Rotary Kiln Residence Time by Saeman, Fill and Bed Motion

Mean residence time of a rotary kiln or dryer by Saeman's geometric method from bed depth, with degree of fill, hold-up, throughput and Froude number bed regime.

Input parameters

Unit system: SI

Parameter	Value	Unit
Kiln inside diameter (inside the lining)	3.0000	m
Kiln length	75.000	m
Kiln slope	1.4321	°
Dynamic angle of repose of the material	38.000	°
Kiln speed	1.2000	rpm
Bed depth at the centre of the chord	0.35000	m
Bulk density of the bed	1,500.0	kg/m³

Calculated results

Parameter	Value	Unit
Degree of fill (cross-section occupied)	6.5231	%
Chord length of the bed surface	1.9261	m
Dimensionless residence time	0.34564	
Mean residence time	177.33	min
Material hold-up	51.872	t
Throughput at this bed depth	17.551	t/h
Rotational Froude number ω²R/g	0.002415	
Critical (centrifuging) speed	24.417	rpm
Speed as a fraction of critical	4.9147	%

Notes for this case

- Bed motion by Henein's Froude-number ranges: rolling. Most kilns run rolling, at 4–20 % of critical speed.
- Saeman's method assumes a uniform bed depth along the kiln (no dams); it reduces to the US Bureau of Mines formula for shallow beds. The throughput is the hold-up divided by the residence time.

Formula and method

$$\bar{\tau} = \bar{\tau}_d \frac{L \sin\xi}{nD \tan\phi}, \quad \bar{\tau}_d = \frac{\sin^{-1} s}{\pi s}, \quad s = \sqrt{(2 - y/R)\, y/R}, \quad f = \frac{\theta - \sin\theta}{2\pi}, \quad \theta = 2\cos^{-1}\frac{R-y}{R}, \quad Fr = \frac{\omega^2 R}{g}$$

Variables

D	Kiln inside diameter (inside the lining)	m
L	Kiln length	m
ϕ	Kiln slope	rad
ξ	Dynamic angle of repose of the material	rad
n	Kiln speed	1/s
y	Bed depth at the centre of the chord	m
ρ_b	Bulk density of the bed	kg/m³
f	Degree of fill (cross-section occupied)	-
L_c	Chord length of the bed surface	m

$\bar{\tau}_d$	Dimensionless residence time	-
$\bar{\tau}$	Mean residence time	s
H	Material hold-up	kg
$\dot{m}$	Throughput at this bed depth	kg/s
Fr	Rotational Froude number ω²R/g	-
n_c	Critical (centrifuging) speed	1/s
n/n_c	Speed as a fraction of critical	-

Method and standards

Saeman geometric residence time and Henein bed-behaviour diagram.

Assumptions and limits

- Uniform bed depth; no dams or lifters; free-flowing solids.

Report details

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

This calculator online

https://calc.firecad.com/chemical/cement/rotary-kiln-saeman-residence-time

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Reopens the calculator with the inputs of this report.