Experimental and Finite Element Study of Laser Cutting Induced Distortion in a Production Environment

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Abstract

Introduction

Recently, laser beam cutting (LBC) has received an increasing attention for a wide variety of applications in industries due to its excellent cut quality with high productivity and flexibility. Compared with oxyfuel gas cutting and plasma cutting, laser beam cutting applies low heat input to a workpiece. However, experiences have showed that distortion may still occur. Little research has been devoted to understand distortion mechanisms associated with thermal cutting processes. It is important to understand the distortion mechanism because the impact of the distortions on various down-stream manufacturing processes, such as welding fabrication, can be enormous. In this paper, laser cutting-induced distortions were investigated by detailed experiments and finite element analyses in a real production environment.

Laser Cutting Experiment

A CO_2 Tanaka laser-cutting machine was used to perform the cutting with 6kW power and 51inch/min travel speed on a large cutting table. Laser sensors were mounted on critical locations to monitor the in-plane and out-of-plane cutting distortions as a function time. During cutting, real time cutting distortions were recorded and shown on the screen of data acquisition system. Two parts from a boom-structure were cut from a 4' by 10' half-inch plate. The total cut length is about 9 meters. The plate surface was initially etched with 4" by 4" grids by low power laser for initial and final distortion measurement. Before cutting, the initial distortion was measured at the intersection points of the grids by CMM system. After cutting, the final distortions were measured again at the intersection points. By subtracting the initial distortion from the final distortions, the cutting-induced distortion can be obtained.

Laser Cutting Simulation

The same laser cutting process was simulated with finite element method (FEM) in this investigation. The finite element method used to simulate the cutting process was similar to that used for the simulation of the welding process. The transient temperature fields were obtained through thermal solution performed by CTSP (a comprehensive thermal solution package) developed by Battelle and Caterpillar. The stress and deformation were calculated by ABAQUS through thermal-elastic-plastic analysis based on the computed temperature fields. The forming of the cutting kerf was simulated by element removing techniques. In both thermal and structural solution, the elements located in the cutting line were removed from the mesh as soon as the heat source passed. The contact between the cut plate and the cutting table could be simulated with a node-based rigid surface. The simulation results show a good comparison of real time in-plane distortion and cut part movement between experiment and FEM.

Conclusion

The laser cutting induced distortion was systematically investigated with experimental methods and finite element analyses in a production environment to understand distortion mechanisms and develop effective modeling procedures. Two types of distortions have been identified. One is dominated by in-plane movement. The other is dominated by out-of-plane distortion. The latter can exhibit buckling for skeletons under certain conditions. The comparison between experimental measurements and predictions shows that the finite element based cutting modeling procedures can predict cutting distortion with reasonable accuracy for cutting distortion mitigations in practical applications.