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A Literature Review of Research on Rotary Friction Welding

Mr. SUSHANT SUKUMAR BHATE
Production Engineering Department
(CAD/CAM/CAE),
K.I.T.'s College of Engineering, Kolhapur (India)

Prof. S. G. BHATWADEKAR
Head of Production Engineering Department,
K.I.T.'s College of Engineering, Kolhapur (India)

Abstract— **Friction welding is an only till date known method to weld similar as well as dissimilar metals. It is an ordinarily used welding process in industries like automobile industries, submarine engineering industries aeronautical industries, and heavy duty industries. In this research paper, review of research papers related to friction welding is done.**

Keywords— **Friction Welding, Dissimilar Metal Welding, Rotary Friction welding.**

I. GENERAL INTRODUCTION

Friction welding is a type of solid state or simply forge welding, where welding takes place by the application of friction between two mating surfaces of metal along with application of pressure. Required heat can be generated by rubbing two metals on each other and the temperature can be elevated to the level where the parts subjected to the friction may be welded together. Friction Welding is a collection of solid state welding processes, where heat is produced by means of mechanical friction between moving and stationary work pieces with the addition of an upsetting force to displace material plastically.

II. TYPES OF FICTION WELDING

A. Linear fiction welding

Linear friction welding (Fig. 1) is so named because the relative motion across the interface is linear, rather than rotary. It is a process of producing high integrity welds with non-melting fusion & little prior surface preparation.

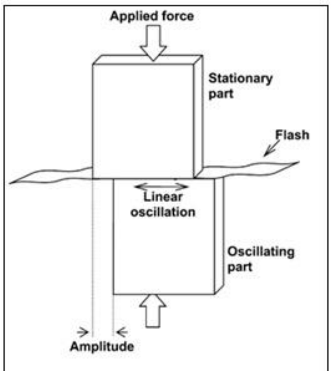

Fig : 1 - Linear Friction Welding

B. Rotary friction welding

Rotary friction welding (Fig. 2) is a type of fiction welding in which one component is rotated against the other, is the most commonly used among the friction welding processes.

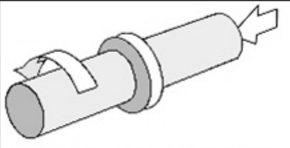

Fig. 2 - Roatary Friction Welding

C. Inertia friction welding

In Inertia Welding (Fig. 3), one of the work pieces is connected to a flywheel and the other held stationary. The flywheel is rotated to a fixed rotational rpm, storing the required kinetic energy. The drive is then disconnected and the work pieces are forced together by the friction welding force. This causes the contacting surfaces to rub together under pressure. Due to which kinetic energy stored in the rotating flywheel generates heat through friction at the weld interface as the speed of flywheel decreases. Then force to generate friction welding may be applied before rotation stops. The force is retained for a fixed time after rotation stops.

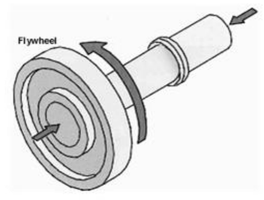

Fig. 3- Inertia Friction Welding

D. Friction surfacing

It is the type of friction welding (Fig. 4) where a layer of coating material is coated on a work piece. Coating material is in the form of rod which is rubbed under pressure on to surface of work piece to form coating.

By moving a workpiece against the face of the rotating rod a plasticized layer of 0.2 to 2.5 mm thick is deposited. This results in creation of composite material demanded by any given application.

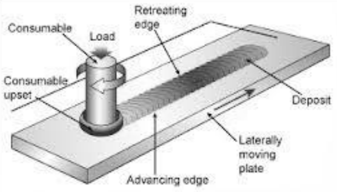

Fig. 4 - Friction Surfacing

E. Friction stir welding

Friction stir welding also produces a required plasticized state of material, but in a different way. A non-consumable rotating tool is held under pressure against the materials to be welded. This tool is like a pin at the center, or probe, followed by the shoulder (Fig. 5). A plastic state material is generated due the heat resulted from friction between tool & materials it is in contact with. As the tool moves along the joint line, material from the front of the tool is cleaned around this plasticized circular region to the rear, so reducing the interface.

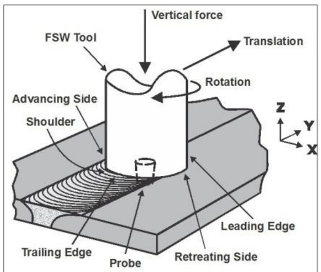

Fig. 5 - Friction Stir Welding

III. ADVANTAGES OF FRICTION WELDING

1. Enables joining of dissimilar materials normally not compatible for welding by other joining methods.
2. Creates narrow, heat-affected zone
3. Consistent and repetitive process
4. Joint preparation is minimal – saw cut surface used most commonly

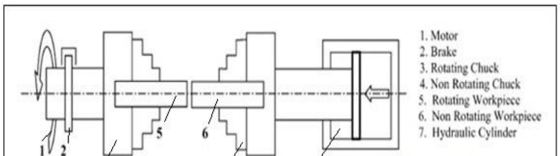

Fig 6 - Schematic Set-up

5. Faster Turn-around Times - compared to the long lead time of forgings.
6. Greatly increases design flexibility – choose appropriate material for each area of a blank
7. Suitable for diverse quantities – from single prototypes to high-volume production
8. No fluxes, filler material, or gases required
9. Environmentally friendly process – no fumes, gases, or smoke generated
10. Solid state process – no possibility of porosity or slag inclusions
11. Creates cast or forge-like blanks – without expensive tooling or minimum quantity requirements
12. Reduces machining labor, thereby reducing perishable tooling costs while increasing capacity
13. Full surface weld gives superior strength in critical areas
14. Reduces raw material costs in bi-metal applications.

IV. WORKING PRINCIPLE

The principle of this process is the changing of mechanical energy into heat energy. One work piece is rotated about its axis while the other work piece to be welded to it is stationary and does not rotate but can be moved axially to make contact with the rotating work piece. The rotation is stopped at the point of fusion and forging pressure is applied axially on to the stationary work piece. The hot work causes refinement of grain structure. Then welding is done, without melting of parent metal.

F. Schematic Set-up

Initially, parts are loaded into the friction welding equipment (Fig. 6). Experienced operators setup the machine for each job to control the 3-step process with a series of parameters unique to each job: Rotational speed, axial force and length. After the three parameters are set, they are recorded and maintained for use all over the entire project. Using this quality attitude ensures continuous consistency for each additional weld produced on the machine. The three steps involved are listed below.

1) Stage 1

One work piece is held in a stationary. The second part is rotated in a spindle, which is then brought up to a pre-defined rotational speed. After the predetermined period of time, pre-defined axial force is applied.

2) Stage 2

These conditions are maintained for a predetermined time. A second step of pressure is applied until the desired temperatures and material state exist. It's during this stage that the two materials are plasticized (become malleable). The green line indicates measurement of "length loss" and triggers the stopping point when the part reaches planned Overall Length.

3) Stage 3

Rotational speed is stopped. Then increased axial force is applied to create "forge pressure" for another predetermined time - completing the weld. This provides grain refinement and molecular bonding through the weld zone.

V. OBJECTIVES OF THE REVIEW

Following are the objectives of the literature review.

a) To study work done in the area of friction welding by different researchers.

b) To study their findings.

c) To identify the research issues.

VI. SCHEME OF REVIEW:

Total 10 papers collected are between the periods of 2003 to 2013 of various journals such as Journals of material processing technology.

VII. LITERATURE REVIEW

Sahin et al., [1] have studied friction welding of plastically deformed steel bars. They worked on continuous drive friction welding of same material but different diameters bars. They used carburizing steel for that purpose.

Mumin Sahin, [2] have worked on computer program simulation of how weld flashes occur in welded joints of equal or different diameter of AISI 1040 (Medium carbon steel). He investigated that the optimum welding parameters obtained from equal diameter parts cannot be used in welding of parts that have different diameter and width. As a result, in welding of parts having different diameter and width, the optimum parameters of the joints should be ordinary selected in the experiments.

Mumin Sahin, [3] have worked on friction welding of high speed steel (HSS—S 6-5-2) and medium carbon steel (AISI 1040) (both of 10 mm dia.). He investigated optimum welding parameters for these combinations of metals. Also, he finds that the tensile strength of welded part is close to that of medium carbon steel (AISI 1040).i. e. the part having weaked of medium carbon steel (AISI 1040).

Satyanarayana et al., [4] have carried out a study on continuous drive friction welding of austenitic-ferritic stainless steel. The parent metal used for that study was AISI 304 austenitic stainless steel and AISI 430 ferritic stainless steel. He used ANOVA technic of Yate's algorithm to analyze the results obtained by experiments.

Meshram et al., [5] conducted an investigation of dissimilar metal joining combinations: Cu–Ni, Fe–Cu, Fe–Ti, Cu–Ni Fe–Ni and Cu–Ti. They observed the influence of interaction time on microstructure and tensile properties of the friction welding of five dissimilar metal combinations.

Moat et al., [6] have studied Microstructural variation across inertia friction welded SCMV (high strength low alloy Cr–Mo steel) and Aermet 100 (ultra-high strength secondary hardening steel). They carried out micro-hardness testing and hard X-ray diffraction mapping on inertia friction welded samples of SCMV steel and super high strength Aermet 100 steel in the as-welded post-weld heat-treated condition.

Dey et al. [7] chose titanium (18 mm dia. & 100 mm length) and 304L stainless (14 mm dia. & 100 mm length) steel to weld by continuous drive friction welding. During this work they have investigated optimum friction welding parameters that produce joints that are stronger than the Ti base material as confirmed by tensile test, and tensile test failure occurred in the Ti base material. As-welded bend test samples failed with almost zero bend ductility. The bend ductility was improved to 5° PWHT (Post weld heat treatment). Corrosion test showed corrosion rate of 10 mpy (milli-inch per year) with boiling nitric acid.

Seli et al., [8] have studied mechanical properties of mild steel and aluminum welded rods to understand the thermal effects. They used an explicit one-dimensional finite difference method to approximate the heating and cooling temperature distribution of the joint. They observed thermal effects of the friction welding to have lowered the welded materials hardness compared to the parent materials.

Winiczenko et al., [9] have investigated friction welding of ductile iron with stainless steel (both 20 mm dia. & 100 mm length). They used stainless steel interlayer in two ductile iron bars to weld it by continuous drive friction welding.

Udayakumar et al., [10] have carried out experimental investigation of mechanical and metallurgical properties of super duplex stainless steel bars welded by friction welding. They carried experiments on specimens of super austenitic stainless steel (UNS S32760) of 16 mm diameters and 100 mm length. A four factor, three level central composite designs (CCD) was used to determine optimal factors of friction welding process of super duplex stainless steel.

VIII. RESEARCH ISSUES IDENTIFIED

From the literature review following research findings are observed,

- Weld quality can be checked by tensile test, fatigue test, impact test, microstructure test, hardness test.
- Weld quality can be improved by [4]
  - i. Optimization of weld parameters
  - ii. Use of interlayer,
  - iii. Changing geometric shape,
  - iv. Pre and/or post processing.
- Weld friction parameters [1]:
  - v. Friction pressure,
  - vi. Friction time,
  - vii. Upset pressure,
  - viii. Upset time,
  - ix. Rotational speed.
- All forgeable varieties of engineering metals can be friction welded. [4]

From the literature review following research issues are identified and are summarized as below,

- It is necessary to optimize the friction welding process parameters to get good weld strength and weld geometry. (welding parameters: Friction time, friction pressure, upset pressure, upset time, rotational speed) [4]
- Optimization of above parameters is highly material specific.
- Parameter optimization of aluminum and low carbon steel is not yet reported.
- The optimum welding parameters that obtained from equal diameters parts could not be used in welding of different diameters parts.

IX. CONCLUSION AND FUTURE SCOPE

The process of friction welding of dissimilar welding is much different than conventional fusion welding process. Result of variation in parameters of friction welding process on the weld strength and weld geometry is needs to be studied. There is a good scope for studying the performance of continuous drive friction welding of aluminium and low carbon welding.

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