PROPERTIES OF HOLLOW EXTRUSION OF HIGH STRENGTH AL-MG-SI-CU ALLOY FOR AIRCRAFT

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ABSTRACT A newly developed Al-Mg-Si-Cu alloy has almost the same strength as 2024-T3, and also has the good formability and corrosion resistance of the 6000 series alloys. It was confirmed in production that 2024 could not be extruded, but the new alloy could be extruded into a hollow section. The new alloy-T6511 had a tensile strength of 398-426MPa and a yield strength of 364-396MPa which satisfied the 2024-T3511 standard in MIL-HDBK-5. Corrosion resistance of the new alloy-T6511 was superior to that of 2024-T3511. When an airplane's pressure deck beam consisting of an assembly structure using rolled sheets and solid extrusions was compared to an integrated structure of the extruded section, a 29% cost saving was estimated.

Keywords: *High strength, High corrosion resistance, Al-Mg-Si-Cu alloy, Airplane's pressure deck beam and Hollow extrusion*

1. INTRODUCTION

Alloy 2024-T3 has been used for many aerospace applications, but it has some problems with corrosion resistance and extrudability. A new Al-Mg-Si-Cu alloy has been developed, and it exhibits a tensile strength equivalent to 2024-T3 and greater than 6013-T6, along with an intergranular corrosion resistance similar to 6061-T6. Resistance to fatigue crack growth of this new alloy was the same as that of 2024-T3, and the new alloy exhibited high temperature properties similar to 2024-T8. This new alloy is expected to be a candidate material for aircraft structures. Also, the formability of the new alloy-T4 was the same as that of 6013-T4 and better than that of 2024-T3[1].

This new alloy is expected to have better extrudability than 2024. Fig. 1 shows the extrusion limit diagram obtained under laboratory conditions. The extrusion limit was determined by surface cracking and the pressure of the extrusion press. The new alloy covers a much wider extrusion limit than 2024, and it can also be extruded into hollow section in production while 2024 cannot be extruded[2].

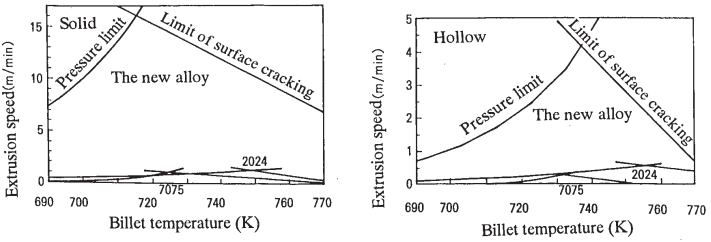


Fig.1 The extrusion limit diagram

2. EXPERIMENTAL PROCEDURE

2.1 Application of the new alloy to aircraft structure

The new alloy was extruded into a complex cross section of an aircraft structure using production equipment, and then its extrudability and properties were estimated[3].

The pressure deck beam was selected as the trial aircraft structure product. Fig.2 shows the beam, which consists of an assembly structure using rolled sheets of 2024-T3 and solid extrusions of 7075-T6511 and 2024-T3511. When the new alloy is applied to the beam, the beam can be an integrated extruded section because of its high extrudability. Consequently, the cost of assembly is expected to decrease because the number of fastners can be reduced. Also, the beam is in a highly corrosive circumstance, accordingly, its life can increase because of its high corrosion resistance.

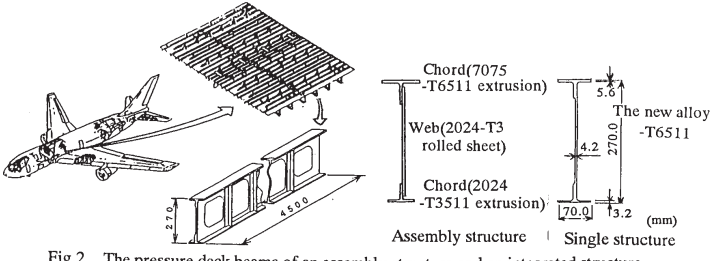


Fig.2 The pressure deck beams of an assembly structure and an integrated structure

2.2 Trial production

The trial production was done using production facilities for all the processes. The billets were cast to 328mm in diameter, and homogenized. The chemical composition is shown in Table 1. The billet was extruded for the beam at a 44 extrusion ratio with a solid die. Also, in order to estimate the tensile properties of the welded seam, the billet was extruded to a triple hollow cross section at a 45

extrusion ratio with a port hole die. The temperature was set at 753K in the solid and at 738K in the hollow. The extrusion speed was set at 3m/min. Both conditions are greater than the extrusion limit of 2024, so 2024 cannot be extruded under both conditions. The extrusions of the new alloy were solution heat treated at 818K, quenched in a polymer, stretched and aged at 463K in 8h.

Table1 The chemical composition of the new alloy (mass%)

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
0.76	0.14	1.65	0.01	0.96	0.16	0.01	0.01	Bal.

2.3 Evaluation of extrusion properties

The tensile test was performed on the extrusions according to ASTM B557. After the extrusions of the new alloy-T6511 and 2024-T3511 were machined to half thickness and the exfoliation corrosion test(MASTMAASIS test) was performed according to ASTM G85 Annex A2. The conventional beam was made by assembling rolled sheets of 2024-T3 and solid extrusions of 7075-T6511 and 2024-T3511, and the new beam was made by a integrated extrusion of the new alloy. The strength of the two types of beam was evaluated using the four-point bending test as shown in Fig.3. Also, the cost saving of the beam by application of the new alloy was estimated.

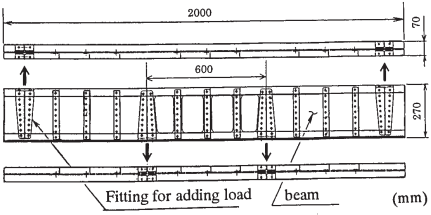


Fig.3 The four-point bending test of the beams

3. RESULTS AND DISCUSSION

3.1 Extrusion

The extrusion for the beam is wide and thin in cross section as shown in Fig.2, and its size is over the limit depending on the extrusion press. Therefore, it was extruded by expanding flow guide. Since the thicknesses of the sides are different, it is diffcult to get the desirable shape because of unequal metal speed of both sides during the extrusion. The desirable shape of the beam shown in Fig.4 was extruded by adjusting the flow guide shape. The extrusion pressure was 404MPa, which was much lower than the capacity of the extrusion press in this condition, therefore, it was expected that the speed could be set higher than 3m/min. The sizes of the extrusion for the beam were within the tolerance of ANSI H35.2.

There was no surface cracking in the triple hollow extrusion shown in Fig.5. The weld seams

were not clear in the metallographic cross-section shown in Fig.6. Therefore, it was considered that the metals in the weld seam were joined tightly together.

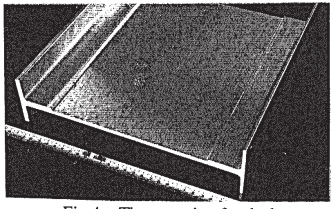


Fig.4 The extrusion for the beam

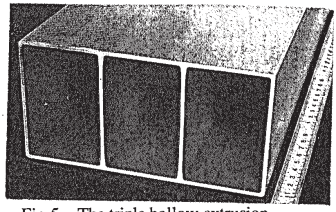
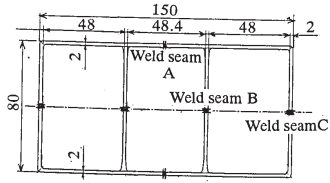


Fig.5 The triple hollow extrusion



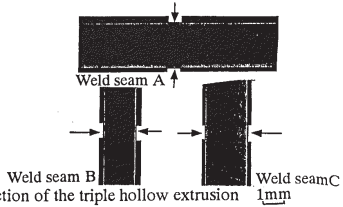


Fig.6 The metallographic cross-section of the triple hollow extrusion

3.2 Properties of extrusions

The tensile properties of the extrusion for the beam must not be less than the standards of 2024-T3511. Fig.7 shows the tensile properties of the extrusion for the beam. The tensile strength was ranging from 398 to 426MPa and the yield strength was ranging from 364 to 396MPa. Their properties were higher than the standards of 2024-T3511, and its yield strength was much higher than the 2024-T3511 standard. Fig.8 shows the tensile properties of the triple hollow extrusion. In the triple hollow extrusion, the tensile properties of the weld seam were equal to those of the solid parts, so it was considered that the metals in the weld seam were jointed tightly together.

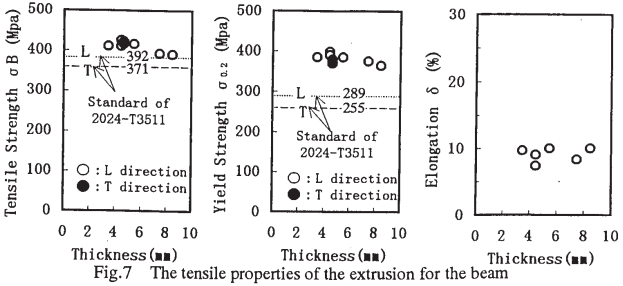


Fig.7 The tensile properties of the extrusion for the beam

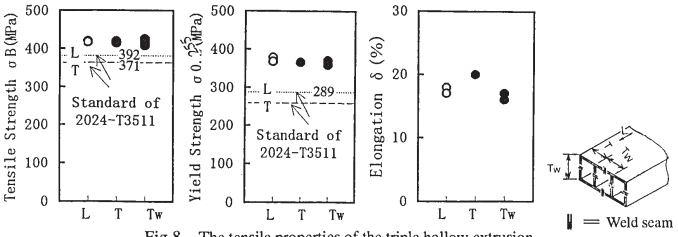


Fig.8 The tensile properties of the triple hollow extrusion

Fig.9 shows the results of the exfoliation corrosion test. On the surfaces of the new alloy, heavy pitting was observed after 168h and superficial exfoliation was observed after 336h. However, on the surface of 2024-T3511, very severe exfoliation was observed after 336h. It was confirmed that the new alloy-T6511 had a much better corrosion resistance than 2024-T3511.

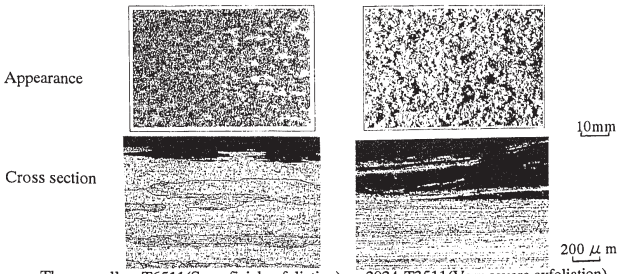


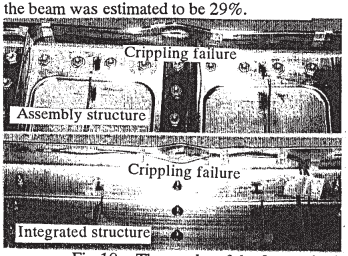
Fig.9 The results of the exfoliation corrosion test (after 336h)

Fig.10 shows the results of the four-point bending test of the beams. For both of the assembly structure and the integrated structure, crippling failure occurred in the flange of the compression side. The loads were almost the same, so the strength of the integrated structure beam was estimated to be equal to that of the assembly structure beam.

3.3 Cost estimation

Fig.11 shows a cost comparison of the beams. The cost of assembling largely decreased because the number of fastners could be reduced using an integrated structure. Also, the material cost decreased because the new alloy had better extrudabiliy than 2024 and 7075. Consequently, the cost

saving of the beam was estimated to be 29%.



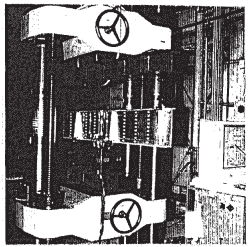


Fig.10 The results of the four-point bending test of the beam

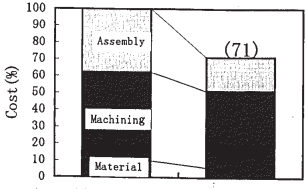


Fig.11 The cost comparison of the beams

4. SUMMARY

(1)A pressure deck beam was selected as the application of the new alloy. The beam can be changed from an assembly structure to an integrated structure using the new alloy extrusion. It was also confirmed that in production, the new alloy was extruded into the triple hollow section while 2024 could not be extruded.

(2)Tensile properties of the new alloy-T6511 extrusion were higher than the standards of 2024-T3511. The tensile properties of the weld seam were as equal to those of the solid parts in the triple hollow extrusion.

(3)The new alloy-T6511 had better corrosion resistance than 2024-T3511.

(4)The strength of the assembly structure beam was equal to that of the integrated structure beam.

(5)The cost saving of the beam was estimated to be 29% by using the new alloy extrusion.

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