EXPLORATION OF ROTARY FRICTION WELDING TECHNIQUE

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Abstract: Friction welding is a solid-state welding system which welds materials without authentic melting it. This study explores papers of different researchers on the friction welding method and it has been observed that the welding parameters like friction time; friction pressure, forge time and forge pressure highly affect properties of welded joints. The reason for this investigation is to exhort industry and the insightful world regarding advantages of revolving friction welding so the technique may be utilized in an ideal manner.

KEYWORDS: Friction, Forge, Solid-state, Micro-hardness.

1 Introduction

In recent years, many industries are opting for wide variety of material in their product for improving the performance and reducing the cost; due to this the demands to weld dissimilar metals have increased in a large scale. Friction welding is a solid state joining process which is used to join different number of metals. It can be used to weld metals of different mechanical properties (*u.caligulu et al*). In friction welding process one component rotates and pressure is applied relative to other mating component, due to this process heat is produced on the surfaces of the component and the softened material is forced out due to applied pressure. The weld is completed before or during an end of the process. It is the only method which is capable of joining dissimilar welds successfully having wide variety of mechanical properties. Main advantages of friction welding are low production cost, have the ability to weld dissimilar metals, high material saving (*Handa.A et al*). It is a welding which is capable of giving good quality welds.

Fig. 1 Friction welding Setup (*M.N.Ahmad fauzi et al.*)

Fig. 2 Sample of prepared weld

2 LITERATURE REVIEW

Handa A. et al. (2014) investigated the characteristics of dissimilar steels AISI304 and AISI1021. The process parameters are rotational speed (800, 1000, 1250, 1430 and 1600rpm) and axial pressure (75-135MPa). Torsion, impact and micro hardness test were performed and the result was evaluated at (1430rpm) and (130MPa) axial pressure maximum torsion strength was obtained. It is also observed that impact strength also increases due to increase in axial pressure, further it was found maximum at (1430rpm) and decreases with increased rotational speed. Inversed axial pressure or rotational speed contributes to increases in hardness. It was found maximum at (1600rpm) and (135MPa) axial pressure due to which it exceeds the 290HV value and the specimen fails without any deformation.

U.Caligulu et al. (2015) experimented rotary friction welding of AISI4340-AISI2205 steels on direct drive friction welding machines. The main process parameters were rotational speed (2200rpm), friction pressure (30MPa), forging pressure (60MPa), friction time (6s) and forging time (3s). The welding joint was evaluated with microstructure, micro hardness and tensile strength test. The results proved that maximum tensile strength (624.89MPa) was achieved at (2200rpm) rotational speed. The microstructure changes shows different zones were formed at welding interface increased rotational speed and forging time decreases the wideness of deformed zone.

Pushpinder Singh et al.(2015) investigated mechanical characteristics of STELLITE-6 coated AISI3162 steel. Coating on specimen was done by detonation gun having various coated thickness ranging between 50 μ m to 150 μ m. The effect of rotary friction welding process parameters were evaluated with the help of micro hardness, tensile strength and impact strength. It is found that on increasing stellite-6 coating micro hardness and impact strength increased by 200% and 42% respectively of coated specimen than non-coated specimen, also tensile strength of coated specimen is found to be decreased by 7% which is negligible as compared to sudden increase in impact strength and micro hardness.

N.Ariuzhagan et al.(2014) investigated the mechanical properties of dissimilar metals AISI4140-AISI304. The process parameters used are friction force (37.5KN), upset force (50KN), rotational speed (2500rpm) and burn-off length (5,7,9,12). The results were carried out with the help of microstructure, hardness and impact strength. It was found that increase in burn-off length increases hardness and decreases toughness. Also for maintaining the uniformity of microstructure optimum burn-off length should be kept which helps in decreasing the number of intermetallics.

M.kimura et al.(2017) investigated the properties of rotary friction welding joint between pure aluminum and AISI304 stainless steel. Parameters such as friction speed (1650rpm), friction pressure (30MPa), friction time (0.04-3.0 s), forging pressure (30-150MPa) and forging time (6s). Approximately 70% of joint efficiency is formed at friction time 0.6 sec and approximately 80% of joint efficiency is formed at forge pressure of (150MPa). The joint had very little suffered area besides the region of CP-Al weld interface bend ductility of 90° at these joints was obtained at forge pressure of (150MPa) and friction time of (1s) and no cracks were produced on the interface. Also because of decrease in tensile strength of CP-Al metals, joints didn't have 100% joint efficiency.

Niyazi Ozdemir et al.(2005) investigated different mechanical properties of rotary friction welded joint of hypereutectoid steels having 4% Al. The main parameters are friction pressure, forging pressure, friction time and rotational speed. It was found out that microstructure changes because the forged region got narrow due to viscous material being carried out because of increase in weld speed, forging and friction pressure. Micro hardness of the specimen was also tested, it was found that that micro hardness was maximum at all interfaces and varies at different rates toward the main material, the martensite formed in this region is due to effect of forging and friction time and pressure. During the tensile strength it was noted that after the rotary friction welding there was no plastic deformation in the specimen.

H.Fret Akala et al.(2003) experimented to weld steel by rotary friction welding technique. Tensile strength, micro hardness and microstructure test were performed and results were evaluated. The various optimum process parameters of carburizing steel were friction time (5 s), friction pressure (30 MPa), upset time (20 s), upset pressure (110 MPa). Tensile strength decreases when the width of the parts increased during welding because of increases in heat capacity and heat loss by rotation. During tensile test it was found that tensile strength was related to micro hardness due variation in heat affected zone (HAZ). In micro hardness test it was found that hardness increases in the horizontal direction and it is also seen that hardness decreases at welding lip. It varies within different region. In microstructure test it was seen that martensite structure due to which welded part did not become stronger.

M.N.Ahmad fauzi et al.(2009) investigated various mechanical properties of aluminum 6061 aluminum welded by rotary friction welding on a friction welding machines. The main process parameters was rotational speed (1250, 1800, 2500rpm). Microstructure, micro hardness and bending strength were performed and tests were evaluated. It was found in microstructure test that the best microstructure was found at 2500rpm rotational speed as compared to others rotational speeds, also three different zones were found at the weld interface i.e. unaffected zone, deformed zone and fully deformed zone. Micro hardness was also found out to be maximum at 2500rpm rotational speed. Hardness also increased due to decrease in grain size during plastic deformation bending strength was minimum at 1250rpm and maximum at 2500rpm.

Billel cheniti et al.(2019) investigated micro structural changes of AISI 3042/c-CO cermet during rotary friction welding. The process parameters were friction time, upset time and upset pressure. Microstructure, tensile strength facts were performed and results were evaluated. It was found that tensile strength increased at maximum value with increases in forging time and pressure and after it detached maximum value it started decreasing with increases in forging time and

pressure tensile strength was found maximum at friction time. In a microstructure test during the friction time of 4s burn-off was the smallest with the increases in friction time of (12s), burn-off increases to 30%. Also due to higher heat generation flash formation tool. Hence, it started from friction time of 8s which leads to more waste deformation. It was found that micro hardness highest at low friction time as the friction time increases hardness went on decreasing. It was also seen that bonding strength was maximum at 8s during the friction time of (4s) bonding strength was 290 ± 35 MPa and it increased by 75% and reached 525 ± 35 MPa at 8s friction time.

Xun li et al.(2016) investigated mechanical properties of TC4/SUS321 joints by varying rotation speeds, the process was done on a continuous drive direct machine. The main process parameters were friction pressure (150 MPa), burn off length (5mm), upsetting pressure (300 MPa), upsetting time (10 s) and rotation speed (400, 600, 200, 1500, 1800 MPa). Various tests such as micro hardness, tensile strength and microstructure were carried out and results were evaluated. After welding of joints at different speeds it was observed that two regions were formed on TC4 side i.e. dynamic recrystallization zone (DRZ) and thermo-mechanically affected zone (TMAZ) and DRZ was found to be larger on TC4 side also width of DRZ decreases with increase in rotation speed. Max hardness of TC4 was found due to grain refinement obtained at higher rotation speed and on SUS321 side it almost remain unchanged as compared to TC4, max tensile strength was found to 465Mpa at 600rpm rotational speed and also strength decreases when the rotational speed increases above 600 rpm.

Peng Li et al.(2017) experimented rotating friction welding of Copper/Aluminium dissimilar joints and evaluated then, mechanical properties. The process was carried on a continuous drive friction welding machine. Various parameters were set as an upsetting pressure, friction speed, upsetting time, and friction pressure time. IT was seen that flash produced was at lower friction pressure (6 MPa) as the friction pressure increases flash also increases and gives better appearance and also seen that heat generation depends on both friction time and friction pressure. The microstructure formed was found out to be strong at friction pressure (12 MPa) and friction time of (12 s). Also the tensile strength of (35 MPa) was found to be max at friction time (12 s) and friction pressure of (12 MPa).

Mumin Sahin(2005) experimented joining of high-speed steel and medium carbon steel by rotating friction welding; the process parameters were friction time, friction pressure, and friction speed. The weld joint was evaluated with different tests that are tensile strength, microstructure, and micro hardness. It was noted that with increases in friction time and friction pressure tensile strength increase and at some particular point strength started decreasing due to further increase in friction time and friction pressure. During the microstructure test it was found that burr was bigger on medium carbon steel side joints. Also it was found that hardness was obtained to be higher in the joints which were not annealed as compared to annealed joints at 650 degree C for 4 hrs. It was also noted that hardness mostly increased in the welding zone.

Mumin Sahin et al.(2007) investigated mechanical Characteristics of AISI1040 which were welded by rotary friction welding on a continuous drive friction welding machine. The main process parameters were rotation speed, friction pressure, friction time, upset time and upset pressure. The weld joint was evaluated with tensile, micro hardness testing. It was noted that tensile strength increases with the increase in friction time and pressure and further started decreasing at some particular point. It was also seen that hardness increases in the horizontal direction at the welding centre and in vertical direction it increases at the end part.

Hazman Sel et al.(2010) investigated various characteristics of mild steel and aluminium by rotary friction welding. The main process parameters were rotational speed and axial force. Hardness, tensile strength tests were done and results were evaluated. It was found that hardness of the joints were lower as compared to their parent metal because of thermal effects of rotary friction welding. The tensile strength was also found to be low at (45 MPa) of joint which was lower than their parent metal. Less tensile strength and hardness was found due to incomplete welding.

P.D Sketchley et al. (2002) experimented rotary friction weld mechanical of Fe3Al based ODS alloys and also found out their Mechanical properties. The parameters were friction force, rotation speed, forge force and displacement. The welds were evaluated with tensile and microstructure testing. It was seen strength of parent metal was not achieved by ODS alloys because the microstructure was irreversible damaged at the bond line. It was also found that there was no difficulty in joining the welds. Also rotary friction welding process is found out to be better than fusion processes in joining the ODS joints.

SongYu-Lai et al.(2008) investigated the distribution of strength on aluminium and nodular cast iron due to rotary friction welding. Welds were obtained by using continuous direct drive machine. The parameters were friction pressure (40 MPa), friction time (6 s), rotational speed (300 rpm), forging pressure (100 MPa) and forging time (3 s). Welds were evaluated with microstructure, tensile strength testing. It was seen that bond strength increased at the interface with increase of radii and after some point it started decreasing with increase of radii. Also it was found that due to intermetallic compound bond strength decreases. At the Central area there is less effect of intermetallic compound because of proper heat input.

A Varis et al.(1998) investigated various characteristics of rotary friction welding of titanium alloy. The main process parameters were friction pressure and friction time. It was noticed that welding conditions increased due to increase of frequency of oscillation, also it is seen that higher frequencies can be obtained at lower friction pressure to have higher power. Larger heat affected zones and higher strength was obtained at lower friction pressure as compared to higher friction pressure. It was also found that welding conditions can be improved at the end of the process by applying forging pressure.

Minjing Wang et al.(2019) experimented rotary friction welding of CuCrZr/316L and also found their mechanical properties. The main process parameters were rotating speed (2500 rpm), friction force (10 kN) and friction time (1.2 s), forge force (10 kN) and forge time (0.3 s). Microstructure, micro hardness and tensile strength tests were performed and results were evaluated. It was seen that mostly the flash was produced on CuCrZr as compared to 316L. It was noted that hardness and tensile strength were increased at the interface because of the aging of as-welded specimen. Also some micro defects were found at the interface.

G.D Wen et al. (2014) experimented rotary friction welding of dissimilar joints Ti-6Al-4V and Ti-6.5 Al-3.5Mo-1.5Zr-0.35i and also found there mechanical properties. The welds were evaluated with microstructure, micro hardness tests. It was seen that two zones were found that is weld zone (WZ) and thermo-mechanically affected zone (TMAZ), also it was seen that there is a large micro structural change occurred due to the martensite present in WZ and grains in TMAZ. Hardness was found to be highest in WZ. A highly durable joint was achieved by rotary friction welding because

the weld line was far away from TC4 side as most of the fatigue failure was obtained on joining dissimilar metals.

Jinglong Li et al. (2014) investigated mechanical properties due to the effect of friction time on Ti6Al4V/SUS321 metals. The main process parameters were friction speed (1900 rpm), friction pressure (184 MPa), upset pressure (330 MPa), friction time (1 - 4 s). It was seen that by increasing friction time from (1 - 4 s), burn off length was increased and also higher tensile strength was obtained at 4sec friction time, mostly the burn off length was found at Ti6AL4V side. Microstructure changes at different friction times, concaved shape was seen at the interface also the dynamic recrystallization zone (Drz) becomes larger with increase in friction time. Hardness of the specimen increases in Drz, also it was found maximum near welded interface. It was also observed that shorter friction time leads to more surface fracture as compared to longer friction time. Also maximum strength was found at 560 MPa at (4 s) friction time.

Amit Handa et al. (2016) experimented the joining of two dissimilar materials AISI304 and 1021 steels by friction welding. The specimens are welded under different friction forces ranges from 75 MPa to 135 MPa and at constant rotational speed of 920 rpm. The tensile strength, torsional strength, impact strength, and micro-hardness tests are performed on the joints. They found that mechanical properties improved at high friction forces and forge pressure. During fractography analysis they observe ductile failures of welds at 120 MPa and 135 MPa axial forces.

CONCLUSIONS

- Important parameters which affect are forge time, forge stress, rubbing time and friction pressure.
- The tensile strength value of welded material at the joint increase with increase in rubbing time and forge stress values.
- The tensile value increase till critical point further it starts declining.
- No harmful emission is discharged during the process.
- The optimal variable must be chosen for the optimum results.
- Process is suitable to weld materials which are considered not suitable for traditional welding technique.

DISCLOSURES STATEMENT

The authors proclaim that there is no dispute on subject of publication of this paper.

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