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Friction Welding of 6061 Aluminum Alloy Pipe to S25C Carbon Steel Pipe

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ABSTRACT

Two kinds of tubular materials with different thermal and physical properties were friction-welded as follows. A welding series was carried out by a brake-type friction-welding method. Welded materials were JIS 6061 aluminum alloy pipe and JIS S25C carbon steel pipe. After welding, both the outer burr and inner burr formed at welds during welding were measured. Also the welded joint quality was examined in a tensile test. The results obtained indicate that the burr grows in a complicated process as the welding time elapses, tensile strength of pipe joints increases in proportion to welding pressure except for extremely thin pipe of 1-mm thickness, and it is possible to estimate the hollow degree of the pipe from the height of the outer burr.

INTRODUCTION

Not only is a pipe used frequently as a conduit which passes gas and liquid, but also for the purpose of reducing product weight and material cost. Up to now, some authors have reported the results of investigation on the friction welding of pipe which consisted of similar materials (Ogawa, 1988; Kobayashi, 1986; Shaitarov, 1979; Sutovskii, 1975; Tou, 1976, 1977). However, the study of friction welding pipe of a dissimilar material is not found at all.

In the friction welding of pipe, the forming of an inner burr on the inside of the pipe differs from that of a solid bar without any inner burr. The forming mechanism of an inner burr varies with the welding conditions, such as the sort of base material and especially the diameter and thickness of the pipe. The outer burr formed on the outside of the pipe can be confirmed and removed easily by machining. However, it is very difficult to identify and remove the inner burr, which obstructs flow when friction-welded pipe is used.

In this paper, the friction welding of an aluminum alloy pipe to a carbon steel pipe having very different thermal and mechanical properties was carried out to discuss the forming mechanism of both outer and inner burrs and joint strength. That is, the influence of the welding condition and shape of pipe on the deformation behavior of welds and tensile strength of pipe joints was examined. This study especially attempted to differentiate the shape of the inner burr from the shape of the outer burr.

(a) Aluminum alloy

Material	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Bi	Pb	Al
A6061-T6	0.58	0.16	0.20	0.01	0.99	0.07	0.01	0.01	-	-	RE

(b) Carbon steel

Material	C	Si	Mn	P	S	Cu	Ni	Cr	Fe
S45C	0.45	0.27	0.72	0.022	0.016	0.040	0.045	0.090	RE

Table 1 Chemical compositions of base materials (mass %)

(a) Aluminum alloy

Material	Proof stress $\sigma_{0.2}$ (MPa)	Tensile strength σ_B(MPa)	Elongation ε (%)	Vickers hardness HV(micro)
A6061-T6	273	289	21.9	125

(b) Carbon steel

Material	Yield point σ_{US} (MPa)	Tensile strength σ_B(MPa)	Elongation ε (%)	Vickers hardness HV(micro)
S45C	422	727	19	213

Table 2 Mechanical properties of base materials

EXPERIMENTAL PROCEDURE

Materials used are the Al-Mg-Si aluminum alloy solid bar (JIS-A6061-T6), and the 0.45% carbon steel solid bar (JIS-S45C) both widely available on the market. The chemical compositions and mechanical properties are presented in Tables 1 and 2, respectively. The materials, of 20 mm in diameter, were cut off by a saw to 80-mm length for the aluminum alloy and 120-mm length for the carbon steel, and then a 30-mm-deep hole was drilled on one end of the face in order to make a pipe. Six types of pipes with different thickness of pipe wall — 1.0 mm, 1.5 mm, 2.0 mm, 2.5 mm, 3.0 mm and 3.5 mm — were machined using drills 18 mm, 17

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KEY WORDS: Friction welding, aluminum alloy, carbon steel, up-set burr, tensile strength, dissimilar pipe, hollow degree in pipe.