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Friction Welding of Aluminum Alloy and Steel

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ABSTRACT

Friction welding of 6061 aluminum alloy and steel was conducted. Sound welds were produced in all A6061/steel combinations, and tensile fracture occurred in the thermal-softened A6061 area. Joint strength depends on the width of this softened A6061 area. Tensile strength of the T62 heat-treated joint was high compared with that of the weld joint.

INTRODUCTION

Friction welding has been widely used for welding of similar and dissimilar metals. However, in friction welding of dissimilar metals, such as aluminum alloy and steel, brittle intermetallic compounds tend to form, making it very difficult to obtain a sound weld (Elliott and Wallach, 1981). Presently, the demand for friction welding of such materials is increasing in many industrial fields. Thus, in order to produce a sound welded joint between such metals, friction welding was undertaken using an insert metal (Sassani and Neelam, 1988; Ochi et al., 1995). In such a case, the problem is to increase the welding process. In this study, the direct friction welding of low-weldability aluminum alloy and steel was conducted, and suitable welding conditions for producing a sound weld were investigated. In particular, the effects of softened aluminum alloy on joint strength were examined, as well as the effects of various heat treatments of the welded joint on joint strength.

EXPERIMENT

The materials used in this investigation included 6061-T6 aluminum alloy (A6061), S15C, S25C, S35C, S45C and S55C carbon steels and SUS304 stainless steel (AISI 304). The chemical compositions and mechanical properties of the base materials are shown in Tables 1 and 2. The welding materials were machined to the shape and their dimensions are shown in Fig. 1. Friction welding was carried out using a brake-type friction-welding method. The effects of the welding conditions (friction pressure P_1, forge pressure P_2, friction time t_1 and rotation speed N) on joint strength were examined. Joint strength was measured using a test specimen without a burr as shown in Fig. 2 in the tensile test. A hardness distribution of welds was measured using a Vickers hardness tester.

Next, the welds were heat-treated, then examined by both tensile and hardness tests. Heat treatments were T42 at 798K for 1 h; T62 at 448K for 8 h after T42; and T62' at 448K for 8 h.

Material	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
A6061-T6	0.59	0.16	0.20	0.01	0.95	0.06	0.01	0.01	Bal

Material	Si	Fe	Cu	Mn	Cr	C	P	S	Ni
S15C	0.20	Bal	0.01	0.42	0.09	0.17	0.017	0.018	0.02
S25C	0.22	Bal	0.08	0.40	0.14	0.22	0.017	0.014	0.04
S35C	0.18	Bal	0.01	0.72	0.06	0.34	0.013	0.017	0.01
S45C	0.26	Bal	0.02	0.78	0.06	0.46	0.019	0.016	0.03
S55C	0.25	Bal	0.01	0.79	0.13	0.54	0.027	0.014	0.02
SUS304	0.25	Bal	—	1.71	18.75	0.06	0.033	0.026	8.26

Table 1 Chemical compositions of base materials (mass %)

Material	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)
A6061-T6	299	319	18
S15C	343	451	32
S25C	282	465	30
S35C	427	617	28
S45C	422	727	23
S55C	461	784	23
SUS304	579	765	39

Table 2 Mechanical properties of base materials

RESULTS AND DISCUSSION

The results show that, among these welding conditions, forge

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KEY WORDS: Friction welding, joint strength, heat treatment, hardness, 6061 aluminum alloy, carbon steel, stainless steel.