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Rotary Friction Welding of Low Carbon Steel

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Abstract

In this present study, friction rotation welding of low carbon steel is presented. The welding was carried out in a machine manufactured in our laboratory and which was very successful. The welding steps were presented sequentially. The microstructure of the welded joint was presented, showing the three distinct zones formed in the welded joint which have different hardnesses.

Keywords: Rotary Friction Welding; Low Carbon Steel

Introduction

Welding is an efficient way to join two metal parts and is widely used in industry. Among the types of welding that exist in our time, we find friction welding and which is based on the friction between the two parts to be welded until their assemblies and without reaching the melting temperature. Moreover, it does not require an electrode as in the case of arc welding. Friction welding is also divided into several types and among these types is rotational friction welding (RFW) which is very simple in its use. As it is shown in Figure 1, RFW is a solid-state material joining process, which involves the coalescence of two joining surfaces using frictional heat generated by the rotation of one part relative to another under the action of an axial compressive force [1]. This type of welding involves joining between a stationary and a rotating element, due to frictional heat generated by undergoing normal forces high at the interfaces [2]. The most important parameters of friction welding are friction pressure, friction time, forging pressure, forging time and rotational speed. The parameters must be carefully chosen to achieve a good quality welded joint. The most important zones in a welded joint obtained by rotational friction are three and which are. A central weld zone (WCZ), a thermomechanically affected zone (TMAZ) and a heat affected zone (HAZ). The extent and microstructural composition of these zones depends on the material and processing conditions used [3]. To perform friction rotation welding, a specific machine must be used. Generally, lathes are used to weld by this process and sometimes researchers set up their own machine as has been done by Rombaut et al [4]. For welding steel with ceramic. In this present research work, a specific rotary friction welding machine was manufactured and welding of low carbon steel was performed. The microstructure and the hardness of the welded steel were investigated.

Experimental Procedure

Friction rotation welding was carried out on two round low carbon steel rods, 6 mm in diameter. The welding is carried out on a friction rotation welding machine and it has been specially designed to achieve our objective (Figure 2). The rotation speed that allows us to make a welded joint is 2500 revolutions per minute. The welded specimen was cut along the longitudinal axis and polished with 100-1000 grit sandpaper, then finished with a 1 micron diamond pad. The polished sample was etched by the chemical reagent (Nital of 2%) in order to reveal the microstructure of the welded joint. The main characterization techniques were optical microscopy and Vickers microhardness using hardness apparatus with a 300g load.

Results and Discussion

Macrscopic evolution during the rotary friction welding

Based on these macroscopic observations of the two steel rods during rotary friction rotation (Figure 3), it was found that the process goes through two essential stages. During the first stage, the two rods (the upper rod is rotating and the lower rod is fixed) are in contact for a period of a few seconds which increases the friction and this is seen by the formation of a red zone by forming a bead in the contact area. In our case, the duration of the first stage is about 46 seconds.

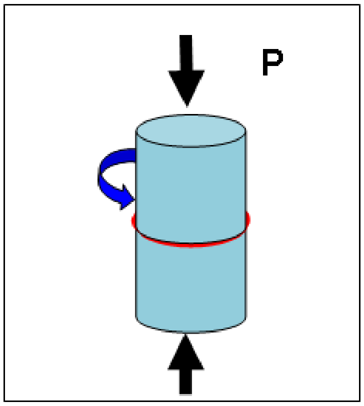

Figure 1: *Schematic representation of rotary friction welding process.*

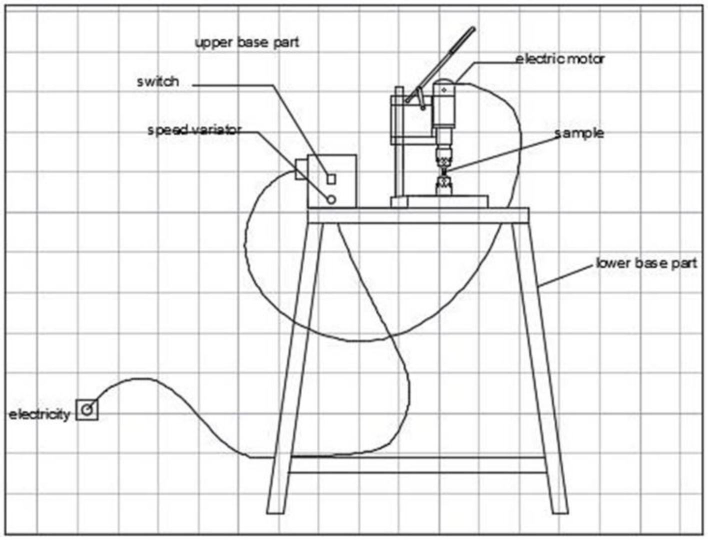

Figure 2: *RFW machine.*

Subsequently, the rotation of the upper rod is stopped and this is directly followed by the application of a higher load with respect to the first stage, which causes the phenomenon of forging. Forging allows the two rods to be welded together until the temperature drops. In this investigation, the forging time is 4 seconds. It has been reported that the frictional heat generated between two metal joining surfaces plasticizes the interface region. The plasticized material is moved from the interface under the action of the axial compressive force. This expels the oxide layer, impurities and other contaminants from the joint surface, promoting a healthy welded joint [5].

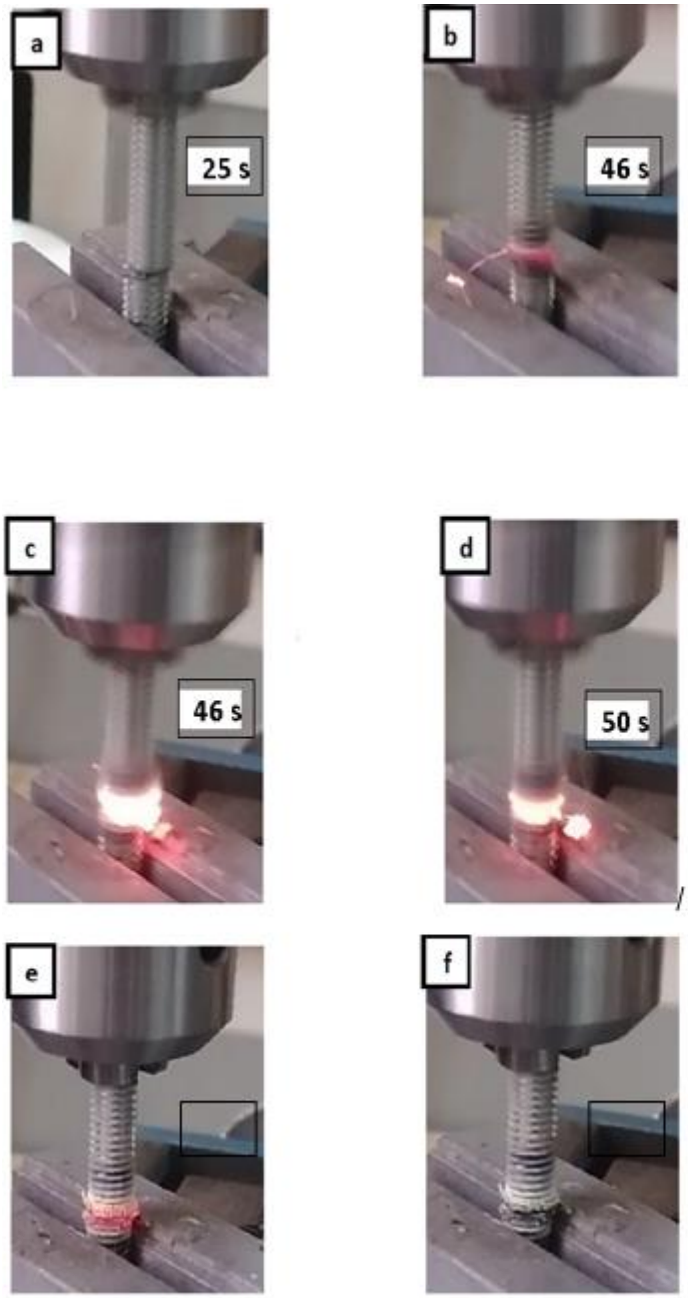

Figure 3: *Rotary friction welding of steel at different stages under a rotation speed of 2500 rpm.*

Microstructure observations and hardness measurements

Figure 4 shows the microstructure of low carbon steel (base metal) which is formed by colonies of pearlite (black color) in a matrix of ferrite (white color). Figure 5 shows a macro view of the surface of the welded specimen along its longitudinal axis where it can be seen that no visual defects were observed. Figure 6 shows the microstructure of the welded joint where we see the difference in grain size from the contact zone between the two steel rods up to a distance a little far. The contact zone is formed of a band of fine grains with a width of about 10 μm unlike the zone far from this contact where the grains are larger. This fine-grained zone is obtained due to the strong deformation and also to the high temperature during welding process, which led to a recrystallization reaction.

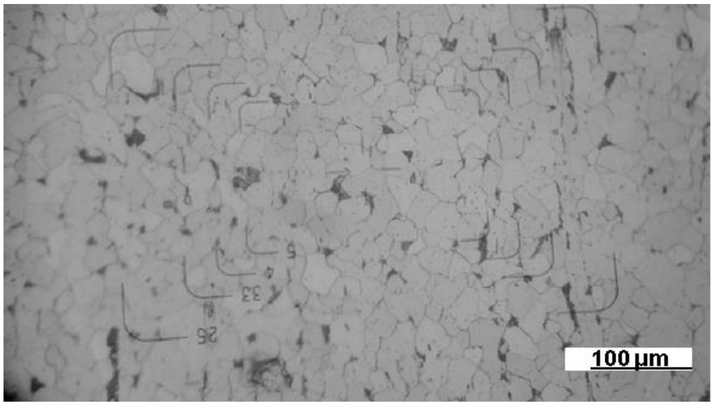

Figure 4: *Microstructure of the low carbon steel.*

Figure 5: *Macro view of welded sample surface.*

The second zone is the thermomechanically affected zone. The third zone is the heat affected zone. Alza [6]. Observed three zones in the welded joint by the RFW process of two steels: a fully dynamic recrystallized zone (FDRZ) and which was observed in our welded steel, followed by a mechanically and thermally affected zone (MTAZ), and finally a third zone called heat affected (HAZ). These distinct areas were also observed in these investigations [7,8]. The difference in microstructure along the welded joint led to the difference in hardness from one zone to another as shown in the hardness values mentioned in the figure 6, where the fine grained zone is harder compared to other zones, because it is characterized by fine grains.

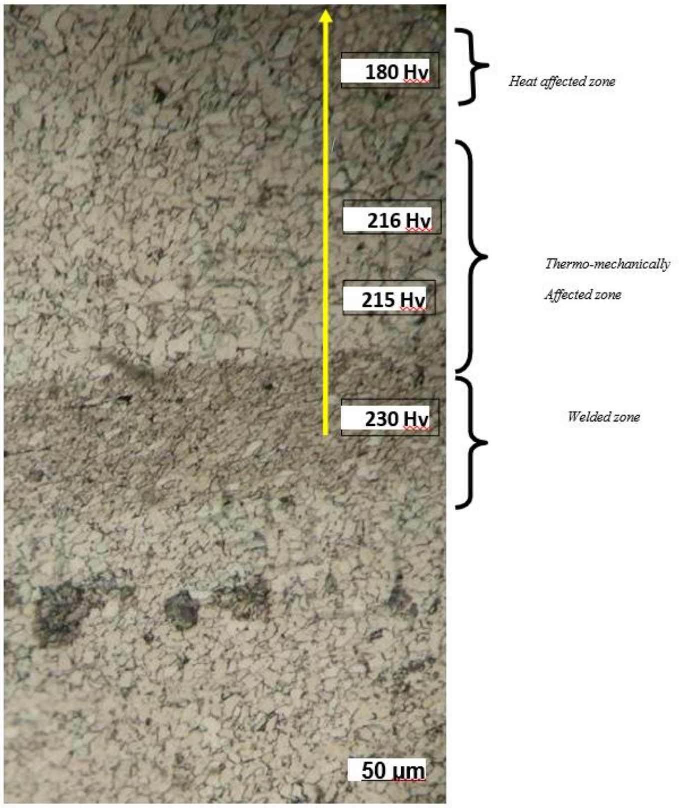

Figure 6: *Microstructure of the joint welded by RFW under 2500 rpm of low carbon steel.*

Our result is in agreement with the work of Haribabu et al [9]. Who observed the formation of very fine grains in the central zone of the welded joint by friction rotation? In addition, they found that the microhardness of the joints increased towards the weld interface from the base metal due to the effect of work hardening and the presence of fine grains at the interface. Akata and Sahin [10]. Investigated the RFW of AISI1040 steel parts and they also found that the maximum hardness values were found through the solder interface.

Conclusion

From this research work on the friction-rotation welding of a low carbon steel, some conclusions can be deduced:

- Friction spin welding of two steel rods was successful
- The time of each welding step has been determined
- The welded joint is composed of three distinct zones
- The hardness varies from one zone to another where the greatest hardness value is recorded at the interface because it is formed of fine grains.

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