

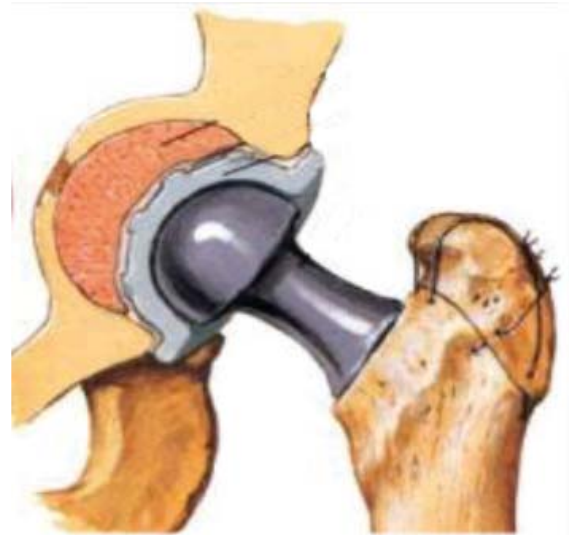
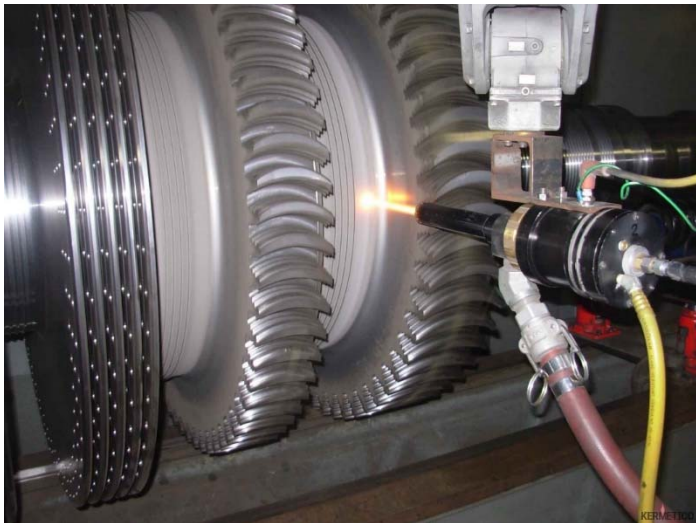
Yield Modes in a Coated Sphere Compressed by a Rigid Flat

Z. Chen, R. Goltsberg, I. Etsion

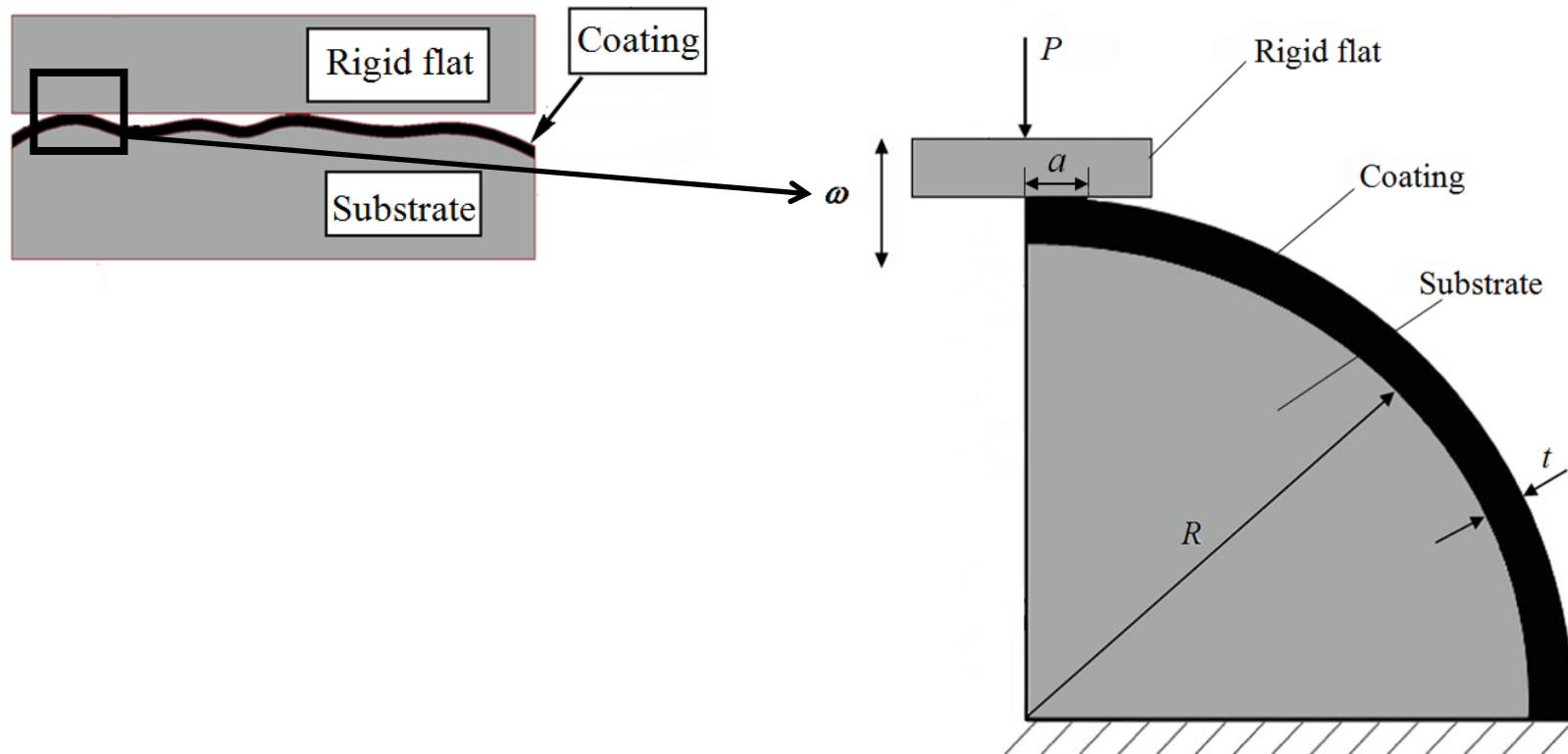
Dept. of Mechanical Engineering

Technion-Israel Institute of Technology, Haifa,
32000, Israel

Motivation

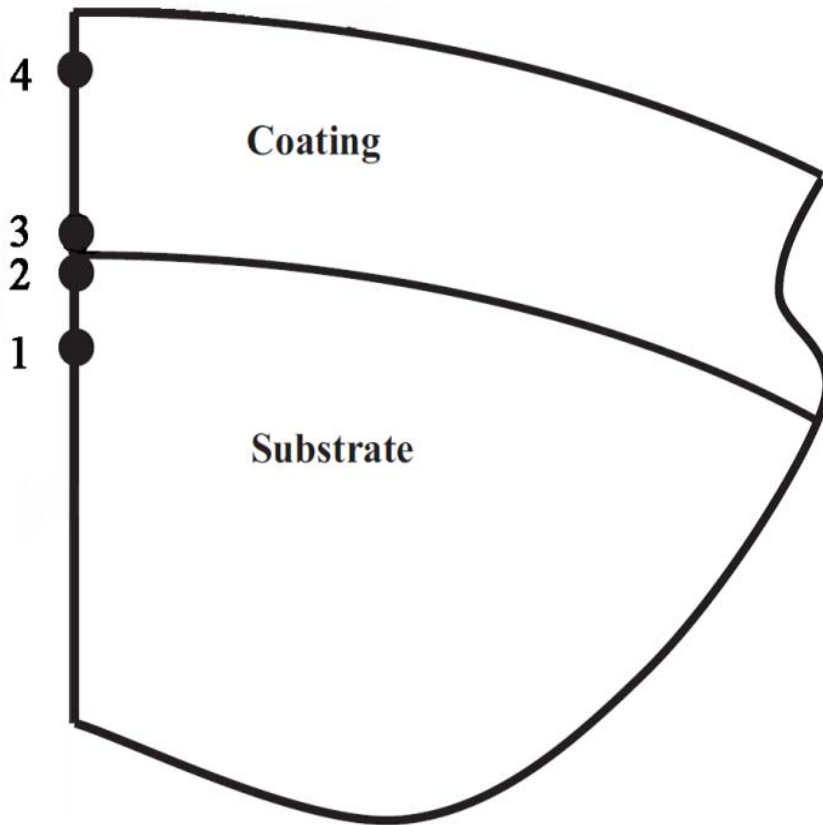


Single asperity of contacting coated rough surfaces



[1] J. Greenwood, J. Williamson, Contact of nominally flat surfaces, The Royal Society (London) 295 (1966), 300-319.

Yield inception locations



$$\begin{matrix} E_{\text{co}} & E_{\text{su}} & Y_{\text{co}} & Y_{\text{su}} \\ & t & R & \end{matrix}$$

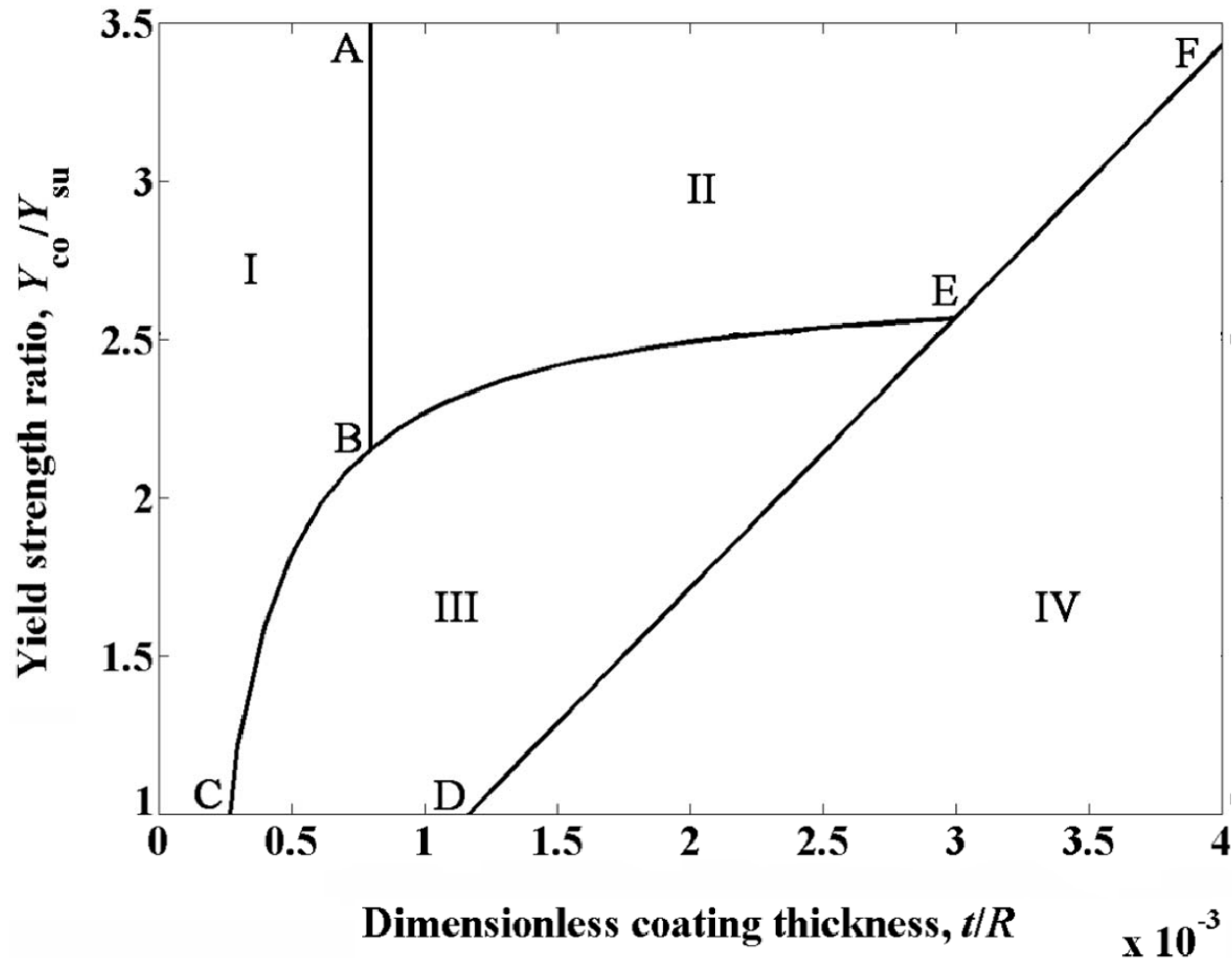
$$E_{\text{co}}/E_{\text{su}}$$

$$E_{\text{su}}/Y_{\text{su}}$$

$$Y_{\text{co}}/Y_{\text{su}} > 1 \text{ (hard coatings)}$$

$$t/R$$

The yield map for $E_{\text{co}}/E_{\text{su}} = 4$ and $E_{\text{su}}/Y_{\text{su}} = 1000$

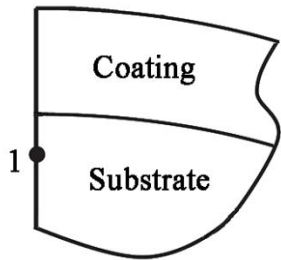


$$2 \leq E_{\text{co}}/E_{\text{su}} \leq 8$$

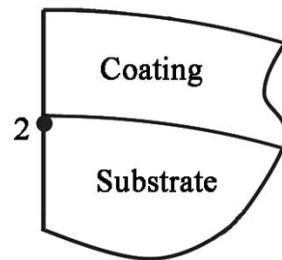
$$500 \leq E_{\text{su}}/Y_{\text{su}} \leq 2000$$

The yield mode in each zone

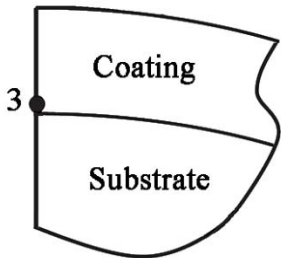
Zone I :



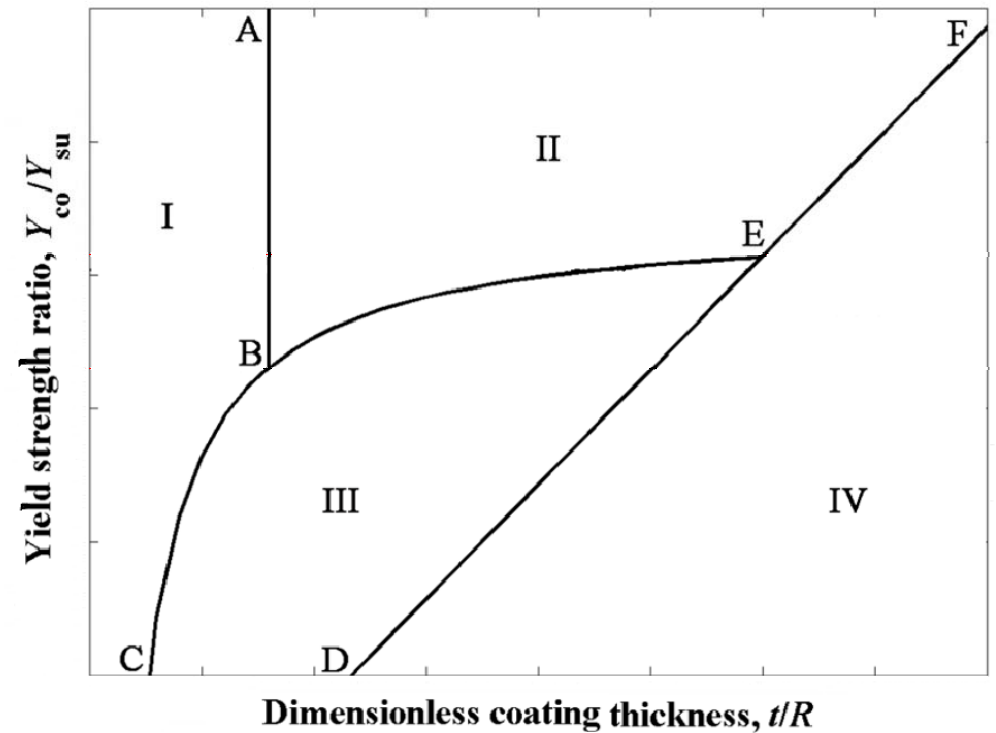
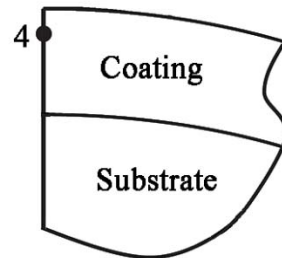
Zone II :



Zone III :

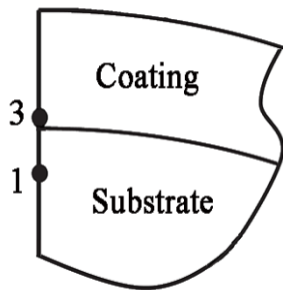


Zone IV :

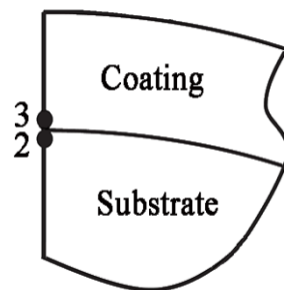


The yield mode on each zone boundary

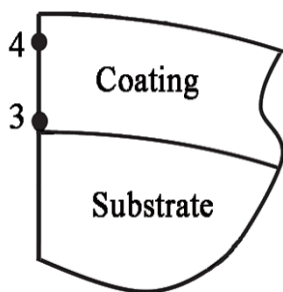
Boundary CB :



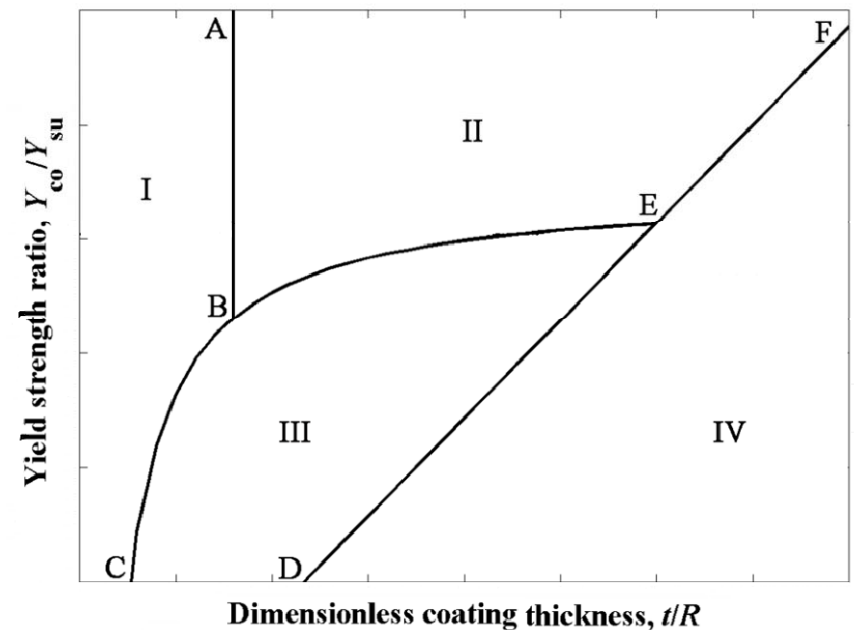
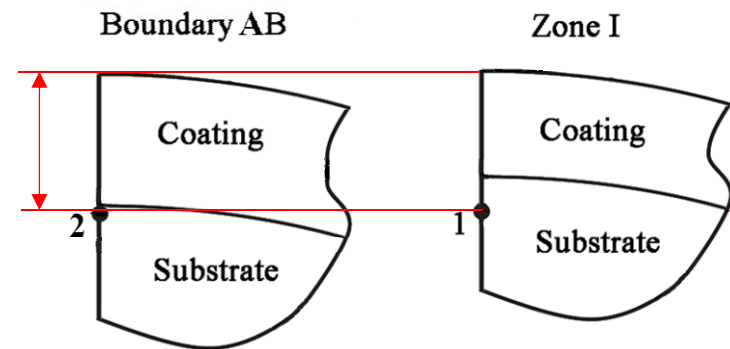
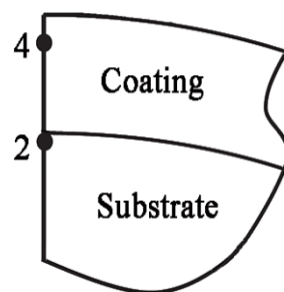
Boundary BE:



Boundary DE:



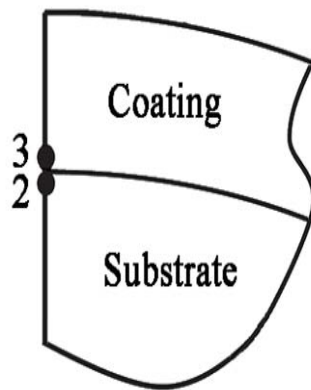
Boundary EF :



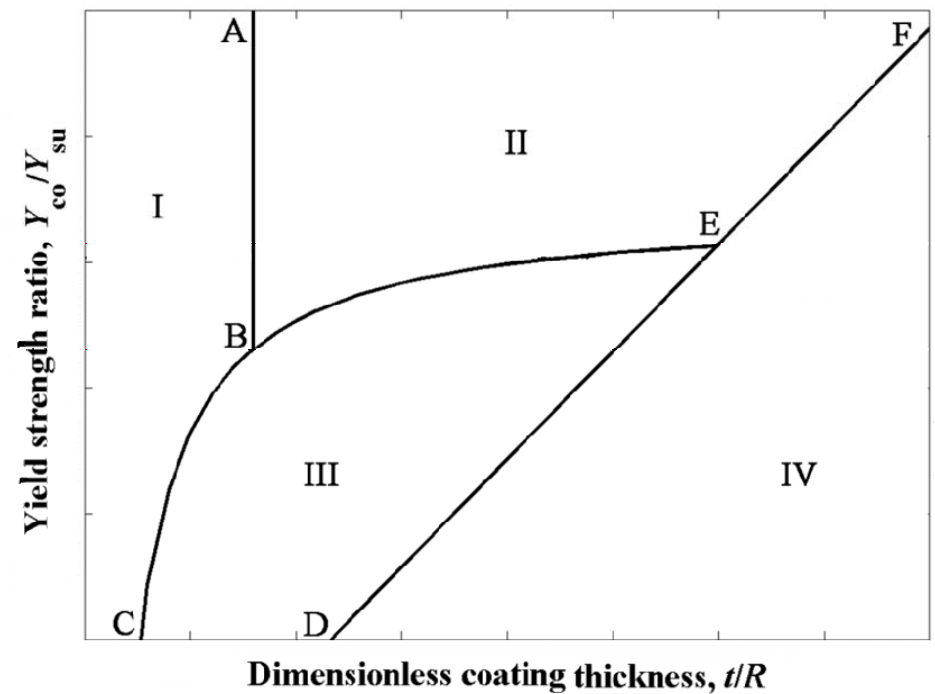
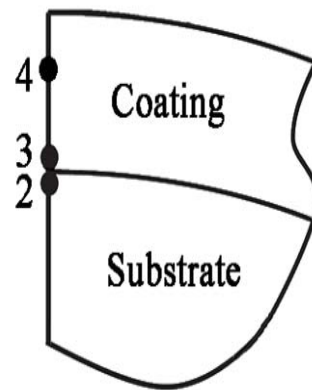
[2] R. Goltsberg and I. Etsion, A model for the weakening effect of very thin hard coatings, Wear 308 (2013) 10-16.

The yield mode at intersection points

Intersection B:



Intersection E:

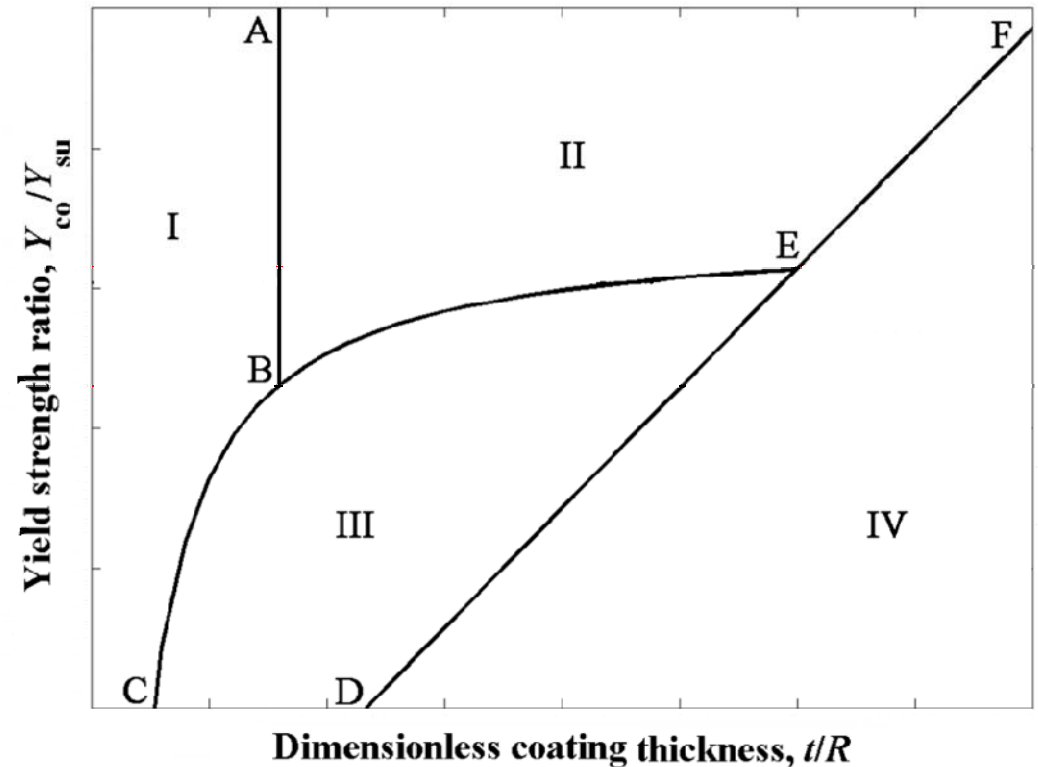


Determination of a yield map

$$\left(\frac{t}{R}\right)_{CBE} = \frac{0.15}{\left[0.912 - (Y_{co} / Y_{su})(E_{co} / E_{su})^{-0.787}\right](E_{su} / Y_{su})}$$

$$\left(\frac{t}{R}\right)_{DEF} = 1.35 \left(\frac{Y_{co}}{Y_{su}}\right) \left(\frac{E_{co}}{E_{su}}\right)^{-0.6} \left(\frac{E_{su}}{Y_{su}}\right)^{-0.9}$$

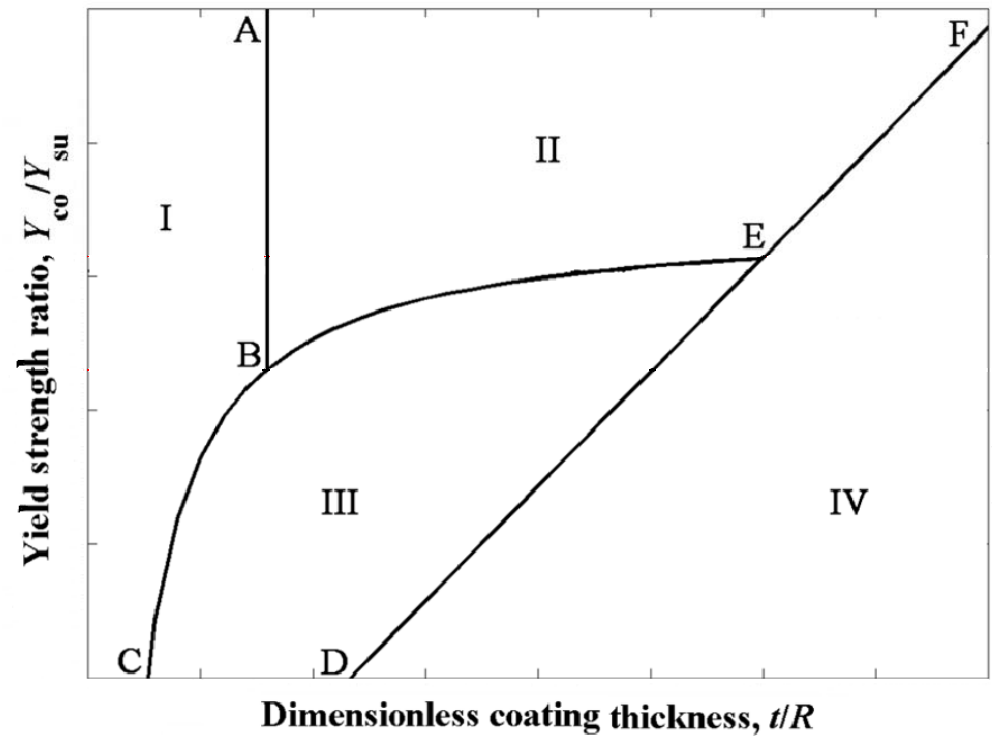
$$\left(\frac{t}{R}\right)_{AB} = \frac{1.066}{(E_{co} / E_{su})^{0.225} (E_{su} / Y_{su})}$$



Determination of the yield mode in a coated system

$$\left(\frac{Y_{co}}{Y_{su}}\right)_E = \left[0.456 + \sqrt{0.208 - \frac{1}{9} \left(\frac{E_{co}}{E_{su}}\right)^{-0.187} \left(\frac{E_{su}}{Y_{su}}\right)^{-0.1}} \right] \left(\frac{E_{co}}{E_{su}}\right)^{0.787}$$

$$\left(\frac{Y_{co}}{Y_{su}}\right)_B = 0.912 \left(\frac{E_{co}}{E_{su}}\right)^{0.787} - 0.141 \left(\frac{E_{co}}{E_{su}}\right)^{1.012}$$

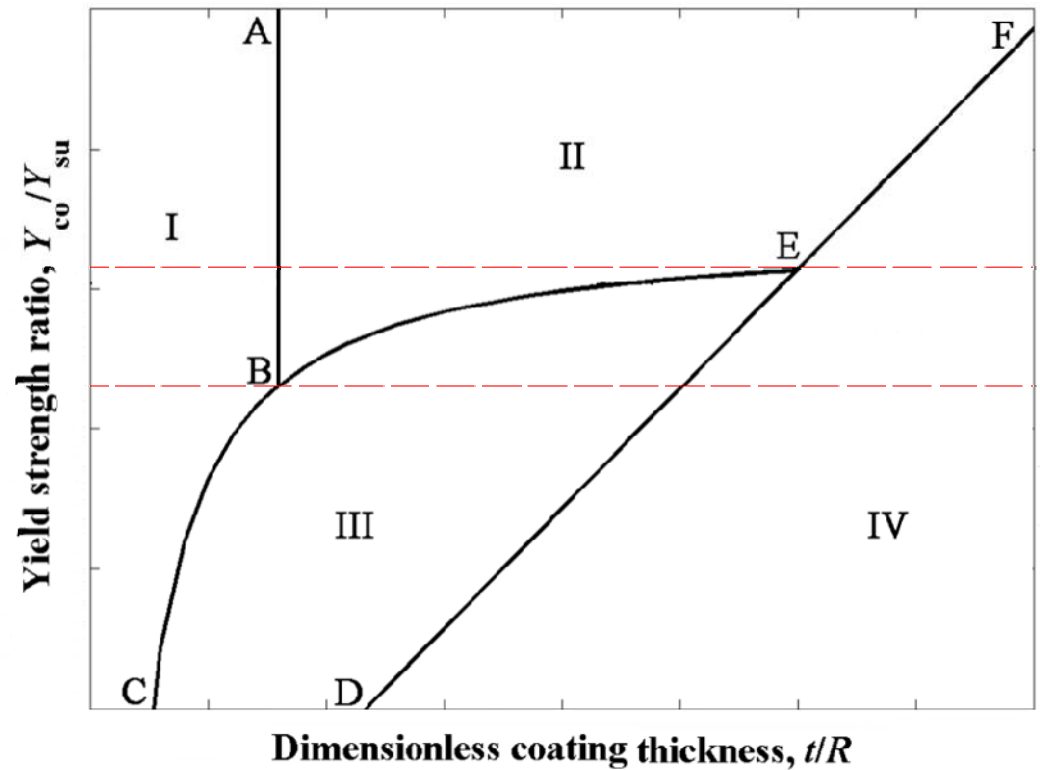


Determination of the yield mode in a coated system

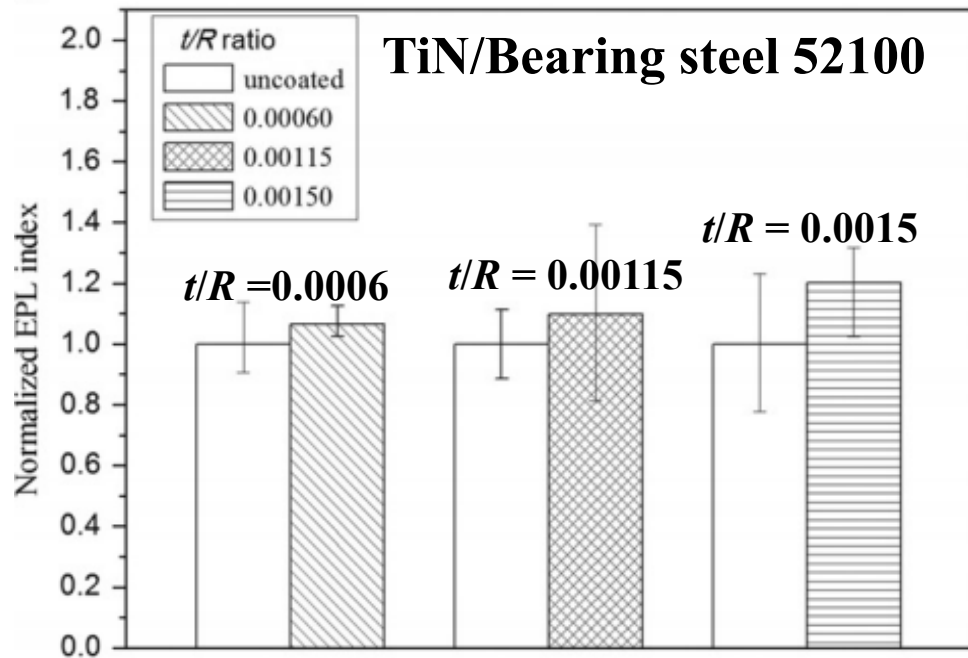
1) $Y_{co}/Y_{su} > (Y_{co}/Y_{su})_E$ I, II or IV Compare t/R with $(t/R)_{AB}$ and $(t/R)_{DEF}$

2) $(Y_{co}/Y_{su})_B < Y_{co}/Y_{su} < (Y_{co}/Y_{su})_E$ I, II, III or IV. Compare t/R with $(t/R)_{AB}$, $(t/R)_{CBE}$ and $(t/R)_{DEF}$

3) $Y_{co}/Y_{su} < (Y_{co}/Y_{su})_B$ I, III or IV Compare t/R with $(t/R)_{CBE}$ and $(t/R)_{DEF}$

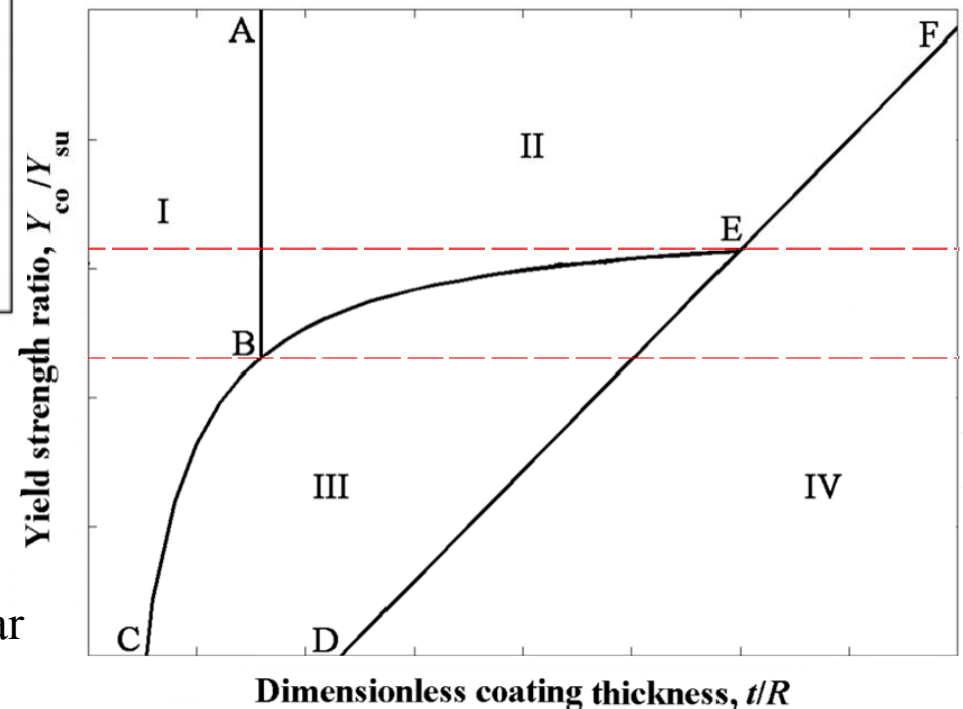


Comparison with experimental results



Actual parameters			Calculated parameters	
E_{co}/E_{su}	E_{su}/Y_{su}	Y_{co}/Y_{su}	$(Y_{co}/Y_{su})_E$	$(t/R)_{AB}$
1.65	140	5.24	1.24	0.0068

Theoretical results: Zone I



Experimental results: Zone I

[2] R. Goltsberg and I. Etsion, A model for the weakening effect of very thin hard coatings, Wear 308 (2013) 10-16.

[3] X. Huang et al., Experimental study of a potential weakening effect in spheres with thin hard coatings, Wear 296 (2012) 590-597.

Conclusion

- Four typical locations of yield inception on the axis of symmetry were found.
- Different yield modes, characterized by the yield inception locations, were found and can be presented in a yield map as a function of Y_{co}/Y_{su} and t/R for given E_{co}/E_{su} and E_{su}/Y_{su} .
- Each of the zones corresponds to a yield mode with a single yield inception location. Four of the zone boundaries correspond to yield modes with double simultaneous yield inception locations and one of the intersection points has a yield mode with triple simultaneous yield inception locations.
- Universal dimensionless expressions for the zone boundaries were derived that enable to determine the yield mode of any coated system based on the material properties and dimensionless coating thickness. The validity of the determination was verified by a comparison with an experimental study.

Thank you for your attention!