Laser assisted roller hemming of non-ductile material for automotive applications

Hongping Gu*a, Boris Shulkin a

*SCFI, Manga International, 375 Magna Drive, Aurora, ON, Canada L4G 7L6

Abstract

In efforts to achieve higher fuel efficiency, car manufacturers increasingly are starting to use light metal alloys, such as aluminum and magnesium alloys, for automotive components. Roller hemming is one of the manufacturing methods to make automotive assemblies such as doors, hoods and decklids. Significant mechanical deformation is applied to the material during the roller hemming process. This could introduce significant challenges to the use of light alloys due to limited ductility under standard conditions and these alloys can fail under conventional processing condition. However, at elevated temperatures, some of these light metal alloys become more ductile and can be roller hemmed successfully. An innovative process was developed at our research center to incorporate a laser beam at the hemming roller to introduce a localized heating source. With this approach, roller hemming of certain Mg and Al sheet alloys can be performed successfully.

Keywords: Roller hemming; laser beam heating; Mg and Al alloy sheet

1. Introduction

In the automotive industry, hemming is one of the assembly methods or processes for manufacturing closure components such as doors, hoods and tailgates etc. By this process, a metal sheet edge of an outer part is bent around an inner part. Robot roller hemming is one of the most flexible hemming technologies. Minimum product specific production equipment is required for robot roller hemming as compared to other methods. It is often a preferred hemming method for production of many different parts without high capital investment.

Magnesium alloys could prove to have a great potential use for closure panels in reducing the mass of an automotive body due to their high strength-weight ratios. However, there is a significant challenge in hemming of sheet Mg alloys. In this operation, the flange of the outer panels undergoes severe plane strain bending deformation. Magnesium alloys don’t exhibit good ductility and formability at room temperature. It tends to crack on the outer surface of the hem under extreme stretching. Therefore it is difficult or impossible to achieve a crisp edge on the panel with desirable surface appearance.

It was shown in the research work by E. Emley (1966) that Mg sheet can be formed into useful shapes in a temperature range of 230 – 400 °C. In a warm forming study of Mg alloy sheet by J. Carsley etc. (2007), it was observed that alloy AZ31 can be flanged for 90° bending at a temperature 210 °C or higher. In a formability study by E. Hsu etc. (2008), the plane strain forming limit of AZ31B was measured to be 67% at 300 °C, which indicates the formability of Mg sheet is greatly enhanced at elevated temperature. For hemming to achieve 180° bending, a minimum temperature of 270 °C is required to obtain acceptable surface quality on the hem. It was also observed that the surface quality is sensitive to the variation in process control. Therefore, a stable temperature is necessary during the hemming procedure to achieve consistent hemming. In roller hemming, the heat must be locally introduced to the bending region of the Mg flange.

* Corresponding author. Tel.: +1-9057267237 .
E-mail address: hongping.gu@magna.com; hpgu@hotmail.com

© 2014 The Authors. Published by Bayerisches Laserzentrum GmbH
Laser beam heating can provide precise and rapid local heating with the capability of achieving a high degree of power control. Stable temperature control is possible with laser beam heating. In this respect, the roller hemming equipment can be modified to incorporate a laser beam in front of the roller to rapidly heat the Mg just prior to hemming. The concept and a basic device of laser beam assisted hemming were disclosed in a patent application (B. Shulkin, etc. 2010). The result of implementation on Mg sheet was presented here.

2. Experimental device and procedures

2.1. Material and test sample coupon

Magnesium alloy AZ31B sheet of 1.1 mm thickness was used for roller hemming experiments. This magnesium alloy has approximate yield strength of 226 MPa, ultimate tensile strength of 296 MPa and breaking elongation of 15.6 % in perpendicular to roll direction based on supplier’s mechanical property data. The hemming samples were cut from warm formed panels which had a flange bend of 90° in the die.

2.2. Roller hemming device

The roller hemming device was designed and built based on a conventional roller hemming device with an additional capability of attaching the laser beam delivery optics. There are two rollers on the device. One is a flat roller and the other is a 30° taped roller. These two rollers are used to carry out a three-step roller hemming process. One roller is involved in two hemming processes.

The laser beam is delivered through an optical fiber cable. Two miniature optics couple the laser beam from the fiber cable and project the laser beam onto the hem flange in front of the rollers. Any laser source that can be delivered through optical fiber can be used for this application. In our research, the laser source is a Trumpf TruDisk laser. The optics was assembled using the stock items from Edmund optics.

![Step 1](image1)

Step 1

![Step 2](image2)

Step 2

![Step 3](image3)

Step 3

Fig.1. Illustration of the three-step hemming process.

2.3. Roller hemming procedures

The roller hemming device is mounted on a robot arm. The robot guides the rollers parallel along the flange to complete the hemming processes. The roller hemming process is carried out in three steps. In between the hemming steps, the orientation of the roller is changed or a different roller is selected. The first step is to bend the flange from 90° to 60° with the taped or angled roller. In our design, the taped roller is used for the second times to carry out the second hemming step. This hemming step brings the flange angle from 60° to 30°. In the last hemming step the flat roller is used to flatten the flange. The three-step bending is illustrated in Figure 1.

At the start of a hemming process, the roller moves in to the flange from the outside of the part. When the roller is about to contact the flange, the laser beam is switched on. As the hemming device is located at the flange, the laser beam spot is already correctly located on the flange. Heating the material at the bending area takes place.

The laser beam stays on during the hemming process until the end of the flange. The moving laser beam heats the material within its irradiated spot. As illustrated in Figure 2, the laser beam is located right in front of the roller. The beam spot is large enough to cover the area where the material bending and stretching is taking place. The heating by laser beam is transient and the temperature increase depends on the laser intensity and moving speed of the roller.
3. Experimental results and discussion

The sample pieces were cut from a die-formed body panel. A section of the panel is shown in Figure 3. The flange has a 90° bent angle. To simulate a hem joint, a piece of the same material was used for the inner part.

The roller with a 30° taper angle was used to perform step 1 and step 2 hemming processes. In step 1, the hemming tool was tilted by 30° from the vertical direction so that it hems the flange to 60°. In our experiment, the sample piece was clamped in the horizontal configuration. Thus, during the next two hemming steps, the roller hemming tool is almost in the vertical orientation and uses the two rollers to finish the hemming processes.

The hemmed sample was shown in Figure 4. To form this hem, a laser power of about 400 W was used. During the first two hemming stages (i.e. step 1 and step 2), a wave pattern is normally formed in the flange. After the final hemming step, the waves should be fully flattened out. If the waves are not flattened, the hem quality is reduced. The picture in Figure 4(b) shows that the flange was fully flattened out in our laser assisted roller hemming process.

The surface quality of a hem can be examined in three main areas, i.e. outer skin, outer radius and inner skin area. Figure 5 gives the detailed pictures of these areas of the hemmed sample. No ripples or warps are shown in the outer and inner skin area. For a quality hem, there should be no cracks and fractures in the outer radius area. For our hemmed samples no cracks can be found in the outer radius area and the stretched skin is smooth and uniform.

A cross section of a hem is shown in Figure 5(d). An outer radius of 2 mm was achieved for an Mg sheet of 1.1 mm thickness. This result demonstrates the capability of laser assisted roller hemming of non-ductile sheet metals.
On a car body, the normal operating motions of the closures require that a gap be maintained between panels. Vehicle quality and esthetics requires that these gaps be uniform and consistent. However, the gap size should be limited or an evenly distributed gap should be created to give a better appearance. The roll-in of the hem is defined as the distance between the outer radius of the completed hem and the original flange of the panel. It is an indication of how to control the gap. For roller hemming of sample pieces, it is difficult to show the proper control of the roll-in of the hem. By local heating using a laser beam, it is possible to control the roll-in of the hem due to the fact that the bending should occur in the softened area.

![Fig. 5. (a) Outer skin area; (b) inner skin area; (c) outer radius area; and (d) cross section of a hem.](image)

4. Summary and future work

With laser beam assisted (LBA) heating, local softening of a spot area in front of the roller occurs immediately before the roller is bending the flange. As a result, roller hemming of Mg AZ31 sheet material is successful. The process has produced good quality hemming results from the die-formed sample piece. A working device has been developed from the concept that was described in our patent application.

This process has also been applied to hemming of Al sheet material in another automotive application. With laser beam heating, a better surface quality in the outer radius area was achieved in comparison to conventional cool roller hemming. In future work, controlled bending at a desired location and with a preferred radius and a preferred bending location will be explored.

References