Flanging and Hemming of Auto Body Panels using the Electro Magnetic Forming technology

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Abstract

Electro Magnetic Forming (EMF) technology has a great number of potential applications for the automotive industry. LABEIN-Tecnalia has worked with this technology for six years and has a good understanding of the automotive industry's needs and challenges. LABEIN-Tecnalia is currently developing new applications with EMF technology. Taking into account the advantages and limitations of EMF, bending and hemming processes present good geometric conditions for the use of this technology. The study presented is based largely on hemming circular configurations which are simplifications of those commonly used on hemmed automotive parts. The parameters of this new EMF bending and hemming processes have been studied, as well as their influence on the final quality of the parts obtained. Conclusions obtained from the basic geometries were tested on a more complicated geometry in order to apply the knowledge acquired. Parallel to the experimental work, fully coupled electromechanical software by LS-DYNA has been used to simulate and extend the present hemming results.

Keywords

Sheet metal, Forming, Aluminum

1 Introduction

Hemming is one of the last operations to be used on auto body panels. Therefore, it has a critical importance on the performance and perceived quality of assembled vehicles. Due to the required precision on the hemming process and the complexity of the parts, most of the bending, flanging and hemming dies are designed based on experience and on lengthy and costly die tests. EMF can be a solution that saves time as well as money and improves the quality of the hem joint, especially when using aluminum alloys.

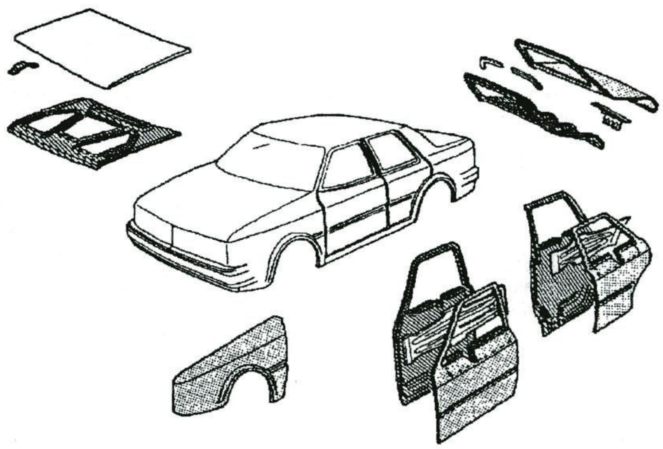

***Figure 1**: Different hemmed parts of the body and white of a car [1]*

Aluminum alloy sheet metal is more difficult to hem due to its susceptibility to strain localization during hemming, which may cause edge cracking on the hemmed edge [2], [3], [4], [5]. As a high-speed deformation method, the electromagnetic forming has some advantages. It can reduce the process time as the whole part is assembled in one rapid operation rather than two separated operations (pre-hemming and hemming). In other words, Electro Magnetic (EM) hemming can save time by not requiring a pre-hemming step.

EMF can also reduce wrinkling on curved areas of the part. This effect is especially important on small radius shrink flanges, expanding the possibilities by allowing the design of new hemming unions for the sharp corners of the parts. EMF will also reduce or avoid edge cracking on aluminum alloys due to the high strain rates achieved during the deformation process.

Before the hemming operation, the auto body panels have to be flanged. The actual mechanical hemming process carries some limitations when dealing with aluminum. For example, the minimum flange height obtained by mechanical flanging is typically greater than 4 mm. Using the EM bending process, this flange height can be reduced. This can be done precisely and will result in an improved electromagnetic hem. This is especially important when hemming sharp edges of the parts.

The discharged energy of the capacitor bank and the relative position between the coil, the part and the tool are input parameters of EM bending and hemming processes that were investigated in this paper.

The measured output parameters are different for each application. As mentioned before, improved quality is the main objective in hemmed unions for the automotive industry. To study the feasibility of the EMF technology for bending and hemming operations these quality aspects are measured after each set of experiments.

In the flanging experiments, three output parameters are measured: the reduction of thickness of the part, the angle of the bended flange and the final diameter of the part.

For the hemmed samples the primary quality parameter measured is the edge radius (the deformation of the hem union). This is an important parameter when analyzing the quality of the hem union because it is directly related to the “Apparent Gap” (a visual effect of distance between two hemmed parts of the auto body).

2 Materials and Geometries

The aluminum alloy used for these experiments was AA6016T4, which is a widely used alloy for external auto body panels. Its mechanical properties are listed in Table 1.

	Re (MPa)	Rm (MPa)	Elongation (%)	Thickness (mm)
AA 6016 T4	123	237	20	1.1

***Table 1**: Mechanical properties of the AA6016T4 aluminum alloy.*

Three different diameter circular geometries were analyzed with two flange heights for each diameter as listed in Table 2.

	External diameter of the part (mm)			Flange height (mm)	
BENDING	30	60	90	5	7
HEMMING	30	60	90	5	7

***Table 2:** Different geometries analyzed for each process.*

3 Hemming Experiments

All the parts were flanged and then hemmed using EMF technology. The relative position between the EMF coil and the part was the process parameter studied for the two flange heights, 5 and 7mm, respectively. Two overlapping flange length percentages were studied, 15% and 60%. A schema of the EM bending experiments set-up and a picture of one of the bending coils are shown in Figure 2.

3.1 Results for the Bending Experiments

The final geometries of the flanged parts were measured. The reduction of the sheet thickness on the 1.2mm radius of the bent section of the part, the final diameter of the whole part and the final angle obtained on the bent flange were the parameters taken into account when making conclusions.

- Overlapping 15% needs more energy to reach the desired final diameter than using greater amounts of overlap, but the reduction in sheet thickness is smaller for the same final diameter. The material is less damaged after EM bending using a 15% of overlapping.
- The bigger the diameter of the whole part the easier it is to achieve this value without damaging the part.
- No rebound was observed between die and part was observed for any of the geometries.

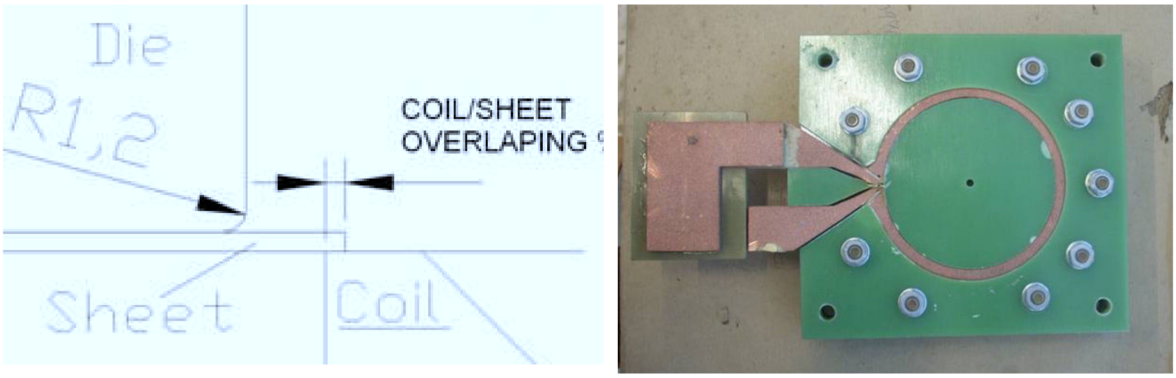

Figure 2: *Partial section view of the circular flanging set-up (left) and one of the EM flanging coils (right) used in these experiments.*

4 Hemming Experiments

LABEIN-Tecnalia has been developing the EM hemming process for the last two years and has published several papers on this field [6], [7]. These studies have demonstrated the importance of the EM impulse application height over the flange. This EM impulse application height is closely related to the quality of the final hem union. The choice of an appropriate flange height where the EM impulse is applied is essential to ensure the inner part is not deformed in the EM hemming operation.

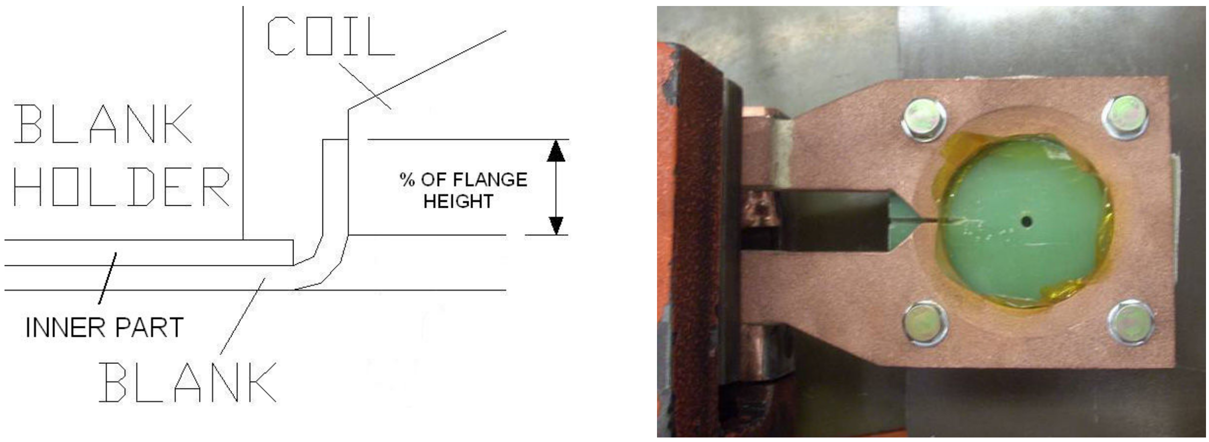

***Figure 3**: Partial section view of the circular hemming set-up with the % of flange height as input variable (left) and one of the hemming coils (right).*

Experiments were conducted with the goal of developing a methodology, which permits the design of coils for hemming complex parts (different diameters of the same geometry). The objective is to determine an EM impulse application height for different diameters avoiding the bending of the inner part and obtaining a good hem union quality. This study of simple geometries will lead us to a methodology for the design of EMF coils for hemming operations and the possibility of hemming more complex parts.

Several different diameters and flange heights were studied changing the percentage of flange where the EM impulse is applied. A schema of the EM hemming experiments set-up and a picture of one of the hemming coils are shown in Figure 3.

4.1 Results for the Hemming Experiments

After the experiments, the parts were analyzed and the most important problem was bending of the inner sheet. As a result criteria to measure and limit this were established. Parts obtained applying the EM impulse at different percentages of the flange height where measured for the same union geometry. Two different aspects of the EM hemming process cause deformation of the inner part. One is that an impact occurs due to a level of impulse that is too high. The other is that the force is applied too near the bend in the flange. The lower percent overlap is needed. To isolate the percentage of flange where the EMF impulse is applied (the scope of this study) the hemming process is performed at a low enough energy so the flange does not impact the inner. Analyzing the geometry at low energy ensures that the deformation of the inner part is caused by the inappropriate application of the EM force and not by the impact of the external part against the inner part. These results are shown in Figure 4 for the 90mm diameter and the 7mm flange height.

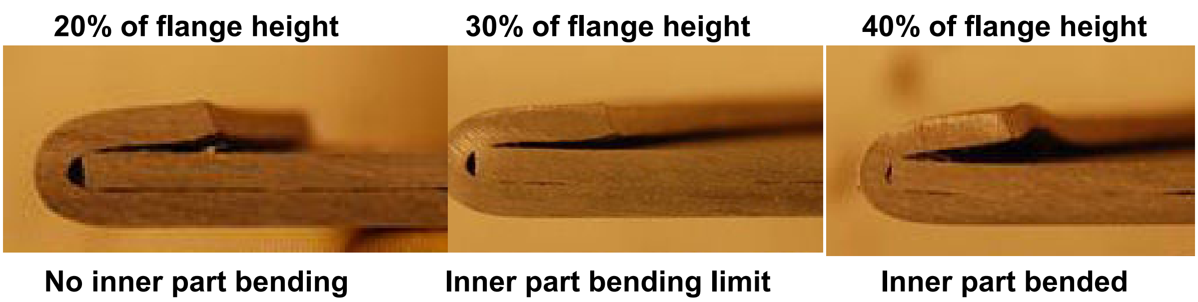

Figure 4: *Optimization of the percentage of flange height where the EM impulse is applied for the 90mm diameter and 7mm flange height geometry.*

Inner part bending limits where established for the rest of the diameters and the results plotted on the graph in Figure 5.

Conclusions of the hemming experiments:

- A relation between the diameter of the part and the EM impulse application height limit has been established.
- This relation is the key factor for continuing development of a methodology for the design of a coil for hemming complex parts.
- This relationship is the same for the 5mm and 7mm flange heights.

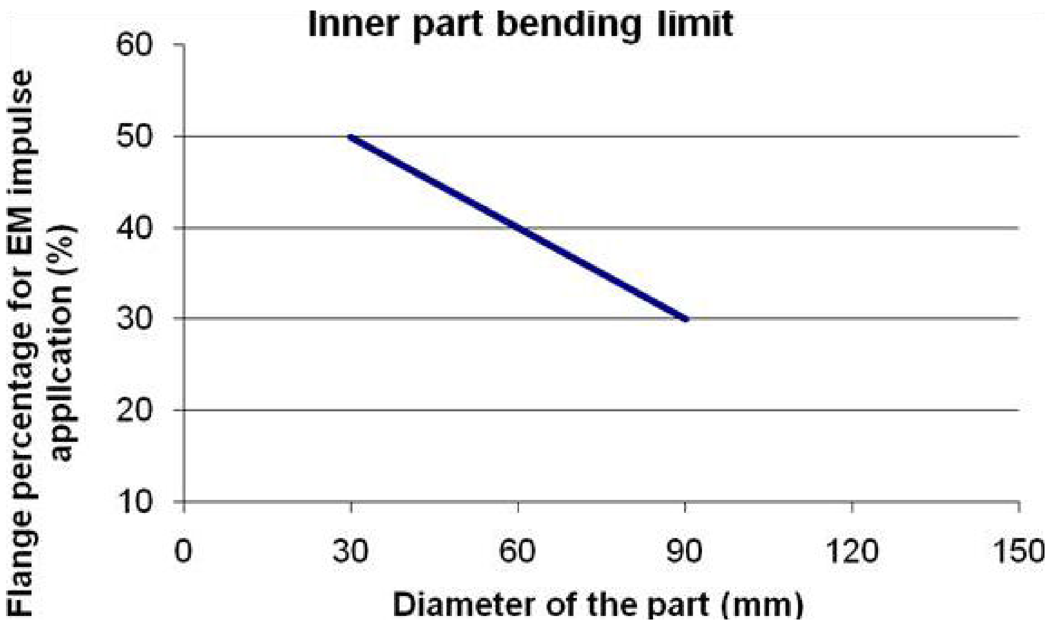

Figure 5: *EM impulse application limit curve for avoiding the deformation of the inner part*

4.2 Simulation Results

Electromagnetic based simulation model of the process was carried out using fully coupled software by LS-DYNA developed by Pierre L'eplattenier at LSTC of Livermore, CA. There is good correlation between the experimental and the simulation results (see Figure 6).

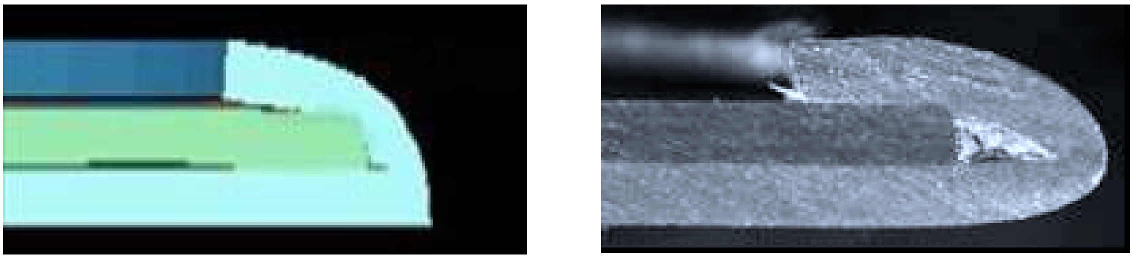

***Figure 6**: FEM union obtained using the fully coupled simulation method by LS-DYNA (left) and one of the unions obtained experimentally (right).*

5 Application of the Developed EM Hemming Coil Design Methodology to a Complex Part

Using basic geometries, the first step for the characterization of the EM hemming process was accomplished by obtaining a relation between the part diameter and the coil geometry needed for obtaining a hemmed union without deforming the inner part. The next step is to prove these conclusions on a more complex part, similar to real auto body panels. For this purpose a new coil was designed and implemented containing different diameters and straight areas on the same hem flange line where conclusions from the basic geometries will be applied on the design of the coil.

A coil designed for a current collaboration project between Svensk Verktygsteknik of Sweden and Professor Daehn of The Ohio State University was used for this second approach. The geometry of this coil is shown in Figure 7.

The small number of available parts of parts and time resulted in only a small area of the part being optimized by applying the methodology developed on the design of hemming coils in this study. This area contained a straight hem line and a circular hem line of 120mm diameter for a constant 7mm flange height as shown in Figure 7.

The chosen area of this new coil was machined in such a way that the 120mm diameter flange area has 20% of the flange height applying the EM impulse over it based on an extension of the line in Figure 5. The straight section can be considered as an infinite diameter. As this is impossible, we consider a minimum of 0% overlap for the straight flange area.

To see the improvement of this method two experiments were conducted. Test 1 used 20% of flange for the EM impulse application on the 120mm diameter area and also on the straight area, and a second one. Test 2 used 20% for the 120mm diameter and 0% for the straight area accordingly to the results obtained with the basic circular geometries.

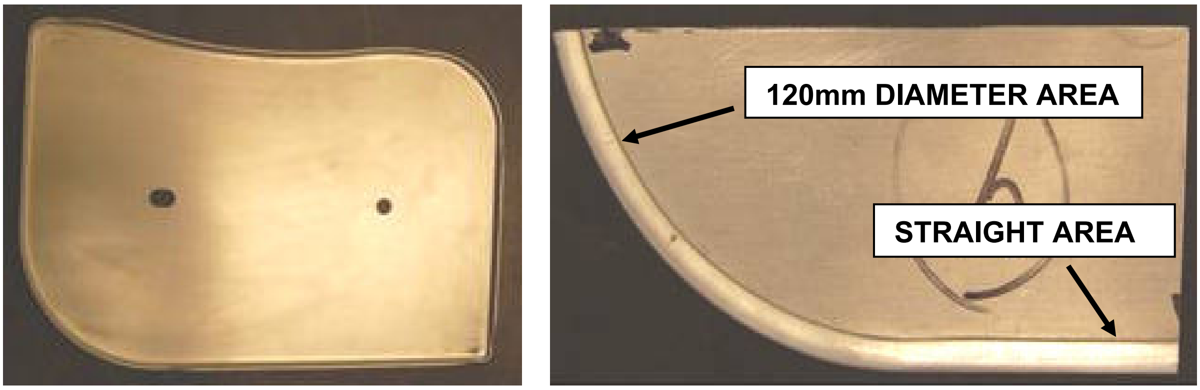

***Figure 7**: Complex part with 5 different diameter on it (left) and the chosen area to be improved applying the methodology developed in this study (right).*

The resulting hem union geometries are shown in Figure 8. The goal of this whole process is obtaining a good hemmed union on different areas of a complex part using one single coil by only changing the EM impulse application percentage over the flange height. Improvement was obtained on the deformation of the straight area while maintaining the same union quality on the 120mm diameter area by only changing the percentage of the flange height where the EM impulse is applied parameter.

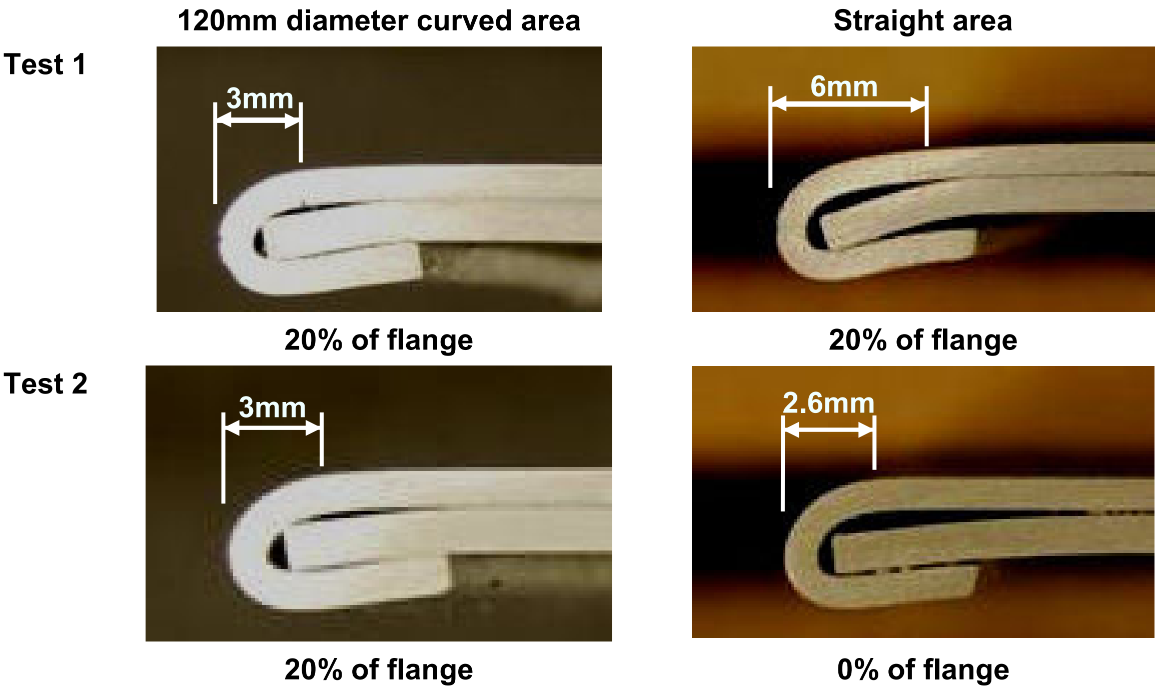

***Figure 8**: Deformation of the hem union for the straight area (left column) and the 120mm diameter curbed area (right column) of the complex part for the First test (upper row) and the Second test (lower row).*

Conclusions for the complex part:

- The methodology for the design of EM hemming coils developed in this study has been applied to the design of a coil for a complex part.
- An improvement in the studied area has been observed after adjusting the percentage of the flange height where the EM impulse is applied, results shown in the graph in the Figure 5.
- By adjusting this parameter, the same hemmed union geometry has been obtained on different geometrical areas of the part using one single coil and one single EM discharge of the capacitor bank.

6 General Conclusions

- The first steps for developing two new process applications for the emerging EMF technology have been established.
- The main process parameters have been studied and relationships have been developed.
- These conclusions have been applied to a complex part giving satisfactory results.
- Good agreement between experimental samples and prediction with the fully coupled simulation method was achieved

7 Future Work

- A complex part will be designed to further prove the conclusions arrived at from these experiments. This methodology will continue to be studied and improved for designing EM coils for hemming operations. This part will contain different diameters and straight areas always moving towards real auto body panels.
- Fully coupled simulations will be used to design the coil for this more complex hemming operation.

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