RESEARCH INTO THE APPLICATION OF ALUMINUM DOOR BEAMS FOR AUTOMOBILES

Hiroyuki YAMASHITA *, Masakazu HIRANO*

*Extrusion Research Section, Aluminum & Copper Division, Chofu Plant, Kobe Steel, Ltd.

14-1 Chofu Minato-machi, Shimonoseki-city, YAMAGUCHI, 752-0953 JAPAN

ABSTRACT The effect of cross-section and type of alloy on the performance of aluminum extrusions as door beams was investigated. As a result, aluminum door beams were developed which have bending properties comparing favorably with those of door beams made of high tensile strength steel with a tensile strength of 1470 N/mm^2. Furthermore, a technology to design door beams with the required performance and bending properties dealing with various car models was developed by making the most of the versatility of aluminum extrusions produced in various types of cross-sections.

Keywords: *aluminum , extrusion ,door beam ,cross-section ,design*

1. INTRODUCTION

The door beam, a small-sized part for attachment in a limited space inside the door, is required to have an ability of energy absorption to soften the shock of collision, and to prevent the door from being largely deformed. In the FMVSS are specified the maximum strength and absorbed energy, obtained when a semicircular cylinder is slowly forced into the door of a fixed car. In the standard laboratory test, these properties are evaluated by three-point bending of a beam simply supported at its both ends as shown in Fig. 1.

The door beam is required to have high rigidity and strength in spite of its limited dimensions. Therefore an aluminum extrusion, the cross-section of which can be variously changed, may be most suitable for it. The object of this investigation was to develop door beams made of aluminum extrusions showing the same bending strength and energy absorption in three-point bending test as door beams made of high tensile strength steel sheet .

2. DEVELOPMENT OF A NEW ALLOY

To save weight as well as to ensure bending strength, it is essential to use high strength alloys. However, high strength materials are generally difficult to be extruded. This restricts the versatility of cross-section, a special feature of extrusions. On the other hand, it is known that a beam with a hollow, closed section has higher rigidity. Therefore, an alloy is required that can be extruded into hollow sections in spite of its high strength. Table 1 shows the mechanical properties of typical 7000 series alloys and whether they can be hollow-extruded or not.

In order to develop aluminum door beams with the same performance as that of the door beam made of high-strength steel pipe with an outer diameter of 31.8 mm and a wall thickness of 2 mm, the relationship between maximum bending strength and strength of material was studied. Fig.2 shows the relationship between tensile strength and maximum bending strength. The aluminum extrusions had the same outer diameter and weight as those of the high strength steel pipe door beam. Fig.3 shows the cross-section of aluminum extrusions and the high-strength steel pipe. The results of Fig.2 show that aluminum alloys with tensile strength not less than 400 N/mm^2 are required to achieve weight savings as well as to have the same bending strength as that of the high-strength steel pipe. A study to develop an alloy that combines strength with extrudability shown in Table 1 has led to the development of a high strength alloy, Z6W.

3. DESIGN OF CROSS-SECTION

The comparison between the material strengths shown in Table 1 indicates that even high strength aluminum alloys have only approximately half the yield strength and approximately one third of the tensile strength of the high strength steel. Therefore, it is essential to invent an optimum cross-section that makes the aluminum extrusion compare favorably with the high strength steel pipe. Generally, hollow box sections have high rigidity, thereby leading to the selection of the box section as a basic cross-section.

The factors to be investigated in the box section are the following :

- Wall thickness of the flange and web.
- Position of the web.
- Corner radius.

These are shown in Fig.4. The effects of these factors upon the performance of the aluminum extrusion were investigated.

3.1 Wall thickness of the flange and web

Effective apportioning of wall thickness in the cross-section is necessary to ensure required bending strength of the aluminum extrusion with limited weight. According to the theory of bending, bending strength is proportional to material strength times section modulus. So it is preferable to apportion the wall thickness in such a way that the section modulus becomes larger.

Fig.5 shows the cross-section that was used for FEM analysis. Using the box section with a constant height H=32 mm, the change of maximum bending strength with the change of flange thickness t_f, web thickness t_w and flange width L was calculated, and the conditions to obtain the maximum bending strength equivalent to that of high strength steel were researched.

Fig.6 shows the relationship between weight saving and the shape parameters based on the FEM analysis, which furnished a guide to determine the wall thickness and width of box section.

3.2 Position of the web

Section modulus is not dependent upon the position of the web according to the calculation of strength of materials. That is, the maximum bending strength by calculation is constant irrespective of the change in the web position. Therefore, the optimum web position was investigated by three-point bending test using the five kinds of cross-sections shown in Fig.7. Fig.8 shows the relationship between web position and maximum bending strength, showing that maximum bending strength obtained by experiment varies with the change of web position even when section moduli are the same.

3.3 Corner radius

Thinning of the wall and widening of the width to obtain a larger section modulus tends to give rise to buckling. Since the corner takes the position of the junction of the flange and web, it is supposed to have an effect to prevent buckling of the flange and web. Table 2 shows the maximum bending strength and the energy absorption of (a) the basic cross-section shown in Fig.9, (b) the cross-section with different corner radius, and (c) that with different t_w.

The results indicate the following :

- With an increase in corner radius, the maximum bending strength increases by only 4 % corresponding to the weight increase, while on the other hand, the energy absorption increases by 29 %.
- In addition, the energy absorption increases further by 44 % with a small increase in the web thickness.
- That is, the corner radius has the effect of improving energy absorption by preventing buckling in the course of deformation after maximum load rather than the effect of improving maximum bending strength. Furthermore, the effect of corner radius is influenced by the web thickness to be combined with which it is associated.

4. DOOR BEAMS MADE OF ALUMINUM EXTRUSIONS

Based on the results obtained hitherto, the cross section shown in Fig.10 was designed. The bending properties by three-point bending shown in Fig.1 of the aluminum door beam was compared with those of the high strength steel door beam. Fig.11 shows the bending strength-displacement curves. Table 3 shows the maximum bending strength, energy absorption, and weight of each door beam.

As the result, an aluminum door beam was successfully developed that had a maximum bending strength equivalent to that of the high strength steel door beam and made it possible to save weight by 22 %. Furthermore, weight savings of about 50 % were achieved for some car models.

The cross-section of the door beam may vary depending upon the car model. The versatility of the cross-section of the aluminum extrusion makes possible designs corresponding to various car models. In Fig.12, in which the abscissa is the length of door and the ordinate is the width of door, the door beams developed are marked with dots. This map represents, in a sense, a menu for door beams available now for various car models. We will be able to supply door beams for any car model by distributing the dots over the whole of this map.

5. SUMMARY AND CONCLUSIONS

1. Application of aluminum to door beams was investigated and aluminum door beams were successfully developed which achieved 22 to 50 % weight saving as compared with the high strength steel door beam by the development of a new high strength aluminum alloy and designing technology of cross-section.
2. Based on the technology mentioned above, a development for various door beams available now was prepared by making the most of the versatility of cross-section of aluminum extrusions. We would be able to supply door beams for any car model yet to be developed.

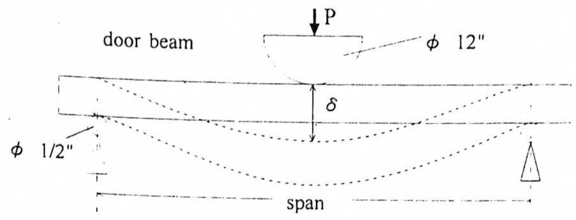
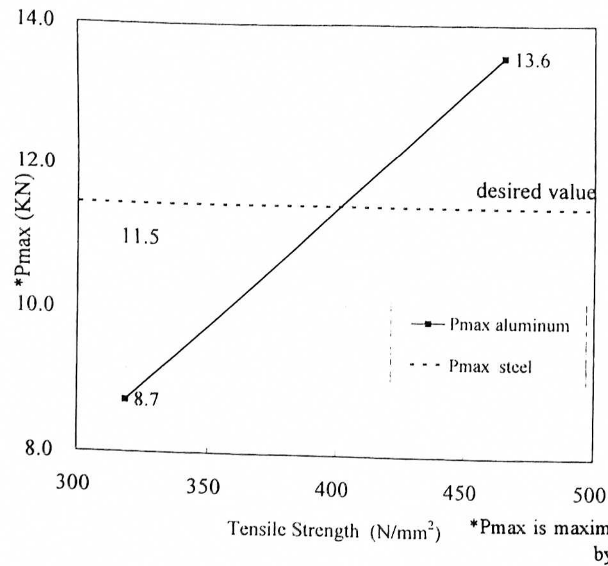


Fig.1 Three-point bending test

Table 1 typical mechanical properties and possibility of hollow extrusion

ALLOY	T.S.	Y.S.	EL.	Extrudability
	N/mm²		%	
7075-T6	529	461	14	poor
JIS7N01-T6	363	294	15	excellent
Z6W-T5	480	420	14	excellent
1470N steel	1529	1029	10	-



*Pmax is maximum bending strength by three-point bending.

Fig.2 Relation of tensile strength and maximum bending strength

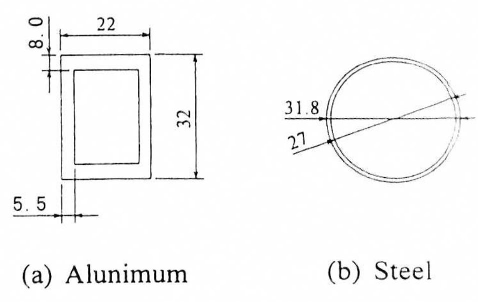


Fig.3 Cross-section of door beam for Fig.2

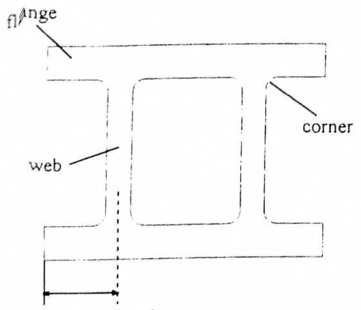


Fig 4 The parameter with box section

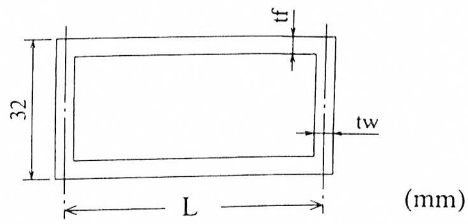
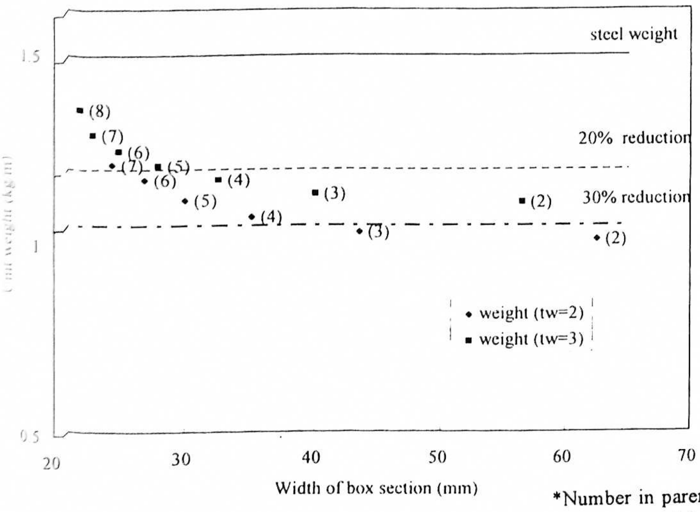


Fig.5 Cross-section for FEM analysis



*Number in parenthesis is thickness of tf.

Fig.6 FEM analysis of box section

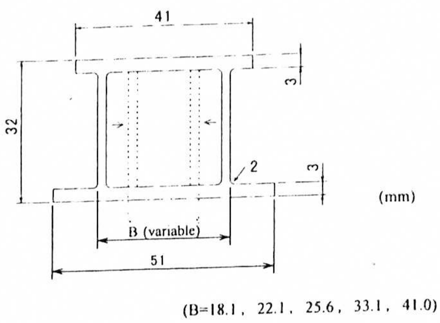


Fig.7 Cross-section which B varied

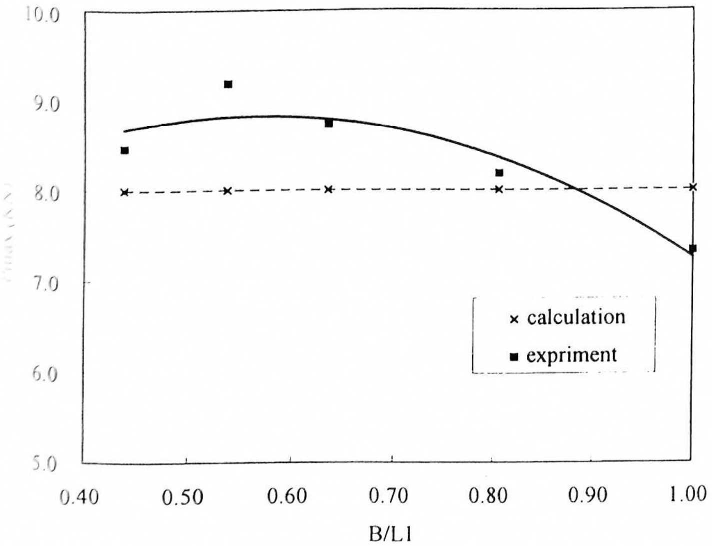
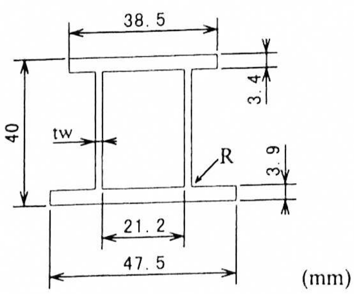


Fig.8 Relation with web position and maximum bending strength



(a):Basic (tw=1.9, R=1)

(b):With different corner radius (tw=1.9, R=4)

(c):With different tw (tw=2.2, R=4)

Fig.9 Cross-section to investigate the corner

Table2 bending properties of door beam on Fig.9

	weight	maximum strength	energy absorption
basic section (a)	1.00	1.00	1.00
modification of corner (b)	1.05	1.04	1.29
addition web thickness (c)	1.09	1.07	1.73

(Ratio for basic section)

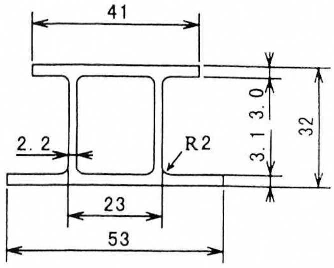


Fig. 10 The final cross-section of aluminum door beam

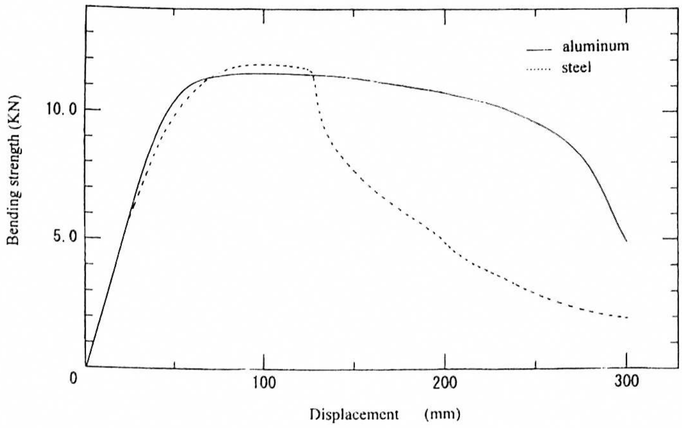


Fig.11 Bending strength of steel and aluminum door beam

Table 3 bending properties of steel and aluminum door beam

	maximum strength (kN)	energy absorption (J) 0 ~ 6"	energy absorption (J) 0 ~ 12"	unit weight (kg/m)
1470N steel	11.8 (1.00)	1359 (1.00)	1980 (1.00)	1.48 (1.00)
aluminum	11.5 (0.97)	1446 (1.06)	2933 (1.48)	1.16 (0.78)

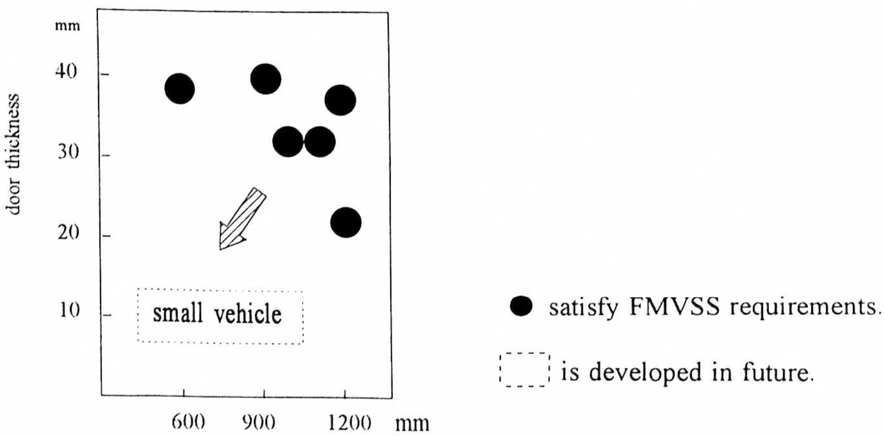


Fig. 12 The development of aluminum door beams