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Integration of high power lasers in bending tools

Bammer F., Holzinger B., Humenberger G., Schuöcker D., Schumi T.*

Vienna University of Technology, Institute for Production Engineering and Laser Technology, Franz-Grill-Straße 1, Arsenal Obj. 207, 1030 Wien, Austria

Invited Paper

Abstract

The integration of high power lasers into bending tools creates a possibility to bend brittle materials with conventional presses. A diode laser, which is based on 200W-laser-bars and a solid state laser with 3kW are used in this work. By heating the material within a narrow zone the ductility is increased and the forming process can be enabled. The assembly of the heat source within the bending tools is a prerequisite in order to feed energy into the workpiece before, during and after the forming process. As a result the heating and forming process can be optimized regarding any material.

Keywords: Bending; Warm-Forming; Diode Lasers

1. Introduction

Up to now brittle materials such as magnesium, titanium, high strength aluminium or high strength steels [1] have been bent by preheating the whole workpiece in order to enable the bending process as the yield stress is decreased and the deformability is increased. This requires a large energy input and a loss of time, due to the additional process step and subsequent cooling. Further the properties of the material might be modified in the entire workpiece as a result of the heating process. It is also not possible to control the temperature during the forming process. The process introduced in this paper only heats the small forming zone, by using laser technology. As a result the heat affected zone is reduced. The overall energy requirement is decreased. In consequence the heat input to the bending tools is reduced, too.

* Corresponding author. Tel.: +43-1-7983321-12; fax: +43-1-7983321-20.
E-mail address: schumi@ift.at.

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Two solutions with different beam sources have been realized. The first uses diode laser bars on micro-channel coolers that were implemented directly in the lower tools of the bending press. The second solution is based on an external fibre-coupled solid state laser, connected to the lower tools, where the laser light is projected on the bending line. Both concepts are constructed modularly such that any user defined bending length can be realized by joining together several single lower tools.

The installation of the laser in the bending tools allows the heating of the metal sheet before and during the forming process. In combination with the measurement of the temperature a control of the temperature was implemented. This allows keeping the temperature at a predefined value during the forming process. The integration of lasers in the lower tools enables the use of this process in conventional presses without major modifications. The additional time needed for heating is usually in the range of 1-5s. Warm bending becomes nearly as simple as cold bending.

2. The Laser Sources

As already mentioned, two different solutions were developed with different lasers. The first solution uses diode lasers and the second one a solid state laser. The diode laser solution is based on diode laser bars [2] with an optical power of 200W and a wavelength of 940nm. They are soldered on micro-channel coolers. The challenge was to integrate these lasers in the narrow lower tool and to ensure that they will get sufficient energy and cooling water. 8 laser diode bars are installed in one diode laser for 100mm bending length. By arranging multiple tools with integrated laser modules, any bending length can be realized. With these modules an optical power of 16 kW per m bending length can be realized. The energy supply and cooling of the modules can be ensured with external aggregates.

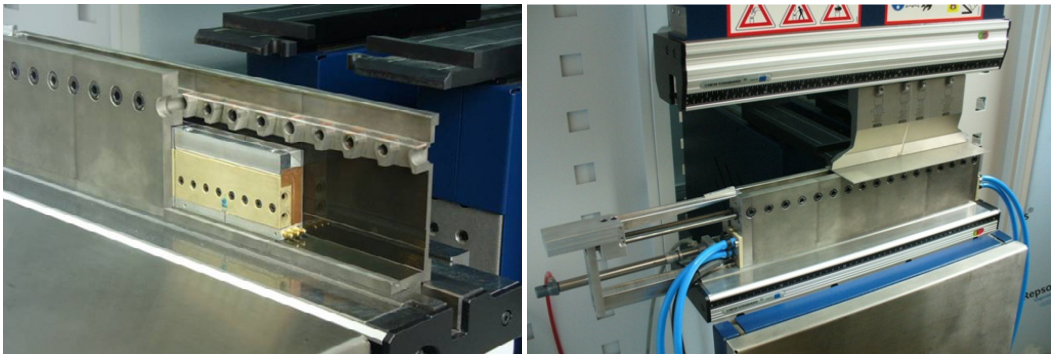

Fig. 1. (a) Assembly of a diode laser module with a lower tool; (b) Setup for laser assisted bending with an optical power of 6.4 kW

The second design, the so called beam-splitter-solution, works with a fibre-coupled solid-state-laser, which is connected via a glass fibre to the lower tools, where the laser beam is distributed with specific optical elements on the workpiece. This is realized with three 50-50 beam splitters, which divide the power into four partial beams. These partial beams are defocused with prisms. A beam shape can be realized, which ensures a constant heating of the workpiece along the bending edge. This special beam splitter is modularly designed too, such that, any user defined bending length can be realized by joining together several single lower tools. The assembly is displayed in figure 2.

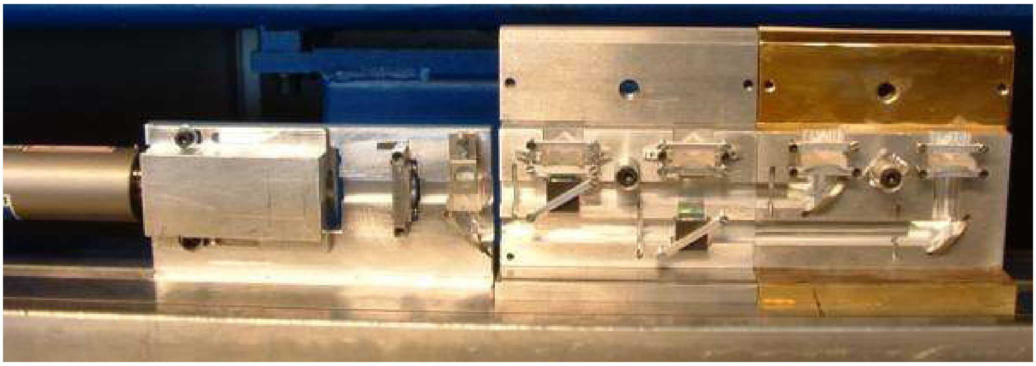

Fig. 2. Assembly of a beam-splitter-solution in the lower bending tool

3. The control of the process

The most important parameter concerning laser assisted bending is the temperature of the workpiece, which was realized with two different methods. The first method uses a pyrometer to measure the temperature on the surface of the workpiece. This method cannot be used to measure the temperature during the bending process, because the upper tool covers the bending line. Further the pyrometer must be calibrated for every new material and surface condition. These deficits are corrected with the second method, where a thermocouple in the upper bending tool is installed. During the bending process the temperature sensor is in contact with the workpiece and a spring ensures a constant contact force. The comparison between this method and a welded thermocouple demonstrates a repeatable difference of the temperature depending on the surface of the workpiece and the temperature curve. The temperature difference, usually below 20°C, can be compensated by using adequate correctional factors. It has to be noted that the temperature is measured at the upper surface of the workpiece but the heating is applied at the lower surface. This effect can be ignored for minor thick metal sheets with a good heat conductance. In contrast the temperature difference between the upper and the lower surface might not be ignored for increasing thickness of the metal sheets respectively decreasing heat conductance.

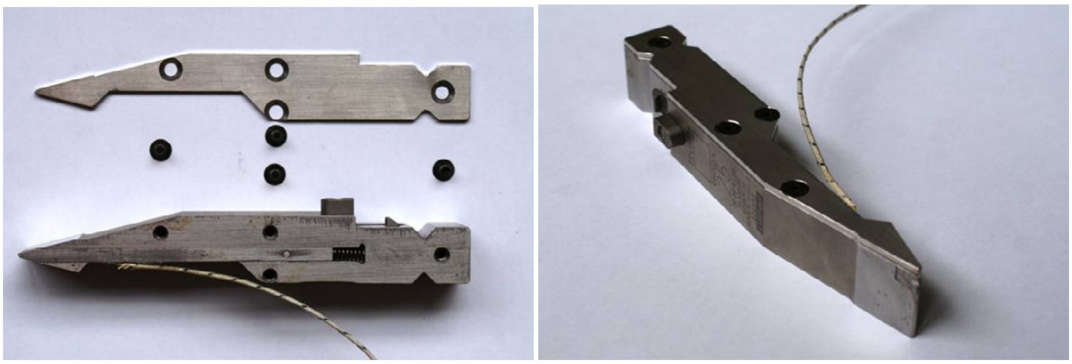

Fig. 3. (a) Disassembled thermocouple and upper bending tool; (b) Assembled thermocouple and upper bending tool

This temperature measurement is the precondition for a temperature control, where the temperature can be kept on a constant level or where a specific temperature profile can be realized. The temperature control and the control of the process were implemented in LABVIEW.

The determination of the controller parameters is done with controller tuning rules based on the step response characteristic of the system [3]. This method works not always well in any case, but because of its easy handling it is an approved method. In most cases the temperature control can be improved by manually fine tuning the controller parameters. It is not possible to point out common validated controller parameters for all cases and materials, because the workpiece, with arbitrary material properties and dimensions, is a part of the control system. For every material and every thickness of the workpiece it is necessary to adjust the controller parameters before the manufacturing process can start.

An example of the temperature curve from a bending process with temperature control (chosen upper limit: 300°C) is shown in Figure 3.

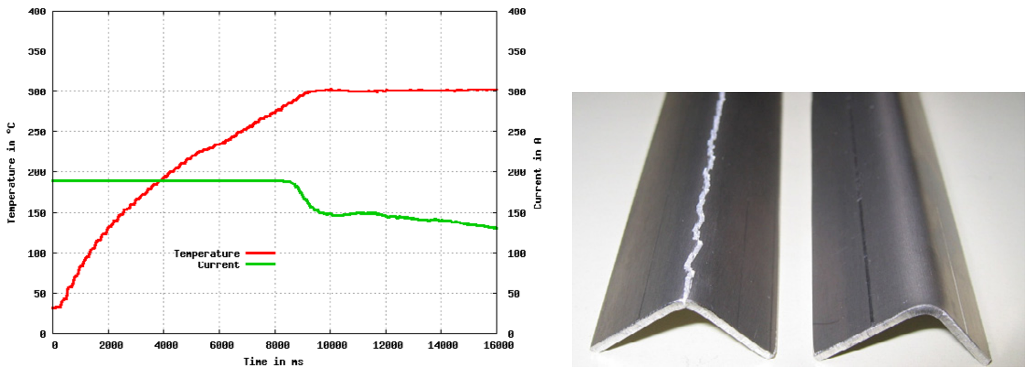

Fig. 4. (a) Temperature curve of Mg-alloy with temperature control; (b) Results of bending of the Mg-alloy AZ 31 without and with laser heating

4. Conclusion

With the introduced method bending of brittle materials can be realized by heating them within a narrow forming zone. The assembly is modularly designed and enables the realization of any bending length. By implementing the laser in the lower bending tool, heat can be applied during the bending process. In combination with temperature control it is possible to keep the temperature within a narrow range and to reproduce any defined temperature profile during the forming process. The heating and forming process can therefore easily be tuned to different materials. Brittle materials such as Mg, Ti, high-strength-Al and some high strength steel alloys can be bent successfully. With these new tools the use of conventional presses can be expanded to laser assisted warm bending, in operation nearly as simple as cold bending.

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