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CHAIN WEAR AND ELONGATION IN ELITE CYCLING: A PRELIMINARY STUDY

Rémi Aubert[1,2,4], Xavier Roizard[1,2], Fabrice Lallemand[2,3] et Frédéric Grappe[4]

[1]Université de Franche-Comté, CNRS, Institut FEMTO-ST, F-25000 Besançon, France

[2]Société AFULudine, F-39100, Dole, France

[3]Université de Franche-Comté, CNRS, Institut UTINAM, F-25000 Besançon, France

[4]Laboratoire Athlète Matériel Environnement (LAME), Centre de Performance Equipe Cycliste Groupama-FDJ, F-25000 Besançon, France

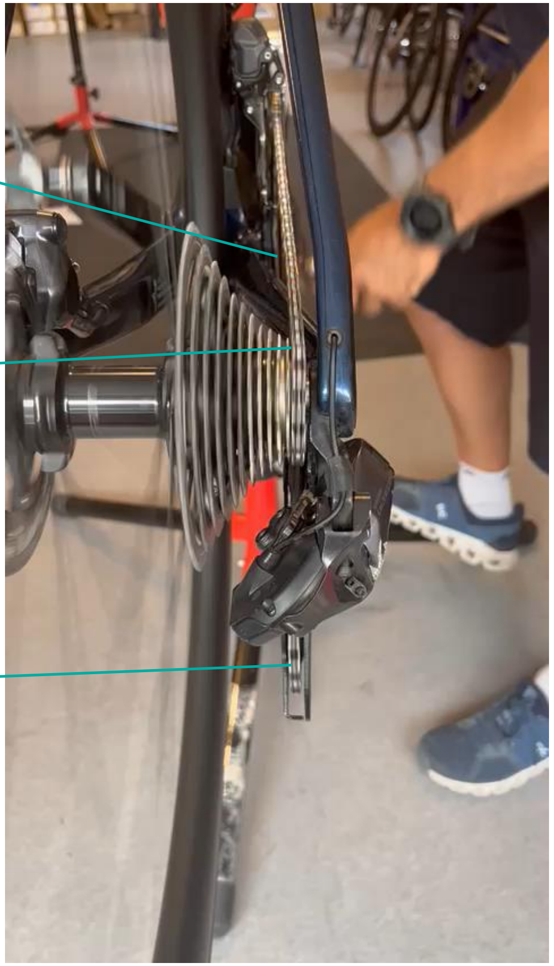
cnrs AFUludine UNIVERSITé DE FRANCHE-COMTé WINSLEEK BY AFULUDINE Groupama · FDJ ÉQUIPE CYCLISTE

Journey of a chain link

Chain velocity

Chain offset

Materials



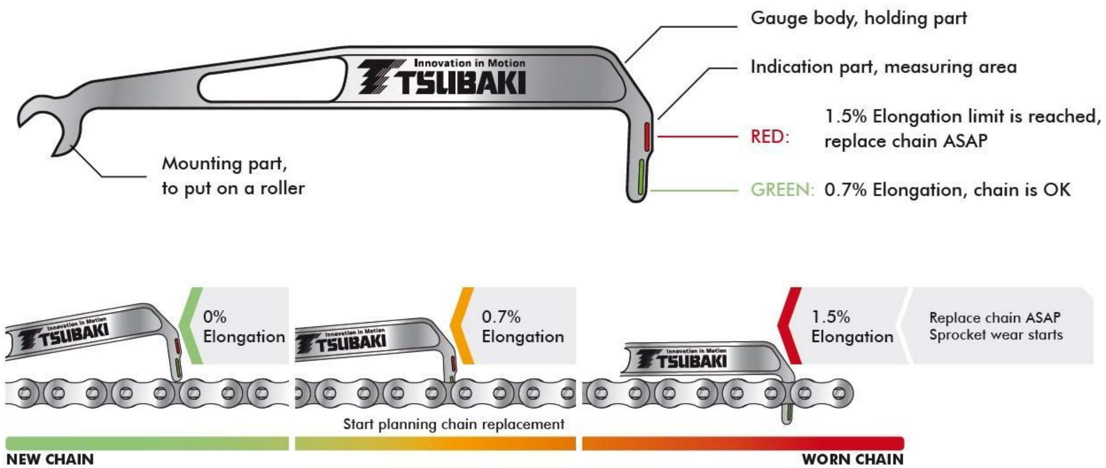
Ring size

Chain tension

Elongation ?

When is a chain worn out ?

zerofrictioncycling.com

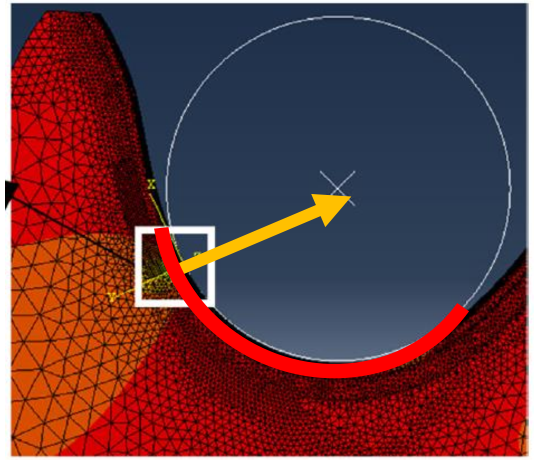


tsubaki.eu

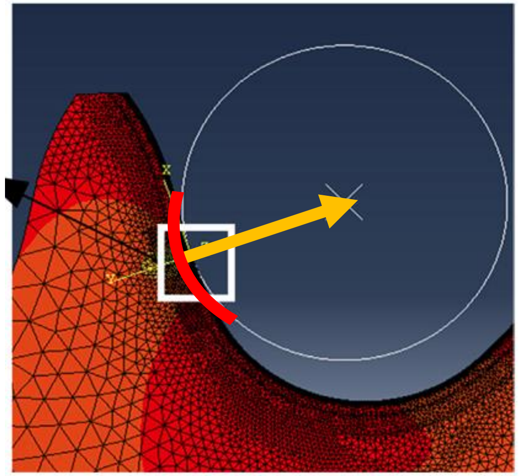
Why should I replace ?

Contact pressure increases with elongation

0% elongation



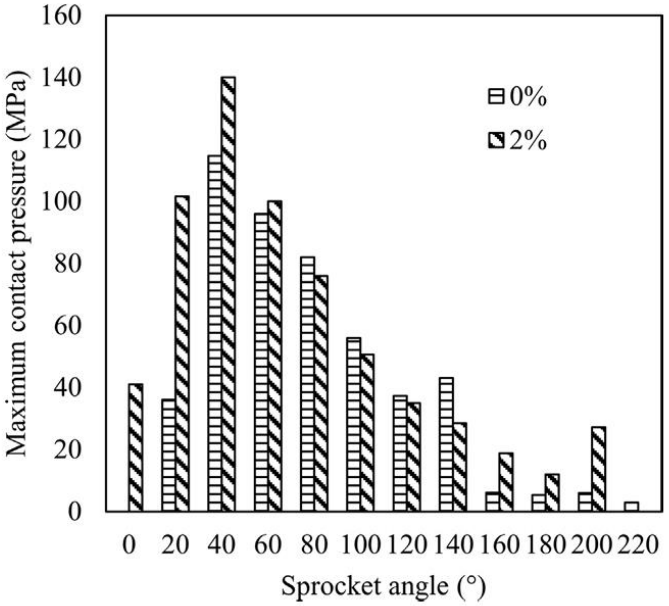
2% elongation



Contact Pressure (Pa) Normal force (N)

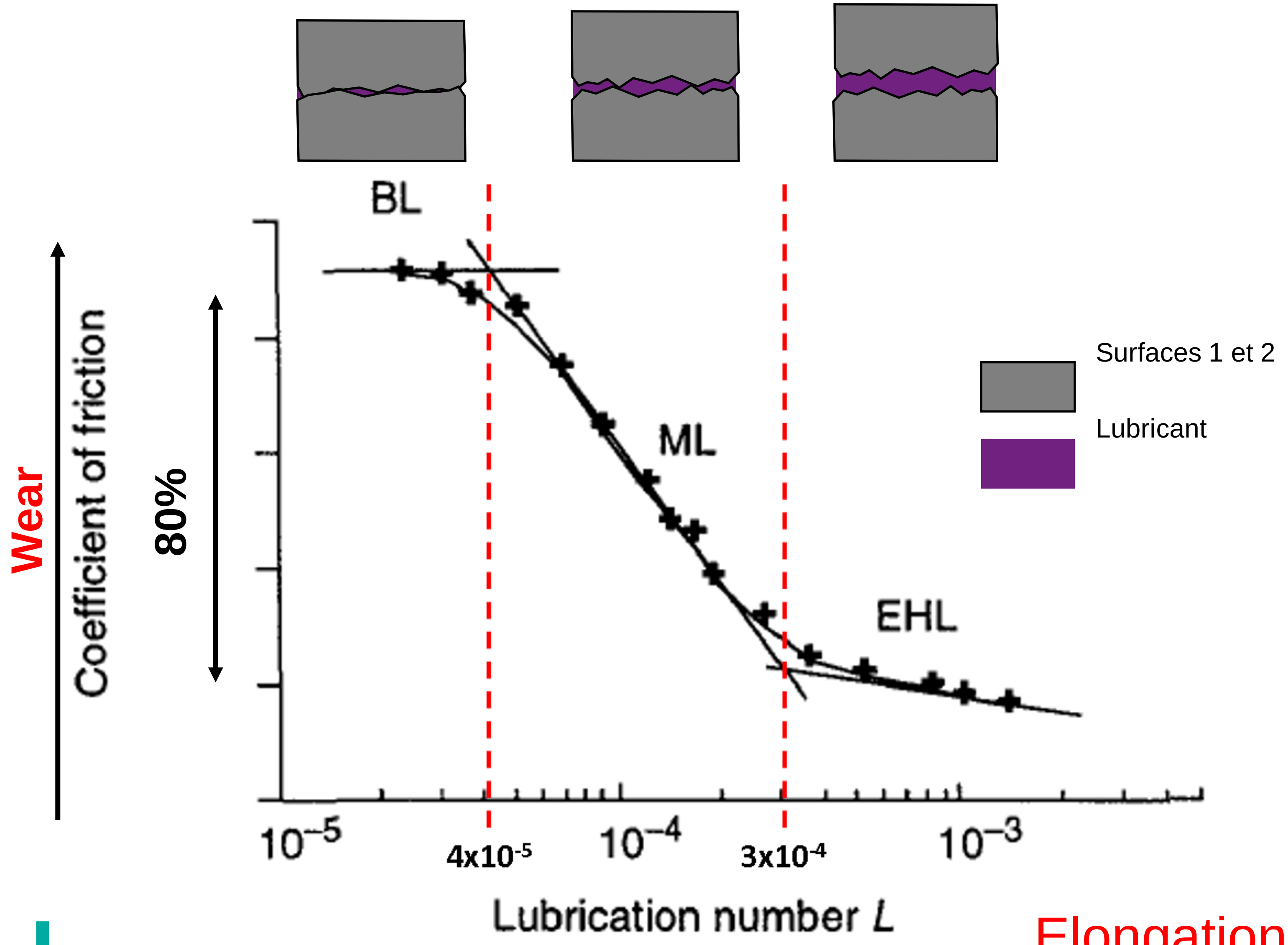
$$P = \frac{F}{A_c} = \frac{F}{L_c * w_c}$$

Contact length (m) Contact width (m)



Sivakumar et al. 2023

An increase in P results in higher elongation



Adapted from Schipper et al. 1995

$$L = \frac{S * \eta}{P * \overline{Ra}}$$

Sliding speed (m.s^-1)

f(cadence, gears, chain geometry)

Dynamic viscosity (Pa.s)

f(lubricant, environment)

Contact pressure (Pa)

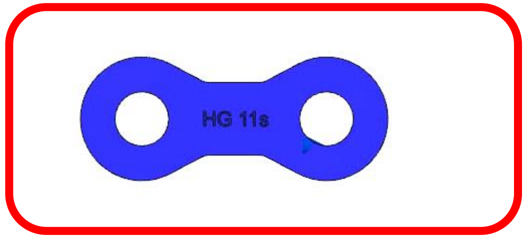
f(power, gear ratio, chain geometry)

Mean center-line average roughness of the surfaces (m)

f(chain material)

Elongation => higher P => higher elongation

Where does chain elongation come from ?

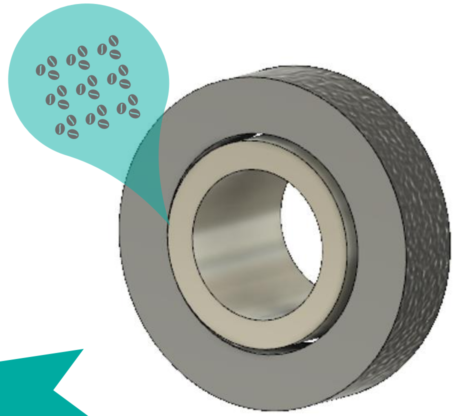


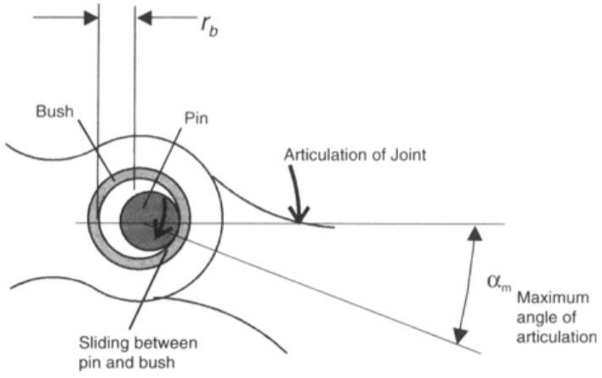
Drivetrain lifetime

Chain elongation

Friction

Shifting

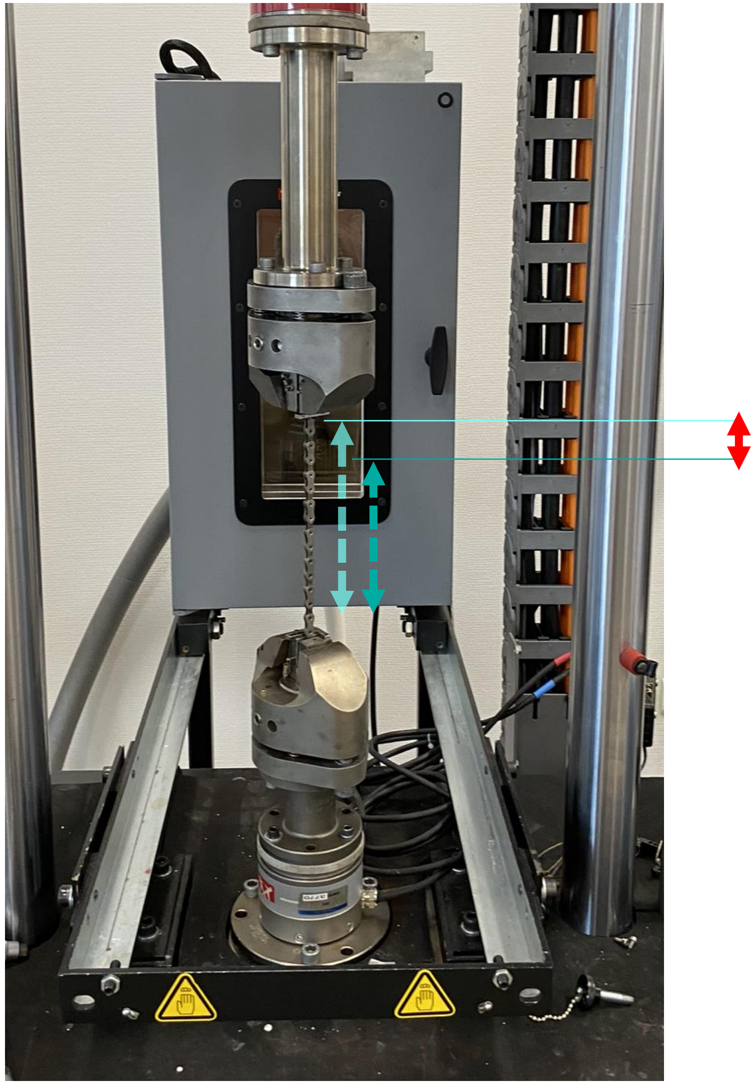


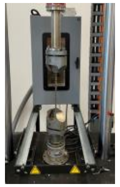


Burgess & Lodge, 2004

What are the mechanisms underneath ?

Measurement of fatigue plastic def.

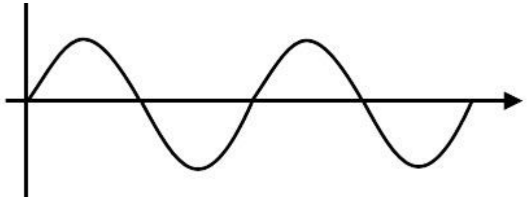




2000 km @250W – 90rpm

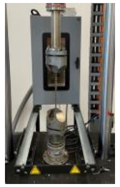
Fatigue tensile tests on Instron E10000 on 15 links

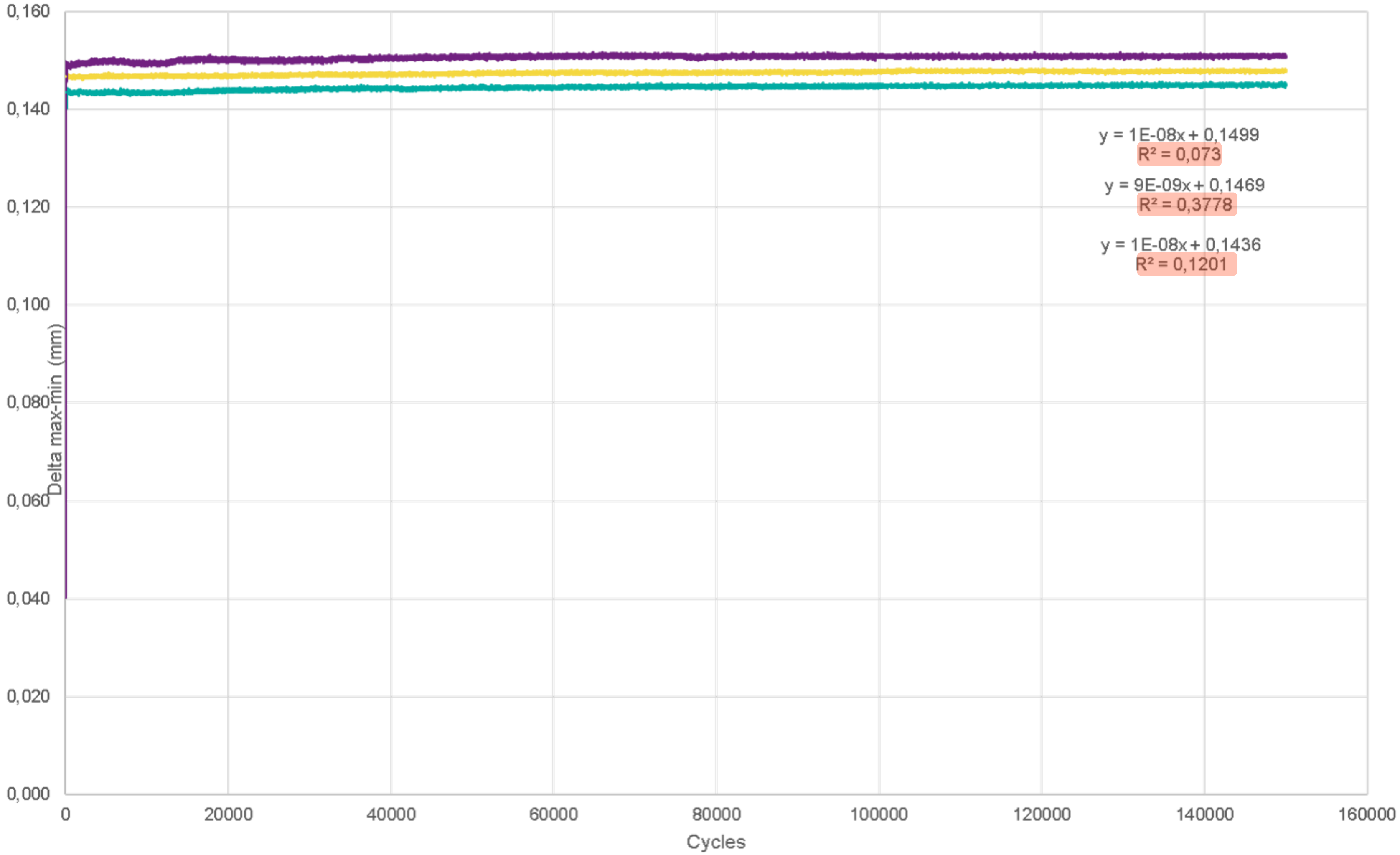
150 000 cycles @Tension 20 N ~> 250 N – Frequency 0.6 Hz



The difference between max and min jaw distance is measured = plastic deformation induced by fatigue

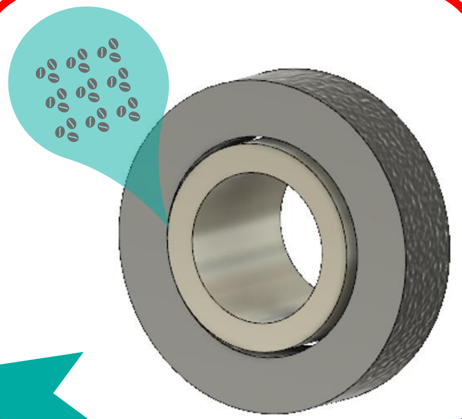
Fatigue induced plastic deformation vs chain cycles





$$\Delta_{l150k} \approx 1\ \mu m < 0.001\ \%$$

Where does chain elongation come from ?

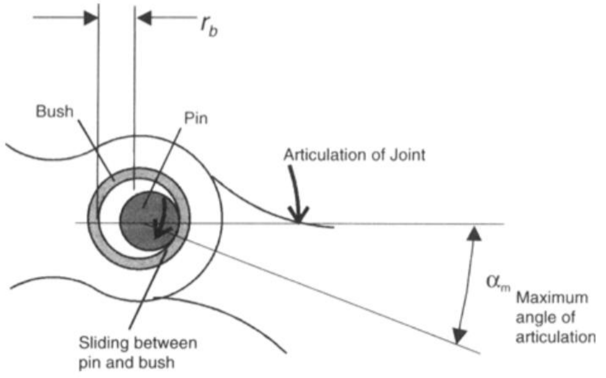


Drivetrain lifetime

Chain elongation

Friction

Shifting



Burgess & Lodge, 2004

What are the mechanisms underneath ?

Chain elongation in riding conditions : protocol

12 high level riders (mostly Groupama-FDJ CT) ; 6 are presented here.

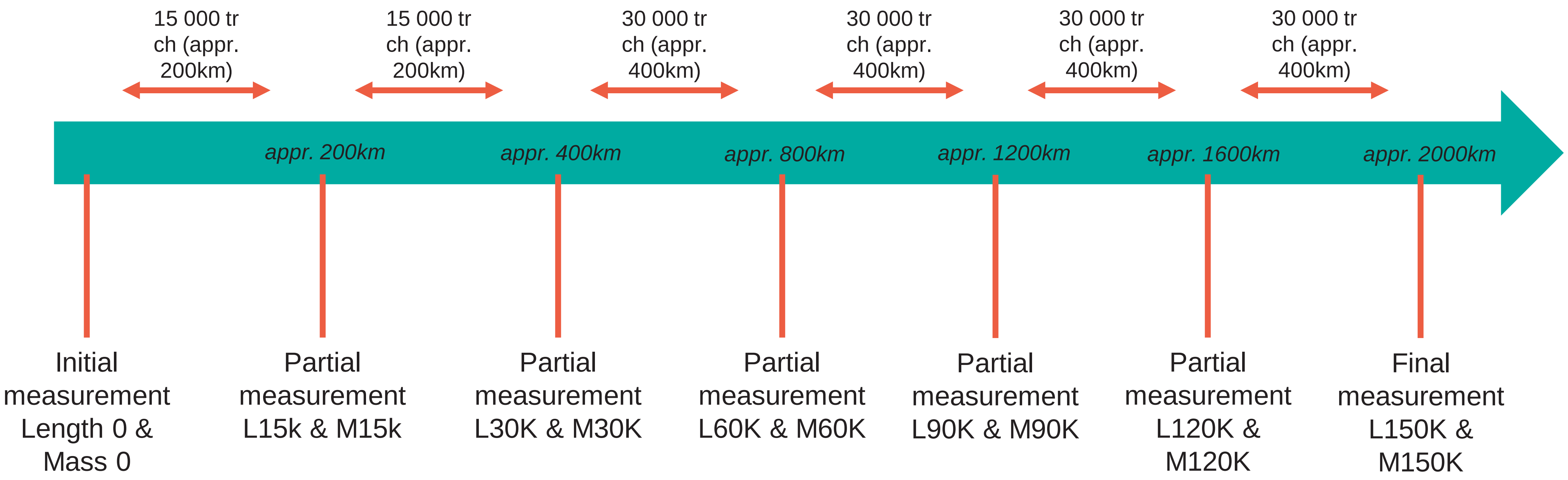
6 identical chains (Shimano MT9100, Shimano, Japan)

Weather, type of training, lubricant application were controlled

- Distance (km)
- Time (s)
- Power output (W)
- Cadence (rpm)
- Front gear
- Rear gear

Cadence (rpm) + Front gear → Nb of chain cycles

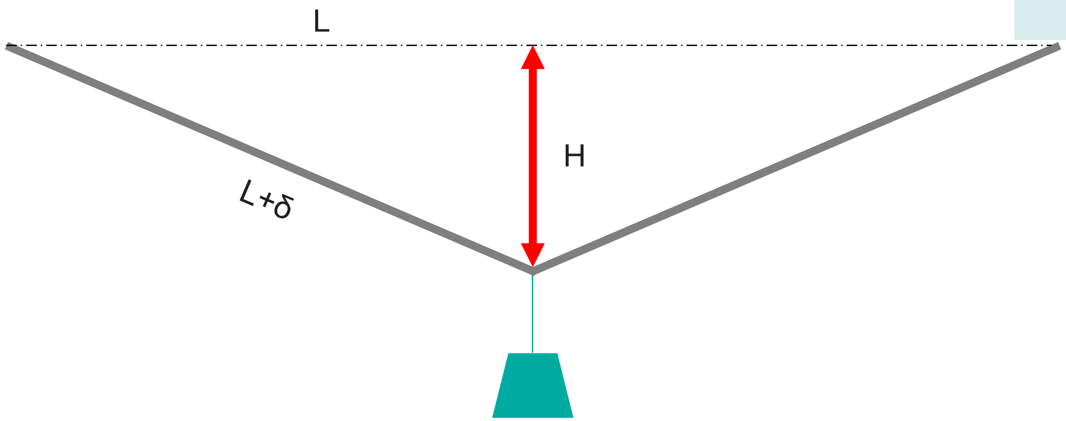
Chain elongation in riding conditions : protocol



=> @ each measure -> Ultrasonic degreasement ; lubrication.

Chain elongation in riding conditions : measurements

Chain elongation (precision 0.0005 mm) through chain sag



$$H = \sqrt{2L\delta + \delta^2} \gg \delta$$

$$\Delta L = 2\delta = 2\sqrt{L^2 + H^2} - L$$

Mass (precision 0.001 g)

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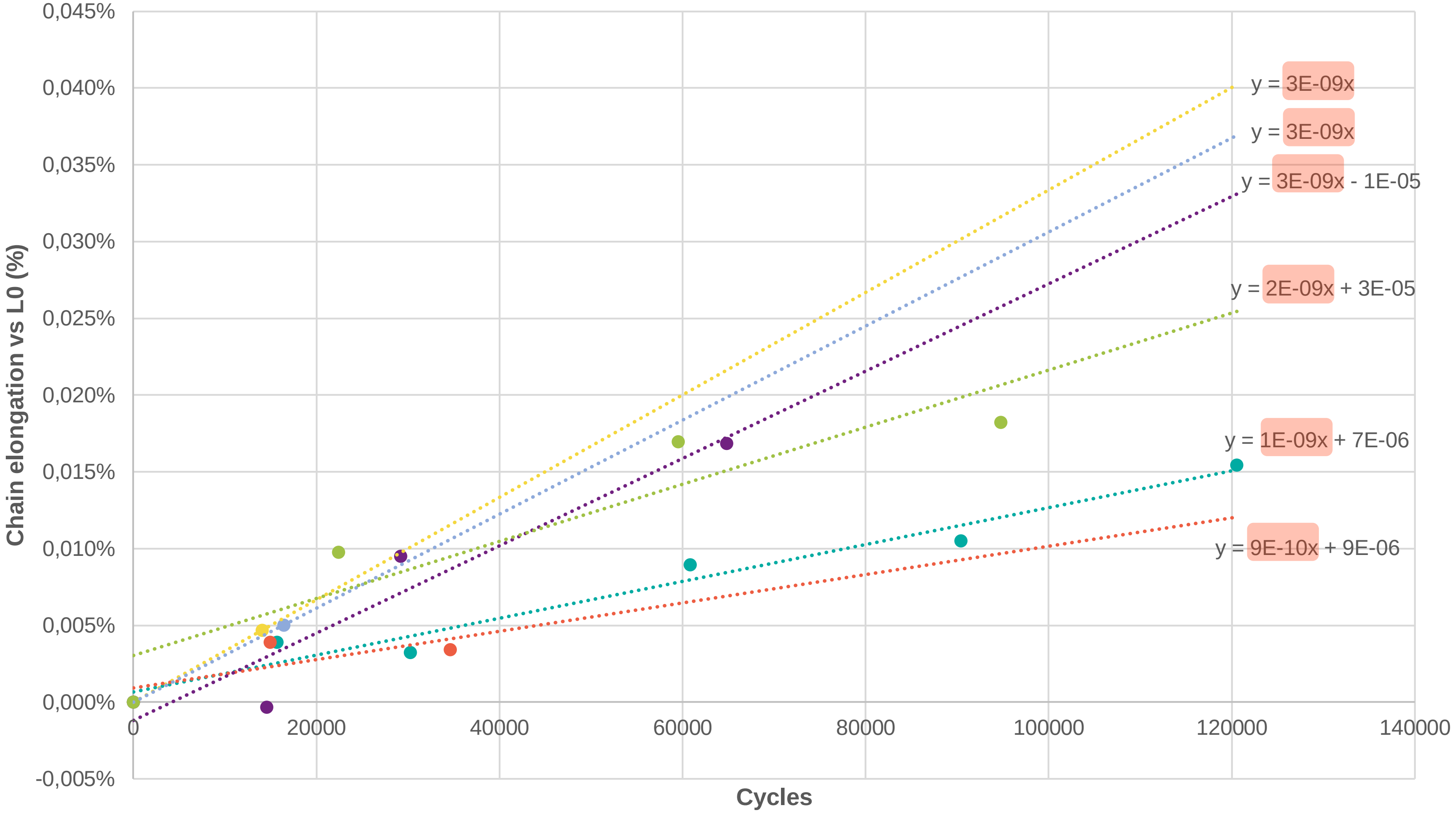
Chain elongation vs chain cycles



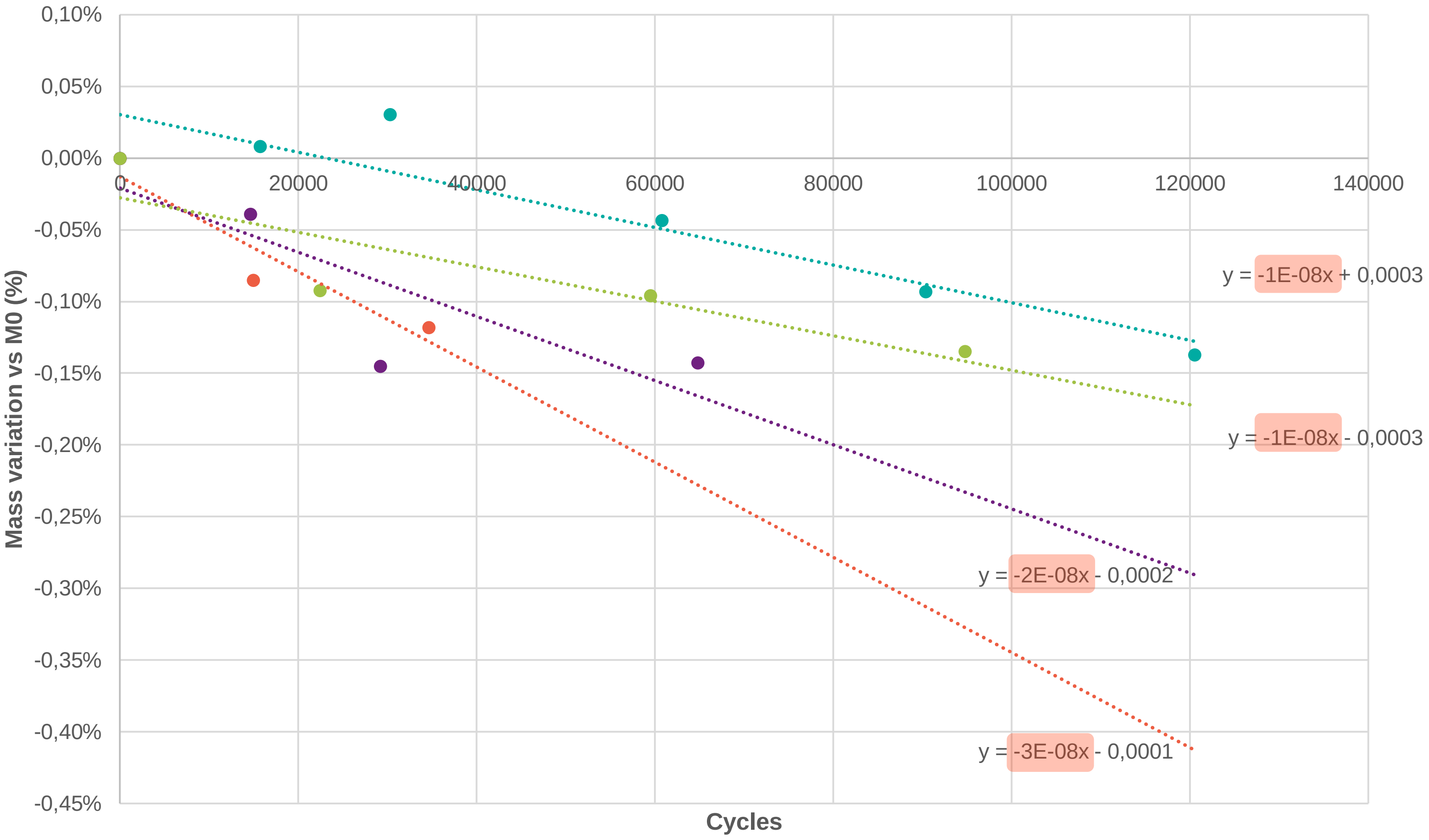
Results : chaque pente

$$\overline{Slope} = 2.2\,E(-09) \pm 1.0E(-09)$$

$$\Delta_{l150k} \approx 260\ \mu m > 0.03\%$$

$$\Delta_{150k}(cycling) \gg \Delta_{150k}(plastic\ def)$$

Mass loss vs chain cycles



$$\overline{Slope} = 1.8\,E(-08) \pm 0.8E(-08)$$

$$\Delta_{m150k} \approx -0.6g \approx 0.27\%$$

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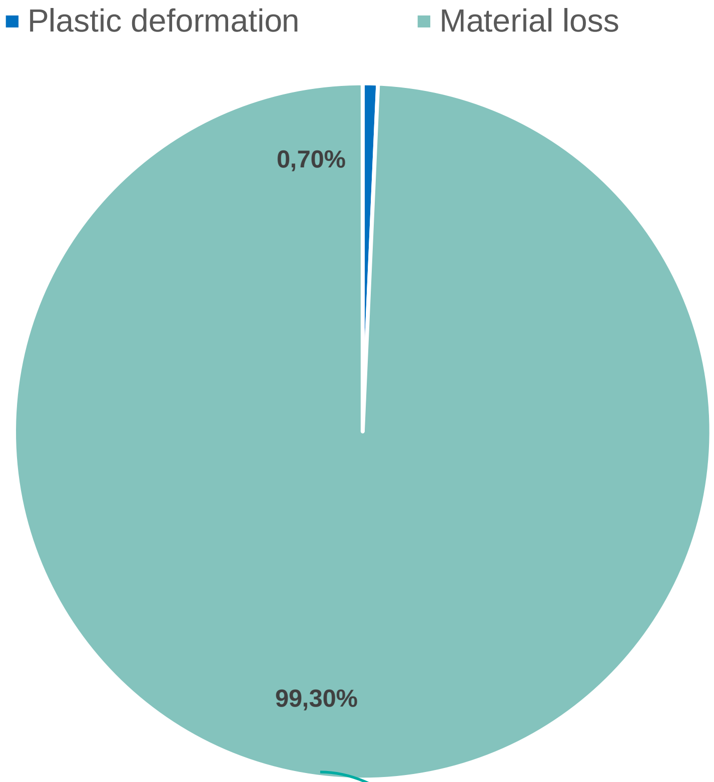
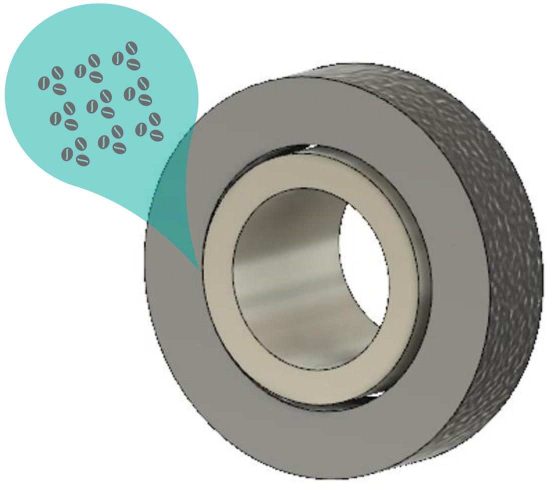
Material loss is predominant…





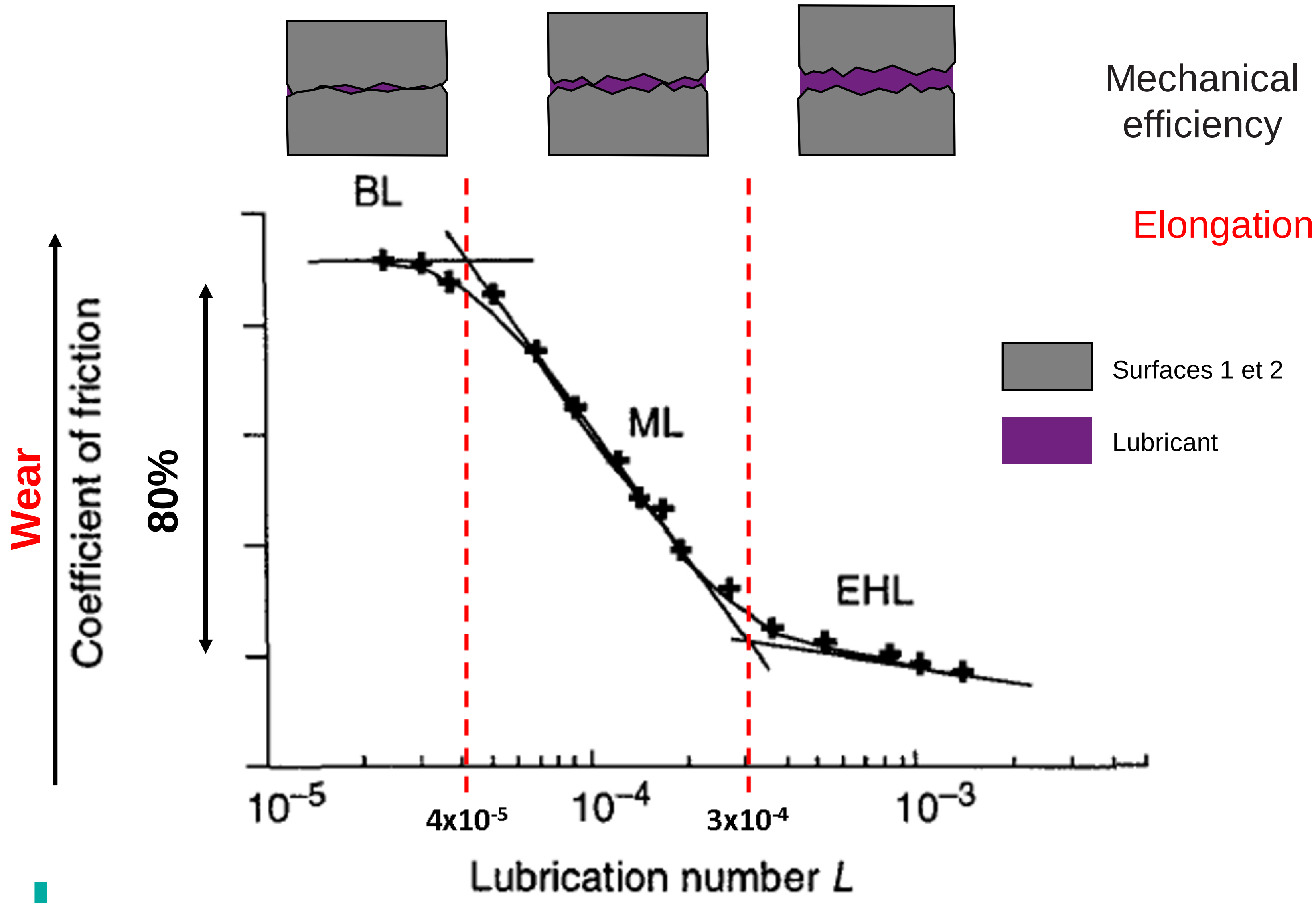
Predominant mechanism

99.3%... of 0.03% !

~ no wear for 2000 km

How can a lubricant reduce wear ?

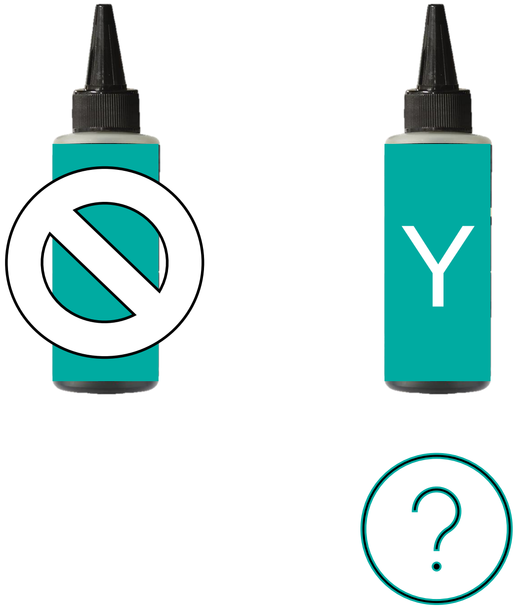
Appropriate lubricants can avoid wear



Adapted from Schipper et al. 1995

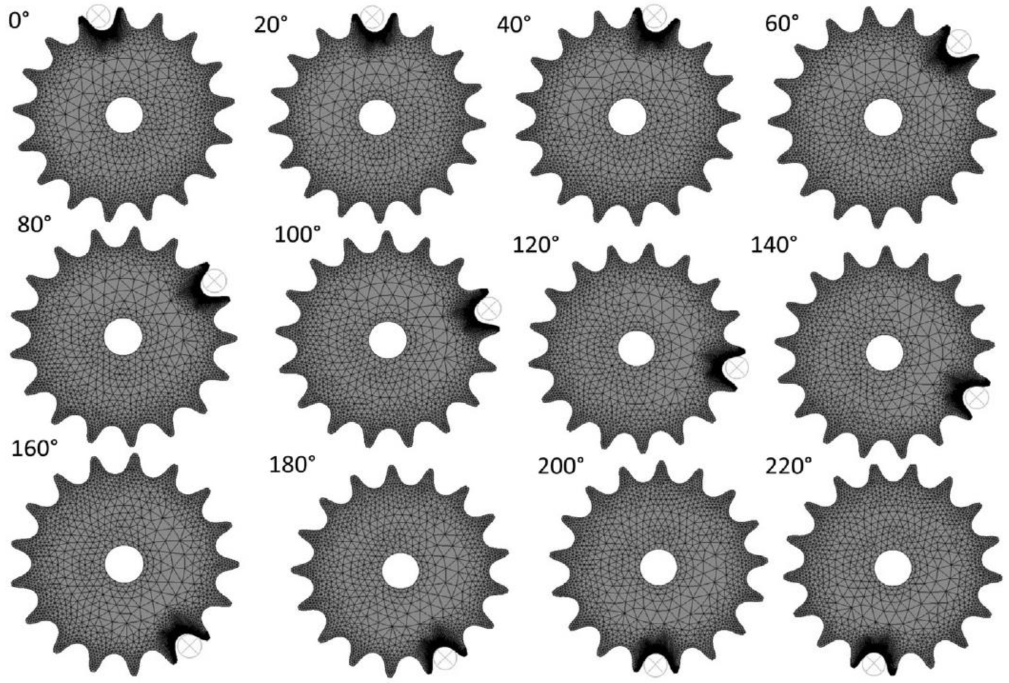
Mechanical efficiency

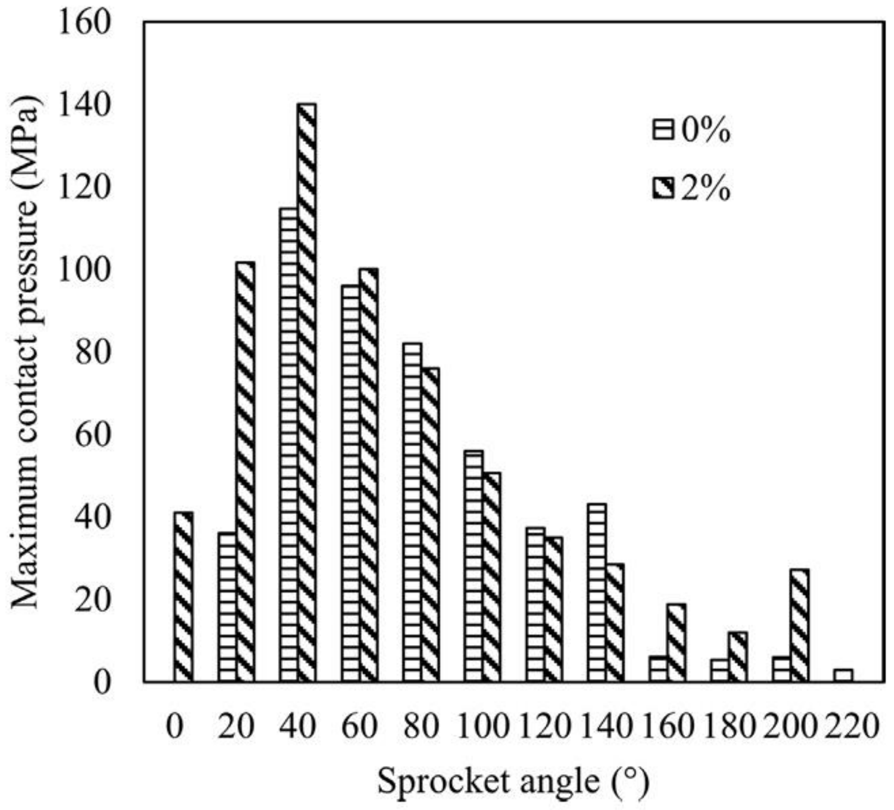
Elongation



Thanks for listening, hope you have questions !

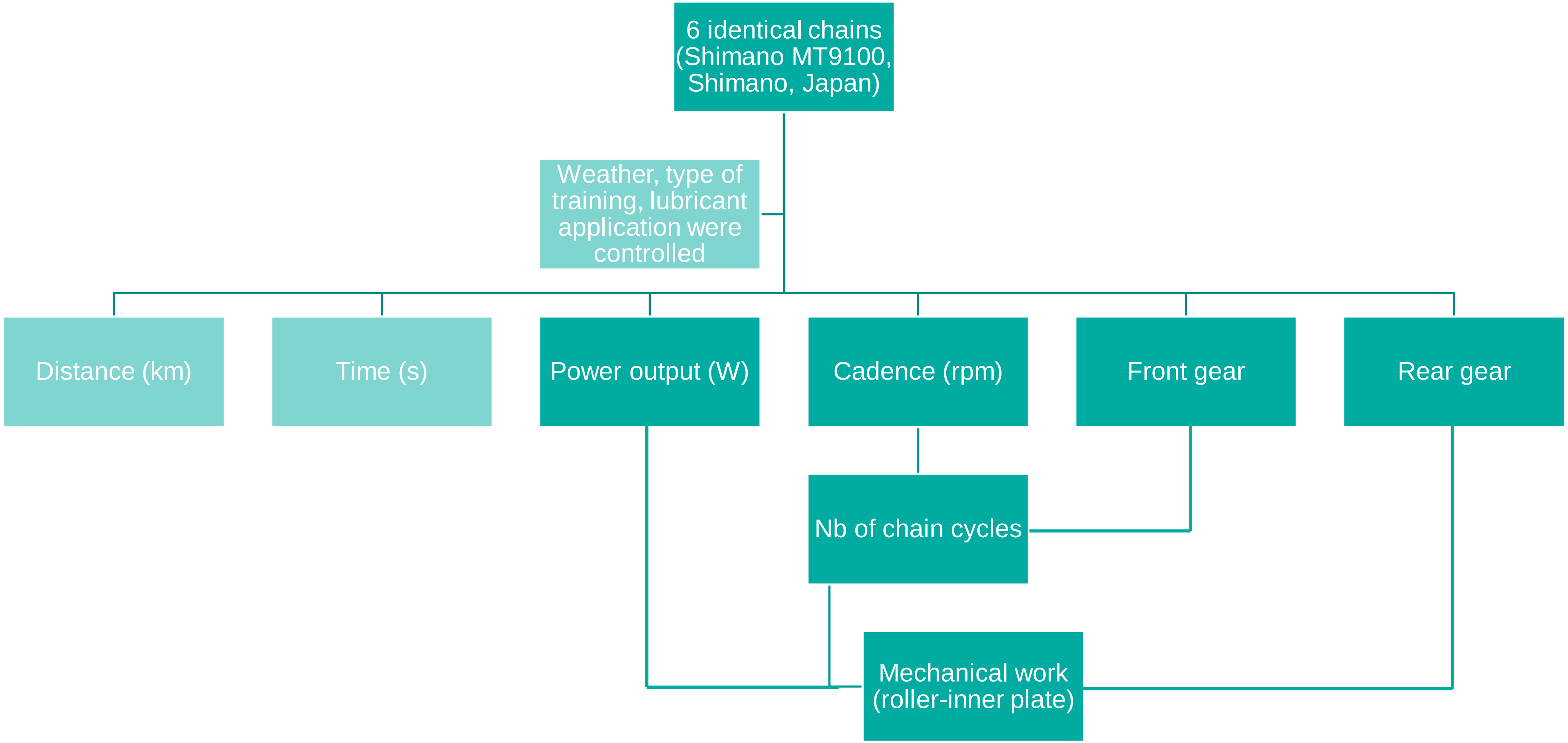
Further : Sivakumar et al. 2023



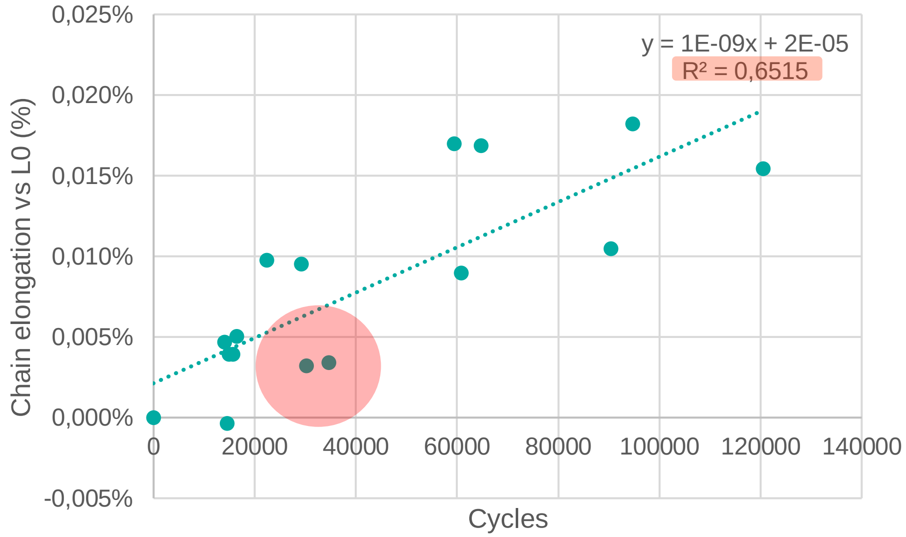


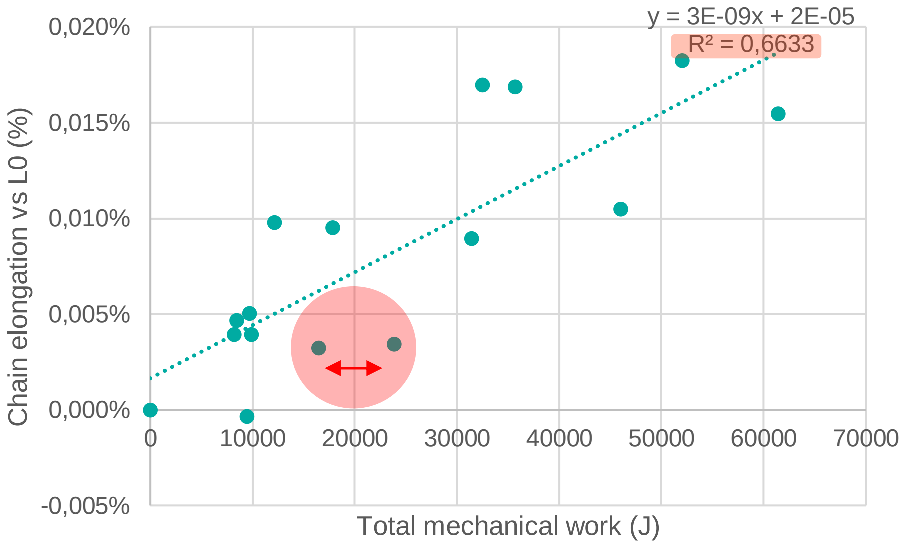
Sivakumar et al. 2023

Further : mechanical work



Further : mechanical work





$$W = Fn * D_{fr} = \sum Fn(t) * 2 * \left(\frac{\Pi_{roller}}{Nt_{sprocket}(t)} + \frac{\Pi_{roller}}{Nt_{chainring}(t)} \right) * Cycles(t)$$