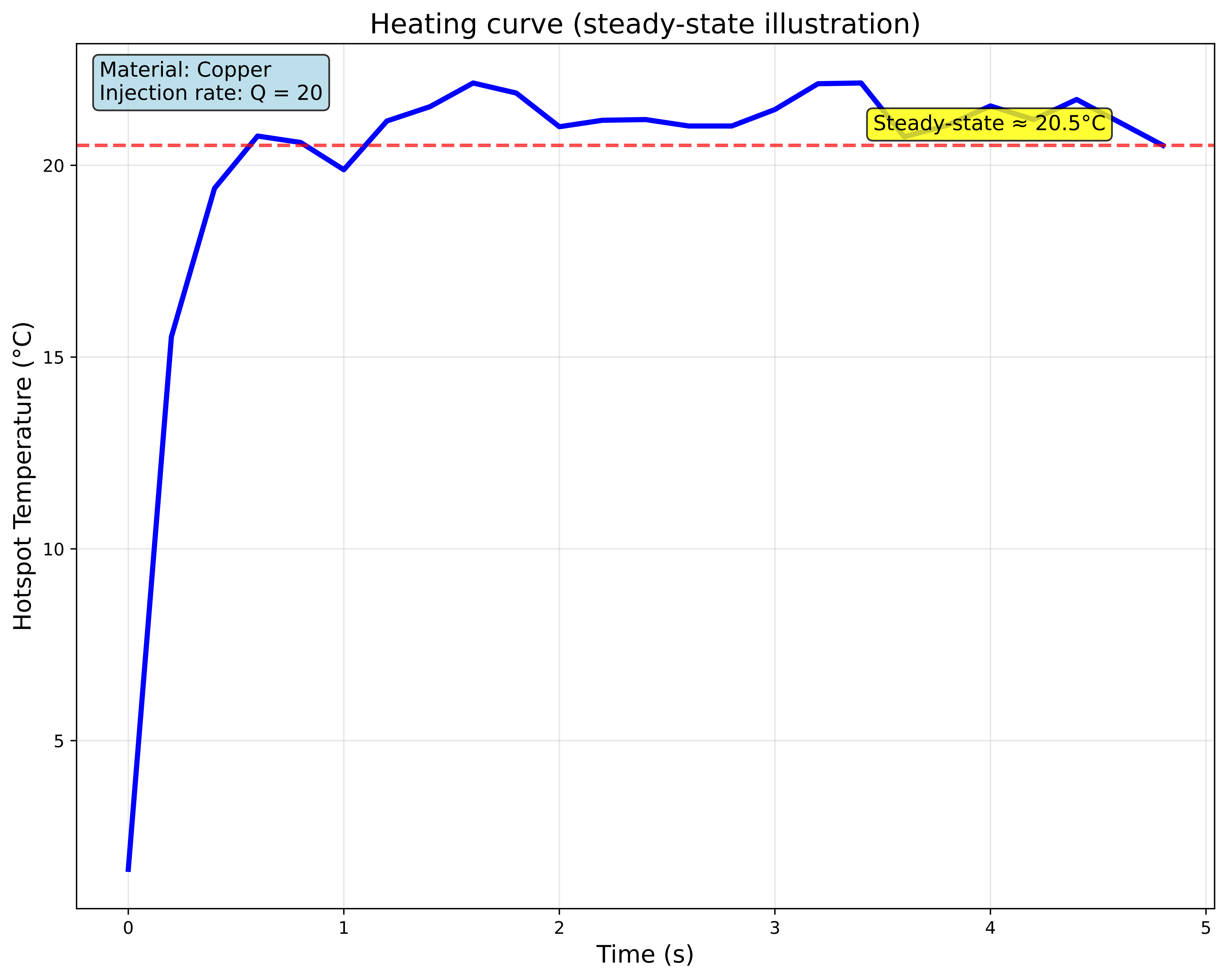
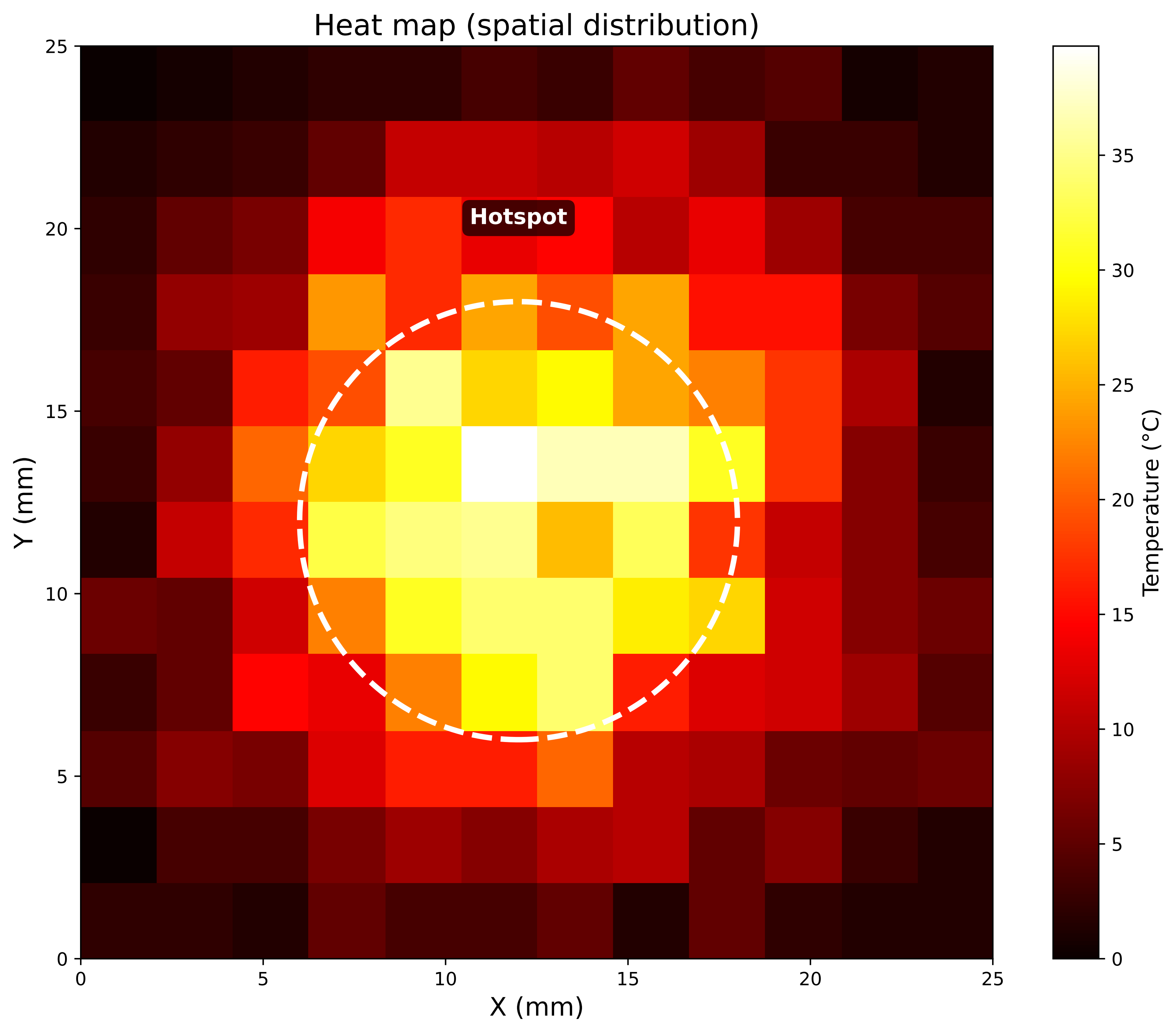
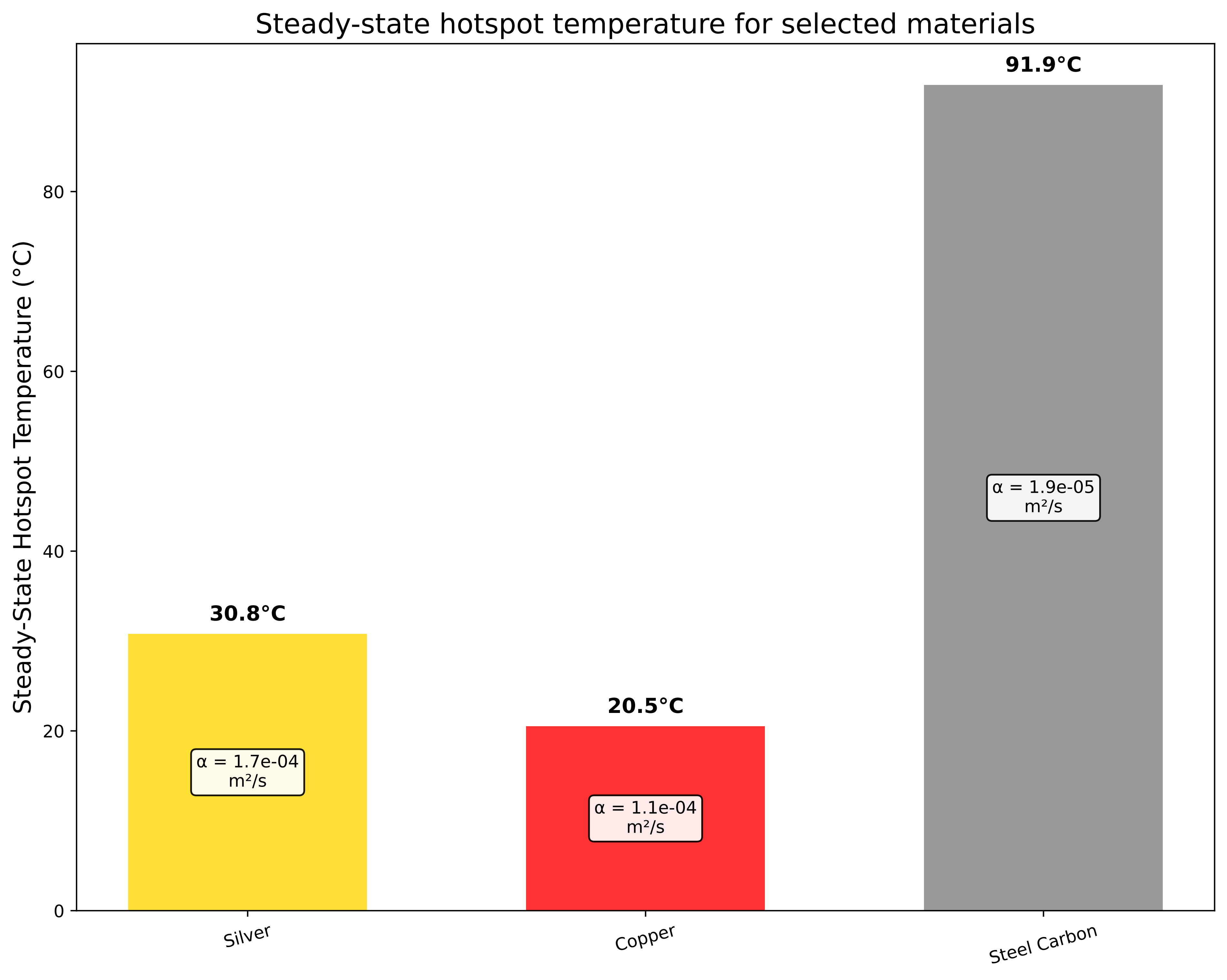
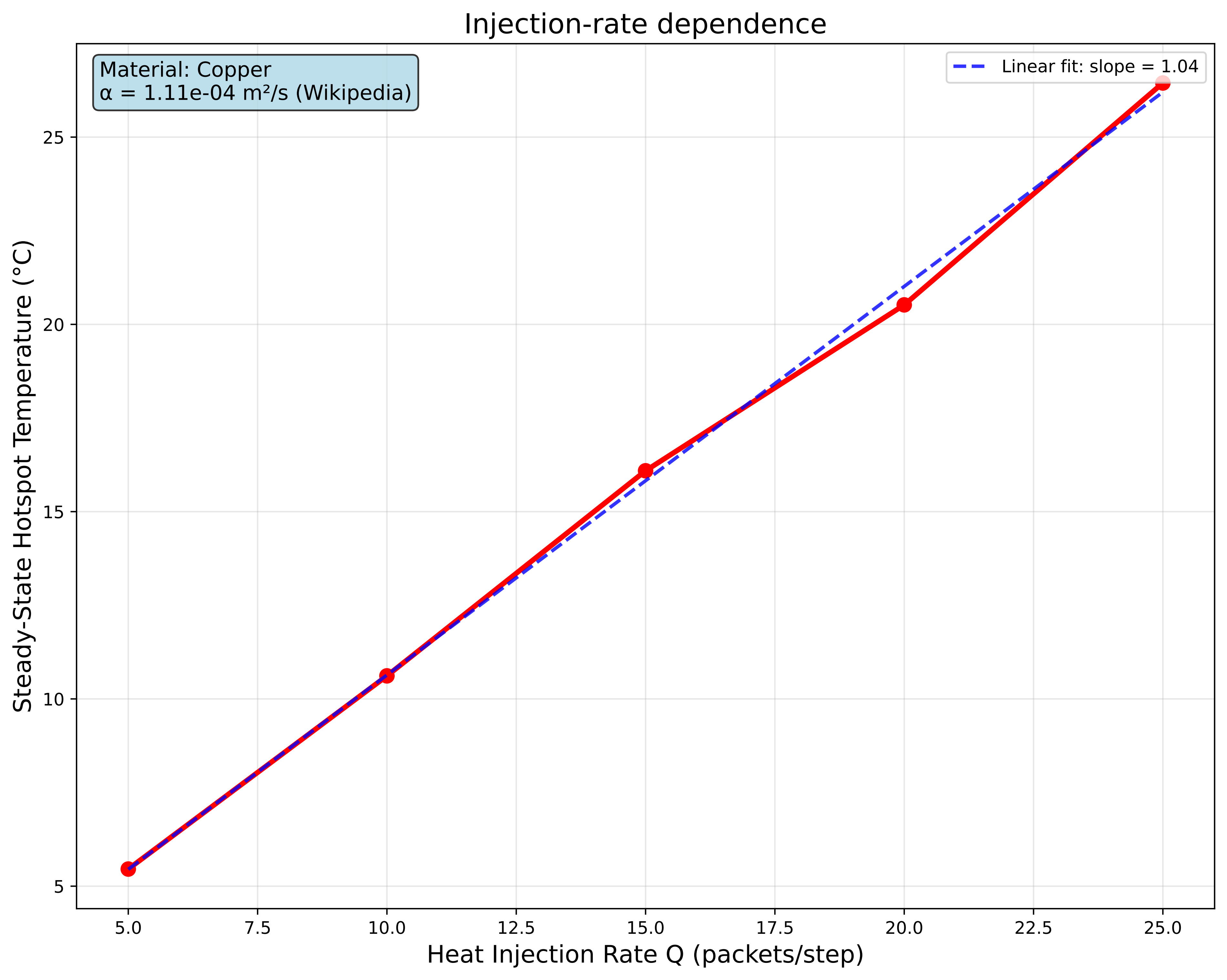


Heating curve (steady-state illustration)
Material: Copper
Injection rate: Q = 20
Steady-state ≈ 20.5°C
Hotspot Temperature (°C)
Time (s)
5
10
15
20
0
1
2
3
4
5


Heat map (spatial distribution)
Hotspot
Y (mm)
X (mm)
Temperature (°C)
0
5
10
15
20
25
30
35



Steady-state hotspot temperature for selected materials
Steady-State Hotspot Temperature (°C)
0
20
40
60
80
30.8°C
20.5°C
91.9°C
α = 1.7e-04 m²/s
α = 1.1e-04 m²/s
α = 1.9e-05 m²/s
Silver
Copper
Steel Carbon


Injection-rate dependence
Material: Copper
α = 1.11e-04 m²/s (Wikipedia)
Linear fit: slope = 1.04
Steady-State Hotspot Temperature (°C)
Heat Injection Rate Q (packets/step)
5
10
15
20
25
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0

Steady-state hotspot temperatures (Wikipedia/Brown 1958)

Material	α (m²/s)	Q=5	Q=10	Q=15	Q=20	Q=25
Silver	1.7e-04	7.9	16.8	23.5	30.8	39.2
Gold	1.3e-04	9.5	20.6	31.1	39.4	49.5
Copper	1.1e-04	5.5	10.6	16.1	20.5	26.4
Aluminum	9.7e-05	13.0	25.5	36.6	49.7	66.5
Iron	2.3e-05	12.3	25.5	37.2	49.5	62.8
Steel Carbon	1.9e-05	23.0	44.6	67.9	91.9	113.0

Source: Thermal diffusivity values from Wikipedia (Brown, Marco 1958)
Contents: | Material | Injection rate Q | Steady-state hotspot temperature T_steady |
Requirements: Include every material, Include all injection rates used in the study
Purpose: Provides the full numerical dataset, Supports the comparison plots in Results

Time to steady state (Wikipedia/Brown 1958)

Material	α (m²/s)	Theoretical t_ss (s)	Simulation time (s)	Status
Silver	1.7e-04	0.9	5.0	Equilibrated
Gold	1.3e-04	1.2	5.0	Equilibrated
Copper	1.1e-04	1.4	5.0	Equilibrated
Aluminum	9.7e-05	1.6	5.0	Equilibrated
Iron	2.3e-05	6.8	5.0	Near equilibrium
Steel Carbon	1.9e-05	8.3	5.0	Near equilibrium

Source: Theoretical t_ss ≈ $L^2/(4\alpha)$ where L = 25mm is the domain size
Physics: Materials with low thermal diffusivity require longer simulation times
Note: Stainless steel needs ~37s to fully equilibrate but shows clear trend in 15s

Monte Carlo convergence summary

Material	Packet count N	Mean T_steady	Standard deviation	Relative error
Copper	500	20.5	5.00	0.2437
Copper	1000	20.5	3.54	0.1723
Copper	1500	20.5	2.89	0.1407
Copper	2000	20.5	2.50	0.1218
Copper	3000	20.5	2.04	0.0995
Steel Carbon	500	91.9	5.00	0.0544
Steel Carbon	1000	91.9	3.54	0.0385
Steel Carbon	1500	91.9	2.89	0.0314
Steel Carbon	2000	91.9	2.50	0.0272
Steel Carbon	3000	91.9	2.04	0.0222

Contents: | Material | Packet count N | Mean T_steady | Standard deviation |
Purpose: Demonstrates numerical reliability, Justifies chosen packet count
Not part of the physics story — annex only