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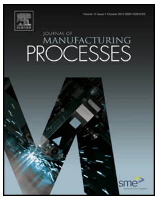

Hemming process with counteraction force to prevent creepage

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ABSTRACT

Creepage, a typical phenomenon in the hemming process, can be defined as undesired roll-in of the panel at the bending line. Creepage also reduces the final panel width and makes the hemming radius larger. In this study, experimental observations are reported, and a finite element model, based on the LS-DYNA® two dimensional plane strain solid formulation, is utilized to study the mechanics of how the hem flange bends and folds during the hemming process. A novel hemming process incorporating a counteraction force is proposed in order to prevent the creepage phenomenon during the hemming process. An experimental hemming tool was designed according to this concept, and optimization of the tooling geometry was carried out utilizing the finite element model. An experimental study was conducted to confirm that the new hemming process can prevent creep be employed to help retain a sharp radius during flanging operation.

1. Introduction

Hemming is widely used in the automotive manufacturing industry to assemble an outer closure panel and an inner closure panel by folding the flange of the outer panel over the edge of the inner panel as shown in Fig. 1a. Hemming is also sometimes used without an inner panel in order to improve panel appearance and to prevent exposure to sharp edges by folding them back. However, the mechanism of hemming is more complex than simply bending a straight flange along a straight line, since the geometry of the bending line is usually three dimensional, as it is shown in Fig. 1b. Most production hemming processes involve a significant amount of trial and error during development, as there is limited information available on the process in terms of research studies. Typically, the hemming radius is desired to be as small as possible because of a visual phenomenon known as the “perceived gap” that exists between two adjacent panels described by Friedman et al. [1], as shown in Fig. 2. A smaller perceived gap enhances the visual appearance and is associated with superior craftsmanship.

Aluminum alloys are being increasingly utilized as a major light weight alternative to steel. The thickness of aluminum panels used to replace steel panels is usually 40–50% greater than that of steel, in order to provide sufficient bending stiffness. The strain of an outer layer of sheet material during a bending operation can be estimated to be $t/(2r_{inner}+t)$, as shown in Fig. 3. Based on this estimation, the aluminum panel experiences substantially higher strain than the steel panel with the same inner hemming radius. In addition, aluminum alloys usually have lower bendability and lower overall formability compared to steels employed in outer skin panel production. These circumstances make hemming of aluminum alloys rather problematic. In early implementation of aluminum panel applications in the automotive industry, hemming was usually accomplished using the rope hem technique where the hem radius is intentionally kept larger than the radius that would result from a flat hem. While aluminum panels are able to be hemmed by this approach, their large radii negatively impact the exterior appearance. As technological advances were made in the areas of alloying and material processing, aluminum alloys with improved bendability became more common, and these alloys to some degree provided the opportunity for sharper radii to be achieved on the outer panels.

Several advanced hemming techniques for achieving sharper hem radii have been developed. Krajewski and Ryntz [2] proposed heat treatment at the area of bending for aluminum 6111-T4, which improved bendability and enabled flat hemming. Carsley et al. [3] proposed thinning the hem line at elevated temperature prior to

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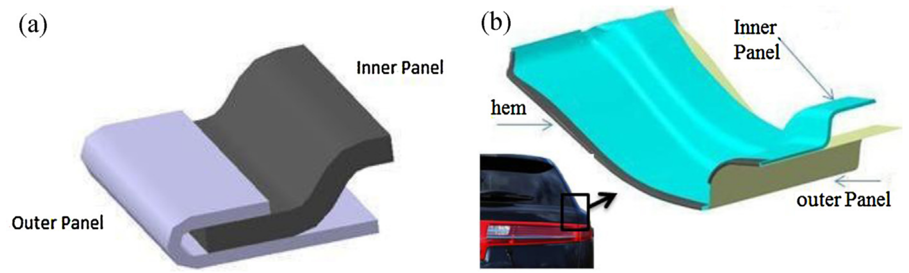


Fig. 1. (a) Folded flange of outer panel over inner panel hem type, (b) a car panel with three dimensional curvature hem.

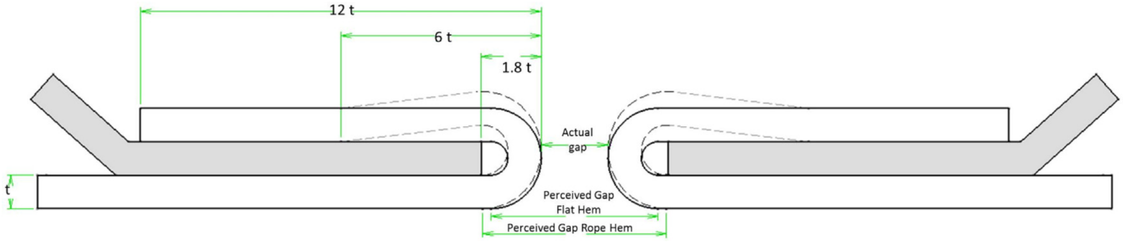
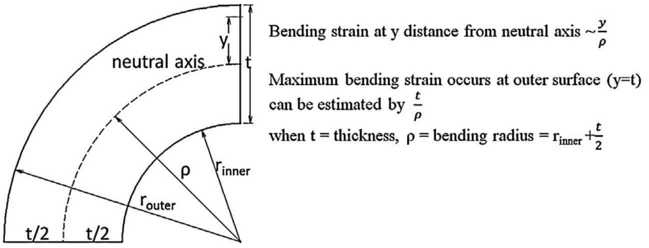


Fig. 2. Comparison of actual gap and perceived gap (flat hem: solid line, rope hem: dashed line).

hemming, which resulted in a decrease in the amount of strain in the material at the hem line for an identical hem radius. However, thinning of a local area of the panel may require rather high forces from specialized tooling. Performing this operation at such high temperatures is feasible only for non-heat-treatable alloys. However, the alloys commonly used in the automotive industry as outer skin panels are heat-treatable alloys, such as 6111-T4 or 6022-T4, and forming these alloys at high temperature may lead to the reduction of formability due to aging effects. For example, after a paint bake cycle, the elongation will drop from 26% to 21%. In general, modifying one local area of the panel can be labor intensive, require at least one additional operation, and can lead to more complicated tooling.

From studies by Bridgeman [4], it was discovered that applying hydrostatic pressure at the stretching area substantially improves material ductility because microcrack development is suppressed by the hydrostatic pressure. Wiens [5] introduced an inclined angle on the hemming tool. With this approach, the radius area of the hem is compressed by the inclined angle of the hemming tool as shown in Fig. 4a, producing a sharper radius compared to the conventional rope hem. The benefit of this technique is greater if the inner panel is thicker. However, for lightweight materials such as aluminum or magnesium alloys, the inner panels made from these materials can have a much thicker gauge, as much as 3–4 times that of the steel outer panel, and there could be interference between the hem radius and the inner panel. Miller and Friedman [6] addressed this issue by machining an angle on the edge of the inner panel, thereby avoiding any interference between the hem radius and the inner panel. One major concern which stands in the way of broad implementation of this approach is variation of the exterior panel location relative to the hemming tool, as well as variation of the length of the hem flange on the inner panel due to trimming tolerances, as shown in Fig. 4b.

The panel location variation of ±0.5 mm is typical, and it is enough to cause problems with this approach. If the panel location is too far outward, then the hem radius can be distorted by the angled portion of the hem tool, resulting in over compressing of the hem radius which may potentially lead to a crack. If the panel location is too far inward, then the angle will not contact the panel and the hem will simply be a flat hem. Friedman et al. [1] addressed this concern by applying the inclined-angle concept to roller hemming, which is able to compensate for location variation. However, roller hemming has considerably higher cycle times as compared to press hemming, and is usually not suitable for high volume production. Similar approaches based upon the fundamental concept of applying hydrostatic pressure to the stretched area, have been introduced by Golovashchenko et al. [7]. By utilizing an elastomeric element as part of the tool, pressure can be applied to compress the elastomeric element, and hence a side pressure can be applied to the stretched area of the panels introducing compression in the area of stretching. While this approach can effectively produce a sharp radius hem, achieving a robust tooling design for applying such pressure during the hemming operation can still be very challenging.



Bending strain at y distance from neutral axis $\sim \frac{y}{\rho}$

Maximum bending strain occurs at outer surface (y=t) can be estimated by $\frac{t}{\rho}$

when t = thickness, ρ = bending radius = $r_{inner} + \frac{t}{2}$

Fig. 3. Bending strain estimation.

2. Creepage in existing hemming processes

The sharp radius at the character line of a panel can also be formed during flanging operation, and need not be formed only during the hemming operation. Golovashchenko [8] proposed a new flanging method which utilizes the fundamental concept of applying hydrostatic pressure to the stretched area, leading to a very sharp radius after flanging but before hemming. By forming the sharp radius during the flanging process instead of during the hemming process, there is an opportunity to avoid overly complex