Orowan Strengthening by Non-Shearable Particles

Yield strength increase from dislocations bowing between hard particles (Ashby–Orowan) for a given particle radius and volume fraction, with particle spacing.

Method: Ashby–Orowan relation

Input parameters

Unit system: SI

Parameter	Value	Unit
Mean particle radius	10.000	nm
Particle volume fraction	1.0000	%
Shear modulus of the matrix	80.000	GPa
Burgers vector	0.24800	nm
Poisson's ratio	0.30000	
Taylor factor	2.7500	

Calculated results

Parameter	Value	Unit
Mean radius on a slip plane √(2/3)·r	8.1650	nm
Edge-to-edge particle spacing on the plane	128.39	nm
Orowan shear stress	98.471	MPa
Yield strength increase	270.79	MPa

Notes for this case

• Dislocations bypass hard, non-shearable particles by bowing between them and leaving loops (Orowan looping). With the Ashby–Orowan form Δτ = 0.4Gb ln(2r̄_s/b)/[π√(1 − ν)λ], spherical particles of radius r give a mean planar radius r̄_s = √(2/3)·r and an edge-to-edge spacing λ = 2r̄_s(√(π/4f) − 1). At a fixed volume fraction, strength rises as particles get smaller until they become shearable; peak ageing is near that crossover.

Formula and method

$$\Delta\tau = \frac{0.4Gb}{\pi\sqrt{1-\nu}}\frac{\ln(2\bar{r}_s/b)}{\lambda}, \quad \lambda = 2\bar{r}_s\left(\sqrt{\frac{\pi}{4f}}-1\right)$$

Variables

r	Mean particle radius	m
f	Particle volume fraction	-
G	Shear modulus of the matrix	Pa
b	Burgers vector	m
ν	Poisson's ratio	-
M	Taylor factor	-
$\bar{r}_s$	Mean radius on a slip plane √(2/3)·r	m
λ	Edge-to-edge particle spacing on the plane	m
$\Delta\tau$	Orowan shear stress	Pa
$\Delta\sigma$	Yield strength increase	Pa

Method and standards

Orowan stress.

Assumptions and limits

- Spherical, randomly placed, non-shearable particles.

References
Ashby–Orowan relation

Report details

Report reference	FCC-BDPQ-F4NS (the same inputs always give the same reference)
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Release checks	3 reference cases of this calculator, computed independently, are checked on every release

Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online
https://calc.firecad.com/materials/properties/orowan-precipitate-strengthening

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Reopens the calculator with the inputs of this report.