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► **To cite this version:**

Vincent Strubel, Nicolas Fillot, Fabrice Ville, Philippe Vergne, Alexandre Mondelin, et al.. Hybrid Rolling Element Bearings: a New Answer Facing the Problem of Debris Entrapment . STLE 70th Annual Meeting, May 2015, Dallas, United States. hal-01185859

HAL Id: hal-01185859

<https://hal.science/hal-01185859v1>

Submitted on 27 Nov 2015

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Hybrid Rolling Element Bearings: a New Answer Facing the Problem of Debris Entrapment

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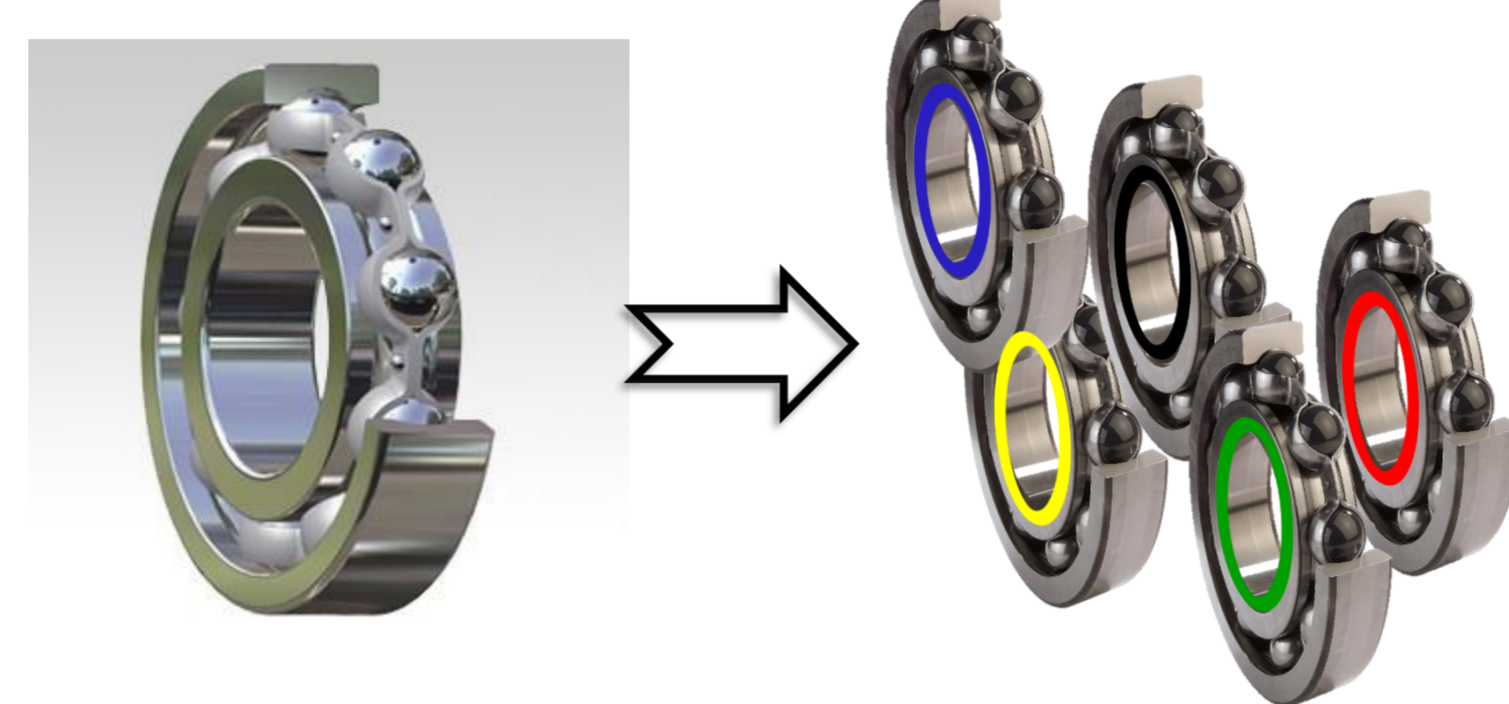
Context/Objectives



In the aeronautical domain, due to **high speeds** and **weight-saving**, **hybrid rolling element bearings (REBs)** are foreseen to replace classical steel REBs. They offer indeed many advantages including a **lower density**.

The **higher hardness** appears also as a preponderant feature to warranty integrity in contaminated lubrication.

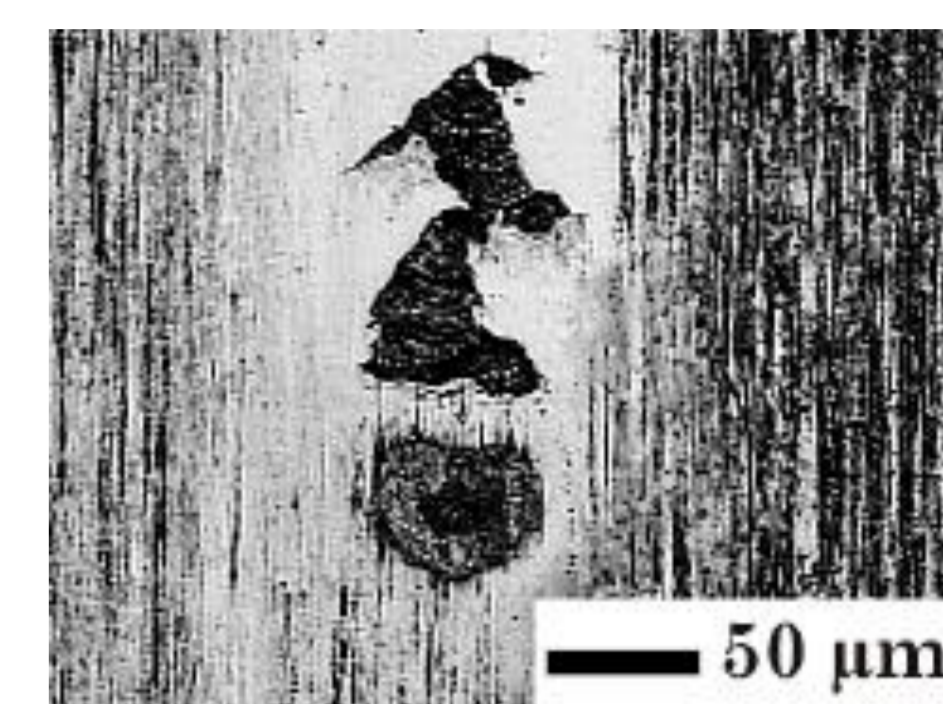
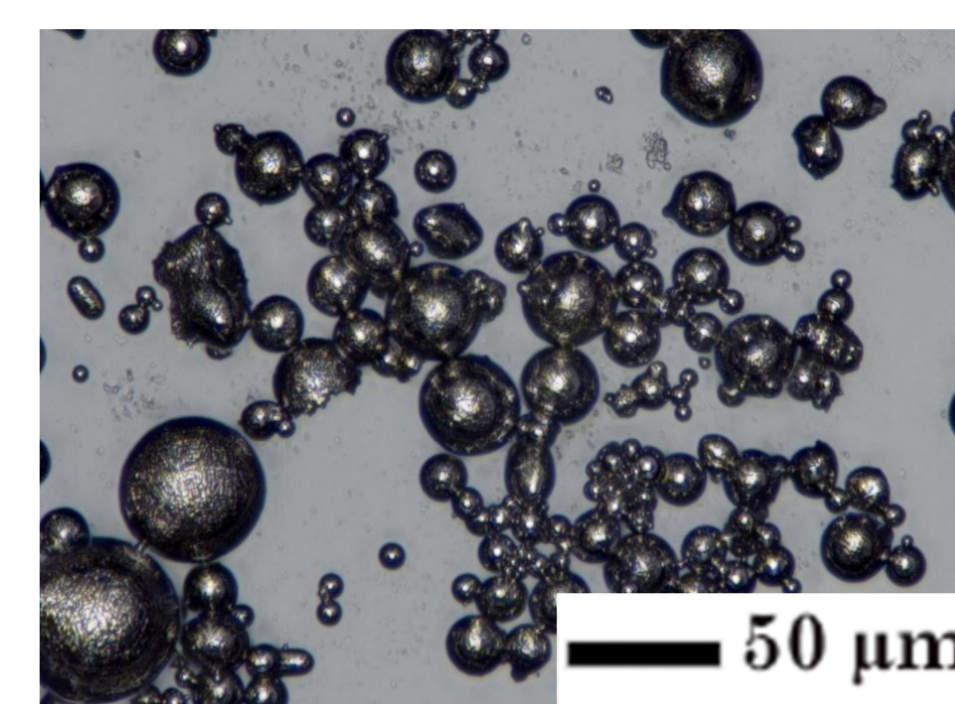
From all-steel to hybrid REBs



"Faster, Higher, Stronger"

Recurrent problem: debris contamination with destructive behavior

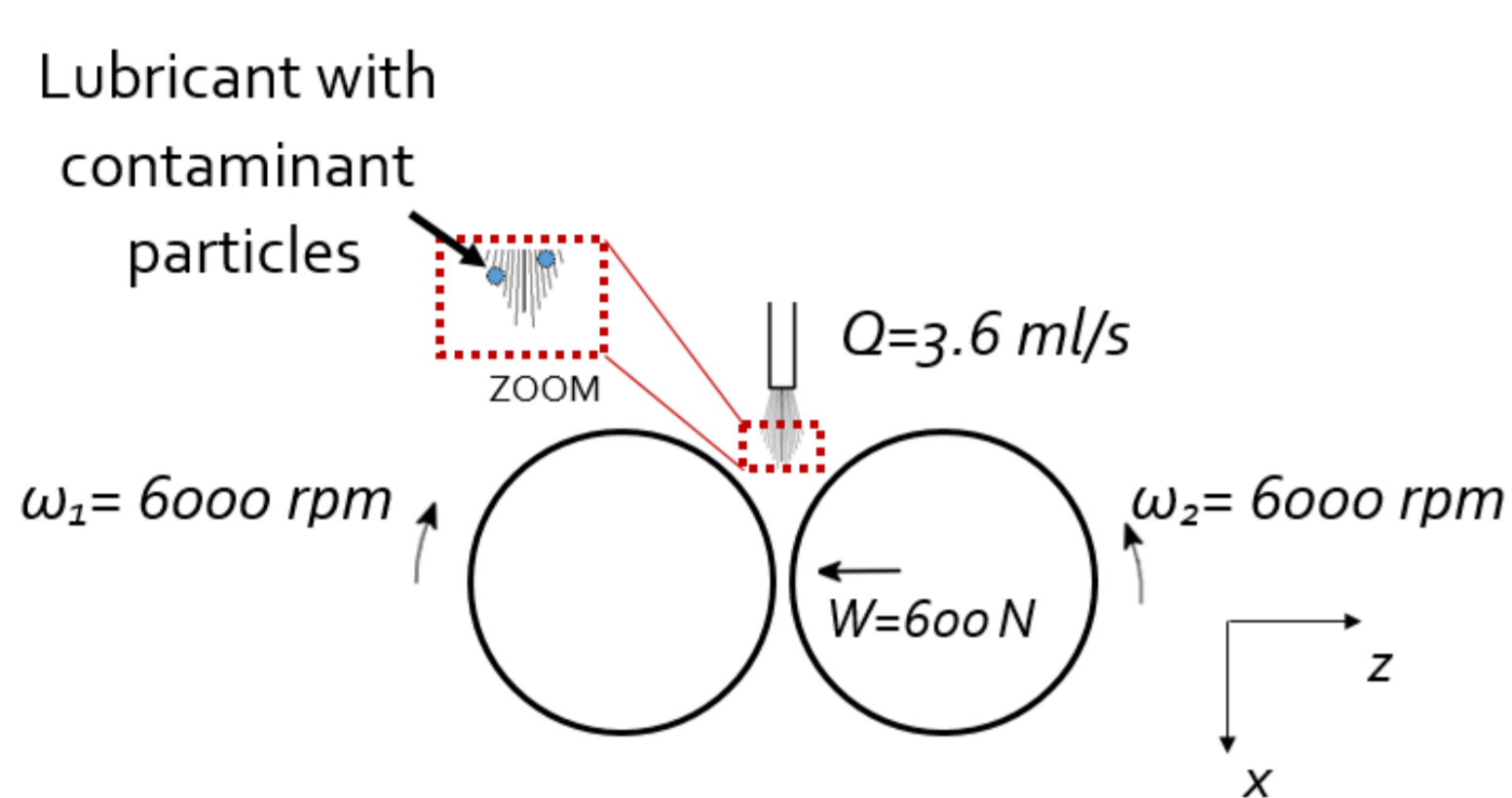
The type of contaminants found in lubricated mechanisms can be very diversified (debris, pollution particles) and from different sources (external or internal).



Spherical M50 steel particles (left) are commonly used to study entrapment phenomena.

Surface spalling on REBs rings (right) can appear when rolling fatigue occurs in presence of **particle dents**.

Twin-disc machine



The twin-disc machine¹ allows to model an elastohydrodynamic (EHD) point contact.

Tests with the twin-disc machine and the contamination test bench: Controlled level of contamination (nature, size, quantities)

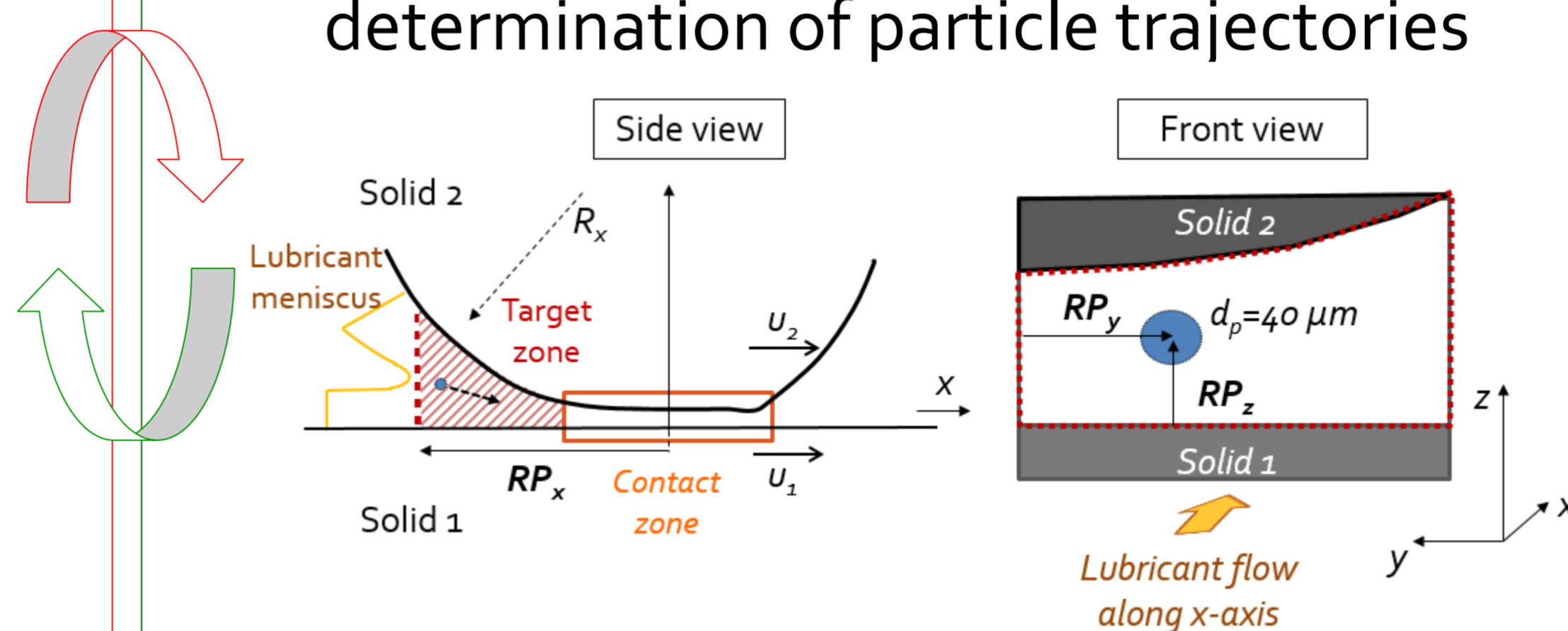
Sieved M50-steel powder

Silicon nitride and steel discs

Pure rolling and fully flooded conditions

Numerical tool

Simulation of the fluid flow and determination of particle trajectories



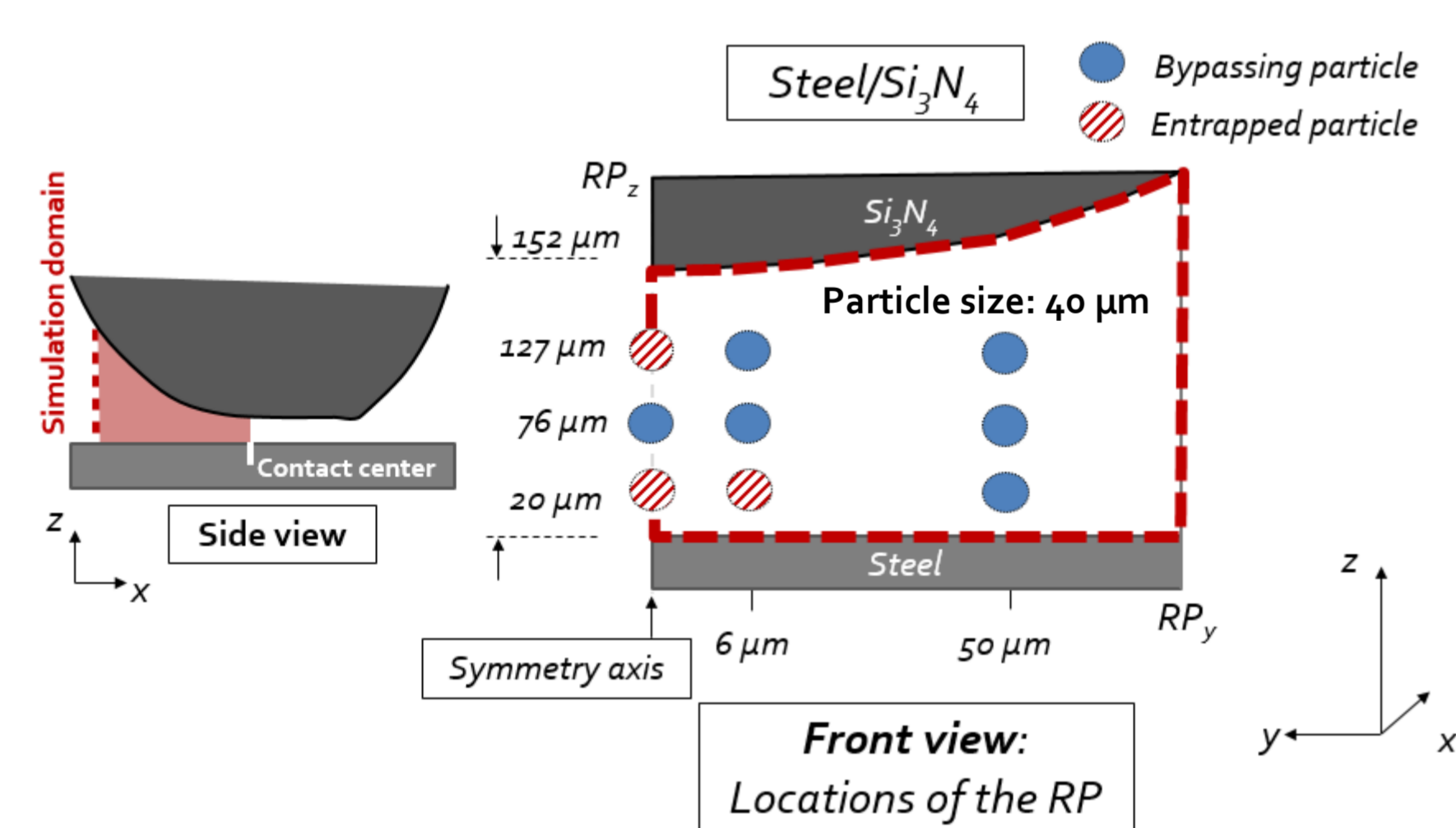
Considering a **contaminated lubricant** supposes to take into account both the **lubricant behavior** and the **particles dynamics**.

Firstly by analyzing **streamlines** and secondly by determining the theoretical **particle trajectories**.

Results

Using numerical simulations

As particles are **dispersed** in the lubricant, they can approach the contact region from different positions, named **release positions (RP)**.

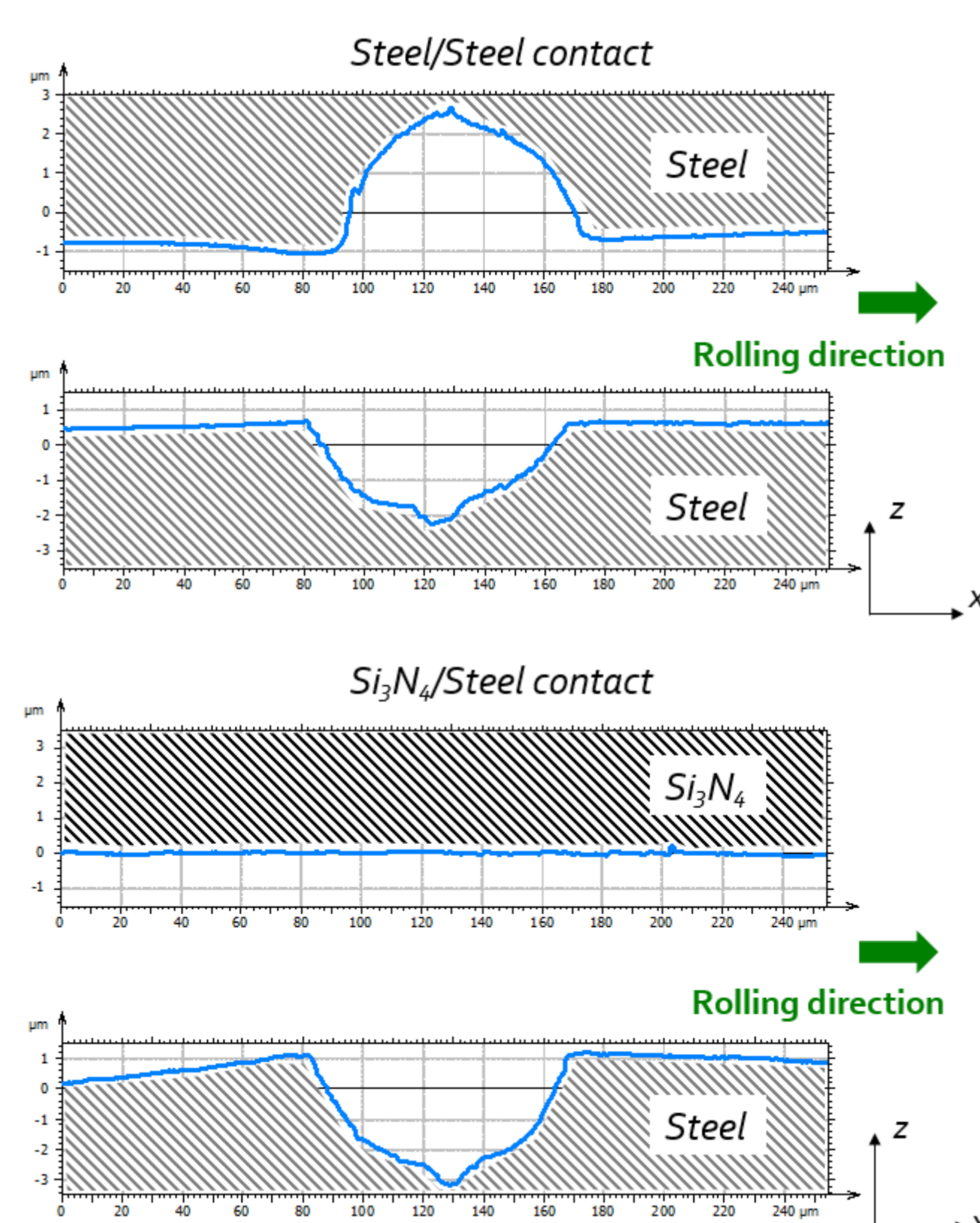


The **release positions normal to the rolling direction (RP_y)** and **across the confinement (RP_z)** influence the **entrapment probability**.

The **closer to the contact center line** and the **nearer from the walls** the particles are released, the more likely they will be entrapped.

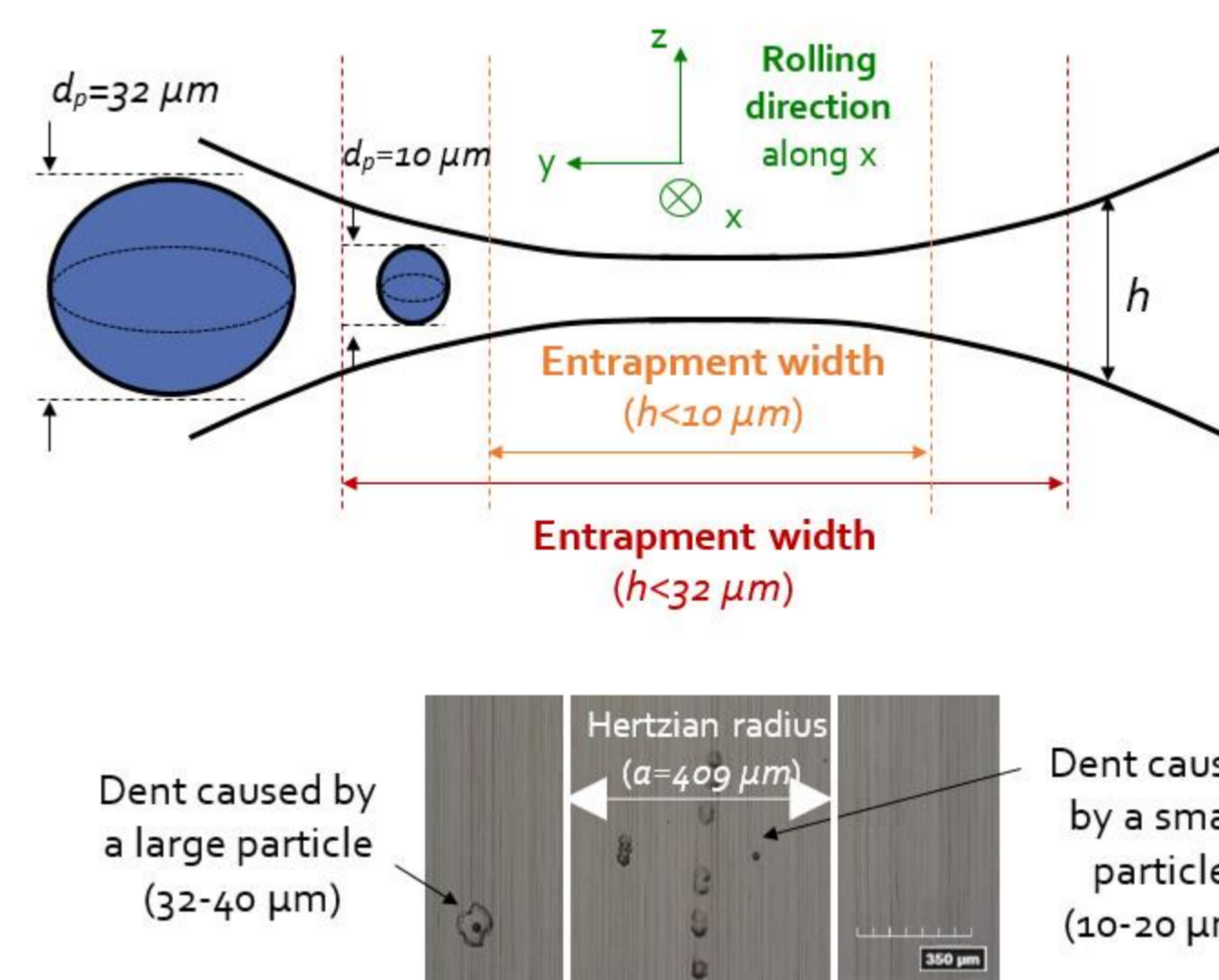
Using experiments

Assumption: each particle is responsible for a single dent → **quantitative and qualitative** comparison of entrapment phenomena.

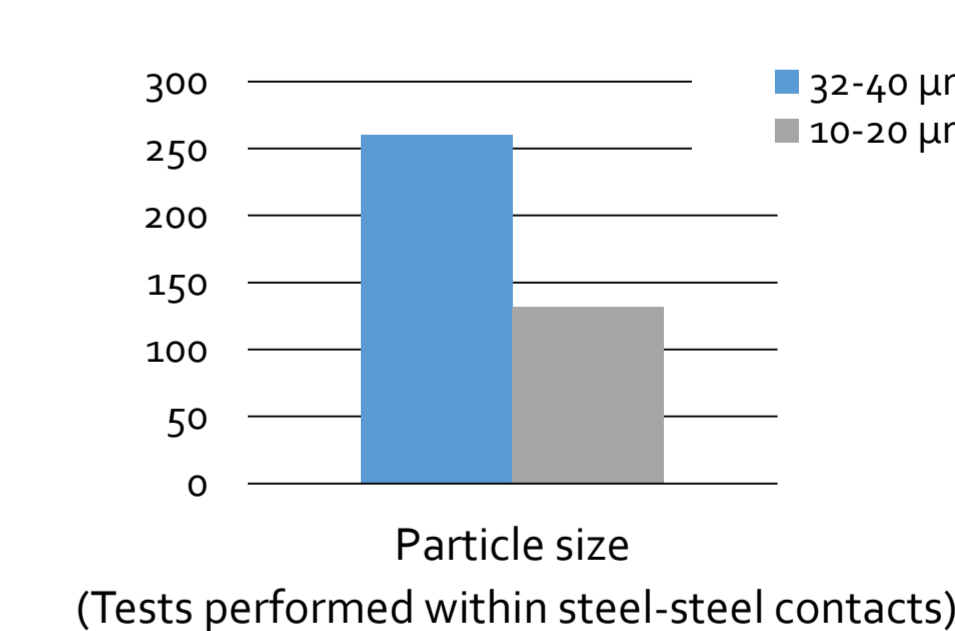
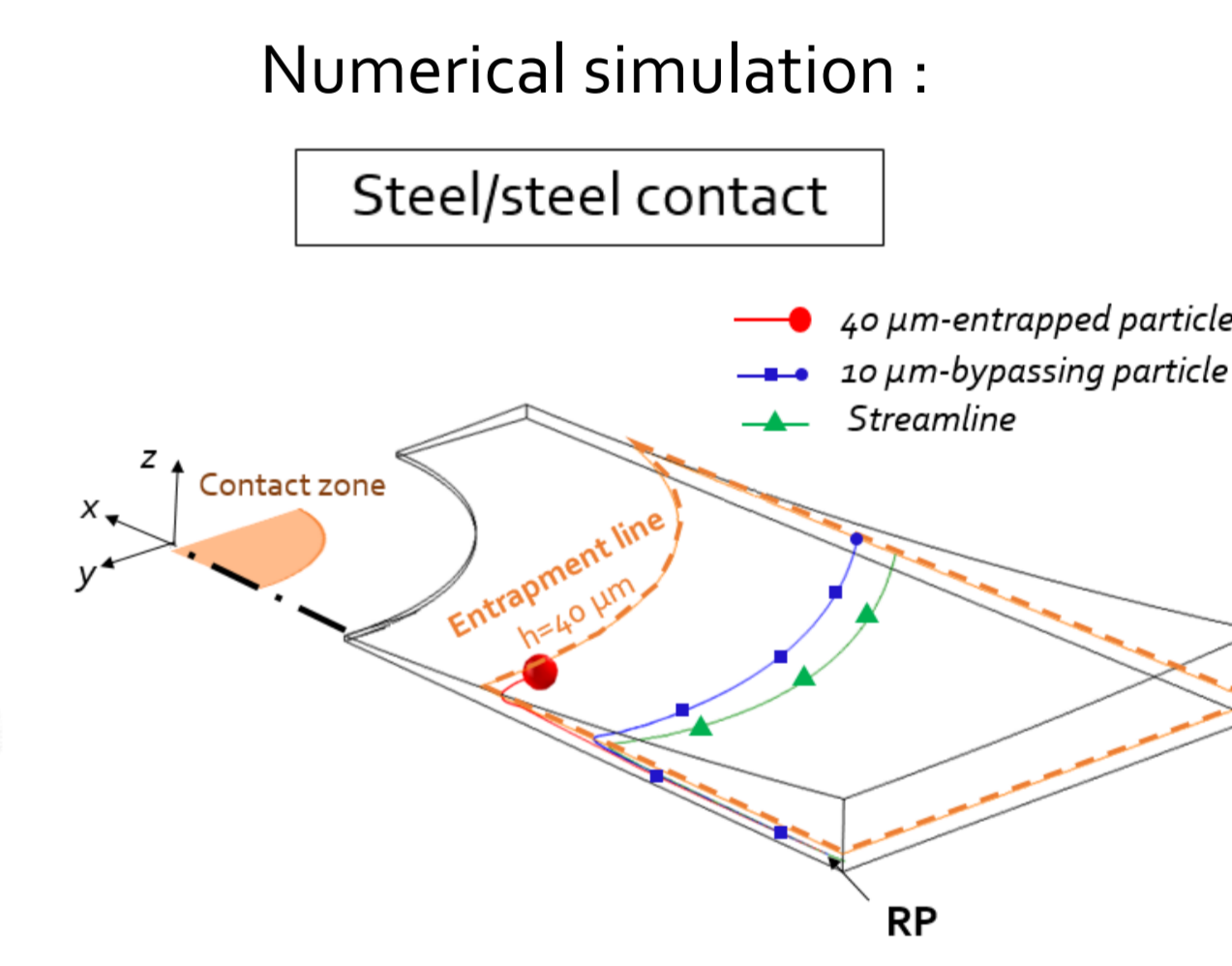
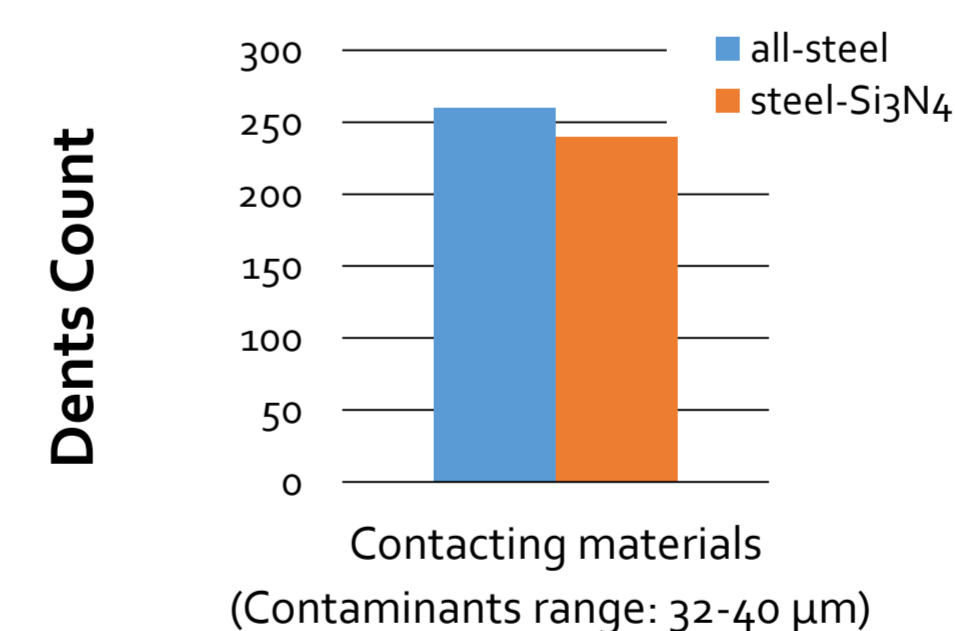


Tests with different couples of materials → discs made of **silicon nitride** withstand indentation by ductile particles (M50 steel).

Mixing both experimental and numerical works



Larger particles are more likely to be entrapped, in accordance with², due here to a larger entrapment width.



From quantitative comparisons:
- larger particles are more likely to be entrapped
- contacting materials have a little influence on the entrapment ratios

Conclusions

Key parameters governing particle entrapment were found :

- **Dependence of particle entrapment** with
 - **Release position**
 - **Particle size and mass**
- Changing **contacting materials** has a minor influence on particle entrapment phenomena
- **Silicon nitride discs** are able to withstand indentation by ductile particles

References

- ¹Ville, F., Nelias, D., Toulonias, G., Flamand, L., and Sainsot, P., (2001), "On the Two-Disc Machine: A Polyvalent and Powerful Tool to Study Fundamental and Industrial Problems Related to Elastohydrodynamic Lubrication," *Tribology Series* 39, pp. 393-402
- ²Dwyer-Joyce, R. S., and Heymer, J., (1996), "The Entrapment of Solid Particles into Rolling Elastohydrodynamic Contacts," *Proceedings of the 22nd Leeds-Lyon Symposium on Tribology, Elsevier Tribology and Interface Engineering Series*, 31, pp. 135-140

Funded by the industrial chair: SKF – Fondation INSA de Lyon

« LUBRICATED INTERFACES FOR THE FUTURE »



STLE 70th Annual Meeting
Dallas, May 17-21, 2015

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