3.3.9 Inertia Forces

While at slow speeds and low accelerations, inertia forces are negligible, at high speeds and accelerations inertia forces become predominant. In Refs. [20] and [21], inertia forces are included in the upper-bound solution. Note that only the inertia terms

$$w_k = \left(\frac{1}{2}\right) g v_f^2 \quad \textit{for wire drawing}$$ Eq. (h)

and

$$w_k = \left(\frac{1}{2}\right) g v_0^2 \left[(R_0 / R_f)^4 - 1 \right] \quad \textit{for extrusion}$$ Eq. (i)

are dependent on the velocity, and to the second power. The inertia term for wire drawing presumes that the product is accelerating from a stand-still position; for extrusion, the initial velocity is presumed to be v_o. The higher the velocity, the more predominant the inertia power, dropping to zero as speed approaches zero. The higher the specific weight and the lower the flow strength of the material, the more pronounced the inertia effect.

In Fig. <17> for extrusion, the abscissa is the percent reduction in area and the ordinate is the relative extrusion pressure. For a typical steel, the two horizontal lines represent that portion of the extrusion pressure which neglects the inertia forces. The upper line represents extrusion at room temperature with strength of $\sigma_o = 2000$ kg/cm², while the lower line represents extrusion at elevated temperature with flow strength of $\sigma_o = 500$ kg/cm². Because steel at low temperatures is not sensitive to strain rates, this portion of the pressure is not sensitive to speed, as indicated by Eqs. (1) and (2).

The dashed lines represent the inertia forces for several rates of extrusion. The inertia term is not sensitive to temperature and, therefore, these lines represent the values to be added to each of the solid lines at the several speeds. At low speed (v_o = 1000 cm/sec), inertia forces are negligible. At higher speeds and higher reductions, the inertia term is more pronounced. The relative weight of the inertia force is more pronounced at elevated temperature, when flow strength is lower. Inertia forces are neither functions of die angle nor of friction.

Please note that inertia energy is stored in the emerging product as kinetic energy, unlike the internal power of deformation and friction shear losses which convert into heat. The inertia-stored kinetic energy reduces as the product slows down. In some high-speed extrusions, the completed billet shoots out of the chamber at the speed of a bullet coming out of a rifle. Occasionally during uncontrolled hydrostatic extrusion, the chamber pressure drops suddenly and the billet within the chamber stops abruptly. The stored kinetic energy in the emerging product is sufficient to pull and tear the product away from the die.