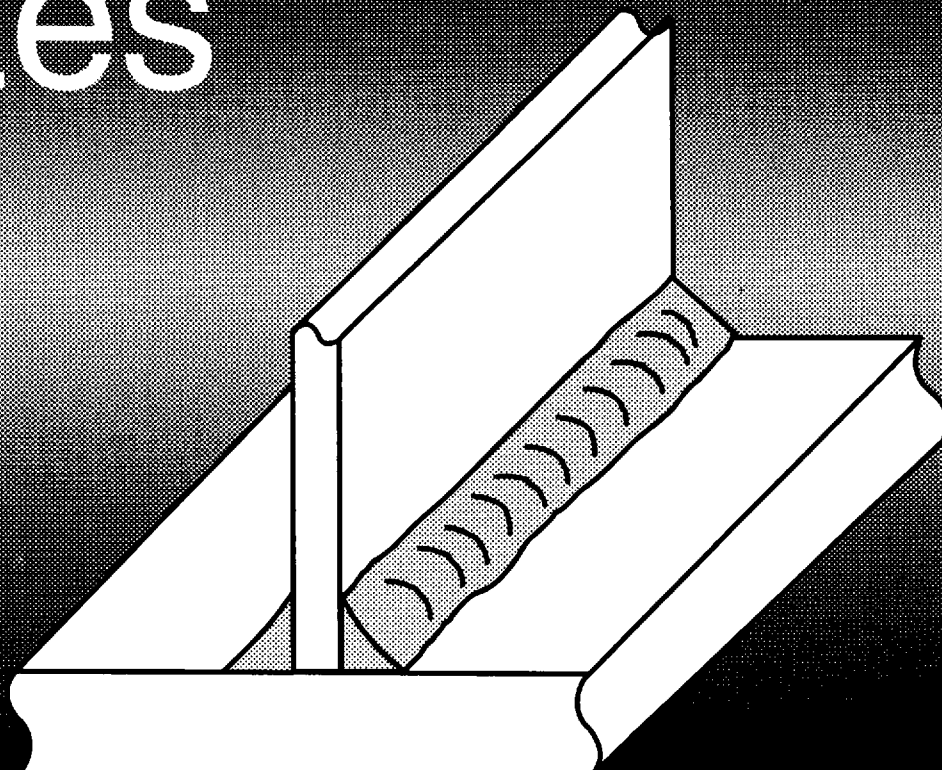




American Welding Society

Design Handbook for Calculating

Fillet Weld Sizes



DESIGN HANDBOOK for CALCULATING FILLET WELD SIZES

**Located, reviewed and reformatted under the
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FOREWORD

The design of a welded connection is usually the first operation in the construction of a welded product. The optimization of the design for the initial manufacturability and the life cycle performance of the component is a challenge to the designer.

Fillet welds are the most common joint designs in the fabrication of many welded products. The use of fillet welds simplifies the material preparation effort and increases the opportunity for using automation in the welding operation.

Traditional designs base the size of the welds on the allowable unit loads that the welds are expected to experience in the intended applications. For sections of different thicknesses, the minimum fillet size can be governed by the thicker member.

While this approach is conservative, the weld sizes may not be the optimum. As the volume of weld metal is severely impacted by the size of the weld, each increase in the specified leg length has a dramatic effect on the amount of welding required.

An alternative system for calculating fillet weld sizes was presented by two researchers. Selection of the correct fillet weld size is essential for the satisfactory performance of many weldments in service today. Fillet welds are used in virtually every industry, and when properly designed, provide effective and efficient connections. An alternate approach to the more traditional design philosophy is the basis for this handbook, and seeks to provide a method for determining the optimum fillet weld size.

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1.0 INTRODUCTION

Selection of the correct fillet weld size is essential for the satisfactory performance of many weldments in service today. Fillet welds are used in virtually every industry, and when properly designed, provide effective and efficient connections.

Traditional designs base the size of the welds on the allowable unit loads that the welds are expected to experience in the intended applications. For sections of different thicknesses, the minimum fillet size is governed by the thicker member (references 1 and 2).

While this approach is conservative, the weld sizes may not be the optimum. Fillet welds can be too large or too small and it is important to have the correct size for each connection. As the volume of weld metal is severely impacted by the size of the weld, each increase in the specified fillet weld leg length has a dramatic effect on the amount of welding required.

The larger than necessary welds will increase the amount of welding material, reduce the speed of welding, and increase the resultant distortion effects. All of these will have a negative impact on the economy of the work and the overall productivity of the operation.

Similarly, too small fillet welds will not provide the necessary performance for the weldment and will most likely result in repair work being required.

An alternative system for calculating fillet weld sizes was presented by two researchers through reference 3. This approach is the basis for this handbook, and seeks to provide a method for determining the optimum fillet weld size. This document is not a standard.

2.0 DEVELOPMENT OF CRITERIA

As the strength and ductility of fillet welded joints varies as a function of the loading direction, design equations must be developed for both longitudinal and transverse shear loads. It is also fundamentally important that the equations be applicable for a wide range of base materials and filler materials.

It is common for all fillet welds to have a combination of longitudinal shear, Figure 1, and transverse shear, Figure 2. For design purposes, bending moments should be similar to transverse loading on the fillet welds. It is common in structural design for the intercostal member to be the "weaker" member in the joint. For these cases, the longitudinal shear connection need only develop the ultimate shear strength of the intercostal member, and the transverse shear connection must develop the ultimate tensile strength of the intercostal member. When welds are designed for these loading conditions, they are normally adequate for the variety of combinations of shear and tension loads that a member can sustain.

Traditionally, fillet weld size is based upon the thickness of the "weaker" member and two mechanical properties, the ultimate tensile strength of the base material, and the longitudinal shear strength of the weld material. The alternate method, presented in this handbook, requires six equations and four mechanical properties, the same two as before, plus the ultimate shear strength of the base material and the transverse shear strength of the weld material for the intercostal member. A similar set of equations is required for the continuous member.

Calculating Fillet Weld Sizes

For each fillet weld connection, there can be a failure in one of three locations in the weld zone:

1. Failure through the throat (ignoring bead reinforcement or penetration).
2. Failure in the heat affected zone of the intercostal member.
3. Failure in the heat affected zone of the continuous member.

Based upon the geometrical relationships and the two directions of loading, a series of equations can be developed that will result in a fillet weld size that will provide a load carrying capacity equal to either the intercostal or continuous member, i.e., a 100% efficient weld.

For longitudinal loading:

Failure Location	Intercostal Member	Continuous Member
Weld Throat	$S = \frac{T_I \times U_{SI}}{1.414 U_{LS}}$	$S = \frac{T_C \times U_{SC}}{0.707 U_{LS}}$
HAZ Boundary (Intercostal)	$S = 0.454 T_I$	$S = \frac{T_C \times U_{SC}}{1.1 U_{SI}}$
HAZ Boundary (Continuous)	$S = \frac{T_I \times U_{SI}}{2.2 U_{SC}}$	$S = 0.909 T_C$

For transverse loading:

Failure Location	Intercostal Member	Continuous Member
Weld Throat	$S = \frac{T_I \times U_{TI}}{1.414 U_{TS}}$	$S = \frac{T_C \times U_{SC}}{0.707 U_{TS}}$
HAZ Boundary (Intercostal)	$S = \frac{T_I \times U_{TI}}{2.2 U_{SI}}$	$S = \frac{T_C \times U_{SC}}{1.1 U_{SI}}$
HAZ Boundary (Continuous)	$S = \frac{T_I \times U_{TI}}{2.0 U_{TC}}$	$S = \frac{T_C \times U_{SC}}{U_{TC}}$

Where:

- S** = Fillet Weld Size
T_I = Thickness of Intercostal Member
T_C = Thickness of Continuous Member
U_{TI} = Ultimate Tensile Strength of Intercostal Member
U_{LS} = Longitudinal Shear Strength of Weld Metal
U_{SI} = Shear Strength of Intercostal Member
U_{TS} = Transverse Shear Strength of Weld Metal
U_{TC} = Ultimate Tensile Strength of Continuous Member
U_{SC} = Shear Strength of Continuous Member

3.0 DEVELOPMENT OF FILLET WELD SIZES

Tables 1 and 2 provide the mechanical properties required to solve the various equations. References 4, 5, and 6 are the sources for the majority of the values. For the base materials that do not have published values for shear strength the following conservative estimates have been made:

$$\text{Shear strength} = 0.75 \times \text{tensile strength (steels)}$$

$$\text{Shear strength} = 0.60 \times \text{tensile strength (aluminum)}$$

Similarly, for the filler material values, selected data is not readily available, so mathematical relationships have been used to complete the table. As documented in reference 3, a conservative value for filler metal transverse shear strength is:

$$\text{Transverse shear strength} = 1.33 \times \text{longitudinal shear strength}$$

4.0 FILLET WELD SIZE TABLES

For most designs, the intercostal member is the weakest member of the assembly for both longitudinal and transverse loads. Exceptions to this include, cases where the intercostal member is much thicker than the continuous member or the strength of the intercostal member is much greater than that of the continuous member.

The tables contained in Appendix A specify the minimum fillet weld size required to provide a 100% connection for those cases where the intercostal is the weaker member. The sizes were derived by solving the six equations presented in Section 2.0 for the intercostal member. To be conservative, the largest calculated value has been selected as the required weld size. For convenience, the decimal value has been rounded up to the nearest 1/16 in. dimension.

For example, where the intercostal member is high strength steel, 1/4 in. thick, the continuous member is high strength steel, 1/4 in. thick, and the weld material is E7018,

then:

$$T_I = 1/4 \text{ in.}$$

$$T_C = 1/4 \text{ in.}$$

and from Tables 1 and 2:

$$U_{SI} = 56250$$

$$U_{LS} = 59200$$

$$U_{SC} = 56250$$

$$U_{TI} = 75000$$

$$U_{TS} = 78000$$

$$U_{TC} = 75000$$

$$S_1 = \frac{(1/4) (56250)}{1.414 (59200)} = 0.169$$

Calculating Fillet Weld Sizes

$$S_2 = 0.454 (1/4) = 0.011$$

$$S_3 = \frac{(1/4) (56250)}{2.2 (56250)} = 0.011$$

$$S_4 = \frac{(1/4) (75000)}{1.414 (78000)} = 0.170$$

$$S_5 = \frac{(1/4) (75000)}{2.2 (56250)} = 0.150$$

$$S_6 = \frac{(1/4) (75000)}{2.0 (75000)} = 0.125$$

Therefore, the controlling size is 0.170 or 3/16.

5.0 ASSUMPTIONS

The fillet weld sizes presented in Appendix A are only valid for 100% efficient double continuous fillet welds. For designs that require unequal fillet legs or require skewed fillet weld connections, alternate sources of information are required.

Also, the values presume that the intercostal member will always be the weaker member of the design. As this is true in the great majority of structural designs, the tables have been constructed accordingly. For those designs having the continuous member as the weaker member, the formulas contained in Section 2.0 for the continuous member may be used to calculate the optimum fillet weld size.

The data presented in Appendix A must be used with correct welding procedures. It is understood that the joining of the materials is controlled by an appropriate welding procedure. Considerations of the essential elements of welding procedures, and other essential features required for a specific weld application, are not incorporated in the derivation of the weld tables.

6.0 REFERENCES

1. *Welding Handbook*, Volume 1, Eighth Edition, American Welding Society, 1987.
2. *Welding Handbook*, Volume 5, Seventh Edition, American Welding Society, 1984.
3. "Reduced Fillet Weld Sizes for Naval Ships," R.P. Krumken, Jr. and C.R. Jordan, *Welding Journal*, American Welding Society, April 1984.
4. MIL-STD-1628, *Fillet Weld Size, Strength and Efficiency Determination*, June 1974.
5. "Evaluation of Fillet Weld Shear Strength of FCAW Electrodes," *Welding Journal*, American Welding Society, August 1989.
6. Mare Island Naval Shipyard Technical Report 138-4-80, Revision A, December 1980.

Table 1.

**BASE MATERIAL
STRENGTH
VALUES**

Base Material Type	Minimum Ultimate Tensile Strength (psi)	Shear Strength (psi)
Quenched and Tempered Alloy Steel (HY-100)	114,000	85,500
Quenched and Tempered Alloy Steel (HY-80)	96,000	72,000
High Strength Steel (A588)	75,000	56,250
Ordinary Strength Steel (A36)	60,000	45,000
Austenitic Stainless Steel	75,000	56,250
Nickel Copper Alloy	70,000	46,000
Nickel Chromium Iron	80,000	57,000
Aluminum Alloy 5456	45,000	27,000
Aluminum Alloy 5454	36,000	21,600
Aluminum Alloy 5086	38,000	22,800
Aluminum Alloy 5083	40,000	24,000
Aluminum Alloy 5052	25,000	15,000
Copper Nickel (70/30)	45,000	22,500
Copper Nickel (90/10)	40,000	20,000