University of technology
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# LASER APPLICATION COURSE
# 4TH YEAR
# LEC.5

# Industrial Applications

- Industry accepted the laser as a tool soon after the laser was invented in 1965. The purpose of this chapter is to discuss the techniques used in material processing with lasers and to point out some of the advantages & disadvantages. The primary concern is with heat treatment, ***drilling, cutting*** & ***welding***.

# Laser Drilling

- One of the very first industrial uses of the laser was reported in 1965 when a diamond die was drilling using pulse ruby laser. A hole 4.7mm in diameter & 2mm deep was made in about 15 minutes; using a mechanical process this had previously taken 24 hours[4].
- When the laser beam is focused on the material, the speed of penetration will be

$$V_P = \frac{H}{\rho(CT_V + L_V)}$$

- Where:
- ***: Penetration Speed (mm/s).***
- ***H: Heat flow or Intensity ($w/m^2$).***
- ***: Density of Material ($kg/m^3$).***
- ***C: Specific heat capacity ($Jkg^{-1}.k^{-1}$).***
- ***$T_V$: Boiling point (k).***
- ***$L_V$: Latent heat of vaporization ($J.kg^{-1}$).***
- *And the maximum depth of penetration (d)[4]:*

$$V_P = \frac{d}{t_\rho} \quad \text{.....(2.2)}$$

- ***Where:***
- ***d: Hole Depth  $t_\rho$: Pulse Duration***

$$d = V_P \times t_\rho \quad \text{.....(2.3)}$$

$$d = \frac{H \ \ t_\rho}{\rho(CT_V + L_V)} \quad \text{.....(2.4)}$$

***Example-4[4]***

Suppose a heat pulse with ($H = 10^{11}\ Wm^{-2}$) & pulse duration ($500\mu s$) is incident on to a copper surface. Calculate the hole depth[4].

$C = 385$ $L_V = 4.75 \times 10^6$ $\rho = 8960$ $T_V = 2855$

***Solution:***

$$d = \frac{H\ t_\rho}{\rho(CT_V + L_V)} = \frac{10^{11} \times 500 \times 10^{-6}}{8960(385 \times 2855 + 4.7 \times 10^6)} = 0.95\text{mm}$$

***Example-5[4]:***

It is required to drill ($1mm$) diameter holes in a Nickel sheet ($1mm$) thickness. Using pulsed Nd:YAG laser with a ($5kW$) peak power output. Estimate the pulse duration for length required[4].

$C = 444$ $L_V = 6.47 \times 10^6$ $\rho = 8900$ $T_V = 3110$

***Solution:***

$$H = \frac{P}{A} = \frac{P}{\pi r^2} = \frac{5 \times 10^3}{\pi(\frac{1}{2} \times 10^{-3})^2} = 6.36 \times 109\ (w/m^2)$$

$$d = \frac{H\ t_\rho}{\rho(CT_V + L_V)} \Rightarrow t_\rho = \frac{d\rho(CT_V + L_V)}{H}$$

$$= \frac{1 \times 10^{-3} \times 8900\ (444 \times 3110\ + 6.47 \times 10^6)}{6.36 \times 10^9} = 0.011\ S$$

***Example-6[4]***

Holes are to be drilled in (0.5mm) thick nickel with a radius of (0.13mm) using a pulsed Nd-YAG laser with a (4kW) peak power output. Use energy balance to estimate the energy needed and the pulse length[2].

$C = 0.44$ J/g.k $\quad \rho = 8.9$ g/cm$^3$ $\quad L_m = 298$ J/g

$L_V = 6303$ J/g $\quad T_V = 3187$ k $\quad R = 60\%$

Solution:

$$U = (CT + L_m + L_V)\rho\pi a^2 Z$$

$= (0.44 \times 3187 + 298 + 6303)\ 8.9 \times \pi \times (0.013)^2 \times 0.05$

$= 1.89$ Joules

Energy Needed = U x 100/100-R

$= 1.89 \times 2.5$

$= 4.725$ Joules

Pulse Length = U/P = 4.725/4000

$= 1$ ms

***Question:*** ***Proof*** that Penetration speed ($V_P$) equal to:

$$V_P = \frac{H}{\rho(CT_V + L_V)}$$

***Answer***:

$$U = (CT + L_m + L_V)\rho\pi a^2 Z$$

$$P = \frac{U}{t} \;\&\; H = \frac{P}{A} \;\&\; V_P = \frac{Z}{t} \;\&\; A = \pi a^2$$

$$U = (CT + L_m + L_V)\rho\pi a^2 Z \;\; \%t$$

$$P = (CT + L_m + L_V)\rho\pi a^2 V_P \;\; \%A$$

$$H = (CT + L_m + L_V)\rho V_P$$

$$V_P = \frac{H}{\rho(CT_V + L_V)}$$