in the US → $120,000 per day

Nominal downtime due to top drive failure → 12 to 24 hours to get rig back up to running

- Cost of a single downtime $60,000 - $120,000
- Does not account for cost of replacement part / service professional

A top drive manufacturer outsourcing CBM to a third party

- Hardware fees in excess of $50,000
- Periodic system maintenance cost

In house development of CBM system

- Less than $15,000 for vibration, thermal, and oil sensors
- Engineering cost

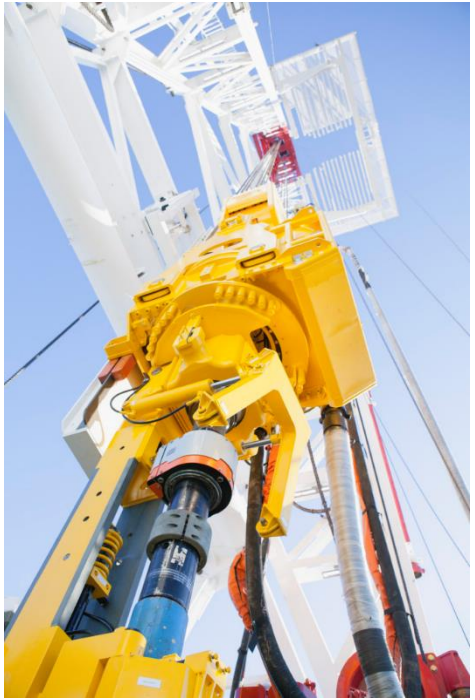
Cost can be recouped with one or two failure detections

Conclusions

- A detailed thermal model of the top drive system is developed to track system parameters to infer information about the health of various top drive components.
- Various available vibration sensors are discussed, and appropriate analysis tools are presented that allow the vibration analysis of top drives
- Off-the-shelf oil monitoring sensors are explored, and appropriate ones are selected for a preliminary oil monitoring analysis.
- With some ingenuity, everyone in the food chain can make money while creating real value.

Future Work

- Extensive testing of the thermal fault detection algorithm in the field to assess its ability in detecting various real system faults
- Testing and pattern analysis of the vibration sensor measurements, to identify the patterns that correspond to specific component faults.
- Development of an oil monitoring algorithm that will best suit the selected sensors and the most dominant oil degradation mechanisms.



Questions?