STUDY ON Al-Li 8090 EXTRUDATES—THEIR MECHANICAL PROPERTIES AND CORROSION PROPERTIES

Z. Lu, J. Qiang, Y. W. Li, Y. L. Wu
Institute of Aeronautical Materials, Beijng, P. R. China

Abstract

The mechanical and corrosion properties of differently shaped 8090 extrusions were investigated. Strength and fatigue properties have been shown to be higher than those of 2024, LY16 and LY12 alloys, but the ductility is much lower compared with 2024-T3 and Ly12CZ. The exfloliation corrosion resistance for 8090 extrusions have been found to be a little lower than traditional alloys and the SCC properties higher than those of Ly16 and Ly12. In general, the properties for 8090 ectrusions can meet the requirments of applications. It can be said that in the near future, 8090 entrusions will be used in aircrafts for structural manufacture.
Key Words: Al-Li 8090 Extrudates, Mechanical Properties, Corrosion Properties.

1. Introduction

The aerospace industry has considerable interest in Al-Li alloys because of their potential to reduce structural weight owing to their higher modulu and lower density compared with traditional alloys[1]. Based on the detailed cost analyse for stringers, outer skin and window frames made by Airbus Company, the thin-walled products have been shown within the net gain range of additional costs associated with weight saving[2]. Therefore, thin-walled extrusions have been thought to be able to replace parts of the traditional aluminium alloys for stringer making because of their low fly-to-buy ratio. It is necessary to study the properties of Al-Li extrudates, so that some data can be gained for the design and manufacture of products.

2. Material and Treatment

The materials used in this study were supplied by Beijing Institute of Aeronautical Materials. The ingots were manufactured using semi-continuous casting technique. After homogenization, the surfaces of the ingots were removed and then extruded. Some kinds of semi-finished products were gained as shown in Fig1. The extrudates were solution treated, water quenched, 2~3% pre-stretched and then artificially aged at 190℃ for 16 hours. The micophotogragh shows that the grain structure of these extrusions is mainly unrecrystallized, as shows in Fig2. The alloy composision is listed in Table 1.

Table 1 Alloy Composition

Li	Cu	Mg	Zr	Ti	Fe	Si	Al
2.40~2.53	1.14~1.18	0.82~0.86	0.08~0.12	<0.05	<0.05	<0.05	bal.

3. Mechanical Properties

Table 2 Tensile properties of extrudates

Alloy	Extrusion	Direction	σ_b(MPa) min.~max. / ave.	$\sigma_{0.2}$(MPa) min.~max. / ave.	δ_5(%) min.~max. / ave.
8090	11×55 mm Extruded bar	L	549~579 / 568	495~541 / 518	4.7~9.4 / 7.0
		LT	511~528 / 521	446~472 / 456	5.6~9.5 / 7.6
8090	Extrudate XC111—48	L	491~543 / 515	429~457 / 439	5.1~6.2 / 5.7
8090	Extrudate XC111—4	L	507~531 / 525	431~448 / 439	5.0~6.3 / 5.7
2024—T3510	Extruded bar	L	494~501 / 497	388~394 / 390	14.2~16.0 / 14.8
2024—T8510	Extruded bar	L	491~493 / 492	441~447 / 444	6.4~9.2 / 7.2
Ly12CZ	Thin-walled extrudates	L	467~506 / 478	363~383 / 370	16.2~17.6 / 16.9
Ly12CS	Thin-walled extrudates	L	475~478 / 476	411~415 / 413	6.8~7.0 / 6.9

Tensile properties of these extrudates are listed in Table 2, compared with those of Ly12 and 2024 alloys.

The ultimate strength for 8090 is higher than that of alloy 2024 and Ly12, the yeild strength is equivalent to that of 2024-T8510 and Ly12CS, but the elongation is much lower than that of 2024-T3510 and Ly12CZ. It has been suggested that the low ductility is caused by the co-planar slip associated with shearing of the coherent δ' particles which result in strain location on grain boundary and the PFZs[3], so that the low ductility must be considered in the applications of this alloy. The fracture surface of 8090 tensile specimen shows a mixed mode of transgranular and intergranular fracture, as shown in Fig. 3.

Compressive properties were tested on the ϕ25mm exruded rod, the size of the test specimen is $\phi 15 \times 15$mm. The results are compared with those for 2024-T3510 and 2024-T8510, as shown in table 3.

Table 3 Compressive properties of 8090, 2024 alloys

Properties \ Alloy and Temper	8090	2024—T3510	2024—T8510
Ec(GPa) min. ～max. / ave.	75～77 / 76	74～75 / 74.5	75～76 / 75.2
$\sigma_{-0.2}$(MPa) min. ～max. / ave.	554～561 / 557	321～335 / 330	415～417 / 438

As can be seen in Table 3, the compressive modulu is higher than that of 2024 alloy, but the difference between these two modulus is less than those gained by tensile tests. The compressive yeild strength of 8090 is about 20% higher than that of 2024-T8510 and 40% higher than that of 2024-T3510.

The results of constant-amplitued fatigue crack growth tests on 11×55mm extruded bar in T-L and L-T direction are shown in Fig. 4 The data shown in these figures were deternined at a R-ratio of 0. 1, cyclic-load freguency of 10HZ, the data are compared with the corresponding data for 2024-T3510 and 2024-T8510. The fatigue creep-growth rate for the 8090 alloy is slower than 2024-T3510 and 2024-T8510.

The results of smooth axial-stress fatigue tests on ϕ25mm extruded rod and the results of notch axial-stress fatigure tests (Kt=3) on extrudate XC111-48 are shown in Fig5. All data in this figure were determind at a R-ratio 0. 1, cyclic-load freqrency of 120HZ and in the L direction. The data in this figure are compared with the data corresponding for 2024-T8510 and Ly12CS. It has been found that the fatigue strength for 8090 is higher than that of 2024-T8510 and Ly12CS.

4. Corrosion Behaviour

Tests of interguanular corrosion properties were performed on extrudate XC111-11. These tests were carried out on unmachined surfaces of the extrudates. The results are compared with those for LY12 alloy, as shown in Table 4.

Table 4 Intergranular corrosion test results

Alloy	Temper	Corr. Depth(mm)	Attack
8090	Artificially aged	0. 23	Intergranular
Ly12CZ	Naturally aged	—	Pitting
Ly12CS	Artificially aged	0. 25	Intergranular

Exfloliation tests were carried out on both machined and original surfaces, the results are shown in Table 5.

Table 5 Exco test results of 8090

Specimen	Original surface	T/10 Machined surface	T/2 Machined surface
Extrudate XC111-48	EB	EC	EC
11×15mm Extruded bar	EA	EB	

As has been shown in Table 5 the and exfloliation corrosion resistance is a little lower than that of traditional alloys. Maybe this is the nature of this alloy. By the way, 8090 alloy must be well protected to prevent surface attack.

The stress corrosion cracking resistance of the extrudates were determined by tensile tests (in L direction) using a 3.5% NaCl solution under constant load, the data of the tests are compared with the corresponding data for Ly12CS and Ly16CS respectively, as shown in Table 6.

Table 6 SCC test results of 8090, Ly12, Ly16

Alloy	Aging temper	Stress (MPa)	Time to failure (hour) min. ~max. / ave.
8090	190℃/16h	338.1	158~380 / 234
		289.8	196~367 / 280
		241.5	356~910 / 612
Ly16	165℃/16h	218	2~22 / 7
	190℃/18h	218	23~123 / 61
	210℃/12h	218	43~168 / 74
	210℃/12h	196	147~218 / 159
	190℃/36h	196	136~341 / 167
Ly12	190℃/6h	347	140~238 / 167
	190℃/8h	347	72~186 / 140
	190℃/12h	282	170~339 / 260
	190℃/12h	347	188~235 / 201

The SCC resistance for 8090 is obviously higher than that of Ly16CS and Ly12CS.

5. Conclusion

The lower density of 8090 compared with traditional alloy 2024, Ly12 and Ly16 provides a potential for weight saving in aerospace applications. The machanical properties have been found to be able to meet the requirments for structure manufacturing. The ductility for 8090 is lower than traditonal alloys, but in some cases, low ductility is not a problem in applications. The exfloliation resistant property for 8090 is a little lower than that of traditional alloys, but in most cases this disadvantage can be compensated by finishing techniques.

In general, it can be said that the 8090 extrudates can be used in aircrafts in the near future for its good properties and relatively low costs compared with other Al-Li semi-finished products.

References

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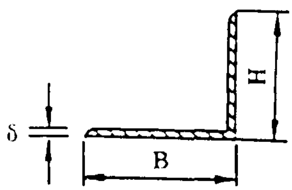

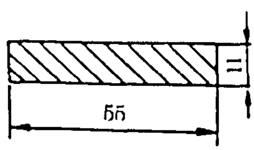

Extrudate	H=B	δ
XC111-48	38	3
XC111-4	15	1
XC111-11	18	1.5

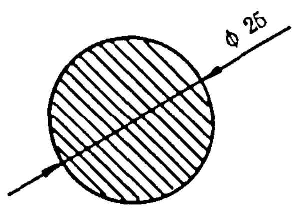

Fig. 1 The sizes and shapes of the extrudates used in this study (Unit: mm)

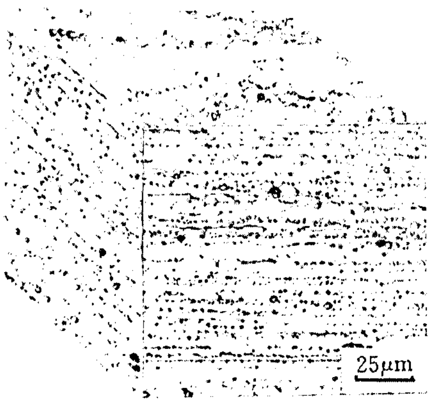

Fig. 2 Optial micrograph of the extrudates

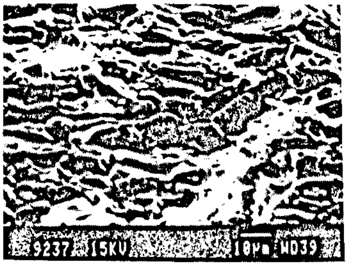

Fig. 3 Scanning electron micrograph of the fracture surface

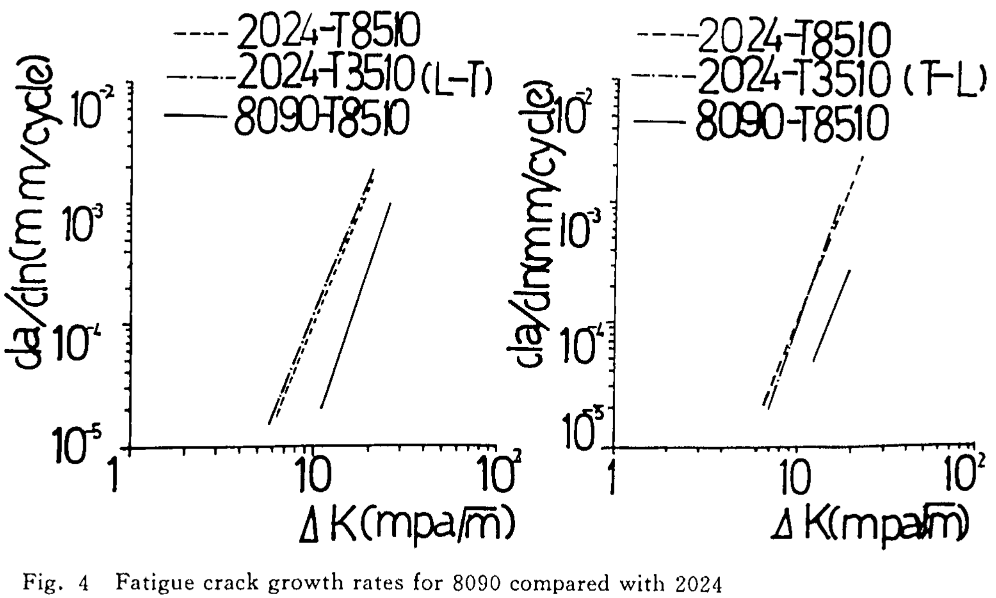

Fig. 4 Fatigue crack growth rates for 8090 compared with 2024

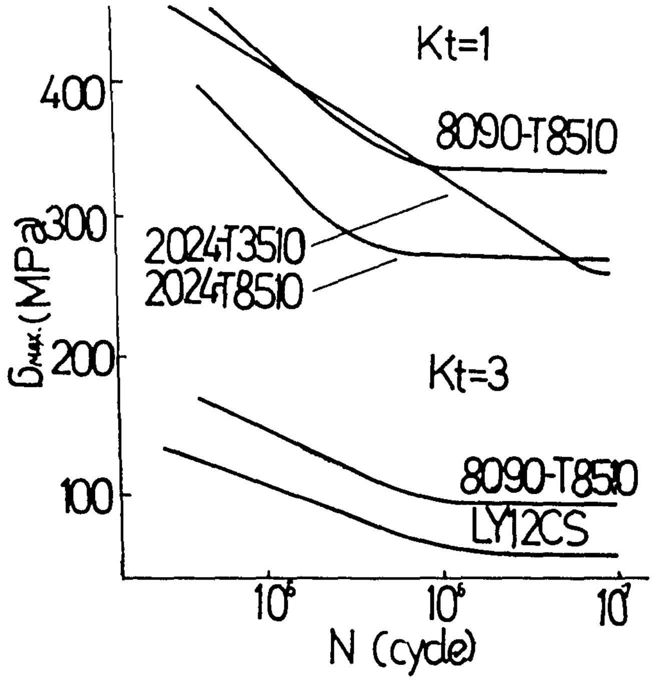

Fig. 5 Stress fatigue data for 8090 compared with 2024 and LY12