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RESISTANCE SPOT WELDABILITY AND TIG WELDABILITY OF Al-Li-Mg ALLOYS

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Abstract

The joining, such as the welding, is indispensable for using aluminum alloys as structural materials. It has been investigated the weldability of Al-2.7mass%Li-2.0mass%Mg alloy extrusions with 4mm in thickness.
The resistance spot welding was conducted by using the rectifier type triple phase spot welding machine. Because the electric conductivity of these Al-Li-Mg alloys was low, the welding current was 70% of the conventional alloy 6005. The tensile shear load value of the spot welded joint of these alloys was higher than that of the 6005 alloy in the same size of a welding nugget. The TIG welding was carried out by using the AC TIG welding machine, flowing the back-shield Ar gas to prevent occurence of a blow hole. The ultimate tensile strength of welded joint was over 280N/mm^2, between that of the 6005 alloy and that of the 7005 alloy. The characteristics of weld cracking evaluated by the fish-bone type weld cracking test was fine, and nearly equal to that of the 6005 alloy.

Introduction

Al-Li alloys are promising structural materials for transport applications which require weight-saving with increased stiffness. The welding has been employed for assembly joining process in transport manufacturing. So, for practical applications, it is important to improve the properties of welding. There are many reports about the arc weldability of Al-Li alloys [1]. Recently, the resistance spot welding, which enables to join in a high efficiency, in a lower cost and in a small strain, is attracting much attention. However, there is scarcely a report about the spot welding [2]. In the present study, the resistance spot weldability and TIG weldability of Al-Li-Mg alloys were investigated in comparison with conventional aluminum alloys.

Experimental procedure

Specimens

Table I Chemical compositions of specimens (mass%)

	Li	Mg	Cu	Zr
No.1	2.69	2.02	0.02	0.13
No.2	2.71	2.02	0.50	0.13

The materials tested were two kind of Al-Li-Mg alloy extrusions, containing 2.7mass%Li and 2.0mass%Mg. Table I shows the chemical compositions of the alloys.

First, the alloys were melted in an Ar gas atmosphere furnace and cast into 228mm diameter DC billets. Next, the billets were homogenized at 723K for 86.4ks and at 813K for 21.6ks, and extruded to 4mm thickness and 130mm width, and press-quenched into cold water. Finally, they were aged at 433K for 86.4ks, to T5 temper.

Table II shows the tensile properties and the electric conductivity of the specimens. In this study, the 6005-T5 alloy, the 7005-T5 alloy and the 5083-O alloy were also investigated in comparison with these Al-Li-Mg alloys.

Table II Tensile properties and electric conductivity of specimens

Alloy	Tensile strength (N/mm^2)	Yield strength (N/mm^2)	Elongation (%)	Electric conductivity (IACS%)
No.1	474	372	4.1	19.7
No.2	515	420	4.5	18.8
6005	266	234	14.7	49.8
7005	440	383	16.3	32.3
5083	290	147	22.0	28.7

Resistance spot welding

Resistance spot welding was carried out in conformity to the controlled pressure method by using the rectifier type triple phase spot welding machine. The specimens were prepared 2.5mm thickness by scalping off. So, a 2.5mm thickness test piece and a 4.0mm thickness test piece were combined, and welded. The electrode tip was a Cu-Cr alloy. The tip of the upper side was 20mm in diameter with radius shape, and that of the lower side was 20mm in diameter with flat shape. The schematic diagram of the welding condition in this controlled pressure method is illustrated in Figure 1. The first welding force was 11.8GPa, and the second welding force was 17.6GPa. The first welding time was 100ms, and the second welding time was 160ms. The first welding current value was varied from 41kA to 47kA.

From the results of preliminary tension shear tests for spot welded joints and forming of nuggets, the optimum welding current value was selected for the tension tests and the fatigue tests. The static strength of spot welded joint was evaluated by the tension shear test. The dynamic strength

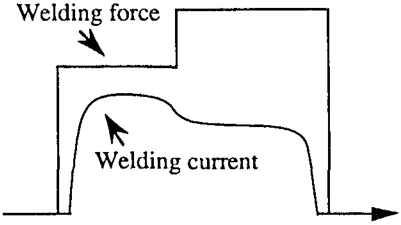


Figure 1 Schematic diagram of the controlled pressure method.

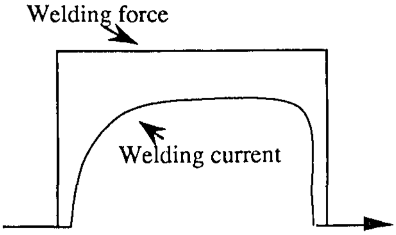


Figure 2 Schematic diagram of the constant low pressure method.

of spot welded joint was evaluated by the fatigue test.

The continuous spot weldability, the effect of the space of the spot welding on the diameter of the nugget, was also investigated. The spot welding was conducted in conformity to the constant low pressure method. The schematic diagram of the welding condition is illustrated in Figure 2. The welding force was 11.8GPa. The welding current value was 26kA for the No.2 alloy and 27.5kA for the 5083 alloy, and the welding time was 133ms. The space of the continuous spot welding was varied from 20mm to 50mm, every 10mm. After spot welding, the upper test piece was teared off by the peel test instrument and the diameter of nugget was measured.

TIG welding

The arc welding was carried out by using the AC TIG welding machine.The susceptibility of weld cracking was investigated by the fish-bone type weld cracking test. Figure 3 shows the fish-bone type weld cracking test piece, that was scalped off to 3.2mm. The filler metal was the 5356 alloy. The welding current value was 115A, and the welding velosity was 2.9mm/s. The susceptibility

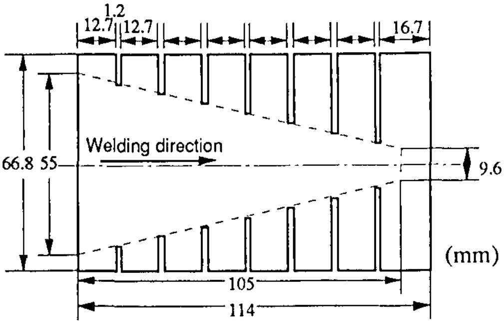


Figure 3 Fish-bone type weld cracking test piece.

Table III TIG butt welding parameters

Alloy	Filler metal	Arc current (A)	Travel speed (mm/s)	Argon flow (l/min)	Back-shield argon flow (l/min)
No.1	same alloy, 5356 alloy	110-120	2.3	15	5
No.2	same alloy, 5356 alloy	110-120	2.8	15	5
6005	5356 alloy	160-165	2.8	15	—
7005	5356 alloy	160	3.1	15	—

of cracking was estimated by measuring the length of the cracking which occured in the weld bead.

The mechanical properties of the butt welded joint were also investigated. The shape of the groove was V-shape, and the groove angle was 60° , and the length of a root face was 1mm. The specimens were degreasing with organic solvent, and wire-brusshed. The specimens were buttwelded under restraint by the exclusive instrument without a backing strip. Table III shows the TIG butt welding condition. The welding current value was 110～120A for Al-Li-Mg alloys. As descrived later, this value was lower than that of the 6005 alloy and the 7005 alloy. And it was passed the back-shield Ar gas in order to prevent the occurence of a blow hole. The tension test for butt welded joints was performed with a reinforcement of weld. The tensile-compressive fatigue test was carried out at a stress ratio of R=-1.

Results and discussions

Resistance spot welding

Relation between welding current and tensile shear load

Figure 4 shows the effect of the welding current value on the tensile shear load and the diameter of nuggets. In the matter of Al-Li-Mg alloys (No.1 alloy and No.2 alloy), the nuggets were formed at about 40kA of the welding current value. The diameter of the nugget grew large, as the welding current went high, and the tensile shear load rose up. At about 45kA, the diameter of the nugget was about 10mm and the tensile shear load was about 10000N. There was not much difference between No.1 alloy and No.2 alloy. Namely, the tensile shear load and the formation of the nugget were hardly influenced by adding 0.5mass%Cu to this Al-Li-Mg alloy. On the other hand, for the 6005 alloy, which was comparative materials, the nuggets were formed at about 64kA of the welding current. At about 67kA, the diameter of the nugget was about 10mm and the tensile shear load was about 8500N. It was considered that since the electric conductivity of these Al-Li-Mg alloys are remarkably lower than that of the 6005 alloy, for these Al-Li-Mg alloys the nugget was formed in the same size at 70% of welding current for the 6005 alloy.

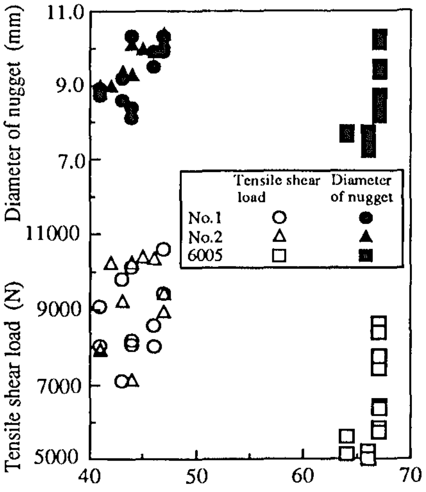


Figure 4 Effect of welding current value on tensile shear load and diameter of nugget.

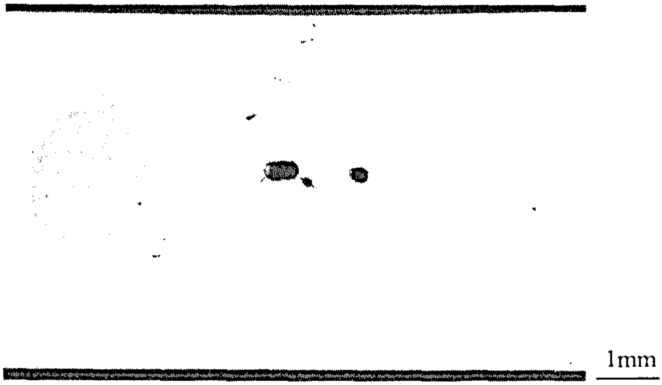
Tensile properties and fatigue properties of spot welded joint

From the results of above tests, for the tensile tests and the fatigue test, the optimum welding current value was selected. For the Al-Li-Mg alloys, it was 44kA, and for the 6005 alloy, it was 67kA.

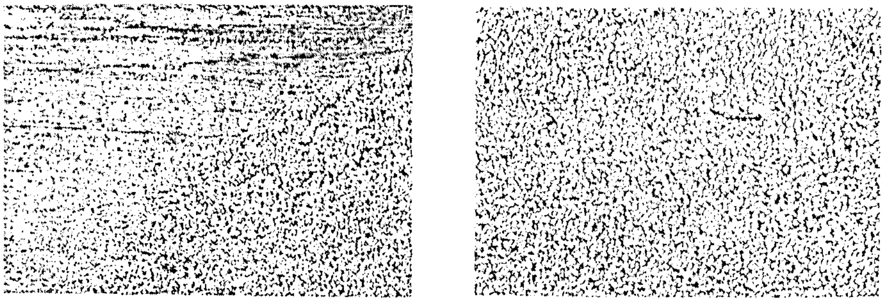
Figure 5 shows the macro and micro structures in cross section of the spot welded joint of the No.1 alloy. The blow holes were observed in the inside of the nugget. But it seems that these blow holes does not influence to the mechanical properties. And the micrographs in the inside of the nugget showed a fine microstructures.

Results of the tension shear test were shown in Figure 6. For the No.1 alloy, the diameter of the nugget was 9.1mm, and the tensile shear load was 9240N. For the No.2 alloy, the diameter of the nugget was 10.0mm, and the tensile shear load was 9810N. The tensile shear load of No.2 alloy was higher a little. It seems that this is the cause of the larger nugget, and is scarcely the cause of the difference of the chemical composition.

While, for the 6005 alloy, the diameter of the nugget was 9.8mm, in the same size to that in the case of Al-Li-Mg alloys. But the tensile shear load was 7530N, about 80% of that of the Al-Li-



(a) Macro structure of nugget



(b) Edge of nugget 100μm (c) Inside of nugget 100μm

Figure 5 Macro and micro structures of spot welded joint of the No.1 alloy.

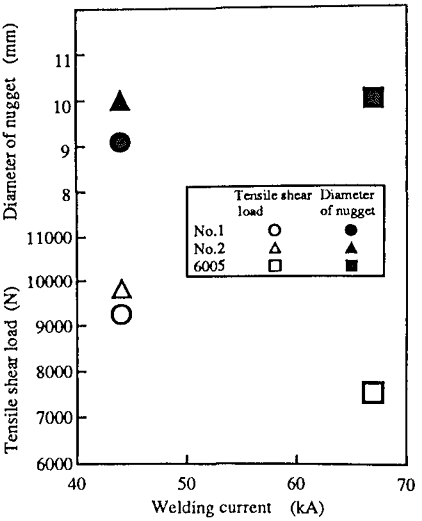


Figure 6 Results of tension shear test.

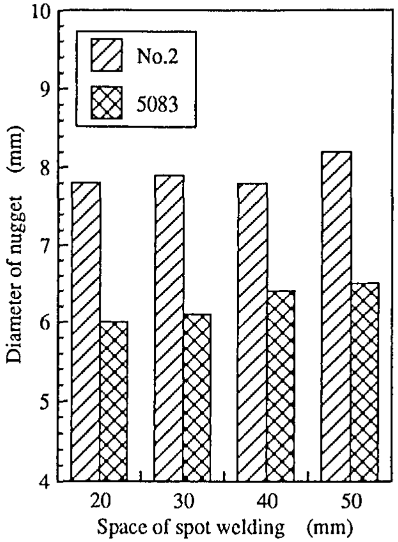


Figure 8 Relation between space of spot welding and diameter of nugget.

Mg alloy.

Figure 7 shows the S-N curves for the spot welded joint. Containing the 6005 alloy, there was hardly difference between the three alloys.

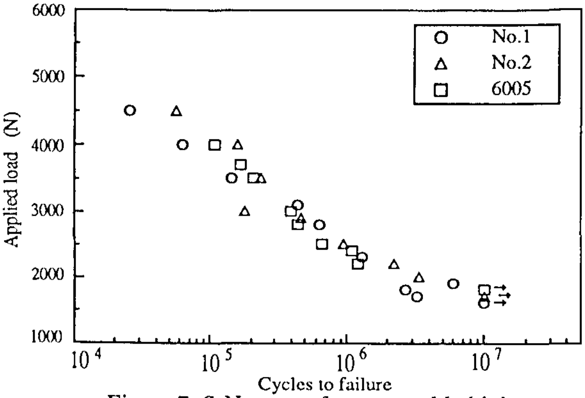


Figure 7 S-N curves for spot welded joints.

Continuous spot weldability

It is said that when the continuous spot welding is carried out, the distribution of the electric current occurs and the size of the nugget grows small. This phenomenon, which will be easy to occur as the space of the spot welding becomes short, has relation to the electric conductivity of the material.

Relation between the space of spot welding and the diameter of the nugget in the continuous spot welding is shown in Figure 8. For the Al-Li-Mg alloy, when the space of spot welding was reduced to 20mm, the diameter of the nugget varied scarcely. But for the 5083 alloy, that became smaller gradually.

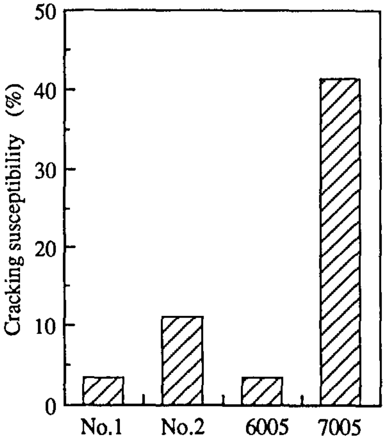
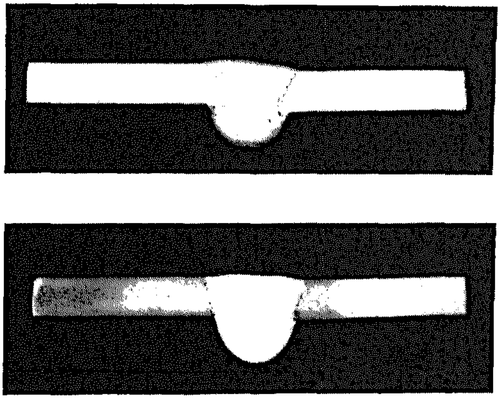


Figure 9 Results of weld cracking test. (Filler:5356)



(b) No.2 alloy (Filler:5356)

Figure 10 Macro structures of butt welded joint.

TIG welding

Susceptibility of weld cracking

Figure 9 shows the results of the weld cracking test. The values of the vertical line represents the weld cracking susceptibility, the ratio of the measured length of cracking to the length of the weld bead. The weld cracking susceptibility of the No.1 alloy was 3.4%. The value was nearly equal to the that of the 6005 alloy. The weld cracking of the No.2 alloy, added Cu, increased to 17.1%. But this value was considerably lower than that of the 7005 alloy. So the weld cracking susceptibility of this Al-Li-Mg alloy was low level enough for practical application.

Tensile properties and fatigue properties of butt welded joints

Both the No.1 alloy and No.2 alloy were easy to melt. So, at the about 70% of welding current of the comparisons, the 6005 alloy and the 7005 alloy, the weld beads of these alloys were formed. Figure 10 shows the macro structures in cross section of the butt welded joint by using the 5356 alloy as the filler metal. The size of the backing bead was large remarkably. But no unusual structures was obsereved in

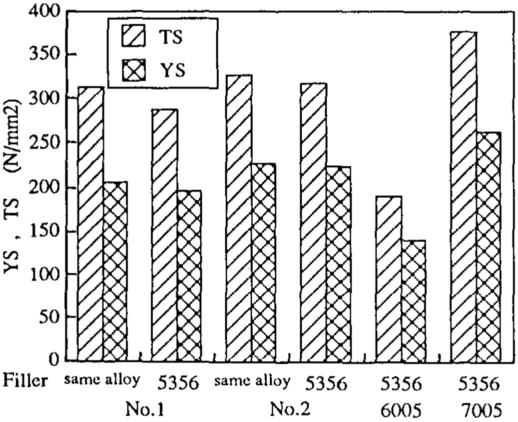


Figure 11 Tensile properties of butt welded joint.

this joint.

Figure 11 shows the results of the tension tests for the butt welded joints, with reinforcement of weld. The tensile strength of the joint of the No.1 alloy, using the 5356 alloy as the filler metal, was 287N/mm^2 and higher than that of the 6005 alloy remarkably. That of the No.2 alloy added Cu was higher about 30N/mm^2 than that of the No.1 alloy.

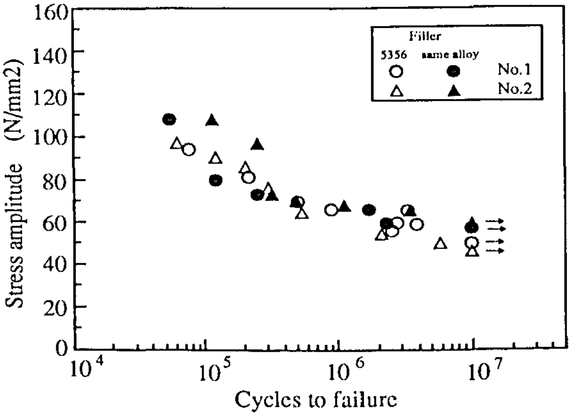


Figure 12 S-N curves for butt welded joints. (R=-1)

Figure 12 shows the S-N curves for the butt welded joints. When the 5356 alloy was used for the filler metal, the fatigue strength at 10^7 cycles of the No.1 alloy was 48N/mm^2 and that of the No.2 alloy was 45N/mm^2. In the case of using the same alloy as the filler metal, the fatigue strength was rose up about 10N/mm^2 in both the No.1 alloy and No.2 alloy.

Conclusions

The resistance spot weldability and TIG weldability of Al-2.7mass%Li-2.0%Mg alloy were investigated.

(1)In the spot welding, the welding current value of Al-Li-Mg alloys was 70% of the conventional alloy 6005, since the electric conductivity of these alloys was low.

(2)The tensile shear load of these alloys was over 9000N and much higher than that of the 6005 alloy in the same size of the nugget.

(3)In the TIG welding, the weld cracking susceptibility of these alloys was excellent enough for practical applications.

(4)The tensile strength of the butt welded joint of these alloys was high over 280N/mm^2 and the fatigue strength of the butt welded joint of these alloys was over 45N/mm^2, when the 5356 alloy was used for the filler metal.

References

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2.U.Kruger, "6th International Aluminium-Lithium Conference, Garmish-Partenkirchen", (1991), 1183