University of technology
Laser and optoelectronics eng. Dept.

LASER APPLICATION COURSE
4^{TH} YEAR
LEC.8

Example-9[4]:

By using an "***Energy Balance***" argument for laser welding, Show that the welding depth (***d***) may be written[4]:

$$d = \frac{2P}{\pi\, r V_m \rho (CT_m + L_m)}$$

Where:

P: Laser power CW. V_m : Welding Speed. r: The focus beam radius.
ρ : Density. C: Specific Heat. L_m : Latent Heat of Melting.
T_m : Melting Point.

Use this model to estimate the welding speed possible when welding two (***1mm***) thick iron plates together using (***2kW***) laser. Assume that the laser output is focused down to a spot of (1mm) diameter, assume surface reflectance of (***0.5***) Take:

C = 449	ρ = 7870	T_m = 1810	L_m = 2.7x 10^5

Solution:

$$U = (CT_m + L_m)\rho\ \pi\ r^2 Z \quad \textbf{\textit{Energy Balance}}$$

$$P = (CT_m + L_m)\rho\pi r^2 v_{dm}$$

$$V_{dm} = \frac{P}{\rho\pi r^2 (CT_m + L_m)} \quad \because \mathrm{V_m} = \frac{\mathrm{DV_{dm}}}{\mathrm{Z}} = \frac{DP}{Z\rho\pi r^2 (CT_m + L_m)}$$

Where: D=2r Diameter or spot size, Z=d (depth or thickness).

$$\mathrm{V_m} == \frac{2rP}{d\rho\pi r^2 (CT_m + L_m)} \Rightarrow d = \frac{2P}{\pi\, r V_m \rho (CT_m + L_m)}$$

$$v_m = \frac{2P(1-R)}{(CT_m + L_m)\rho\ \pi\ r\ d} =$$

$$\frac{2(2\times10^3)\times0.5}{\pi\times(0.5\times10^{-3})(7870)(1\times10^{-3})(449\times1810+2.7\times10^5)} = 149\, mm.s^{-1}$$

Example-10 [2]

Consider the weld of steel with a CO_2 laser capable of providing a power of (2.5 kW) at the workpiece. A weld depth of (2mm) is desired with a weld width of (1mm). Using the energy balance model & assuming (50%) reflectivity, estimate the ***energy*** that is required to bring the material to T_m & the ***pulse length***. According to the uniform irradiance model estimate the ***time*** required to reach T_b at the surface[2].

$\rho = 7.87$ g/cm^3 $\quad$ $C = 0.46$ J/g.C° $\quad$ $K = 0.21$ cm^2/s

$L_m = 272$ J/g $\quad$ $T_m = 1547$ C° $\quad$ $T_b = 2752$ C° $\quad$ $k = 0.75$ W/cm.C°

Solution:

$$U = (CT_m + L_m)\rho\,\pi\,r^2 Z = (0.46 \times 1547 + 272)\,7.87 \times \pi \times (1\times10^{-1}/2)^2 \times 2 \times 10^{-1}$$

$$= 12.16 \text{ J}$$

Note: U should be doubled (to compensate for heat conduction losses)[2]

$\therefore U = 24.32$ J

$U_{total} = 24.32/(1-0.5) = 48.64$J

$P = U/t \Rightarrow t = U/P = 48.64 / 2.5\text{x}10^3 = 19.5$ ms

Applications for Surface Treatment

- Lasers have been used in a number of ways to modify the properties of surfaces, especially the surfaces of metals. Most often, the objective of the processing has been to harden the surface in order to provide increased wear resistance. In some cases, the goal has been to provide improved resistance to corrosion.
- Laser applications in surface treatment have been dominated by the CO_2 laser, usually operating at multikilowatt levels, although there have been demonstrations of surface treatment using Nd:YAG, carbon monoxide, and excimer lasers. We shall
- describe several different approaches to surface modification with lasers, including heat treating, glazing, surface alloying, and cladding

Surface Hardening

- Laser surface hardening (heat treatment) is a process whereby a defocused beam (generally from a 1kW CW or higher power CO_2 laser) is scanned across a hardenable material to raise the temperature near the surface above the transformation temperature. Normally the cooling rate due to self-quenching by heat condition into the bulk material is sufficiently high to guarantee hardening.

Re-melting (Glazing)

- Thin layer of the material surface is melted, and on solidification, a structure of ***fine-grains*** is produced by the fast quench rate. This structure gives glassy appearance with some desirable characteristics. This technique is applied to metals & Ceramics.