Abstract

The numerical investigations presented in the thesis are concerned with the prediction of hardened zone in laser transformation hardening (LTH) process. The numerical predictions are based on three-dimensional transient heat conduction. The heat load is considered as a moving laser source of some known energy distribution, which irradiates a work specimen of finite dimensions.

Explicit finite difference method is used for solving the governing heat conduction equations with appropriate initial and boundary conditions. To make the predictions accurate, temperature dependent thermo-physical properties are incorporated. The effects of pertinent process parameters like incident laser power, scanning speed, spot diameter, beam energy distribution, and material properties are analysed for temperature distributions and heating /cooling rates in the workpiece.

A carbon diffusion model is used to calculate for the completely austenitised zone. The influence of the process parameters and interlamellar spacing between cementite and ferrite phases in the original pearlite colonies, on the completely austenitised depth can be studied using this model.

By judiciously selecting a group of dimensionless parameters, computations for thermal field and carbon diffusion length are simplified and the results are made generally applicable to different materials as well as different operating conditions.

To study applicability of the theoretical model, experimental investigations on laser surface hardening are carried out. A laser processing set up is designed and fabricated in-house using a 130 W continuous wave carbon dioxide laser system and various peripheral units.

Successful laser hardening of AISI 4340 alloy steel and pearlitic gray cast iron is done with the 130W CW CO_2 laser system. This is unique in the sense that the available power is much lower as compared to the laser systems of much higher power (500 Watt to several kilowatts) used by other researchers for similar experimentation. Laser hardening can be carried out on such low power unit by performing the processing at a lower scanning speed and a lower spot size. But in the process of doing this, the maximum achievable case depth falls off, rarely more than 150 μm.

To make the observations more comprehensive a full range of experiments are conducted simultaneously using the high power transverse flow CO_2 laser system developed and available at Centre for Advanced Technology, Indore, India, to transformation harden C20, C40 and C60 grades of plain carbon steel.

Single pass experiments are concentrated on micro structural changes, width and depth of heat affected zone and variation of hardness along depth below the surface as a function of process parameters like beam power, scanning speed, spot size, carbon content, pre-treatment like annealing, and absorptive coating. Optical microscopy reveals no unusual metallurgical phases during laser hardening. A peak hardness of 880 H_v for C60 steel, 710 H_v for C40 steel and 450 H_v for C20 steel is observed. The increase in hardness is attributed to the formation of martensite phase. The type and fineness of martensite may vary within the transformed zone with different process parameters.

One of the feasible ways, to cover an area larger than the spot size, is by sweeping it with a series of successive overlapping passes. Effect of such overlapping passes on hardness during laser hardening is also studied. A periodic change in hardness distribution is found in the overlapped region. On microscopic study such distribution is attributed to the formation of tempered martensite and carbide dispersion by the overlapping pass.

On corroboration of the numerical results with the experimental ones good agreements are found. Based on the gathered experience some recommendations for future work on experimental and theoretical studies of laser transformation hardening are suggested.

Key words : Laser transformation hardening, Thermal model, Surface hardening, Carbon diffusion, Finite difference method, Transformed zone, Microhardness, Martensite.