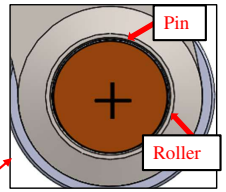
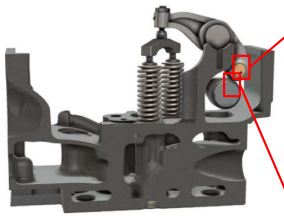
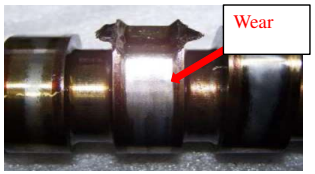
Motivation & Background

- Cam and roller follower (CF) mechanisms are subjected to harsh operating conditions
- Slip at the CF interface directly effects wear and failure
  - The interface is generally assumed to be pure rolling
  - Evidence exists of slip[1-3]

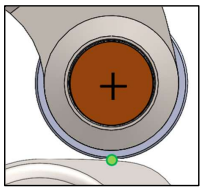
Lubrication plays an important role between pin and the roller







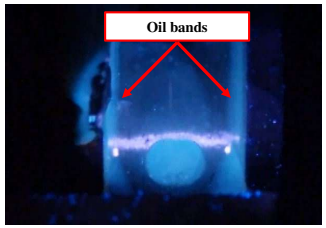
Contact between cam and roller is subjected to high contact stress leading to reduction in fatigue life

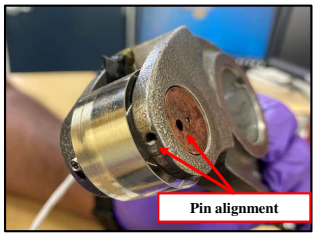


1. M. Khurram, R. A. Mufti, R. Zahid, N. Afzal, and U. Bhutta, "Experimental measurement of roller slip in end-pivoted roller follower valve train," Proc. Inst. Mech. Eng. Part J . Eng. Tribol., 2015.
2. J. Lee and D. J. Patterson, "Analysis of Cam/Roller Follower Friction and Slippage in Valve Train Systems," 1995.
3. P. E. Duffy, "An Experimental Investigation of Sliding at Cam to Roller Tappet Contacts," SAE Tech Paper 2010

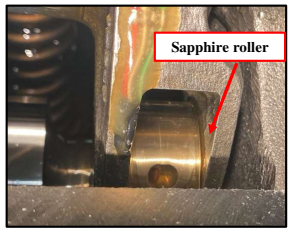
Lubrication Study of Pin Roller

- High speed camera was setup to capture lubrication flow in the roller during operation in VTTR
- Starvation was observed during testing
- The starvation region increased during loading and at high speeds

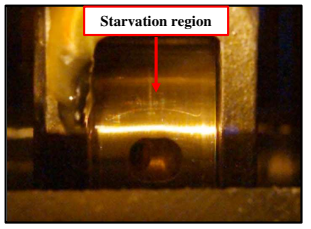




Rocker arm with sapphire roller



Rocker arm with sapphire roller installed

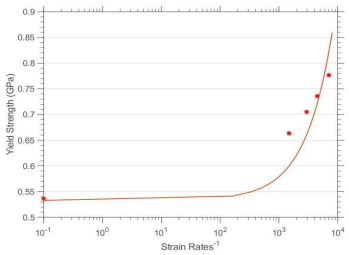


Starvation region during loading condition

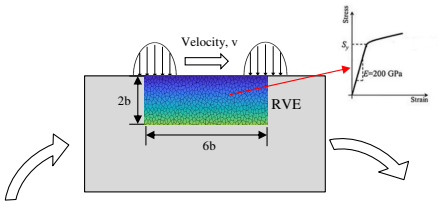
Overview of the Model

- Mechanical properties of the materials are influenced by strain rate hardening [1]
- For higher strain rates ($> 10^3$), there is a drastic variation in the yield stress value [2]
- Strain rate dependent relation is given as,

$$S_{yd} = S_{ys}\{1 + (\dot{\varepsilon}/C)^{\frac{1}{n}}\}$$



Numerical model



Yield strength value is updated based on strain rate

Stresses are calculated at the grain boundaries

$$\Delta N = \frac{\Delta D}{\left(\frac{dD}{dN}\right)_{crit}}$$

Jump in cycles approach

$$\frac{dD}{dN} = \left(\frac{\sigma_{von}^2 R_v}{2ES\,(1-D)^2}\right)^q \dot{p}$$

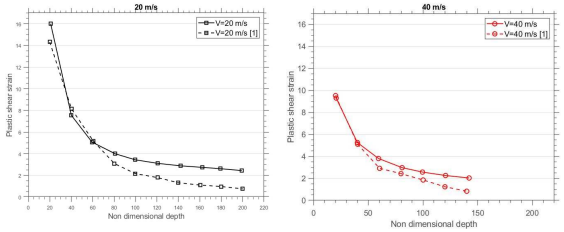
Von mises failure criterion is used

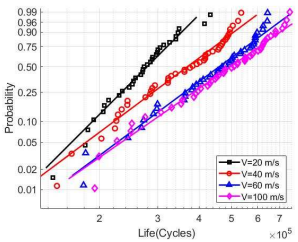
Constants S and q are calculated from the S-N torsion curve for pearlitic mild steel,

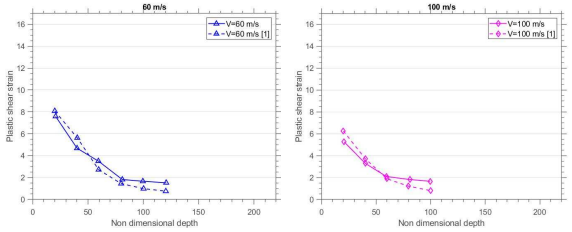
1. Wang, Wei, et al. "Strain rate effect on tensile behavior for a high specific strength steel: From quasi-static to intermediate strain rates." *Metals* 8.1 (2017): 11.
2. Park, Jeong Min, et al. "Strain rate effects of dynamic compressive deformation on mechanical properties and microstructure of CoCrFeMnNi high-entropy alloy." *Mat Sci & Eng. A* 719 (2018): 155-163.

Effect of Strain Rate on Plastic Deformation

- The plastic shear strain is measured as, $\gamma = tan(\delta)$
- The plastic shear strain accumulation is high at low speeds
- Plastic deformation is significantly less at high speeds
- Fatigue life increases with increase in strain rate due to strain rate hardening of the material







1. He, C. G., et al. "Experimental investigation on the effect of operating speeds on wear and rolling contact fatigue damage of wheel materials." *Wear* 364 (2016): 257-269.
2. Ringsberg, J. W., Loo-Morrey, M., Josefson, B. L., Kapoor, A., & Beynon, J. H. (2000). Prediction of fatigue crack initiation for rolling contact fatigue. *International Journal of fatigue*, *22*(3), 205-215.