

Chapter 27 and 29



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CHAPTER 27 & 29 INTRODUCTION TO WELDING & FUSION WELDING PROCESS

Dr. Tasnim Firdaus Ariff Welding Fundamentals Overview of Welding

Technology 2. The Weld Joint 3. Features of a Fusion Welded Joint 1. 2 Joining

and Assembly Distinguished Joining - welding, brazing, soldering, and

adhesive bonding i,— These processes form a permanent joint between parts

Assembly - mechanical methods (usually) of fastening parts together i,—

Some of these methods allow for easy disassembly, while others do not 3

Welding Joining process in which two (or more) parts are coalesced at their

contacting surfaces by application of heat and/or pressure i,— Many welding

processes are accomplished by heat alone, with no pressure applied i,—

Others by a combination of heat and pressure i,— Still others by pressure

alone with no external heat i,— In some welding processes a filler material is

added to facilitate coalescence 4 Limitations and Drawbacks of Welding Most

welding operations are performed manually and are expensive in terms of

labor cost i,— Most welding processes utilize high energy and are inherently

dangerous i,— Welded joints do not allow for convenient disassembly i,—

Welded joints can have quality defects that are difficult to detect i,— 5 Types

of Welding Processes Some 50 different types of welding processes have

been catalogued by the American Welding Society (AWS) i,— Welding

processes can be divided into two major categories: i,— i,— Fusion welding

i,— Solid state welding 6 Five Types of Joints 1. 2. 3. 4. 5. 7 Butt joint Corner

joint Lap joint Tee joint Edge joint Butt Joint Parts lie in same plane and are

joined at their edges Figure 30. 2 Five basic types of joints: (a) butt Corner

Joint Parts in a corner joint form a right angle and are joined at the corner of

the angle Figure 30. 2 (b) corner Lap Joint Consists of two overlapping parts

Figure 30. 2 (c) lap Tee Joint One part is perpendicular to the other in the

approximate shape of the letter "T" Figure 30. 2 (d) tee Edge Joint Parts in an edge joint are parallel with at least one of their edges in common, and the joint is made at the common edge(s) Figure 30. 2 (e) edge Types of Welds Each of the preceding joints can be made by welding;— Other joining processes can also be used for some of the joint types;— There is a difference between joint type and the way it is welded - the weld type;— 13 Fillet Weld;— Used to fill in the edges of plates created by corner, lap, and tee joints;— Filler metal used to provide cross section in approximate shape of a right triangle;— Most common weld type in arc and oxyfuel welding;— Requires minimum edge preparation Figure 30. 3 Various forms of fillet welds: (a) inside single fillet corner joint; (b) outside single fillet corner joint; (c) double fillet lap joint; and (d) double fillet tee joint. Dashed lines show the original part edges. 14 Groove Welds;— Usually requires part edges to be shaped into a groove to facilitate weld penetration;— Edge preparation increases cost of parts fabrication;— Grooved shapes include square, bevel, V, U, and J, in single or double sides;— Most closely associated with butt joints Figure 30. 4 Some groove welds: (a) square groove weld, one side; (b) single bevel groove weld; (c) single V-groove weld; (d) single U-groove weld; (e) single J-groove weld; (f) double V-groove weld for thicker sections. Dashed lines show original part edges. 15 Spot Weld Fused section between surfaces of two plates;— Used for lap joints;— Closely associated with resistance welding Figure 30. 6 (a) Spot weld Welding Methods and Procedures 1. 2. 3. 4. 5. 6. 7. 8. 17 Arc Welding Resistance Welding Oxyfuel Gas Welding Other Fusion Welding Processes Solid State Welding Weld Quality Weldability Design Considerations in Welding Two Categories of Welding Processes;— Fusion welding - coalescence is accomplished by

melting the two parts to be joined, in some cases adding filler metal to the joint

Examples: arc welding, resistance spot welding, oxyfuel gas welding

Solid state welding - heat and/or pressure are used to achieve coalescence, but no melting of base metals occurs and no filler metal is added

Examples: forge welding, diffusion welding, friction welding

18 Arc Welding (AW)

A fusion welding process in which coalescence of the metals is achieved by the heat from an electric arc between an electrode and the work

Electric energy from the arc produces temperatures ~ 10,000 F (5500 C), hot enough to melt any metal

Most AW processes add filler metal to increase volume and strength of weld joint

19 What is an Electric Arc?

An electric arc is a discharge of electric current across a gap in a circuit

It is sustained by an ionized column of gas (plasma) through which the current flows

To initiate the arc in AW electrode is brought into contact with work and then quickly separated from it by a short distance

20 Arc Welding

A pool of molten metal is formed near electrode tip, and as electrode is moved along joint, molten weld pool solidifies in its wake

Figure 31. 1 Basic configuration of an arc welding process.

21 Two Basic Types of AW Electrodes

Consumable — consumed during welding process

Source of filler metal in arc welding

Welding rods (a. k. a. sticks) are 9 to 18 inches and 3/8 inch or less in diameter and must be changed frequently

Weld wire can be continuously fed from spools with long lengths of wire, avoiding frequent interruptions

Nonconsumable — not consumed during welding process

Filler metal must be added separately

Made of tungsten which resists melting

Gradually depleted during welding (vaporization is principal mechanism)

Any filler metal must be supplied by a separate wire fed into weld pool

22 Power Source in Arc Welding

Direct current (DC) vs. Alternating current (AC) – AC machines less expensive to purchase and operate, but generally restricted to ferrous metals – DC equipment can be used on all metals and is generally noted for better arc control

23 Consumable Electrode Arc Welding Processes

- Shielded Metal Arc Welding (SMAW) Uses a consumable electrode consisting of a filler metal rod coated with chemicals that provide flux and shielding – Sometimes called "stick welding" – Power supply, connecting cables, and electrode holder available for a few thousand dollars
- Welding Stick in SMAW Composition of filler metal usually close to base metal – Coating: powdered cellulose mixed with oxides, carbonates, and other ingredients, held together by a silicate binder – Welding stick is clamped in electrode holder connected to power source – Disadvantages of stick welding: – Sticks must be periodically changed – High current levels may melt coating prematurely
- SMAW Applications Used for steels, stainless steels, cast irons, and certain nonferrous alloys – Not used or rarely used for aluminum and its alloys, copper alloys, and titanium
- Gas Metal Arc Welding (GMAW) Uses a consumable bare metal wire as electrode and shielding accomplished by flooding arc with a gas – Wire is fed continuously and automatically from a spool through the welding gun – Shielding gases include inert gases such as argon and helium for aluminum welding, and active gases such as CO₂ for steel welding – Bare electrode wire plus shielding gases eliminate slag on weld bead - no need for manual grinding and cleaning of slag

28 Gas Metal Arc Welding

31. 4 Gas metal arc welding (GMAW). 29 GMAW Advantages over SMAW

- Better arc time because of continuous wire

electrode sticks must be periodically changed in SMAW Better use of electrode filler metal than SMAW End of stick cannot be used in SMAW Higher deposition rates Eliminates problem of slag removal Can be readily automated

30 Flux-Cored Arc Welding (FCAW) Adaptation of shielded metal arc welding, to overcome limitations of stick electrodes Electrode is a continuous consumable tubing (in coils) containing flux and other ingredients (e. g., alloying elements) in its core Two versions: Self-shielded FCAW - core includes compounds that produce shielding gases Gas-shielded FCAW - uses externally applied shielding gases

31 Flux-Cored Arc Welding Figure 31. 6 Flux-cored arc welding. Presence or absence of externally supplied shielding gas distinguishes the two types: (1) self-shielded, in which core provides ingredients for shielding, and (2) gas-shielded, which uses external shielding gases.

32 Electrogas Welding (EGW) Uses a continuous consumable electrode, either flux-cored wire or bare wire with externally supplied shielding gases, and molding shoes to contain molten metal When flux-cored electrode wire is used and no external gases are supplied, then special case of self-shielded FCAW When a bare electrode wire used with shielding gases from external source, then special case of GMAW

33 Electrogas Welding Figure 31. 7 Electrogas welding using flux-cored electrode wire: (a) front view with molding shoe removed for clarity, and (b) side view showing molding shoes on both sides.

34 Submerged Arc Welding (SAW) Uses a continuous, consumable bare wire electrode, with arc shielding provided by a cover of granular flux Electrode wire is fed automatically from a coil Flux introduced into joint slightly ahead of arc by gravity from a hopper Completely submerges operation, preventing sparks, spatter, and radiation

35 SAW Applications and

Products
 36 Steel fabrication of structural shapes (e. g., I-beams) Seams for large diameter pipes, tanks, and pressure vessels Welded components for heavy machinery Most steels (except hi C steel) Not good for nonferrous metals
 Nonconsumable Electrode Processes
 Gas Tungsten Arc Welding
 Plasma Arc Welding
 Carbon Arc Welding
 Stud Welding
 37 Gas Tungsten Arc Welding (GTAW) Uses a nonconsumable tungsten electrode and an inert gas for arc shielding
 A. k. a. Tungsten Inert Gas (TIG) welding
 In Europe, called " WIG welding"
 Used with or without a filler metal
 When filler metal used, it is added to weld pool from separate rod or wire
 38 Melting point of tungsten = 3410 C (6170 F)
 Applications: aluminum and stainless steel most common
 Advantages / Disadvantages of GTAW
 Advantages:
 High quality welds for suitable applications
 No spatter because no filler metal through arc
 Little or no post-weld cleaning because no flux
 Disadvantages:
 Generally slower and more costly than consumable electrode AW processes
 39 Plasma Arc Welding (PAW) Special form of GTAW in which a constricted plasma arc is directed at weld area
 40 Tungsten electrode is contained in a nozzle that focuses a high velocity stream of inert gas (argon) into arc region to form a high velocity, intensely hot plasma arc stream
 Temperatures in PAW reach 28, 000 C (50, 000 F), due to construction of arc, producing a plasma jet of small diameter and very high energy density
 Advantages / Disadvantages of PAW
 Advantages:
 Good arc stability
 Better penetration control than other AW
 High travel speeds
 Excellent weld quality
 Can be used to weld almost any metals
 Disadvantages:
 High equipment cost
 Larger torch size than other AW
 Tends to restrict access in some joints
 41 Resistance Welding (RW) A group of fusion welding

processes that use a combination of heat and pressure to accomplish coalescence

- Heat generated by electrical resistance to current flow at junction to be welded
- Principal RW process is resistance spot welding (RSW)

42 Advantages / Drawbacks of RW

Advantages:

- No filler metal required
- High production rates possible
- Lends itself to mechanization and automation
- Lower operator skill level than for arc welding
- Good repeatability and reliability

Disadvantages:

- High initial equipment cost
- Limited to lap joints for most RW processes

43 Resistance Spot Welding (RSW)

Resistance welding process in which fusion of faying surfaces of a lap joint is achieved at one location by opposing electrodes

- Used to join sheet metal parts using a series of spot welds
- Widely used in mass production of automobiles, appliances, metal furniture, and other products made of sheet metal
- Typical car body has ~ 10,000 spot welds
- Annual production of automobiles in the world is measured in tens of millions of units

44 Spot Welding Cycle

Figure 31. 13 (a) Spot welding cycle, (b) plot of squeezing force & current in cycle

- (1) parts inserted between electrodes,
- (2) electrodes close, force applied,
- (3) current on,
- (4) current off,
- (5) electrodes opened.

45 Resistance Seam Welding (RSEW)

Uses rotating wheel electrodes to produce a series of overlapping spot welds along lap joint

- Can produce air-tight joints
- Applications:
 - Gasoline tanks
 - Automobile mufflers
 - Various other sheet metal containers

46 Resistance Projection Welding (RPW)

A resistance welding process in which coalescence occurs at one or more small contact points on parts

- Contact points determined by design of parts to be joined
- May consist of projections, embossments, or localized intersections of parts

47 Cross-Wire Welding

Figure 31. 18 (b) cross-wire welding.

48 Oxyfuel Gas Welding (OFW)

Group of

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fusion welding operations that burn various fuels mixed with oxygen. OFW employs several types of gases, which is the primary distinction among the members of this group. Oxyfuel gas is also used in flame cutting torches to cut and separate metal plates and other parts. Most important OFW process is oxyacetylene welding.

49 Oxyacetylene Welding (OAW)

Fusion welding performed by a high temperature flame from combustion of acetylene and oxygen. Flame is directed by a welding torch. Filler metal is sometimes added. Composition must be similar to base metal. Filler rod often coated with flux to clean surfaces and prevent oxidation.

50 Acetylene (C₂H₂)

Most popular fuel among OFW group because it is capable of higher temperatures than any other - up to 3480 C (6300 F). Two stage chemical reaction of acetylene and oxygen:

- First stage reaction (inner cone of flame): $C_2H_2 + O_2 \rightarrow 2CO + H_2 + \text{heat}$
- Second stage reaction (outer envelope): $2CO + H_2 + 1.5O_2 \rightarrow 2CO_2 + H_2O + \text{heat}$

51 Oxyacetylene Torch

Maximum temperature reached at tip of inner cone, while outer envelope spreads out and shields work surfaces from atmosphere.

Figure 31.22 The neutral flame from an oxyacetylene torch indicating temperatures achieved.

52 Safety Issue in OAW

Together, acetylene and oxygen are highly flammable. C₂H₂ is colorless and odorless. It is therefore processed to have characteristic garlic odor.

53 Other Fusion Welding Processes

FW processes that cannot be classified as arc, resistance, or oxyfuel welding. Use unique technologies to develop heat for melting. Applications are typically unique. Processes include:

- Electron beam welding
- Laser beam welding
- Electroslag welding
- Thermit welding

54 Electron Beam Welding (EBW)

Fusion welding process in which heat for welding is provided by a highly-focused, high-

intensity stream of electrons striking work surface

- Electron beam gun operates at:
 - High voltage (e. g., 10 to 150 kV typical) to accelerate electrons
 - Beam currents are low (measured in milliamps)

55 Three Vacuum Levels in EBW

- High-vacuum welding — welding done in same vacuum chamber as beam generation
- Highest quality weld
- Medium-vacuum welding — welding done in separate chamber with partial vacuum
- Vacuum pump-down time reduced
- Non-vacuum welding — welding done at or near atmospheric pressure, with work positioned close to electron beam generator
- Vacuum divider required to separate work from beam generator

56 EBW Advantages / Disadvantages

Advantages:

- High-quality welds, deep and narrow profiles
- Limited heat affected zone, low thermal distortion
- High welding speeds
- No flux or shielding gases needed

Disadvantages:

- High equipment cost
- Precise joint preparation & alignment required
- Vacuum chamber required
- Safety concern: EBW generates x-rays

57 Laser Beam Welding (LBW) Fusion welding process in which coalescence is achieved by energy of a highly concentrated, coherent light beam focused on joint

- Laser = "light amplification by stimulated emission of radiation"
- LBW normally performed with shielding gases to prevent oxidation
- Filler metal not usually added
- High power density in small area, so LBW often used for small parts

58 Comparison: LBW vs. EBW

- No vacuum chamber required for LBW
- No x-rays emitted in LBW
- Laser beams can be focused and directed by optical lenses and mirrors
- LBW not capable of the deep welds and high depth-to-width ratios of EBW
- Maximum LBW depth = ~ 19 mm (3/4 in), whereas EBW depths = 50 mm (2 in)

59 Thermit Welding (TW) FW process in which heat for coalescence is produced by superheated molten metal from the chemical

reaction of thermite is, — Thermite = mixture of Al and Fe_3O_4 fine powders that produce an exothermic reaction when ignited is, — Also used for incendiary bombs is, — Filler metal obtained from liquid metal is, — Process used for joining, but has more in common with casting than welding 60

Thermit Welding Figure 31. 25 Thermit welding: (1) Thermit ignited; (2) crucible tapped, superheated metal flows into mold; (3) metal solidifies to produce weld joint. 61 TW Applications Joining of railroad rails is, — Repair of cracks in large steel castings and forgings is, — Weld surface is often smooth enough that no finishing is required is, — 62