VOL. 11, NO. 6, MARCH 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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DESIGN OF HOLLOW SECTION OF HIGH STRENGTH STEEL SHEETS JOIN BY HEMMING PROCESS FOR ENERGY ABSORBTION APPLICATION

Zamzuri Hamedon[1], Ahmad Razlan Yusoff[1], Mohd Azmir Mohd Azhari[1], Yohei Abe[2] and Ken-Ichiro Mori[2]
[1]Automotive Excellence Centre, Universiti Malaysia Pahang, Pekan, Pahang, Malaysia
[2]Department of Mechanical Engineering, Toyohashi University of Technology, Tempaku-cho, Toyohashi, Japan
E-Mail: zamzuri@ump.edu.my

ABSTRACT

A high strength steel sheet is used to make the hollow sections for the body structure of automobiles. The hollow sections, which are typically joined by resistance spot welding, have insufficient energy absorption because the joins are not continuous. Thus, to overcome this problem, the hollow section is joined using the hemming process. The hemming of the high strength steel sheet was successfully performed using punch with stopper. The high strength steel hollow sections joined by hemming and resistance spot welding were then examined by tensile and fatigue tests. The hollow section with hemmed joins showed better performance in both tests. The overlapping joins of the hemmed hollow section have greater strength as compared to the resistance of spot welding joins.

Keywords: hemming, high strength steel, springback, spot welding, absorbed energy.

INTRODUCTION

Since the number of vehicles is increasing over the last two decades, the number of accident and injuries are also increasing. For that, it is strongly desirable for the vehicle to improve passenger safety and at the same time to reduce the weight of the vehicles. The materials for body in white (BIW) of the cars is changed to the high strength steel and the structrure is improved by using hollow section, Merklein *et al*. (2012) has suggested applying bulk-forming operations to sheet metals to produce high quality sheet metal components with heavily loaded functional elements. Continuous researches are carried out in optimizing the design of vehicle body structure to obtain efficient energy absorbent parts during accident and to protect the user of the vehicle.

The use of stronger materials and the optimization of structure of body members are applied for the improvement. Abe *et al* (2013) had used the high strength steel hollow sections for body structure of the automobiles for this purpose. The structures of hollow sections are optimized to increase crashworthiness of vehicles for human safety. In the crash situation, kinetic some of energy is absorbed by the hollow section. A current hollow sections used typically are joined by resistance spot welding, though have insufficient energy absorption because join are not continuous. Although laser welding is a better approach to overcome this problem, high heating temperatures reduce the quality, accuracy and reliability of joined parts (K. Mori *et al*., 2013).

The hollow sections or tubes with different shape have been widely adopted as the energy absorbers in most of the vehicles. The hollow sections, which are typically joined by resistance spot welding have insufficient energy absorption because the joins are not continuous. Laser welding is a better approach to overcome this problem. Car manufacturers also believe that high heating temperature reduces the quality, accuracy and reliability of joined parts.

In order to overcome this problem, the hollow section was joined using the hemming method. However, designing the hemmed part is not easy and is influenced by the mechanical properties of the bended part. The main problem in the automotive industry is to bend the high strength steel sheets. For the high strength steel sheets, the dimensional accuracy of formed products deteriorates due to large springback and die deflection, and the formability is small. Hamedon *et al*. (2014) detected the occurance of the springback during the flanging process using borescope. Livatyali *et al.* (2000) improved hem quality and pre-hemming operation by using simulation. Mori *et al*. (2010) used the numerical simulation to study a multi-step hemming process on concave and convex curved surface for a curved hemmed edge.

Hemming the high strength steel sheets becomes more unpredictable due to its susceptibility to strain localization during the process hence the design of stamping processes of high strength steel sheets becomes difficult. This will cause cracking on the hemmed edge. Mori *et al*. (2010) improved the expansion of a hole of a punched ultra-high strength steel sheet by smoothing fracture surface of the sheared edge using a conical punch. Abe *et al*. (2013) developed a gradually contacting punch to increase the stretch flangeability of the ultra-high strength steel sheets.

In this study, the high strength steel sheets hollow section was joined by hemming and was examined through an experiment using tensile and fatigue tests. The result was compared with the hollow section joined by resistance spot welding.

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EXPERIMENTAL PROCEDURE

Hemming process of high strength steel sheets

Both edges of hollow sections are joined by the hemming process to produce continuous joining without external heat supply. Figure-1 shows the geometry of the hollow section having welded (a) and hemmed joins (b). Since the hollow section having hemmed joins is overlapped, the strength is increased as compared to the resistance spot welding joins. Thus, hemming is effective for increasing energy absorption during the crash test.

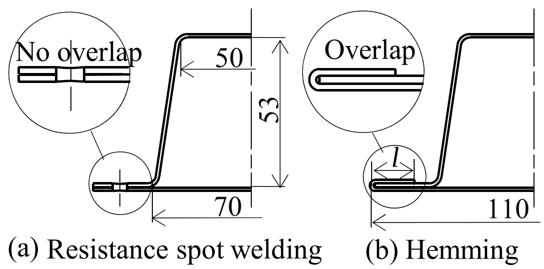

Figure-1. Hollow section having welded and hemmed joins.

The high strength hat-shaped part and the flat sheet were joined by hemming to form a hollow section. The hollow section is then crashed to determine the absorbed energy. Same thickness (1.22 mm) of the sheet with different tensile strength are used. The mechanical properties of the sheets are given in Table-1.

Table-1. Mechanical properties of hemmed sheets.

Sheets	JSC590 YN	JSC780 YN	JSC980 YN
Tensile strength /MPa	628	813	1026
Elongation /%	22.7	17.3	14.7
Reduction in area /%	63	56	53
n-value	0.11	0.10	0.07

Generally the hemming process is performed in three stages. Figure-2 shows the three stages of the hemming processes. In the 1st stage the outer panel is bent to 90° and in the 2nd stage, the sheet is inverted then bent to 135°. The inner sheet is added in the 3rd stage before the bending of 180° is performed to join the two sheets. When hemming the high strength sheets having low ductility, a crack tends to occur at the outer surface of the hemming due to the small radius produced. In order to prevent the envelopment of cracks, a punch with a stopper was employed in the 3rd step. The dimensions of the tools used in the hemming process are shown in Figure-2. The sheet is bent in the 3 steps to join the sheets and form the hollow section by the hemming process, 90°, 135°and 180° bending. The clearance between the die and punch in the 1st step was fixed to 100% of the thickness.

A servo press with a load capacity of 800kN and a maximum ram speed of 700 mm/s was used for the crash test. The range of the flange length for hemming was between 5 and 20 mm.

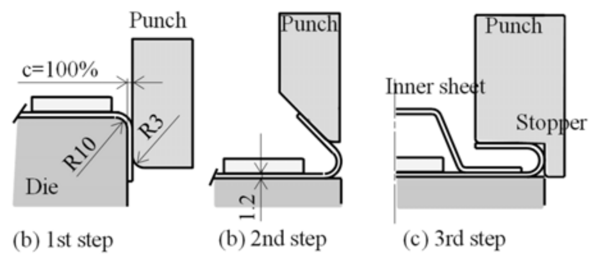

Figure-2. Dimensions of tools used in hemming process.

The comparison between the hemmed sheets for the punches with and without the stopper for JSC980YN is shown in Figure-3. Without the stopper, cracks tend to develop at the outer surface, whereas the occurrence of cracks was prevented with the stopper.

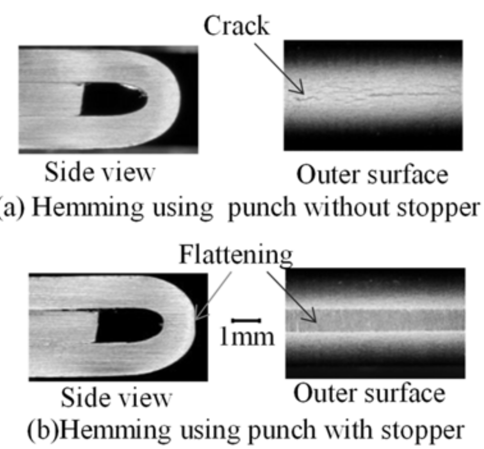

Figure-3. Comparison of hemming sheet between conventional punch and punch with stopper for JSC980YN.

RESULTS IN CRASH TEST OF HIGH STRENGTH STEEL HOLLOW SECTIONS

Result of crash test

Both of the hollow section having hemmed joins and resistance spot welded joins are crash separately by using press machine. The load-stroke curve for JSC980YN is shown in Figure-4. The maximum load for the hollow section having hemmed joins is almost double as that for the welded joins.

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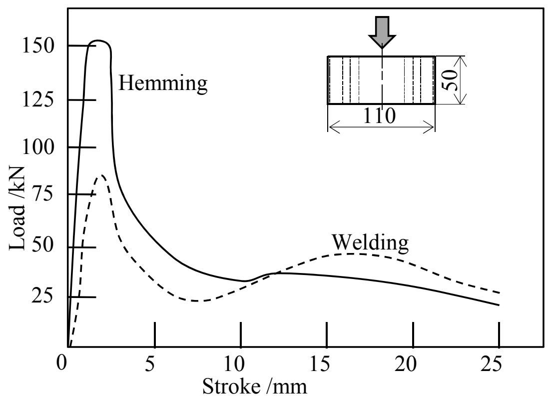

Figure-4. Load-stroke curve for JSC980YN.

The relationship between the absorbed energy and stroke for JSC780YN and JSC980YN is shown in Figure-5. The amount of the absorbed energy for the hollow section having hemmed joins is approximately 10% larger than that for the hollow section having welded joins.

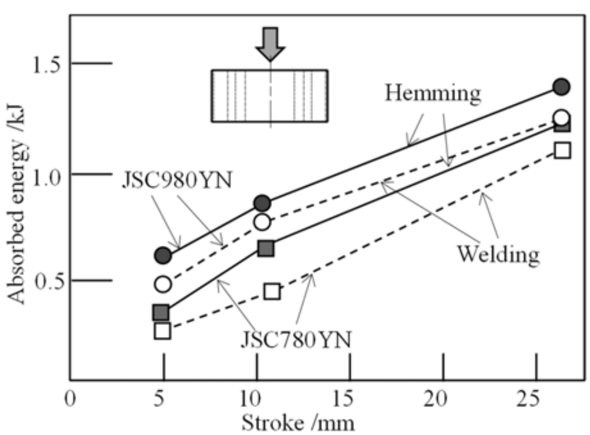

Figure-5. Relationship between absorbed energy and stroke for JS7980YN and JSC980YN.

The hollow sections after the crash test are shown in Figure-6. After the crash, the inner sheet and the outer sheet with 1 welded join and 2 welded joins are not attached to other whereas for the hemmed joins hollow section, the sheets are remained sticking together.

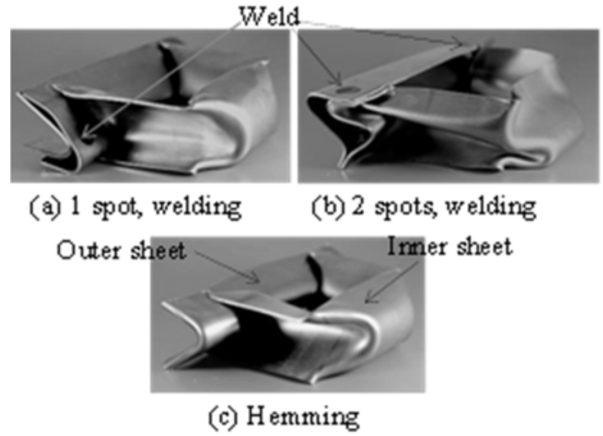

Figure-6. Hollow sections after crash test for JCS590YN.

The load-curve of the hollow section having 1 and 2 spots welded joins and hemmed joins for JSC590YN is shown in Figure-7. The maximum load for the hollow section having the hemmed joins is larger than those for the hollow section having 1 and 2 spots welding, 25% and 15%, respectively.

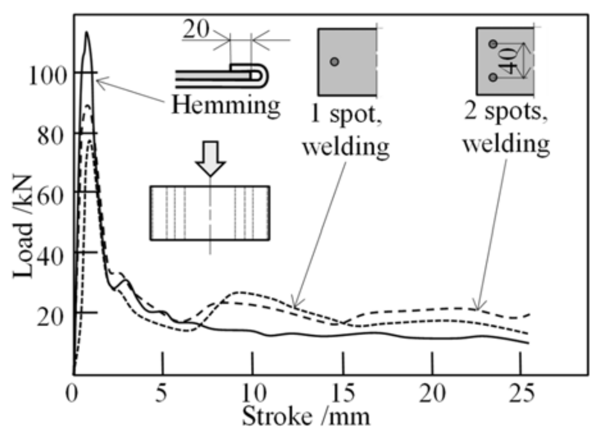

Figure-7. Load-stroke curve for axial direction, 1, 2 spots welding, hemming and JSC590YN.

The relationship between the absorbed energy and stroke for the hollow section having joins by 1 and 2 spots welding and hemming for JSC590YN is shown in Figure-8. As the stroke increased, the absorbed energy also increased. The absorbed energy for the hollow section having hemmed joins is larger than those for the hollow section having 1 and 2 spots welding.

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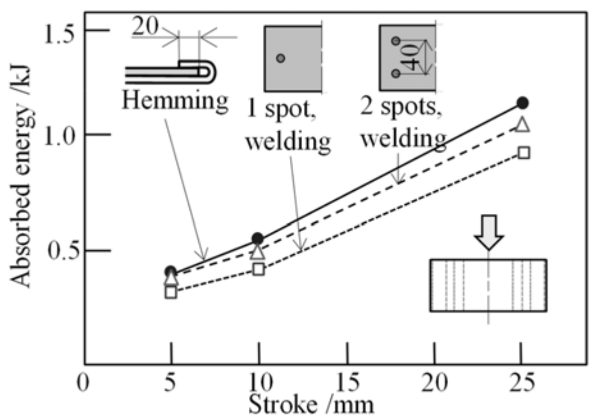

Figure-8. Relationship between absorbed energy and stroke for 1 and 2 spots welding, hemming and JSC590YN.

Determination of flange length in hemming

To determine the flange length of the hemming, *l*, the crash test was performed. Figure-9 shows the relationship between load and the flange length of hemming and between absorbed energy and the flange length of hemming for different strokes, *s* and JSC980YN. As the flange length of the hemming, *l* increased, the maximum load is increased. However, for *l* = 15 and 20 mm, the maximum load only showed small different. In addition n, for the flange length of the hemming, *l* = 15 and 20 mm of the absorbed energy are almost the same for all crash stroke, thus *l*=15 mm is considered an optimized flange length of hemming.

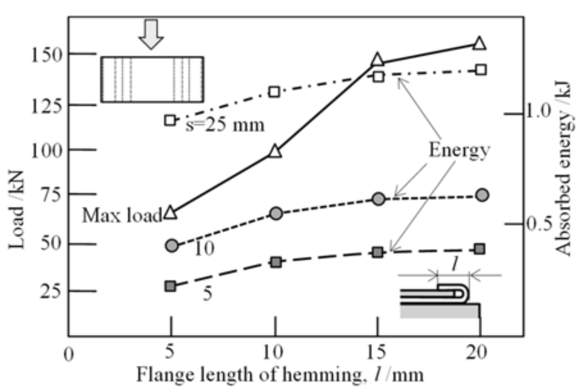

Figure-9. Relationship of load, absorbed energy and flange length of hemming for different strokes and JSC980YN.

CONCLUSIONS

The hollow section having hemmed joins is effective for absorbing the energy during the crash test compared to the resistance spot welding. Since the maximum load during the crash test and the absorbed energy for the hollow section having hemmed joins is larger than welded joins, the safety of the passenger inside the cabin is increased.

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