The Effects of Alternative Top of Rail Friction Materials on Pre-existing Rolling Contact Fatigue Cracks

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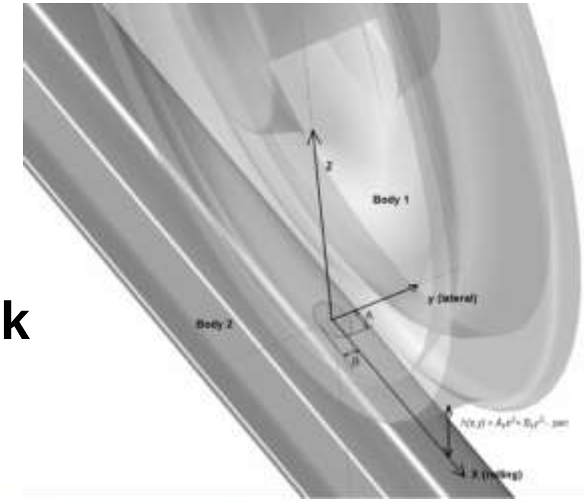
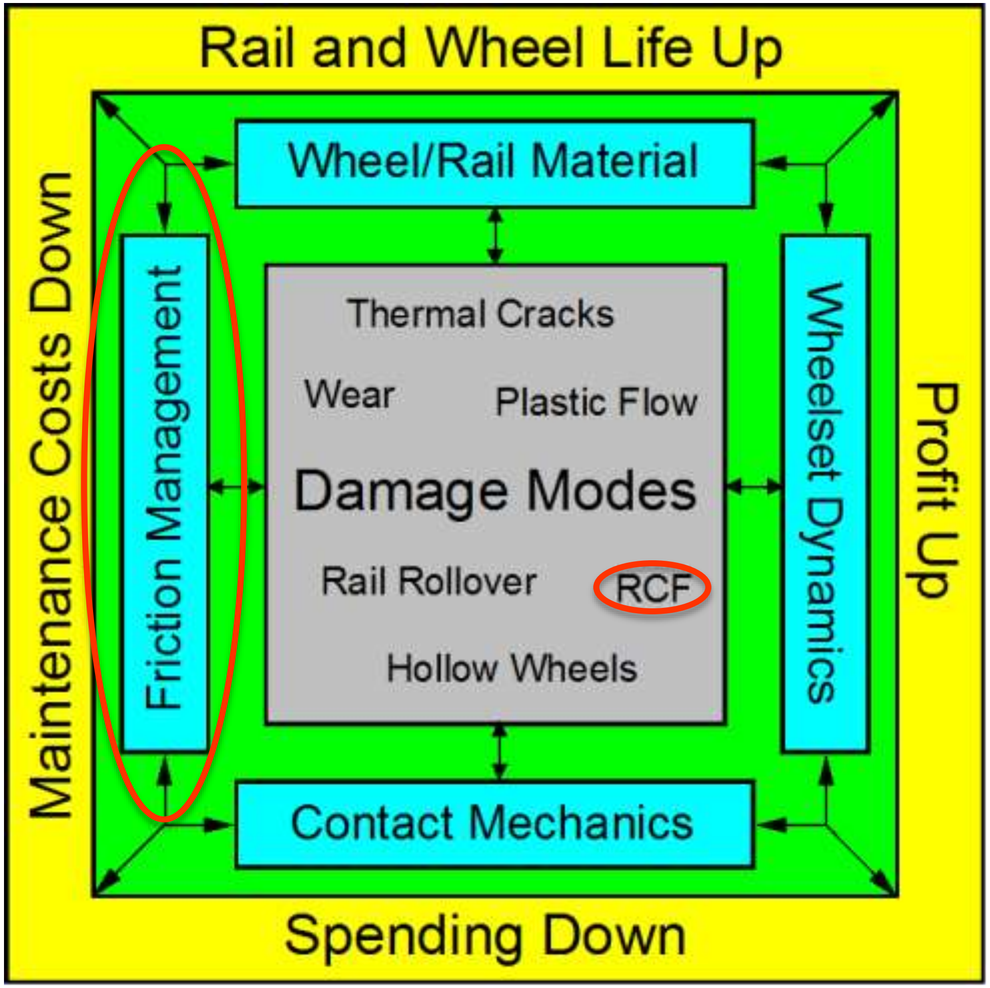


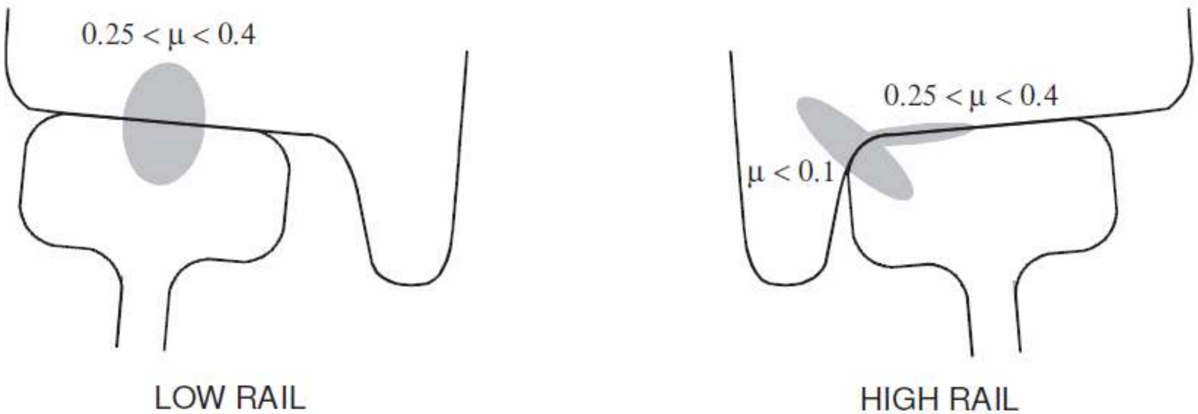
Wheel Rail Interface - Management



Friction Management

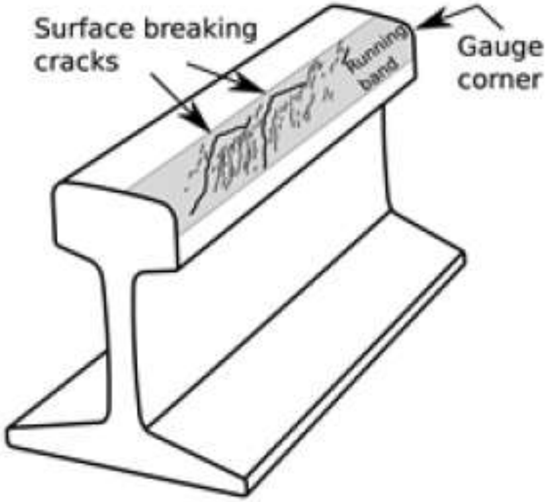
Desired friction levels

- **Low Friction – Lubricants (Liquid / Solid)**
- **Intermediate Friction – TOR FMs**
- **High Friction – Adhesion enhancers**

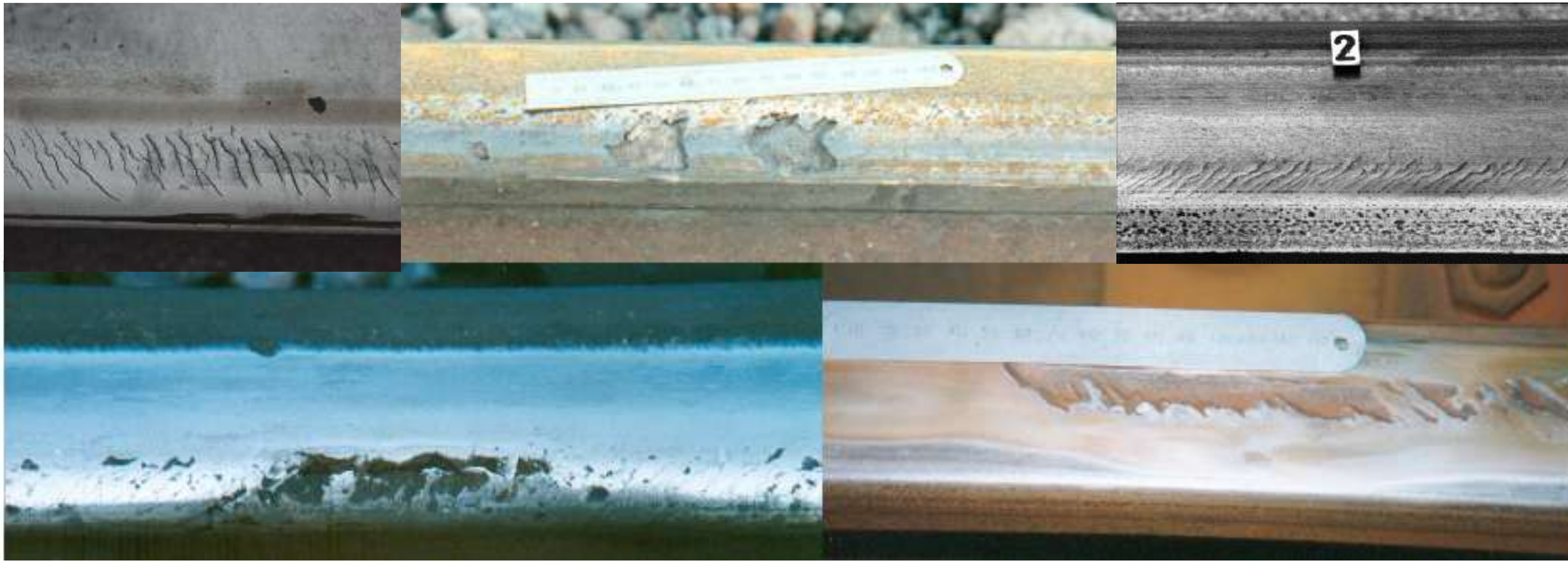


RCF Defects – Rail Surface cracking

- **RCF defects consist of a series of surface breaking cracks in the top or gauge corner of the rail**
- **Typically form on the both High and Low rails**
- **They do often result in chips of the rail gauge corner breaking away – Surface spalling**
- **Can propagate to form deep cracks or transverse rail breaks**



RCF Defects



ROLLING CONTACT FATIGUE wheels and rails IHHA workshop,
New Delhi, February 2013 Dr Stuart L Grassie

RCF Defects – Consequences

- **Maintenance is required – rail grinding to remove small cracks – Multiple passes for deeper**
- **Rail replacement if there is severe cracking**
- **Regular non-destructive inspection (e.g. ultrasonic and visual inspection) to spot the early stages of cracking**
- **Friction management to control rail surface friction levels to prevent cracks forming**
- **Careful management prevents safety problems, but costs a lot of money**
- **If cracks are missed or grow quickly there's the potential for a rail break, and train derailment**

RCF Defects – Consequences

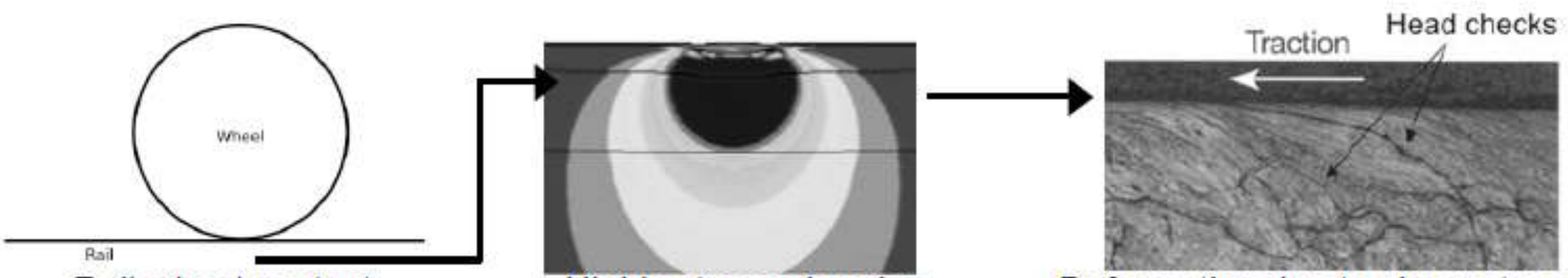
- **On Tuesday 17 October 2000 the 1210 GNER Intercity 225 train from London to Leeds was derailed at around 115mph**

- **4 people were kill and many injured**

Rolling Contact Fatigue - Defects

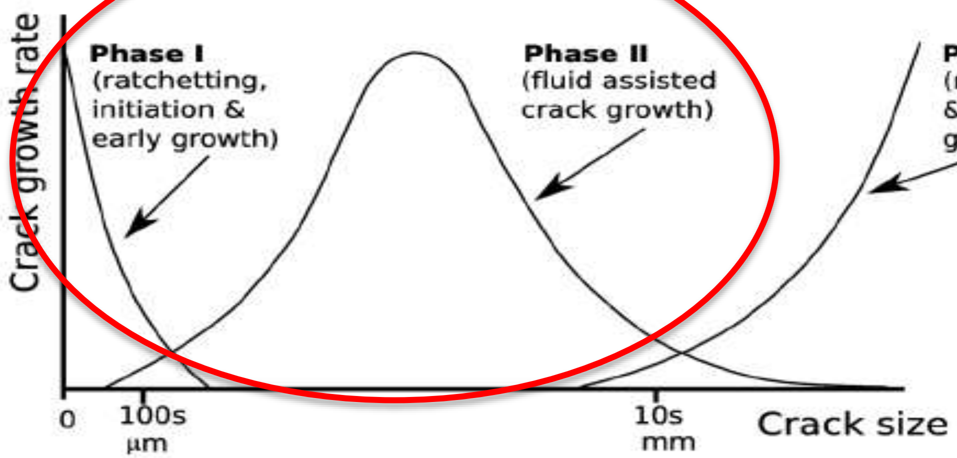
- Cyclic Loading and Unloading (Low Stress $<\sigma_y$)
  - Inducing Stress and Deformation
    - Elastically Recovered

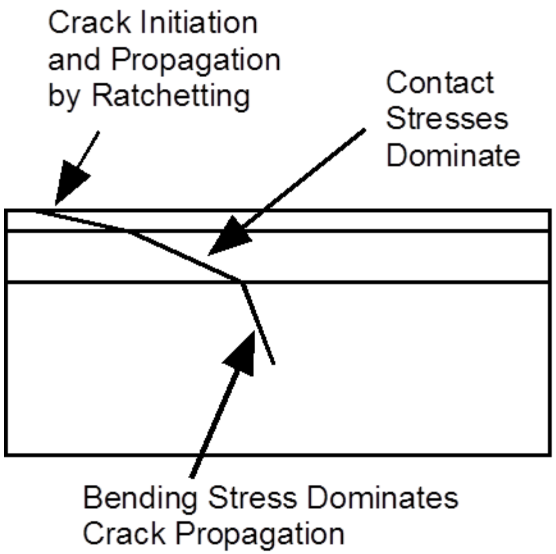
- Cyclic Loading and Unloading (High Stress $>\sigma_y$)
  - Inducing Stress and Deformation
    - Not Recovered – Plastic Ratchetting

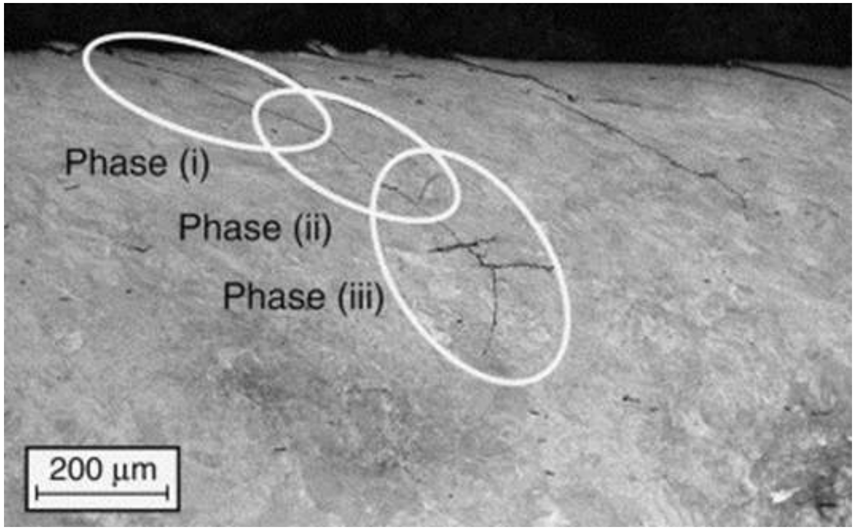


Rail-wheel contact   Highly stressed region   Deformation due to shear stress

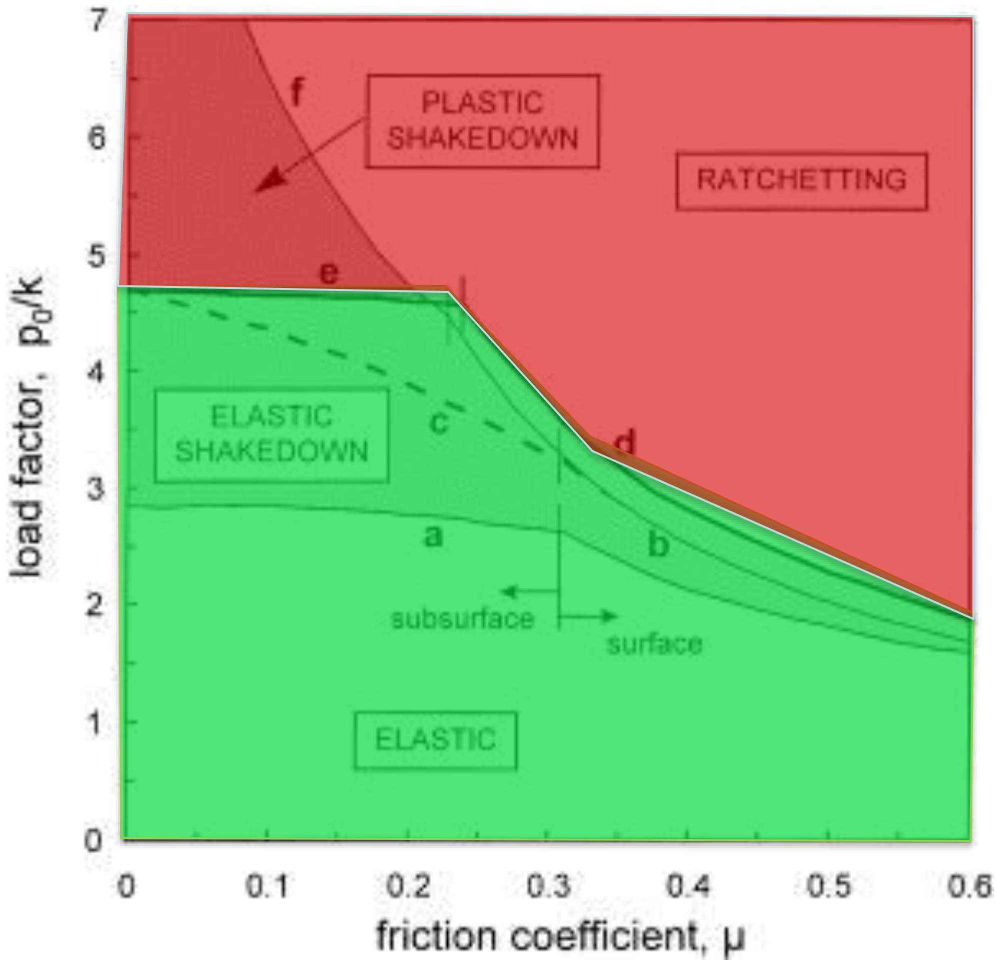
RCF Crack Propagation







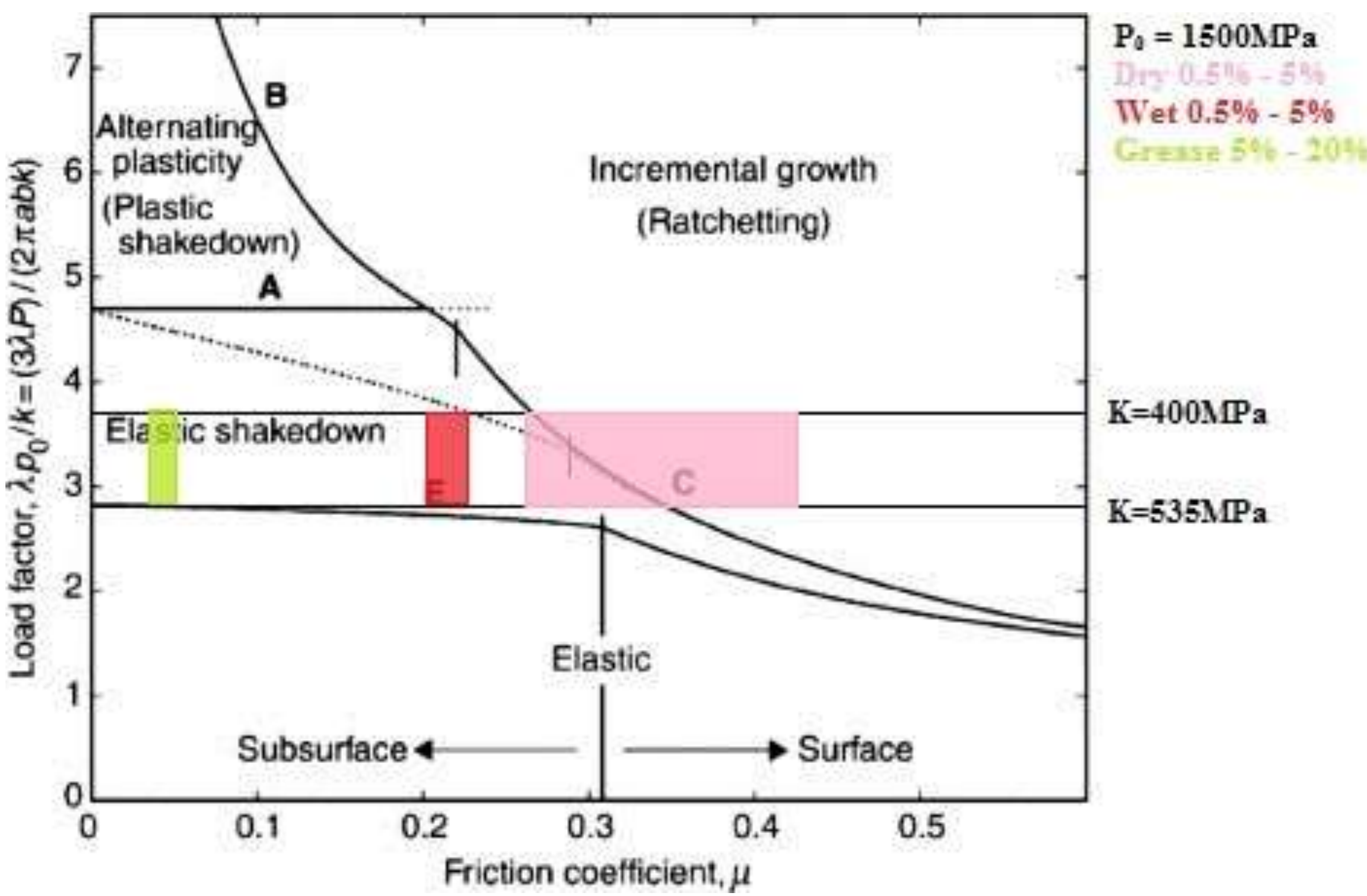
RCF – Shakedown



RCF DEFECTS WILL OCCUR

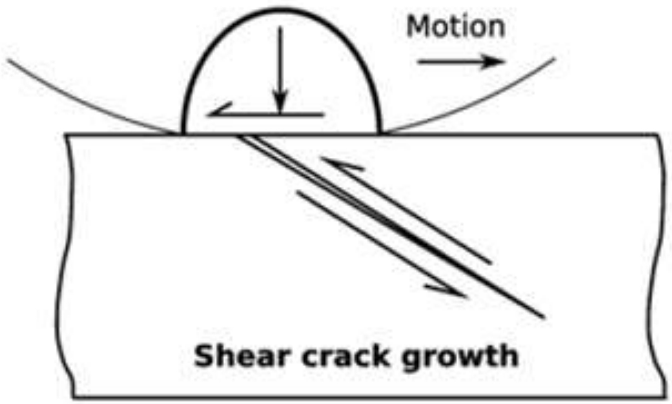
Deformation Stress Recovered Elastically

RCF – Shakedown - Flanging



RCF – Fluid Assisted Crack Growth

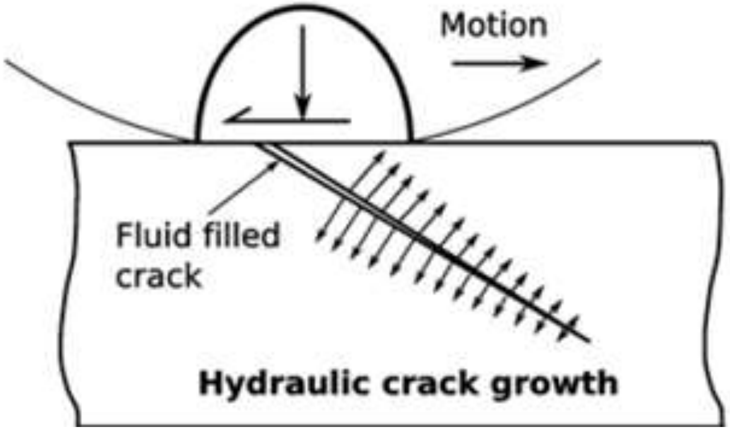
Shear Crack Growth (Crack Flank Lubrication)



- **Fluid Entrained it to contact**
- **Lubrication of Crack faces allow shear crack Growth**
- **Will not occur if μ>0.2**

RCF – Fluid Assisted Crack Growth

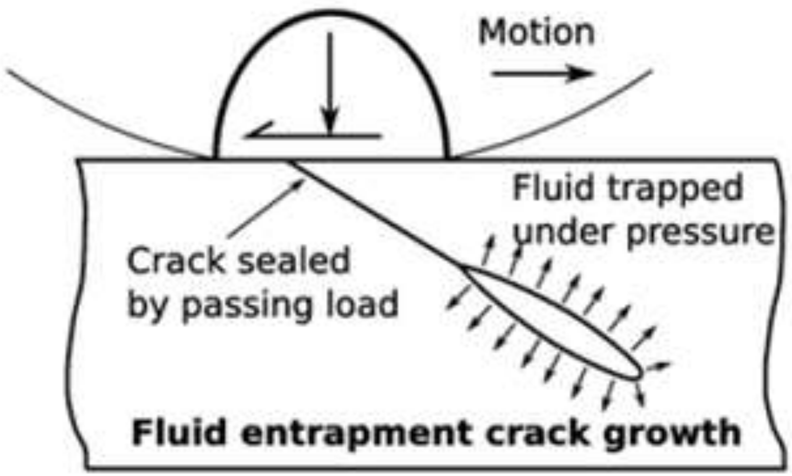
Hydraulic Crack Growth



- Fluid Entrained it to contact (Not Sealed)
- Direct transmission of hydraulic pressure

RCF – Fluid Assisted Crack Growth

Fluid Entrapment Crack Growth



- **Fluid Entrained it to contact Sealed**
- **Pressurization of the crack tip.**

Basis For Study

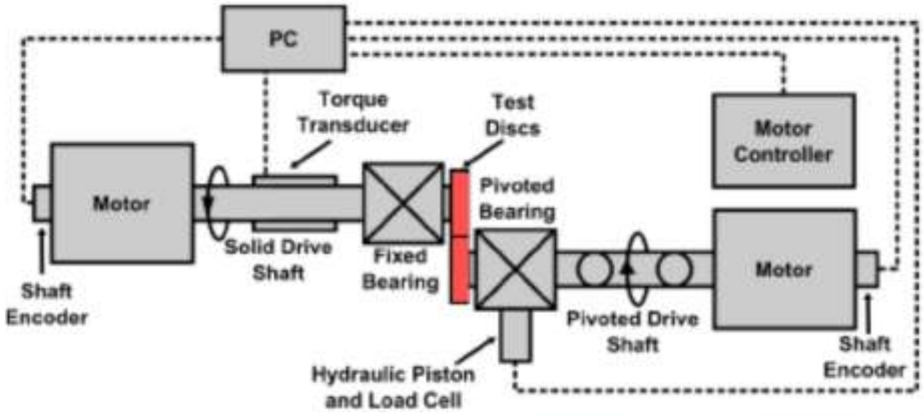
Rolling Contact Fatigue (RCF)

- **Increased axle loads, speeds, capacity**
- **Wide range of friction managements products**
- **Effects on wear documented, (on fresh rail)**

Study and compare effects of different friction managements products on rail with existing damage!!!

SUROS – Twin-disc Machine

- **Specimens cut from wheels and rails**
- **Variable contact pressure, slip, speed**
- **Torque, speed, load sensors**
- **Feedback loop to control slip**
- **Adhesion**
- **Monitor wear, crack initiation**



Test Methodology – Twin Disc

New Rail/Wheel Specimens → Impart Some Surface Damage → Assessment of damage

New Rail/Wheel Specimens → Impart Some Surface Damage → Product Application → Assessment of damage

Test Methodology

Twin-disc Testing

- Realistic contact conditions (1500MPa)
- Two rail grades – One wheel material (R8T)
  - 260grade Rail (European Transit)
  - 350HT Rail (Heavy Haul)
- Four products investigated
  - Water based (Dry Film) TOR Friction Modifier
  - Synthetic Oil based TOR Friction Modifier
  - Grease Based TOR Friction Modifier
  - Premium gauge face lubricant

Test Methodology

Twin-disc Testing

- 1500 MPa Contact Pressure
- 1% Creep
- Typical of previous RCF studies

Cycles

- 4000 cycles dry (590m rolling)
- 21000 cycles with product application (3100m)

Test Methodology

Product Application

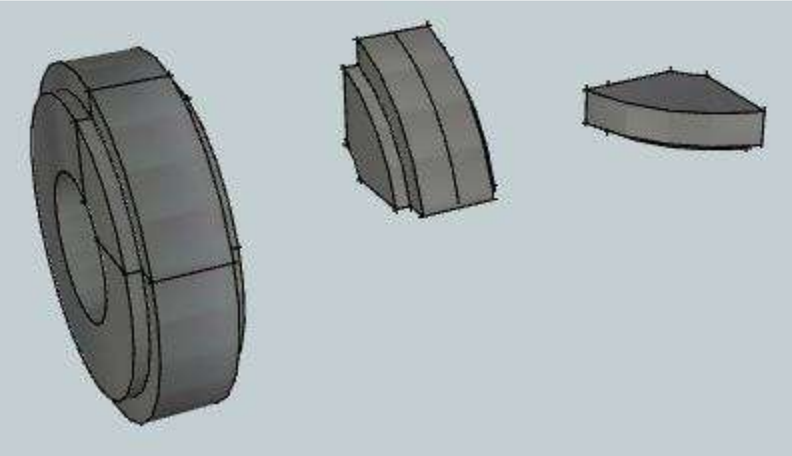
- Water - Baseline
  - 1 drip per second
- Rail Products
  - All friction management products
- 0.05g every 500cycles (74m)

Test Methodology

Test	Rail Material	Product	Dry Cycles	Product Cycles	Notes
1	350 HT	N/a	4000	0	Baseline (initial conditions)
2	350 HT	N/a	25000	0	Baseline Dry (Full Cycles)
3	350 HT	Water	4000	21000	Wet Rail Comparison
4	350 HT	A	4000	21000	Water Based (Dry Film) TOR FM
5	350 HT	B	4000	21000	Gauge Face Grease
6	350 HT	C	4000	21000	Synthetic Oil Based TOR FM
7	350 HT	D	4000	21000	Grease Based TOR FM

Analysis Techniques

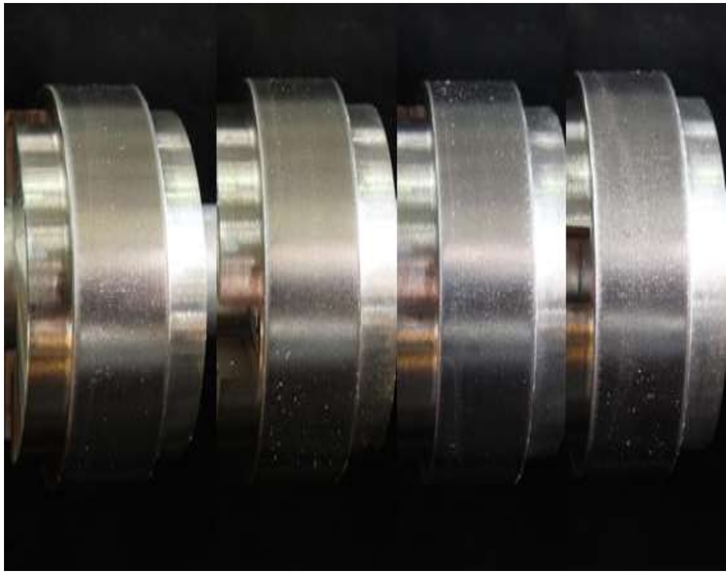
- Mass loss – calculation of wear rates
- Surface Appearance
- Frequency of cracks
- Length and depth of cracks in cross section of rail sample



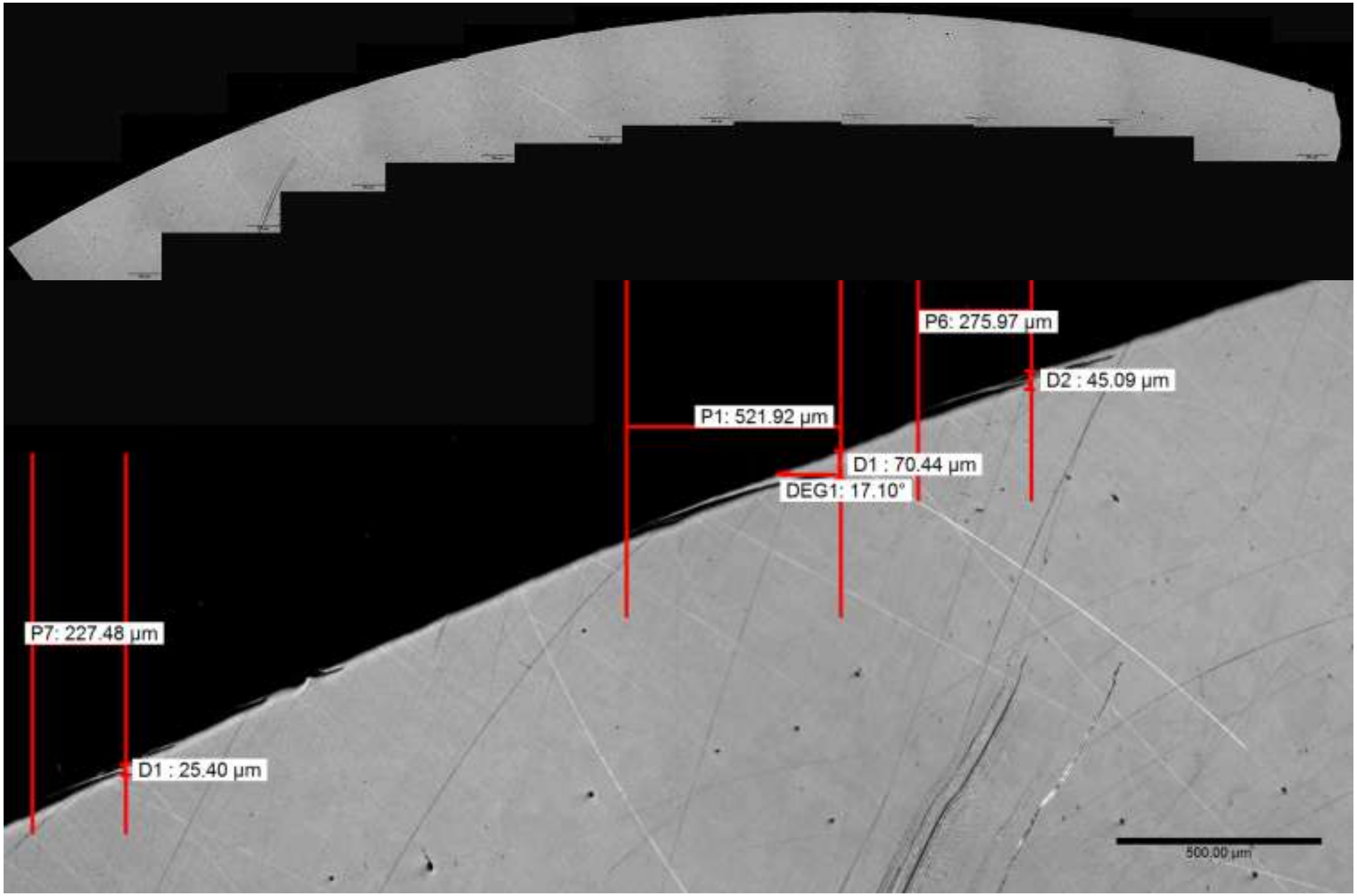
Results Dry 4000 Cycles

Baseline

- Surface Appearance
  - Minimal damage
  - No visible cracks
  - No signs of Spalling



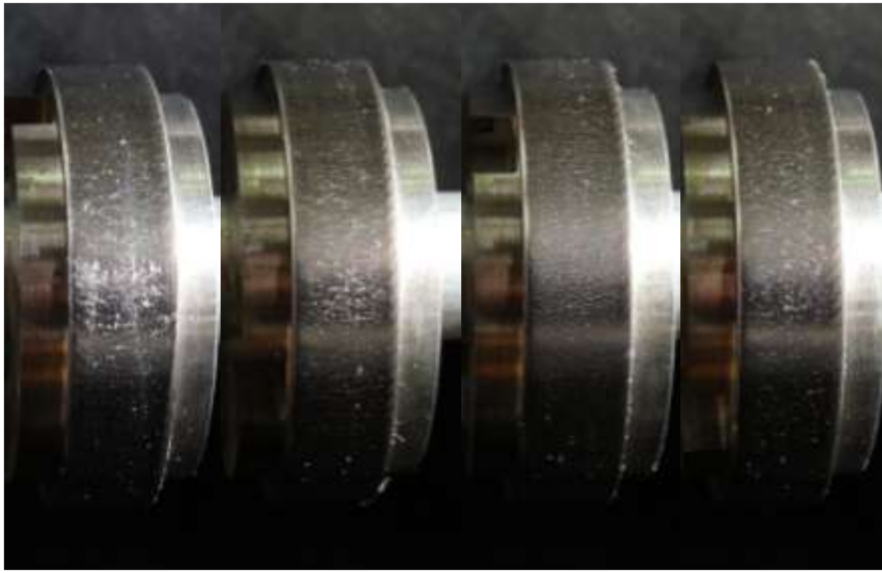
Results Dry 4000 Cycles



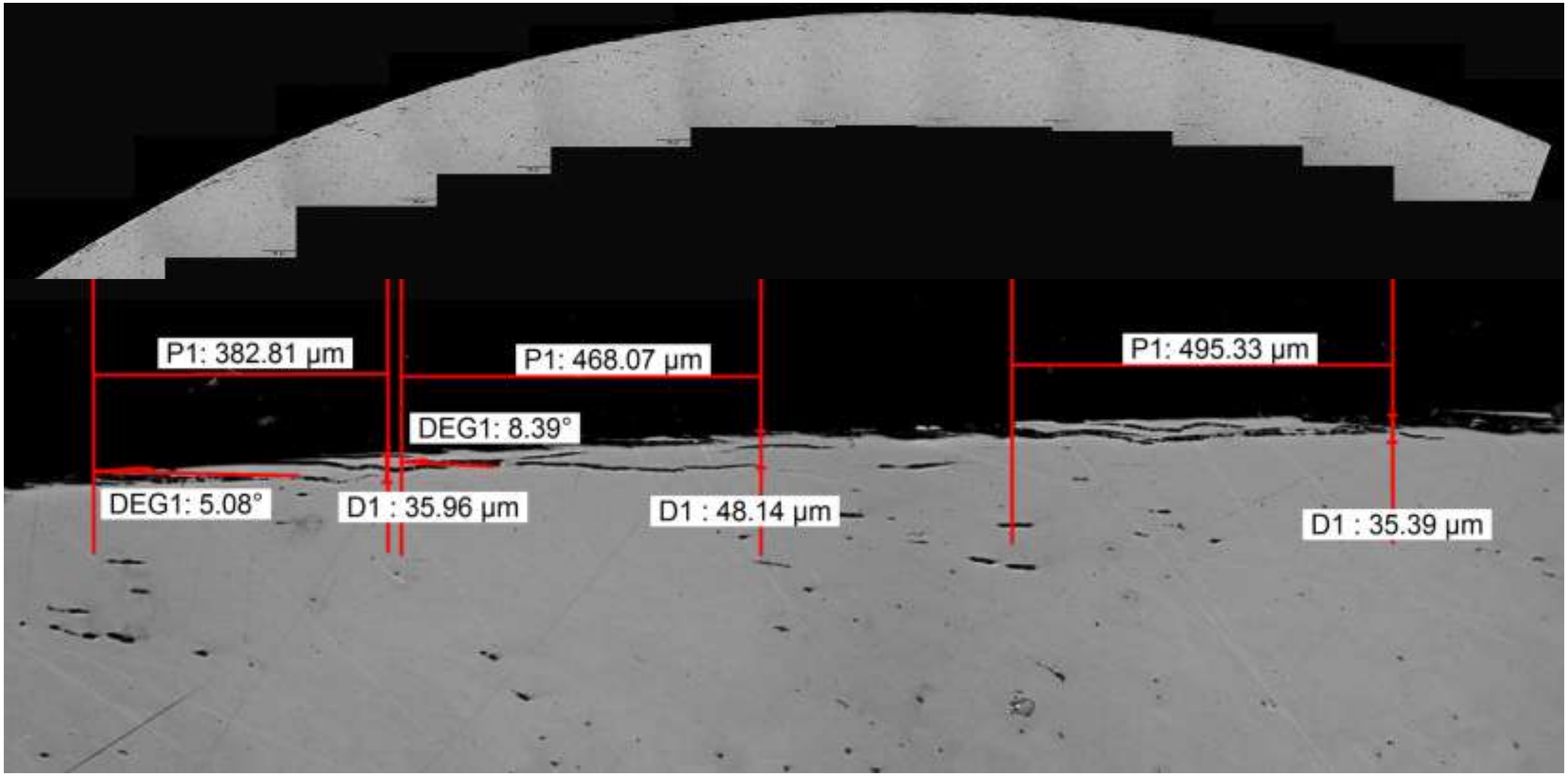
Results Dry 25000 Cycles

Baseline

- Surface Appearance
  - Increased Damage
  - Fine surface cracking
  - Rougher
  - No large material removed



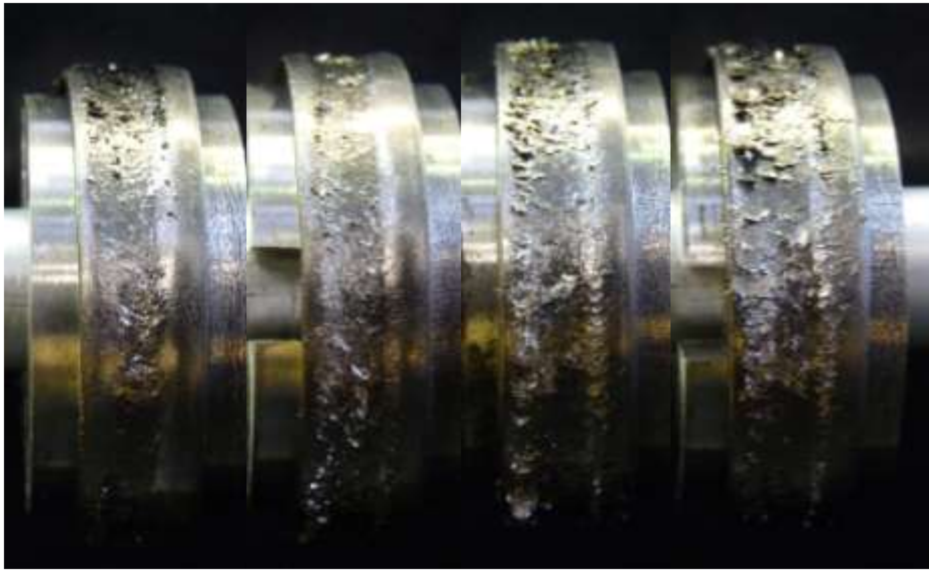
Results Dry 25000 Cycles



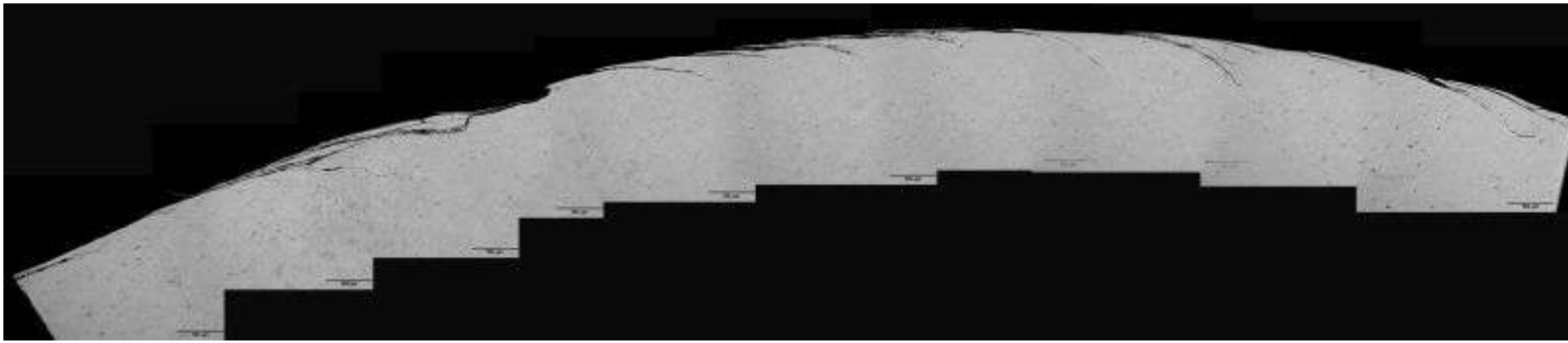
Results Water

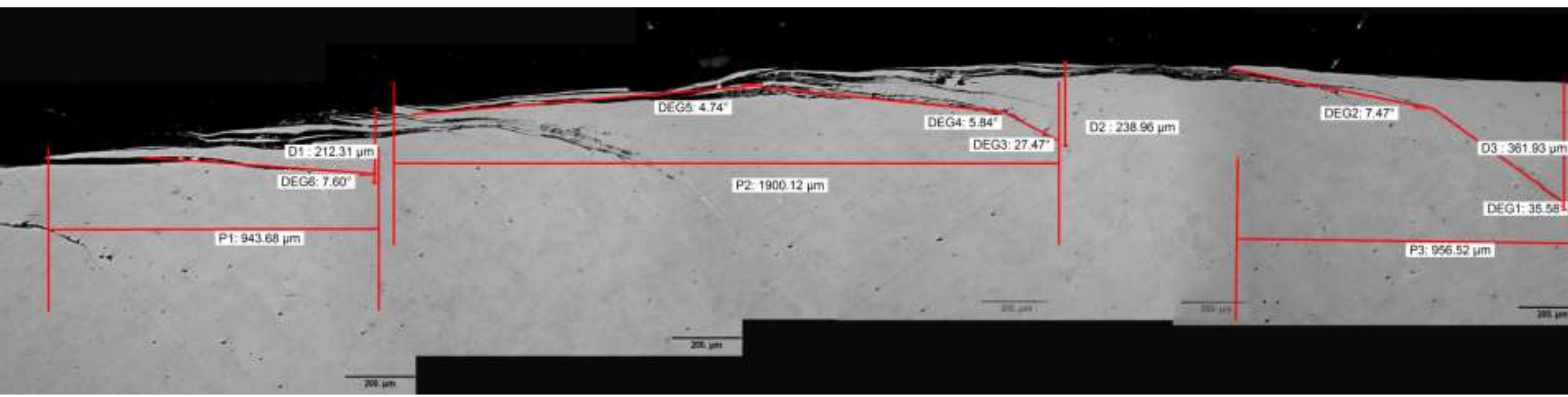
Surface Appearance

- Massive damage
- 19 X increase in wear
- Large scale delamination
- Some spalling
- Wear – large flakes



Results Water



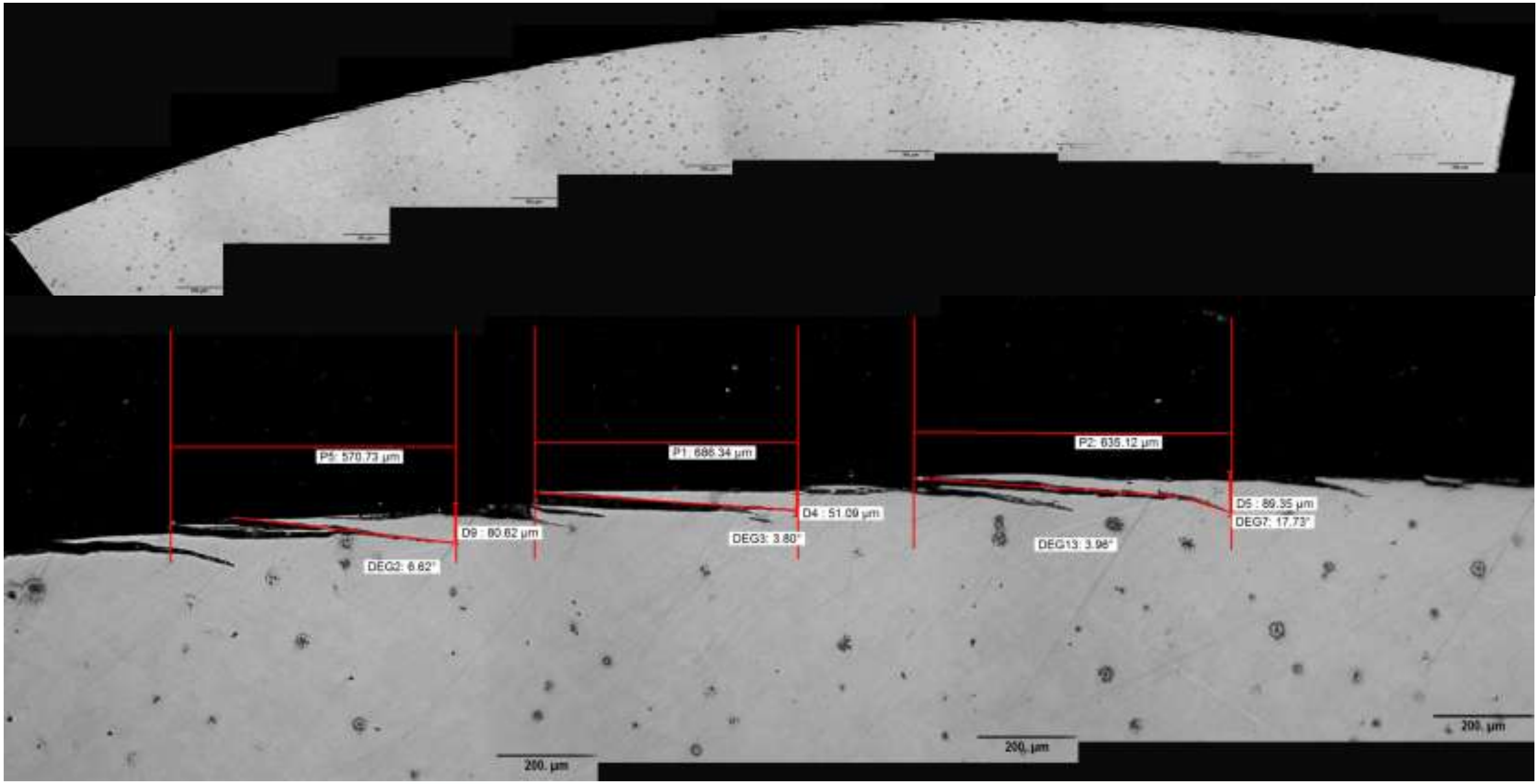


Results Water Based (Dry Film) TOR FM

Surface Appearance

- Similar to dry baseline
- No visible cracks
- Surface scoring
- No Spalling
- FM material wearing

Results Water Based (Dry Film) TOR FM

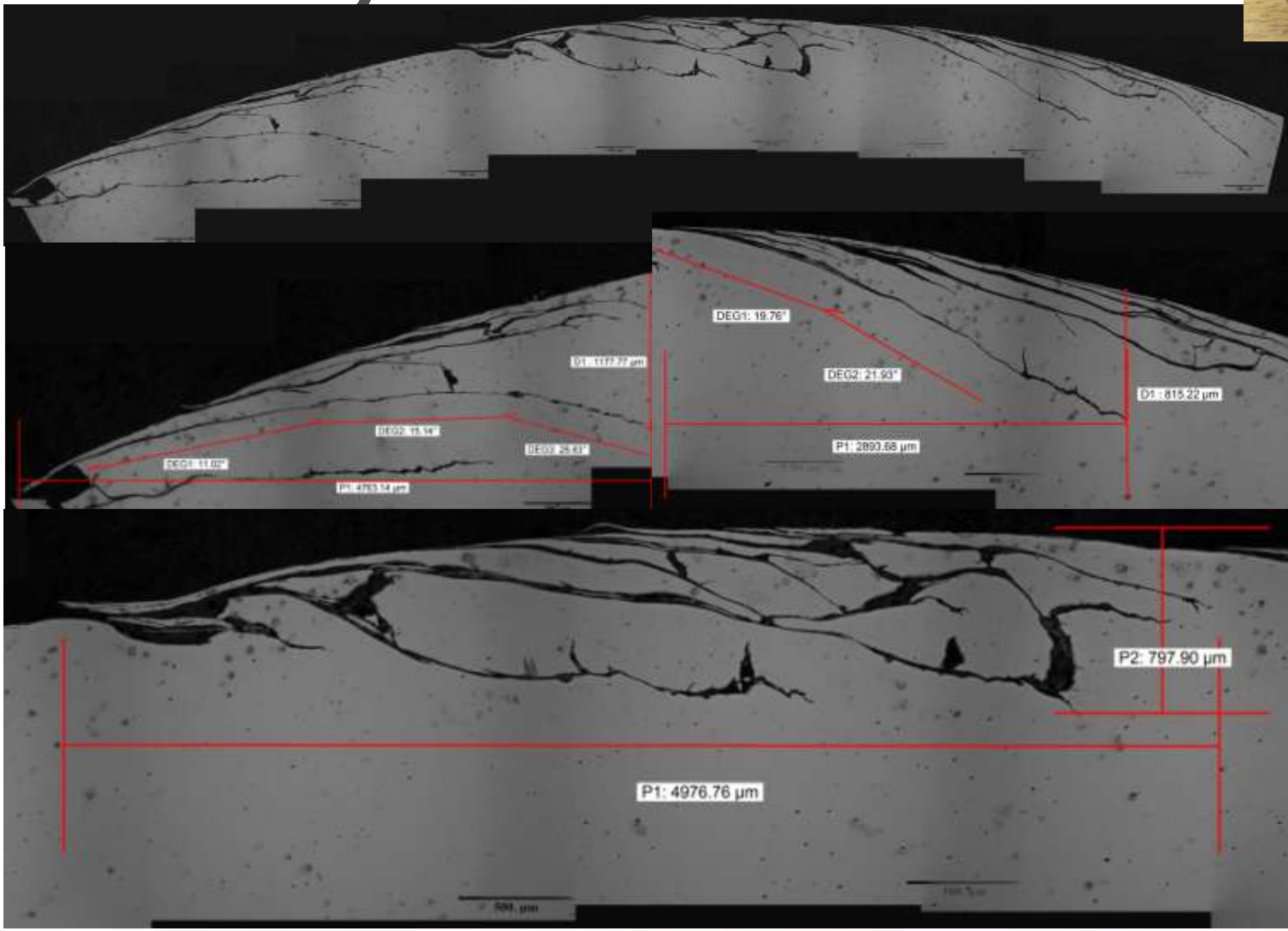


Results Synthetic Oil Based TOR FM

Surface Appearance

- Similar to water
- Very cracked
- Flakey
- 14 x wear increase

Results Synthetic Oil Based TOR

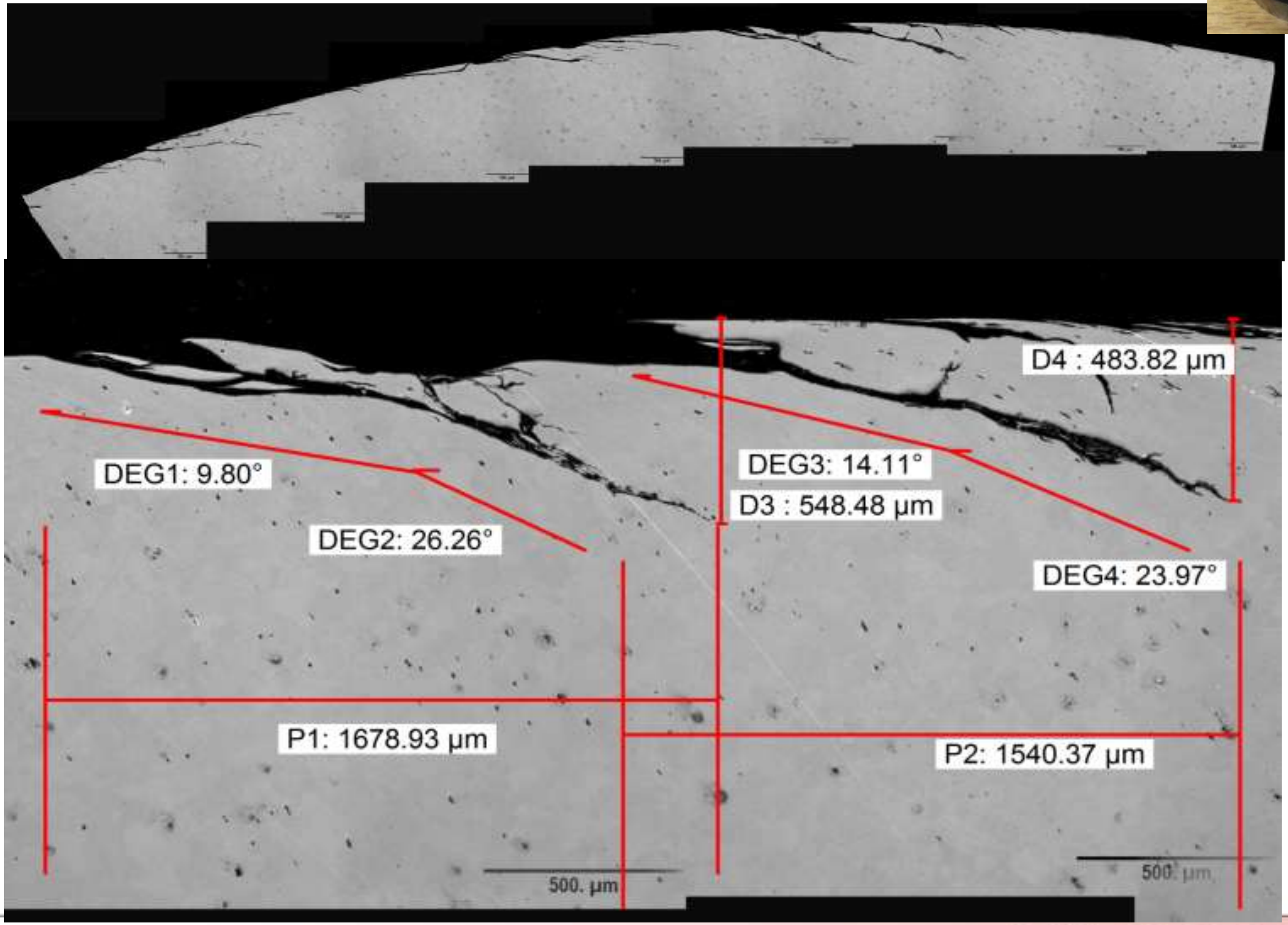


Results Grease Based TOR FM

Surface Appearance

- Increased Damage
- Similar to Dry
- Not as severe as
  Water
  Oil Based TOR
- Large material
  removal (Spalling)

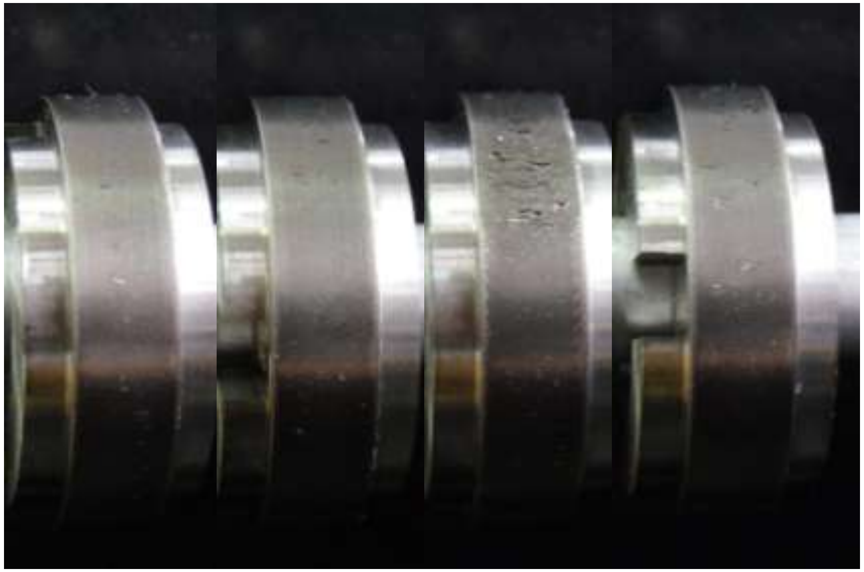
Results Grease Based TOR FM



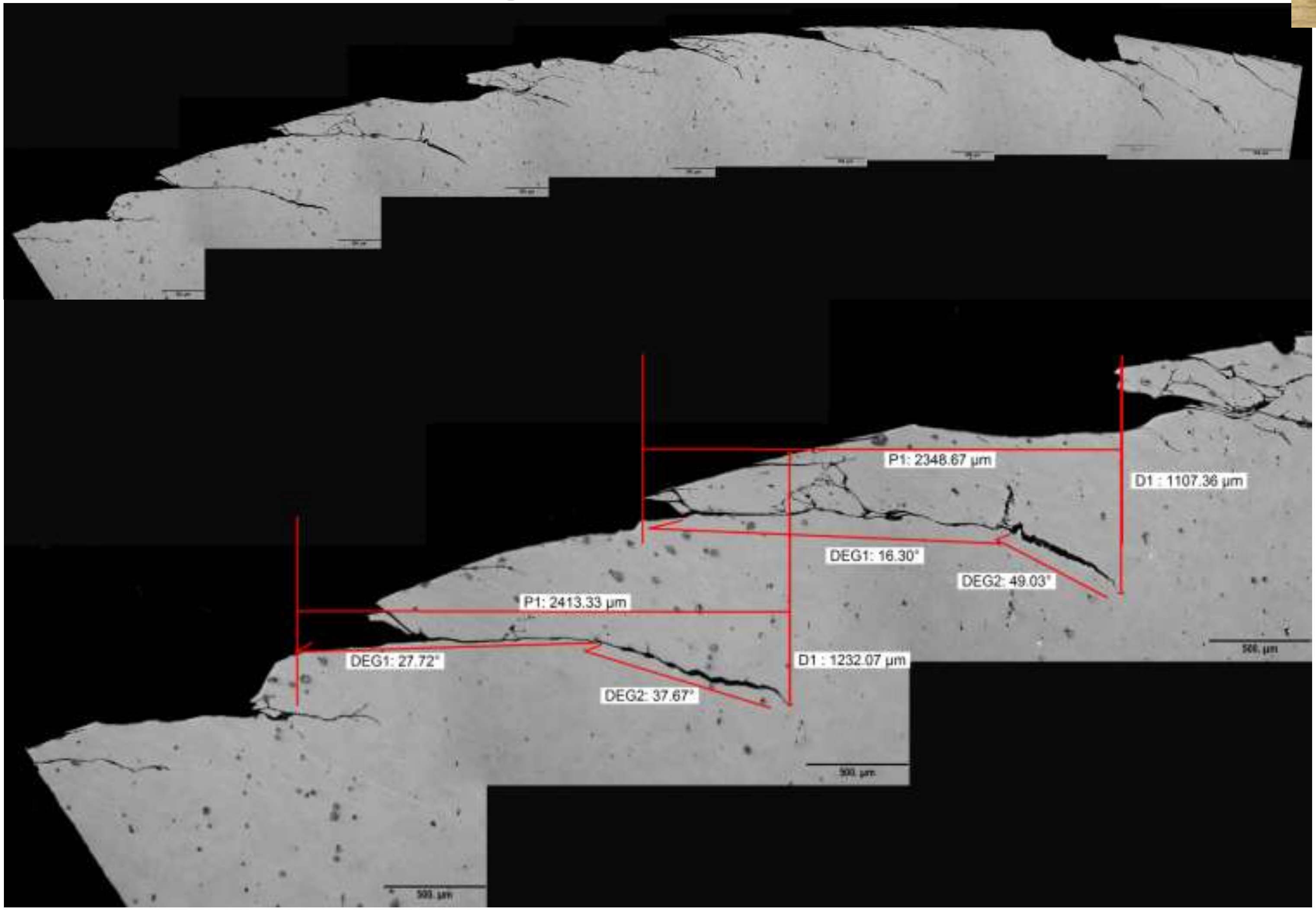
Results Gauge Face Lubricant

Surface Appearance

- Similar to the dry baseline
- Signs of surface cracking
- Spalling present

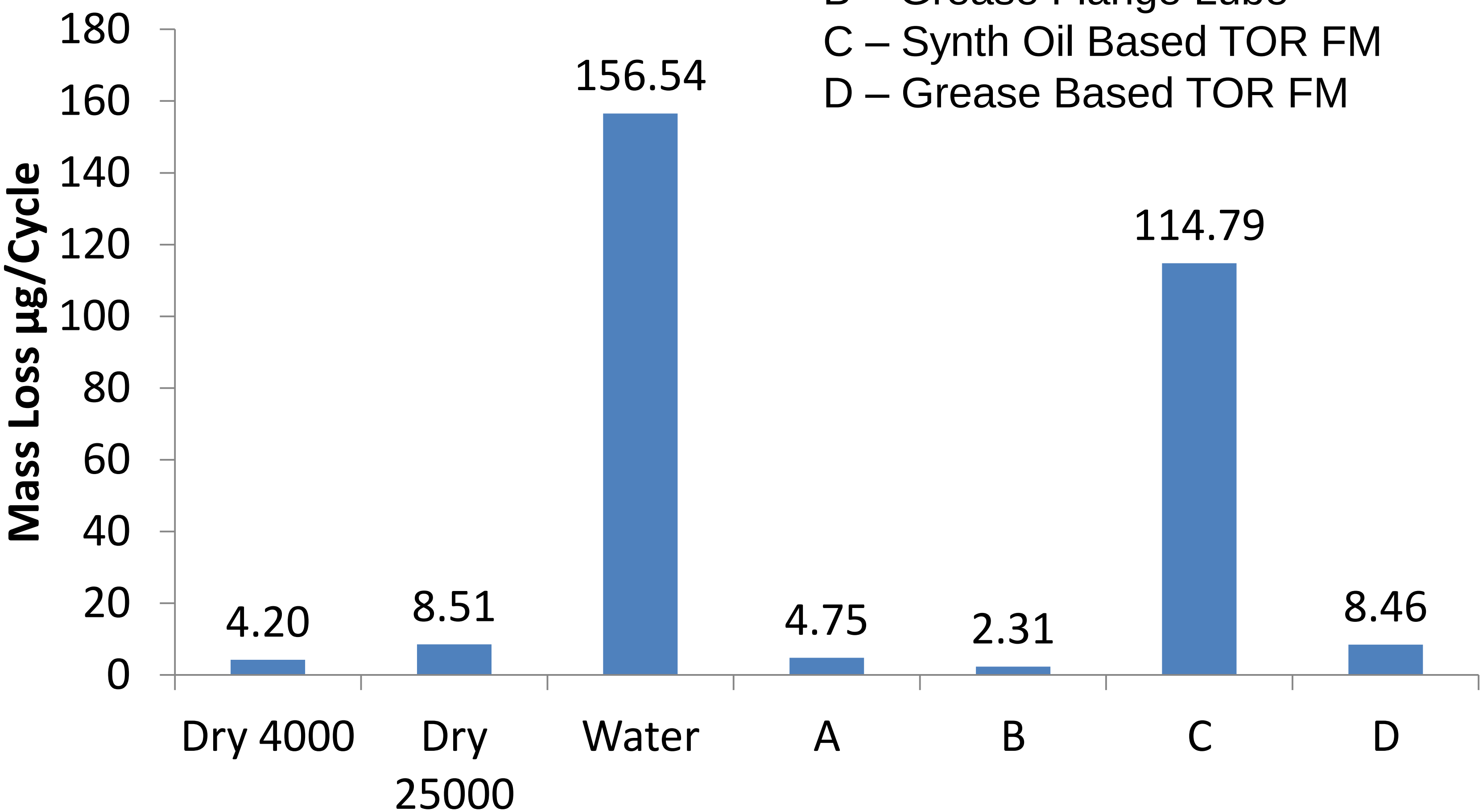


Results Gauge Face Lubricant



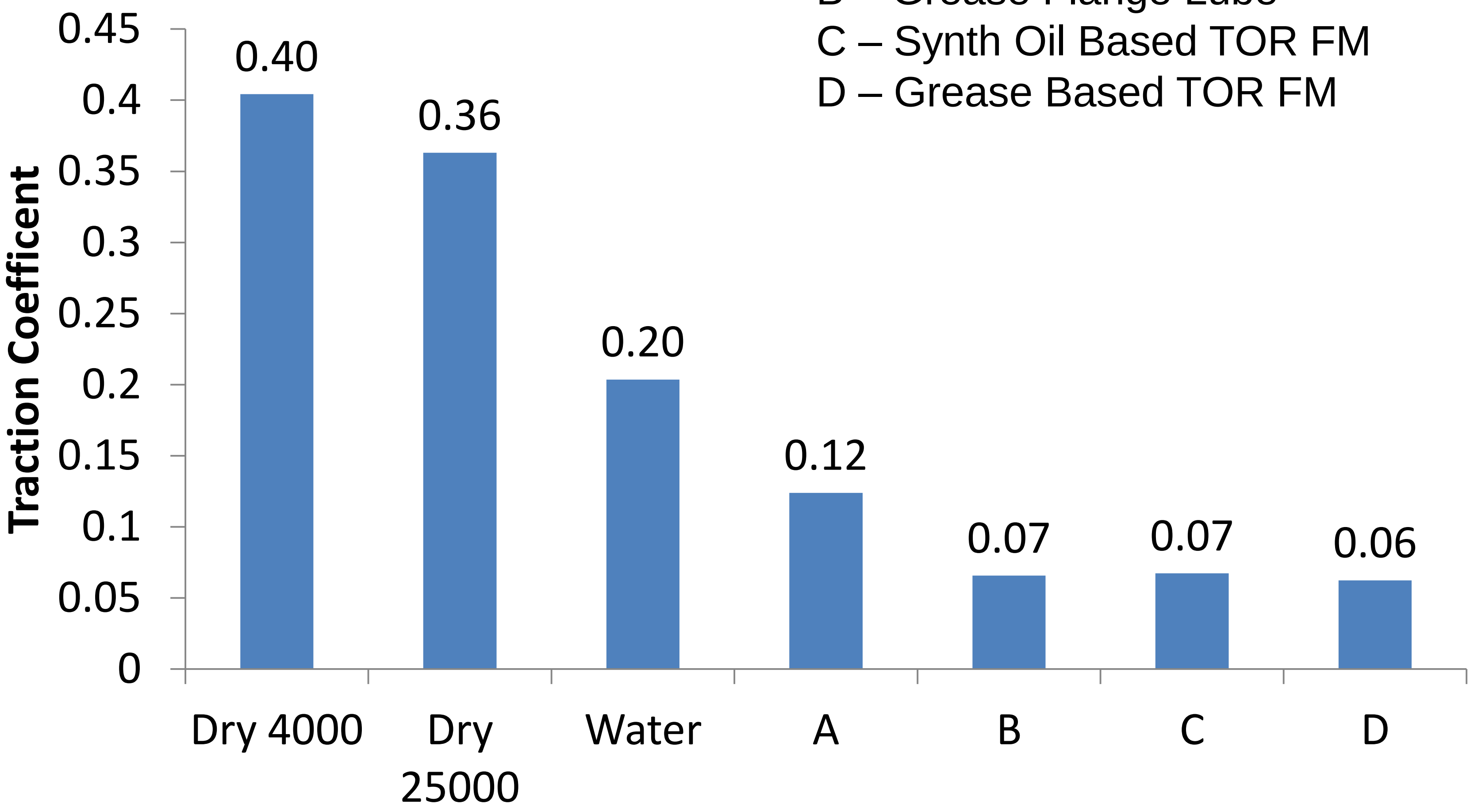
Results Mass Loss

A – Water Based (Dry Film) TOR FM
B – Grease Flange Lube
C – Synth Oil Based TOR FM
D – Grease Based TOR FM



Results Traction Coefficient

A – Water Based (Dry Film) TOR FM
B – Grease Flange Lube
C – Synth Oil Based TOR FM
D – Grease Based TOR FM



Discussion Severity Ranking

Little Effect on Crack Propagation

- **Water Based (Dry Film) TOR FM**
- **Gauge Face Lubricant**
- **Grease Based TOR FM**
- **Synthetic Oil Based TOR FM**
- **Water**

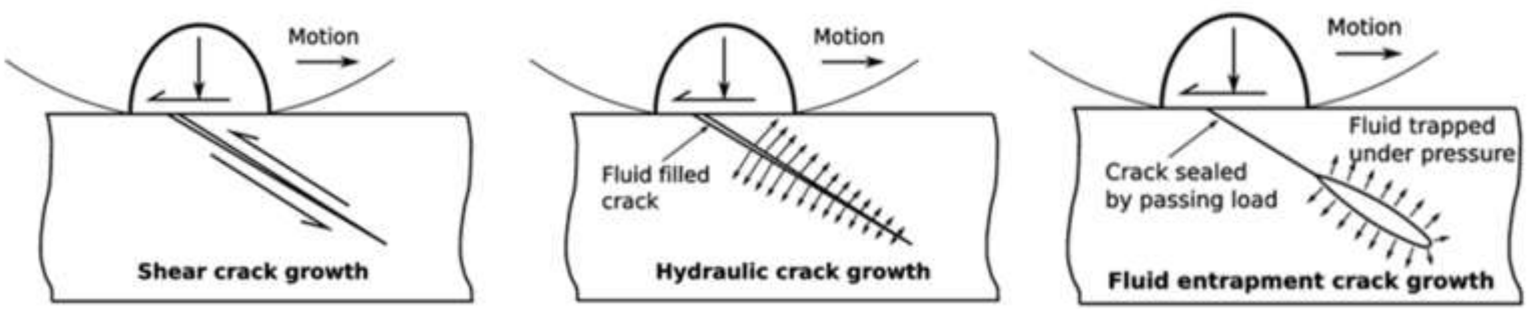
Accelerated Crack Growth

Discussion What is happening

Fluid Assisted Crack Growth

Crack Hydro pressurization.

Crack Flank Lubrication.



A.F. Bower. The influence of crack face friction and trapped fluid on rolling contact fatigue cracks. ASME Journal of Tribology, 110: 704 711, 1988

The Future Further Investigations

Specimen Analysis

- Number of surface cracks in given area
- Subsurface deformation depth

Product Analysis

- Viscosity
  - Temperature and shear
- Compressibility

Full Scale Lab Testing

- Time is a limitation

Questions?