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K. Saito, J. Watanabe, O. Yokoyama, K. Nakao. APPLICATION TECHNOLOGY OF ALUMINUM BLOW FORMING FOR AUTOMOTIVE CLOSURE PANEL. EuroSPF 2008, Sep 2008, Carcassonne, France. hal-00349245

HAL Id: hal-00349245

<https://hal.science/hal-00349245>

Submitted on 26 Dec 2008

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APPLICATION TECHNOLOGY OF ALUMINUM BLOW FORMING FOR AUTOMOTIVE CLOSURE PANEL

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Abstract

Replacement by aluminum for the closure panels is one of the common methods for lightening car body. However the application used to be limited into shallow drawing parts like hood because of its low stamping formability. As a solution to cover the low stamping formability of aluminum, Blow forming technology of aluminum which is one of the superplastic forming technologies has been researched in Honda for closure panel application. High cycle blow forming technology has been realized for shortening the forming time, which used to be a problem for mass production and the mass production line could be build. This technology has been used for the fender and trunk of 05M LEGEND(05M ACURA RL), which is luxury sports sedan of Honda, and achieved enlightenment with high design performance. In this report, high cycle blow forming technology which is comprised of die technology, forming technology and material technology will be introduced.

Keywords :

Automotive closure panel, Aluminum blow forming, High cycle blow forming,

1 INTRODUCTION

Nowadays replacement with light materials has been increased in car body application with increasing environmental concerns. Specifically for the closure panels, aluminum is widely used even in low price mass production car, mainly for hood application. On the other hand, we often find unique design of car insisting the originality of its brand, as normal in motor show. Under these circumstances, replacement into plastics can also be found as hood material with complicated shape. However, aluminum has much expectation because of its high recycle ability. By the way production technology must be competitive as well, in terms of production cost. However, ideal production line has not been found easily, because of its low formability and low products accuracy of aluminum. Honda engineering has been developing blow forming technology since 1991 as one of the forming process suitable for aluminum. In 1995 this technology was firstly used into fuel tank of racing motorcycle (RS125), then used next into outer panel of car body (S2000 hard-top). [1] However because of its low productivity, this technology could not be used for mass production car. In this paper, newly developed high cycle blow forming technology will be introduced, which found its application in 05M LEGEND (05M ACURA RL) achieving higher productivity. [2,3]

2 DEVELOPMENT BACKGROUND

In order to achieve attracting design worthy for LEGEND, which is the most luxury sedan model in Honda, application of blow forming technology into front fender R/L, trunk skin and trunk frame was requested. Main features of its design are 1) widely projected shape of front fender symbolizing Honda unique design and 2) Rear shape with round curve that was never found in Honda or even in any other brand and the unique shape of visor above the license plate for trunk skin (**Figure 1**). Also forming a complicated shape which gives high rigidity of the trunk frame was needed to achieve luxurious shut feeling

suitable for luxury car. However it seemed difficult to make even one part of them with the conventional stamping technology. Moreover there were other difficulties in die manufacturing because of the relatively large amount of spring back and in quality control in mass production line, which affected the quality and cost competitiveness of the products. In order to solve the above-mentioned problems, development of high cycle blow forming technology was started so that we could supply all the 4 parts with acceptable productivity for the mass production line of LEGEND.



Figure 1 : Aluminum closure panels produced by blow forming

3 TARGET OF DEVELOPMENT

Main aim of this project was to achieve light weight and high design performance of the parts by blow forming technology that was not possible with the stamping technology (**Figure 2**). However the conventional blow forming technology needed long time. Blow forming process starts from sandwiching the aluminum sheet with die and the sheet is preheated up to enough high temperature giving high elongation and then it is expanded and fit into the die by applying compressed gas. The advantages of this technology are high accuracy in size achieved by less amount of spring back with less residual stress in high temperature forming and uniform elongation achieved by relatively uniform stress. However, forming into complex shape with small radius curve consumes long time because the sheet fits to the die gradually. Therefore it result in long cycle time and low productivity. In this project, high productivity of 10,000 parts per month which is necessary targeted for supplying parts for LEGEND, whereas 300 parts per month was the maximum productivity with the conventional blow forming technology.

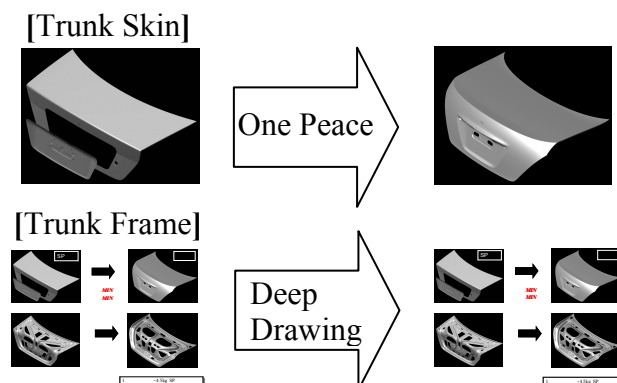


Figure 2 : Design performance achieved with new blow forming technology in comparison to the conventional stamping technology

4 PROBLEM FOR ACHIEVING HIGH CYCLE

Two hurdles were found to apply blow forming technology in LEGEND. One was to shorten the cycle time up to 1/6 or less compared to the conventional process, for achieving high productivity. Forming cycle comprises mainly the technologies shown below.

- 1: Forming Technology
- 2: Die Technology
- 3: Material Technology
- 4: Equipment

These details of there four items are described as follows.

5 FORMING TECHNOLOGY

5.1 CONDITION OF FORMING

There is an equation on blow forming time and forming radius as;

$$\dot{\epsilon} = A\sigma^{1/m} \quad \dot{\epsilon} : \text{strain rate; } A: \text{material coefficient} \quad (1)$$

$$\sigma = PR/2t \quad m: \text{strain rate sensitivity coefficient; } P: \text{forming pressure} \quad (2)$$

σ : stress R : forming radius t : thickness

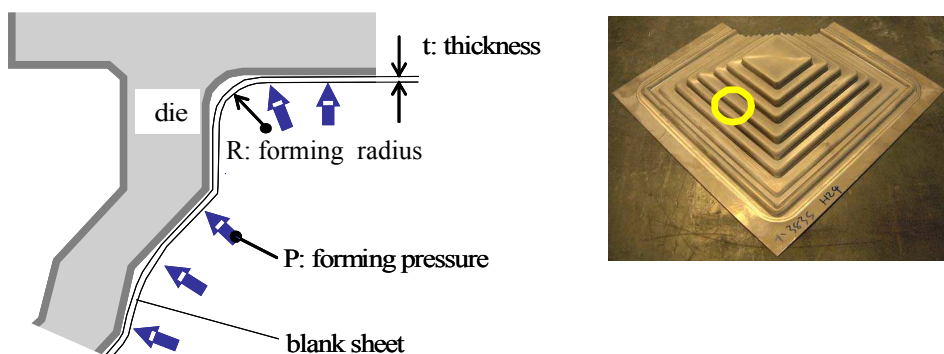


Figure 3: Relation between forming radius and forming time with various conditions of forming pressure and temperature

Where in case forming radius (R) and sheet thickness (t) are relatively similar, strain rate ($\dot{\epsilon}$) is controlled by forming pressure (P) and m related factor material (**Figure3**).

Therefore the relation between forming radius and forming time was investigated fundamentally on various conditions of forming pressure and temperature, thereafter forming condition was determined in terms of forming time shortening (**Figure4**). [2]

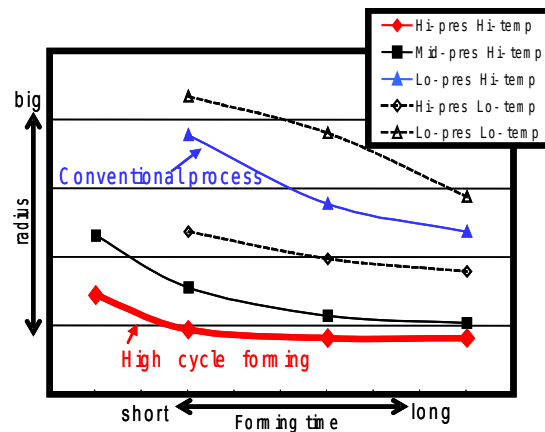


Figure 4 : Relation between forming radius and forming time with various conditions of forming pressure and temperature

5.2 MODELING

Model setting for the blow forming process is relatively similar to that of the conventional stamping process, since the product is finished with trimming and / or bending after blow forming. But since the formability limit and forming method is different from the conventional stamping process, advantage in high elongation should be utilized in modeling the blow forming process. On the other hand, strain control, touch timing control and suppression of deformation on detaching the formed panel from the die are the factors that must be controlled simultaneously. Practically most suitable model was determined through quantitative evaluation of formed panel with simulation which were based on qualitative understanding of the theoretical model. **Figure 5** shows an example of the simulation, where strain is analyzed with simulation software of PAM/STAMP and LS/DYNA using experimental data for material properties and friction coefficient.

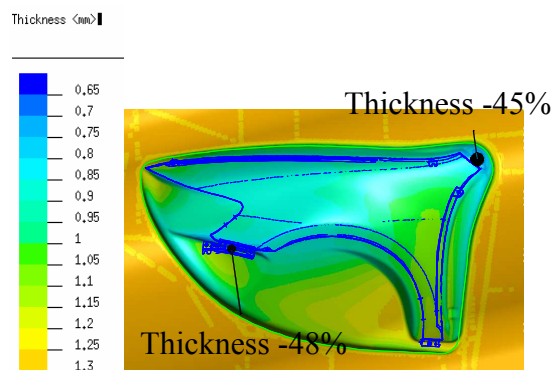


Figure 5 : An example of simulated results of thickness

6 DIE TECHNOLOGY

6.1 SEAL TECHNOLOGY

For high cycle forming, forming time must be shortened with raised forming pressure. Key technology for sealing high pressure air should be within bead structure. Satisfied seal has been gained with 2 beads of rectangular shape on die face, which bites blank

panel with shut pressure of the die. Also, stress relief system was attached nearby the seal beads in order to avoid transmission of forming stress onto the seal beads. This system can prevent the tear of the panel and successive pressure leak that can be encountered by the forming stress concentration onto the seal beads. With the above technology, stable production has been achieved without pressure leak trouble. [4]

6.2 EXTRACTION STRUCTURE

Formed panel must be extracted in short time without deformation to keep stable accuracy. However, high temperature formed panel is soft and easily sticks to the die. So, simultaneous extraction technology in accordance with die opening has been developed by adding picking up force of press ram and die gravity onto the formed panel.

The load (or picking up force) must be minimized and added uniformly, for extracting soft panel. First, load was minimized by draft angle optimization and sticking force of panel to the die was decreased. Also, die was partly finished into fine surface roughness for small draft part such as deep drowned vertical wall. On the other hand, for uniform loading, load must be added onto broad area (not onto a point). So circumference flange of the panel has been gripped by blank holder and lower die. **(Figure 6)** This structure enabled short time extraction without deformation, because only the upper die holding forming surface is lifted up in accordance with die opening in this structure.[4]

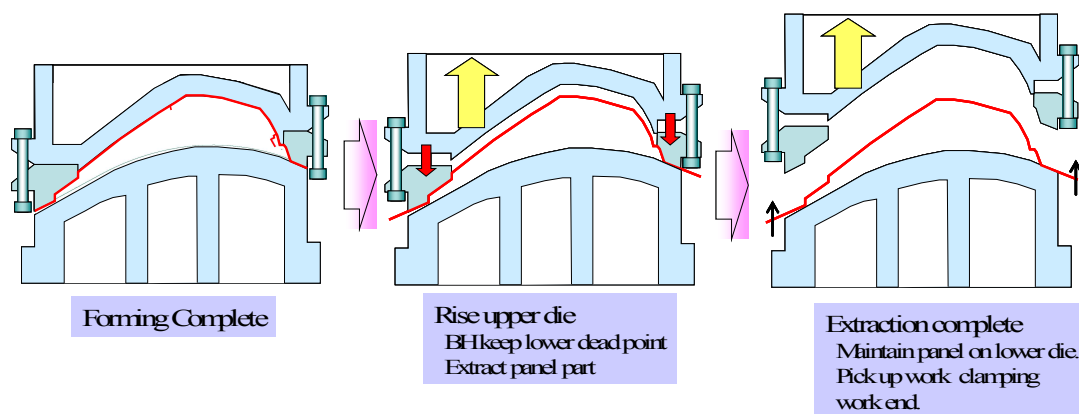


Figure 6: Die Structure and Formed-Panel Extraction

7 MATERIAL

On selecting the material, mechanical properties after high cycle blow forming must be taken into account since it determines the property of the product. For cost reduction, application of 5182 and 5xxx were expected for inner and outer panel respectively, where heat treatment conventionally conducted for outer panel was expected to be discarded. Mechanical properties with high cycle blow forming were evaluated on the specification of the material property. While 5xxx satisfied properties needed for inner and outer panel, property of 5182 failed as it showed grain growth with the condition of initial forming pressure and additional alloy element **(Figure 7)**. Then in order to suppress the grain growth, additional element and forming pressure are controlled. As a result, mechanical property of the material has been satisfied and the forming condition satisfying cycle time has been found. [2]

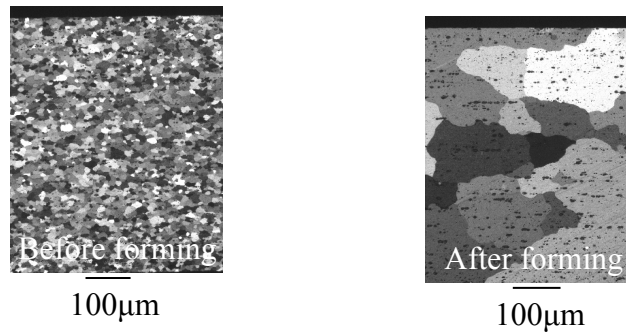


Figure 7: Optical microstructures of 5182 before and after the conventional blow forming, showing grain growth

8 EQUIPMENT

8.1 RAPID BLANK HEATING

Conventionally the sheet used to be heated within the die up to the forming temperature. Since heat is transmitted by air, productivity was low. In the new process, the sheet is heated by sandwiching it with the heated steel plates. Heating efficiency increased up to 10 times more than the conventional process because of this conducting heating without intermit by air.

8.2 HIGH CYCLE BLOW FORMING SYSTEM

This blow forming technology has been installed into a production line of closure panels which has been newly set up in Sayama factory. This production line is made up with blow forming machine, preheat equipment, transfer robot, panel-cooling stage, lubricant applying equipment and panel feeding and piling stage. Blow forming machine is equipped with 13500[kN] hydraulic press and it has a pair of heater unites above and below into which dies are set. Compressed air is sent into the dies from compressor through pipes out of furnace. Also this forming machine can accommodate 2 sets of dies in parallel enabling to produce one couple of forming in one cycle, where one couple of equipments are accommodated in symmetrical position from preheat machine to robot. Pairs of trunk skin and frame, and right and left fender are produced alternatively in mass production. It follows the procedure; lubricant applied panels are set onto the feeding stage and transferred by robot into preheat equipment, where the panels are heated above 500[] in short time. When heating is finished, the panels are transferred into forming machine and dies are pressed simultaneously with its closure and forming process starts with compressed gas blowing. After finishing the forming, the panel is extracted from the dies simultaneously with its opening and picked up by robot onto the panel-cooling stage, where the panel is cooled in the air. Then the panel is transferred to the piling stage and forcibly cooled down.

9 CONCLUSION

Weight reduction achieved by the introduction of blow forming is shown in **Figure 8**. High design performance and weight reduction of 6[kg] in 4 parts were achieved in comparison to conventional steel parts. Also die costs are reduced by integration of multiple parts. In addition, cycle time is shortened up to 6 times with the high cycle process and productivity was increased up to 12 times with multiple forming in one

processing cycle, which reduced processing costs dramatically so as to achieve the cost target. In addition, removal of surface oxide of formed panel has been discarded with shortened heating cycle that was necessary with the conventional blow forming process. It has been almost 17 years since blow forming technology was studied in Honda. During this period equipment, die and materials found each evolution and the productivity increased up to 30 times. High cycle blow forming technology developed in this study is positioned as one of the most rapid process achieved in the world. But for the more global expansion of this technology there are still several problems in respect to materials supply and production capacity. On the other hand, high cost of aluminum eliminates its application, whereas weight reduction is the global needs. For further development of this technology, technology enabling higher productivity, higher energy efficiency and lower investment will be searched.

Parts		Front Fender R/L	Trunk Lid Skin	Trunk Lid Frame	
Contents	Material (blank)	5x x x -H18	5x x x -H18	5182-H18	
	Mechanical property of after forming	Ts	>275MPa	>275MPa	>200MPa
		Ys	>125MPa	>125MPa	>80MPa
		EL	>16%	>16%	>12%
Amount of weight reduction		-2.6kg	-3.6kg		
Characteristic		<ul style="list-style-type: none"> ●High design performance ●Weight reduction 	<ul style="list-style-type: none"> ●High design performance ●Weight reduction ●Parts unification 	<ul style="list-style-type: none"> ●Highly rigid ●Weight reduction ●Parts unification 	

Figure 8: Weight reduction achieved by the introduction of blow forming

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