Slider–Crank: Piston Displacement, Velocity and Acceleration

Piston displacement, velocity and acceleration of a slider–crank at a crank angle from crank radius, rod length and speed, with mean piston speed.

Method: Rattan; Theory of Machines; ...

Input parameters

Unit system: SI

Parameter	Value	Unit
Crank radius	50.000	mm
Connecting rod length	200.00	mm
Crank speed	1,500.0	rpm
Crank angle from inner dead centre	45.000	°

Calculated results

Parameter	Value	Unit
Piston displacement from inner dead centre	17.795	mm
Piston velocity	6.5511	m/s
Piston acceleration (m/s²)	877.41	
Mean piston speed	5.0000	m/s
Connecting rod angle	10.182	°

Notes for this case

• Exact relations; the common approximations v ≈ rω(sin θ + sin 2θ/2n) and a ≈ rω²(cos θ + cos 2θ/n) are close for n = l/r above about 3.5. The acceleration here is in m/s².

Formula and method

$$x = r(1-\cos\theta) + l - \sqrt{l^2 - r^2\sin^2\theta}, \quad v = r\omega\left(\sin\theta + \frac{\sin\theta\cos\theta}{\sqrt{n^2-\sin^2\theta}}\right)$$

$$a = r\omega^2\left(\cos\theta + \frac{n^2\cos 2\theta + \sin^4\theta}{(n^2-\sin^2\theta)^{3/2}}\right), \quad \bar{v} = 4rN, \quad \sin\phi = \frac{\sin\theta}{n}, \quad \omega = 2\pi N, \; n = \frac{l}{r}$$

Variables

r	Crank radius	m
l	Connecting rod length	m
N	Crank speed	1/s
θ	Crank angle from inner dead centre	rad
x	Piston displacement from inner dead centre	m
v	Piston velocity	m/s
a	Piston acceleration	m/s²
ω	Crank angular speed 2πN	rad/s
n	Rod ratio l/r	-
$\bar{v}$	Mean piston speed	m/s
ϕ	Connecting rod angle	rad

Method and standards

Exact slider–crank relations.

Assumptions and limits

- Rigid links; constant crank speed.
- The acceleration is given in m/s² in every unit system.

References

• Rattan
• Theory of Machines
• 4th ed. (McGraw-Hill, 2014); Bhandari
• Design of Machine Elements
• 4th ed. (McGraw-Hill, 2017) (slider–crank: exact displacement, velocity and acceleration)

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/mechanical/machine-design/slider-crank-kinematics

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Reopens the calculator with the inputs of this report.