On the meaning and requirements of the concept of an effective indenter

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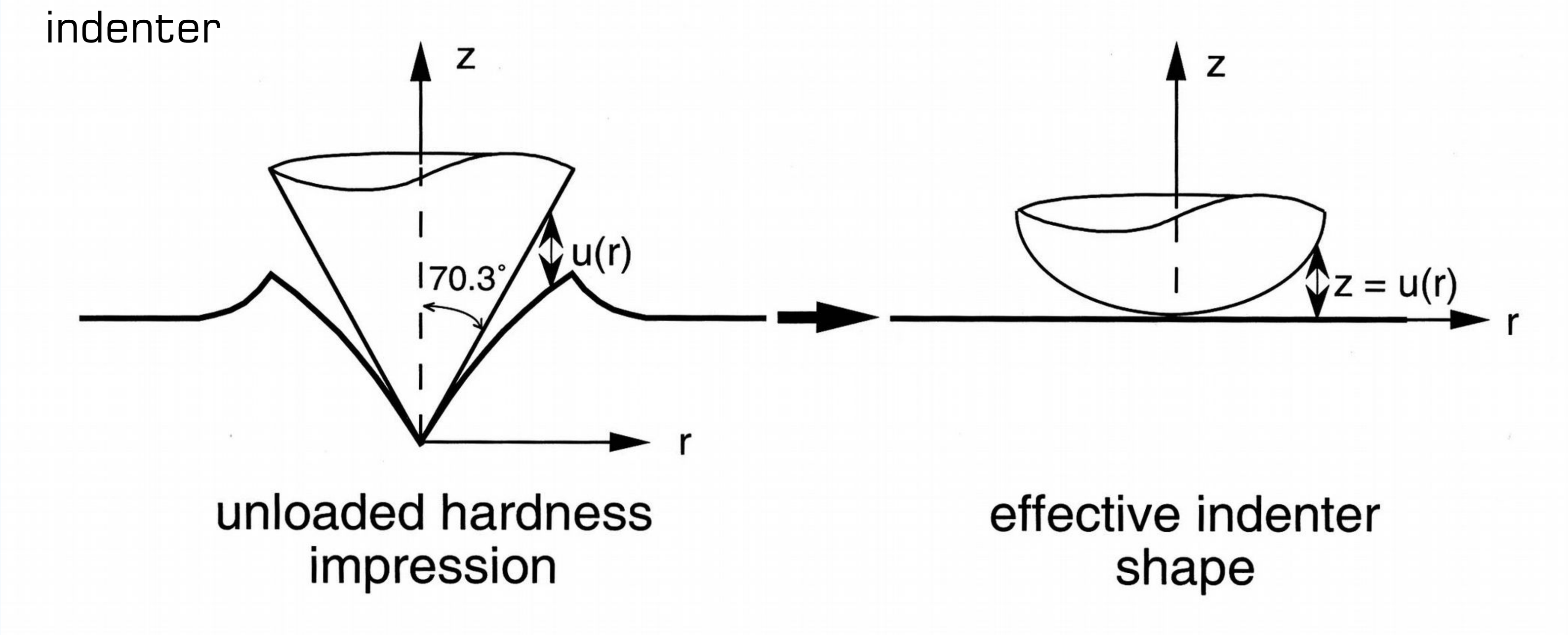
Introduction: Oliver&Pharr Method[1]

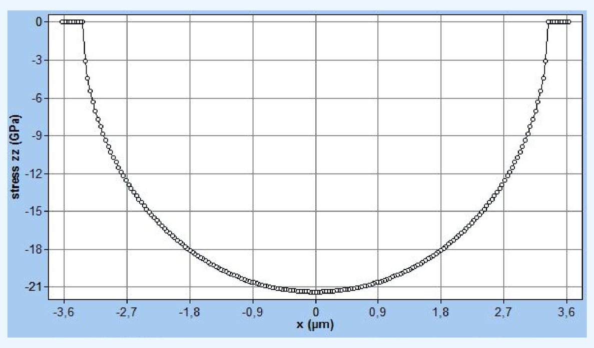
- *implicit* idea[2]: quasi-conform transformation of real indenter to flat elastic monolithic half space and an effectively shaped indenter



→effective material parameters:

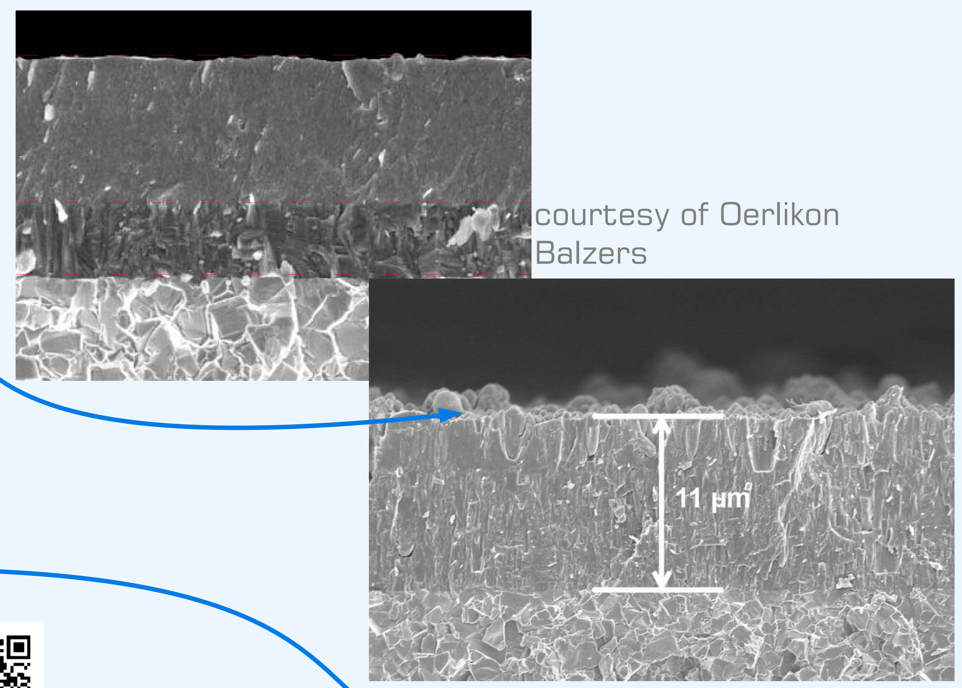
- effective Young's modulus E_{eff}
- effective hardness H_{eff}

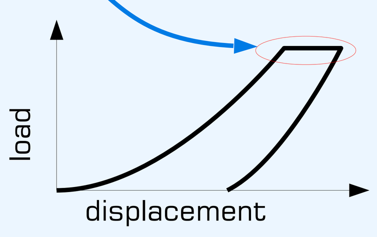
- normal surface stress derived by Bolshakov[2] (see figure)

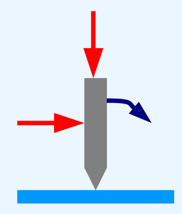


Motivation: Real Life

- **material structure**
- indenter shape
- **surface curvature/topography**
- temperature
- interface adhesion
- sample geometry
- **time-dependency (creep)**[5, 6, 7, 8]
  →poster EP 7
  →O&PfC Creep Edition
- friction between indenter and surface
- lateral force
- **tilting**
- more on www.siomec.de/pubs

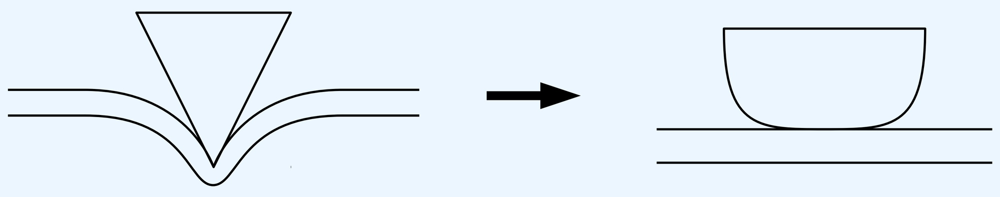




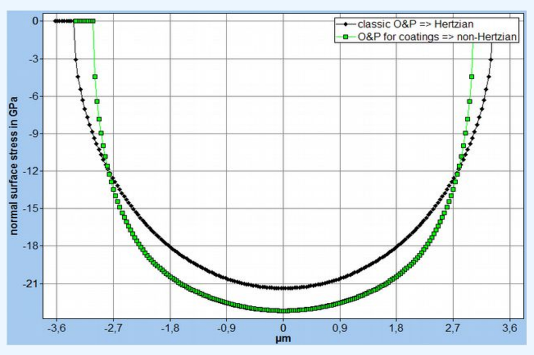


These effects are – unfortunately – not taken into account in the classic concept of the effectively shaped indenter by Pharr and Bolshakov!

Example #1: Extension to Layered Coatings[3]



different normal surface stress:



implemented in O&PfC:

in addition, complete solution of elasto-plastic contact field:

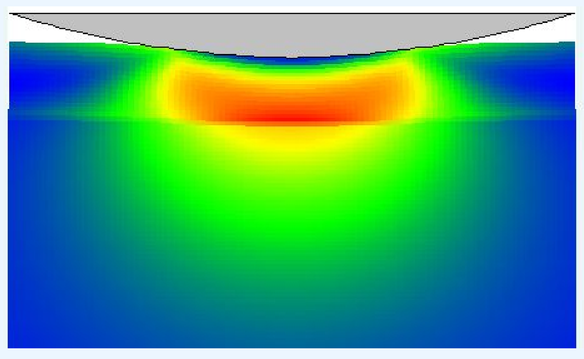


Fig.: cross section of von Mises stress profile as one example of 29 field components

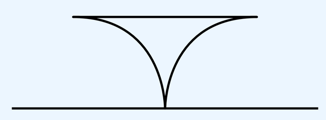
→ $E_{coating}$, $E_{substrate}$, $H_{corrected}$, Y_C, Y_S

Example #2: Extension to Time-Dependency (Creep)[5, 6, 7, 8]

Power law fit: $F = c\,h_e^m$

If: $m>2$

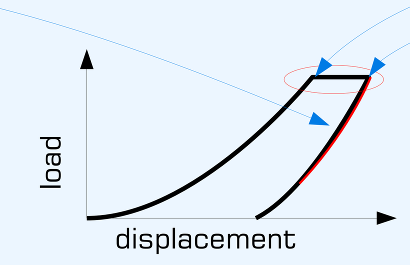
Oliver & Pharr
(implicit assumption)

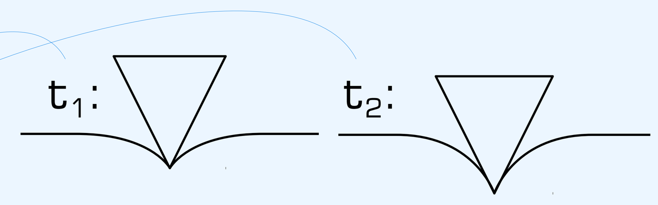


$Z(r) = B\,r^n$

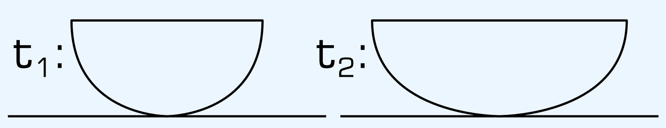
$\rightarrow 0 \le n < 1$

Singularity at r=0!





extended for time-depency by Schwarzer



possible solution:

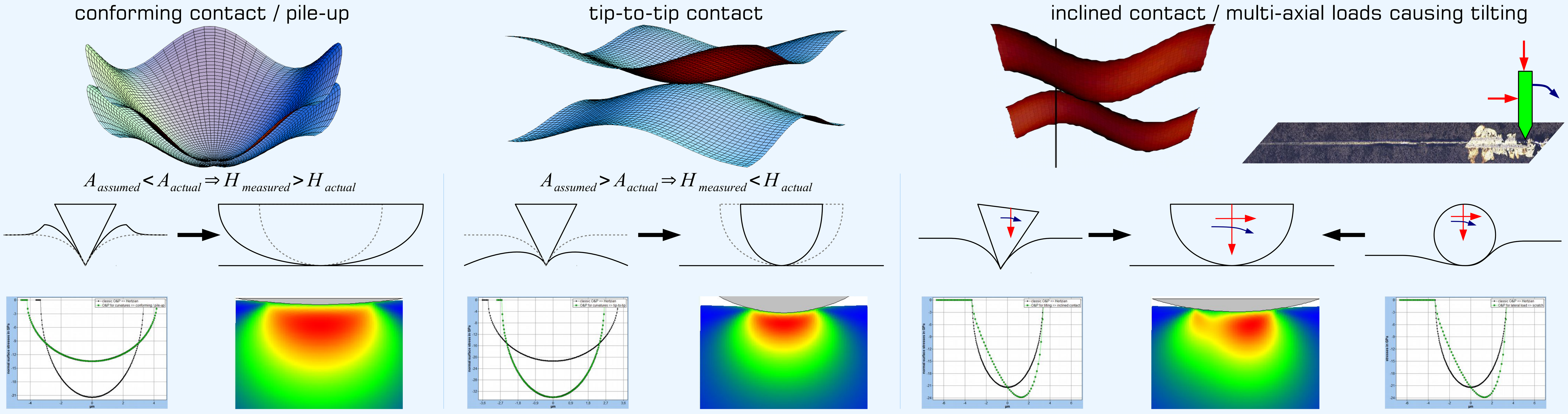
$F = c(t)\,h_e(t)^{m(t)} \Leftrightarrow Z(r,t) = B(t)\,r^{n(t)}$

→ new material law: $E(t) = E_0 + E_1 e^{-\frac{t}{\tau}}$

more:

- poster EP 7
- software O&PfC Creep at www.siomec.de/OPfC-Creep

Example #3: Extension to Surface Curvature (Roughness)[9], Multi-Axial Loads, and Tilting[10]



- enables physical analysis of scratch test and tribology experiments (e.g. pin-on-disc, nano-fretting)
- basis for **predictive wear modeling** using generic wear parameters[11]
- more: N. Schwarzer, talk **TS2-2-2**, Friday, 8:20 am, Royal Palm 1-3 and: J. Becker, talk **E3-2-7+G**, Friday, 10:00 am, Golden West
- implemented in FilmDoctor, www.siomec.de/FilmDoctor

Conclusions

✔ real contact problems can be very complex
✔ Oliver&Pharr method extended by Schwarzer allows modeling
✔ concept of effective indenter helps understanding real-life effects
✔ analytical model → calculations are very quick
✔ complete solution → **phiysical analysis → generic physical material parameters**
✔ implemented in available software → ready-to-go

References

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