Temperature in metal cutting

High temperature
- Reduces strength of the tool and formation of create wear.
- Shortens tool life
- Causes thermal distortion
- Caused dimensional change in work piece, making of control dimensional accuracy difficult

Heat generation in metal cutting

a) Region AB is Primary shear zone-plastic deformation ($P_p$)
b) Region BC is Secondary shear zone friction ($P_s$)
c) Region BD Between tool & work piece plowing force (negligible)

\[ P_m = F_rV \]
\[ P = P_p + P_s \]
\[ P = F_jV_c = F_jr_V \]
\[ \rho \] Density of the material
\[ c \] Specific heat of a material
\[ t, w \] Uncut thickness and width of cut

When a material particle moves across the primary deformation zone, the temperature rise is given by $\theta_p$:

\[ \theta_p = \frac{(1-\Lambda)P_p}{\rho \times c \times t \times w} \]
Heat generation in metal cutting

\[ \Lambda = \text{a function of shear angle } \phi \text{ and a nondimensional quantity } \Theta \]

\[ \Theta = \frac{\rho cvt}{k} \]

\[ k = \text{Thermal conductivity of a material} \]

\[ \Lambda = 0.15 \ln \left( \frac{27.5}{\Theta \tan \phi} \right) \]

Temperature distribution in metal cutting

The corresponding average temperature rise is obtained by:

\[ \Theta_{av} = \left( \frac{P_s}{\rho cvt w} \right) \]

Example

Determine the maximum temperature at the rake face of the tool when machining steel with the following given parameters:

- \( \tau_s = 450 \text{N/mm}^2 \)
- \( c = 502 \text{J/Kg}^\circ\text{C} \)
- \( v = 2 \text{m/s} \)
- \( \theta_0 = 45 \text{ C} \)
- \( w = 2.5 \text{mm} \)
- \( k = 43.6 \text{W/m}^\circ\text{C} \)
- \( \mu = 0.55 \)
- \( t = 0.26 \)
- \( \rho = 7200 \text{kg/m}^3 \)

\[ \frac{l}{L_v} = \left[ 1 + \tan(\phi - \alpha) \right] \]

\[ \Theta_s = 1.13 \sqrt{\frac{\Theta l}{t}} \left( \frac{P_s}{\rho cvt w} \right) \]

\[ \Theta_s = 1.13 \left[ \frac{1}{\rho cvt l (1 + \tan(\phi - \alpha) \right]} \left( \frac{P_s}{w} \right) \]
Temperature distribution in metal cutting

Temperature distribution at $V = 25\%$, HSS

Effect of cutting speed on temperature distribution

Measurement of temperature

1. Thermocouple
   - It is the most common method
   - The limitation is, it doesn’t give chip-tool interface temperature
Measurement of temperature cont.

2. Infrared radiation
   - It is used to measure the temperature distribution in the cutting zone

Heat dissipation in metal cutting

- Chip carries away 60-80% of $q_1$
- The work piece sinks 10-20% of $q_2$
- The cutting tool carries away 10% of $q_3$

With the application of coolant the total heat drawn away by the chip can be as big as 90% of the total heat generated.

Cutting temperature control

Temperature in metal cutting can be controlled by
- Application of cutting fluid(coolant)
- Changing the cutting condition by reduction of cutting speed and/or feed.
- Selection of proper cutting Geometry
  ex. Positive tool orthogonal rake angle

Temperature and Cutting Fluid

Function of cutting fluids
- Lubrication
- Reduction of cutting force and energy
- Cooling
- Chip removal
- Improves surface finish
- Prevents corrosion
Methods of application of Cutting fluids

1. Manually
2. Flooding: steady stream of fluids are directed

![Diagram of flooding on the rake face and the flank face](image)

Cutting fluids

The cutting fluid should possess the following properties:

- It should have high thermal conductivity and high specific heat
- It should possess good lubricating properties
- It should be odorless
- Non-corrosive to work and machine, non-toxic to operating personnel
- It should have low viscosity to permit free flow of the liquid

Types of cutting fluids

- Oil based
- Water based
  - Chlorinated oil
  - Mineral oils
  - Fatty oils
  - Sulphurized oil
  - Soluble oils
Cutting fluids

<table>
<thead>
<tr>
<th>Cutting fluids</th>
<th>Cooling properties</th>
<th>Lubricating properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>Excellent</td>
<td>Poor</td>
</tr>
<tr>
<td>Mineral oils</td>
<td>Fairly good</td>
<td>Good</td>
</tr>
<tr>
<td>Fatty oils</td>
<td>Fair</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

Factors that affect Selection of cutting fluids

- Cutting conditions: V, F, d
- Material: Cutting tool, Work material
- Cost of cutting fluid

Cutting fluids

- For steel and wrought iron: water soluble oil or sulphur based
- High strength steel: sulphurized mineral oils
- For aluminum: mineral oils or fatty oils can be used
- Magnesium alloys: Mineral oils can be used
- For brass, copper, bronze: soluble oils may be used
- Cast iron: it can be machined dry
Cutting fluids

![Graph showing cutting speed and tool life for different cutting conditions.](image)

Cutting fluids

![Graph showing cutting ratio and cutting speed for different fluids.](image)