5.7 CONTROL OF DISTORTION AND RESIDUAL STRESS

5.7.1 General

In the assembly and joining of parts of a structure or of built-up members and in the welding of reinforcing parts to members, the procedure and sequence shall be such as will maintain distortion and shrinkage within the required structural limits.

NOTES:

1 Guidance distortion and shrinkage is given in AS 3990, AS 4100 and NZS 3404.1.

2 The order in which weld joints and/or weld runs are deposited can have an effect on the residual stress, mechanical properties, hardness, corrosion, distortion, ease of welding, likelihood of defects including lamellar tearing, fatigue and final appearance, and so influence the performance of the final joint. For critical joints, bead placement should be carefully considered by the fabricator when developing the welding procedure specification.

In the making of welds under conditions of severe external shrinkage restraint, the welding shall be carried continuously to completion, or to a point that will ensure freedom from cracking before the joint is allowed to cool below the minimum specified preheating and interrun temperatures.

5.7.2 Stressed parts

Parts that are stressed shall not be cut or welded, except where—

(a) the effect of such actions on the flexural, tensile and compressive capacity of the member is considered;

(b) the matter is discussed between the fabricator and the principal in accordance with Appendix D; and

(c) appropriate safety precautions are taken to prevent damage to or failure of the structure.

NOTE: See the requirements for modification of existing structures in AS 4100 or NZS 3404.1, as appropriate.

5.7.3 Peening

Peening may be used on intermediate weld runs for control of shrinkage stresses in thick welds, to prevent cracking. No peening shall be done on the root or surface layer of the weld or in the base metal at the edges of the weld. Care should be taken to prevent overlapping or cracking of the weld or base metal.

The procedure to be adopted for peening shall be established by the fabricator and approved by the principal prior to use in accordance with Appendix D.

5.7.4 Correction of distortion

Distortion resulting from welding and fabrication may be corrected by mechanical means, heating or the controlled application of weld runs. Where flame-heating methods are applied, the following restrictions shall apply:

(a) Where solid water jets are used for cooling, their use shall be agreed to in accordance with Item (q), Appendix D.

(b) The temperature of steels shall not exceed the tempering temperature less 20°C.

Improperly fitted parts may be cut apart and rewelded provided the procedure is established and approved in accordance with Appendix D.

5.8 BACKGOUGING AND REPAIR OF DEFECTS IN WELDS

5.8.1 General

Where welds are found to have defects as classified by Clause 6.7, either the defects shall be repaired, or the entire weld shall be removed and replaced. Repairing or rewelding shall be carried out in accordance with this Standard, and the principal shall be advised of all such repairs.

5.8.2 Removal of weld metal

Removal of the weld metal or portions of the base metal shall be effected by machining, grinding, chipping, oxygen gouging, air-arc gouging or plasma gouging, in such a manner that the remaining weld metal or base metal is not nicked or undercut. Unacceptable portions of the weld shall be removed, without substantial removal of the base metal. The surfaces shall be cleaned thoroughly before welding. Oxygen-gouged and air-arc-gouged surfaces shall be at least cleaned by grinding or machining, to remove all carbon absorption or contamination.

Gouged areas requiring rewelding shall have a root radius of not less than 5 mm and sufficient width to allow the welder reasonable access to reinstate the weld.

Unacceptable undercutting shall be made good by the deposition of additional weld metal in accordance with this Standard or by the removal of the undercut by grinding in accordance with Clause 5.8.3.

NOTE: The use of preheat prior to air-arc gouging should be considered. Guidance may be obtained from WTIA Technical Note 15.

5.8.3 Grinding

Grinding shall comply with the following requirements:

(a) The ground area shall blend smoothly into the surrounding surface, without abrupt changes in contour.

(b) The grinding shall not extend below the surface of the parent material by more than—

  (i) for material less than 10 mm thick, 0.5 mm; or

  (ii) for material not less than 10 mm thick, the lesser of 0.07 times the nominal thickness and 3 mm.

5.8.4 Stop/Starts

Where stop/starts occur in the length of continuous automatic longitudinal fillet or butt weld, with stress ranges for detail Category 112 or 125 as specified in AS 4100 or NZS 3404.1, they shall be repaired by the following procedure:

(a) Grind the stopped end of the weld so that it tapers to the root of the joint with a slope of at least 4:1.

(b) Restart the weld from the top of the taper slope.

(c) Grind the repaired weld to a smooth surface.

The site of the repair shall be subjected to 100% magnetic particle examination in accordance with Section 6.

NOTE: In rectangular hollow section joints, welds should not be started or stopped at corners.

5.9 TEMPORARY ATTACHMENTS

Welds joining temporary attachments to the structure shall be made to the same standards as final welds. All temporary attachments shall be removed, unless otherwise specified on the drawings or other documents. Temporary welds and attachments shall not be allowed on the tension flanges of beams, girders and similar members. When temporary welds or attachments are removed, the surface shall be—

(a) reinstated to a reasonably smooth condition, by grinding or by a combination of welding and grinding;

(b) checked by magnetic particle examination or other suitable method, to ensure soundness; and

(c) finished to the requirements of Clause 5.8.3.

5.10 ARC STRIKES

Arc strikes outside the area of permanent welds should be avoided on any material. Cracks or blemishes resulting from arc strikes on members, other than those that are essentially statically loaded, shall be ground to a smooth contour in accordance with Clause 5.8.3 and checked by magnetic particle examination or other suitable method to ensure soundness.

5.11 CLEANING OF FINISHED WELDS

Slag shall be removed from completed welds. The weld and adjacent base metal shall be cleaned by brushing or other suitable means. Tightly adhering spatter remaining after the cleaning operation is acceptable, unless its removal is required for subsequent non-destructive testing or surface treatment.

Welded joints shall not be painted until after the welding has been completed, inspected and accepted.

5.12 DRESSING OF BUTT WELDS

The surface of butt welds that have been dressed flush shall be finished so as to—

(a) reduce the thickness of the thinner base metal or weld metal by more than 0.8 mm or 5% of the thickness, whichever is the lesser; or

(b) leaving reinforcement that exceeds 0.8 mm.

Reinforcements shall be removed where the weld forms part of a faying or contact surface. Any dressing of reinforcement shall blend smoothly into the plate surfaces.

In addition, Category FP welds shall be dressed in accordance with the fatigue requirements of AS 3990, AS 4100 or NZS 3404.1, as appropriate.

SECTION 6 QUALITY OF WELDS

6.1 WELD CATEGORIES

According to the intended application, welds shall be Category GP, Category SP or Category FP (see Clause 1.6).

The compliance of the completed welds with these categories shall be determined in accordance with the different inspection requirements and different acceptance levels of imperfections for the categories, as given in Clause 6.2.

6.2 METHODS OF INSPECTION AND PERMISSIBLE LEVELS OF IMPERFECTIONS

6.2.1 Methods of inspection of completed welds

Welds shall be inspected in accordance with Clause 7.3 and, where appropriate, with Clause 7.4.

In addition, for Category SP and Category FP butt welds, where radiographic or ultrasonic examination is required by the principal and is specified on the drawings or other documents, examination for the relevant types of imperfections shown in Table 6.3 shall be carried out in accordance with Clause 6.3 or Clause 6.4, as appropriate.

NOTE: Table 7.4 includes guidance on the suggested extent of non-destructive examination, which is consistent with the principles on which this Standard is based.

6.2.2 Permissible levels of imperfection

The size, number and spacing of imperfections that are permitted for the weld categories shall not exceed the relevant levels given in Table 6.2 and Table 6.3.

6.2.3 Adjacent imperfections

6.2.3.1 *Aligned*

Where adjacent imperfections are aligned, they shall be assessed as shown in Figure 6.2.3(a).

6.2.3.2 *Overlapping*

Where there is a horizontal displacement between adjacent imperfections, the effective length (L) shall be as shown in Figure 6.2.3(b).

6.2.3.3 *Overlapping vertical displacement*

Any imperfections occurring one above the other in the vertical plane of the weld shall be assessed as shown in Figure 6.2.3(c).

6.2.4 Interpretation of tests

Where qualification by macro test and side-bend test is required (see Clause 4.7), the bend test shall be used solely to reveal imperfections not observed in the macro-section. Tearing at the ends of imperfections shall not be considered for the purposes of assessing the depth or height of imperfections. Any imperfections observed may be assumed to extend the total length of the weld, unless additional sections are taken to show the extent of the imperfections.

TABLE 6.2

PERMISSIBLE LEVELS OF IMPERFECTIONS IN BUTT AND FILLET WELDS AS DETERMINED BY VISUAL, MAGNETIC PARTICLE AND LIQUID PENETRANT EXAMINATION OF THE WELD ZONE

Imperfection		Sym-bol	Maximum allowable dimension or number of imperfections (see Figure 6.2)		
Type	Parameter		GP	SP	FP
Butt welds					
Cracks	Length	l	Crater cracks only	No cracks allowed	
	Cumulative length	Σl	6 mm in 1000 mm weld (crater cracks only)		
Lack of fusion or incomplete penetration	Depth for GP Length for SP	As for undercut depth		l: Where located more than $3t$ from end of weld, $2t/3$, but not greater than 20 mm Where located within $3t$ from end of weld, 3 mm Σl: t in $6t$ length, but proportionally less for shorter length	Not allowed (if exposed at weld surface)
Undercut (continuous)	Depth	h	$t/10$, but not greater than 1.5 mm (see Note 3)	$t/20$, but not greater than 1 mm (see Note 3)	Not allowed
Undercut (intermittent)	Depth	h	$t/5$, but not greater than 2 mm (see Note 3)	$t/10$, but not greater than 1.5 mm (see Note 3)	Not allowed
Shrinkage grooves Root concavity	—	—	As for undercut		Not allowed
Reinforcement (each side)	Height	h	Not limited	For $t \le 12$ mm ..... 3 mm For $12 < t \le 25$ mm ..... 5 mm For $t > 25$ mm ..... 6 mm	1 mm max. Smoothly blended at weld toes
Excess penetration	Height (depth)	—	As for reinforcement		
Linear misalignment	—	—	See Clauses 5.2.2 and 5.2.3		
Overlap	Length	l	$2t$, but not greater than 20 mm	t, but not greater than 10 mm	Not allowed
	Cumulative length	Σl	60 mm in 300 mm, but proportionately less for shorter lengths	30 mm in 300 mm, but proportionately less for shorter lengths	
Toe shape (other than above)	—	—	No restriction	Suitable to permit required NDE	Smoothly blended
Surface pores	Size of pore	d	Not limited	$t/3$, but not greater than 5 mm	Not allowed
	Number of pores	—	Six per $12t$ length	Two per $12t$ length	
Loss of cross-sectional area (see Note 4)	L of A		≤ 10%	≤ 5 percent	≤ 3%
Fillet welds					
Reinforcement	Height	h	Not limited	For $S \le 12$ mm ..... 2 mm For $12 \le S < 25$ mm ..... 3 mm For $S > 25$ mm ..... 4 mm	1 mm max. Smoothly blended at weld toes (see Note 5)
Undersize—intermittent (see Note 5)	Leg length	—	$S/5$, but not greater than 4 mm	$S/10$, but not greater than 3 mm	$S/10 \le 2$ mm
Other surface imperfections	—	—	As for butt welds		Not allowed
Loss of cross-sectional area (see Note 4)	L of A	—	As for butt welds		≤ 3%

NOTES TO TABLE 6.2:

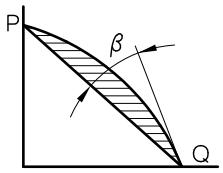
1 For adjacent imperfections, see Clause 6.2.3.

2 For a welding procedure qualification, the assessment of the test piece for compliance with the permissible levels of imperfections should be done with the aid of the macro test specimen. For calculation of the loss of cross-sectional area, internal imperfections are estimated from the macro test specimen.

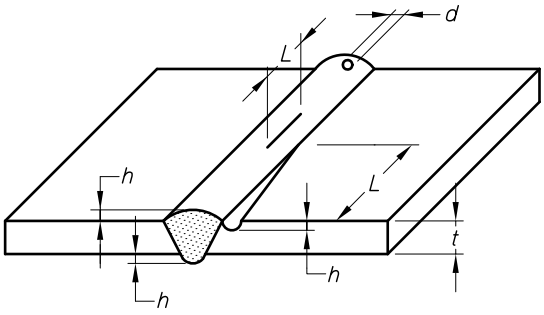
3 Undercut less than 0.5 mm in depth should be disregarded for Category GP and Category SP welds.

4 For the calculation of the loss of cross-sectional area, all relevant surface imperfections shall be included. Where lack of root fusion is evident, the inspector shall assess the approximate depth of the imperfection. The macro test specimen from the welding procedure qualification may need examination for this purpose.

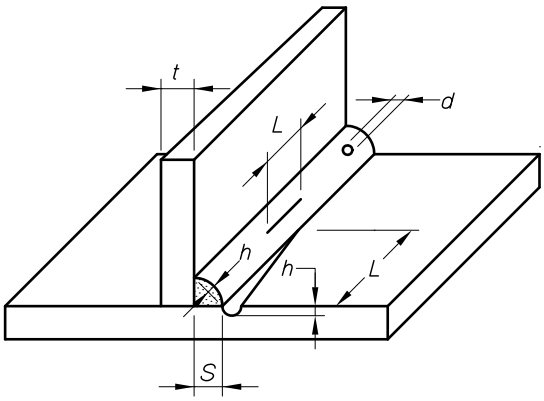
5 The angle β between the plane tangential to the weld bead surface at the toe and the plane through the line PQ shall be ≤15°. Slightly concave welds shall be acceptable, provided the design throat thickness requirements are fulfilled. This requirement also applies for the angle between the tangential planes between multi-run welds.



6 The cumulative length of intermittent undersize fillet welds shall not exceed 10% of the length of the weld.

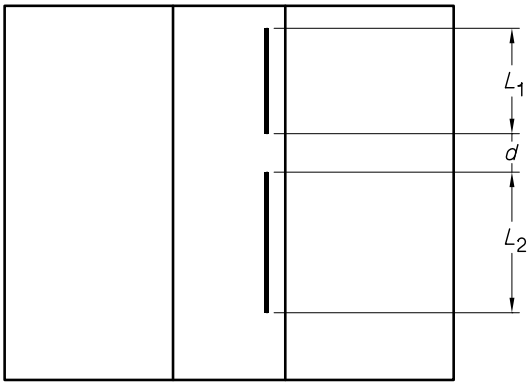


(a) Butt weld



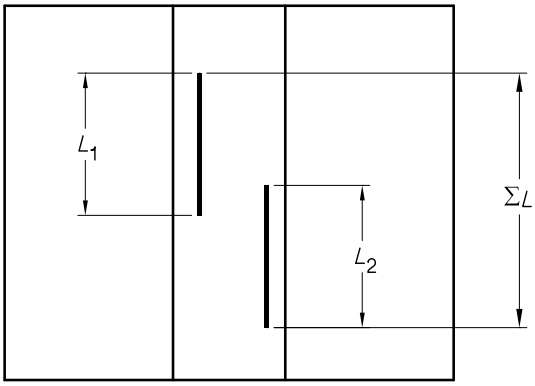
(b) Fillet weld

FIGURE 6.2 DIMENSIONS REFERRED TO IN TABLE 6.2

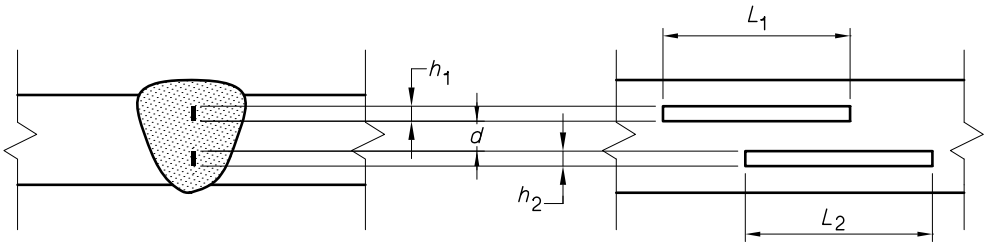


Where d is less than L_1 the smaller imperfection, $\Sigma L = L_1 + L_2 + d$
Where d is not less than L_1 the smaller imperfection, $\Sigma L = L_1 + L_2$

(a) Aligned imperfections



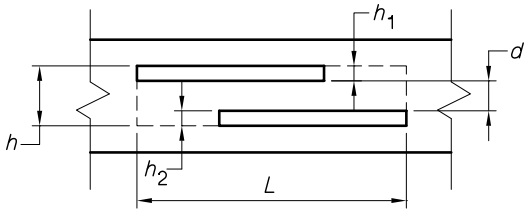
(b) Overlapping imperfections



(i) Cross-section

NOTE: Treat as separate defects.

(ii) Longitudinal section, where $d > 5$mm



NOTE: Treat as a single defect with dimensions h and L as shown.

(iii) Longitudinal section, where $d \leqslant 5$mm

(c) Overlapping vertical displacement

FIGURE 6.2.3 ASSESSMENT OF ADJACENT IMPERFECTIONS

6.3 RADIOGRAPHY

6.3.1 Method

When required, radiography shall be carried out in accordance with AS 2177.1, using the following test methods as designated by AS 2177.1, for which '*z*' is 'S', 'DWS' or 'DWD' as appropriate:

(a) For Category SP, the technique shall be selected in accordance with the thickness of the material as follows:

(i) For material thicknesses of not more than 12 mm, XR2/*z*; except that GR1/*z* or GR2/*z* may be used, provided that this is agreed with the principal.

(ii) For material thicknesses of more than 12 mm, XR2/*z*, GR1/*z* or GR2/*z*.

Where materials of different thicknesses are examined, the technique shall be selected according to the thinner plate.

(b) For Category FP, only method XR2/*z* shall be used.

6.3.2 IQI sensitivity

IQI sensitivity for each technique shall be as required by Table 6.3.2. The IQI sensitivity shall be measured through the weld, using wire type IQI in accordance with AS 2177.2. At least one IQI should be used with each radiograph.

TABLE 6.3.2

SMALLEST DISCERNIBLE WIRE

Weld category	Method (see Note 1)	Wire number (see AS 2177.2)							
		Weld metal thickness, mm							
		≤6	> 6 ≤10	>10 ≤12	>12 ≤18	>18 ≤25	>25 ≤35	>35 ≤50	> 50
SP	XR2/*z*	13	12	11	10	9	8	7	See Note 2
	GR1/*z* or GR2/*z*	12	11	11	10	9	8	7	See Note 2
FP	XR2/x	13	12	11	10	9	8	7	See Note 2

NOTES:

1 As designated by AS 2177.1, for which '*z*' is 'S', 'DWS' OR 'DWD' as appropriate.

2 For thicknesses of more than 50 mm, an IQI sensitivity of 2.0% is required.

6.3.3 Acceptance limits

The maximum permissible levels of imperfections shall be as given in Table 6.3(A) or Table 6.3(B), as applicable. Where imperfections in excess of the limits of Table 6.3(A) or 6.3(B) are detected, the unacceptable areas shall be repaired and re-radiographed in accordance with this Clause or, by mutual agreement, be examined using ultrasonics in accordance with Clause 6.4, in which case the results of such ultrasonic examination shall be taken as the basis for acceptance.

Alternatively, the weld may be considered to be defective and dealt with in accordance with Clause 6.7.

NOTE: Where non-complying welds are detected during a spot examination, two additional spots, each of the same length as the original spot, should be examined. They should comply with the following requirements, as appropriate:

(a) Where the two additional spots pass, only the original spot should be repaired and re-radiographed.

(b) Where either of the two additional spots fail, the entire weld should be radiographed or replaced.

TABLE 6.3(A)

PERMISSIBLE LEVELS OF IMPERFECTIONS AS DETERMINED BY RADIOGRAPHIC OR ULTRASONIC EXAMINATION FOR CATEGORY SP WELDS

Type of imperfection (see Notes 1, 2 and 3)	Thickness of thinner parent metal (*t*), mm (see Note 4)	Weighting factor					Maximum permissible imperfection level (see Notes 5, 6 and 7)
		Height of imperfection (*h*), mm					
		≤2	>2 ≤4	>4 ≤10	>10 ≤20	>20	
Cracks	All	Not permitted					
Inclusions, lack of penetration or lack of fusion	≤10	2	X	X	X	X	L/5
	>10 ≤20	2	4	X	X	X	L/4
	>20 ≤40	1	2	5	X	X	L/2
	>40	1	2	5	10	X	L
Porosity	All	See Notes 8 and 9					

LEGEND:
X = not permitted
L = weld length under consideration

TABLE 6.3(B)

PERMISSIBLE LEVELS OF IMPERFECTIONS AS DETERMINED BY RADIORAPHIC OR ULTRASONIC EXAMINATION FOR CATEGORY FP WELDS

Type of imperfection (see Notes 1, 2 and 3)	Thickness of thinner parent metal (*t*) mm (see Note 4)	Weighting factor					Maximum permissible imperfection level (see Notes 5, 6 and 7)
		Height of imperfection (h), mm					
		≤2	>2 ≤4	>4 ≤10	>10 ≤20	>20	
Cracks	All	Not permitted					
Inclusions, lack of penetration, or lack of fusion	≤10	X	X	X	X	X	X
	>10 ≤20	4	8	X	X	X	L/8
	>20 ≤40	2	4	10	X	X	L/4
	>40	2	4	10	20	X	L/2
Porosity	All	See Notes 8 and 9					

LEGEND:
X = not permitted
L = weld length under consideration

NOTES TO TABLES 6.3(A) AND 6.3(B):

1 For adjacent imperfections, see Clause 6.2.3.

2 For the purpose of radiographic examination or routine ultrasonic examination, *h* shall be taken as 2 mm. If the ultrasonic or radiographic examination indicates that *h* may be greater than 2 mm, *h* shall be determined by sectioning or vertical ultrasonic sizing in accordance with AS 2207.

3 Where any imperfection is suspected as being a lamellar tear, it should be recorded on the NDE report and referred to the principal for consideration.

4 See also Clause 3.2.1.

5 For any weld length under consideration, the imperfection level is calculated by multiplying the length of each imperfection by its weighting factor and adding these weighted lengths to determine a total imperfection level. The total imperfection level shall be less than the maximum permissible imperfection level.

6 Any imperfection within a distance of *t* from the end of a weld shall have a height of not more than the greater of 2 mm and *t*/20.

7 Where the length of a continuous weld exceeds 1 m, the maximum permissible imperfection level shall not be exceeded in any continuous weld length of 1 m.

8 Where continuous or adjacent imperfections cross the division between examination lengths, the examination lengths shall be relocated to include the most severe combination of imperfections.

9 Porosity is not considered to be a particularly serious imperfection, and is cause for rejection of a weld only where it is present in sufficient quantity to render difficult an inspection for the other imperfections listed in the above Table. Any such level of porosity shall be recorded and referred to the principal for consideration. For radiographic inspections, porosity levels representing a loss of projected area not exceeding 2% are permitted. If required, reference may be made to porosity charts in AS 4037, to assist in assessing the appearance of this level of porosity on a radiograph.

6.4 ULTRASONIC EXAMINATION

6.4.1 Method

One of the following shall be carried out:

(a) Ultrasonic examination complying with AS 2207. For this test shear probes shall have a dominant frequency in the range 2.0 MHz to 2.5 MHz, and an essentially square or circular transducer in the size range 15 mm to 22 mm. For plate thicknesses of less than 15 mm, the transducer size may be reduced to 8 mm and frequencies increased to 5 MHz. Compression probes shall have a dominant frequency in the range 4 MHz to 5 MHz, and an essentially square or circular transducer in the size range 10 mm to 20 mm.

Variations to the equipment requirements may be used upon agreement with the principal. Such variations include transducer sizes and frequencies.

(b) Alternative method of test that is acceptable to the principal (see Clause 1.3).

6.4.2 Evaluation

For welds on material with a thickness of not more than 50 mm, evaluation shall be carried out at Level 2, in accordance with AS 2207. For welds on material with a thicknesses of more than 50 mm, evaluation shall be carried out at Level 3. Planar imperfections should be evaluated at an incident angle of less than 10°. Where this is not possible, additional gain shall be added in accordance with Table 6.4.2. For the purposes of Table 6.4.2, planar imperfections shall be considered to lie along the welding preparation faces. The probe angle shall be the actual measured angle, not the nominal angle.

6.4.3 Acceptance limits

The maximum permissible levels of imperfections shall be as given in Tables 6.3(A) and 6.3(B). Where welds fail to meet these criteria they shall be either repaired and retested, or considered defective and dealt with in accordance with Clause 6.7.