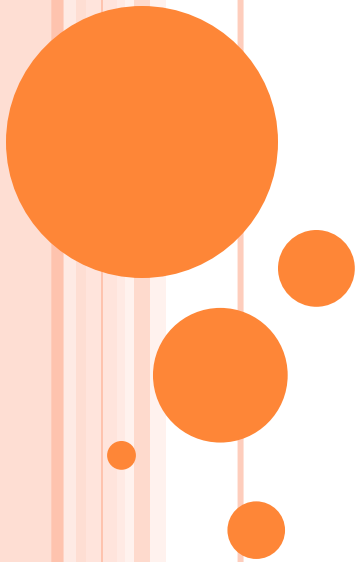


University of technology

Laser and optoelectronics eng. Dept.

LASER APPLICATION COURSE
4TH 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:

$C = 449$	$\rho = 7870$	$T_m = 1810$	$L_m = 2.7 \times 10^5$
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Solution:

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

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

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

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

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

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

$$\frac{2(2 \times 10^3) \times 0.5}{\pi \times (0.5 \times 10^{-3}) (7870) (1 \times 10^{-3}) (449 \times 1810 + 2.7 \times 10^5)} = 149 \text{ mm} \cdot \text{s}^{-1}$$



Example-10^[2]

Consider the weld of steel with a CO₂ 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].

$$\begin{aligned} \rho &= 7.87 \text{ g/cm}^3 & C &= 0.46 \text{ J/g.C}^\circ & K &= 0.21 \text{ cm}^2/\text{s} \\ L_m &= 272 \text{ J/g} & T_m &= 1547 \text{ C}^\circ & T_b &= 2752 \text{ C}^\circ & k &= 0.75 \text{ W/cm.C}^\circ \end{aligned}$$

Solution:

$$\begin{aligned} U &= (CT_m + L_m)\rho \pi r^2 Z = (0.46 \times 1547 + 272) 7.87 \times \pi \times (1 \times 10^{-1}/2)^2 \times 2 \\ &\times 10^{-1} \\ &= 12.16 \text{ J} \end{aligned}$$

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

$$\therefore U = 24.32 \text{ J}$$

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

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



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 CO₂ 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 CO₂ 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 conduction 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.

