VII INTERNATIONAL CONFERENCE

MODELLING AND SIMULATION OF THE FRICTION PHENOMENA IN THE PHYSICAL AND TECHNICAL SYSTEMS "FRICTION 2012"

WARSAW, May 22, 2012

Two scale modelling of wear and oxidation processes

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Materials and their applications

FUNCTIONAL NANOCOMPOSITE COATINGS
- Nanocomposite TiC/a-C(:H) coatings
- MoS2-Ti- coatings
- Oxide coatings –V2O5,

Functionaly gradied materials (FGM)
Cu-Al2O3- systems, Al2O3-NiAl

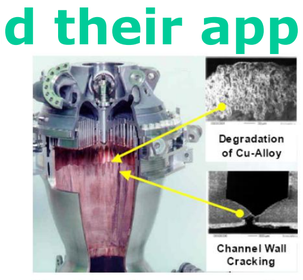
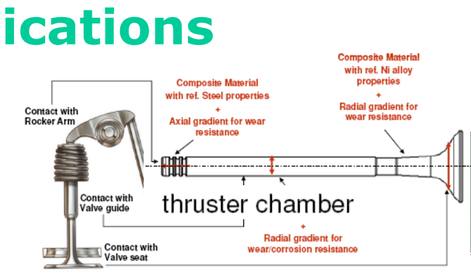
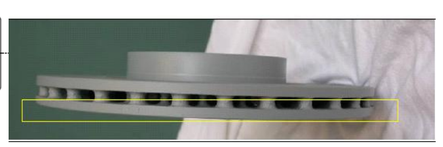


Figure 0-1 Source: www.eads.net, International Technology Days 2003.

thruster chamber



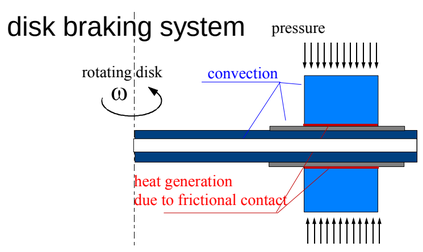
exhaust engine valve

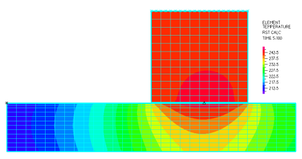


Brake disk

Macroscopic scale

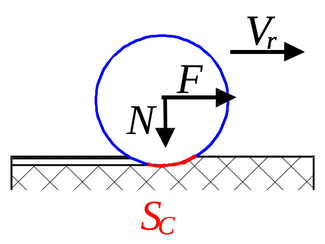
Thermo-mechanical analysis of coupled wear –oxidation and temperature field at transient and steady state



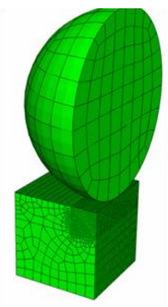


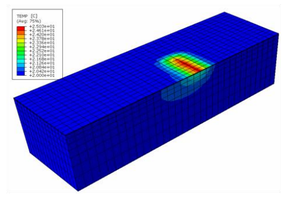
- disk temperature distribution

(steady state)



ball on disk test



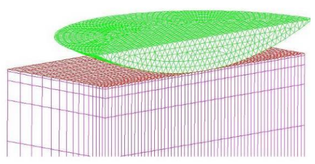


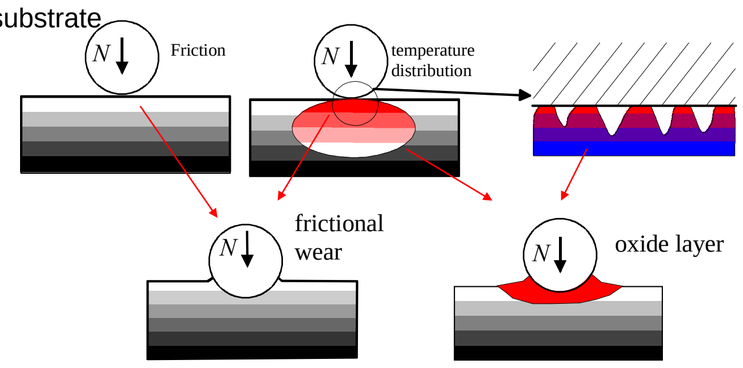
Wear process
modified Archard law

$$\dot{w}_i = \frac{\beta}{H}\left(\langle\mu\rangle\sigma_n\right)\|v_t\|$$

Wear-oxidation model – two-scale aproximation

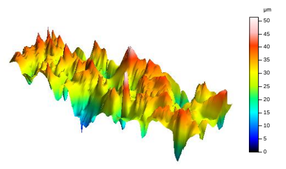
Macroscopic scale:
sliding on the smooth frictional substrate
ball on disk; braking system





different oxidation kinetics in contact and free boundary zone

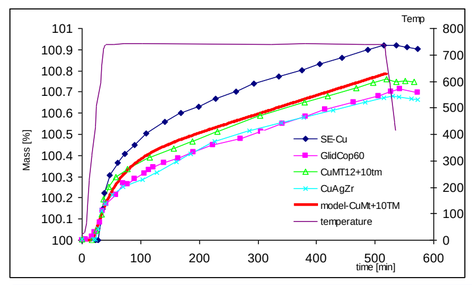
Asperity scale



roughness,real contact area
flash temperature at the asperity from heat flux balance equation

TGA - thermo-gravimetric analysis

Model of oxidation kinetics FGM (thruster, brake disk)



$$\dot{m} = A(T)\left(A_f + (A_i - A_f)\exp(-A_3 t)\right)$$

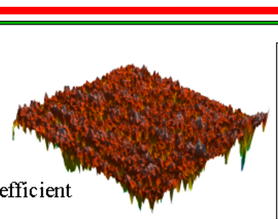
Asperity scale

Input data

actual surface topography

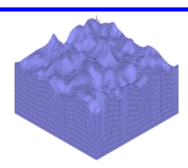
material parameters (thermal , elastic)

$\mu(T)$ variation of friction coefficient with temperature

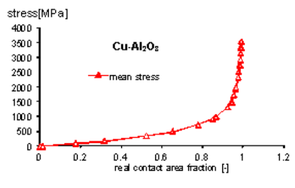


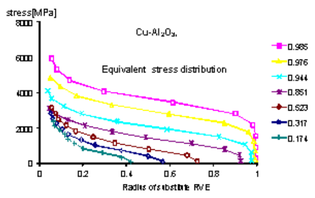
Representative Element

Equivalent stress distribution on the l RVE



FEM contact analysis at asperity scale



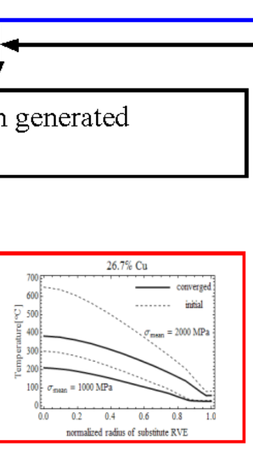


Boundary condition

T Surface temperature at micro scale

V Sliding velocity

Heat flux calculation generated by frictional sliding



FEM calculation temperature distribution

$$\varepsilon_T = \frac{1}{S}\int_S (T_i - T_{i-1})dS < \varepsilon_0$$

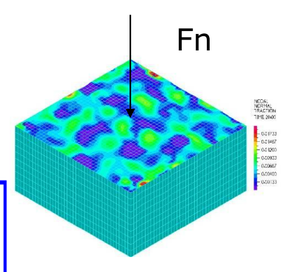
N

Y

$\langle A_v \rangle$ Calculation averaged oxidation activity factor

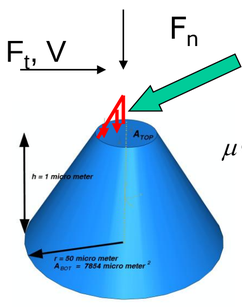
$\mu(T, \sigma_n)$ friction coefficient

Asperity scale



Fn

simplified representative element



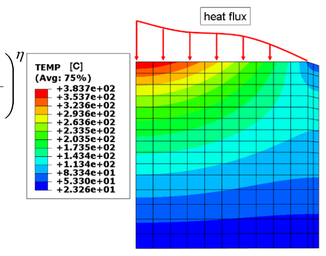
heat flux affected by friction

$$q = f\tau V = f\sigma\,\mu V$$

$$\mu(T) = \mu_{\max} - (\mu_{\max} - \mu_{\min})\left(\frac{T - T_{\min}}{T_{\max} - T_{\min}}\right)^{\eta}$$

V- sliding velocity

f – fraction of frictional contact heat distributed to body



Stress distribution

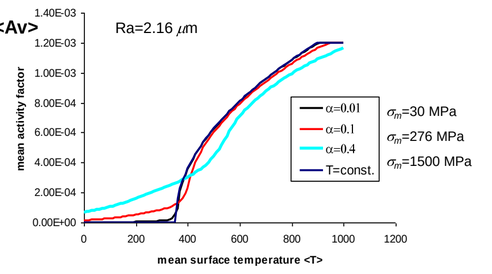
axisymetric RVE

Temperature distribution within representative element

Averaged **oxidation activity factor**

$$\langle A_v \rangle = A(r) = \frac{1}{S}\int A\,dS = 2\int_0^1 A(T) r dr,$$

$$A(T) = \begin{cases} 0 & T < T_{\min} \\ A_0\left(\frac{T(r) - T_{\min}}{T_{\max} - T_{\min}}\right)^k & T_{\min} \le T \le T_{\max} \\ A_0 & T > T_{\max} \end{cases}$$



Averaged **friction coefficient**

$$\langle \mu \rangle = \frac{F_t}{F_n} = \frac{\int \tau_n dS}{S\langle \sigma_n \rangle} = \frac{2\int_0^1 \mu(T)\sigma_n(r) r dr}{\sigma_{mean}}$$

Conclusion

- oxidation starts from Tmin
- macromodelling does not allow for oxidation (obtained temperatures are smaller than Tmin)
- micromodelling results in flash temperatures bigger than T_{min} – oxidation can be desribed
- assumption that friction coefficient is a function of temperature $\mu(T)$ in asperity scale provides macroscale $\mu(T, \sigma_n)$

The results presented in this paper have been obtained within the project "KomCerMet" (contract no. POIG.01.03.01-14-013/08-00 with the Polish Ministry of Science and Higher Education) in the framework of the Operational Programme Innovative Economy 2007-2013 and were supported by the EU FP7 Project "Micro and Nanocrystalline Functionally Graded Materials for Transport Applications" (MATRANS) under Grant Agreement no. 228869