REPAIR QUALITY STANDARD FOR EXISTING SHIPS

CONTENTS:

1. Scope

1.1 This standard provides guidance on quality of repair of hull structures. The standard covers permanent repairs of existing ships.
Whereas the standard generally applies to

- Conventional ship types,
- Parts of hull covered by the rules of the Classification Society,
- Hull structures constructed from normal and higher strength hull structural steel, the applicability of the standard is in each case to be agreed upon by the Classification Society.

The standard does generally not apply to repair of

- Special types of ships as e.g. gas tankers
- Structures fabricated from stainless steel or other, special types or grades of steel.

1.2 The standard covers typical repair methods and gives guidance on quality standard on the most important aspects of such repairs. Unless explicitly stated elsewhere in the standard, the level of workmanship reflected herein will in principle be acceptable for primary and secondary structure of conventional design. A more stringent standard may however be required for critical and highly stressed areas of the hull, and is to be agreed with the Classification Society in each case. In assessing the criticality of hull structure and structural components, reference is made to ref. 1, 2 and 3.

1.3 Restoration of structure to the original standard may not constitute durable repairs of damages originating from insufficient strength or inadequate detail design. In such cases strengthening or improvements beyond the original design may be required. Such improvements are not covered by this standard; however it is referred to ref. 1, 2 and 3.

2. General requirements for repairs and repairers

2.1 In general, when hull structure covered by classification is to be subjected to repairs, the work is to be carried out under the supervision of the Surveyor to MCO. Such repairs are to be agreed prior to commencement of the work.

2.2 Repairs are to be carried out by workshops, repair yards or personnel who have demonstrated their capability to carry out hull repairs of adequate quality in accordance MCO's requirements and this standard.

2.3 Repairs are to be carried out under working conditions that facilitate sound repairs. Provisions are to be made for proper accessibility, staging, lighting and ventilation. Welding operations are to be carried out under shelter from rain, snow and wind.

2.4 Welding of hull structures is to be carried out by qualified welders, according to approved and qualified welding procedures and with welding consumables approved by MCO, see Section 3. Welding operations are to be carried out under proper supervision of the repair yard.

2.5 Where repairs to hull which affect or may affect classification are intended to be carried out during a voyage, complete repair procedure including the extent and sequence of repair is to be submitted to and agreed upon by the Surveyor to MCO reasonably in advance of the repairs. See Ref. 8.

3. Qualification of personnel

3.1 Qualification of welders

3.1.1 Welders are to be qualified in accordance with the procedures of the Classification Society or to a recognized national or international standard, e.g. EN 287, ISO 9606, ASME Section IX, ANSI/AWS D1.1. Recognition of other standards is subject to submission to the Classification Society for evaluation. Repair yards and workshops are to keep records of welder's qualification and, when required, furnish valid approval test certificates.

3.1.2 Welding operators using fully mechanized of fully automatic processes need generally not pass approval testing, provided that production welds made by the operators are of the required quality. However, operators are to receive adequate training in setting or programming and operating the equipment. Records of training and production test results shall be maintained on individual operator's files and records, and be made available to the Classification Society for inspection when requested.

3.2 Qualification of welding procedures

Welding procedures are to be qualified in accordance with the procedures of the Classification Society or a Recognized national or international standard, e.g. EN288, ISO 9956, ASME Section IX, ANSI/AWS D1.1. Recognition of other standards is subject to submission to the Classification Society for evaluation. The welding procedure should be supported by a welding procedure qualification record. The specification is to include the welding process, types of electrodes, weld shape, edge preparation, welding techniques and positions.

3.3 Qualification of NDE operators

3.3.1 Personnel performing nondestructive examination for the purpose of assessing quality of welds in connection with repairs covered by this standard are to be qualified in accordance with the Classification Society rules or to a recognized international or national qualification scheme. Records of operators and their current certificates are to be kept and made available to the Surveyor for inspection.

4. Materials

4.1. General requirements for materials

4.1.1 The requirements for materials used in repairs are in general the same as the requirements for materials specified in the Classification Society's rules for new constructions, (ref. 5)

4.1.2 Replacement material is in general to be of the same grade as the original approved material. Alternatively, material grades complying with recognized national or international standards may be accepted by the Classification Societies provided such standards give equivalence to the requirements of the original grade or are agreed by the Classification Society. For assessment of equivalency between steel grades, the general requirements and guidelines in Section 4.2 apply.

4.1.3 Higher tensile steel is not to be replaced by steel of a lesser strength unless specially approved by the Classification Society.

4.1.4 Normal and higher strength hull structural steels are to be manufactured at works approved by the Classification Society for the type and grade being supplied.

4.1.5 Materials used in repairs are to be certified by the Classification Society applying the procedures and requirements in the rules for new constructions. In special cases, and normally limited to small quantities, materials may be accepted on the basis of alternative procedures for verification of the material's properties. Such procedures are subject to agreement by the Classification Society in each separate case.

4.2. Equivalency of material grades

4.2.1 Assessment of equivalency between material grades should at least include the following aspects;

- heat treatment/delivery condition
- chemical composition

- mechanical properties
- tolerances

4.2.2 When assessing the equivalence between grades of normal or higher strength hull structural steels up to and including grade E40 in thickness limited to 50 mm, the general requirements in Table 4.1 apply.
4.2.3 Guidance on selection of steel grades to certain recognized standards equivalent to hull structural steel grades specified in Classification Societies' rules is given in Table 4.2.

5. General requirements to welding.

5.1 Correlation of welding consumables with hull structural steels
5.1.1 For the different hull structural steel grades welding consumables are to be selected in accordance with IACS UR W17 (see Ref.5).

5.2 General requirements to preheating and drying out

5.2.1 The need for preheating is to be determined based on the chemical composition of the materials, welding process and procedure and degree of joint restraint.
5.2.2 A minimum preheat of 50$_{o}$ C is to be applied when ambient temperature is below 0°C. Dryness of the welding zone is in all cases to be ensured.
5.2.3 Guidance on recommended minimum preheating temperature for higher strength steel is given in Table 5.1.
For automatic welding processes utilizing higher heat input e.g. submerged arc welding, the temperatures may be reduced by 50$_{o}$ C. For re-welding or repair of welds, the stipulated values are to be increased by 25° C.

Items to be considered	Requirements	Comments
Chemical composition	- C; equal or lower - P and S; equal or lower - Mn; approximately the same but not exceeding 1.6% - Fine grain elements; in same amount - Deoxidation practice	The sum of the elements, e.g. Cu, Ni, Cr and Mo should not exceed 0.8%
Mechanical properties	- Tensile strength; equal or higher - Yield strength; equal or higher - Elongation; equal or higher - Impact energy; equal or higher at same or lower temperature, where applicable	Actual yield strength should not exceed Classification Society Rule minimum requirements by more than 80 N/mm^2
Condition of supply	Same or better	Heat treatment in increasing order; - as rolled (AR) - controlled rolled (CR) - normalised (N) - thermo-mechanically rolled (TM)[1)] - quenched and tempered (QT)[1)] 1) TM- and QT-steels are not suitable for hot forming
Tolerances	- Same or stricter	Permissible under thickness tolerances; - plates: 0.3 mm - sections: according to recognised standards

Table 4.1 Minimum extent and requirements to assessment of equivalency between normal or higher strength hull structural steel grades

5.3 Dry welding on hull plating below the waterline of vessels afloat

5.3.1. Welding on hull plating below the waterline of vessels afloat is acceptable only on normal and higher strength steels with specified yield strength not exceeding 355 MPa and only for local repairs. Welding involving other high strength steels or more extensive repairs against water backing is subject to special consideration and approval by the Classification Society of the welding procedure.
5.3.2. Low-hydrogen electrodes or welding processes are to be used when welding on hull plating against water backing. Coated low-hydrogen electrodes used for manual metal arc welding should be properly conditioned to ensure a minimum of moisture content.
5.3.3 In order to ensure dryness and to reduce the cooling rate, the structure is to be preheated by a torch or similar prior to welding, to a temperature of minimum 5oC or as specified in the welding procedure.

Table 4.2 Guidance on steel grades comparable to the normal and high strength hull structural steel grades given in Classification Society rules

Steel grades according to Classification Societies' rules (ref. 5)							Comparable steel grades			
Grade	Yield stress R_{eH} min. N/mm²	Tensile strength R_m N/mm²	Elongation A_5 min. %	Average impact energy Temp. °C	J, min. L	T	ISO 630-80 4950/2/3 1981	EN EN 10025-93 EN 10113-93	ASTM A 131	JIS G 3106
A B D E	235	400 - 502	22	+20 0 -20 -40	- 27 27 27	- 20 20 20	Fe 360B Fe 360C Fe 360D -	S235JRG2 S235J0 S235J2G3 S275NL/ML	A B D E	SM41B SM41B (SM41C) -
A 27 D 27 E 27	265	400 - 530	22	0 -20 -40	27	20	Fe 430C Fe 430D -	S275J0G3 S275N/M S275NL/ML	- - -	- - -
A 32 D 32 E 32	315	440 - 590	22	0 -20 -40	31	22	- - -	- - -	AH32 DH32 EH32	SM50B (SM50C) -
A 36 D 36 E 36	355	490 - 620	21	0 -20 -40	34	24	Fe 510C Fe 510D E355E	S355N/M S355N/M S355NL/ML	AH36 DH36 EH36	SM53B (SM53C) -
A 40 D 40 E 40	390	510 - 650	20	0 -20 -40	41	27	E390CC E390DD E390E	S420N/M S420N/M S420NL/ML	AH40 DH40 EH40	(SM58) - -

Note : In selecting comparable steels from this table, attention should be given to the requirements of Table 4.1 and the dimension requirements of the product with respect to Classification Society rules.

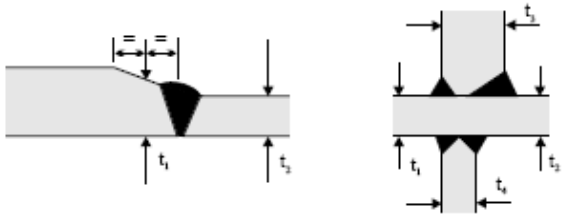
Carbon equivalent 1)	Recommended minimum preheat temperature (^{0} C)		
	$t_{comb} \leq 50$ mm 2)	50 mm$<t_{comb} \leq$ 70 mm 2)	t_{comb} >70 mm 2)
Ceq ≤ 0.39	-	6	
Ceq ≤ 0.41	-	3	
Ceq ≤ 0.43	-	50	100
Ceq ≤ 0.45	50	100	125
Ceq ≤ 0.47	100	125	150
Ceq ≤ 0.50	125	150	175

Table 5.1 Preheating temperature

NOTES

1) $Ceq = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$ (%)

2) Combined thickness $t_{comb} = t_1 + t_2 + t_3 + t_4$, see figure



6. Repair quality standard
6.1 Welding, general

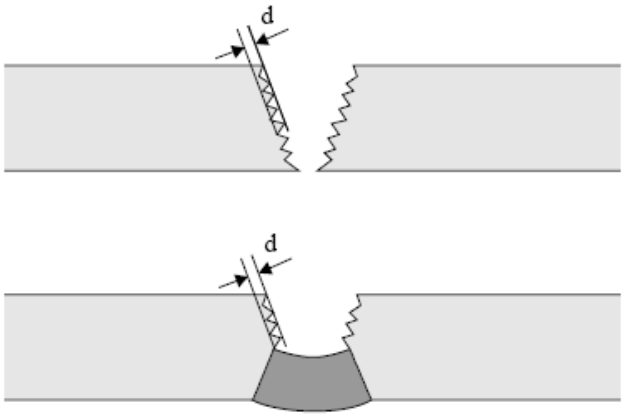


Fig. 6.1 Groove roughness

Item	Standard	Limit	Remarks
Material Grade	Same as original or higher		See Section 4
Welding Consumables	IACS UR-W17 (ref. 6)	Approval according. to equivalent international standard	
Groove / roughness	See note and Fig. 6.1	d < 1.5 mm	Grind smooth
Pre-Heating	See Table 5.1	Steel temperature not lower than 5°C	
Welding with water on the outside	See Section 5.3	Acceptable for normal and high strength steels	-Moisture to be removed by a heating torch
Alignment	As for new construction		
Weld finish	IACS guide for inspection of ship hull welds (ref. 10)		
NDE	IACS guide (ref. 10)	At random with extent to be agreed with attending surveyors	

NOTE :
Slag, grease, loose mill scale, rust and paint, other than primer, to be removed.

6.2 Renewal of plates

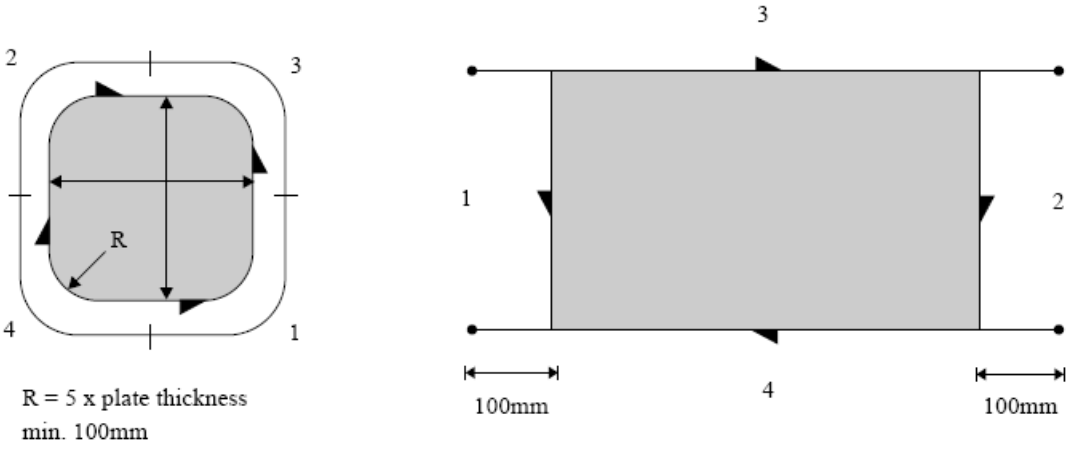


Fig 6.2 Welding sequence for inserts

Item	Standard	Limit	Remarks
Size insert	Min. 300x300mm R = 5 x thickness Circular inserts: D_{min}=200mm	Min. 200x200mm Min R = 100 mm	
Material grade	Same as original or higher		See Section 4.
Edge Preparation	As for new construction		In case of non compliance increase the amount of NDE
Welding sequence	See fig.6.2 Weld sequence is 1→ 2 → 3 → 4		For primary members sequence 1 and 2 transverse to the main stress direction
Alignment	As for new construction		
Weld finish	IACS guide for inspection of ship hull welds (ref. 10)		
NDE	IACS guide (ref. 10)		

6.3 Doublers on plating

Local doublers are normally only allowed as temporary repairs, except as original compensation for openings, within the main hull structure.

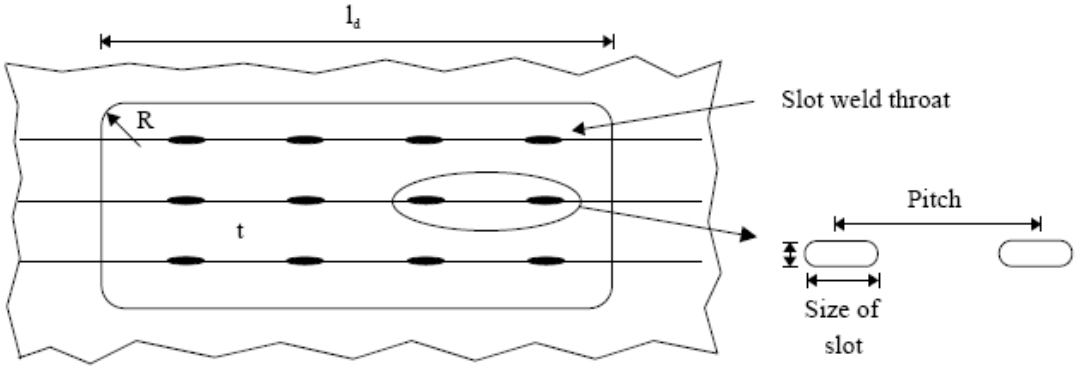


Fig. 6.3 Doublers on plates

Item	Standard	Limit	Remarks
Existing plating		General: $t \geq 5$ mm	For areas where existing plating is less than 5mm plating a permanent repair by insert is to be carried out.
Extent/size	Rounded off corners.	min 300x300mm $R \geq 50$mm	
Thickness of doubler (t_d)	$t_d \leq t_p$ (t_p = original thickness of existing plating)	$t_d > t_p/3$	
Material grade	Same as original plate		See Section 4
Edge preparation	As for [newbuilding] new construction		Doublers welded on primary strength members: (L_e: leg length) when $t > L_e + 5$mm, the edge to be tapered (1:4)
Welding	As for [newbuilding] new construction		Welding sequence similar to insert plates.
Weld size(throat thickness)	Circumferencial and in slots: 0.6 x t_d		
Slot welding	Normal size of slot: (80-100) x 2 t_d Distance from doubler edge and between slots: $d \leq 15\ t_d$	Max pitch between slots 200mm d_{max} = 500mm	For doubler extended over several supporting elements, see figure 6.3
NDE	IACS Recommendation 20 (Ref. 10)		

6.4 Renewal of internals/stiffeners

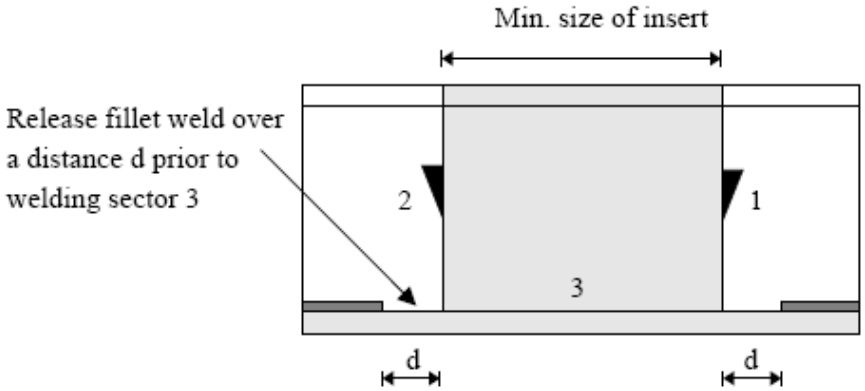


Fig 6.4 Welding sequence for inserts of stiffeners

Item	Standard	Limit	Remarks
Size insert	Min. 300 mm	Min. 200mm	
Material grade	Same as original or higher		See Section 4.
Edge Preparation	As for new construction. Fillet weld stiffener web/plate to be released over min. d = 150 mm		
Welding sequence	See fig.6.4 . Weld sequence is 1→ 2 → 3		
Alignment	As for new construction		
Weld finish	IACS guide for inspection of ship hull welds (ref. 10)		
NDE	IACS guide (ref. 10)		

6.5 Renewal of internals/stiffeners - transitions inverted angle/bulb profile

The application of the transition is allowed for secondary structural elements.

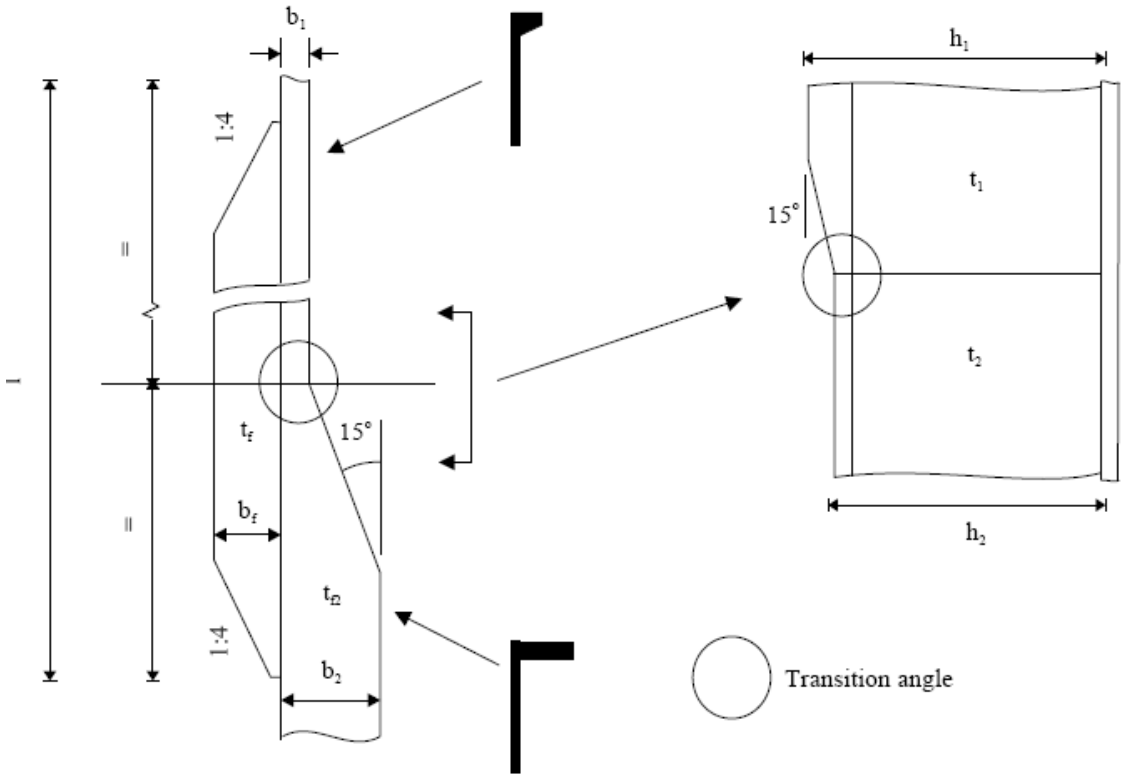


Fig. 6.5 Transition between inverted angle and bulb profile

Item	Standard	Limit	Remarks
$(h_1 - h_2)$	$\leq 0.25 \times b1$		
$\lvert t_1 - t_2 \rvert$	2 mm		Without tapering transition.
Transition angle	15 degrees		At any arbitrary section
Flanges	$tf = tf_2$ $bf = bf_2$		
Length of flatbar	$4 \times h_1$		
Material			See Section 4.

6.6 Termination of straps

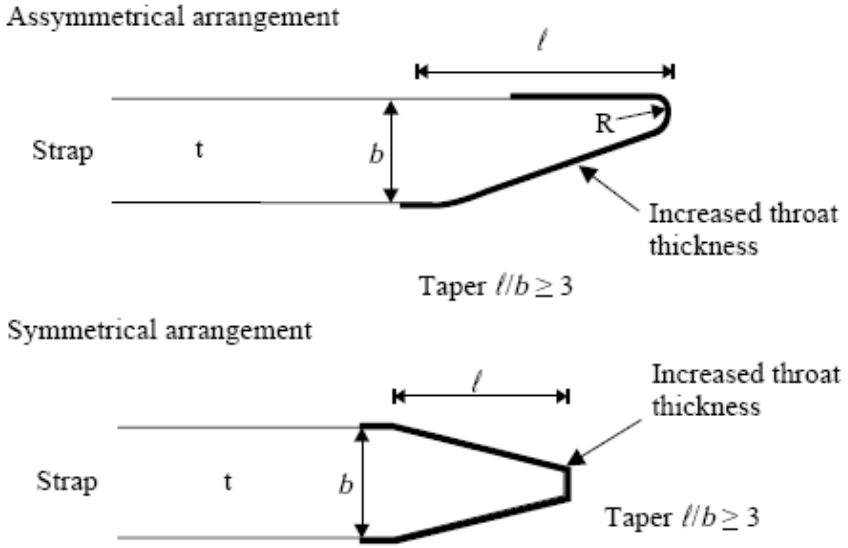


Fig. 6.6 Termination of straps

Item	Standard	Limit	Remarks
Tapering	$\ell/b > 3$		Special consideration to be drawn to design of strap terminations in fatigue sensitive areas.
Radius	0.1 x b	min 30mm	
Material			See paragraph 2.0 General requirement to materials.
Weld size			Depending on number and function of straps. Throat thickness to be increased 15 % toward ends.
Welding	Welding sequence from middle towards the free ends		See sketch. For welding of lengths > 1000mm step welding to be applied.

6.7 Welding of pitting corrosion

NOTES:
Shallow pits may be filled by applying coating or pit filler. Pits can be defined as shallow when their depth is less than 1/3 of the original plate thickness.

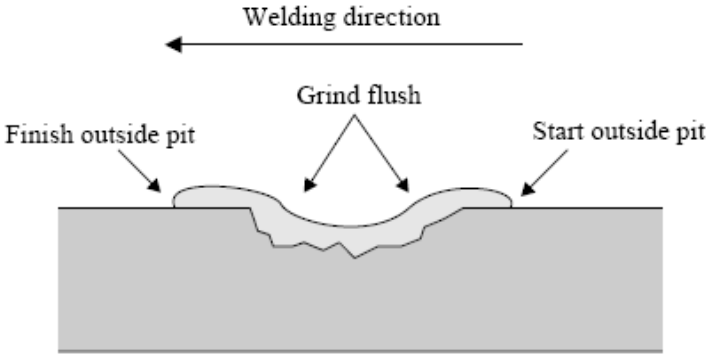


Fig. 6.7 Welding of pits

Item	Standard	Limit	Remarks
Extent/depth	Pits/grooves are to be welded flush with the original surface.	If deep pits or grooves are clustered together or remaining thickness is less than 6 mm, the plate should be renewed.	See also IACS Recommendation 12 (Ref.9)
Cleaning	Heavy rust to be removed		
Pre-Heating	See Table 5.1	Required when ambient temperature < 5°C	Always use propane torch or similar to remove any moisture
Welding sequence	Reverse direction for each layer		See also IACS guide no. 12
Weld finish	IACS guide for inspection of ship hull welds (ref. 10)		
NDE	IACS guide (ref. 10)	Min. 10% extent	Preferably MPI

Reference is made to TSCF Guidelines, Ref. 2 & 3.

6. 8 Welding repairs for cracks

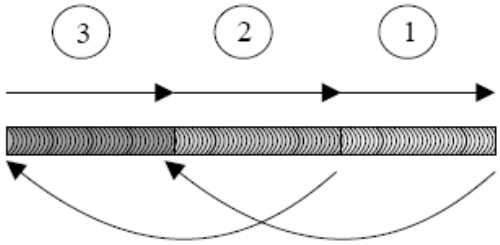


Fig. 6.8.a Step back technique

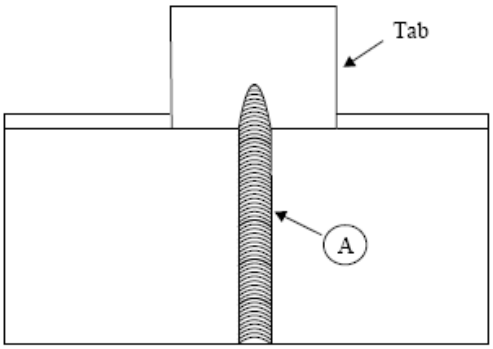
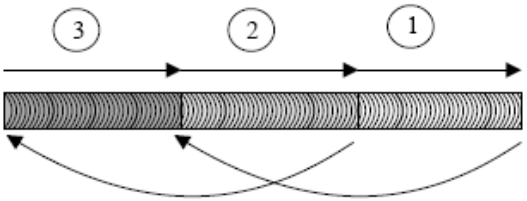


Fig 6.8.b End crack termination



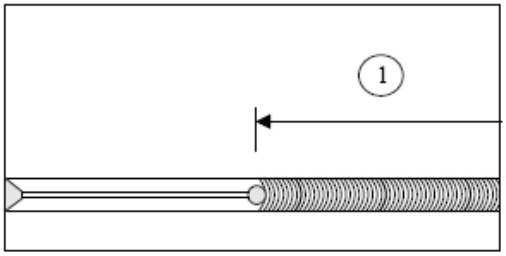


Fig 6.8.c Welding sequence for cracks with length less than 300 mm

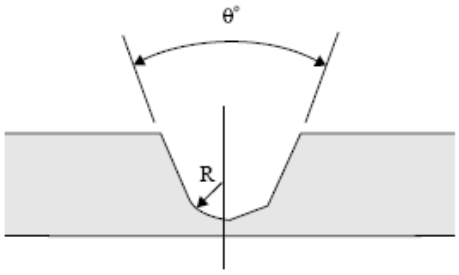
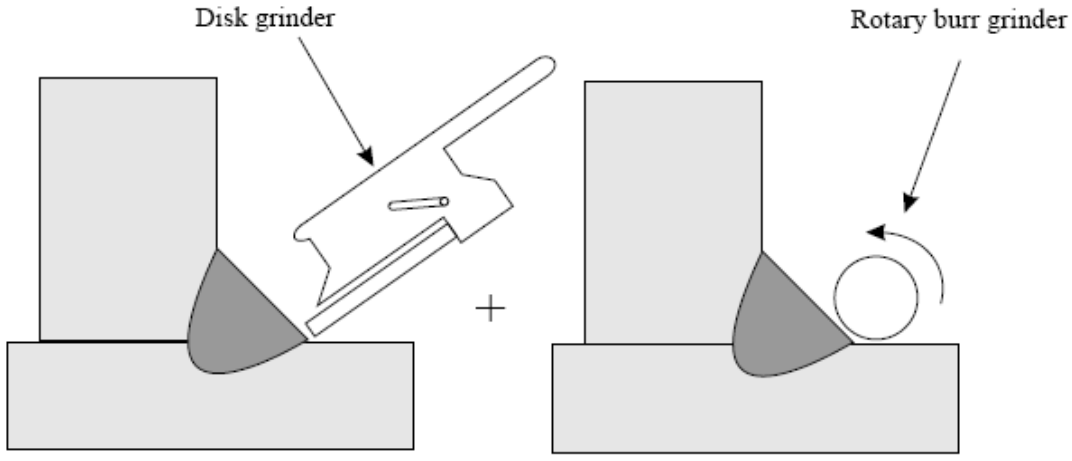


Fig. 6.8.d Groove preparation
(U-groove left and V-groove right)

Item	Standard	Limit	Remarks
Groove preparation	θ=45-60° r= 5 mm		For through plate cracks as for newbuilding. Else see fig 6.9.d
Termination	Termination to have slope 1:3		For cracks ending on edges weld to be terminated on a tab see Fig 6.9.b
Extent	On plate max. 400 mm length. Vee out 50 mm past end of crack	On plate max 500 mm. Linear crack, not branched	
Welding sequence	See fig 6.9.c for sequence and direction	For cracks longer than 300 mm step-back technique should be used Fig 6.9.a	Always use low hydrogen welding consumables
Weld finish	IACS guide for inspection of ship hull welds (ref. 10)		
NDE	IACS guide (ref.10)	100 % MP or PE of groove	100 % surface crack detection + UE or RE for butt joints

6.9 Grinding of shallow cracks



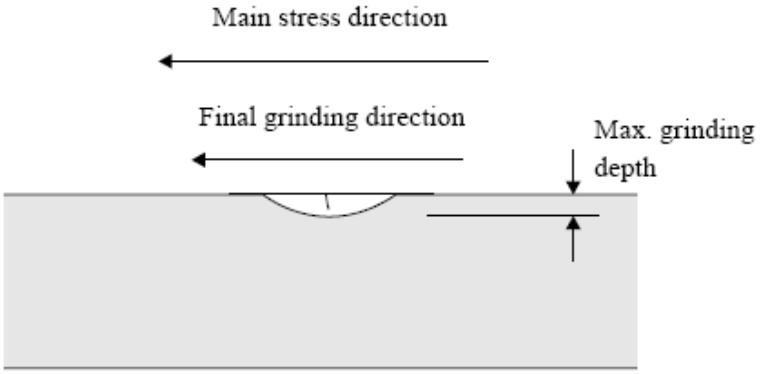


Fig 6.9 Grinding

Item	Standard	Limit	Remarks
Extent	For short cracks only max. 4 t t = Plate thickness	Max. length 100 mm	See also IACS recommendation 12, (ref. 9)
Grinding direction	Final grinding microgrooves parallel to main stress direction		Grinding always to be finished by a rotating burr and not a disk grinder
Grinding depth	Max. 0.2 t t = Plate thickness		Always smooth transition
NDE	IACS guide for inspection of ship hull welds (ref. 10)		100 % MPI