Sequence IVA Driveline Torsional Dynamics Task Force

June 11, 2012 Meeting Minutes

1. Introduction

The attendees of this meeting are listed below:

Lubrizol – George Szappanos
Test Monitoring Center – Richard Grundza
Intertek Automotive Research – Al Lopez
Exxon Mobil – Mark Mosher

2. Scope of Task Force

To investigate how driveline torsional vibration affects camshaft wear

3. Driveline Effects on Dynamic Torsional Vibration on Sequence IVA Engine Stand

- Powerpoint attached.

4. Camshaft Wear as a Multiple Energy Domain System

- Powerpoint attached.

5. Group Discussion

- Al Lopez expressed interest in examining the hydrodynamic effect of oil on the generation the oil film on the cam lobes with respect to torsional vibration dynamics on the camshaft. This will require extensive instrumentation on the engine to measure the twist in the camshaft, crankshaft, and driveshaft simultaneously. This study is to be considered at a later date.
- Based on the variability of recent Sequence IVA reference test results, Richard Grundza suggests that the driveshaft can potentially "age" and shift the severity of the test.
- **Action Item no. 1:** Eric Liu will follow up with additional testing on the driveshaft used during the preliminary experiment. This driveshaft was used to reference Stand 54 during the last reference period. The goal is to detect if there are any measurable changes in torsional vibration dynamics in the driveline from one reference period to the next. Results will be presented at the next Task Force meeting.
- Mark Mosher suggests that other stands should be checked for the 4x synchronous vibration mode that was observed during the preliminary investigation on Stand 54 with the solid shaft installed.
- **Action Item no. 2:** Eric Liu will follow up with additional testing on other test stands to check for the presence of a 4x synchronous vibration mode. Results will be presented at the next Task Force meeting.

6. Next Meeting

- Mid-August 2012

End of Meeting

DRIVELINE EFFECTS ON DYNAMIC TORSIONAL VIBRATION ON SEQUENCE IVA ENGINE STAND

Eric Liu, Research Engineer

Southwest Research Institute

June 11, 2012

Background
Sequence IVA Test Severity Issues

- Engine lubricant testing labs unable to discriminate between a severe wear lubricant and a mild wear lubricant
- Unable to produce severe wear on cam lobes
- Severity Task Force formed in 2008-2009

Hypothesis

- Demonstration showed different driveline configurations allowed labs to regain discrimination in cam lobe wear
- **Driveline of different *stiffness* changed the *torsional vibration dynamics* of the test stand**
- ***Torsional vibration dynamics* have a direct effect on *cam lobe wear***

Objective

- To quantify differences in torsional vibration dynamics in the engine test stand system between drivelines of different stiffnesses

Solid Shaft

Damped Shaft

Experimental Setup

Measuring Driveshaft Twist

Flywheel

120 teeth

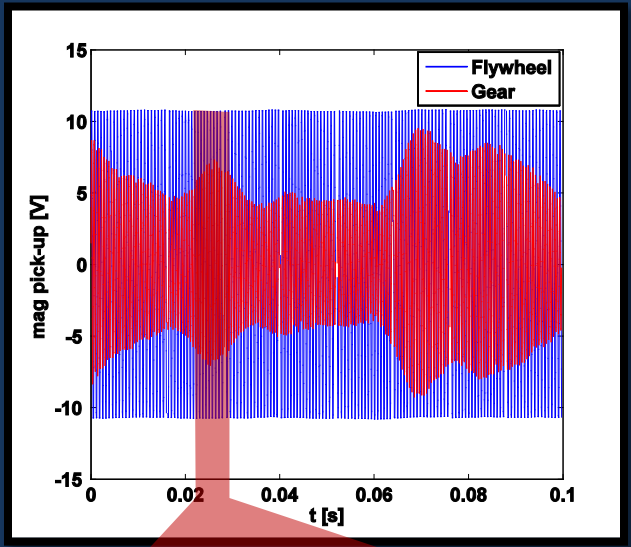
0.0524 rad/tooth

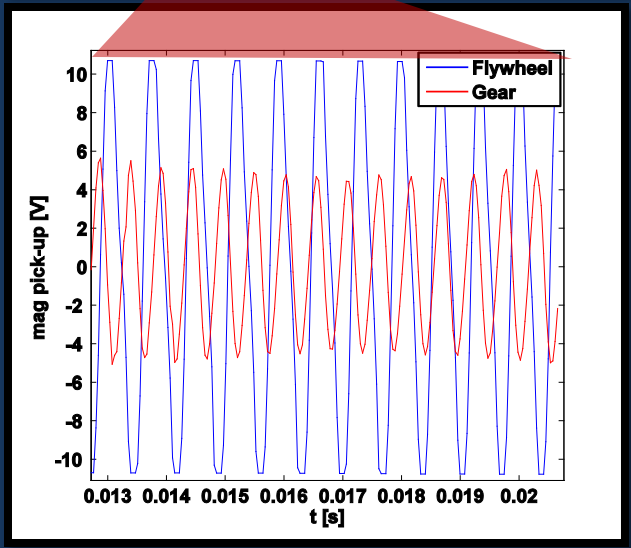
Dyno-Side Gear

160 teeth

0.0393 rad/tooth

Raw Data Generated





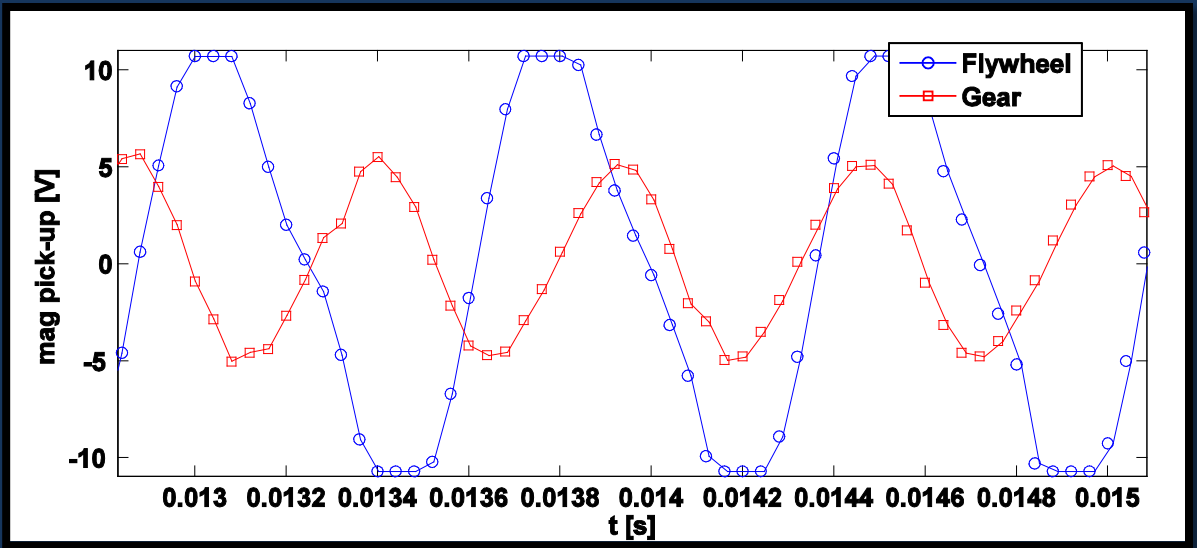
NI myDAQ

Sample rate: 25 kHz

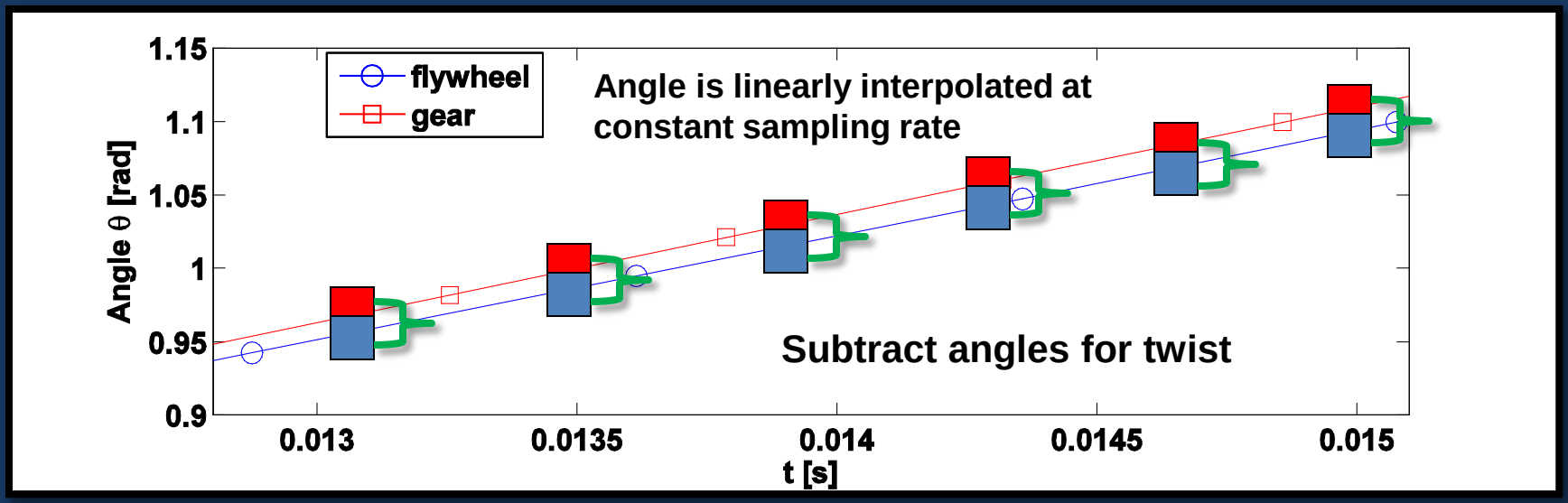
No. of points sampled: 2500

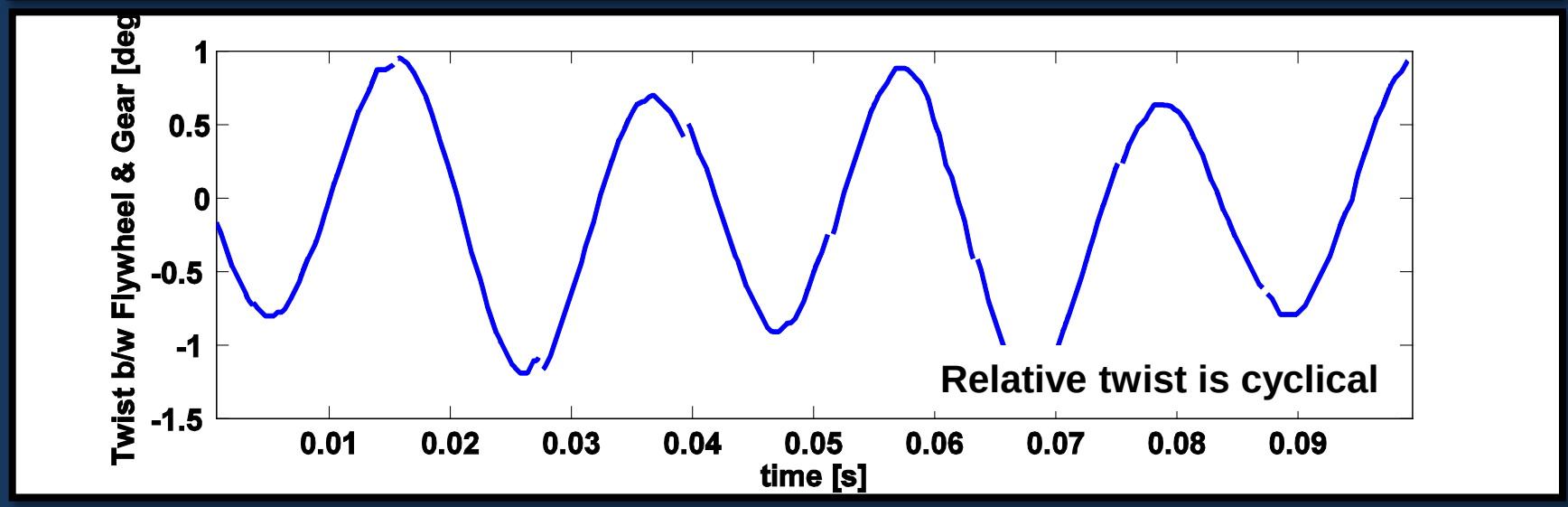
Total sample time: 0.1 sec

Each oscillation represents a tooth pass on the gears

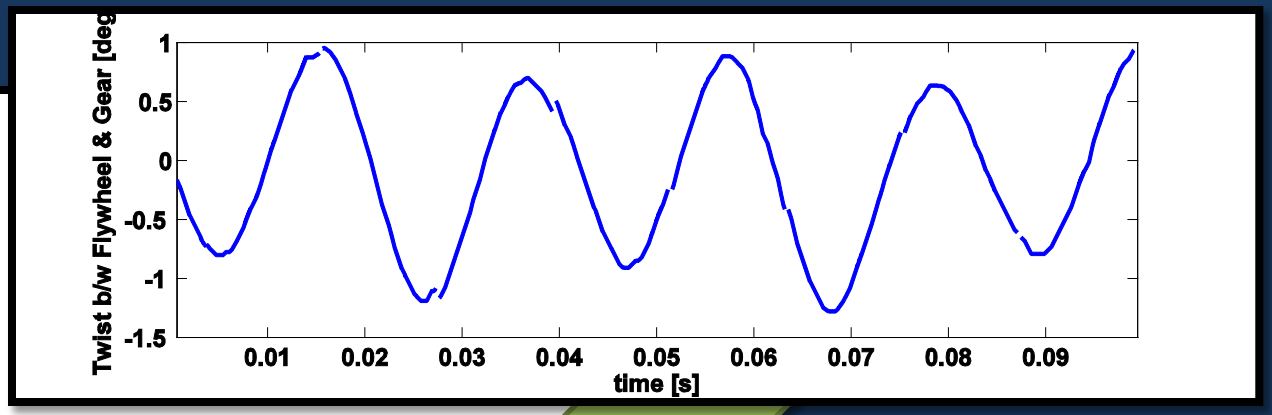


Evaluating Driveshaft Twist Angle

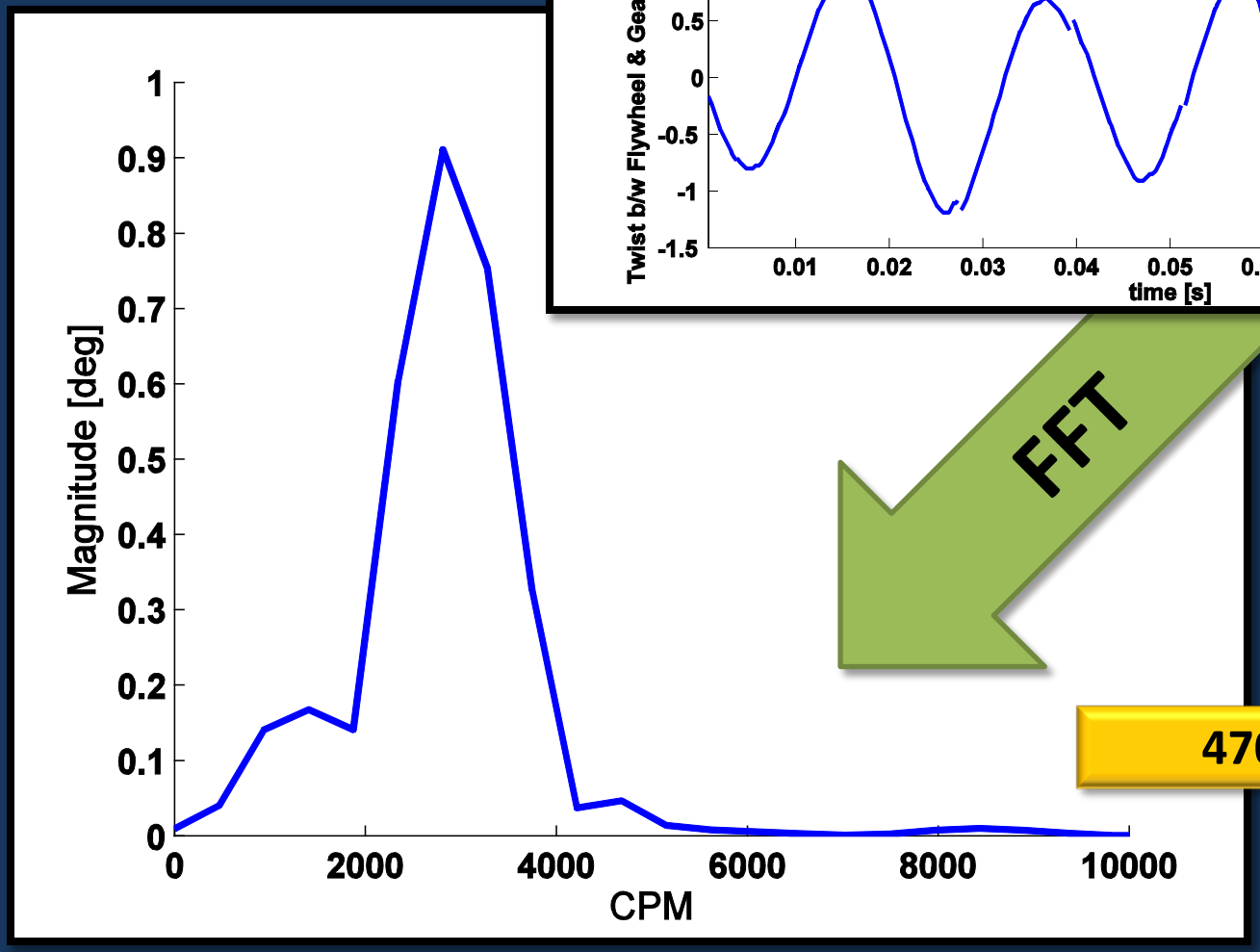




Extracting Frequency Content

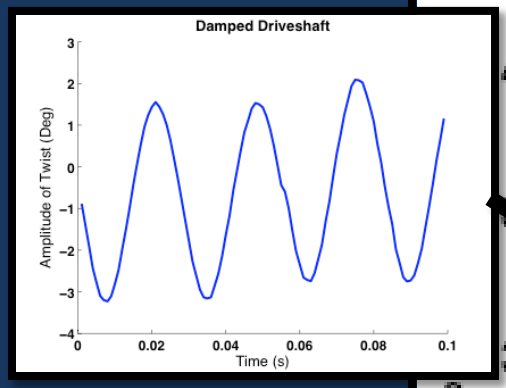


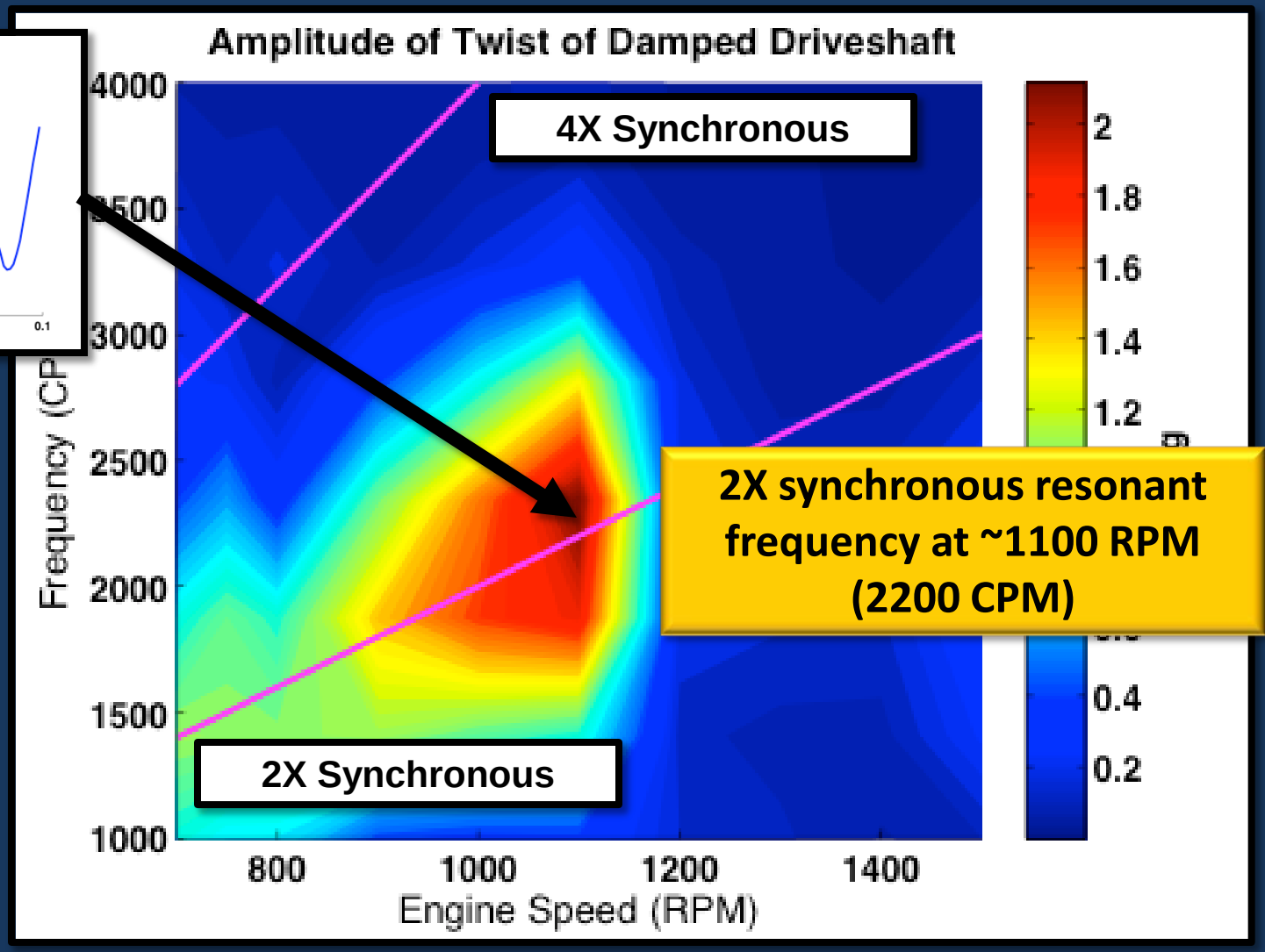
FFT



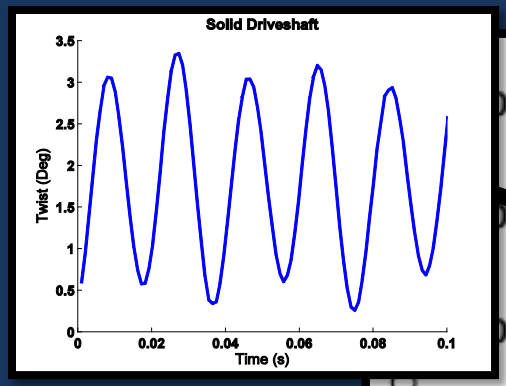
470 CPM Bin Width

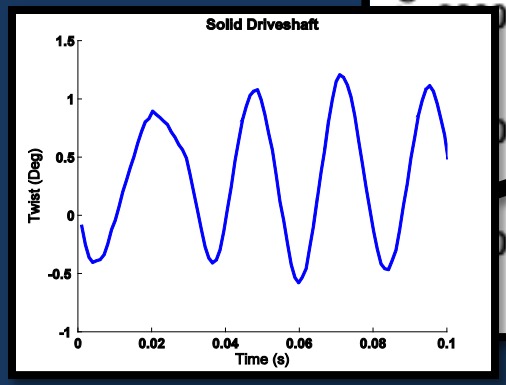
Spectrograph of Damped Shaft Twist Angle Amplitude

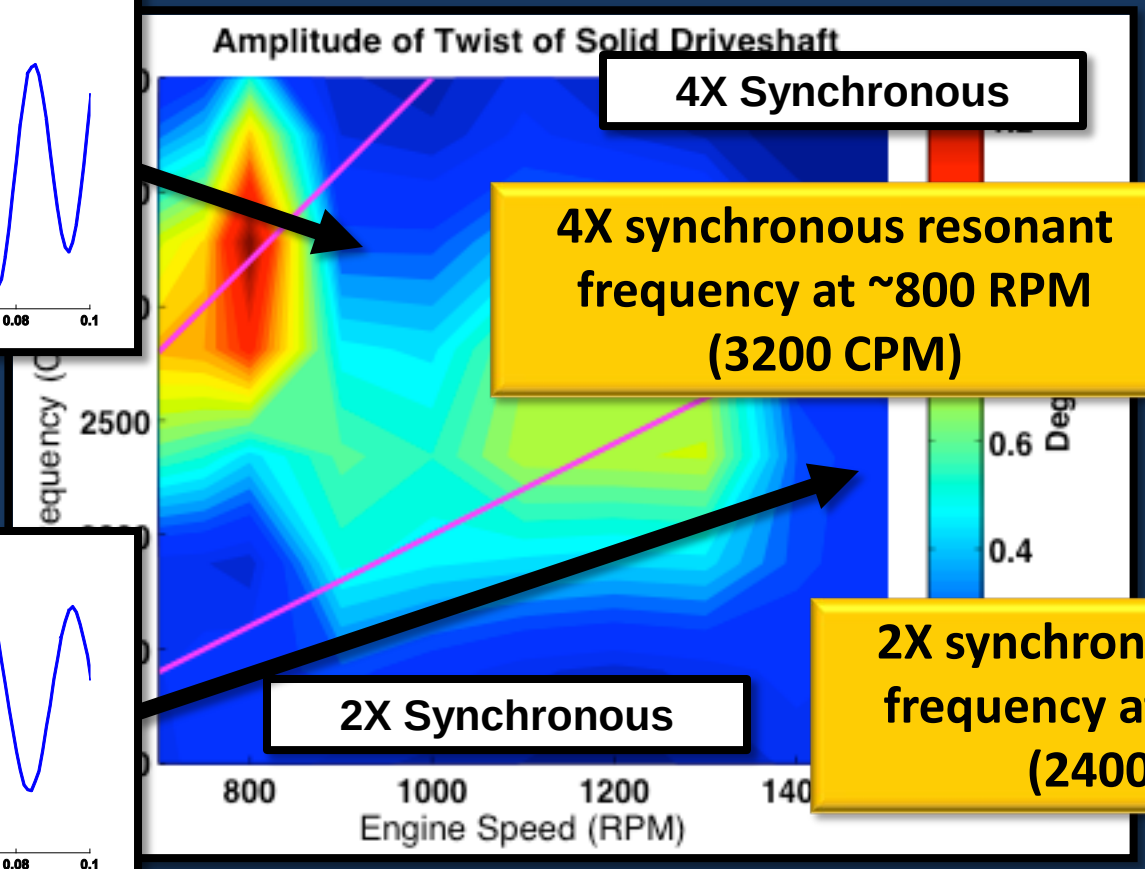




Spectrograph of Solid Shaft Twist Angle Amplitude







4X Synchronous

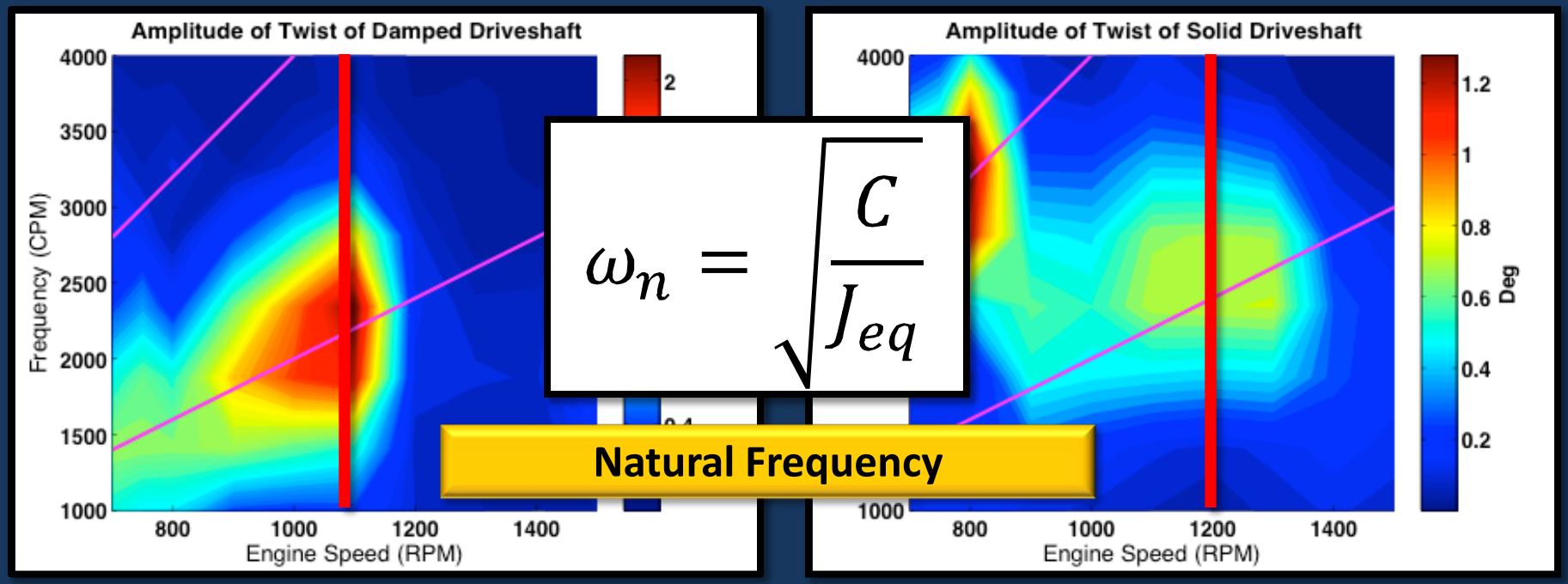
4X synchronous resonant frequency at ~800 RPM (3200 CPM)

2X Synchronous

2X synchronous resonant frequency at ~1200 RPM (2400 CPM)

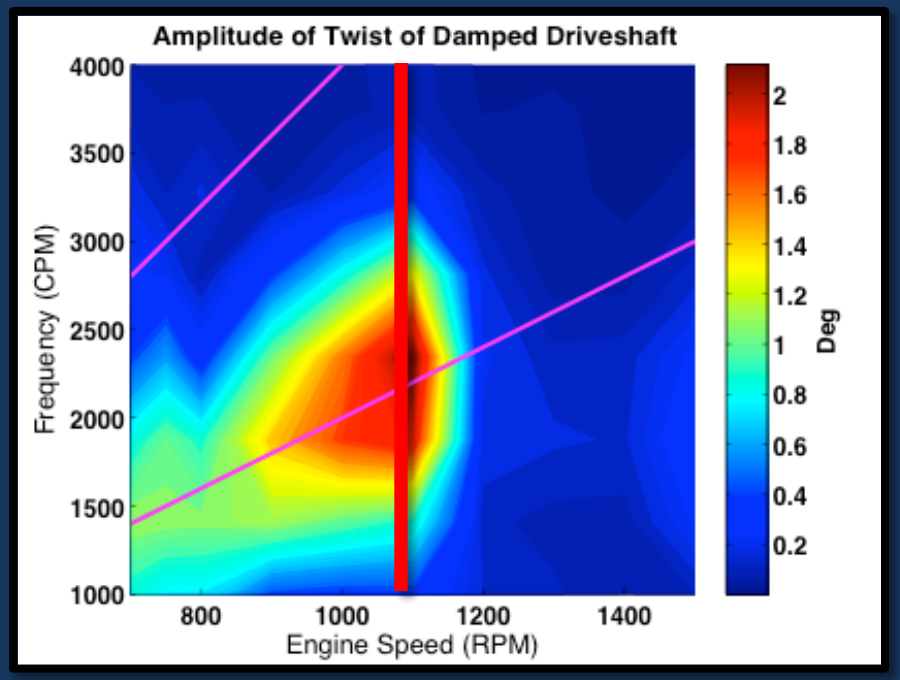
Discussion

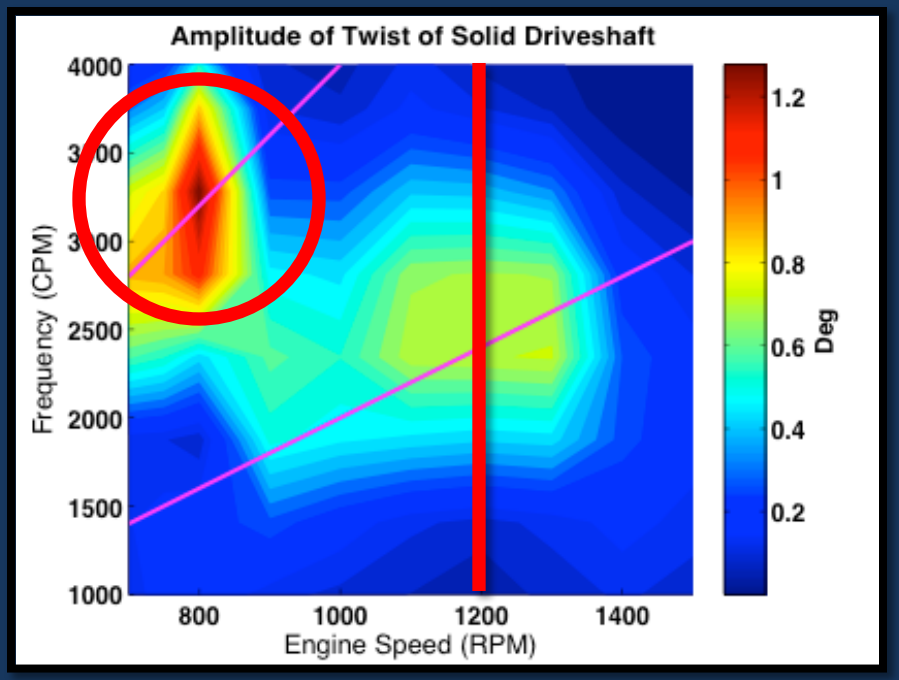
- Resonant frequency along 2x synchronous mode shifted to higher frequency for the stiffer shaft (solid)



Discussion

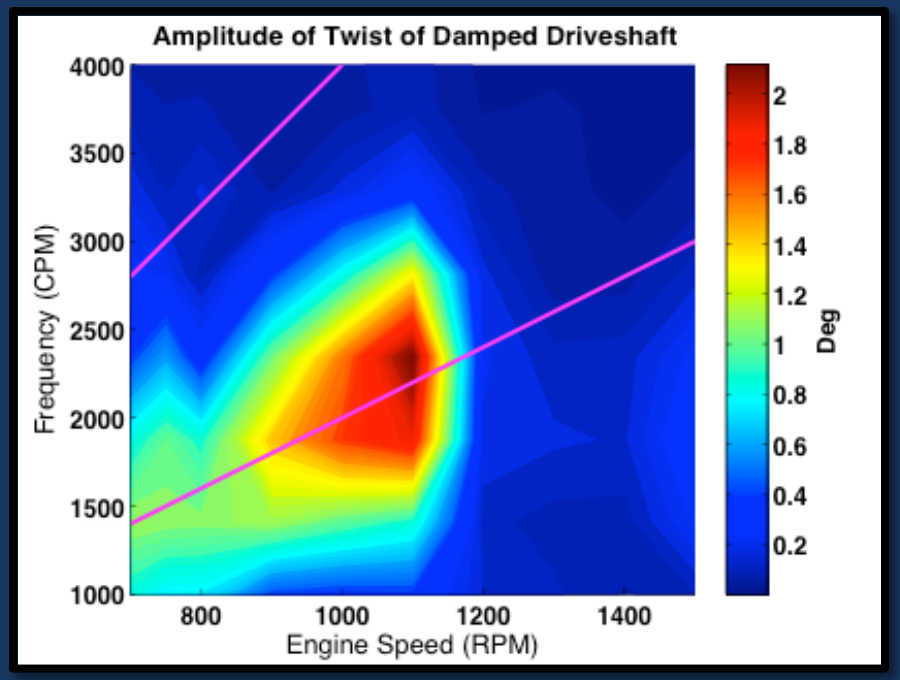
- Resonant frequency along 2x synchronous mode shifted to higher frequency for the stiffer shaft (solid)
- 4x synchronous mode resonant frequency detected in system with solid shaft

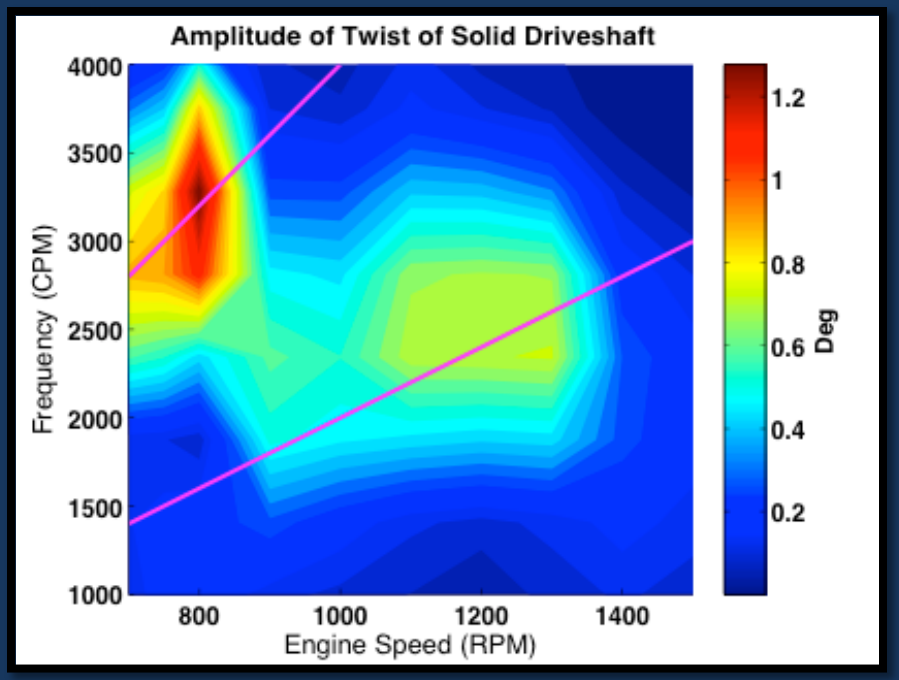




Discussion

- 2x synchronous mode is in line with the engine firing sequence
- ***How can we explain the 4x synchronous mode in the solid shaft?***





Conclusions

- **Driveline of different *stiffness* changed the *torsional vibration dynamics* of the test stand**
  - 2x and 4x synchronous modes present in system
  - Different resonant frequencies detected on both 2x and 4x synchronous modes

Recommendations

- Develop a method to measure driveline stiffness
- Data acquisition equipment
  - Sample rate at least 25 kHz
  - Sample time must be longer
- Further investigation of the 4x synchronous mode in system with solid shaft

Acknowledgments

- Daniel Sparkman – Project Partner
- Jose Garza – Project Partner
- David Ransom – Mentor
- Dr. Sean Tavares – Mentor
- Chris Peyton – Technical Support

Questions

Thanks for listening in

CAMSHAFT WEAR AS A MULTIPLE ENERGY DOMAIN SYSTEM

Eric Liu, Research Engineer

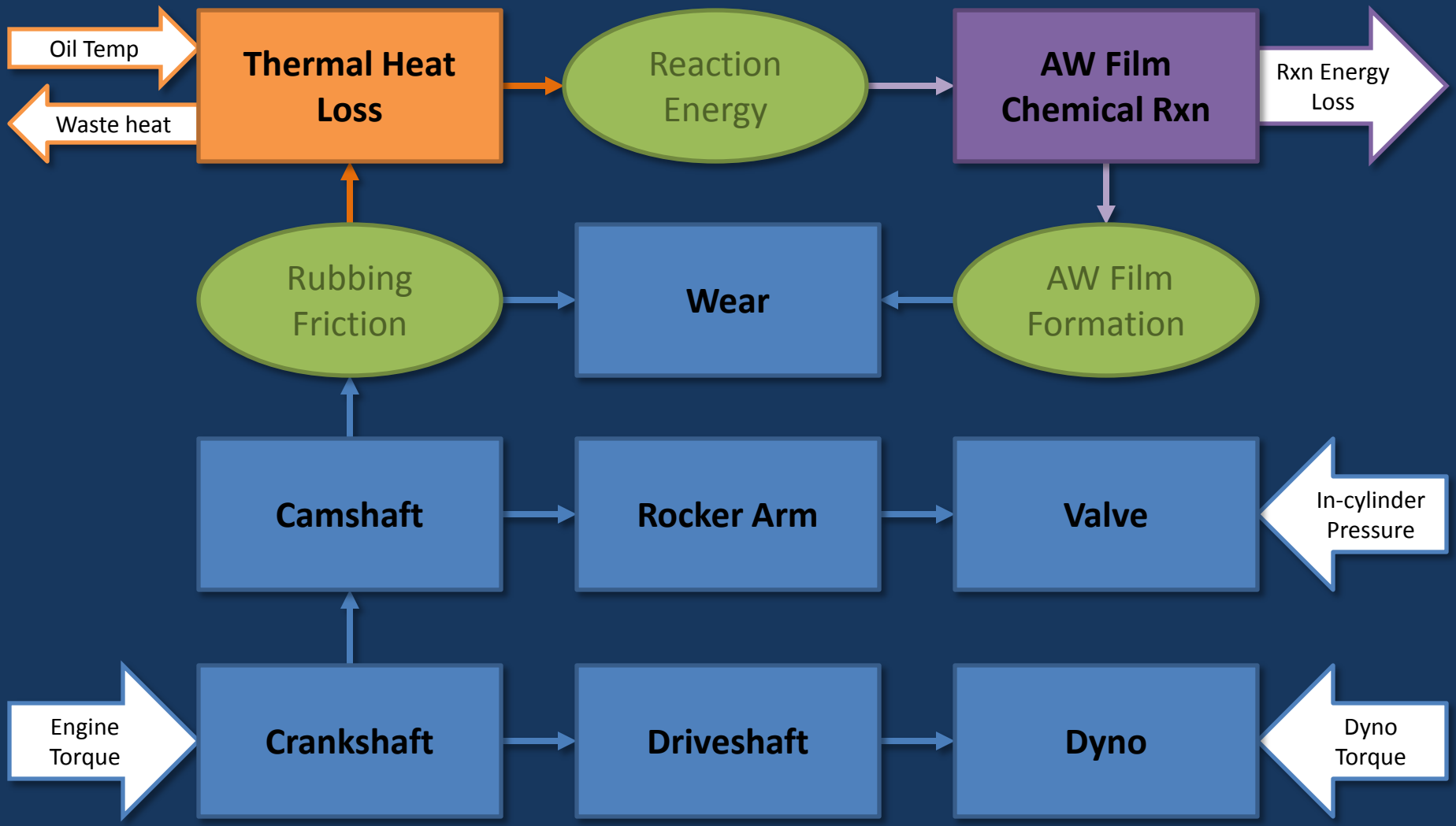
Southwest Research Institute

June 11, 2012

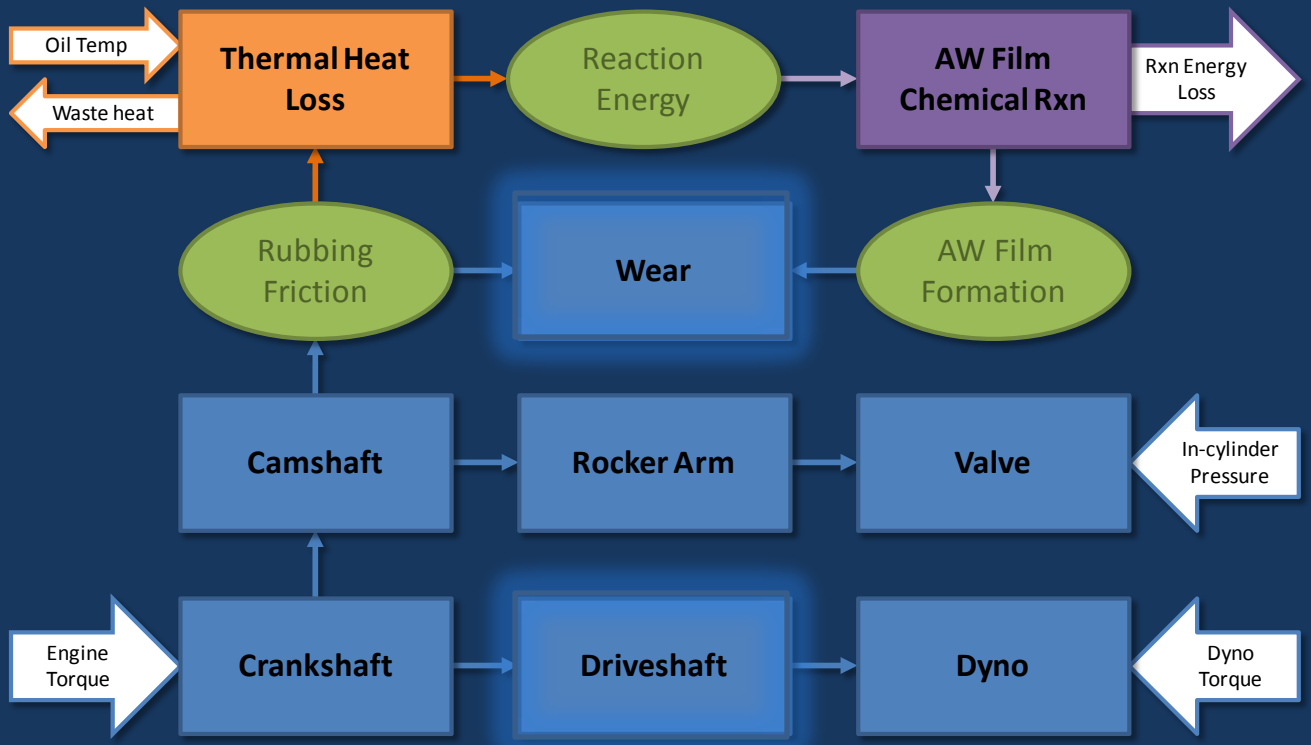
Hypothesis

- Driveline of different *stiffness* changed the *torsional vibration dynamics* of the test stand
- ***Torsional vibration dynamics*** **have a direct effect on** ***cam lobe wear***

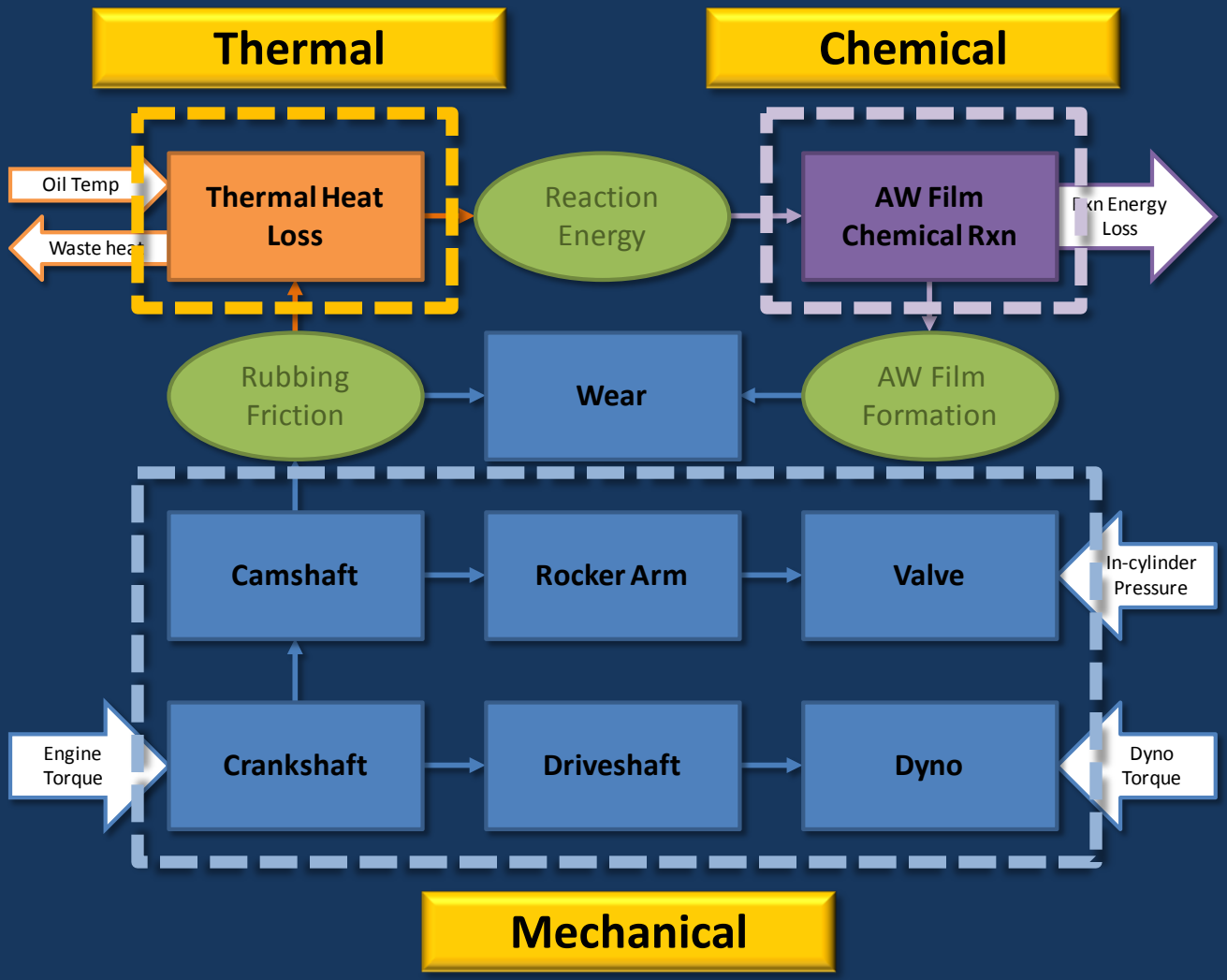
Energy Flow from Engine to Antiwear Film



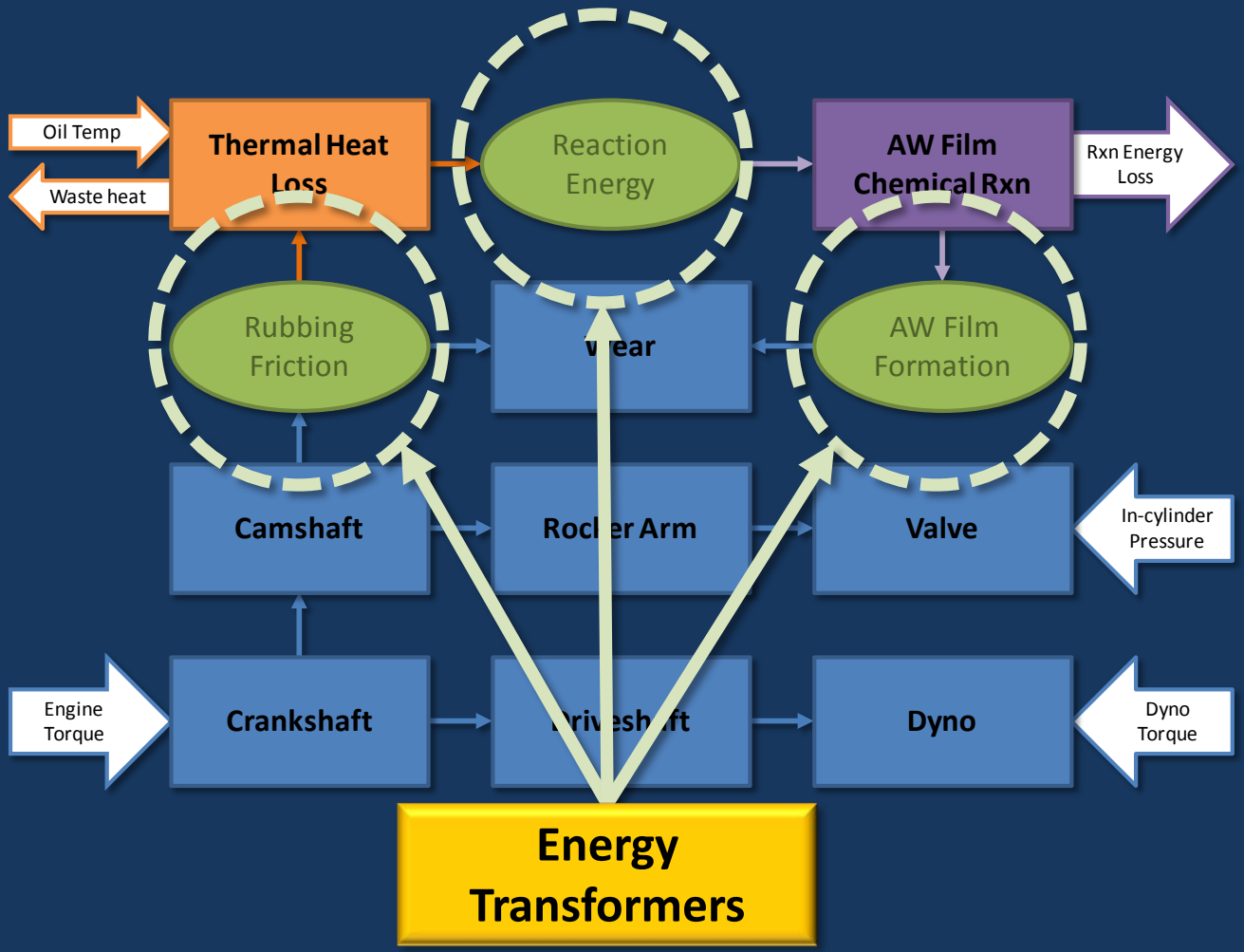
Areas in Question



Energy Domains



Energy Transformers



Points to Consider

- System describing camshaft wear is a ***system with multiple energy domains***
- Torsional vibration dynamics caused by the driveline ***indirectly affects camshaft wear through non-mechanical energy domains***
  - Camshaft wear ***may NOT be a purely mechanical phenomenon***
  - Chemical and thermal domains may need to be considered in our analyses

Questions

Thanks for listening in