PO.145

Investigation of wind turbine gearbox bearing subsurface damage considering transient loading and the separation of MnS inclusions

H. Al-Tameemi (hahal-tameemi1@Sheffield.ac.uk), H. Long (h.long@sheffield.ac.uk) and R.S. Dwyer-Joyce (r.dwyer-joyce@sheffield.ac.uk)

Department of Mechanical Engineering, The University of Sheffield, United Kingdom

Wind turbine bearing failure

Wind energy has attracted significant amount of investment during the last decades. However, some of the Wind Turbine (WT) parts, such as Gearbox (GB) bearings, are vulnerable to premature failures which causing exorbitant cost of maintenance.

- Unsteady winds, grid faults, operational events → transient dynamic loading, torque reversal;
- Machine elements operating under different speeds and loads but the same lubricant is used;
- Misalignment and harsh operational environment;

Premature bearing failure: one of the main bearing failures which occurs well below the L_{10} bearing fatigue life is the White Structure Flaking (WSF) or the White Etching Cracks (WECs).

Premature failures and classical Rolling Contact Fatigue (RCF)

Premature failure

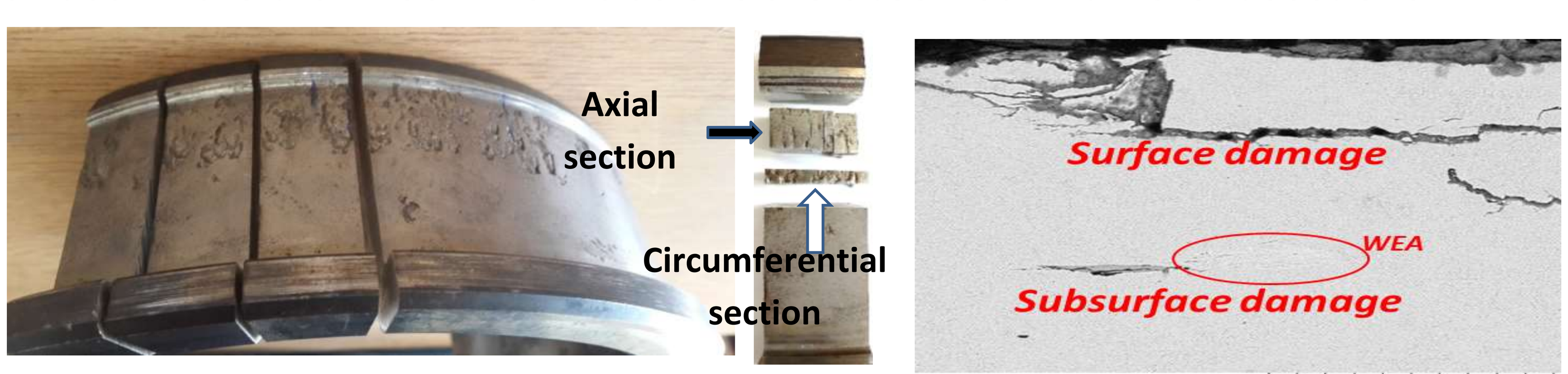
- Microstructure changes appear as irregular white area;
- Life can not be predicted accurately and the failure occurs much earlier than the L_{10} life

Classical RCF failure

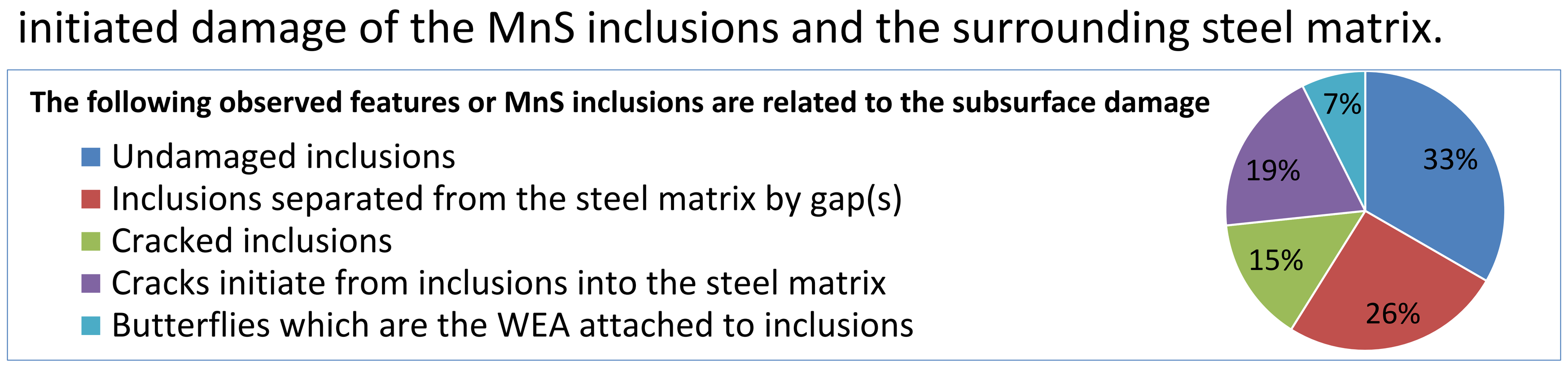
- Appears as white and dark bands of 30˚ or 80˚ with the rolling direction;
- Life can be calculated as the L_{10} life.

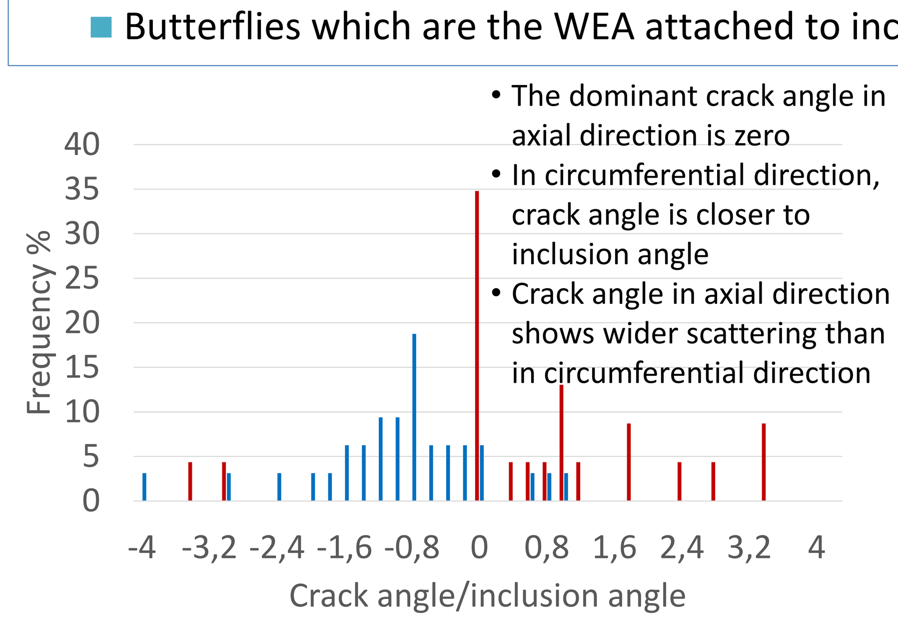
Destructive investigation of a failed bearing

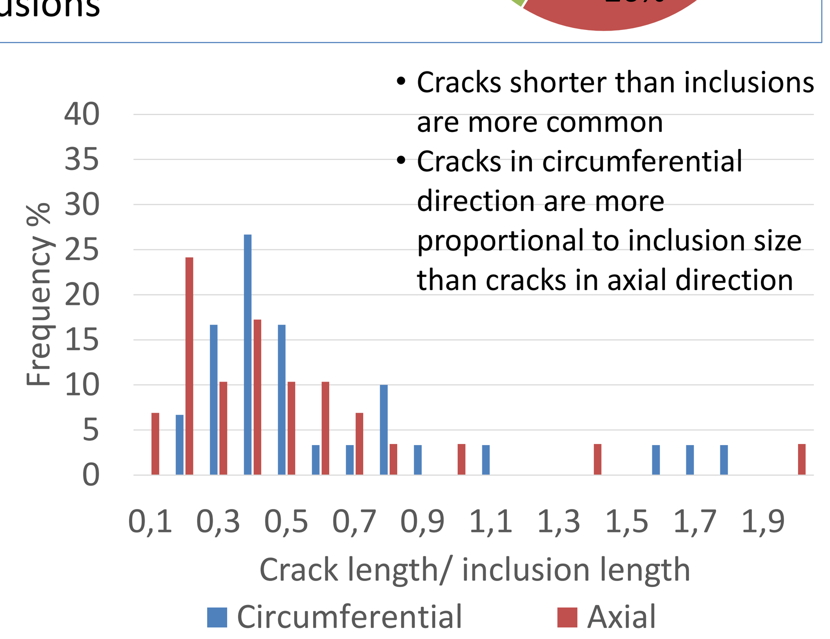
To develop a better understanding of the deterioration of wind turbine bearings during service, an examination of a bearing failed prematurely during the service is performed. It is a sub megawatt WT GB bearing. The microscopic examination of the subsurface area covered more than 1 mm depth from the surface. More than 200 MnS inclusions are observed in different sections.



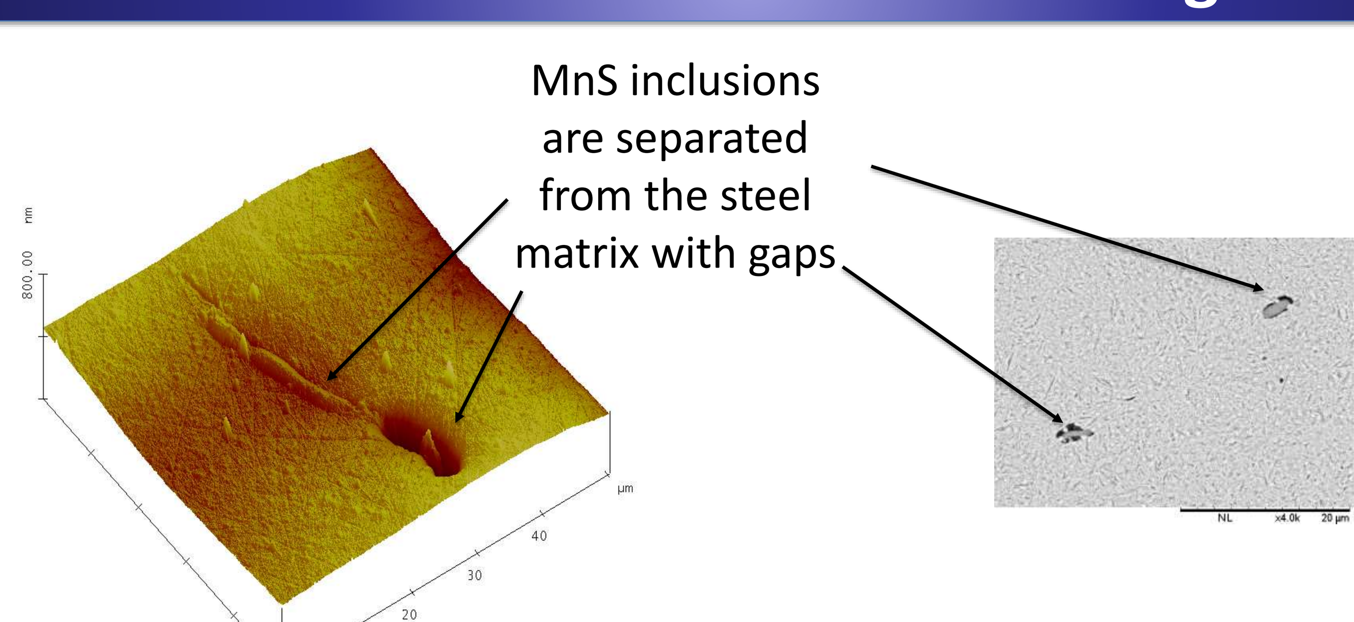
The failures may initiate either on the surface or near the surface of contact in the bearing raceways. In this study, the examination focused on the subsurface initiated damage of the MnS inclusions and the surrounding steel matrix.



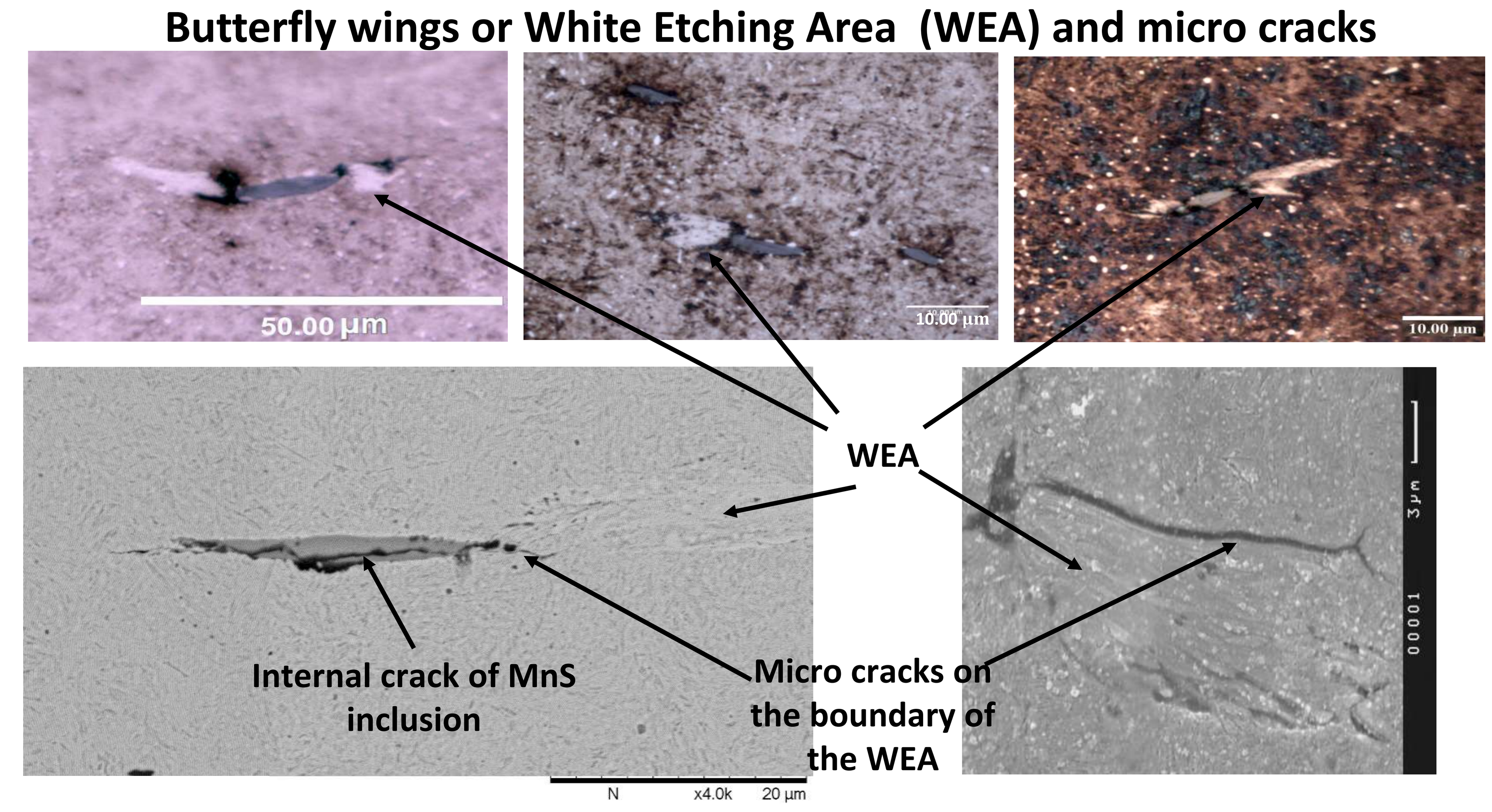




Subsurface features and damage



Butterfly wings or White Etching Area (WEA) and micro cracks



Load and contact pressure

The torque and speed measured at the low speed shaft of NREL 750 kW WT are used to calculate the load on each raceway of the planetary bearing. The radial load acting on each planetary bearing is shown in Equations 1.

$$F_r = \frac{Torque_{in} * \omega_c}{3 * R_s * \omega_s} \qquad 1$$

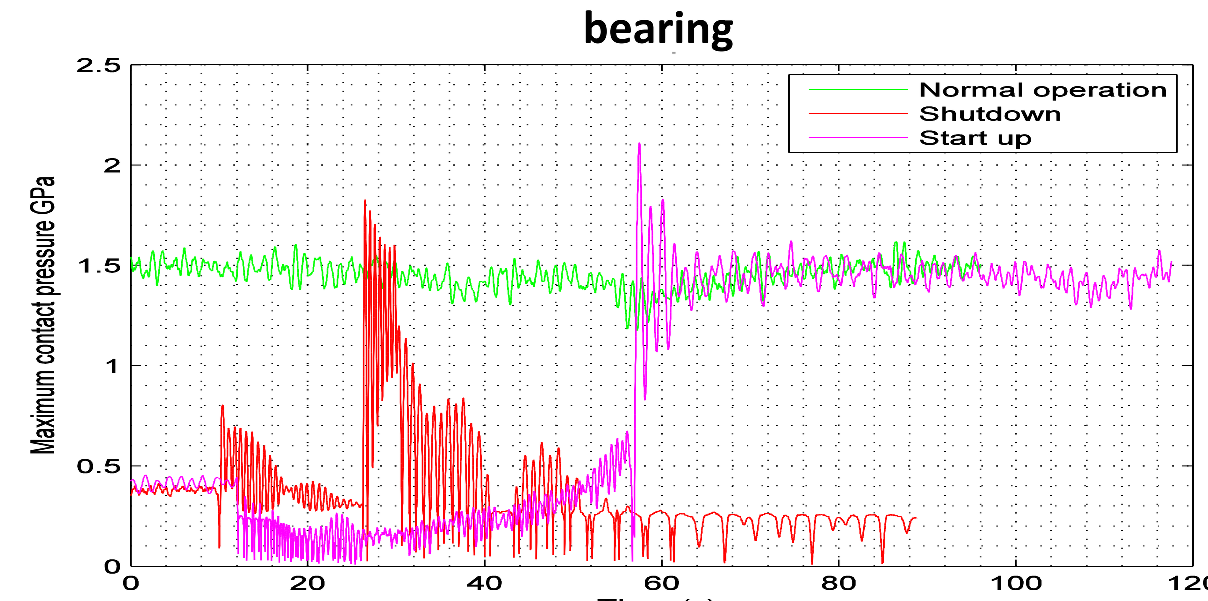
The radial load on the upwind bearing is calculated assuming 50% more load than the downwind bearing1. The maximum contact pressure on the inner race is calculated from Equation 2 where Q_0 is the maximum roller-raceway normal load. The maximum subsurface shear stress τ_1 is calculated from Equation 3.

[1]W. LaCava, J. Keller, and B. McNiff, "Gearbox Reliability Collaborative: Test and Model Investigation of Sun Orbit and Planet Load Share in a Wind Turbine Gearbox; Preprint," April, 2012.

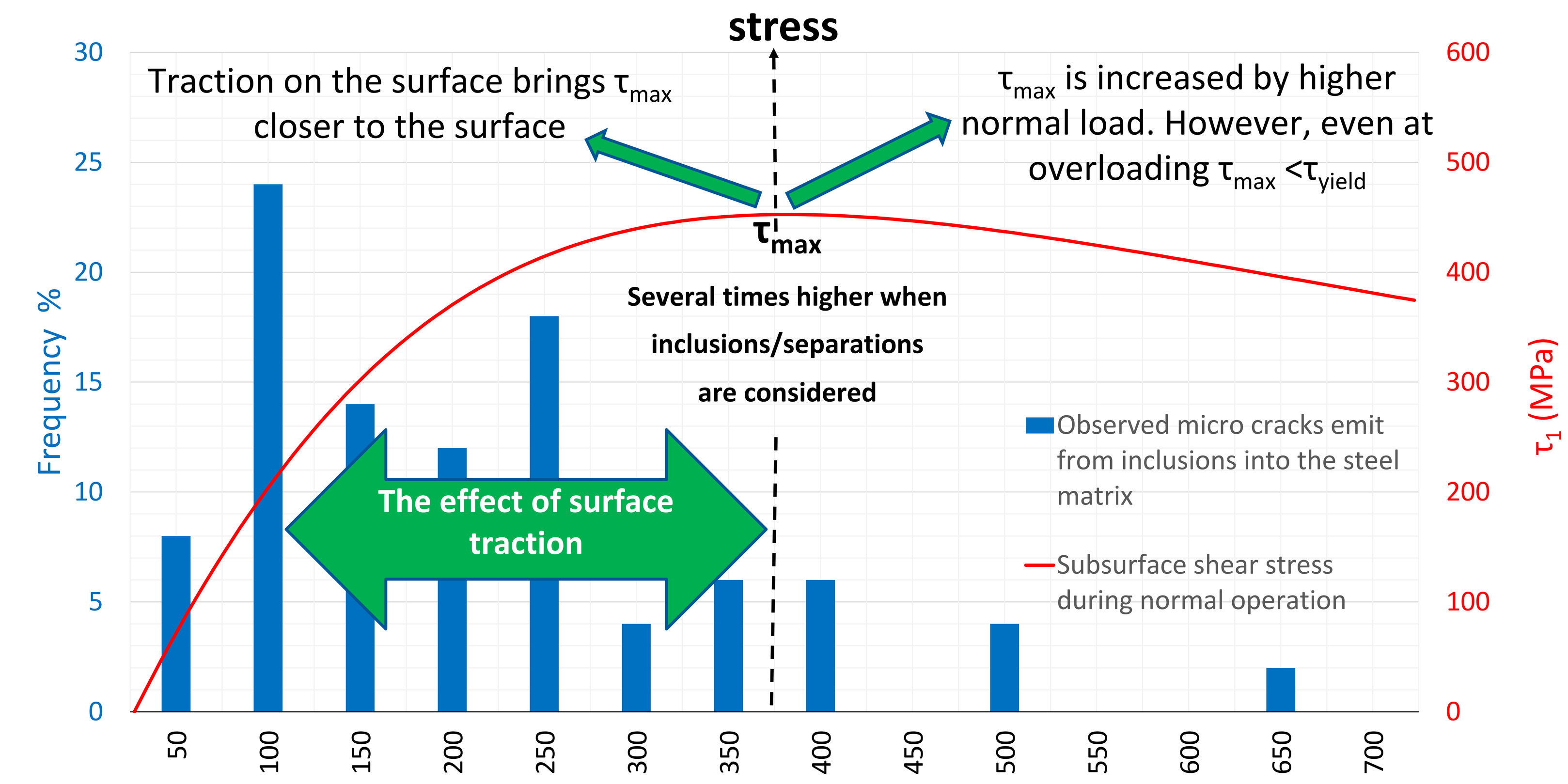
$$p_{max} = \frac{2 * Q_0}{\pi * L * b} \qquad 2$$

$$\tau_1 = \sqrt{\left(\frac{\sigma_{xx}-\sigma_{zz}}{2}\right)^2 + \tau_{xz}^2} \qquad 3$$

Maximum contact pressure at the inner ring of planetary bearing



Depth of micro cracks and the distribution of subsurface shear stress



Conclusions

- The observed types of damages: inclusions separated from the matrix by gaps; internal micro cracks of the inclusions; micro cracks initiate from inclusions into the steel matrix; WEA around the inclusion (Butterflies).
- Without considering the effect of inclusions or gaps, overloading could not cause subsurface yielding.
- The effect of high surface traction can be seen clearly by comparing the dominating depth of the subsurface micro cracks with the depth of the maximum shear stress.