Economics of Cold Spray-Cost Analysis

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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Procedure

1. Define coating dimensions (area, thickness)
2. Define operating conditions (pressure, temperature, etc.)
3. Define material characteristics (particle size, melting point, etc.)
4. Calculate deposition efficiencies
5. Input costs rates (powder, gas, labor)
6. Calculate cost

Aerodynamics and Deposition

- **Classical isentropic gas dynamics (adiabatic, frictionless)**
- **Particles do not influence gas conditions**

$$\frac{A_1}{A_2} = \frac{M_2}{M_1}\left\{\frac{1+[(\gamma-1)/2]M_1^2}{1+[(\gamma-1)/2]M_2^2}\right\}^{\frac{(\gamma+1)}{2(\gamma-1)}}$$

Isentropic flow area/Mach number relationship

$$m\frac{dV_p}{dt} = C_D(\pi/8)\rho_g d^2(V_g - V_p)^2$$

Particle drag/velocity relationship

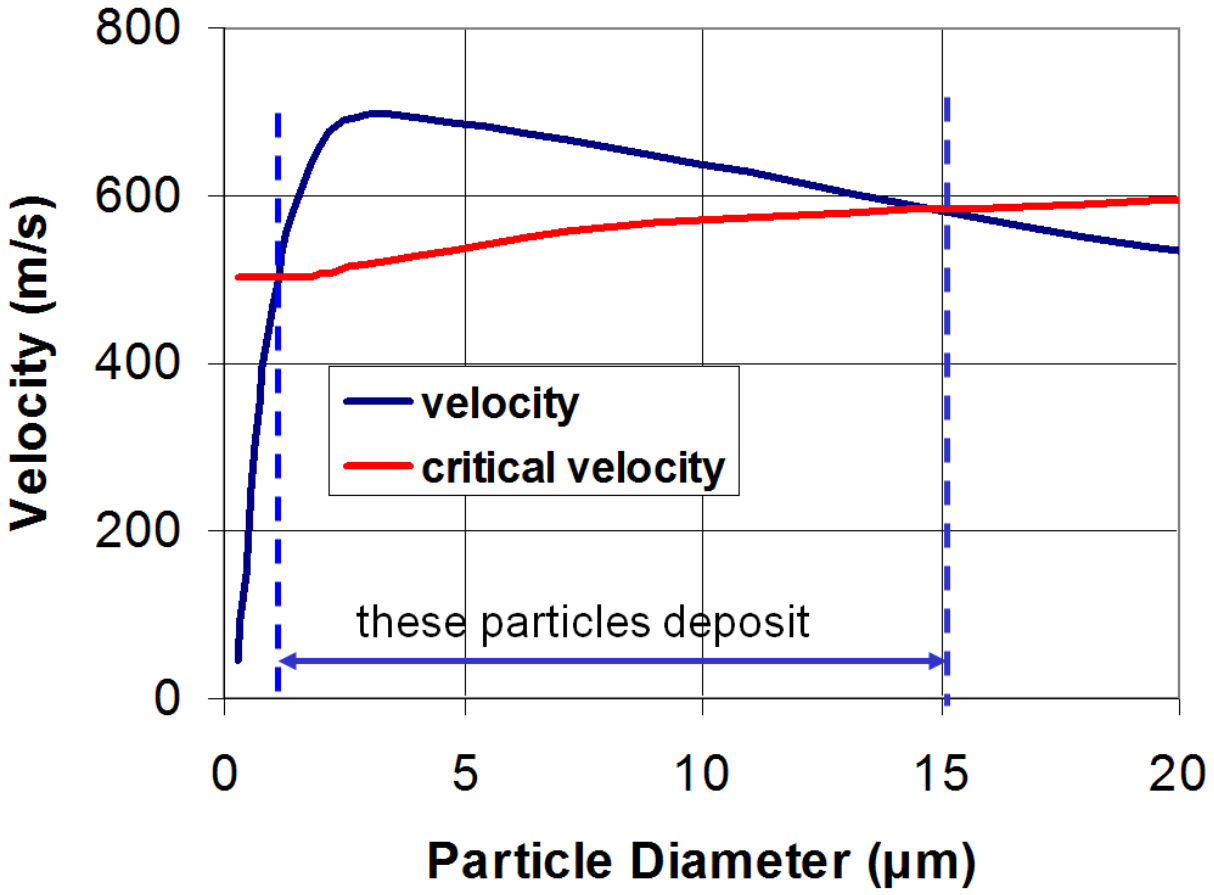
$$c_p\frac{dT_p}{dt} = (N_u k/d_p)(A_p/m)(T_g - T_p)$$

Particle temperature/gas temperature relationship

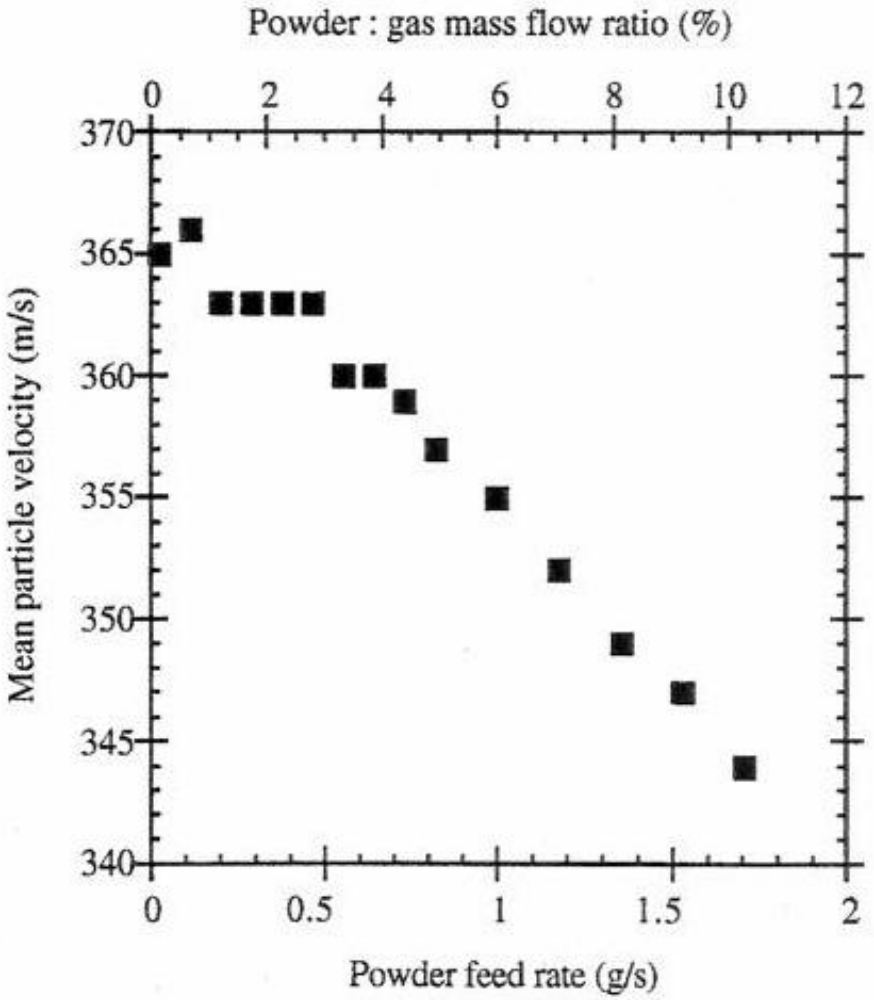
$$V_{crit} = \sqrt{\frac{4F_1\sigma_{TS}\left(1-\frac{T_i}{T_m}\right)}{\rho} + F_2 C_p(T_m - T_i)}$$

Critical velocity for deposition

Criteria for Deposition



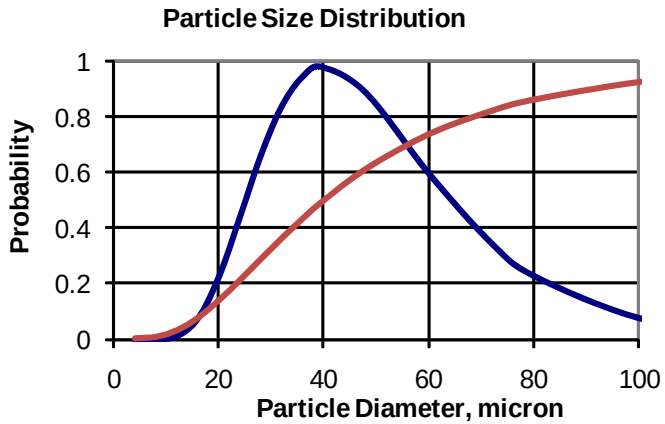
The Affect of Powder Loading

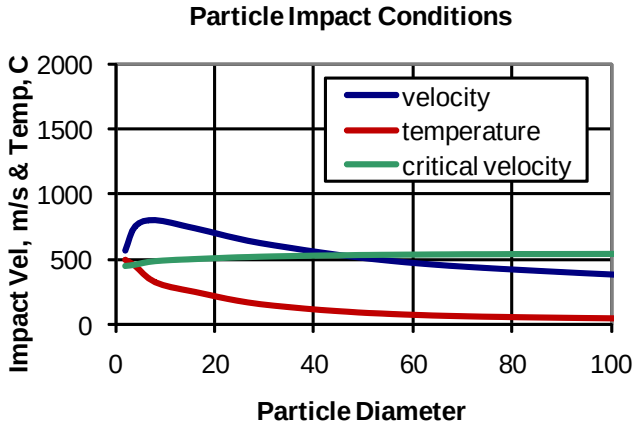


Copper particles in air from Gilmore, et al, JTST, 1999

Interactive Calculator

throat diameter	2.7	mm	area	144	sq inch
nitrogen (0) helium (1)	0		thickness	20	mil
feed rate	10	pound/hour	overspray	10	%
raster speed	400	mm/sec	time for completion	0.4	hours
increment	1	mm	number layers	6.7	
gas temp after heating	500	degree C	powder usage	4.3	pounds
compressed gas pressure	500	psig	electricity usage	15.9	kWhr
geometric mean diameter	40	micron	powder cost/wt	200	$/pound
standard deviation	1.5		nitrogen cost/SCF	0.4	$/100 SCF
shape factor	1.2		helium cost/SCF	20	$/100 SCF
material density	8.9	gm/cc	set-up time per piece	0.10	hours
melting point	1453	degree C	hourly labor rate	125	$/hr
specific heat	450	J/kg-K			
ultimate stress	195	Mpa	powder cost	$861	
			gas cost	$5	
gas flow	47.8	SCFM	labor cost	$66	
wt% powder to gas	4.5	%	unit cost	$934	
deposition efficiency	23.9	%			





Recommendations

1. Use nitrogen when spraying inexpensive powders
2. Use helium when spraying expensive powders
3. Use the highest possible feed rate
4. Use powders with small diameter particles
5. A narrow particle size distribution (small SD) is best
6. Irregularly shaped particles are better than spherical

? Questions ?