

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

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Introduction

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

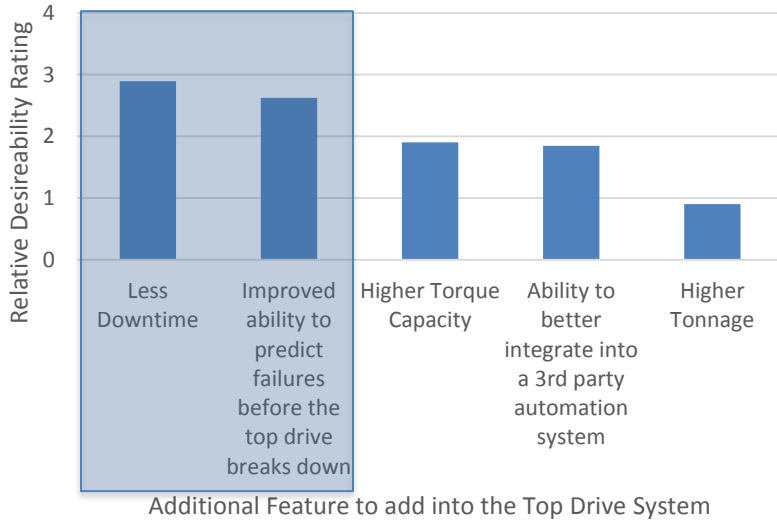
Consequences of a top drive failure:

- 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

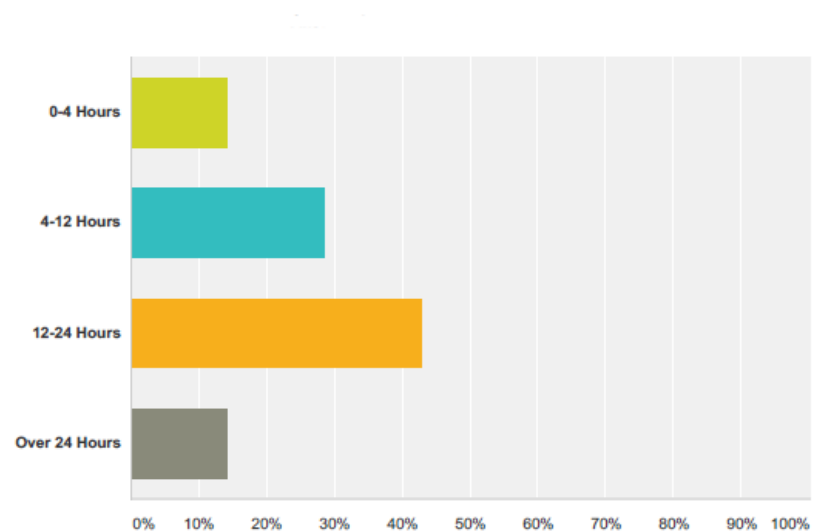


Customer Survey

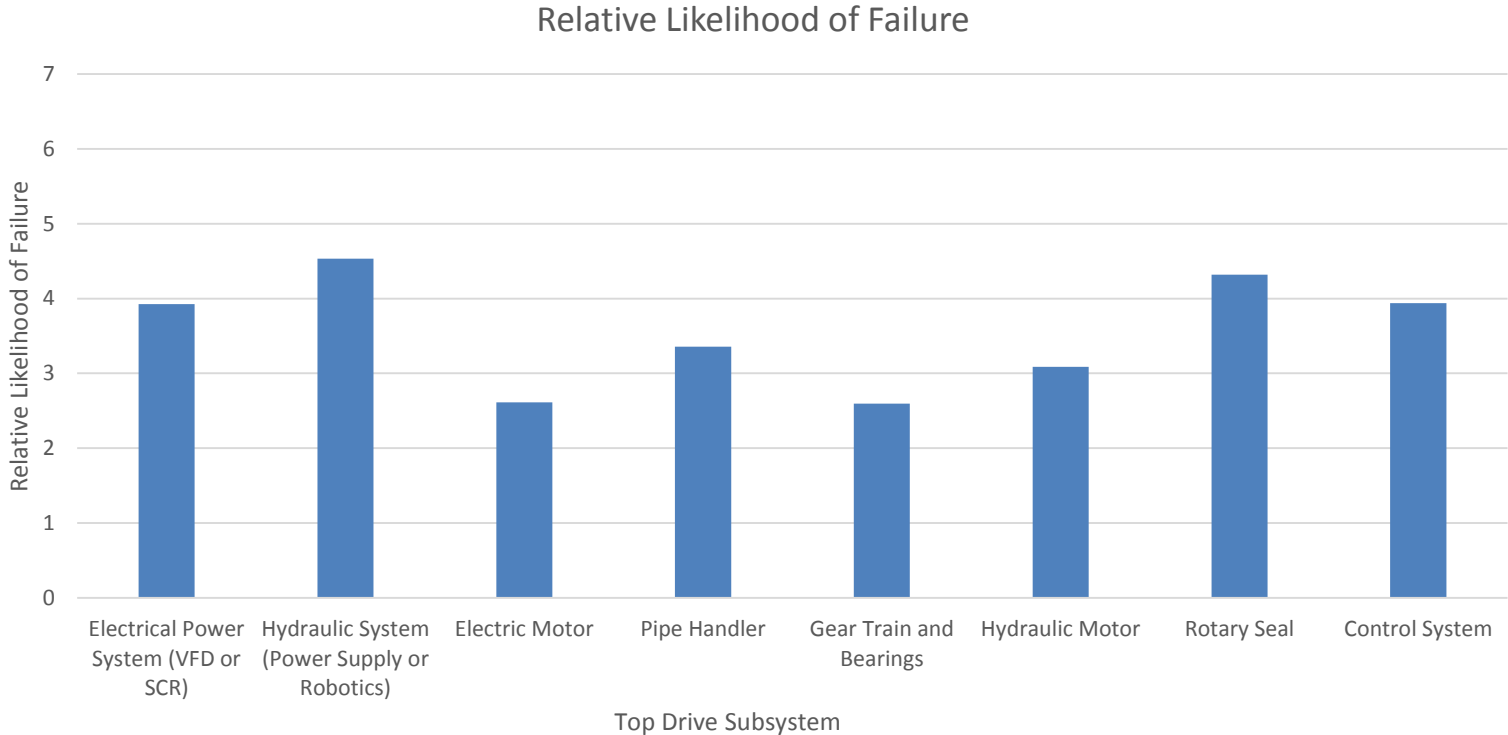
Relative Desire for Top Drive Features



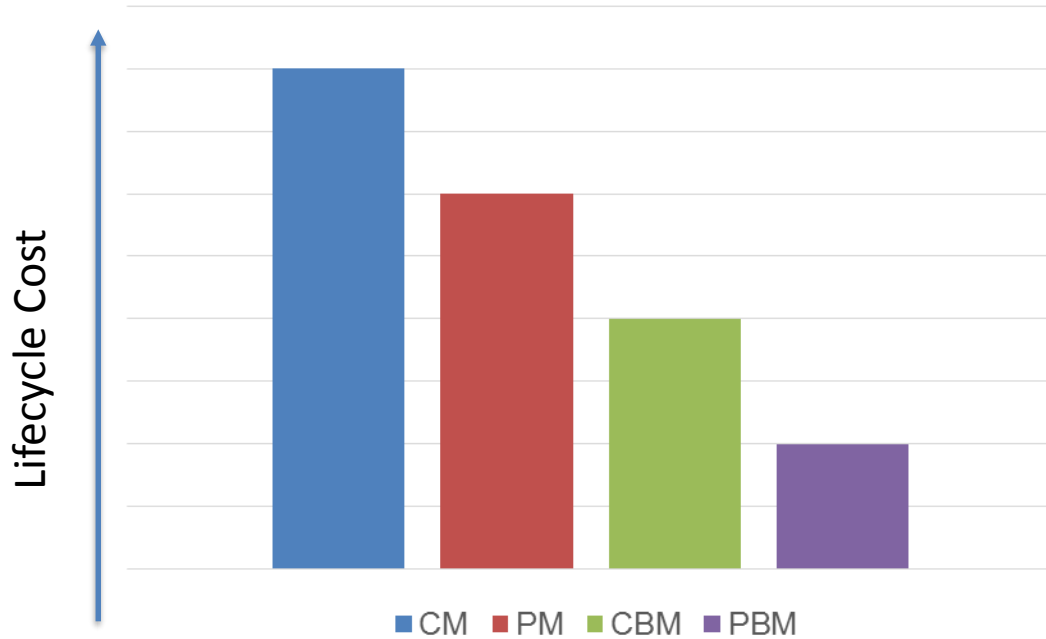
When you call for service on your top drive, how long is it until you are back up and running?



Different Problems on a Top Drive



Asset Management Strategy



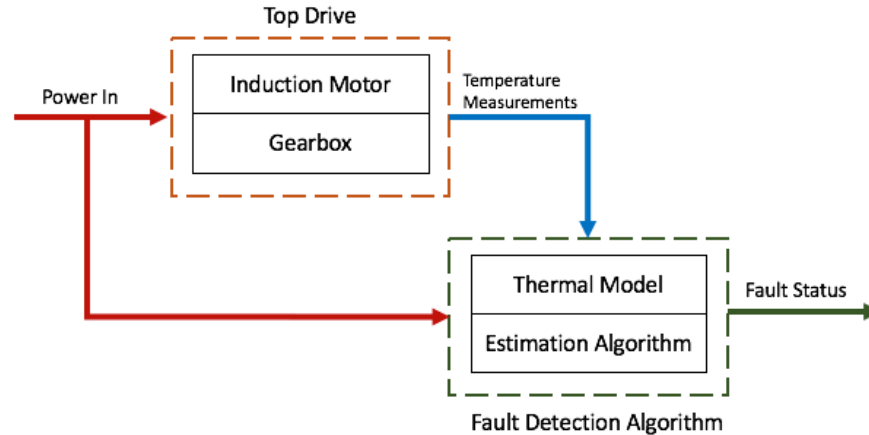
CM – Corrective Maintenance, PM – Preventive Maintenance
CBM – Condition-Based Maintenance, PBM – Performance-Based Maintenance

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

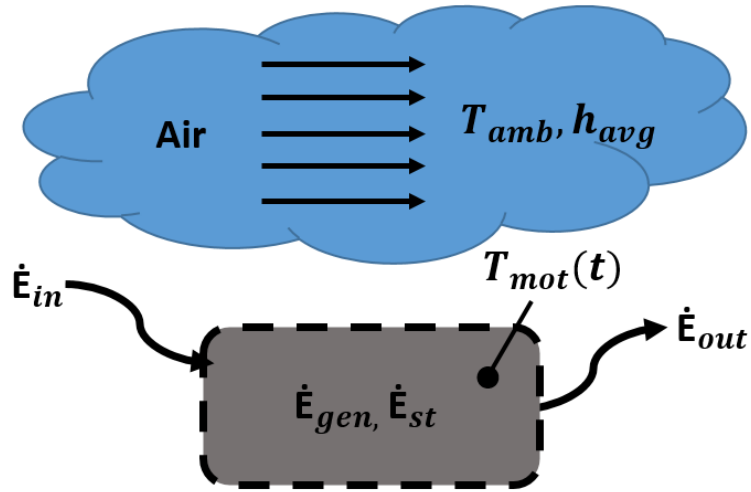
Thermal Modeling +
Vibrations Monitoring +
Oil Monitoring

Top Drive Thermal Monitoring

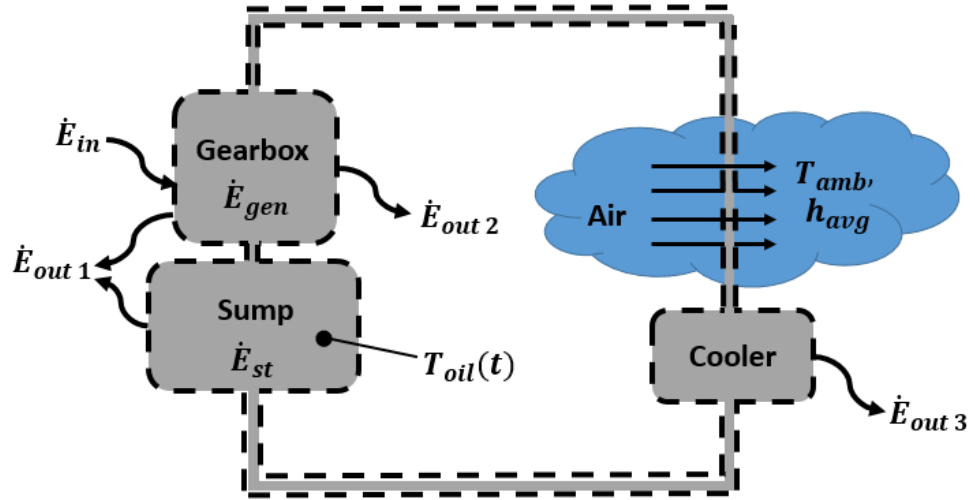
- Leverages temperature sensors already installed on most top drives :
 - Motor winding temperature sensors
 - Gearbox oil temperature sensors
- Estimation of model parameters from real-time temperature measurements
- Determine whether estimated parameters are “healthy”.



Physics Based Models



Electric Motor



Gearbox – Oil Sump

Induction Motor Thermal Model

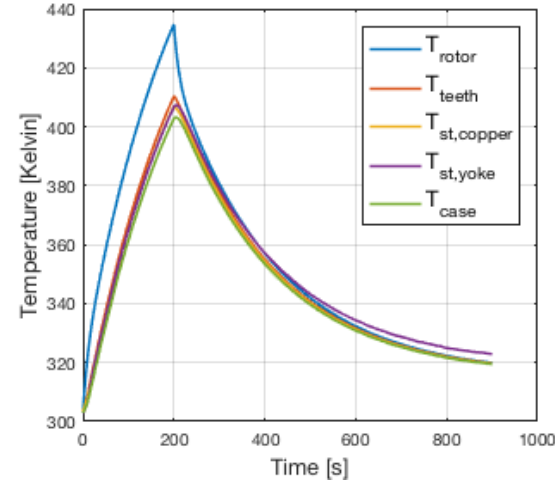
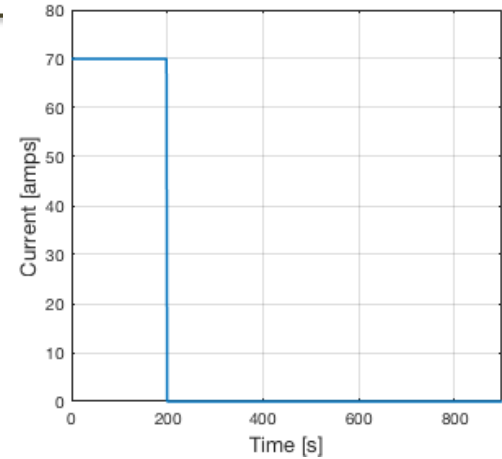
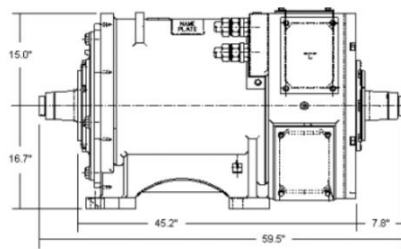
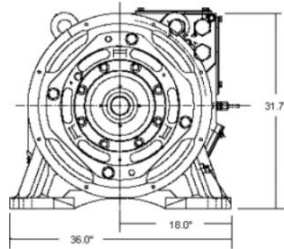
$$C_{rotor} \frac{dT_{rotor}}{dt} = P_{jr} - \frac{1}{R_1}(T_{rotor} - T_{case}) - \frac{1}{R_2}(T_{rotor} - T_{teeth})$$

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

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

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

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

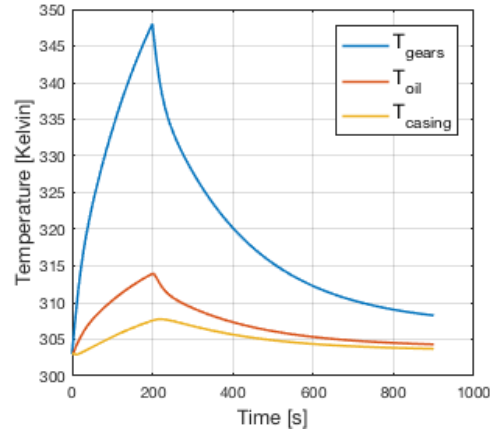
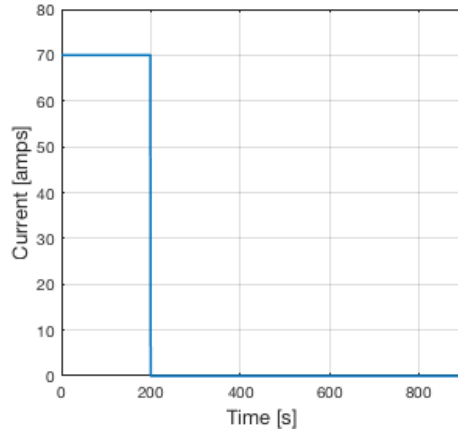


Gearbox – Oil Sump Thermal Model

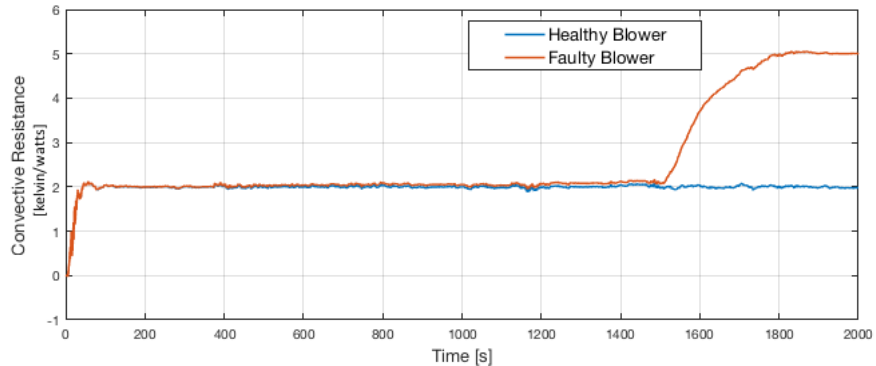
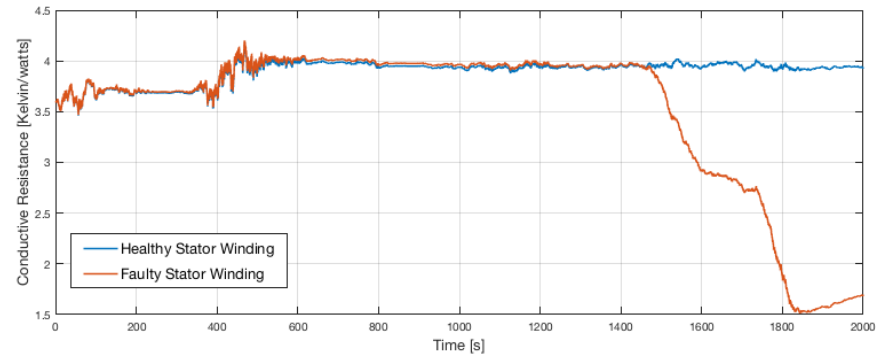
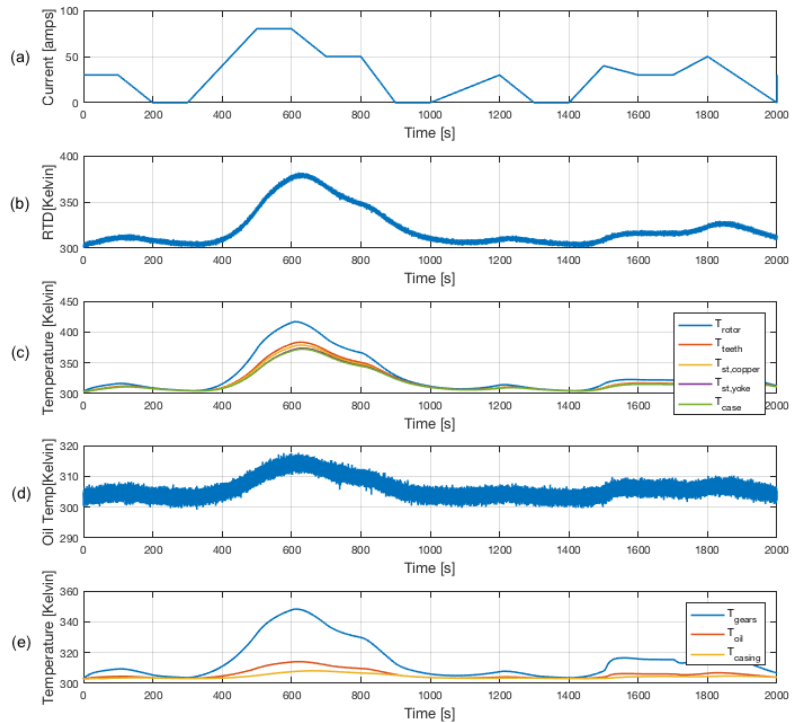
$$C_{gears} \frac{dT_{gears}}{dt} = \frac{1}{R_8} (T_{rotor} - T_{gears}) + P_{gb} - \frac{1}{R_9} (T_{gears} - T_{oil})$$

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

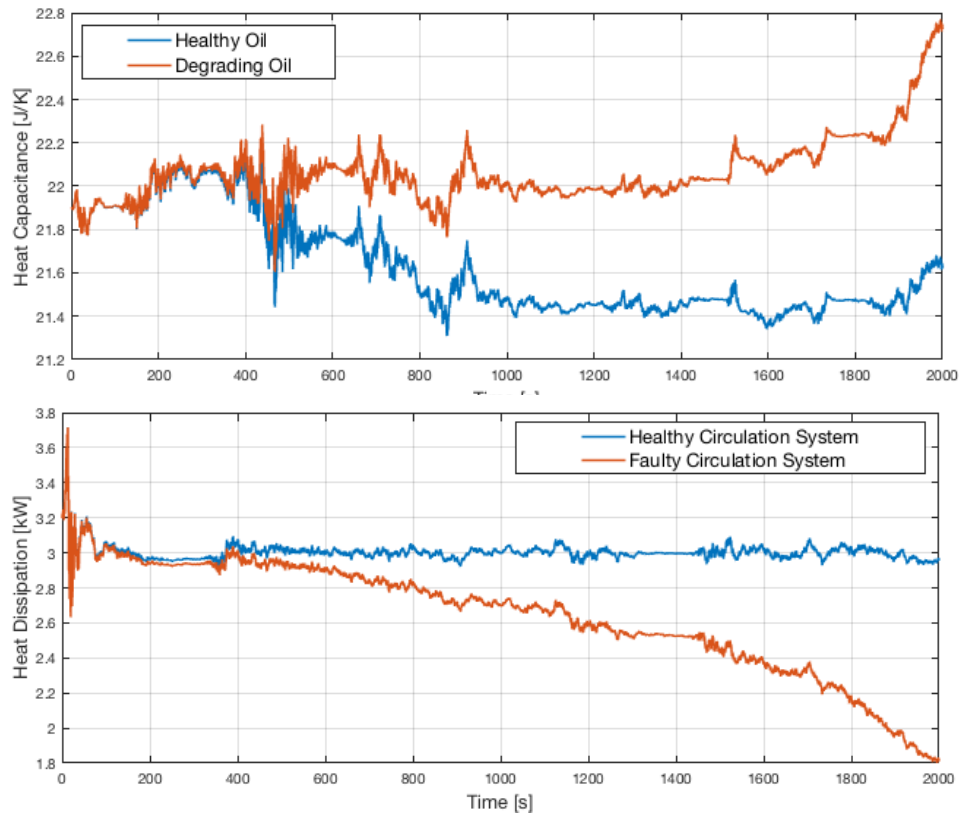
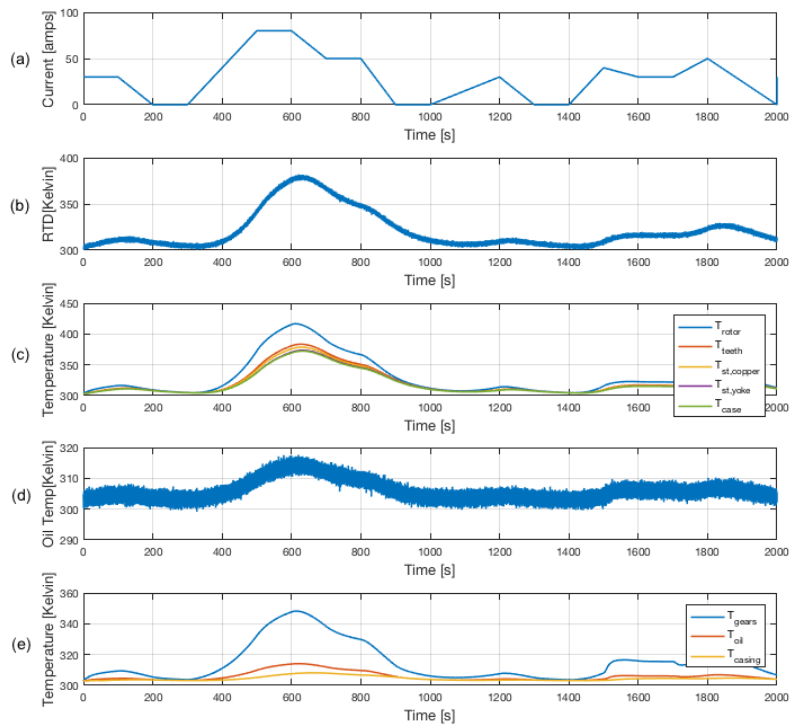
$$C_{gearbox} \frac{dT_{gearbox}}{dt} = \frac{1}{R_{10}} (T_{oil} - T_{gearbox}) - \frac{1}{R_{11}} (T_{gearbox} - T_{amb})$$



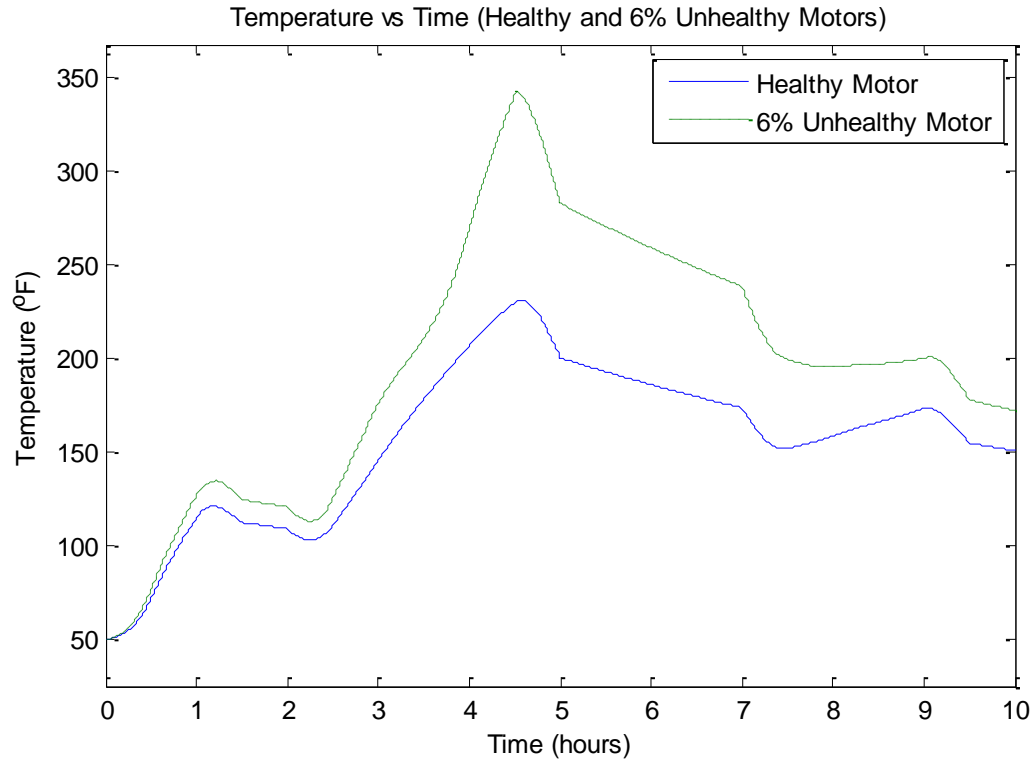
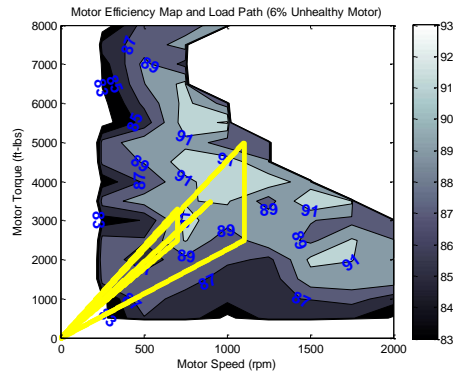
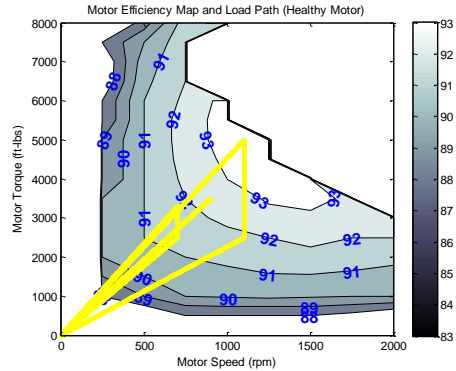
Results- Motor Faults



Results- Oil Degradation



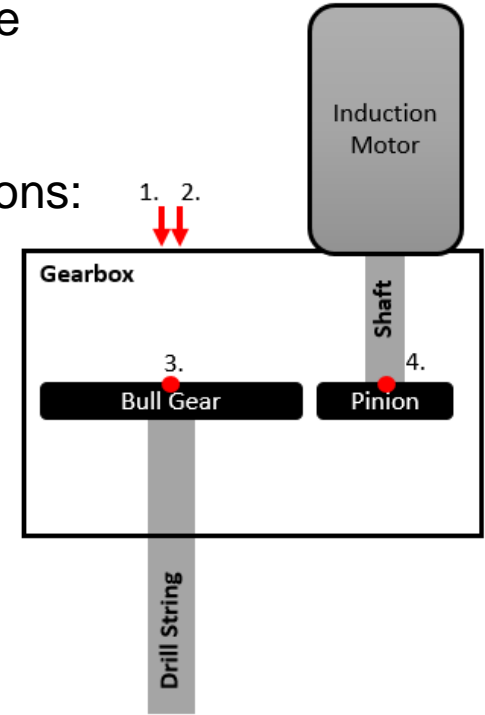
Performance Based Maintenance



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



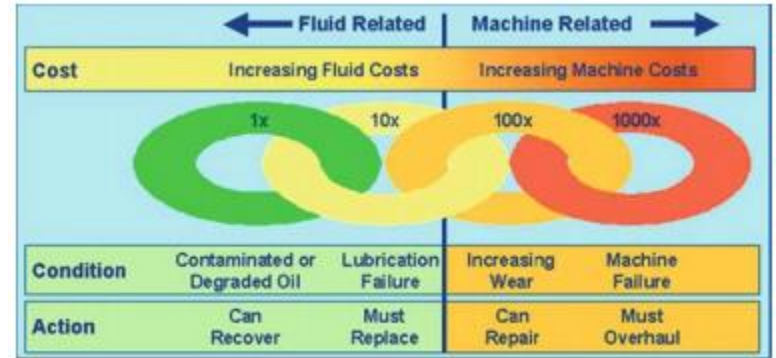
Top Drive Oil Monitoring

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?