International Journal of Mechanical Engineering and Technology (IJMET)
Volume 13, Issue 6, June 2022, pp. 42-48. Article ID: IJMET_13_06_005
Available online at https://iaeme.com/Home/issue/IJMET?Volume=13&Issue=6
ISSN Print: 0976-6340 and ISSN Online: 0976-6359
DOI: https://doi.org/10.17605/OSF.IO/JN2D7

EFFECT OF FORGE FORCE ON MECHANICAL PROPERTIES OF DISSIMILAR METAL FRICTION WELDS OF STAINLESS STEEL AND LOW CARBON STEEL

P. VenkataRamana[1], M. Pratyusha[2,*], K. Ramanjaneyulu[3], P.Narsimha[4]
[1,2, 4] Department of Mechanical Engineering (Mechatronics),
[3]Department of Metallurgical and Materials Engineering,
Mahatma Gandhi Institute of Technology, Gandipet, Hyderabad, Telangana, India.
*Corresponding Author

ABSTRACT

Several structural applications demand use of steels like low carbon steels and stainless steels because their sound weldability and ductility. Fusion welding of these steels especially in dissimilar metal combination attracts many problems such as cracking, porosity, low ductility etc. To overcome these problems, solid-state welding processes such as friction welding has to be employed as it can provide a solution to the recurrent problems arising in fusion welding. An attempt is made in this work to study the effect of forge force on mechanical properties such as tensile strength and impact toughness of the similar and dissimilar metal friction welds of stainless steel and low carbon steel. It is observed that tensile strength of dissimilar metal welds increased with increase in the forge force while the impact toughness decreased with increase in the forge force.

Keywords: Friction Welding; Stainless Steel; Low Carbon Steel; Tensile Strength; Impact Toughness

Cite this Article: P. VenkataRamana, M. Pratyusha, K. Ramanjaneyulu, P. Narsimha, Effect of Forge Force on Mechanical Properties of Dissimilar Metal Friction Welds of Stainless Steel and Low Carbon Steel, *International Journal of Mechanical Engineering and Technology (IJMET)*, 13(6), 2022, pp. 42-48.
https://iaeme.com/Home/issue/IJMET?Volume=13&Issue=6

1. INTRODUCTION

Numerous structural applications, especially, in pharmaceutical and chemical industries demand class of steels like low carbon steels and stainless steels because these metals have sound weldability and ductility. In order to fabricate components by means of these steels, one of the candidate processes is welding. Fusion welding techniques namely Metal Inert Gas Welding, Gas Tungsten Arc welding are extensively used for welding these steels. But the problems with welding of these steels employing fusion welding techniques are decrease in toughness and ductility, increased cracking and porosity. Welding of dissimilar combination of metals is in general more difficult than welding similar materials. This is because of differences in the physical, chemical and mechanical properties of the parent materials welded. Another problem in welding dissimilar metals is matching filler materials suitable for both the dissimilar metals. Hence study about this dissimilar metal welding is significant since many aspects are required to be addressed other than that involved with welding of similar materials. Differences in properties like electrical conductivity, thermal expansion, thermal conductivity and melting temperatures etc are responsible for the problems not only during the welding process but also at the subsequent service. More the difference, severe is the difficulty in welding. Metallurgical compatibility between the metals to be welded is also important to produce the required joint. Metallurgical incompatibility may be responsible for HAZ cracking, uncontrollable weld metal or the microstructure of weld metal that cannot provide required corrosion or mechanical performance. When the dissimilar metals are welded using arc welding process, because of the thermoelectric currents in between the hot and cold parts of the joint and different thermal conductivities of the dissimilar metals arc blow or deflection of arc which is not controllable possibly will occur. These differences are also responsible for residual stresses[1-5].

To overcome all the problems arising in fusion welding, the alternate process of fabricating the components is solid state welding process namely Friction Welding which will be suited especially for welding of materials with different melting points [6]. This process can provide a solution to the recurrent problems of control of diffusion of various elements across the interface, columnar grains, segregation of elements in conventional welding, solidification cracking and liquation cracking[7]. One of such solid-state welding processes is friction welding used in the present work. Friction welding is used to join those metals which are very difficult to join using fusion welding process. Friction welding is particularly attractive, as it avoids the use of additional weld material and the associated problems. It is most suitable process for joining many similar and dissimilar materials where other welding processes are not capable to weld them without using additional filler material [8].

Friction welding does not involve melting. The weld zone undergoes thermo-mechanical working leading to refined grain structure in the bond zone. These characteristics of friction welds are likely to offer better properties than conventional fusion welds. Continuous drive friction welding is employed in the present investigation. The main variables in the continuous drive friction welding process are friction pressure, upsetting (forge)pressure, friction time and speed of rotation [9]. Using friction welding process welding can be done for both ferrous and nonferrous metals [10]. An attempt is made in this work to evaluate the mechanical properties such as tensile strength and impact toughness of the similar and dissimilar metal friction welds of stainless steel and low carbon steel.

In an effort to determine the practical limits to which the various parameters should be investigated, the amount of forge force was varied for a single arbitrary value of friction force and burn-off. The steels were joined by varying amount of forge force (after some preliminary feasible studies), while keeping the other friction welding parameters such as friction force, burn-off and speed of rotation as constant at appropriate levels. The joint characterization includes evaluation of mechanical properties such as tensile strength and impact toughness.

2. PARENT MATERIALS

The materials used in this study are austenitic stainless steel (AISI 304) and low carbon steel (AISI 1018). Both stainless steel and low carbon steel are supplied as 18 mm diameter circular rods. The chemical composition of the parent materials is given in the Table 1.

Table 1 The chemical composition of the parent materials

Material	Element (% wt.)					
	C	**Ni**	**Cr**	**Si**	**Mn**	**Fe**
AISI 304	0.05	9	18.5	0.6	1.2	Bal.
AISI 1018	0.18	-	-	0.6	0.65	Bal.

3. WELDING PROCESSES

The solid-state welding process employed in the present work is continuous drive friction welding (FW) process. Fig. 1 shows the details of weld design and assembly for FW. The equipment used for the friction welding is shown in the Fig. 2. In this process heat is generated due to the transformation of mechanical energy due to the friction between the surfaces to be joined [11].

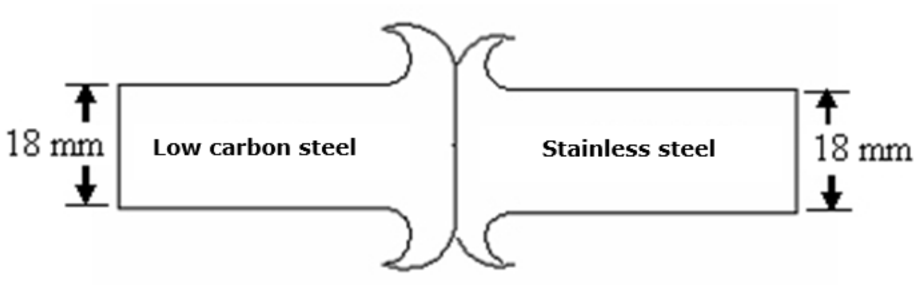

Figure 1 Weld design and assembly for friction welding

Figure 2 Continuous drive friction welding machine

In the present work, only the effect of forge force is studied. The other parameters are maintained as constant at appropriate levels. Trial runs were conducted by changing one of the process variables and remaining others as constant. The working range of forge force was explored by inspecting cross section for the presence of defect(s). Weld parameter regime was based on defect free welds. During friction welding, forge force ranged from 25 kN to 45 kN and friction force at 15 kN, burn-off length at 4 mm and rotational speed at 1800 rpm were kept constant. The welded samples are designated (throughout this whole paper) on the basis of the three welding parameters used to process them, namely friction force, forge force and burn-off length. For example, designation X-Y-Z for a sample reveals the values for the used friction force, forge force and burn-off length respectively.

4. MECHANICAL TESTS

Mechanical properties such as tensile strength and impact toughness of all the welds were evaluated. Standard specimen configurations of American Society for Testing and Materials (ASTM) were employed for tensile and impact testing. Instron 1185 UTM at a cross head speed of 0.5 mm/min was used to carry out notch tensile tests for all the welds. The specimen geometry is taken as per ASTM standards (ASTM E28). The geometry used for the notch tensile specimen is shown in the Fig.3. Three test specimens for each condition were tested to get the average of the tensile properties.

Tinius Oslon impact testing machine was used to conduct impact tests at room temperature. Standard size specimens of the dimensions 10mm x 10mm and notch depth-2mm and with notch location at the weld centre are used for conducting the impact tests. The specifications of the specimens are as per ASTM E23-28 (ASTM standards, 1970). Shadowgraph was used to check the notch dimensions. Test was carried out on three specimens to get the average impact toughness values.

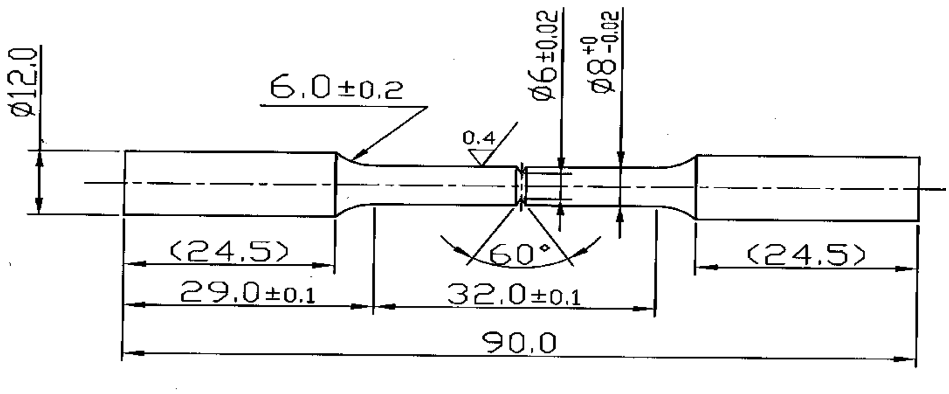

Figure 3 Notch tensile test specimen used in friction welding

5. RESULTS AND DISCUSSION

5.1. Visual Examination

A view of the friction-welded joints of similar and dissimilar metal weld combinations is shown in Fig. 4 and Fig. 5. It is observed that similar metal welds exhibit symmetrical and identical flash width, while in the case of dissimilar metal welds, it was noticed that the amount of flash (upset) was much higher on low carbon steel compared to that of stainless steel. Upsetting of the parts begins when they are relatively cold. However, as the upsetting continues, the temperature at the weld interface reaches the forging temperature range of the steels. The extent to which low carbon steel and stainless steel are upset is dependent on their strength at high temperature. Stainless steel exhibits relatively higher high temperature strength than low carbon steel. Therefore, during welding more of low carbon steel would be squeezed out through the flash.

Figure 4 Specimens of Similar and dissimilar metal friction welds

Figure 5 Specimens of dissimilar metal friction welds

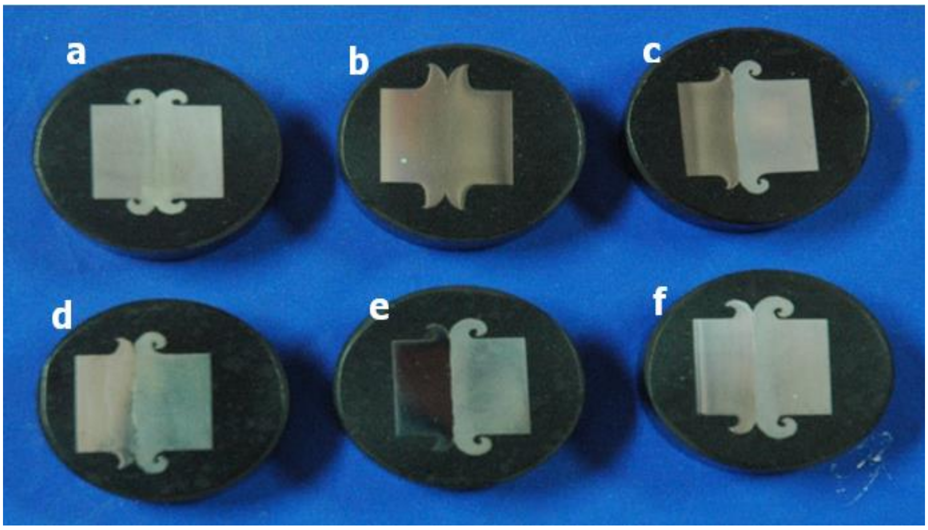

Figure 6 Optical macrographs of similar metal friction welds(a - low carbon steel, b - stain less steel); c, d,e,f - dissimilar metal friction welds of stainless steel and low carbon steels (c- 15-15-4, d – 15-25-4, e - 15-35-4, f – 15-45-4)

In all the welds examined, the integrity of the welds as determined by optical examination was high. No cracks, areas incomplete bonding or other flaws were observed. Optical macrographs, shown in Fig 6 show the extent of flash formation with the increase in the forge force. As the forge force is increased there is an increase the amount of material squeezed out as flash.

5.2. Tensile Properties

The tensile strength properties of the similar and dissimilar metal friction welds are presented in Table 2. From the Table 2, it is evident that the tensile strength of dissimilar welds is increasing with increase in the forge force. This may be attributed to the fine grain structure in the vicinity of the weld line. As reported in several works, fine grain structure will be there in the vicinity of the weld line. Typical notch tensile specimen is shown the Fig. 7.

Figure 7 Notch tensile specimen

Table 2 Notch tensile strength and impact toughness properties of similar and dissimilar friction welds of stainless steel to low carbon steel

Weld combination	Welding Condition	YS(MPa)	UTS (MPa)	Impact Toughness(J)
AISI 304 to AISI 304	15-30-4	717	825	35
AISI 1080 to AISI 1080	15-30-4	687	780	87
AISI 304 to AISI 1080	15-15-4	660	684	26
AISI 304 to AISI 1080	15-25-4	672	772	25
AISI 304 to AISI 1080	15-35-4	696	805	18
AISI 304 to AISI 1080	15-45-4	752	835	11

5.3. Impact Toughness

The impact toughness properties of the similar and dissimilar metal friction welds of stainless steel and low carbon steel are given in Table 2. From the Table 2 it is observed that the impact toughness of the dissimilar metal welds has decreased with the increase in the forge force. This may be attributed the presence of aligned structure in the weld zone. Typical impact test specimen is shown the Fig. 8.

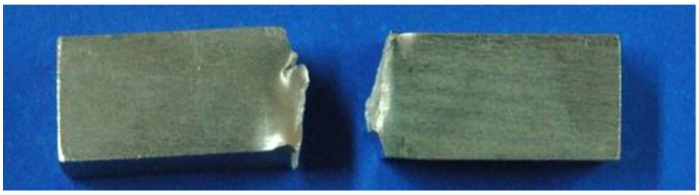

Figure 8 Typical impact test specimen

6. CONCLUSIONS

The present work was aimed at studying the influence of forge force on the mechanical properties such as tensile strength and impact toughness of similar and dissimilar metal friction weldments of stainless steel and low carbon steel.

The following conclusions are drawn from the investigation carried out:

- In dissimilar metal welds, the flash size increased with the increase in the forge force.
- Tensile strength of dissimilar metal welds increased with increase in the forge force.
- The impact toughness of dissimilar metal welds decreased with increase in the forge force.

REFERENCES

[1] V.V. Satyanarayana, G. Madhusudhan Reddy, T. Mohandas, Dissimilar metal friction welding of austenitic-ferritic stainless steels, Journal of Materials Processing Technology,160 (2),2005, 128-137.

[2] G.Madhusudhan Reddy and P.Venkata Ramana, Role of nickel as an interlayer in dissimilar metal friction welding of maraging steel to low alloy steel, Journal of Materials Processing Technology, 212 (1), 2012, 66-77.

[3] S.D. Meshram, T. Mohandas, G. Madhusudhan Reddy, Friction welding of dissimilar pure metals, Journal of Materials Processing Technology, 184 (1–3), 2007, 330-337

[4] P. J. Withers and H. K. D. H. Bhadeshia, Residual Sress Part 1 - Measurement Techniques, Materials Science and Technology, 17, 2001, 355-365

[5] P. J. Withers and H. K. D. H. Bhadeshia, Residual Stress Part 2 - Nature and Origins, Materials Science and Technology, 17, 2001, 366-375

[6] Yashwant Chapke, Dinesh Kamble, Saoud Md. Salim Shaikh, Friction welding of Aluminium Alloy 6063 with copper, E3S Web of Conferences 170, 020040, 2020, 1-6.

[7] Paventhan, R., Lakshminarayanan, P. R., & Balasubramanian V, Optimization of friction welding process parameters for joining carbon steel and stainless steel, Journal of Iron and Steel Research International, 19(1), 2012, 66-71.

[8] Rahul Chhibber, Yogesh Kumar Singla, Bijan Kumar Dutta, Optimization of Process Parameters for Friction Welding of Bimetallic Welds, Advanced Materials Research, 585 2012, 440-444.

[9] Mumin Sahin, Joining of aluminium and copper materials with friction welding, International Journal of Advanced Manufacturing Technology, 49, 2010, 527–534.

[10] Chhibber, R., Singla, Y. K., & Dutta, B. K, Optimization of Process Parameters for Friction Welding of Bimetallic Welds, Advanced Materials Research 585, 2012, 440-444.

[11] Ratković, N. R., Arsić, D. M., Lazić, V. N., Nikolić, R. R., Hadzima, B., Palček, P., & Sedmak, A. S, Influence of friction welding parameters on properties of the Al-Cu joint, FME Transactions, 45(1), 2017, 165-171.