The radial temperature distribution of a constricted oxygen arc in plasma arc cutting

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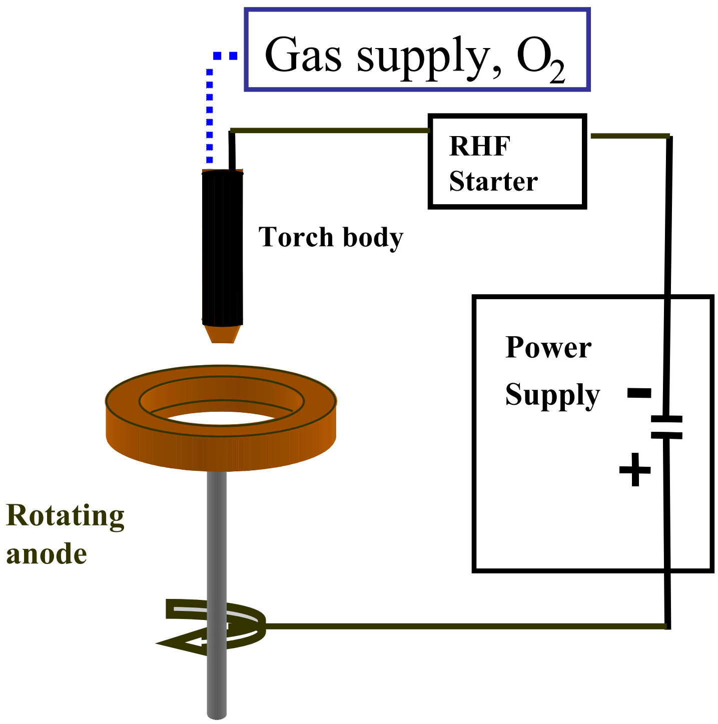
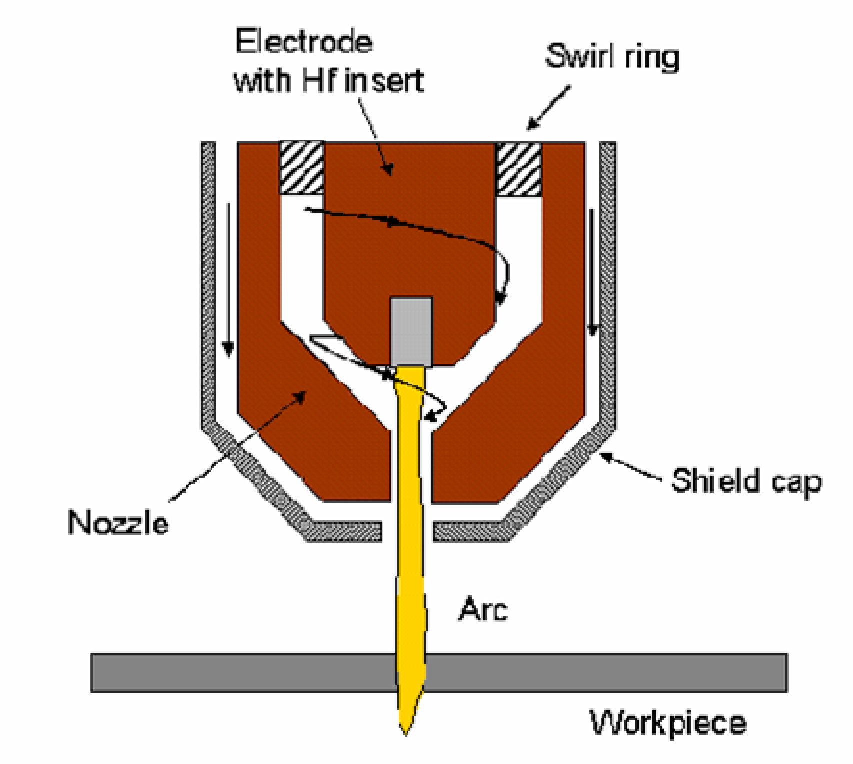
Plasma Arc Cutting

Components of cutting system



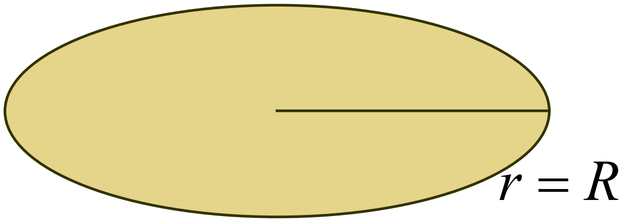
Cutting torch components



Elenbaas-Heller Equation

$$\frac{1}{r}\frac{d}{dr}\left[rk(r)\frac{dT}{dr}\right]=\lambda(T)-\sigma(T)E^2$$

$$I=2\pi\int_0^R E\sigma(r)rdr=2\pi\cdot E\int_0^R \sigma(r)rdr$$

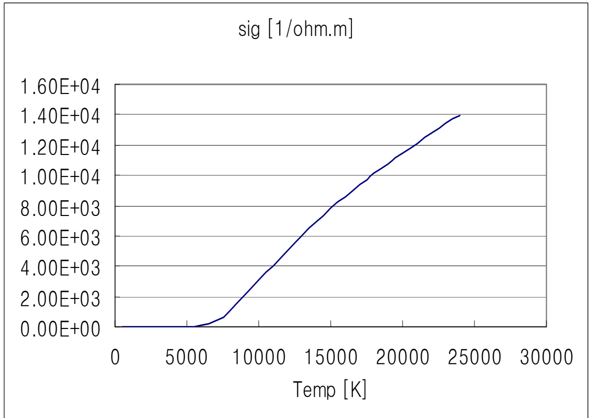


$\lambda(T)=0$ $\quad 0\le T\le 4\times10^3\ ^\circ K$

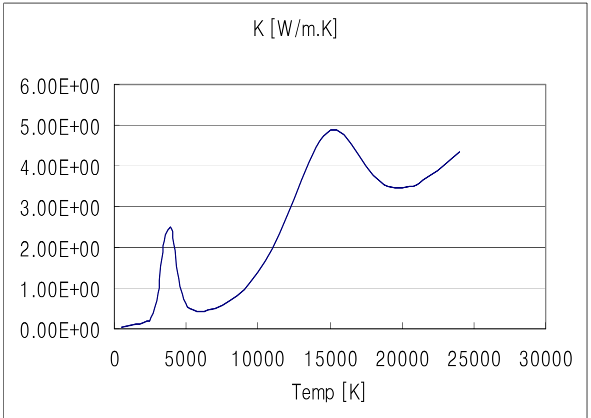
$\lambda(T)=1.18512\times10^{10}\left[(T-4000)/12800\right]^{4.795} ergs/cm^3\cdot\mathrm{sec}$ $\quad 4\times10^3\ ^\circ K\le T\le 16\times10^3\ ^\circ K$

$\lambda(T)=1.8641\times10^{16} ergs/cm^3\cdot\mathrm{sec}$ $\quad T>16\times10^3\ ^\circ K$

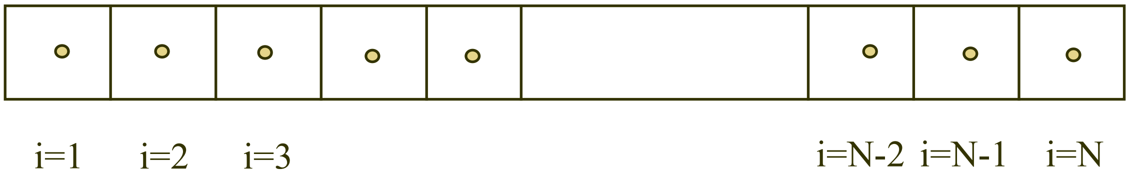
$\sigma(T)$



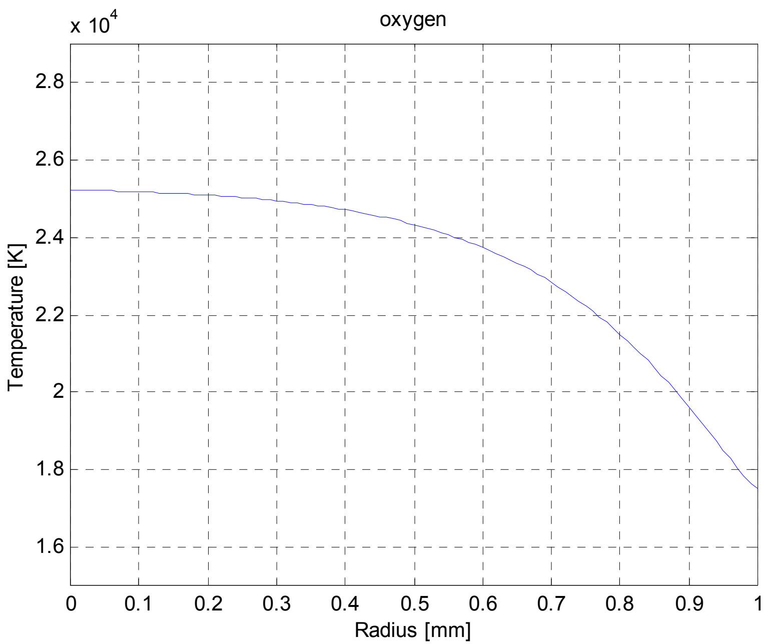
$k(r)$

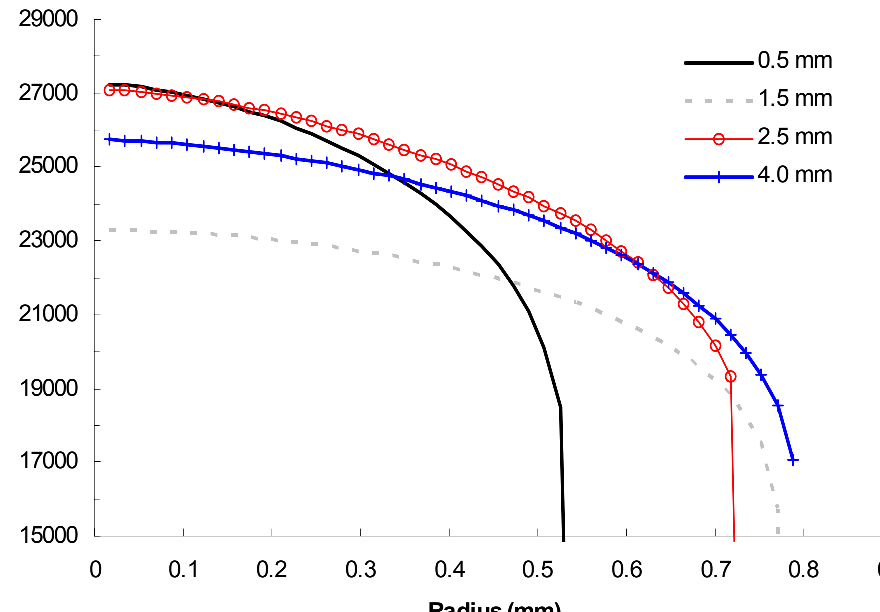


Gauss-Siedel Method



$$\frac{1}{r_i}\frac{d}{dr}\frac{r_{i+1/2}k_{i+1/2}\frac{T_{i+1}-T_i}{dr} - r_{i-1/2}k_{i-1/2}\frac{T_i-T_{i-1}}{dr}}{dr} = \lambda_i - \sigma_i E_i^{2} \qquad E_i = \frac{I}{2\pi\sum_i \sigma_i r_i dr}$$





Heat transfer to the anode

$$q_a = j\phi_w + 3.203\frac{k_B}{e} jT_e - K_h \frac{dT_h}{dx} - K_e \frac{dT_e}{dx} - j_i(\varepsilon_i - \phi_w)$$

$$j = \sigma E_x \qquad I = 2\pi\int_0^R jrdr = 2\pi E_x \int_0^R \sigma\, rdr$$