10 Economics of Metal Removal

10.1 Optimization of Parameters in Turning

The cost of producing components is made up of the raw material, and machining costs and factory overheads. In many machining operations the percentage of raw material utilized in the finished product is extremely low, and in these cases considerable savings can often be made by adopting metal forming or casting rather than metal cutting techniques. By using value analysis, which is an uninhibited approach to reducing product costs, drastic reductions can sometimes be obtained, by changing either the design or the manufacturing process, or both.

Despite this, machining may still be the most economical method of production and it is often necessary to machine away large volumes of material. It is surprising, therefore, that this is usually done with little concern for the economic selection of machining parameters. The turning process has been investigated fairly exhaustively by Brewer and Rueda and PERA, but the other machining processes do not appear to have received much attention.

Once the process has been selected raw material cost will presumably be fixed, so in compiling the cost equation the only elements considered are those relating to machining cost and overhead. These elements are as follows:

(a) set-up and idle time cost/piece, $K_1$;
(b) machining cost/piece, $K_2$;
(c) tool changing cost/piece, $K_3$;
(d) tool re-grinding cost/piece, $K_4$;
(e) tool depreciation cost/piece, $K_5$.

If throw-away tips are used, tool regrinding can be ignored.

For turning, assume a cylindrical component of length $L$ mm (in) and diameter $D$ mm (in) is turned, using a feed $f$ mm rev$^{-1}$ (in/rev) and a cutting speed of $V$ m s$^{-1}$ (ft/min). The cost/min of labour and overhead
is $k_1$ and cost of regrinding a tool is made up of two components, $k_2$ and $k_3$, where $k_2$ is the setting cost and $k_3$ is the cost per mm (in) of tool ground.

**Set-up and idle time cost**

$$K_1 = k_1 \cdot t_s,$$
where $t_s$ is the set-up and idle time/piece.

**Machine cost**

$$K_2 = k_1 \cdot t_m,$$
where $t_m = (L \cdot \pi \cdot D)/f \cdot V$, the machining time/piece, assuming the metal is removed in a single cut.

**Tool changing cost**

$$K_3 = k_1 \cdot t_c \times \text{no. of tool changes/component},$$
where $t_c$ is the time required to change a tool.

The number of tool changes/piece $= \frac{t_m}{T}$, where $T$ = tool life.

Using equation (8.8) for a specified amount of tool wear,

$$VT^n(f \cdot G)^m = \lambda$$

$$K_3 = k_1 \cdot t_c \cdot \frac{L \cdot \pi \cdot D}{f \cdot V} \left(\frac{V}{\lambda}\right)^{1/n} (f \cdot G)^{m/n}$$

**Tool regrinding cost**

Assuming that the permitted size of the wear land on the flank face before regrinding is $W$, it is seen from Fig. 10.1 that the minimum amount reground perpendicular to the clearance face of the tool is $AB = W \sin \delta$,

$$K_4 = (k_2 + k_3 \cdot W \sin \delta) \times \text{tool changes/piece}$$

$$= (k_2 + k_3 \cdot W \sin \delta) \frac{L \cdot \pi \cdot D}{f \cdot V} \left(\frac{V}{\lambda}\right)^{1/n} (f \cdot G)^{m/n}$$

**Tool depreciation cost**

If the total amount which can be ground off the flank face of a new tool before it is no longer of use is $A$, the permitted number of regrinds is $A/W \sin \delta$, and hence the total number of tool lives/tool is $1 + (A/W \sin \delta)$. 