ELSEVIER

Journal of Materials Processing Technology 168 (2005) 202–210

Journal of Materials Processing Technology

www.elsevier.com/locate/jmatprotec

Joining with friction welding of high-speed steel and medium-carbon steel

Mümin Sahin

Mechanical Engineering Department of Trakya University, 22030 Edirne, Turkey

Received 15 May 2003; received in revised form 29 October 2004; accepted 20 November 2004

Abstract

Machine parts can be produced by one of various manufacturing methods such as forging, machining, casting or welding methods. Choice of the manufacturing method depends on production costs of the alternatives for individual parts. Friction welding method as a mass production process is finding increasing industrial acceptance, particularly for joining dissimilar materials. One of the areas using much more of the method is the tool industry.

In this study, an experimental set-up was designed and produced to achieve the friction welding of components having equal diameter. The set-up was designed as continuous drive, and transition from friction to forging stage can be done automatically. In the experiments, high-speed steel (HSS—S 6-5-2) and medium-carbon steel (AISI 1040) were used. Post-weld annealing was applied to the joints at 650 °C for 4 h. First, the optimum welding parameters for the joints were obtained. Later, the strengths of the joints were determined by tension, fatigue and notch-impact tests, and results were compared with the tensile strengths of materials. Then, hardness variations and microstructures in the post-weld of the joints were obtained and examined.

Then, obtained results were compared with those of previous studies.

Keywords: Welding; Friction welding; High-speed steel; Medium-carbon steel

1. Introduction

Friction welding is one of the methods, which is getting higher state among the other welding methods. Friction welding method is one of the most economical and highly productive methods of joining different metals and alloys, in the tool industry.

In the process, heat is generated by conversion of mechanical energy into thermal energy at the interface of the work pieces during rotation under pressure. Some advantages of the friction welding are high material save, low production time and making the welding of parts, which are made of different metals or alloys possible. Friction welding can also be used in joining of components that have circular or non-circular cross-sections. The most interesting parameters in friction welding are friction time, friction pressure, forging time, forging pressure and rotation speed.

Generally, the friction welding machines can be examined in two types as continuous drive and inertia welding.

In continuous drive method, one of the parts that are to be welded at constant speed (s) is rotated, while another is pushed toward the rotated part by a sliding action. The components are brought together under axial friction pressure (P_f) for a certain friction time (t_f). Then, the drive is closed, and the rotary component is quickly stopped while the axial pressure being increased to a higher upsetting pressure (P_u) for a predetermined time (t_u). The parameters of the welding method are shown in Fig. 1.

Both theoretical and experimental studies on these parameters can be seen in various articles. Various researchers such as Vill and Tylecote investigated the parameters that influence the welding quality, the strength of the joint and the hardness of the heat-affected zone (HAZ) [1,2].

Dobrovidov et al. [3] investigated selection of optimum conditions for the friction welding of high-speed steel R6M5 to carbon steel 45. Voinov et al. [4] examined fatigue

E-mail address: mumins@trakya.edu.tr.

0924-0136/$ – see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.jmatprotec.2004.11.015

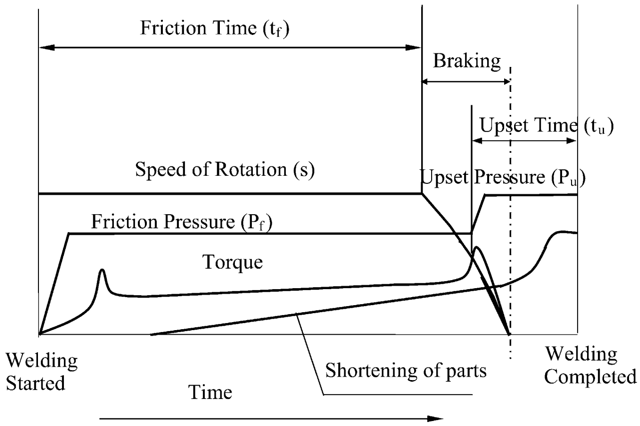

Fig. 1. Parameters on continuous drive friction welding.

strength of friction-welded joints between steels 20 and 40 kh. Imshennik and Fomichev [5] investigated characteristic of the upset process in the friction welding of high-speed tool steel to structural steel. Popandopulo and Tkachevskaya [6] examined structure of shiny non-fusion rings in friction-welded high-speed steels. Fomichev [7] made the friction welding of new high-speed tool steels to structural steels.

Then, Ishibashi et al [8] chose stainless steel and high-speed steel as representative materials with an appreciably difficult weldability, and their adequate welding conditions were established. The distributions of the alloy elements at and near the weld interface with sufficient strength were analysed using an X-ray microanalyser. Murti and Sundaresan [9] directed a study about parameter optimisation in friction welding of dissimilar materials and same authors [10] investigated structure and properties of friction welds between high-speed steel and medium-carbon steel for bimetal tools.

Then, Tanicheva et al. and Khazanov and Fomin made studies on “bright ring” occurring in and on friction welding [11–13]. Yılmaz [14] investigated hardness variations and microstructures in the welding zone of welded dissimilar materials.

Then, Sahin and Akata [15] investigated the welding-quality using tensile test results of welded parts that have different cross-sections. Akata et al. [16] conducted a detailed study on the friction welding set-up. Sahin and Akata [17] made an investigation on friction welding of medium-carbon steel and austenitic-stainless steel.

In the light of previous studies, in the presented study, high-speed steel and medium-carbon steel parts having equal diameters were welded using the friction welding method. Firstly, the optimum welding parameters were selected using statistical approach. Later, the strengths of the joints were determined by tension tests, and compared with those of base materials. Then, hardness variations and microstructures in the welding zone were obtained and investigated by macro and microphotographs.

Table 1
Standard chemical composition of high-speed steel [18]

Material	High-speed steel
DIN	(1.3343) S 6-5-2
C (%)	0.86–0.94
Cr (%)	3.80–4.50
Mo (%)	4.70–5.20
V (%)	1.70–2.00
W (%)	6.00–6.70
Si (%)	≤0.45
Mn (%)	≤0.40
P (≤%)	0.030
S (≤%)	0.030
Co (%)	–
Tensile strength after annealed (MPa)	925

2. Experimental procedure

The set-up used in the friction welding experiments is shown in Fig. 2. The set-up was designed and constructed as continuous drive.

2.1. Geometry of specimens and testing materials in friction welding experiments

Specimens were machined from S 6-5-2 and AISI 1040 steels as purchased. The standard chemical composition of the materials is shown in Tables 1 and 2 [18].

Specimen sizes used in the experiments are shown in Fig. 3.

2.2. Selection of welding parameters using statistical approach

When a statistician suggests the experimental runs to be made in a series of tests, data analysis can be quite straightforward. Often, however, an analysis must be carried out on results that have been accumulated as part of a test program or as a series of related test programs, and an empirical predictive model must be constructed from the results obtained. Terms for possible inclusion in the model might involve not only the principal variables but also variables such as cross products, squares, or other combinations, or transformations, of the principal variables [19].

Table 2
Standard chemical composition of medium-carbon steel [18]

Material	AISI 1040
C (%)	0.37–0.44
Mn (%)	0.60–0.90
P (≤%)	0.040
S (≤%)	0.050
Cr (%)	–
Mo (%)	–
Ni (%)	–
Tensile strength after annealed (MPa)	800