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Development of scan strategies for controlled 3D laser forming of sheet metal components

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Abstract

Laser forming offers the industrial promise of controlled iterative shaping of metallic and non-metallic components. In order to fulfil this promise in a manufacturing environment the process must have a high degree of control, be repeatable and have a minimal impact on the material and mechanical properties of the part to be formed. A new approach for the development of scan strategies for controlled 3D laser forming of sheet metal components is presented in this paper based on a reverse analysis. A patched modular virtual press tool is employed in a commercial FE package to extract the required distribution of in-plane strain, bending strain and principal minimal strain to achieve a given shape from a starting condition. The laser processing conditions have then been extracted from the magnitude of strain and displacement of each patch, closed loop control iterative approach has then been used to ensure part accuracy.

Keywords: 3D laser forming; FEM simulation; close loop control

1. Introduction

In laser forming, the deformation of sheet metal is produced by thermal stresses, which is generated by a controlled defocused laser beam scanned over the surface. (Kyrsanidi 1999) Important advantages of laser forming include the absence of external mechanical tooling, flexibility and automatic control. During laser forming, the non-

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uniform expansion is caused by non-uniform thermal stresses; therefore the plastic deformation will be generated when the thermal stresses exceed the yield point of the material. (Shitanshu Shekhar Chakraborty 2012)

A large number of relevant two-dimensional laser forming studies have been done to date. However, for the production of complex 3D shapes, such as the ship hull shape and airplane fuselages shape, the two-dimensional laser forming is limited. Therefore, in order to advance process for realistic applications, the investigation of the 3D scanning strategies becomes more necessary, which accompanies both in plane shortening and out-of-plane bending as seen in Fig. 1. In additional, in order to determining the scanning patterns and process parameters for forming any arbitrary 3D shape, numerical simulation is a strong tool to analyse the scan strategies and the processing parameters.

In the presented investigation, the object is to develop optimal irradiation patterns and parameters to form the S275 steel square thin plate to the given shape, which is ship hull shape. The work consists two parts, finite element simulation and experiment verification. The numerical simulation is developed using COMSOL Multiphysics 5.2. The laser beam is modelled as a step-wise moving heat source with Gaussian distribution of heat flux.

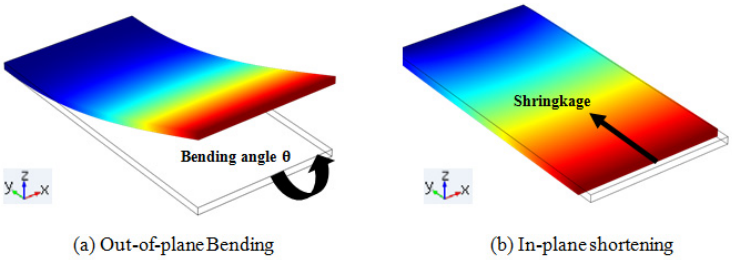

Fig. 1. (a) Temperature Gradient Mechanism (b) Upsetting Mechanism.

2. Overall Strategy

An overall strategy for process design of laser forming involves four sequential stages as shown in Fig. 2. At the beginning, the top surface of initial shape is divided into a combination of plane patches for easily controlling and analysing the errors between the target shape and formed shape.

First of all, for a given desired shape, a strain and displacement field can be obtained by computer modelling using a virtual tool to develop an initial shape to the desired shape.

The second step is to synthesize the direction and magnitude of the in-plane and out-of-plane strains, which is an important function to determine the laser scanning paths and processing parameters. For example, in terms of the contribution of the in-plane strain and bending strain, the scanning paths can be chosen either perpendicular to the in-plane strain or the bending strain.

The third step is to evaluate the nodal displacements provided by computational simulations of the laser forming process, and then compared with the target shape to determine the optimal heating conditions, such as laser power levels and scanning velocities, for the scanning paths.

Finally, laser forming data obtained by computational simulations will be verified by empirical experiments and surface profile measuring. This paper illustrates the proposed strategy by applying it to a ship hull representative shape. The target shape and initial shape are shown in Fig. 3.