# Strain Rate Effects in Titanium, Tantalum and Iron

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**Purpose**: To find the ratio of Activation Energy over temperature ($E_K$/kT) and study the effects of Strain rate and temperature in **α-Iron** and **Tantalum monocrystal.** The activation energy can be thought as the energy required dislocation to overcome the barrier at a given thermal conditions. The A.E ratio model developed here and its different significances are based on dislocation mobility law which is thought to affect brittle to ductile transition condition in BCC metals. To study strain rate effects in **Titanium**, was investigate with more details the Dynamic Strain Aging (DSA), this is a effect of the interaction between intertitials elements (C,N,H and O) and dislocations.

## Method

Swegle-Grady Eqn

$$\dot{\varepsilon} = a \times P_{Shock}^{4}$$

$$\tau = -\frac{1-2\upsilon}{2(1-\upsilon)} P_{Shock}$$

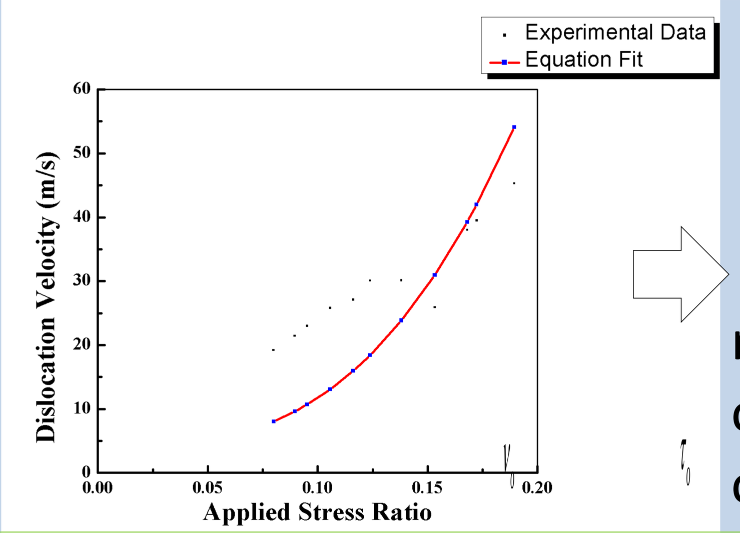
$$v_S\left\{1 - A\exp\left[-B\left(\frac{\tau}{\tau_P}\right)^m\right]\right\}$$

$$v_D = B\left(\frac{\sigma^a}{\tau_P}\right)^m \qquad v_D = A\exp\left(\frac{-E_K}{kT}\right)$$

Prefactor B & Exponent M depend on Temperature

$$A = (0.52 + 40\times(\sigma^a/\tau^P))\times 10^7$$

Tantalum



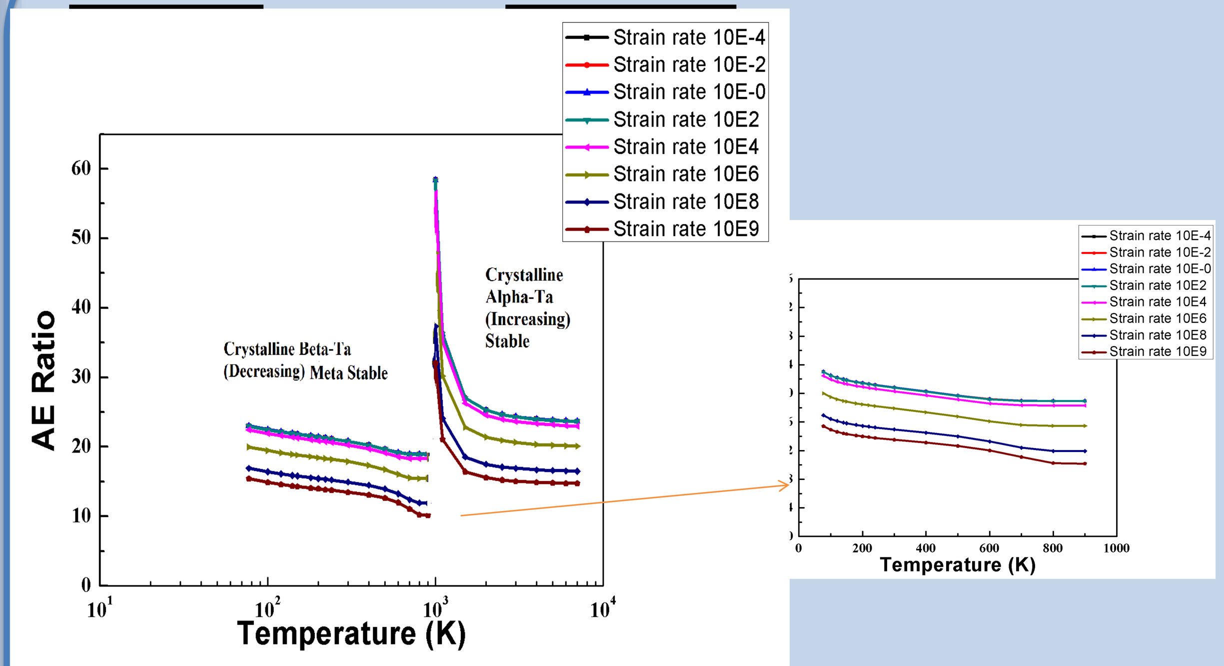

$$v_D = v_o\left(\frac{\tau}{\tau_o}\right)^m \exp\left(\frac{-E_k}{kT}\right)$$

m(t), $\tau_o$(t) & $v_o$(t) are Third order polynomials dependent on Temperature

α- Iron

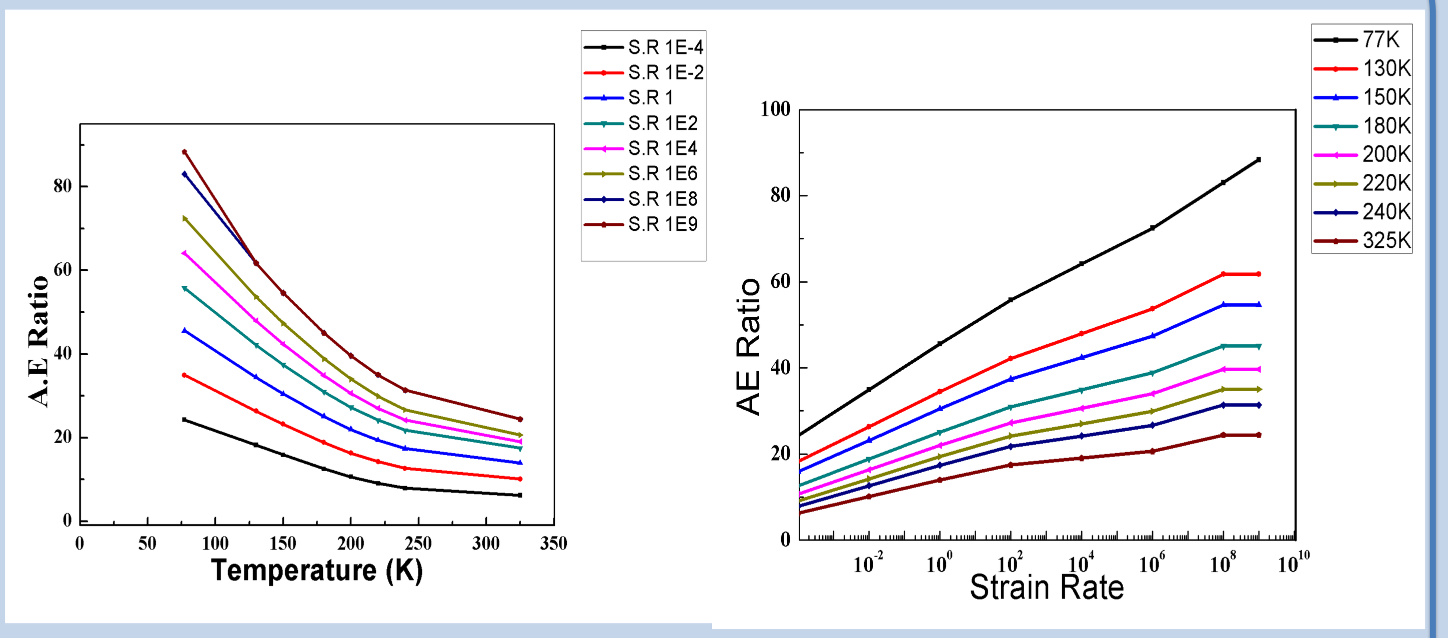
## Results:

### Tantalum



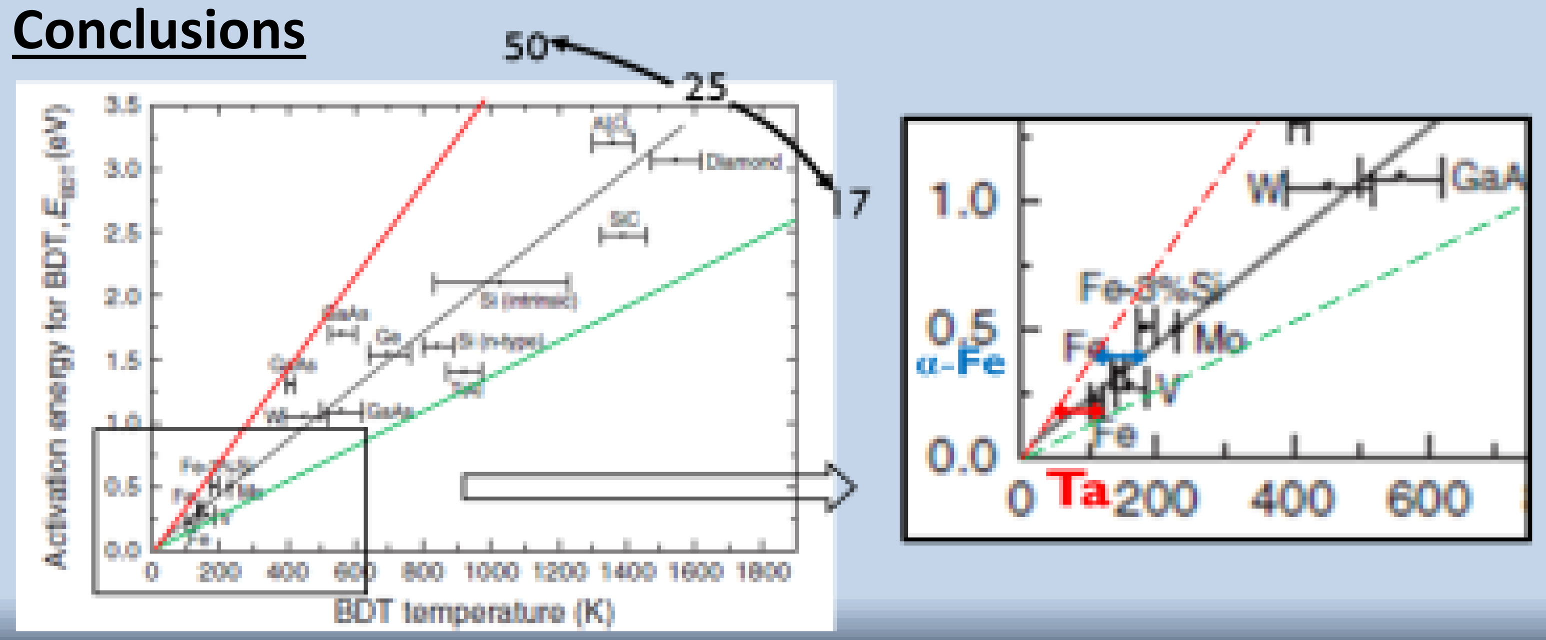

- AE Ratio ~ 23 obtained for BDT condition at 77K, $\dot{\varepsilon} = 10^{-4}s^{-1}$
- T > 940K ,"Jump" in AE ratio probably due to Metastable β-Ta to stable α-Ta transformation

### α- Iron



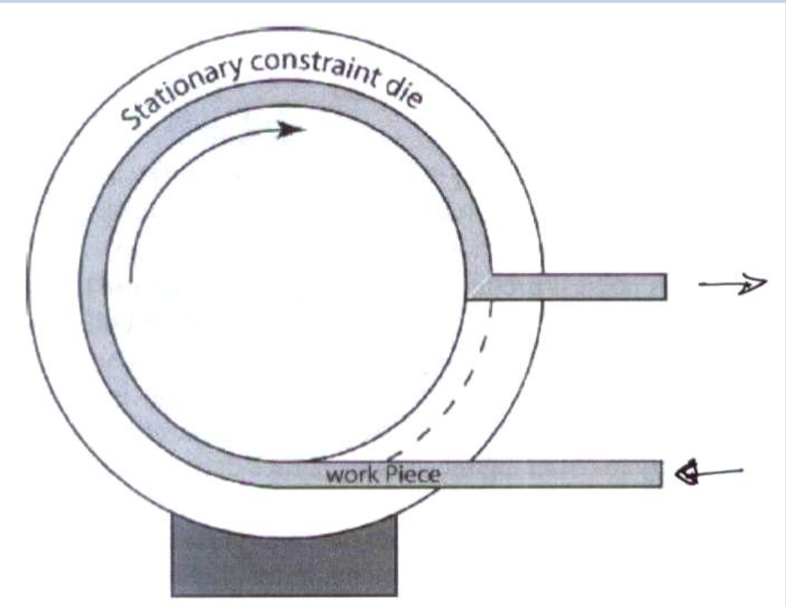

- BDT Condition 140K at Strain rate: $\dot{\varepsilon} = 10^{-3}s^{-1}$
- AE Ratio :- 19 (Experiment ~ 25)
- Low Temp - Double Kink Mechanism
- High Temp- Phonon Drag

## Conclusions



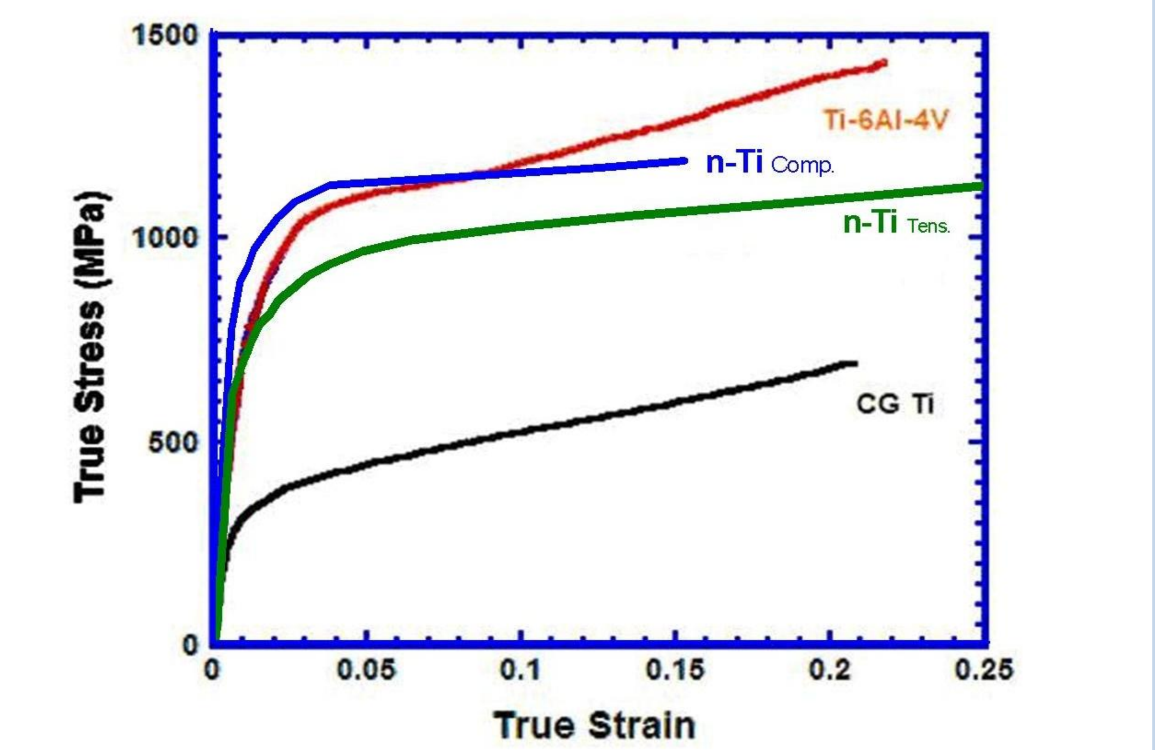

- Uniform Activation energy ratio ~ 25 during the DBT condition
- BDTT shift under effect of $\dot{\varepsilon}$ in Iron but not in Tantalum
- A.E ratio ~ rate of intensity of fracture
- Predict Sharp/Gradual Brittle to Ductile transition in BCC metals
- DSA happens at RT for different Ti, with more or less magnifications.

## Titanium

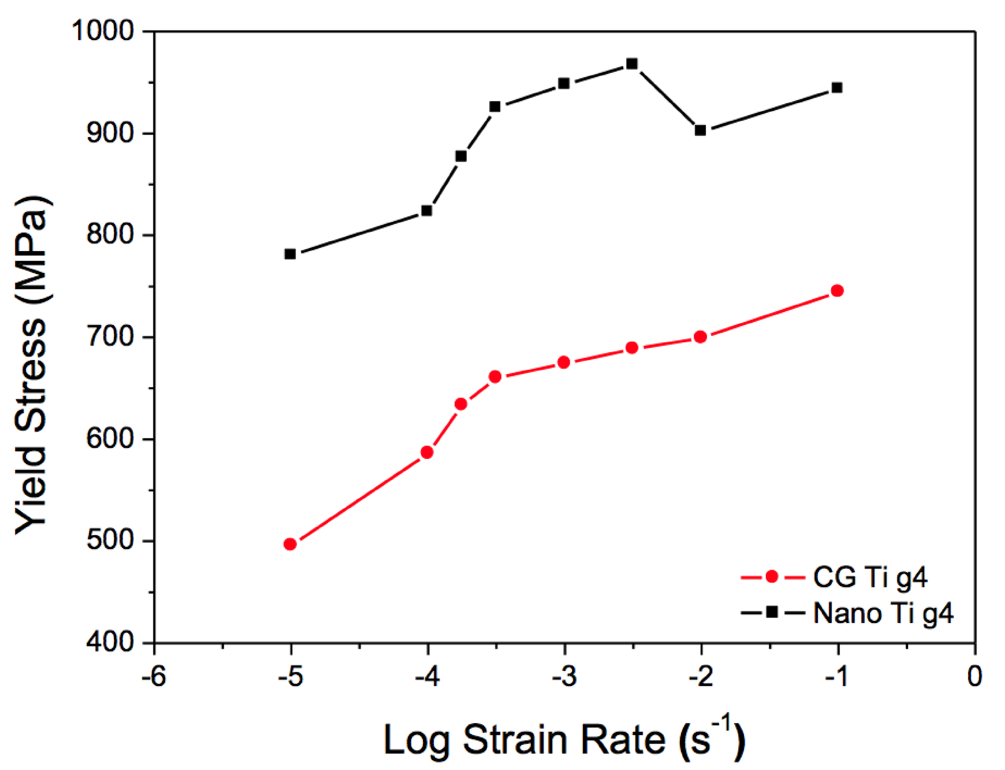



ECAP-Conform

- Commercially pure Titanium (CP Ti) grade 4.
- CP Ti is better than Ti-6Al-4V for implants.
- Nano Ti, mechanical strength was improved by ECAP-Conform.
- Anomalous effect under mechanical tests .

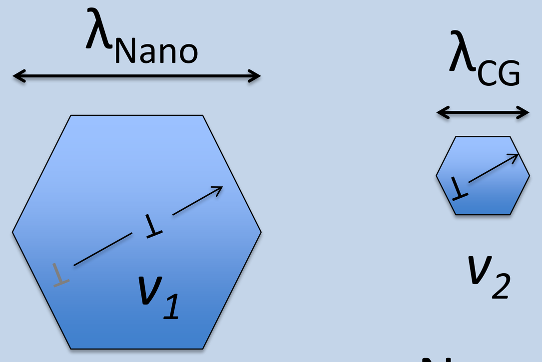


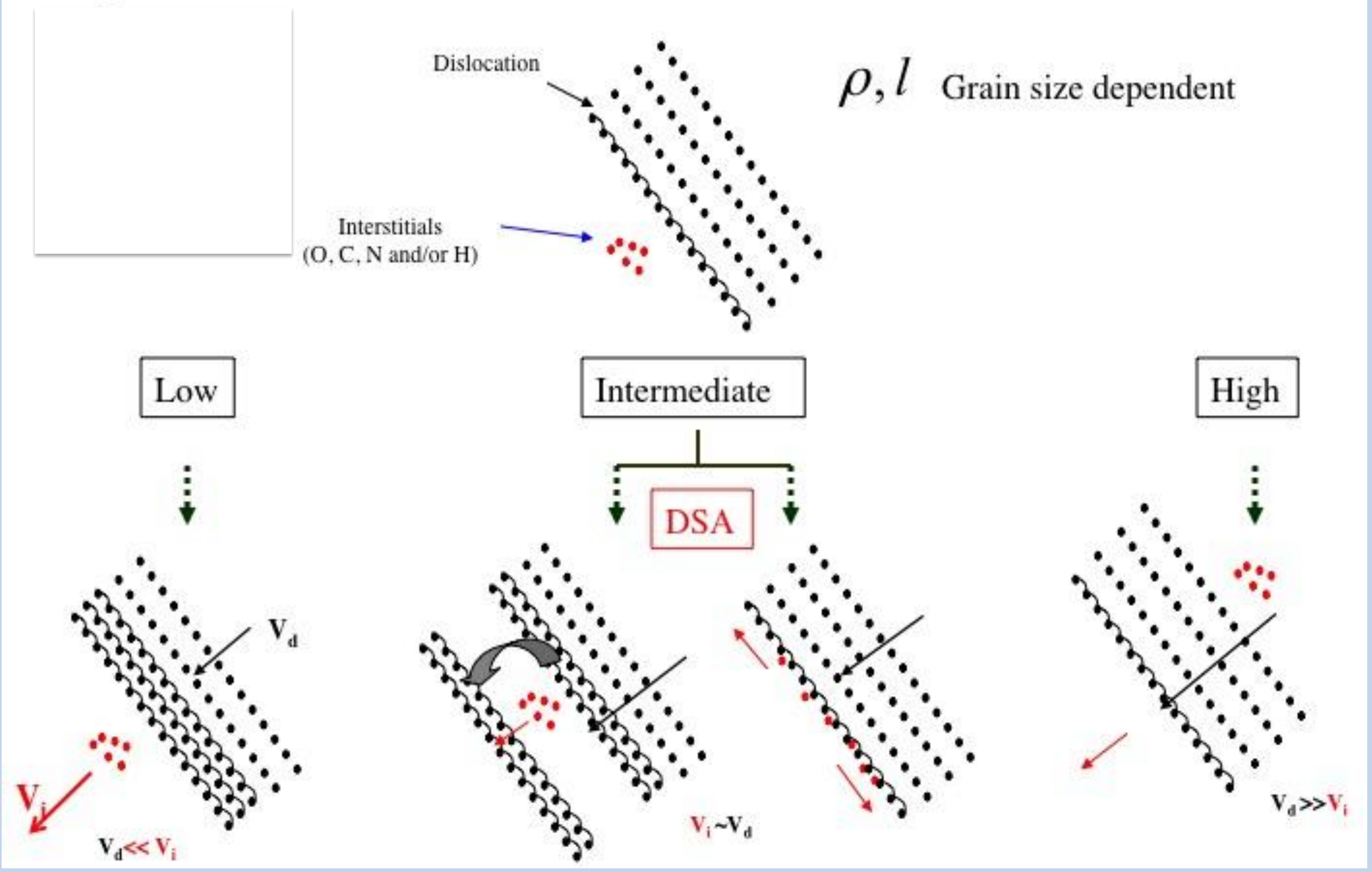

- Pure Ti nano and conventional grain size compared with Ti alloy.




- Graph of Yield stress versus strain rate in compression test.

- Dislocations motions in different strain rates.




*Orowan Equation*

$\gamma = \rho b \lambda$ ; $\rho_{Nano} >> \rho_{CG}$, at constant $\gamma$

$\dot{\gamma} = \rho b v$ ; v for DSA = $v_{dsa}$

$$\frac{\dot{\gamma}}{\lambda b} = v_{dsa}$$

$$\frac{\dot{\gamma}_{Nano}}{\lambda_{Nano} b} = \frac{\dot{\gamma}_{CG}}{\lambda_{CG} b} \Rightarrow \dot{\gamma}_{Nano} = \frac{\rho_{Nano}\dot{\gamma}_{CG}}{\rho_{CG}}$$

- Confirming what is happening

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