NOMENCLATURE

a  height or depth
b  width
C  cost of material of round stock, height of conical nose
C_4  cost of powder material
C_d  cost of the die (only the part being replaced)
C_m(i)  maintenance cost for method (i), i = 1,...,5
C_p(i)  power cost for method (i), i = 1,...,5
C_r(i)  waste recovery cost for method(i), (i) i = 1,...,5
C_{r'}(i)  capital recovery cost for method (i), i = 1,...,5
C_s  cost of scrap material
C_t(i)  total cost for method (i), i = 1,...,5
d  diameter of cylindrical portion of punch
D  diameter of disc
F  flat to flat distance
F_1  estimated salvage value
H  number of working hours per year
i  interest rate
J  upper bound energy consumption, externally applied power
l  length of the round stock for producing one nut, length of punch
L  combined length of the piece unutilised on both ends of a single drawn bar stock
L_f  one full length of the drawn stock
L_{r'}(i)  labour cost for (i) type of labour
L_{r'}(ii)  labour cost for (ii) type of labour and so on
\[ t_p \] mean time between two consecutive die replacements
\[ T_2 \] thickness
\[ T_1 \] tariff
\[ T \] thickness
\[ T_{l} \] loading time
\[ T_m \] machinery time
\[ T_u \] unloading time
\[ u \] punch velocity
\[ U_{i,s} \] components of velocity vectors
\[ U_{\theta} \] tangential components of the velocity
\[ U_{\phi}, U_{\psi} \] circumferential velocity components
\[ U_r \] radial component of the velocity
\[ U_y \] axial component of the velocity
\[ V \] volume, velocity
\[ v \] velocity discontinuity
\[ V_{\text{flash}} \] flash volume
\[ w \] connected load
\[ \dot{W} \] power (work per unit time)
\[ \dot{W}_b \] power associated with back pull or external tractions
\[ \dot{W}_d \] internal power of deformation
\[ \dot{W}_{f_1}(k) \] frictional power dissipation in different regions for different shaped punches
\[ \dot{W}_e \] total frictional work dissipation rate
\[ \dot{W}_p \] total plastic work dissipation rate
\[ \dot{W}_{p1}, \dot{W}_{p2}, \dot{W}_{p3} \] plastic work dissipation rate in different regions
\[ \dot{W}_f \] frictional power dissipation in different regions
plastic work dissipation rate in different regions for different shaped punches

$W_{pi(k)}$ or $\dot{W}_{pi(k)}$

components of coordinate system

$x, y, z$

axial coordinate of cylindrical coordinate system

$\alpha$

angle, slope

$\varepsilon$

strain

$\dot{\varepsilon}$

strain rate

$\theta$

axis in cylindrical coordinate system, angle

$\phi, \psi$

angles

$\sigma_0$

yield strength of material in compression

$\tau$

year stress

$\rho$

density

Superscripts

$max$

maximum

$min$

minimum

$i$

$1, 2, 3, \ldots$

$k$

$1, 2, 3, \ldots$

$ij$

denoting component of a tensor

$d$

differential or infinitesimal value

$\delta$

very small portion

$\Delta$

difference

$\theta$

origin

$f$

function, friction