

ABSTRACT

Optimization of the variables of laser drilling process for producing a quality hole with minimum energy consumption has been the broad objective of the present work. The experimental and numerical investigations presented in the thesis are concerned with the prediction of drill hole profile, and drill parameters like depth and diameter of the hole. As the one dimensional estimations available in the literature preclude the effect of variation of beam parameters and temperature dependent material properties, the numerical predictions in this thesis are based on three dimensional transient heat conduction model.

Explicit finite difference method is used for solving the governing heat conduction equation for a finite workpiece irradiated with pulsed laser beam of gaussian energy distribution. The analysis evaluates transient temperature distribution which in turn helps to predict the threshold intensity. The effects of beam parameters like the beam diameter and pulse duration, and variation of thermophysical material properties on threshold intensity are considered. Threshold intensity values for melting as well as vaporization are estimated for different materials and compared with the few one dimensional estimations available in the literature. The effects of variation of beam parameters and thermophysical properties on threshold intensity are clearly brought out.

The model is further extended to predict hole profile and drill parameters. The numerical predictions are corroborated with the experiments carried out under similar conditions; there has been a good qualitative agreement between predicted and experimental results.

Experiments were planned and carried out using modified design of experiment technique given by Taguchi, for different materials. The technique gives less number of experiments to be performed with the same confidence level. The postprocessing of experimented specimens is carried out to estimate the output responses which are then analysed using "analysis of variance" (ANOVA) to determine significant factors and the interactions.

The simultaneous optimization of the two output responses is carried out using a gradient loss function to obtain optimum setting of input process parameter combinations for drilling of three different materials, namely, aluminum, titanium, and copper. Confirmatory tests and comparisons are carried out for the so obtained optimal settings. The results lie within the confidence interval at 95 % level of significance.

A few experimental investigations are carried out on drill speed estimation for titanium under different environmental conditions and the findings are presented.

Key words : laser drilling, threshold intensity, finite difference method, conduction, ANOVA, gradient loss function, multivariate analysis, optimization, Taguchi methods, orthogonal array, non-linear regression