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Journal of Materials Processing Technology 120 (2002) 322–326

Journal of Materials Processing Technology

www.elsevier.com/locate/jmatprotec

Process planning for laser-assisted forming

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Accepted 5 September 2001

Abstract

Laser forming has emerged as a viable means of assisting conventional forming processes with geometrical accuracy-related problems. By combining the incremental nature of laser forming with conventional processes such as brakeforming which forms material by a single continuous movement of the tooling, the exact specified bend angle and radius of curvature of the bent component may be approached. This may be achieved by sequential or simultaneous application of the conventional tooling and the laser beam. The laser beam may be applied once to the forming zone or multiple laser beam scans may be used.

The combined process allows the forming of highly accurate sheet metal products in a cost effective way, through the possibility to make corrections to the bend angle in a controlled way. Furthermore, the combined process makes it possible to form intricate products that cannot be bent on a press brake due to collision problems or problems emanating from spring-back.

Consequently there are new implications for process planning in brakeforming when a laser beam is used in combination. These implications are discussed for some primitive applications.

Keywords: Laser forming; Combined processes; Process planning; Sheet metal

1. Introduction—laser forming

Laser forming is a non-contact forming process realised by introducing thermal stresses into the surface of a workpiece with a laser beam to induce plastic strains that results in forming as shown in Fig. 1. It may proceed by two primary forming mechanisms which includes out-of-plane or in-plane strain. The mechanism activated is dependent on the laser processing parameters employed, the geometry of the workpiece and the material properties. Out-of-plane deformation is induced by the introduction of a steep thermal gradient to the sheet via a rapidly scanning laser beam applied to the surface of the material to be processed. Initially, the sheet bends away from the irradiated surface and then towards the laser beam. A material with a low thermal conductivity and a relatively small second moment of area (e.g. a sheet material) coupled with a rapid heat input facilitates this. Out-of-plane strain results in bending (see Fig. 2).

In-plane strain occurs when the heat generated from the laser beam is fully penetrative through the sheet thickness, the heated width is large compared to the sheet thickness and when the geometry (e.g. a box section material) resists out-of-plane bending. In-plane strain results in shortening (refer Fig. 3).

The laser is useful as a power source for forming as:

1. Mechanical contact between the workpiece and the forming tool (the laser beam) is not required.
2. Potential for accuracy and controllability of the amount of forming is great.
3. Material may be formed remotely.

Large-scale applications of laser forming may be found in ship building and it has been applied successfully to the alignment of miniature structures in the micro-electronics industry [1]. It is not likely that laser forming will replace batch or mass production forming techniques for large sheet metal components. This is because laser forming is still in its infancy in terms of some of these more complicated forming tasks, and only recently has progress been made towards symmetrical three-dimensional laser forming [2].

Compared to laser forming, conventional forming processes such as brakeforming or swing-type forming are fast and large deformations can be obtained in one process step. However, process control can present problems, as discussed in [3] for air bending. One of the main problems is the direct influence of material properties on the bend angle. Even when adaptive in-process control is used, variations in

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0924-0136/02/$ – see front matter
PII: S0924-0136(01)01134-7

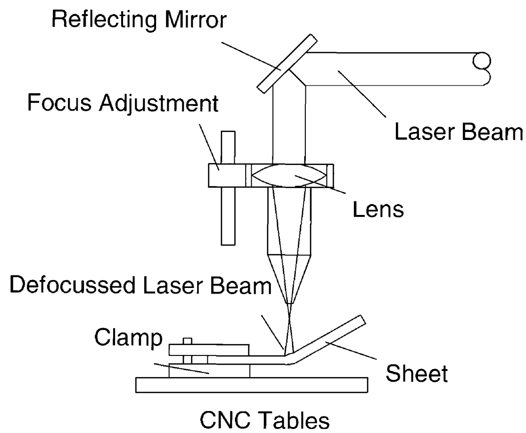

Fig. 1. A laser forming set-up.

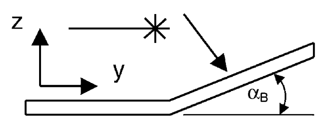

Fig. 2. Out-of-plane bending.

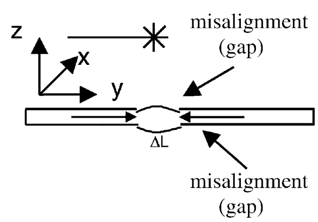

Fig. 3. In-plane shrinkage.

spring-back angle cannot be addressed in such a way that their effect is eliminated completely.

Near-net-shape forming has been gaining increasing popularity due to improved processes, high material utilisation, suitability for high value-added and/or low-volume production and superior mechanical material properties. As a result, brakeformed sheet metal components have on average become increasingly intricate. In this paper, a simple rectangular box is used as an example. This suffices to demonstrate the problems of conventional forming and the advantages of hybrid processing. However, these problems and advantages become even more profound in the case of intricate sheet metal components.

2. Accuracy-related problems with conventional forming

A simple box is shown in Fig. 4. The overlap conditions between front, back and side sections give constraints for the bending sequence. This is a result from the necessity to overbend the bends under loading in order to compensate for spring-back. Normally, the overlap conditions will be such

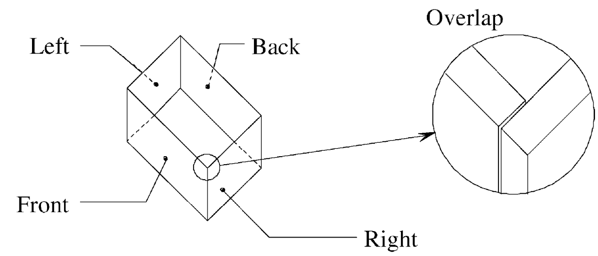

Fig. 4. Simple sheet metal box.

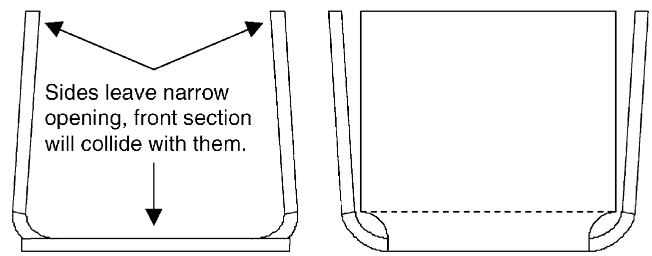

Fig. 5. Collision danger (left) and unwanted gap (right).

that the shorter bends are processed first as this allows processing of all the bends with one set of tools.

When bending sheet metal, variations in bend angle can occur, mainly due to the variations in sheet thickness and material properties. When the bends are still overbent after spring-back, then the front section will not pass between the sides (Fig. 5, left). If no special measures are taken, this will result in a collision. Due to the variations in bend angle, there will also be components with bends that are not completely bent to 90° (Fig. 5, right). This could also be the result of a deliberate collision avoidance strategy. The result is that an unwanted gap exists between the sides of the box.

Conventional bending processes could be enhanced by a method to make small, controlled adjustments to the bend angle. In this way, the gaps in the above example could be eliminated. Furthermore, the overall accuracy of components could be improved. Even for intricate components, it is possible to plan the bend sequence and part positioning in such a way that the best accuracy is obtained [4]. When this is still not sufficient or invokes high costs, then it would be beneficial to study the effect of this improved bend angle accuracy.

3. Hybrid processing

The advantages of combined conventional and laser processing have been described generally in [5]. Below, the specific advantages of possible hybrid processes are described on the basis of the example of the sheet metal box.

3.1. Hybrid forming

Hybrid forming potentially combines the speed of conventional forming with the accuracy of laser forming. The