Lapping and Honing Operations

Lapping is a final abrasive finishing operation that produces extreme dimensional accuracy, corrects minor imperfections of shape, refines surface finish and produces close fit between mating surfaces. Most lapping is done with a tooling plate or wheel (the lap) and fine-grained loose abrasive particles suspended in a viscous or liquid vehicle such as soluble oil, mineral oil or grease.

Advantages and limitations

Any material, hard or soft, can be lapped, as well as any shape, as long as the surface is flat.

Advantages. There is no warping since the parts are not clamped and very little heat is generated. No burrs are created. In fact, the process removes light burrs. Any size, diameter, and thickness from a few thousandths thick up to any height the machine will handle can be lapped.

Limitations. Lapping is still something of an art. There are so many variables that starting a new job requires experience and skill. Even though there are general recommendations and assistance from manufacturers, and past experience is useful, trial and error may still be needed to get the optimal results.

Honing is a low-velocity abrading process. Material removal is accomplished at lower cutting speeds than in grinding. Therefore, heat and pressure are minimized, resulting in excellent size and geometry control. The most common application of honing is on internal cylindrical surfaces. The cutting action is obtained using abrasive sticks mounted on a metal mandrel. Since the work is fixed in such a way as to allow floating, without clamping or chucking, there is no distortion.

Advantages and limitations

Honing has developed into a productive manufacturing process, with particular advantages and disadvantages:

Advantages: The workpiece need not be rotated by power, there are no chucks, faceplates, or rotating tables needed, so there are no chucking or locating errors. The hone is driven from a central shaft, so bending of the shaft cannot cause tapered holes as it does when boring. The result is a truly round hole, with no taper or high or low spots, provided that the previous operations left enough stock so that the hone can clean up all the irregularities.

Honing uses a large contact area at slow speed compared with grinding or fine boring, which use a small contact area at high speed. Because of the combined rotating and reciprocating motion used, a crosshatched pattern is created which is excellent for holding lubrication. Diameters with 0.001 to 0.0001 inch and closer accuracies can be honed by using diamond stones similar to diamond wheels.

Limitations: Honing is though of as a slow process. However, new machines and stones have shortened hone times considerably. Horizontal honing may create oval holes unless the work is rotated or supported. If the workpiece is thin, even hand pressure may cause a slightly oval hole.

Sources and causes of heat generation and development of temperature in machining:

During machining heat is generated at the cutting point from three sources, as indicated in Fig. Those sources and causes of development of cutting temperature are:

- Primary shear zone (1) where the major part of the energy is converted into heat
- Secondary deformation zone (2) at the chip – tool interface where further heat is generated due to rubbing and / or shear
- At the worn out flanks (3) due to rubbing between the tool and the finished surface.

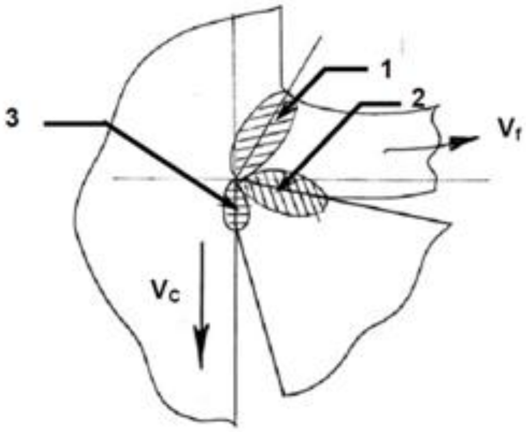
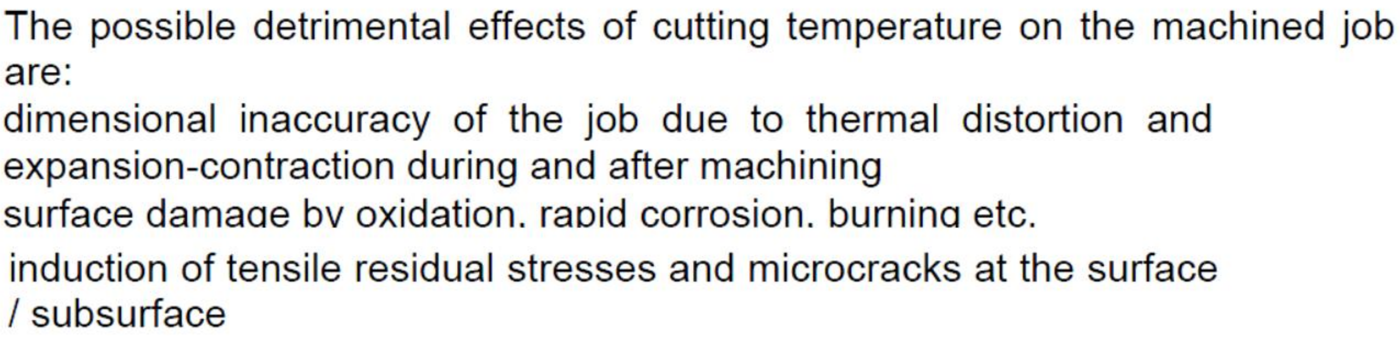


Fig. Sources of heat generation in machining

The possible detrimental effects of the high cutting temperature on cutting tool (edge) are

- rapid tool wear, which reduces tool life
- plastic deformation of the cutting edges if the tool material is not enough hot-hard and hot-strong
- thermal flaking and fracturing of the cutting edges due to thermal shocks
- built-up-edge formation



The possible detrimental effects of cutting temperature on the machined job are:

dimensional inaccuracy of the job due to thermal distortion and expansion-contraction during and after machining

surface damage by oxidation, rapid corrosion, burning etc.

induction of tensile residual stresses and microcracks at the surface / subsurface

The magnitude of the cutting temperature need to be known or evaluated to facilitate

- assessment of machinability which is judged mainly by cutting forces and temperature and tool life
- design and selection of cutting tools
- evaluate the role of variation of the different machining parameters on cutting temperature
- proper selection and application of cutting fluid
- analysis of temperature distribution in the chip, tool and job.

The temperatures which are of major interests are:

θ_s : average shear zone temperature

θ_i : average (and maximum) temperature at the chip-tool interface

θ_f : temperature at the work-tool interface (tool flanks)

θ_{avg} : average cutting temperature

Cutting temperature can be determined by two ways :

- analytically – using mathematical models (equations) if available or can be developed. This method is simple, quick and inexpensive but less accurate and precise.
- Experimentally – this method is more accurate, precise and reliable.

• Analytical estimation of cutting temperature, θ_s

(a) Average shear zone temperature, θ_s

Equation(s) have to be developed for the purpose. One simple method is presented here.

The cutting energy per unit time, i.e., $P_Z V_C$ gets used to cause primary shear and to overcome friction at the rake face as, and to overcome friction at the rake face as,

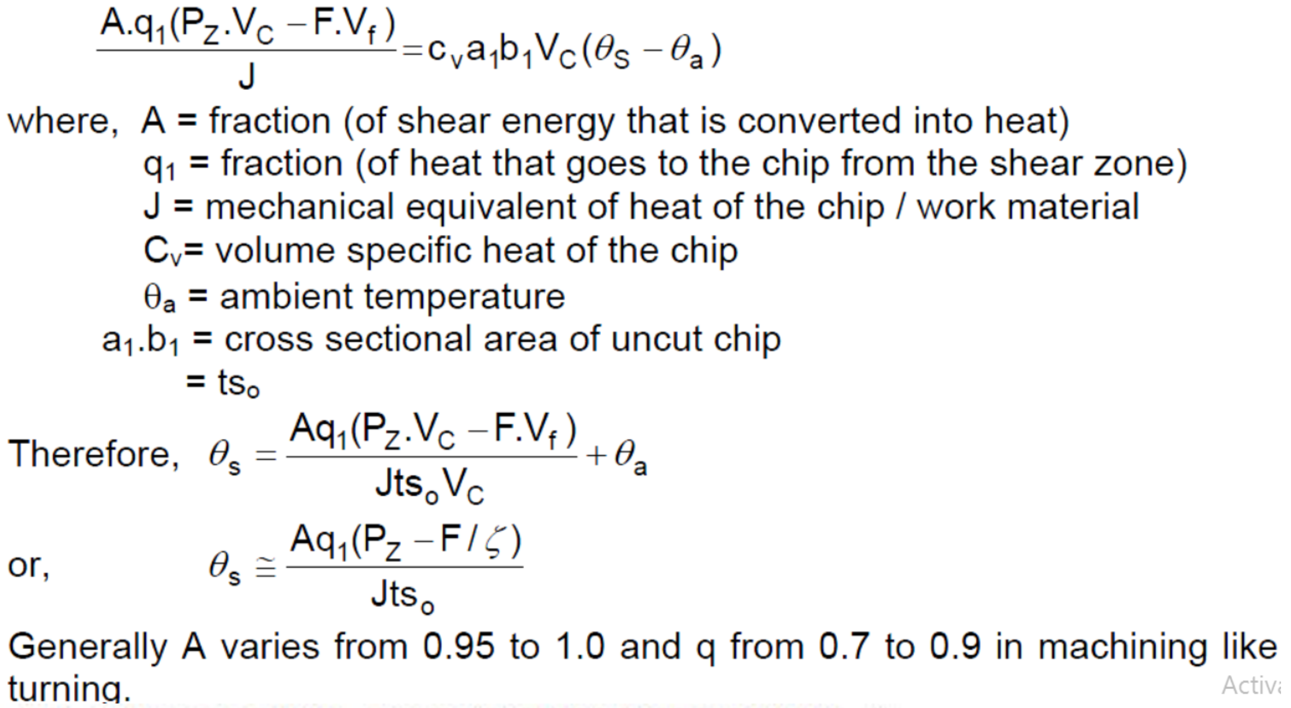
$$P_Z.V_C = P_S.V_S + F.V_f$$

where, V_S = slip velocity along the shear plane

and V_f = average chip – velocity

So, $P_S.V_S = P_Z.V_C – F.V_f$

Equating amount of heat received by the chip in one minute from the shear zone and the heat contained by that chip, it appears,



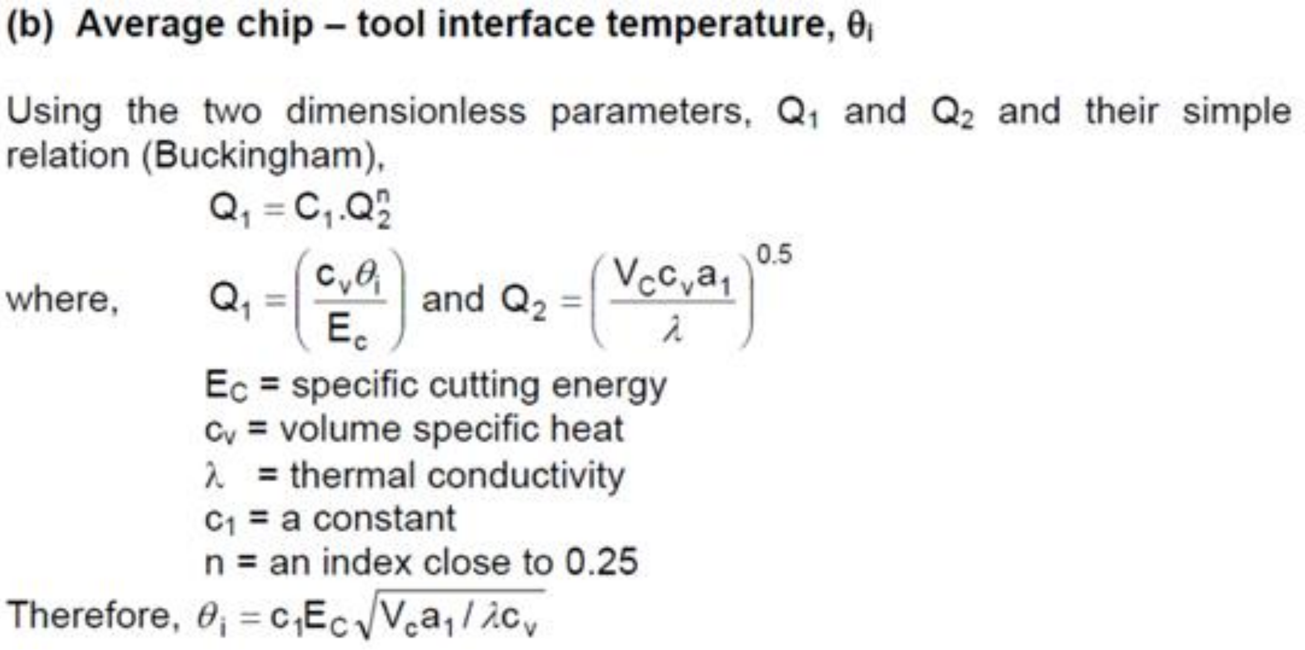
$$\frac{A.q_1(P_Z.V_C - F.V_f)}{J} = c_v a_1 b_1 V_C(\theta_S - \theta_a)$$

where, A = fraction (of shear energy that is converted into heat)
q_1 = fraction (of heat that goes to the chip from the shear zone)
J = mechanical equivalent of heat of the chip / work material
C_v= volume specific heat of the chip
θ_a = ambient temperature
$a_1.b_1$ = cross sectional area of uncut chip
= ts_o

Therefore, $$\theta_s = \frac{Aq_1(P_Z.V_C - F.V_f)}{Jts_oV_C} + \theta_a$$

or, $$\theta_s \cong \frac{Aq_1(P_Z - F/\zeta)}{Jts_o}$$

Generally A varies from 0.95 to 1.0 and q from 0.7 to 0.9 in machining like turning.



(b) Average chip – tool interface temperature, θ_i

Using the two dimensionless parameters, Q_1 and Q_2 and their simple relation (Buckingham),

$$Q_1 = C_1.Q_2^n$$

where, $$Q_1 = \left(\frac{c_v\theta_i}{E_c}\right) \text{ and } Q_2 = \left(\frac{V_C c_v a_1}{\lambda}\right)^{0.5}$$

E_C = specific cutting energy
c_v = volume specific heat
λ = thermal conductivity
c_1 = a constant
n = an index close to 0.25

Therefore, $\theta_i = c_1 E_C \sqrt{V_c a_1 / \lambda c_v}$

Experimental methods of determination of cutting temperature

Amongst θ_S, θ_i, and θ_f, θ_i is obviously the highest one and its value is maximum almost at the middle of the chip – tool contact length. Experimental methods generally provide the average or maximum value of θ_i. Some techniques also enable get even distribution of temperature in the chip, tool and job at the cutting zone.

The feasible experimental methods are :

- Calorimetric method – quite simple and low cost but inaccurate and gives only grand average value
- Decolourising agent – some paint or tape, which change in colour with variation of temperature, is pasted on the tool or job near the cutting point; the as such colour of the chip (steels) may also often indicate cutting temperature
- Tool-work thermocouple – simple and inexpensive but gives only average or maximum value
- Moving thermocouple technique
- Embedded thermocouple technique
- Using compound tool
- Indirectly from Hardness and structural transformation
- Photo-cell technique
- Infra ray detection method

The aforesaid methods are all feasible but vary w.r.t. accuracy, preciseness and reliability as well as complexity or difficulties and expensiveness.

Some of the methods commonly used are briefly presented here.

- **Tool work thermocouple technique**

Fig. shows the principle of this method.

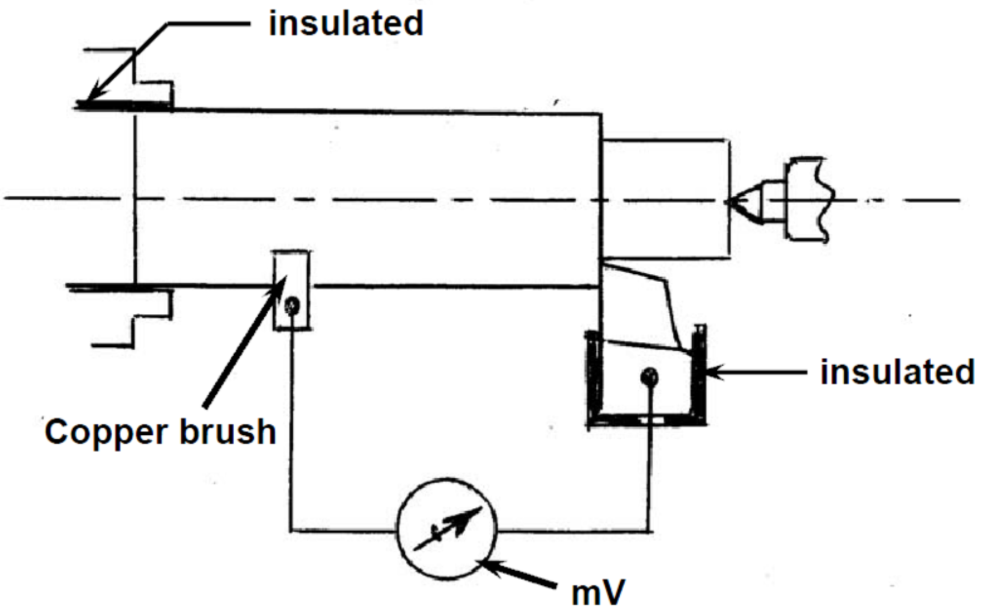


Fig. *Tool-work thermocouple technique of measuring cutting temperature.*

The magnitude of cutting temperature is more or less governed or influenced by all the machining parameters like :

- Work material : - specific energy requirement
  - ductility
  - thermal properties (λ, c_v)
- process parameters : - cutting velocity (V_C)
  - feed (s_o)
  - depth of cut (t)
- cutting tool material : - thermal properties
  - wear resistance

- chemical stability

- tool geometry : - rake angle (γ)
  - cutting edge angle (φ)

- clearance angle (α)
- nose radius (r)

- cutting fluid : - thermal and lubricating properties
  - method of application

Many researchers studied, mainly experimentally, on the effects of the various parameters on cutting temperature. A well established overall empirical equation is,

$$\theta_i = \frac{C_\theta (V_C)^{0.4} (s_o \sin\phi)^{0.24} (t)^{0.105}}{\left(\frac{t}{s_o}\right)^{0.086} (r)^{0.11} (ts_o)^{0.054}}$$

where, C_θ = a constant depending mainly on the work-tool materials.

Equation above clearly indicates that among the process parameters V_C affects θ_i most significantly and the role of t is almost insignificant. Cutting temperature depends also upon the tool geometry. Equation above depicts that θ_i can be reduced by lowering the principal cutting edge angle, φ and increasing nose radius, r. Besides that the tool rake angle, γ and hence inclination angle, λ also have significant influence on the cutting temperature. Increase in rake angle will reduce temperature by reducing the cutting forces but too much increase in rake will raise the temperature again due to reduction in the wedge angle of the cutting edge.

Proper selection and application of cutting fluid help reduce cutting temperature substantially through cooling as well as lubrication.