Influence of the Lubricant on the Functional Behaviour of DLC Coatings

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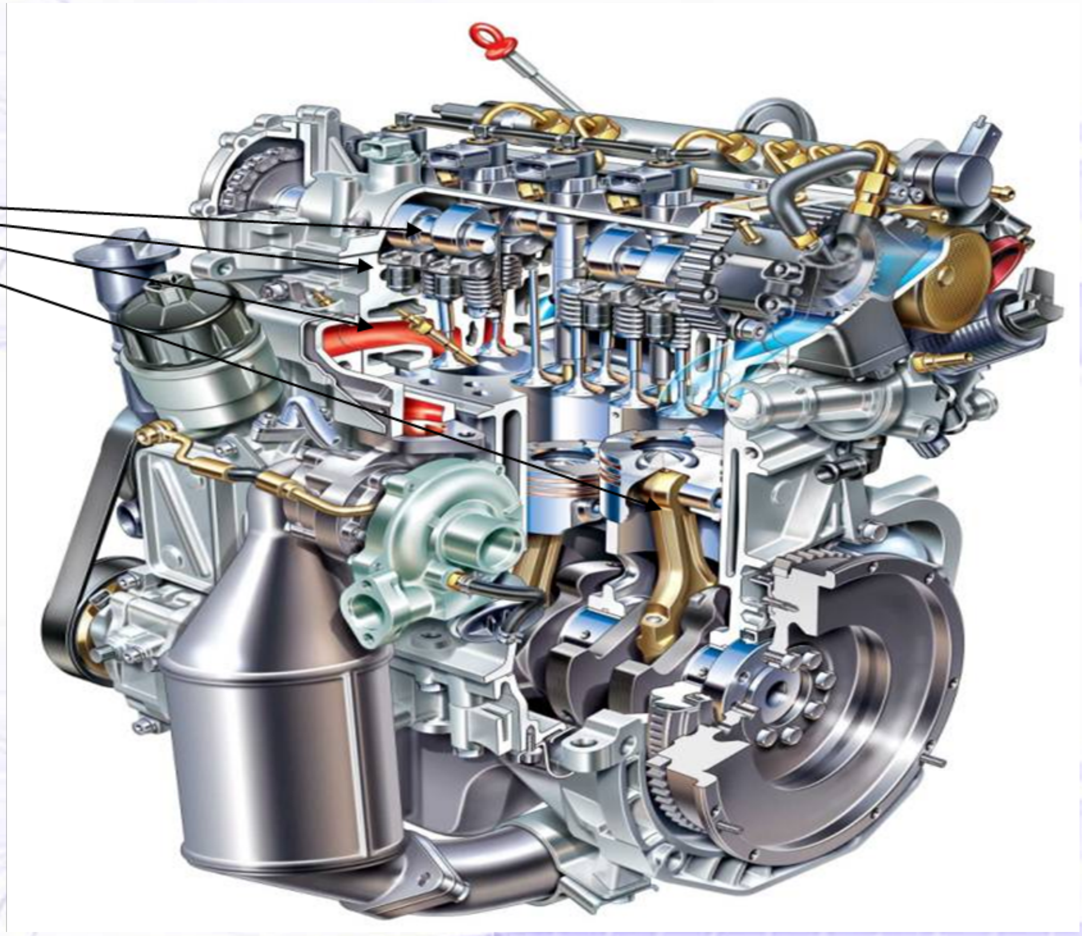
Agenda

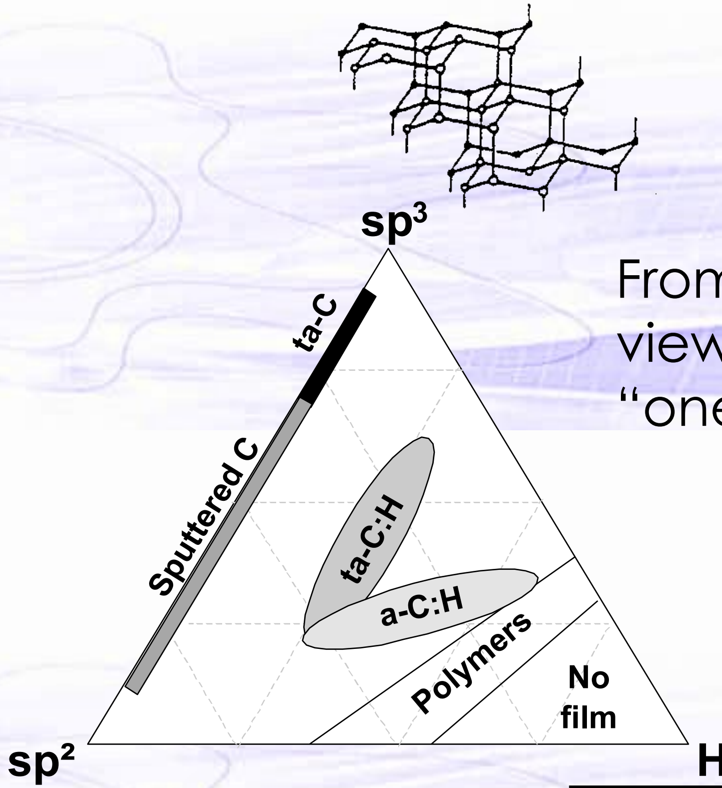
- Purpose of the research work
- Choice of the experimental protocol
- Effect of bad coating affectation
- Friction test in SAE5W30
- Friction test in 150 N
- Friction test in PAO 6
- Friction test in PAO 6 + 1%GMO as friction modifier
- Wear rate of coatings
- Conclusion
- Outlook

DLC coatings for engine friction reducing

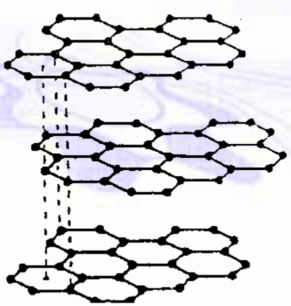
DLC coatings



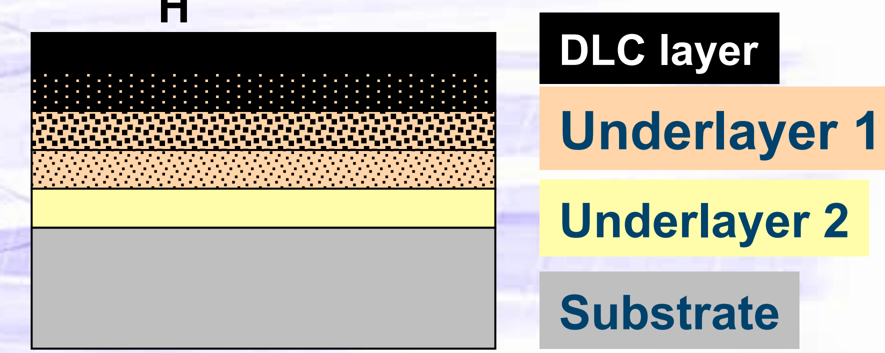
DLCs



From a tribological point of view, there is no such thing as "one DLC".



Multilayer system

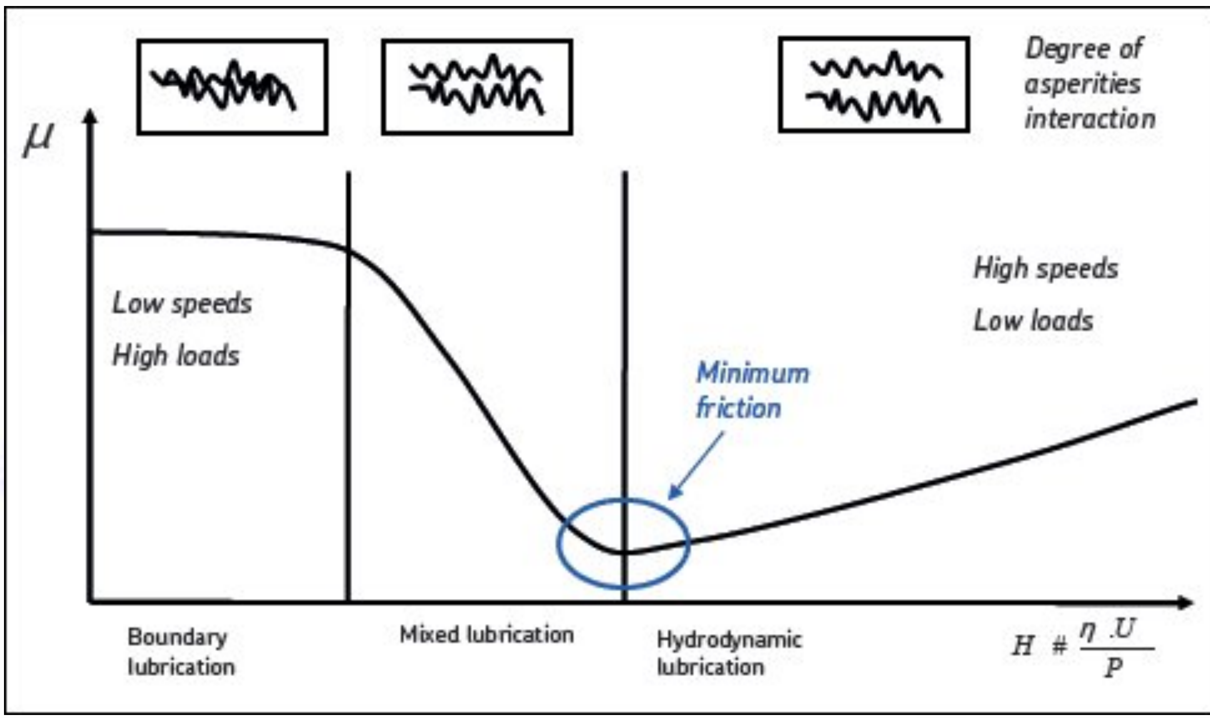


Purpose of the research work

- Study the tribological behaviour of DLC/steel contacts in boundary lubrication.

- Evaluate the influence of oil additives on friction coefficient, and wear rate.

- Evaluate the effect of DLC nature.



boundary lubrication :
- low speed
- low viscosity
- high pressure

Choice of the experimental protocol

- Oil heated at 110°C
  - low viscosity to promote boundary lubrication
  - enhance additive reactivity for representativeness of engine conditions

- Low sliding speed at 3.5 cm/s to promote boundary lubrication

- High contact pressure, P mean : 540 MPa, P max = 810 MPa to promote boundary lubrication

- Test : ball on flat sample reciprocating sliding test (sinus speed profile),
friction track length : 10 mm

- Ball diameter : 10 mm, Load : 5N resulting in a Hertzian contact of 90 µm in diameter

- 15000 cycles for friction stabilisation

Coating affectation

2 possibilities:

- **DLC coated ball / uncoated steel flat sample**
- DLC coated flat sample / uncoated steel ball

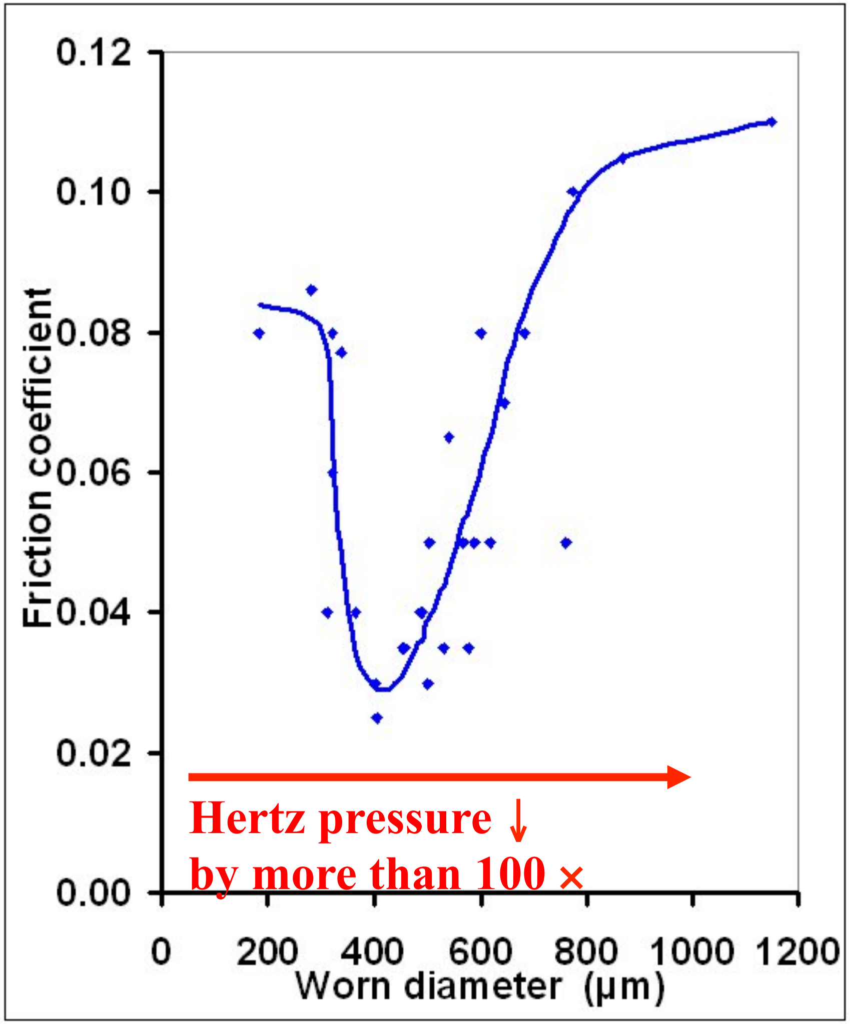
First configuration was selected.

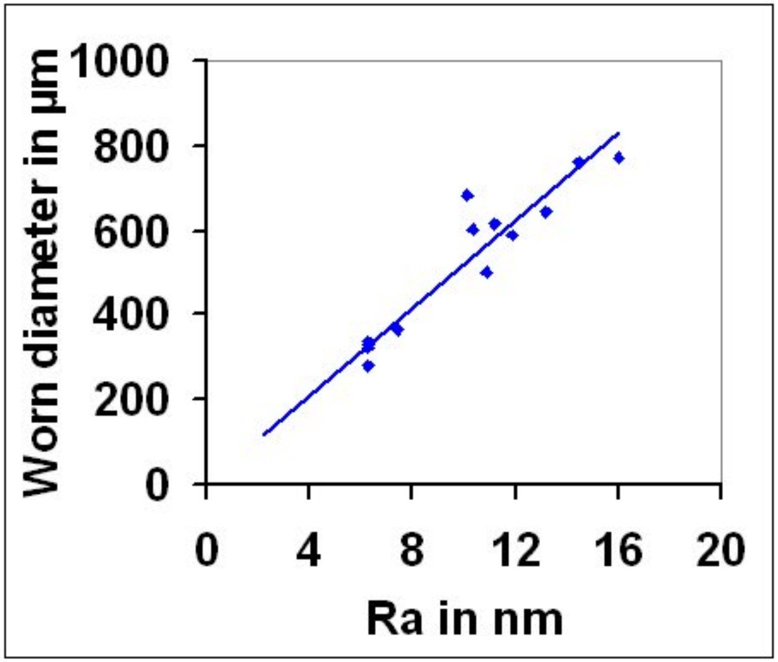
In ball/flat tribology test (or cylinder/flat), the ball is more worn than the flat sample because of the kinematics.

In the present case, the ratio of cinematic length between the ball and the flat surface is around 110. The lubrication regime can change along the test because of the wear on the ball, from boundary to mixed.

Applying DLC on the ball allows minimising its wear, keeping the contact pressure high. In addition, DLC wear rate can then be measured.

Effect of bad coating affectation (Steel ball/ DLC coated flat sample, oil : SAE 5W30)





Very low roughness of DLC (measured by AFM)

⇒ Very large differences in wear diameter on steel ball at the end of test.

Experimental domain

Tested coatings :

- a-C:H : CERTESS DCX (HEF coating)
- taC 1 : arc evaporation
- taC 2 : filtered arc evaporation

Oils :

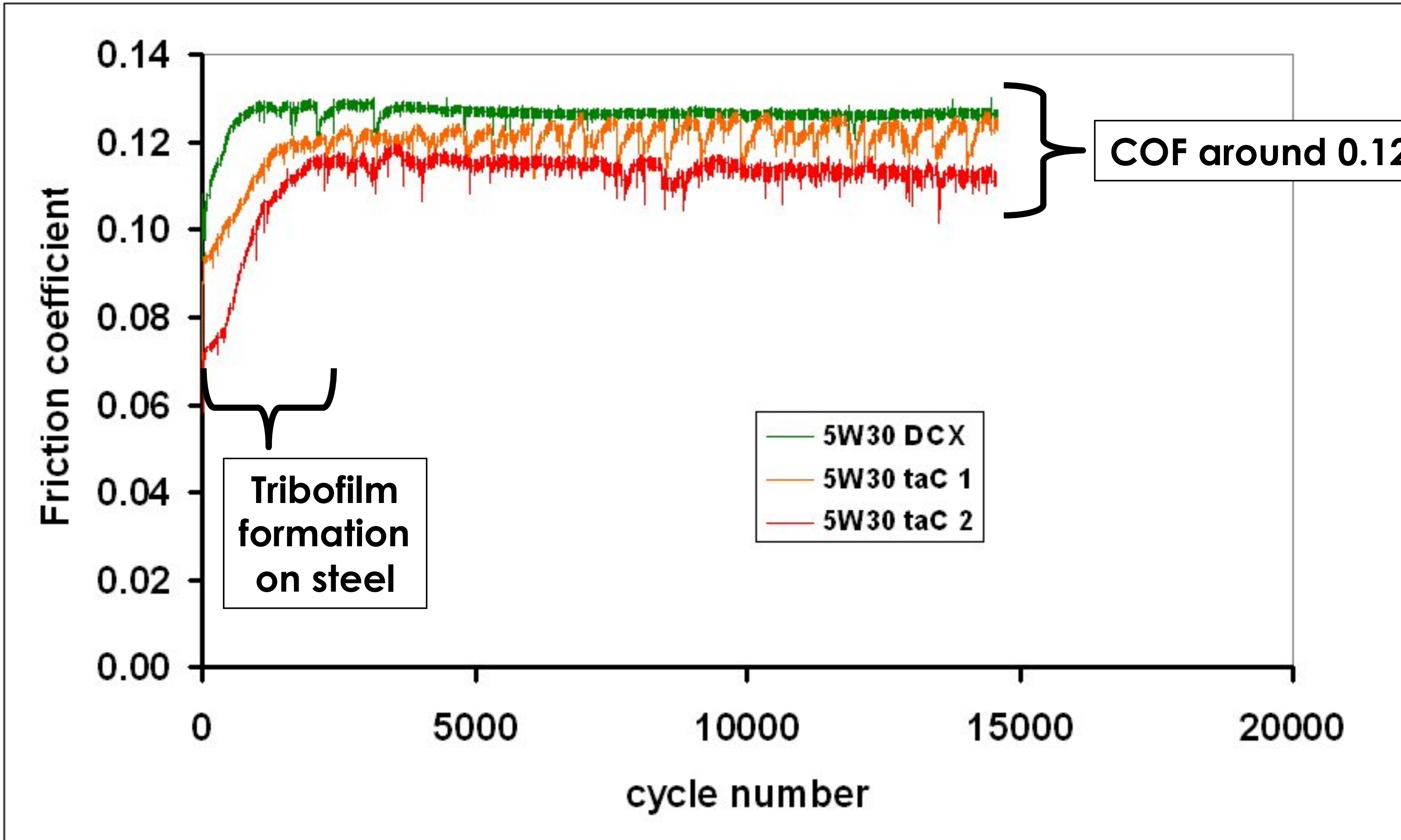
- SAE 5W30
- 150NS
- PAO 6
- PAO 6 + 1 % GMO

	a-C:H	taC 1	taC 2
E' (GPa)	200	350	330
Hv (kg.mm^{-2})	3000	4600	5500
Abrasive wear rate a.u.	1.00	0.74	Not measured

Measurements :

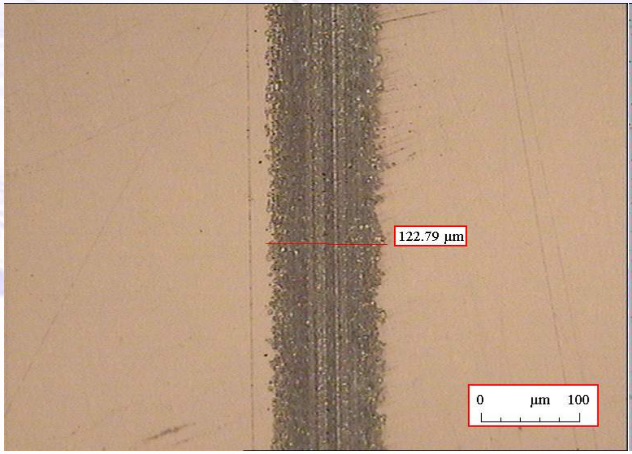
- Friction coefficient (COF)
- Wear scare diameter on the DLC coated ball

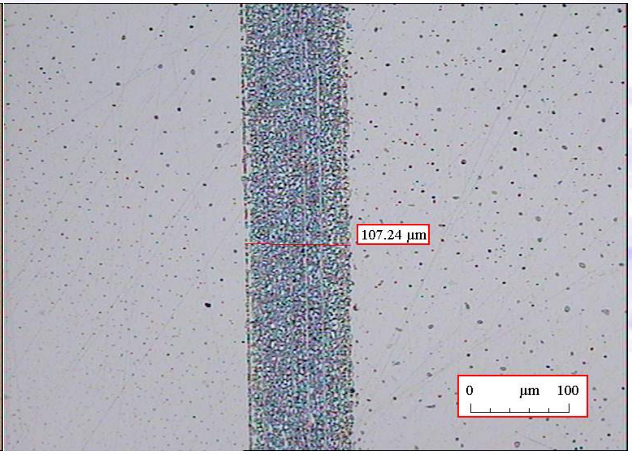
SAE 5W30 oil at 110 °C



Examination SAE 5W30 / interpretation

Friction track on steel

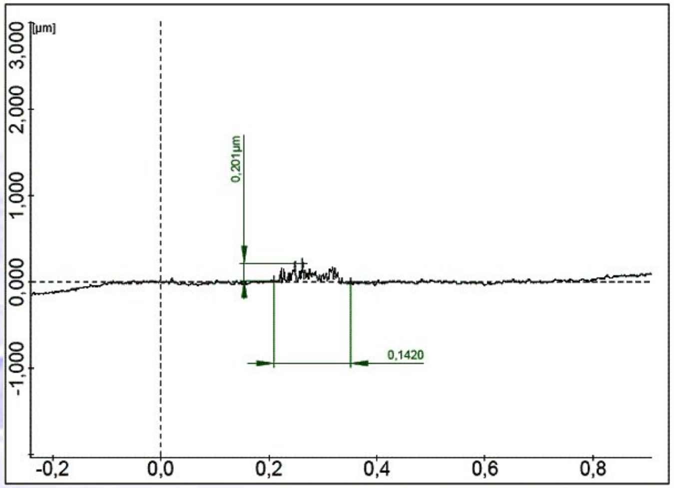




Against DCX coated ball **Against taC1 coated ball**

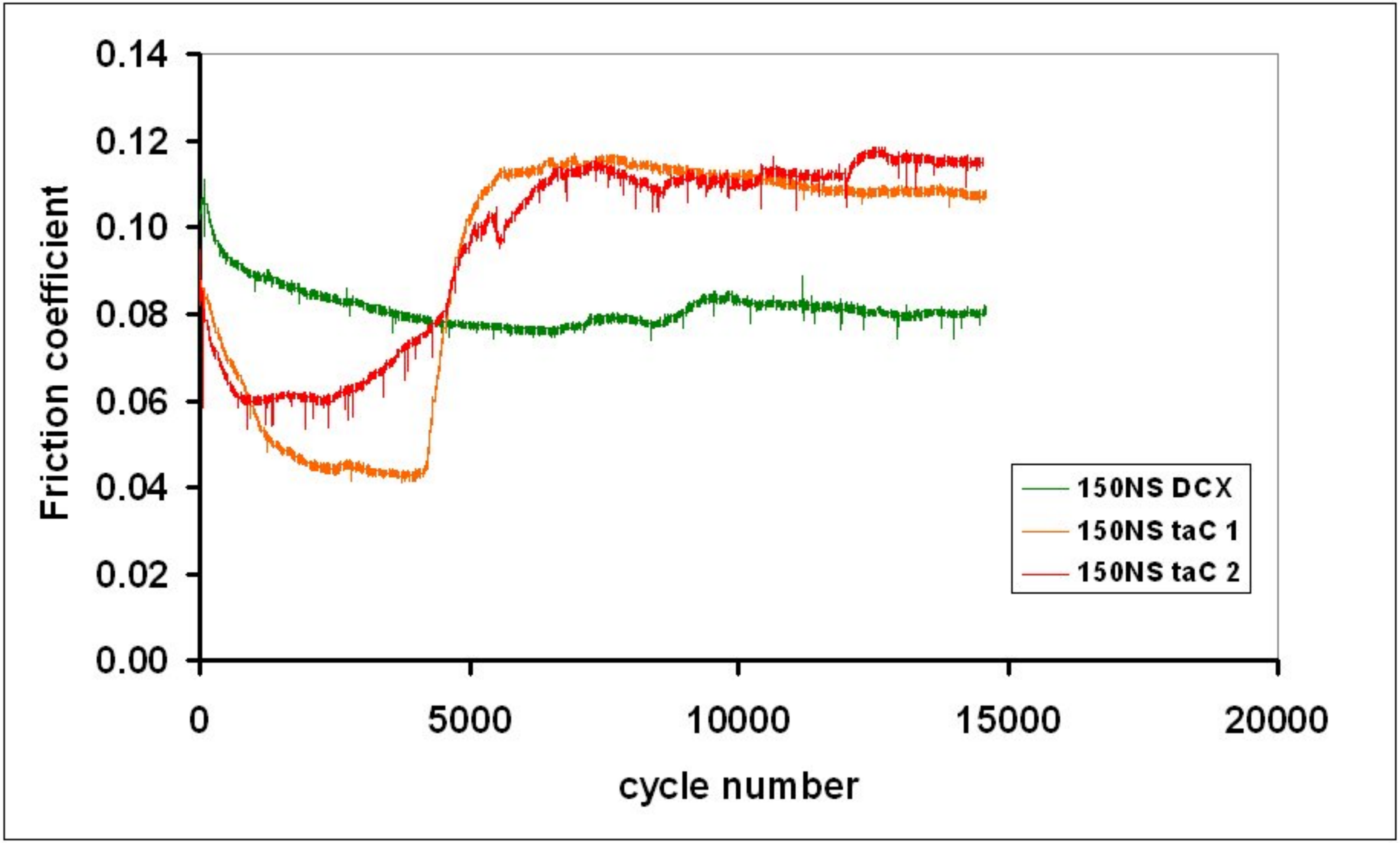
In all cases, the antiwear tribofilm forms on steel

=> at the beginning of test, steel / DLC contact
COF < 0.10
=> along the test, antiwear film / DLC contact
COF # 0.12



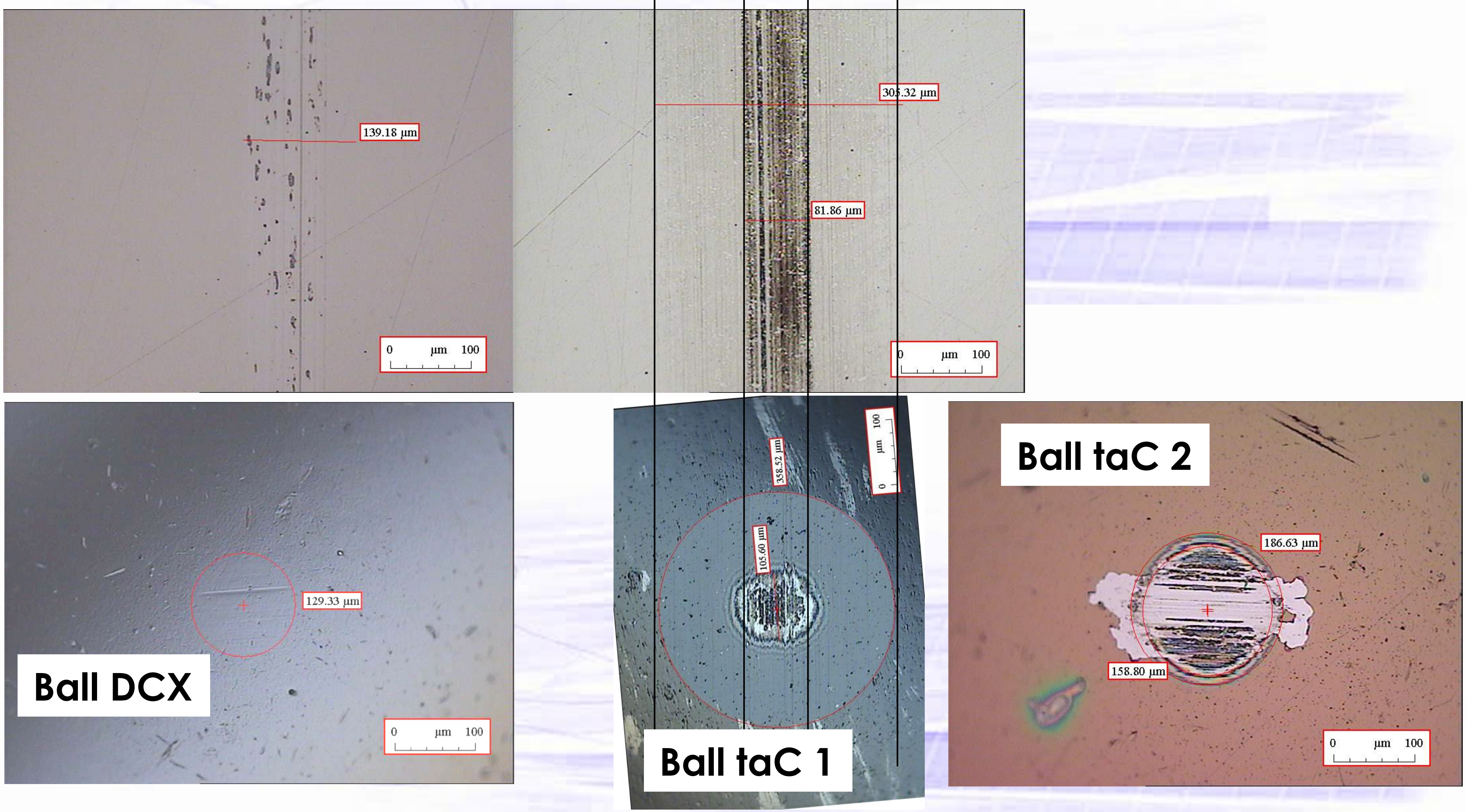
=> antiwear tribofilm on steel increases the roughness

150NS oil at 110 °C



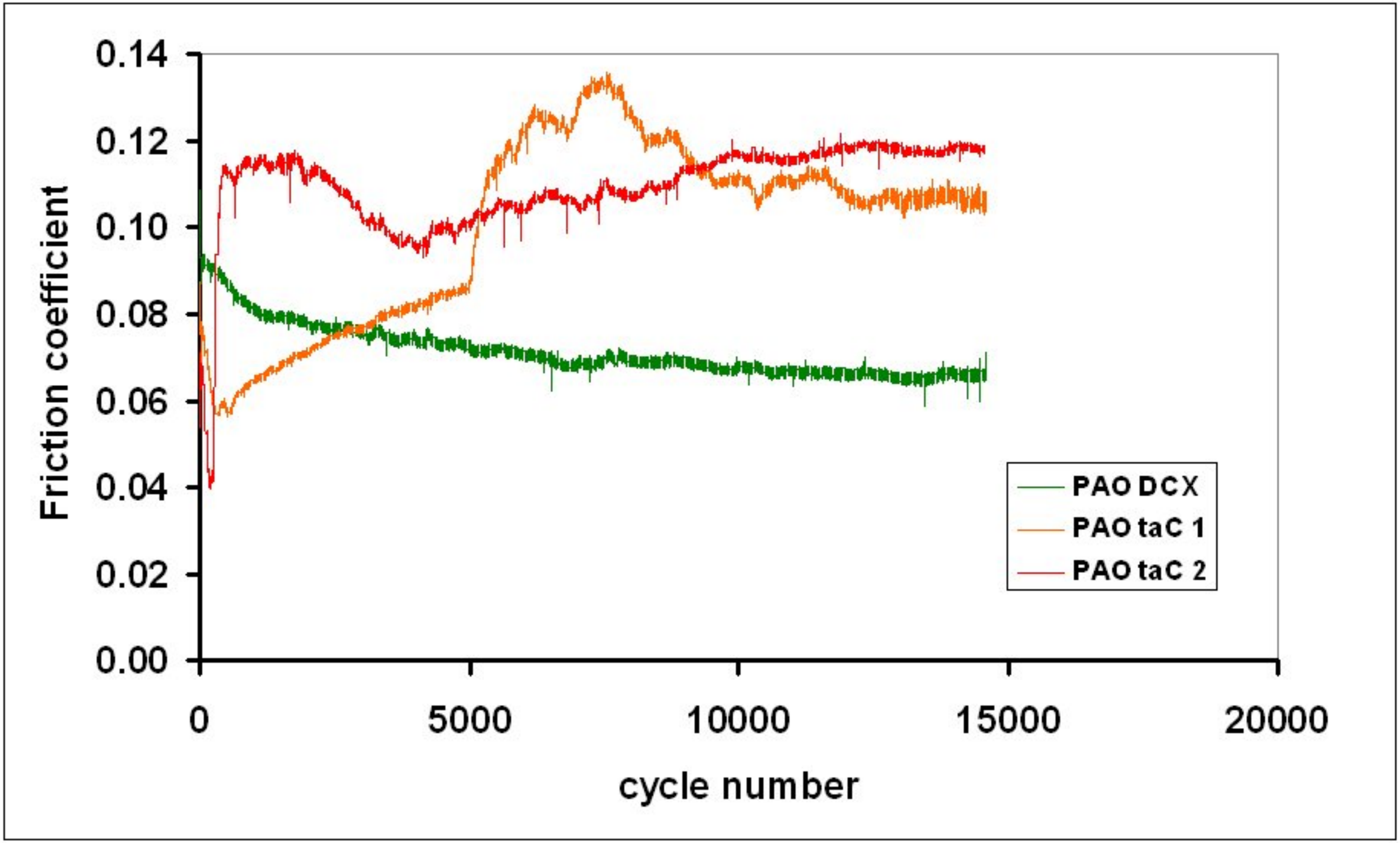
Examination 150NS / interpretation

Friction track on steel



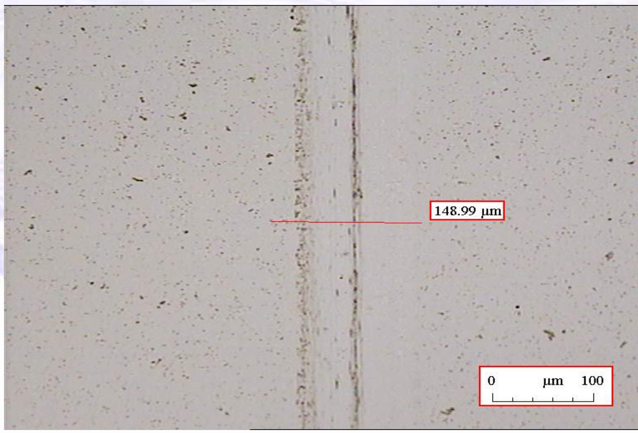
taC 1 and 2 are completely worn, as if they were polished by fine abrasive particles. taC 2 also presents some flaking.

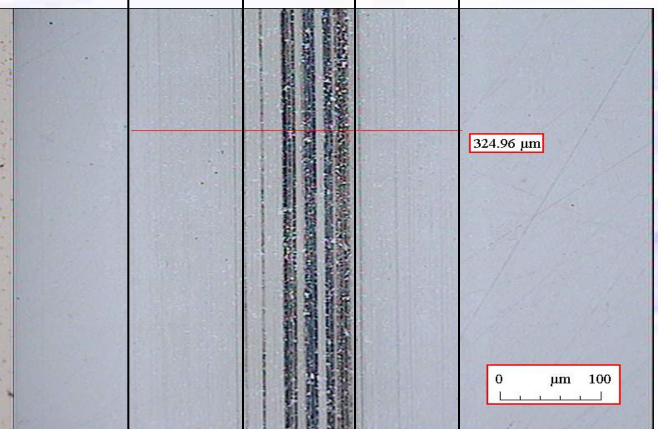
PAO oil at 110 °C



Examination PAO / interpretation

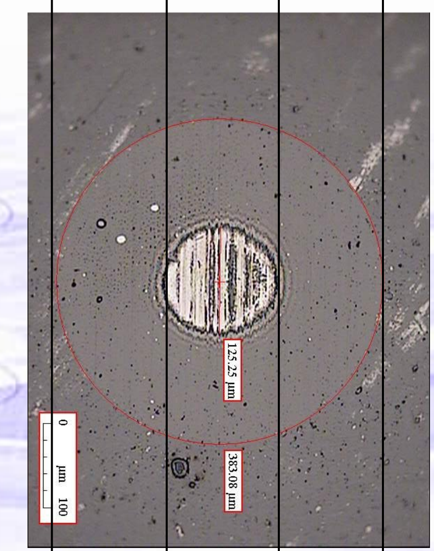
Friction track on steel





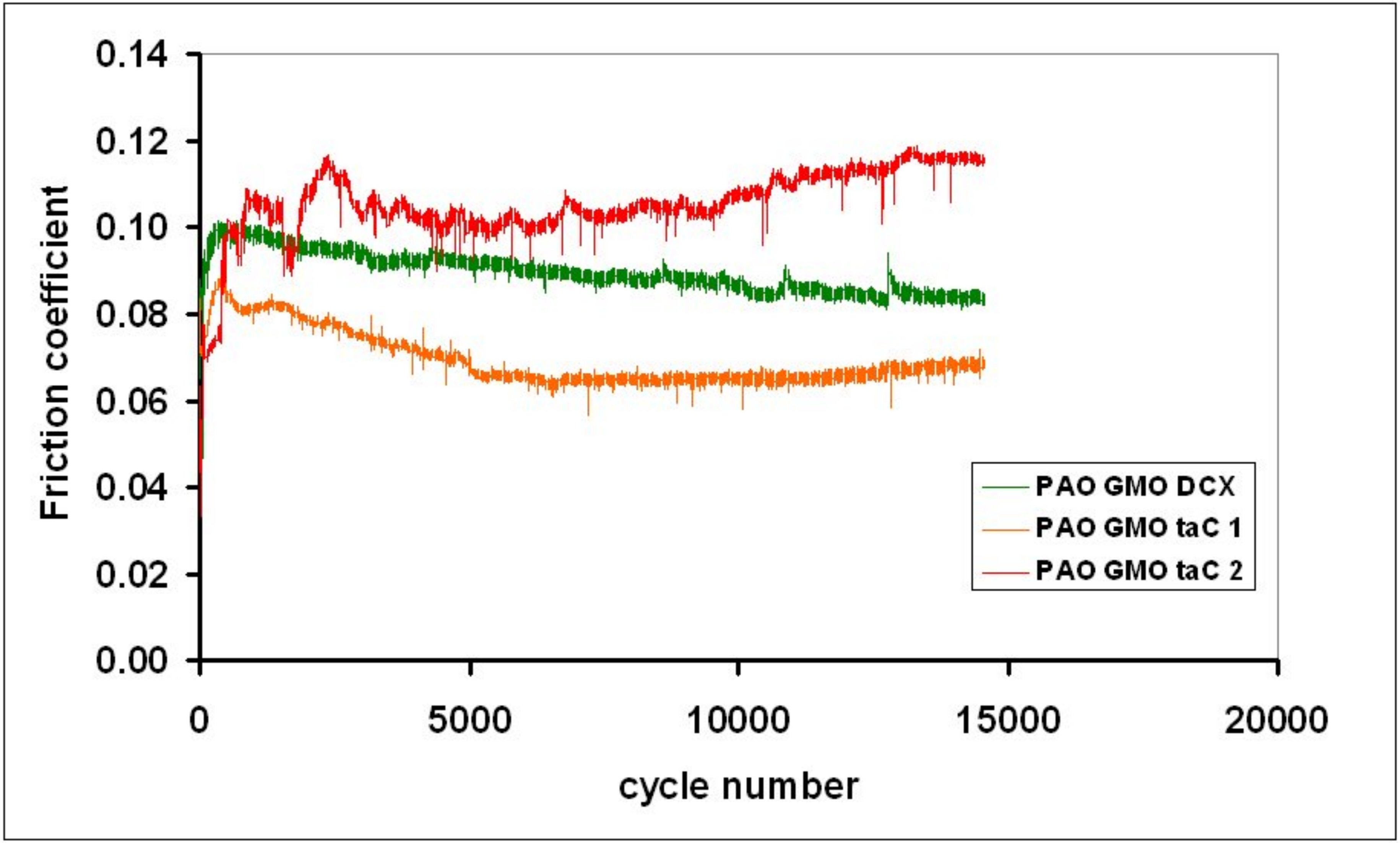
Against DCX coated ball

• taC 1 and 2 are completely worn as in 150NS oil



Ball taC 1

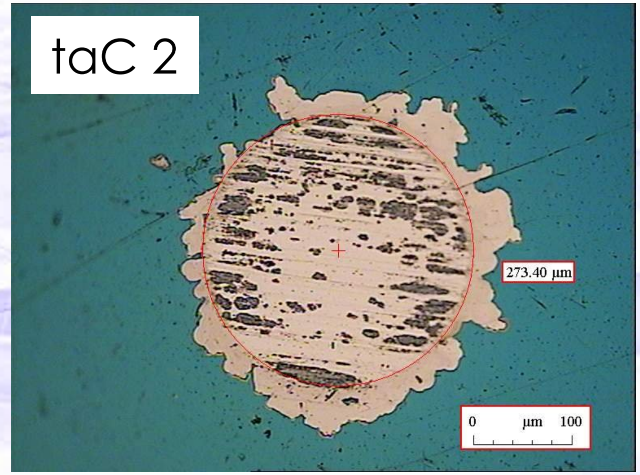
PAO oil + 1% GMO at 110 °C



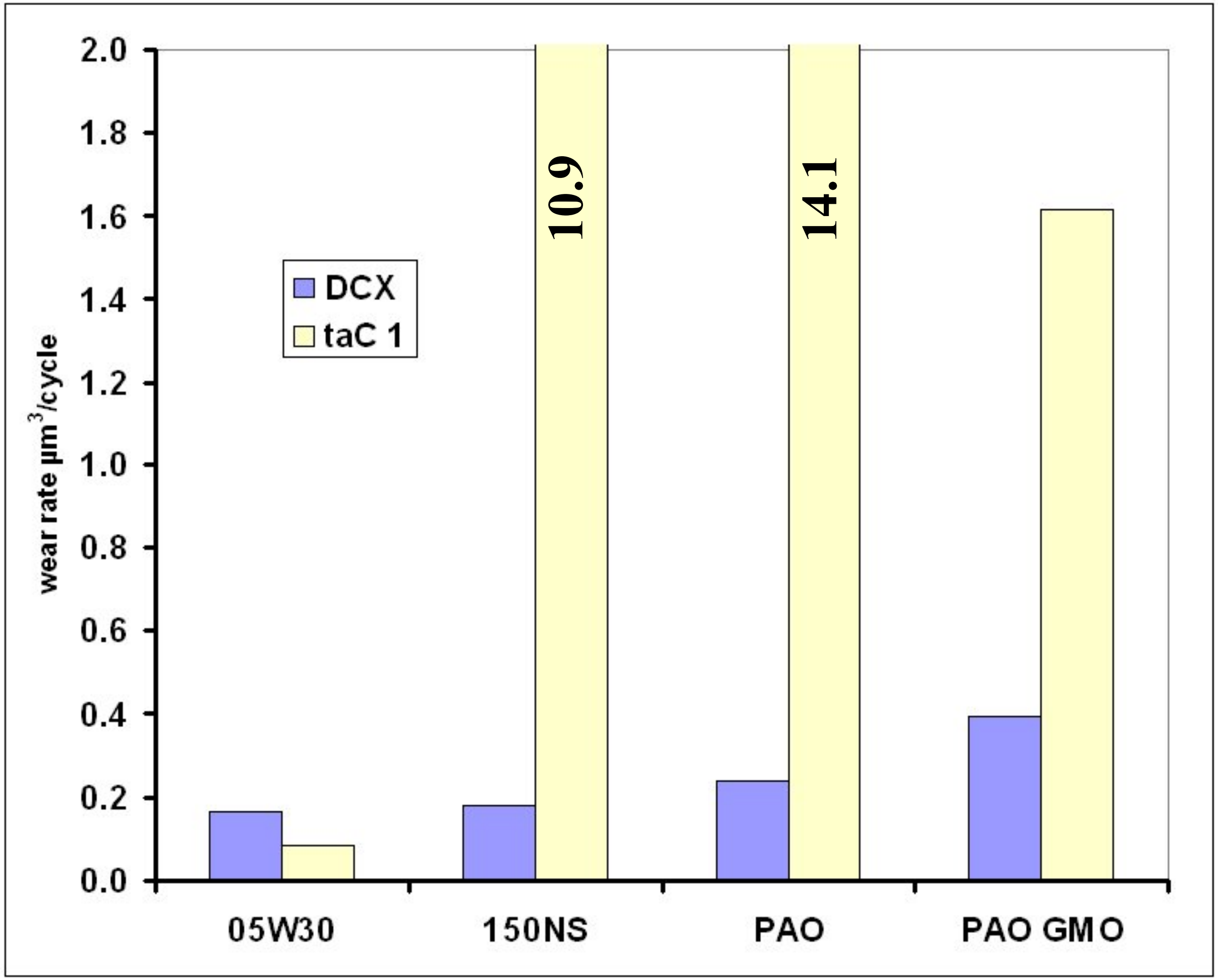
Examination PAO GMO/ interpretation

Friction track on steel

- nothing specific to observe on the DCX and the taC 1
- taC 2 as flaked off



Wear of the ball : calculated wear rate



Volume calculation :
- diameter measurement on the ball
Hypothesis : flat wear
- calculation of the worn height
=> calculation of the volume

- **The wear rate of the coatings is not correlated to the hardness of the coating.**
- **Strong influence of oil composition.**

Conclusions

• COF in SAE 5W30 and wear rate is similar for the tested coatings.

• Antiwear additives in SAE 5W30 are detrimental to the COF of DLC coatings. The COF increases during the phase of tribofilm formation on steel.

• The taC coatings are surprisingly severely worn in oils without additives (150 NS or PAO 6).

• a-C:H coatings are much less worn and show COF much lower than in SAE 5W30 (30 to 50 % lower)

• The addition of GMO to PAO have not shown supralow friction. The COF was even slightly higher. For taC coatings, the addition of GMO to PAO seems to reduce its wear rate, while it tends to slightly increase it for a-C:H.

• It is important to optimise the COF, but it must not be detrimental to the wear rate of the DLC, some tribochemical wear has been evidenced.

Outlook

Oil including friction modifier