ME 677 Laser Material Processing
HW 3

Assigned: 1/4/2019
Due: 8/4/2019

1. A penetration depth of 5 mm is required for welding SS304. (α=1.86x10^{-5} m^2/s) Assume the beam size is 0.2 mm at the surface and the effective beam diameter lies at the focal point 1 mm below the surface. What scan velocities could be used for 6, 4 and 2 KW laser for realizing the process.

   The price of power is 8 Rs/kwhr and 1 million mm length of welding is required. Which laser will you recommend? Neglect the initial cost.

2.
   a. Explain laser blocking in welding
   b. Explain mechanism of transformation hardening

3. The surface of an AISI 1045 steel cam is heat treated using 2.5 kW CO2 laser to enhance the wear resistance. The defocused beam diameter is 5 mm, and the scan rate is set at 10 mm/s.
   a. Determine the spacing of pearlite plates that will enable the pearlite colonies to fully transform to austenite under these conditions
   b. Estimate the extent of the region where martensite can be formed
   c. Determine the volume fraction of martensite and the maximum hardness value.
   d. The A1 and A3 values are 723 and 769°C, respectively. If the peak temperature decreases first to 750 and then to 700°C find the new hardness values for these temperatures.
      Assume
      - The temperature is time dependent
      - The diffusion constant D0 is 2 mm^2/s
      - The activation energy Q is 84.15 kJ/mole
      - Reflectivity is 80%
      - Ambient temperature is 25°C
      - Use peak temperature and thermal constant from the paper by Ashby and Esterling.

4. Find the temperature plots after 5 seconds of travel and sub-surface hardness distribution plots obtained for the two intensity distributions mentioned below. The sub-surface hardness plots should be on a grid in Y-Z plane if the laser is scanned along X-axis. The two different intensity distributions used for a circular beam of 0.2 mm in radius are: (a) uniform; (b) Gaussian. Use following physical and material properties

   Material: AISI 5150 steel.
   Laser power: 100 W

Velocity: 2 mm/s
Thermal conductivity: 42.7 W/mk
Diffusivity: 11.24 mm^2/s
Specific capacity: 473 J/kgk
Pre-exponential carbon in austenite = $1* 10^5 m^2/s$
Activation energy of austenite = 135 KJ/mol
Grain radius = 5 μm
Peak temperature = 1200 K
The time constant τ has to be calculated from the paper by Esterling and Ashby.

If the base material hardness is 200HV, what is maximum percentage increase in hardness for Gaussian and Uniform?