An integrated surface technology for friction reduction in vehicles

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Proj ID
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Overview

Timeline

- Start April 1, 2007
- Ends Nov 15, 2010
- 70% complete

Budget

- Total=$436.5
- FY08=$165K
- FY09=$198K

Enabling technology to achieve fuel economy

- Cost
- Lack of design guideline
- High load

Targets

- Low cost fabrication
- Works under high load
- Provide design guidelines

Partners

Caterpillar, Cummins, Ford, GM

Technology validation and testing

Objectives

- To demonstrate multi-scale texture patterns that can work across the speed and load ranges encountered in vehicles to achieve friction reduction of components
- Develop a coating system to protect the textures
- Develop relevant surface chemistry to protect the coating to ensure durability

Milestones

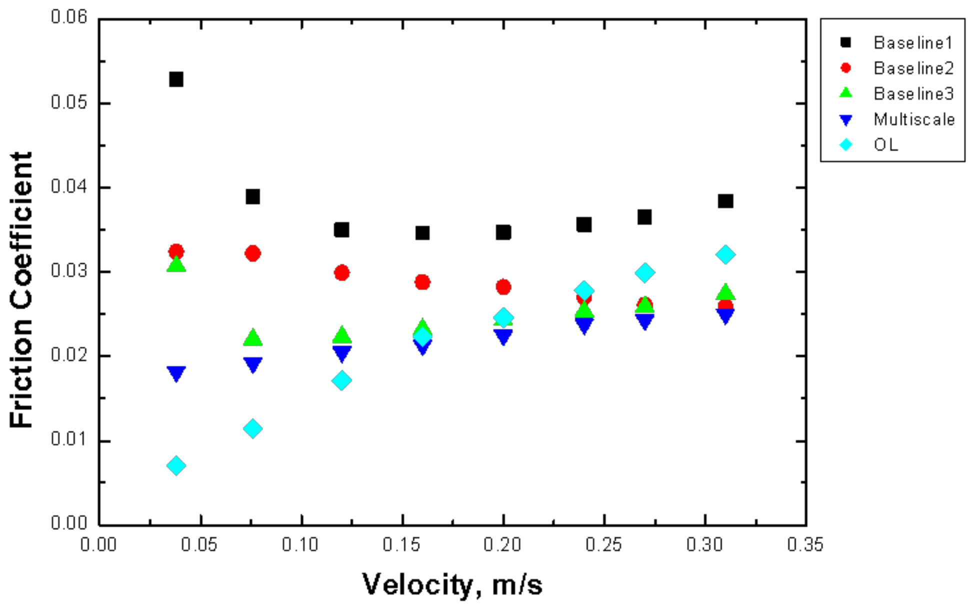
- FY 2008
  - ***Develop multi-scale surface textures that can function both in the low load high speed regime and high load low speed regime***
  - ***Develop thin film to protect textures***
  - ***Develop chemistry to work with thin films***
- *FY 2009*
  - *Develop model to explain why textures works*
  - *Develop a chemically bonded self-lubricated film on Diamond-like-Carbon (DLC) surfaces to provide engine component protection*
  - *Develop a high load mechanical scriber capable of texturing high chromium steel surfaces*

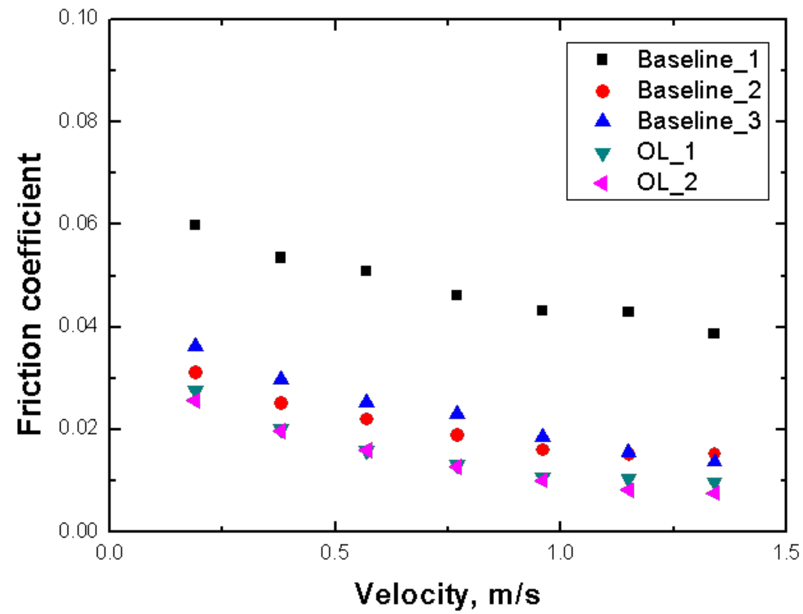
Approach

- Conduct theoretical analysis coupled with single texture in situ observation to observe fluid flow
- Conduct contact mechanics analysis to understand how hydrostatic pressure can build up within a texture to provide lift force to lower friction
- Fabricate textures of various size, shape, patterns
- Conduct friction tests under conditions encountered in engine components
- Select thin films and analyze failure mechanisms
- Select chemistry based on theoretical understanding
- Validate these selections by experiments

Accomplishment: FY 08 milestone 1

Multiscale texture demonstrated to work

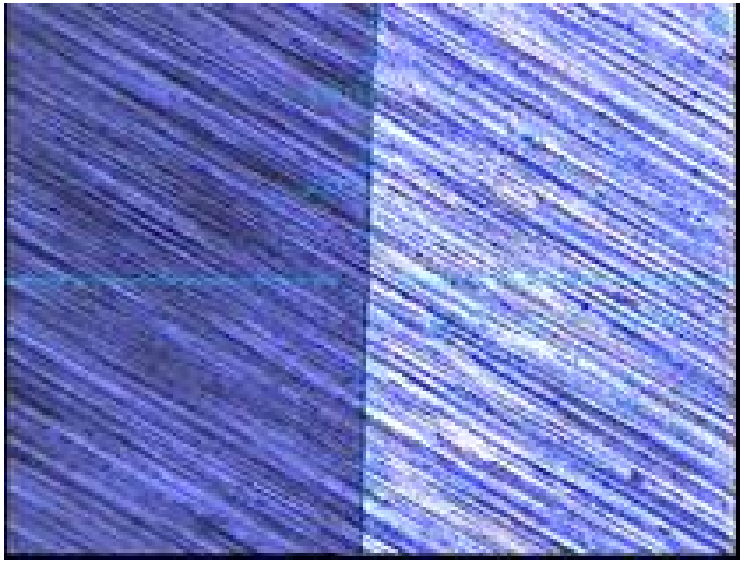




Friction reduction of mixed texture patterns under 0.15 MPa apparent contact pressure on Pin-on-disk tester

Comparison of the baselines with the compound texture patterns under high load low speed conditions (157 MPa apparent contact pressure) using a four ball tester.

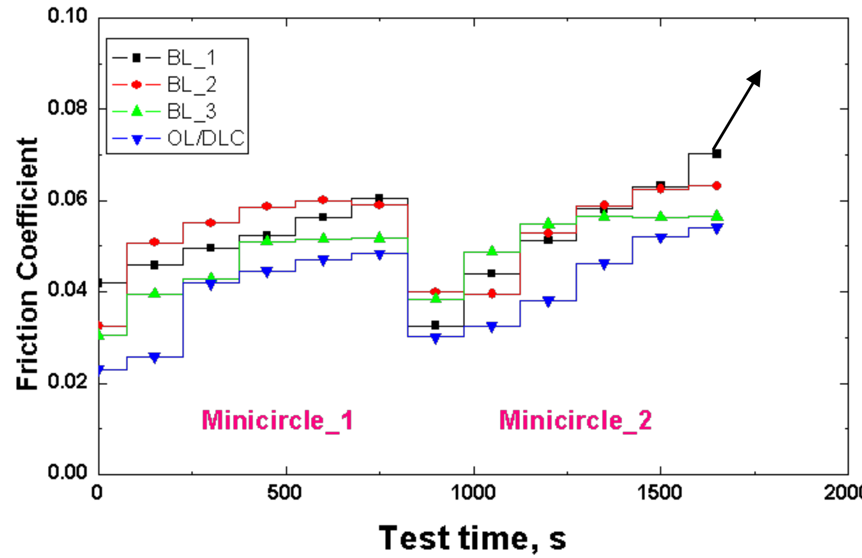
Evaluation of protective films



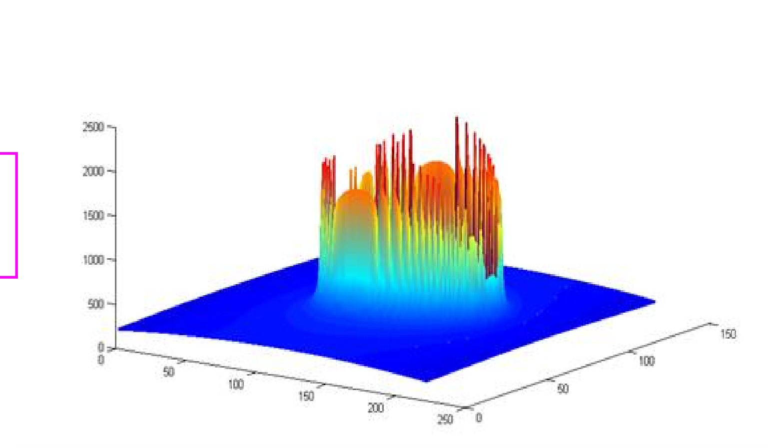
Coated DLC
90 nm19 GPa

Uncoated
side

Plastic deformation
induced fracture



Durability of film + textures



Edge stress around the dimple

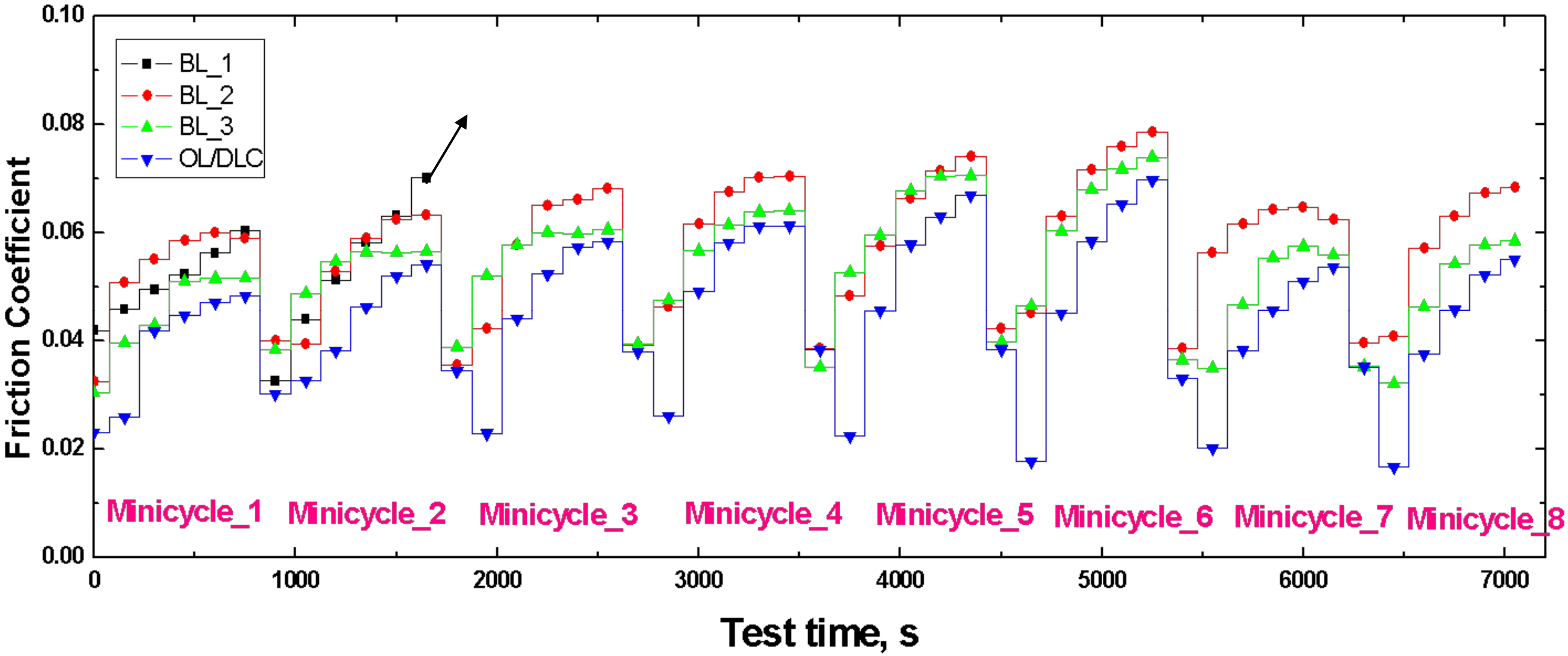
Coating selection

- Evaluated carbides, nitrides, of tungsten, and titanium
- Thick hard coatings crack upon loading
- Fractures at the edges the dominant failures
- Selection of thin DLC coatings
- Optimization of thickness, hardness, and adhesion characteristics

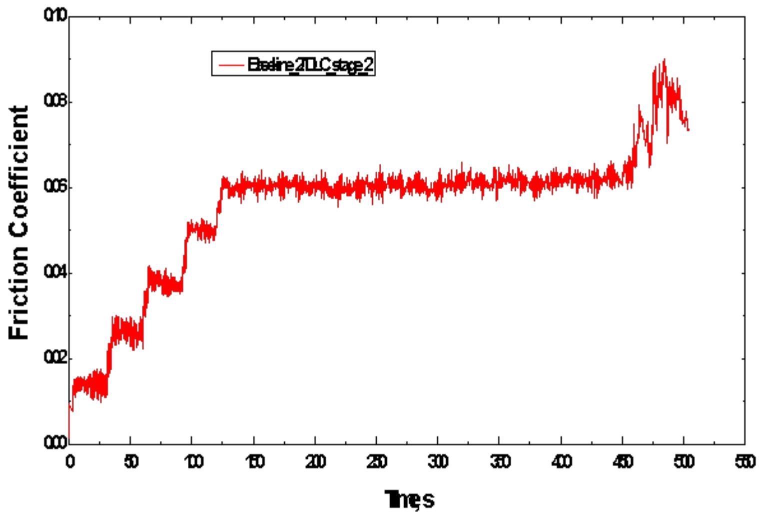
Selection of chemistries

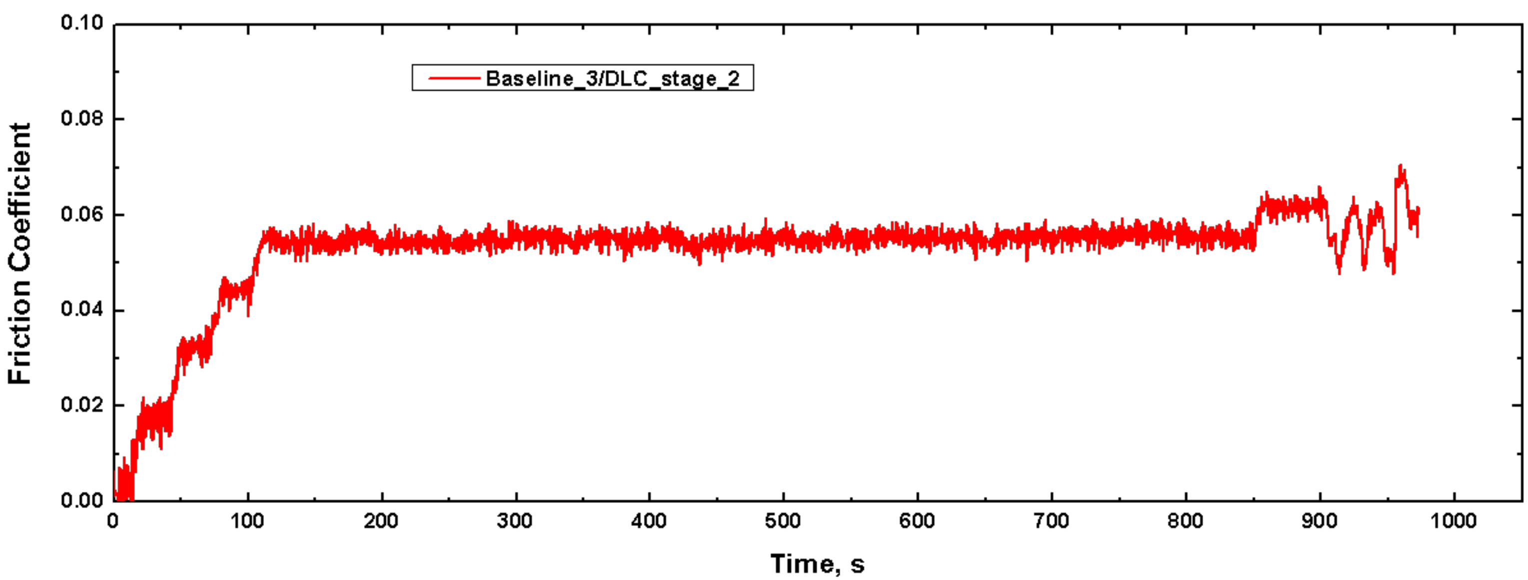
- Switched to Mobil 1 (5W-30) as a baseline
- Added selective chemicals into the lubricant and tested with the DLC coated samples
- Under these conditions, the test procedures have to be modified several times to get to <u>the time to failure points</u>

Final combination data
150 nm DLC
Mobil 1 + oxygenates

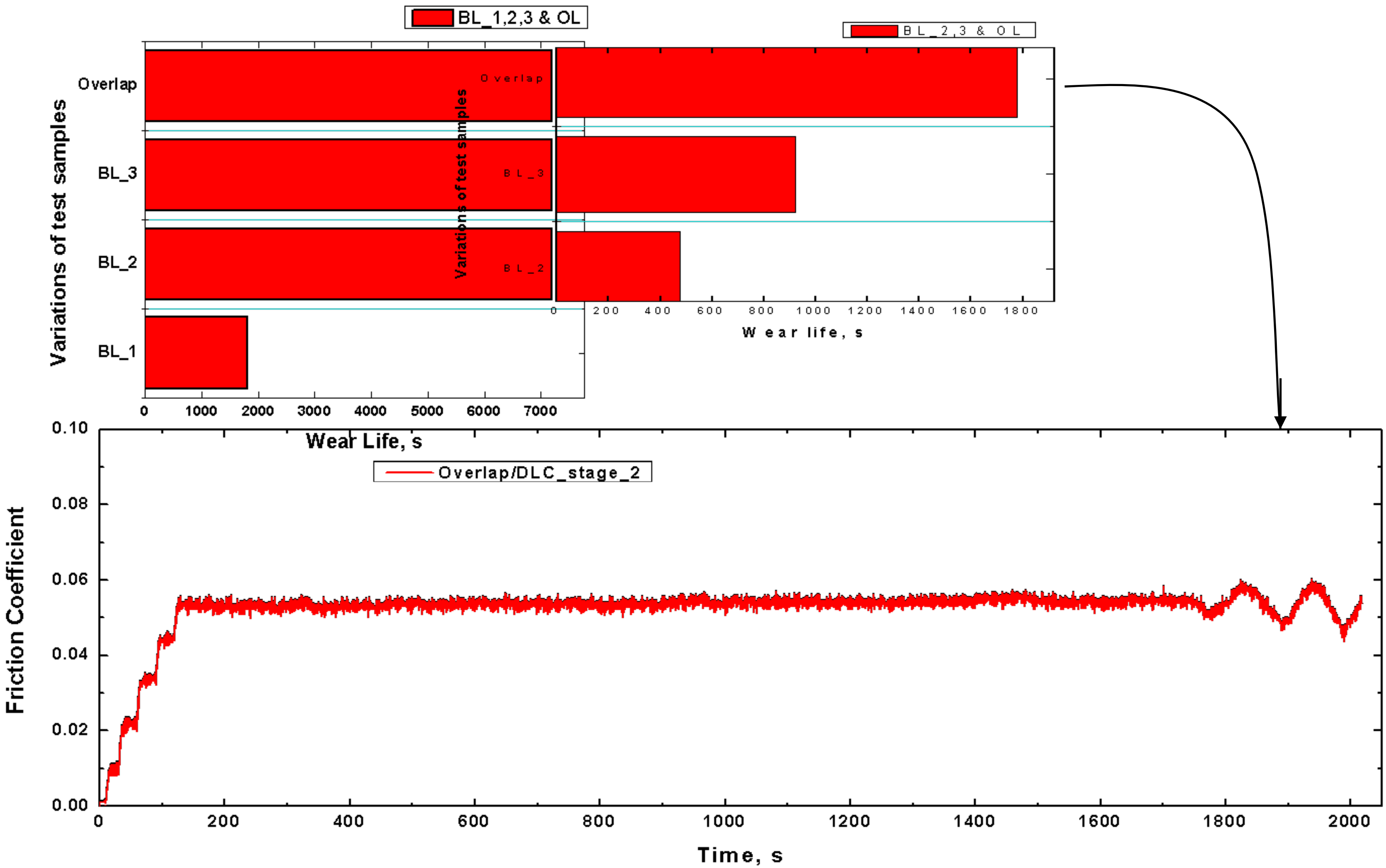


Instead of continuing the test, the procedure was changed to one hour at a specific load and speed and continues


Friction Coefficient


Baseline_3/DLC_stage_2
Friction Coefficient
0.10
0.08
0.06
0.04
0.02
0.00
0
100
200
300
400
500
600
700
800
900
1000
Time, s

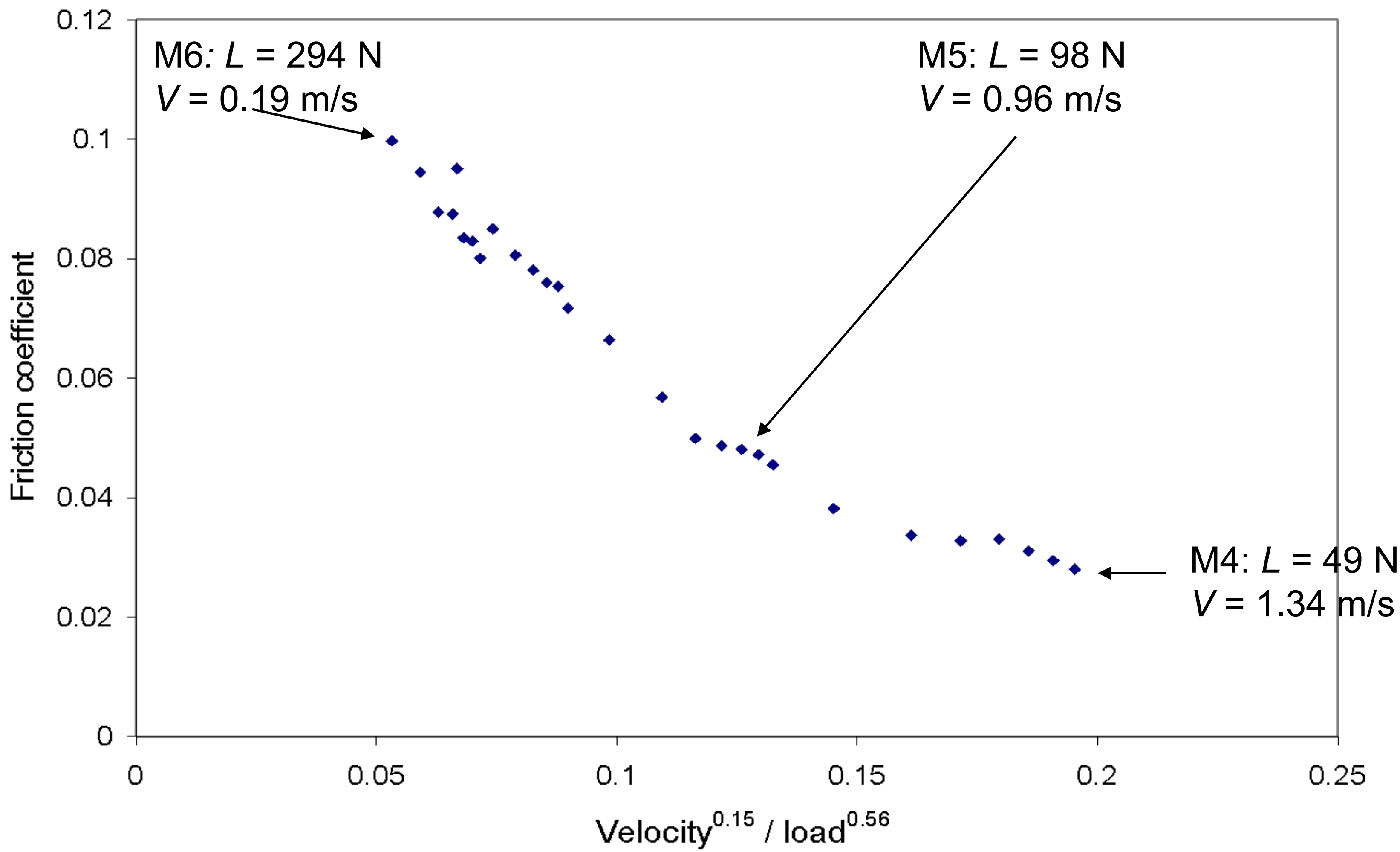
Final combined result, at least 10x life



Surface texture + DLC + Chemistry

- Successfully achieved the goal of extending the life of multiscale textures to 10 times without DLC and chemistry
- There are rooms to improve and optimize the technology
- Feasibility of concept demonstrated
- To be validated in actual applications
- However, actual application requires more data, fabrication techniques, and model before proceeding

FY 09 milestone: model to explain why texture works



Hydrodynamic parameters were able to describe a large number of data

Future work : challenges to technology validation in engines

- Cannot control oil chemistry
- Therefore the FY 09 milestone: *developed a chemically bonded film to bring the right chemistry to the engine regardless of oil chemistry*
- Piston ring hard to fabricate textures
- Therefore, FY09 milestone: *develop a much higher load machine to be able to fabricate textures on rings*

Future work II

- Fabricate and validate technology in engines next year
- Develop design guidelines for the surface technology
- Realize potential fuel savings in vehicles