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TECHNICAL NOTE

On Cold-Formed Steel Construction

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WELDING COLD-FORMED STEEL

<u>This Technical Note updates and replaces LGSEA Technical Note 560-b1</u>

Summary: In cold-formed steel construction, welding is a viable connection method. Of the various forms of welding, arc welding is most commonly used to join both cold-formed steel members and hardware components. Prefabrication of roof trusses, panelization of walls, and hardware connections are all ideal applications where welding may be the preferred joining method. This Tech Note provides information on the applicable codes, processes, procedures, design considerations, fabrication and inspection.

INTRODUCTION

Welds used to connect cold-formed steel may be either arc welds or resistance welds. In building construction, however, welds are generally made using the arc welding process. Resistance welds are commonly used for connecting thin sheet steels in the automotive or appliance industries. Arc welding is the process of fusing material together by an electric arc, usually with the addition of weld filler metal.

The design of welds for cold-formed steel construction is typically governed by the *North American Specification for the Design of Cold-Formed Steel Structural Members* (AISI S100-07) and the *Structural Welding Code – Sheet Steel* (AWS D1.3 2008). Both AISI and AWS documents contain requirements for the following types of welds: (1) groove weld, (2) arc spot weld (puddle weld), (3) arc seam weld, (4) fillet weld, (5) flare groove weld and (6) plug weld.

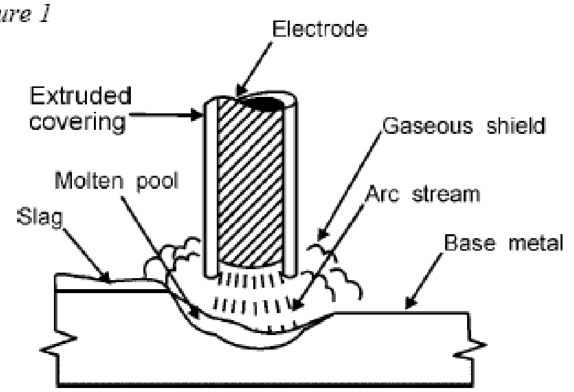
The most common weld type to connect sheet-to-sheet or sheet-to-thicker member is the fillet weld. Groove welds are commonly used during the roll-forming process to connect flat sheet of one coil to the next coil. Arc spot welds, also called puddle welds, are used extensively to attach deck and panels to bar joists or hot-rolled shapes.

AISI S100 stipulates that arc welds on steel where at least one of the connected parts is equal to or less than 3/16 inch in nominal thickness shall be made in accordance with AWS D1.3. The AWS D1.3 welding code provides requirements for the following: prequalification of WPS (Welding Procedure Specifications), qualification/preparation of WPS, fabrication of a welded connection and inspection of a weld.

WELDING PROCESSES

AWS D1.3 defines welding electrodes that appropriately match the strength of the approved base metals. The welding code lists the following as approved welding processes: shielded metal arc welding (SMAW), gas metal arc welding (GMAW), flux cored arc welding (FCAW), gas tungsten arc welding (GTAW), and submerged arc welding (SAW).

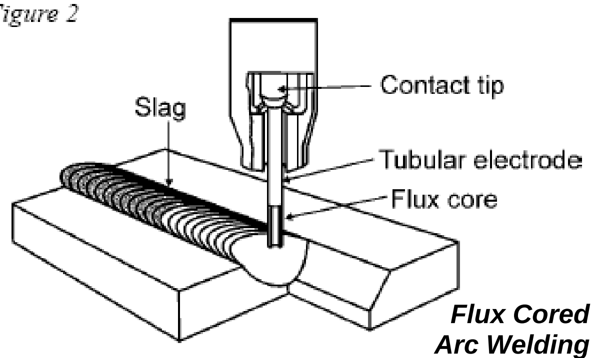
Figure 1



Shielded Metal Arc (SMAW)

Shielded metal arc welding (Fig. 1), commonly known as stick electrode welding or manual welding, is the oldest of the arc welding processes and is characterized by versatility, simplicity and flexibility. The SMAW process commonly is used for tack welding, fabrication of miscellaneous components, and repair welding. SMAW has earned a reputation for depositing high quality welds dependably. It is, however, slower and more costly than other methods of welding, and is more dependent on op-

Figure 2



Flux Cored Arc Welding

erator skill for high quality welds and is difficult to use on thin materials.

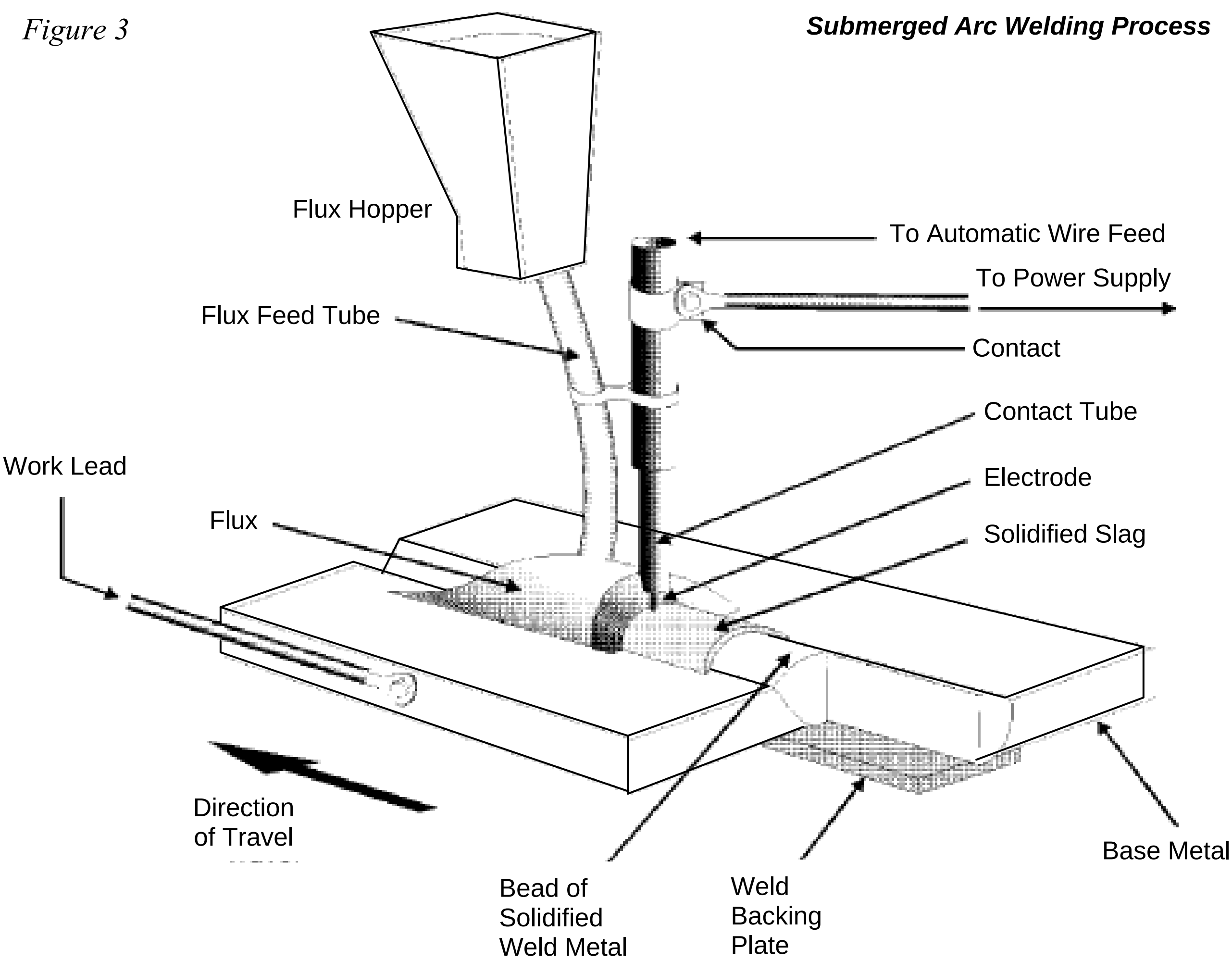
Flux Cored Arc Welding (FCAW)

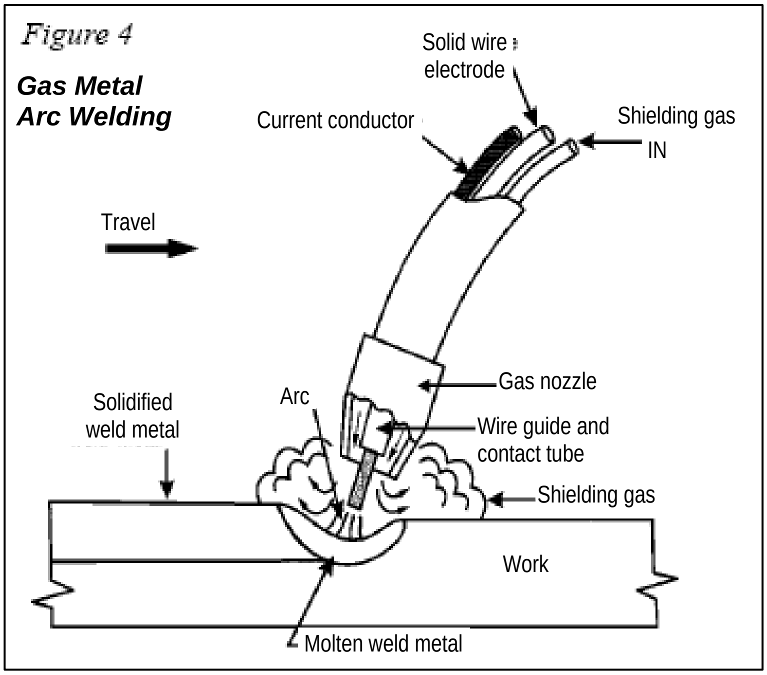
The flux cored arc welding process (Fig. 2) offers two distinct advantages over shielded metal arc welding. First, the electrode is continuous. This eliminates the built-in starts and stops that are inevitable with shielded metal arc welding. Not only does this have an economic advantage because the operating factor is raised, but the number of arc starts and stops, a potential source of weld discontinuities, is reduced. Another major advantage is that increased amperages can be used with flux cored arc welding, with a corresponding increase in deposition rate and productivity. Several .035 and .045-inch diameter electrodes are specifically designed for welding galvanized sheet steel.

Submerged Arc Welding (SAW)

Submerged arc welding (Fig. 3) differs from other arc welding processes in that a layer of fusible granular material called flux is used for shielding the arc and the molten metal. The arc is struck between the work piece and a bare wire electrode, the tip of which is submerged in the flux. Since the arc is completely covered by the flux, it is not visible and the weld is made without the flash, spatter, and sparks that characterize the open-arc processes. The nature of the flux is such that very little smoke or visible fumes are released to the air. SAW is typically not used for thin material unless the process is automated.

Figure 3 ***Submerged Arc Welding Process***





Gas Tungsten Arc Welding (GTAW)

Gas tungsten arc welding (Fig. 5) or tungsten inert gas (TIG), as it is some times known, is a process where coalescence is produced by heating with an arc between a tungsten electrode and the base metal. The hot tungsten electrode, arc, and weld pool are shielded by an inert gas or mixture of inert gases. Filler metal may be added, if needed, by feeding a filler rod into the weld pool either manually or automatically. The weld quality is high, however, GTAW is usually not used for production since it takes more time to produce a weld than any other method.

Gas Metal Arc Welding (GMAW)

Gas metal arc welding (Fig. 4) utilizes equipment much like that used in flux cored arc welding. Indeed, the two processes are very similar, except GMAW uses a solid or metal cored electrode and leaves no appreciable amount of residual slag. Gas metal arc has been a popular method of welding in the fabrication shop and is ideal for sheet steel. However, GMAW is not generally used in the field due to the potential loss of shielding gas. A variety of shielding gases or gas mixtures may be used. Carbon dioxide (CO_2) is the lowest cost gas, and while acceptable for welding carbon steel, the gas is not inert but active at elevated temperatures. This has given rise to the term MAG (metal active gas) for the process when (CO_2) is used, and MIG (metal inert gas) when predominantly argon-based mixtures are used.

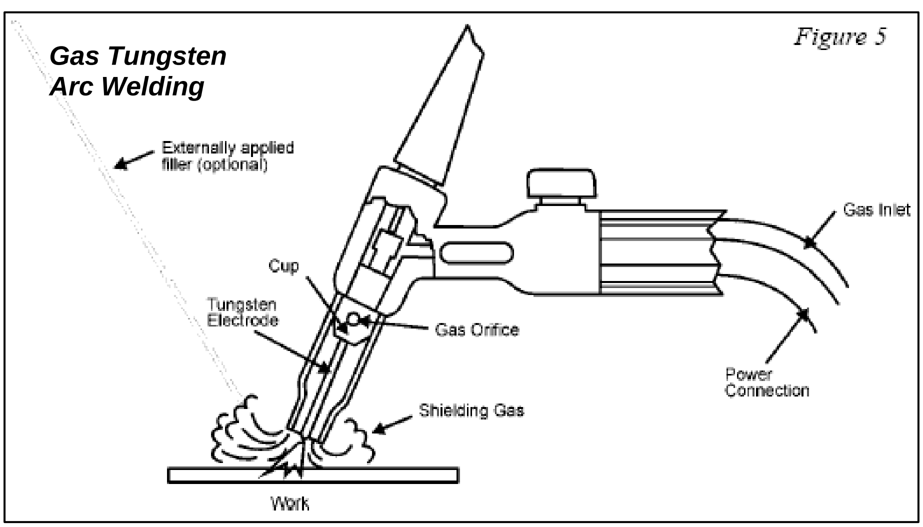
FABRICATION

AWS D1.3 stipulates that the surfaces to be welded shall be smooth, uniform, and free of imperfections. Also, surfaces to be welded and surfaces adjacent to a weld shall be free of loose scale, slag, rust, moisture, grease or other foreign material that would prevent proper welding or produce objectionable fumes. When welding galvanized sheet, suitable ventilation shall be provided. Also, welding of sheet steels shall not be done when the ambient temperature is lower than 0° F, when the surfaces are wet, or when the welder is exposed to inclement weather. The parts to be joined shall be brought into close contact to facilitate complete fusion. The closeness of the two parts can not be over-emphasized, especially for arc spot welds. If any gap exists between the members prior to spot welding, the strength of the weld may be substantially reduced. Also, to obtain consistently sound welds, the welding current must be controlled.

Qualification

Prequalified Welding Procedure Specifications (WPSs), which are exempt from WPS qualification tests, can be established based on the applicable welding code provisions in AWS D1.3. A WPS is a written set of instructions that defines the joint details, welding electrodes, base metals, electrical parameters, and other procedural variables. Any time welding is performed in accordance to AWS D1.3, a written WPSs must be used, even for prequalified WPSs.

When the welding parameters do not conform to the prequalified status, the welding procedure must be qualified by testing. This happens, for instance, when a



base metal other than given on the approved list is used, or when the joint detail does not match one of the prequalified details. A Procedure Qualification Record (PQR) is used to record the actual values of the welding procedure test. After the welded specimens pass the destructive tests, a qualified Welding Procedure Specification can be written. Welding Procedure Specifications are the responsibility of the manufacturer or the contractor. The required tests, test methods, and required results are prescribed by AWS D1.3. Once a contractor has qualified a welding procedure, the procedure shall be considered qualified for its use indefinitely.

Inspection

AWS D1.3 requires only visual inspection of welded sheet steel joints. The visual inspection shall determine compliance with contract documents. Particular emphasis shall be placed on verifying proper location, size, and length of a weld, in addition to the bead shape, reinforcement, and undercut. Inspectors are also responsible for confirming that qualified or prequalified WPSs and qualified welder are used in performing the work.

DESIGN CONSIDERATIONS

Of primary importance to the structural design engineer is the design strength of a welded connection. Strength equations for the six weld types are stipulated by the *North American Specification for the Design of Cold-Formed Steel Structural Members* (AISI S100) which is in general agreement with the *Structural Welding Code – Sheet Steel* (AWS D1.3). The paramount difference between the strength of a welded connection in cold-formed steel and a welded connection in hot-rolled steel is the dominance of sheet tearing as a possible failure mode. Although the design provisions provide guidance on determination of the weld strength, the connection design is often limited by the tearing of the base steel.

The design engineer must also consider workmanship, quality, and inspection when determining if a weld is an appropriate connection method.

For additional information pertaining to the background and application of the S100 equations the reader may refer to Yu and LaBoube (2010).

Design Equations

A design equation is a mathematical relationship that models the failure of a welded connection. The following presents an overview the AISI S100 strength equations for the applicable weld types. AWS D1.3 also provides design equations; however the design equations are based on allowable stress design principles and may not yield the same design strength as AISI S100. It is noteworthy that the 2009 International Building Code (IBC) references AISI S100 for weld connection design.

Arc Seam Weld. (Fig. 6) The behavior of the arc seam weld is similar to the behavior of the arc spot weld. Provisions are provided in AISI S100 for sheet-to-thicker supporting member and sheet-to-sheet connections. Although AISI Section E2.3 prescribes a design equation for the weld strength, the strength of an arc seam weld typically is governed by tearing of the sheet at the perimeter of the weld.

Fillet Weld. (Fig. 7A & 7B) The fillet weld design provisions covered by the AISI Section E2.4 apply to the welding of joints in any position. The welded connection may be either sheet-to-sheet or sheet-to-thicker steel member. AWS D1.3 requires the use of a matching strength electrode; thus the weld material will be of an equal or higher strength than the connecting elements. Also, in a lap joint the leg dimension against the sheet edge will be less than the other leg. This creates a design situation for which the strength of the connection will typically be governed by the tearing of the connected element.

Flare Groove Weld. (Fig. 7C & 7D) AISI Section E2.5 is structured to provide guidance for the design of sheet-to-sheet connections accomplished by either a flare-V groove weld or flare-bevel groove weld, and sheet-to-thicker steel member for a flare-bevel groove weld. The primary failure mode for groove welds is a tearing of the thinner cold-formed steel sheet along the contour of the weld.

Groove Weld. (Fig. 7, E & F) The strength of a groove weld depends on the type and direction of load application. For example, when a groove weld is subjected to either tension or compression normal to the axis of the weld, the strength of a groove weld is defined by the yield strength of the sheets being connected, that is AISI Equation E2.1-1. However, when the weld experiences shear, both the weld strength and the connected sheets must be investigated (AISI Equations E2.1-2 and E2.1-3).

Figure 6: Arc Seam Weld

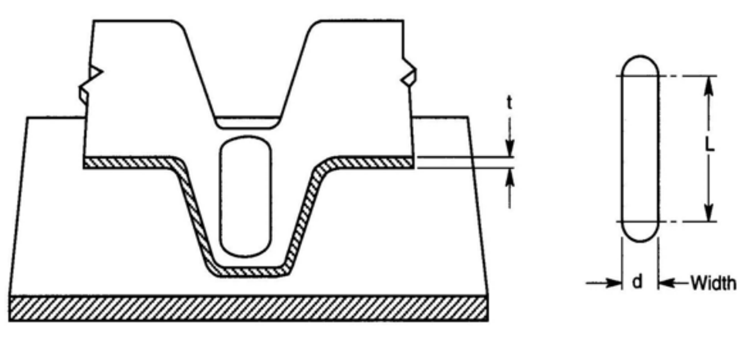
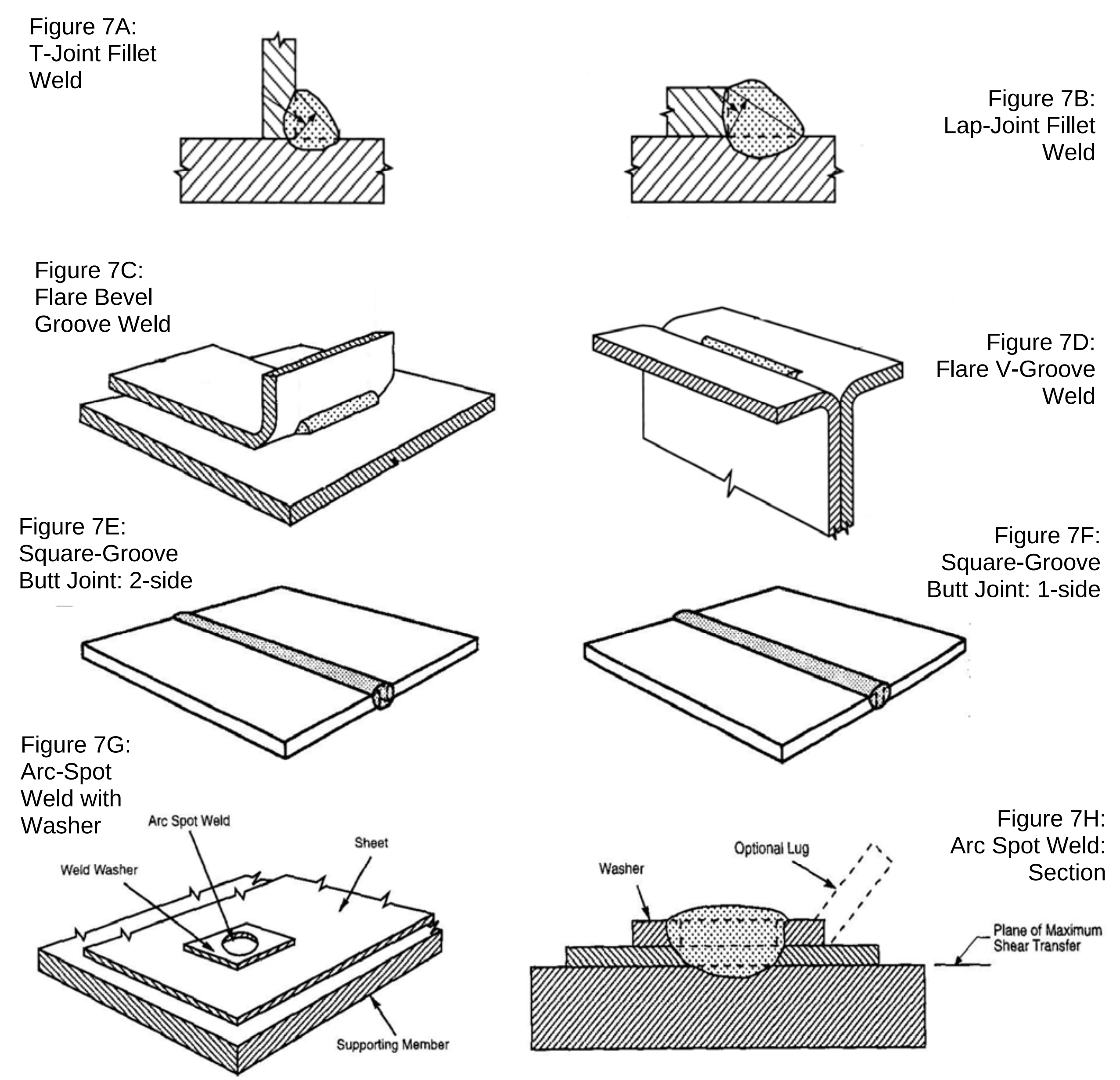


Figure 7: Common Sheet Steel Weld Types



Arc Spot Weld. (Fig. 7G) An arc spot weld is typically made by first melting through the top sheet and fusing the sheets together with the addition of filler metal. Both sheet-to-thicker supporting member and sheet-to-sheet connections are permitted by S100. AISI Section E2.2 summarizes the strength design rules for arc spot welds.

Specifically, Section E2.2.1 addresses the design strength for shear connections whereas Section E2.2.2 provides the design strength provisions for tension connections.

Recently completed research by Stirnemann and LaBoube (2008) provides an interaction equation for combined shear and tension, that appears in the 2010 supplement to AISI S100.

Although strength equations are stated for the weld strength, the primary focus of the design equations is the tearing of the sheet around the perimeter of the weld.

Arc Plug Weld. (Fig. 7G & 7F similar) An arc plug weld is similar to an arc spot weld except that the first sheet has a hole prepared prior to welding. During welding, filler metal is added to fill the hole and fuse the base metals together. The current AISI Specification does not address this type of weld; however, the AWS D1.3 Section 2.2.6 provides design equations which may be used.

Safe Practices

Annex F of AWS D1.3 summarizes safe practices for welding. Arc welding is a safe occupation when sufficient measures are taken to protect the welder from potential hazards. When these measures are overlooked or ignored, welders can encounter such dangers as electric shock, over-exposure to radiation, fumes and gases, and fire and explosion; any of these can result in fatal injuries. Everyone associated with the welding operation should be aware of the potential hazards and ensure that safe practices are employed. Infractions should be reported to the appropriate responsible authority. For specific safety precautions refer to ANSI Z49.1, Safety in Welding, Cutting, and Allied Processes (2005).

References

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