NIPPON STEEL

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ABREX™ —Guidelines for Welding—
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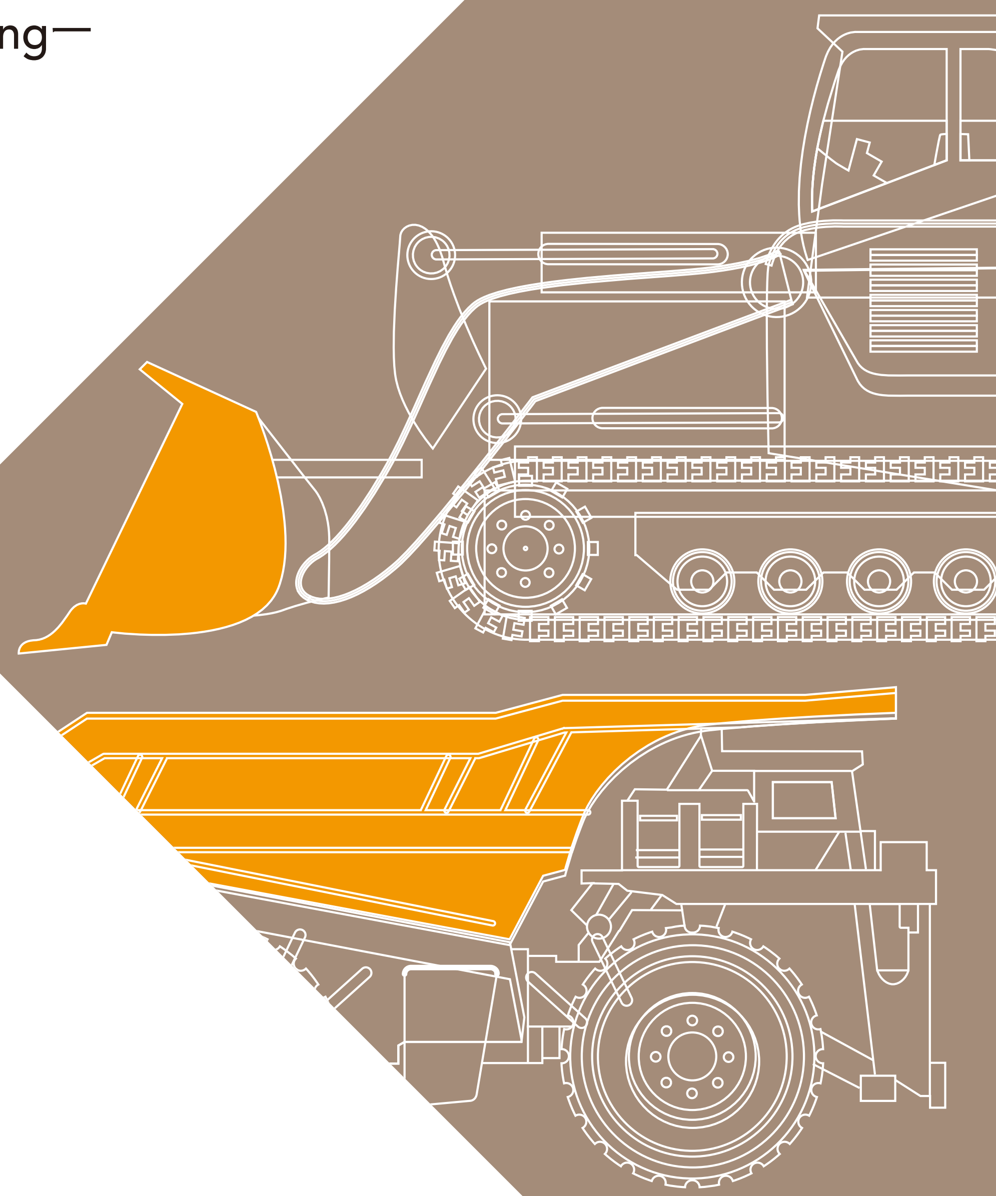
NIPPON STEEL

Steel Plates

ABREX™

Abrasion-resistant Steel Plates —Guidelines for Welding—



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The abrasion-resistant steel plate "ABREX™ Series" from NIPPON STEEL enjoys broad support as an abrasion-resistant material for construction equipment and many other types of industrial machinery.

ABREX™ is an outstanding abrasion-resistant steel designed with welding performance in mind. However, it is a high-hardness steel, and thus it is essential to use it with a correct understanding of its performance. There are concerns that problems such as cold cracking may occur if welding is not done properly.
We hope that by referring to these guidelines, you will be able to use ABREX™ more appropriately and efficiently.

This brochure is provided for reference only for welding work to be performed by the users of ABREX™ steel plate, in order to describe typical welding methods and other related information. Although NIPPON STEEL has made every effort to ensure that the information in this publication is correct, it is furnished without any warranty, express or implied, as to its accuracy, completeness or fitness for any particular use, or with respect to the results that may be obtained by any person using it. Accordingly, the use of any information provided herein is at the reader's own risk, and it is the reader's responsibility to determine whether it is suitable for the reader's intended application. The information in this publication is subject to change without notice. Nothing in this brochure is intended as a recommendation to use any product, method or process in violation of any intellectual property rights governing such product, method or process. NIPPON STEEL DISCLAIMS ANY AND ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION WARRANTIES OF MERCHANTABILITY AND FITNESS FOR ANY PARTICULAR PURPOSE RELATED TO ANY INFORMATION PROVIDED HEREIN.

Contents

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1. Welding material selection

Table 1 Normal welding materials

Ⅰ) Welding material not requiring abrasion resistance at the weld metal (Weld metal hardness: HBW180 class)

Steel type	Welding method		Welding material			
			Brand name	Classification	Shielding gas	Welding position
ABREX 400 ABREX 450 ABREX 500	SMAW		L-55	JIS Z3211 E4916U AWS A5.1 E7016	–	All positions
	GMAW	General type	YM-26	JIS Z3312 YGW11 AWS A5.18 ER70S-G	CO_2	Flat-position, horizontal fillet, and horizontal
	GMAW	General type	YM-28S	JIS Z3312 YGW15 AWS A5.18 ER70S-G	$Ar+CO_2$	All positions
	FCAW	General type	SF-1	JIS Z3313 T49J0T1-1CA-UH5 AWS A5.20 E71T-1C-H4	CO_2	All positions
	FCAW	General type	SX-26	JIS Z 3313 T49J0T15-0CA-UH5 AWS A5.20 E71T-1C-H4	CO_2	Flat-position, horizontal fillet
	FCAW	Preheat reduction type	SF-1CF	JIS Z 3313 T49J0T1-1CA-UH5 AWS A5.20 E71T-1C-H2	CO_2	All positions
	FCAW	Preheat reduction type	SX-60CF	JIS Z 3313 T59J1T15-0CA-G-UH5 AWS A5.28 E80C-G H2	CO_2	Flat-position, horizontal fillet

Ⅱ) Welding material requiring abrasion resistance at the weld metal (Weld metal hardness: HBW240,300 class)

Steel type	Welding method		Welding material					
			Brand name	Classification	Shielding gas	Required preheat temperature (℃)	Interpass temperature (℃)	Welding position
ABREX 400	SMAW		L-80	JIS Z3211 E7816-N5CM3U AWS A5.5 E11016-G	–	≧100	100~150	All positions
	GMAW	General type	YM-80C	JIS Z3312 G78A2UCN5M3T AWS A5.28 ER110S-G	CO_2	≧100	100~150	Flat-position and horizontal fillet
	GMAW	General type	YM-80A	AWS A5.28 ER110S-G	$Ar+CO_2$	≧100	100~150	Flat-position and horizontal fillet
	GMAW	General type	YM-100A	–	$Ar+CO_2$	≧100	100~150	Flat-position and horizontal fillet
	FCAW	Preheat reduction type	SF-80CF	JIS Z 3313 T780T1-1CA-N4M2-UH5 AWS A5.29 E111T-GC-H2	CO_2	≦50*	100~150	All positions
	FCAW	Preheat reduction type	SX-80CF	JIS Z3313 T782T15-0CA-N4C1M2-UH5 AWS A5.28 E110C-G H2	CO_2	≦50*	100~150	Flat-position and horizontal fillet

*The required preheat temperature varies depending on the thickness of the steel. Please consult us as needed.

Due to the high strength of Abrasion resistance steel, it is relatively susceptible to cold cracking. Therefore, it is important to select welding materials with the appropriate strength for the intended use and as low diffusible hydrogen as possible.

When the abrasion resistance of the weld is not considered, using general welding materials for mild steel, as shown in Table 1-1, can help suppress cold cracking.

For fillet welds and other welds where some abrasion resistance is required, welding materials for high tensile strength steel, as shown in Table 1-2, are recommended. However, for root pass welding, where the weld metal is particularly prone to hardening, it is recommended to use welding materials for mild steel as long as the target properties of the weld can be maintained.

The preheat temperatures listed in Table 1-2 are the minimum preheat temperatures required for the welding materials. In welding operations, adopt the higher of the necessary preheat temperatures for the welding materials and the steel plate used. Refer to Table 2 for the necessary preheat temperatures for the steel plate used.

If you'd like to reduce the preheat temperature, you can use "CF wire" that allow for reduced preheating work, as shown in Table 1-1 and Table 1-2.

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2. Preheat and interpass temperature

To avoid the cold-cracking of the abrasion-resistant steel, it is necessary to select a suitable preheat temperature corresponding to the steel type, thickness, and welding material.

1) Index of steel cold-cracking susceptibility

$$CEN = C + A(C)\left\{\frac{Si}{24} + \frac{Mn}{6} + \frac{Cu}{15} + \frac{Ni}{20} + \frac{(Cr+Mo+Nb+V)}{5}\right\} \cdots (1)$$

$$A(C) = 0.75 + 0.25\tanh\{20(C-0.12)\}$$

For the estimated preheat temperature required, a method considering steel chemical composition, thickness, weld metal diffusible hydrogen amount, welding heat input, residual stress, and joint restraint, etc., is proposed by Yurioka, et al.[1)]

In this method, carbon-equivalent CEN shown by formula (1) is used as an index to evaluate the effect of steel alloy on cold-cracking susceptibility. The hardness of the heat-affected zone (HAZ) is determined by the relationship between hardenability and the C content (which determines the hardness of martensite). Mutual effect with CEN is considered, and the weldability of steel over a wide range can be evaluated.

1) N.Yurioka and T.Kasuya: *Quarterly Journal of Japan Welding Society*, 13 (1995), 347

2) Guidelines for the necessary preheat temperature

Table 2 Guideline for preheat temperature when abrasion resistance is not required for the weld metal (weld metal hardness HBW180 class)

Ⅰ) Guideline for preheat temperature using general welding materials

Steel Material	Welding Material	Welding condition	Plate thickness(mm)					
			~11	~20	~25	~36	~50	~100
ABREX 400	YM-26 YM-28S SF-1 SX-26	Typical Welding (Small Constraints)	RT	RT	50℃	50℃	75℃	125℃
		Repair Welding (Medium Constraints)	RT	RT	75℃	75℃	100℃	150℃
ABREX 450		Typical Welding (Small Constraints)	RT	RT	50℃	75℃	75℃	–
		Repair Welding (Medium Constraints)	RT	50℃	75℃	100℃	100℃	–
ABREX 500		Typical Welding (Small Constraints)	RT	50℃	75℃	100℃	125℃	–
		Repair Welding (Medium Constraints)	RT	100℃	100℃	150℃	150℃	–

HI=1.7kJ/mm Diffusible hydrogen content : <3mL/100g

RT : Room Temperature (If the temperature is 5℃ or less, it is recommended that you perform preheating to 20℃ or more)

Ⅱ) Guideline for preheat temperature using welding wire capable of reducing preheat work (CF wire)

Steel Material	Welding Material	Welding condition	Plate thickness(mm)					
			~11	~20	~25	~36	~50	~100
ABREX 400	SF-1CF SX-60CF	Typical Welding (Small Constraints)	RT	RT	RT	RT	RT	50℃
		Repair Welding (Medium Constraints)	RT	RT	RT	RT	RT	75℃
ABREX 450		Typical Welding (Small Constraints)	RT	RT	RT	RT	RT	–
		Repair Welding (Medium Constraints)	RT	RT	RT	RT	50℃	–
ABREX 500		Typical Welding (Small Constraints)	RT	RT	RT	RT	RT	–
		Repair Welding (Medium Constraints)	RT	RT	RT	75℃	75℃	–

HI=1.7kJ/mm Diffusible hydrogen content : <1mL/100g

RT : Room Temperature (If the temperature is 5℃ or less, it is recommended that you perform preheating to 20℃ or more)

Table 3 Guideline for preheat temperature when requiring some abrasion resistance for the weld metal (weld metal hardness HBW240 class)

Ⅰ) Guideline for preheat temperature using general welding materials for high tensile strength steel

Steel Material	Welding Material	Welding condition	Plate thickness(mm)					
			~11	~20	~25	~36	~50	~100
ABREX 400	YM-80C YM-80A	Typical Welding (Small Constraints)	100℃	100℃	100℃	100℃	100℃	125℃
		Repair Welding (Medium Constraints)	100℃	100℃	100℃	100℃	100℃	150℃

HI=1.7kJ/mm

Ⅱ) Guideline for preheat temperature using welding materials capable of reducing preheat work (CF wire for high tensile strength steel)

Steel Material	Welding Material	Welding condition	Plate thickness(mm)					
			~11	~20	~25	~36	~50	~100
ABREX 400	SF-80CF SX-80CF	Typical Welding (Small Constraints)	RT	RT	RT	RT	50℃	75℃
		Repair Welding (Medium Constraints)	RT	RT	RT	RT	75℃	100℃

HI=1.7kJ/mm

RT : Room Temperature (If the temperature is 5℃ or less, it is recommended that you perform preheating to 20℃ or more)

Table 2-Ⅰ) shows a guideline for the necessary preheat temperature when using the welding materials for mild steel, assuming the abrasion resistance of the weld is not required. Please maintain the preheat temperature until the welding is completely finished.
Table 2-Ⅱ) shows a guideline for the necessary preheat temperature when using "CF wire" which the preheat reduction type welding material (Please refer in Table 1-1). Due to the extremely low diffusible hydrogen content of "CF wire" (Typical management value: 1mL/100g or less), the preheat can be significantly reduced compared to welding with general welding materials.
Table 3-Ⅰ) shows a guideline for the necessary preheat temperature when using the welding materials for high tensile strength steel, assuming the abrasion resistance of the weld is required. The weld metal obtained with the welding materials for high tensile strength steel is more occured cold cracking than it for mild steel, so the higher of the necessary preheat temperatures for the base material and welding material is listed.
Table 3-Ⅱ) shows a guideline for the necessary preheat temperature when using "CF wire" which the preheat reduction type welding material (Please refer in Table 1-2). Due to the extremely low diffusible hydrogen content of "CF wire" (Typical management value: 1mL/100g or less), the preheat can be significantly reduced compared to welding with general welding materials.
Tables 2 and 3 shows the preheat temperatures for "typical welding" and "repair welding" respectively. Typical welding means that assumes with less stringent restraints, such as fillet welding or butt welding. Repair welding generally requires higher preheat temperatures than typical welding due to faster cooling rates and more stringent constraint stresses. The preheat temperature for column welding, tack welding, and welding of small items such as pieces and jigs should be the same as for repair welding.
The necessary preheat temperature is influenced not only by carbon equivalent, diffusible hydrogen content in the weld, yield strength of the weld metal, heat input, and plate thickness, but also by ambient temperature, number of passes, groove shape, preheat method, and presence of post-heat. Therefore, the preheat temperatures in Tables 2 and 3 should be considered as guidelines only.
Even in the case of RT (no preheating), if the ambient temperature or steel plate surface temperature is below 5° C, there is a risk of condensation on the groove surface, so preheating to above 20° C is recommended. Additionally, if condensation is observed inside the groove even at temperatures above 5° C, it must be removed by heating or other means.

3) Interpass temperature

Preheat temperature ≤ Interpass temperature ≤ 200℃

The lower limit of the interpass temperature must be the necessary preheat temperature or more.
If the interpass temperature is high, the cooling speed is slow. This may reduce the hardness and toughness of the HAZ. It is recommended that you set the upper limit of the interpass temperature to 200℃.

4) Preheating method

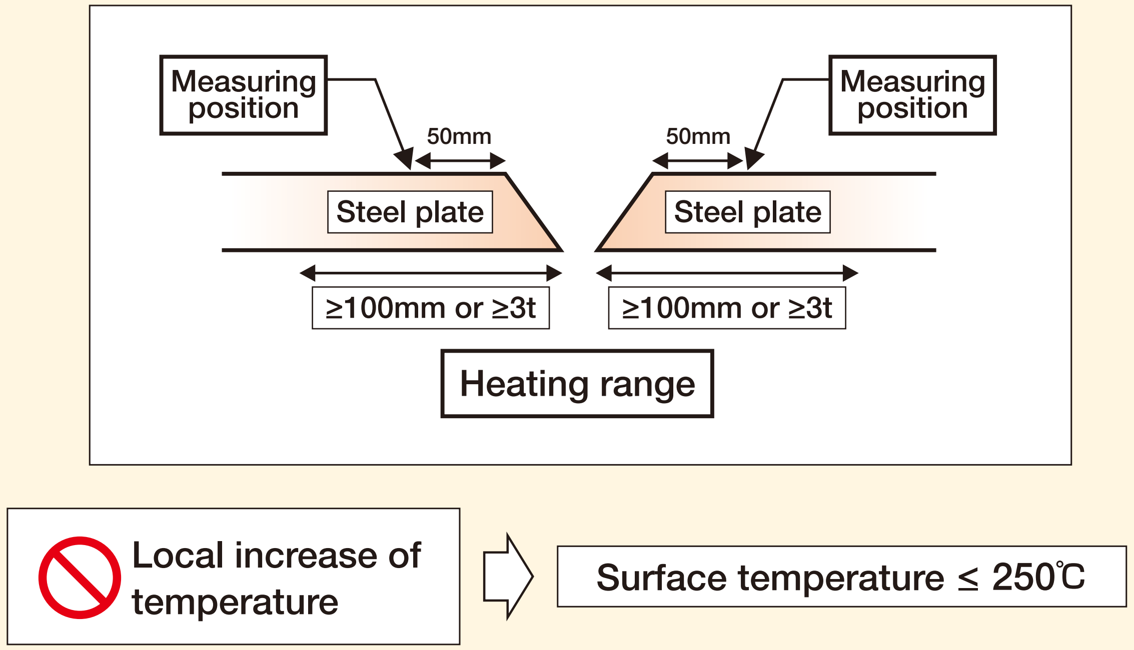

Fig. 1 Preheating range and measuring positions under preheating

In preheating, it is necessary to heat a wide area to some degree in order to heat up to the surface opposite to the heating surface to the predetermined temperature, not heating only a narrow area in the groove. In this case, please note that the local temperature may not be increased excessively. (Control the surface temperature not to exceed 250℃.) Specifically, the heating range should be about 100 mm at both sides of the weld line (or three times the thickness). The temperature should be measured at the position about 50 mm from both sides of the weld line (see Fig. 1).

A simple method for preheating is by using a gas burner. To perform heating uniformly for a long time, it is recommended that you use an electric-resistance heater with a thermostat.

If welding is interrupted, it is necessary to perform preheating again before the restart of welding.

3. Post heating (Heat treatment just after welding)

If the necessary preheat and interpass temperatures are high and if it is difficult to carry out operation, the preheat and interpass temperatures can be reduced to a certain degree by employing post heating. In addition, if the thickness is large or if restraint is very strong, Post heating together with preheating can improve the function to control cold-cracking. Post heating must be immediately performed without reducing the temperature of the object for welding to the room temperature after welding or during any interruption of welding. The purpose of post heating is to remove hydrogen from the welds. As a guideline, the necessary procedure for the treatment is approximately 200℃ with 1hr or more.

4. Precautions for welding

1) Precautions for the handling of welding material

(1) Welding material for SMAW

Dry the materials sufficiently and store them in a special container.

🚫 Water, rust, oil stain, primer etc.

A welding material for SMAW needs to be fully dried according to the specified conditions (temperature and time) of the welding material manufacturer before use because the flux deteriorates if the temperature is too high. If it is exposed to the atmosphere or placed on the ground after drying, it will reabsorb moisture and increase the diffusible hydrogen content. Store it in a storage container (the storage conditions such as the temperature should comply with the specified conditions of the welding material manufacturer). When it is left for a long time, dry it (the allowable exposure time after drying should also comply with the specified conditions of the welding material manufacturer). SMAW is susceptible to humidity when welding. In particular, if welding is performed under high-temperature and high-humidity conditions, the preheat temperature should be set high, in order to avoid the increase of the diffusible hydrogen amount due to the absorption of humidity in the flux or due to effect of the ambient atmosphere. Water, rust, oil stain, primer etc., at areas for welding may become a source of diffusible hydrogen. In the welding for ABREX™ these should definitely be removed before welding. The arc length should be kept short because longer arc length tends to increase the diffusible hydrogen content.

(2) Welding material for GMAW

🚫 Water, rust, oil stain, primer

🚫 Wind speed ≥ 0.5m/sec. ⇨ Wind speed < 0.5m/sec. or use of windbreaker

In case of GMAW, the diffusible hydrogen content increases if extending CTWD (tip-work distance) or increasing arc voltage. Water, rust, oil stain, primer at areas for welding, or wire rust, etc., may become a source of diffusible hydrogen. In the welding for ABREX™ these should always be removed before welding. The cleaning area should be from the groove in Fig. 1 to around the temperature measuring point. Use a wire brush, grinder, and so on to remove. For MAG (MIG) wires, do not use them if you notice a defect such as rust.

2) Precautions for defect prevention in MAG (MIG) welding

(1) Precautions for welding

- Comply with the recommended conditions of the welding material manufacturer as to constraints for welding position, adequate current and voltage, welding speed, polarity (normally DCEP (Direct Current Electrode Positive), and CTWD (Chip To Work Distance).
- The adequate flow rate of shielding gas is 20 to 25 L/min. Too high a flow rate causes a turbulent flow, engulfing the air.
- When the wind velocity is 0.5 m/sec. or more, avoid welding or use a screen to protect against the wind.
- Before welding, make sure that no excessive spatter has adhered inside the nozzle, and that an orifice has been attached.
- In order to prevent the slag inclusion, remove slag generated on the bead surface for each welding pass.
- In order to prevent lack of fusion in multi-layer welding, take note of the layering method so that an acute valley-like shape will not be formed between each bead, and between the bead and groove surface. In case the acute valley-like shape is formed, grind it to a smooth shape with a grinder, etc. and weld the next pass.
- In case of Welding in the groove, weld defects are likely to occur such as incomplete penetration and slag inclusion. Select welding conditions, such as increasing the welding speed or employing drag angle, to prevent the weld defects.

(2) Securement of wire feedability

- Use adequately sized feed rollers, conduit liners and contact chips suitable to the wire diameter.
- In case the contact chip is damaged (worn, fused), replace them with new ones.
- The allowable bending range of the conduit cable is generally one turn per 500 mm in diameter only.
- If using a conduit liner for a long period of time, it will decrease wire feedability due to wear of the inner surface, adhesion of foreign substances (ground wire refuse, lubricant, etc.), and so on clean as recommended by the manufacturer or replace with new one.

3) Heat input limit in view of base metal properties

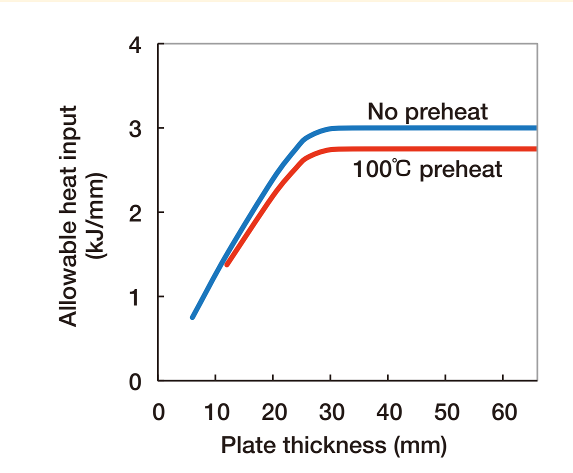

Fig. 2 Guideline for allowable heat input

In view of the prevention of cold-cracking, it is desirable to have high welding heat input. When the heat input is high, the welding HAZ becomes coarse and the cooling speed becomes slow, which results in low toughness. When the cooling speed is slow, the softening range of the HAZ becomes large. Fig. 2 shows a guideline for the upper limit welding heat input corresponding to thickness. In case preheat is required, it is preferable to lower heat input than when no preheat is required, in order to inhibit the softening width of the HAZ.

Welding heat input (J/mm) = (60×Current[A]×Voltage[V])/Welding speed[mm/min]

4) Precautions for repair welding

Bead length of repair welding ≥ 80 mm

In repair welding, the cooling speed is generally faster and the restraint stress is stronger. As shown in Table 2, a preheat temperature higher than the temperature for normal welding is required. It is recommended that you use a bead length of 80 mm or more with two passes or more for repair welding. Because cracks tend to occur in the HAZ after repair welding, it is recommended to inspect scars by the NDT. For instance, the following procedure is recommended. Checking the range and positions of cracks by visual check and NDT → (Making a stop hole beforehand in order to inhibit development of cracks, etc. as required) → Removing a defect → Checking removal of defect by the NDT again → Group machining → Repair welding → Finally checking by the NDT again for any defect caused by repair welding after taking time for hydrogen diffusion, such as 48 hours later.

If arc air gouging is used to remove defects, use a grinder for touch-up.

5) Precautions for tack welding

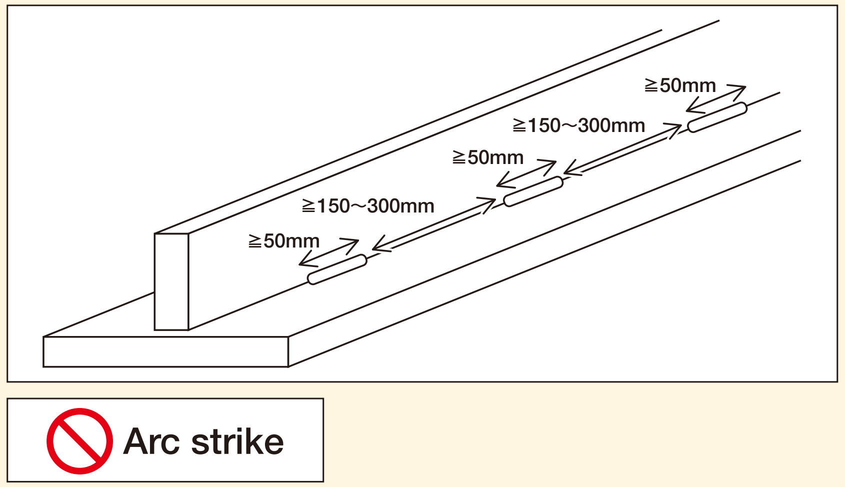

Fig. 3 Bead length and distance of tack welding

In tack welding, it is necessary to pay attention to cold-cracking more than in repair welding. In particular, if the bead length of a tack welding is short, the cooling speed is very fast and the weld metal and the base metal HAZs are hardened, resulting in high cracking susceptibility. Therefore, set the bead length of the tack welding to 50 mm or more. In addition, set the spacing of the tack welding to 150 to 300 mm (see Fig. 3).

It is recommended to have the preheat temperature for tack welding set as same as the preheat temperature during repair welding in Table 2. Avoid arc strikes on the base metal. Because a tack weld zone cracks easily, it is recommended to remove slag before final welding and check that the weld zone is not cracked.

6) Welding of different steel types and different thicknesses

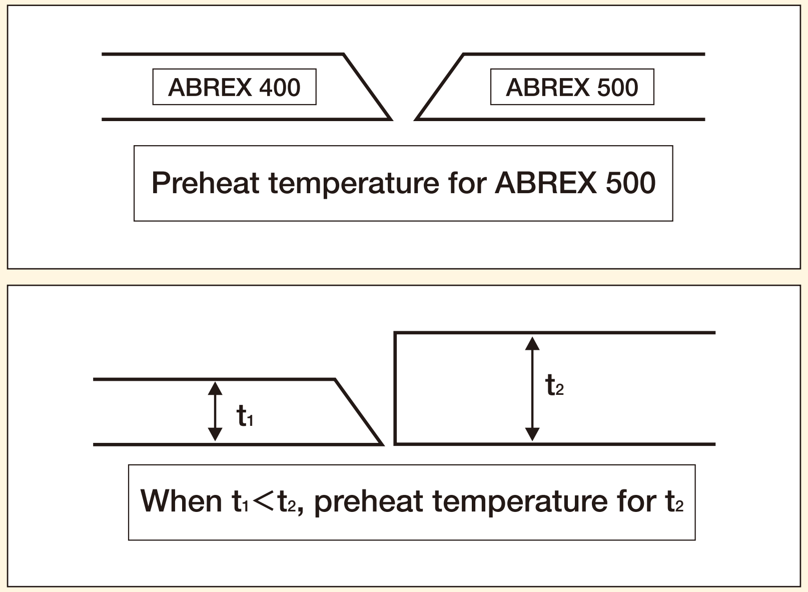

Fig. 4 Dicision procedure of preheat temperature

When ABREX™ steel with different hardness is welded, employ the higher value of the necessary preheat temperatures in Tables 2.

If ABREX™ steel is welded to a different steel material and the mating steel for ABREX™ is normal steel and high-tensile-strength steel of grade 590 N/mm² or less, employ the ABREX™ preheat temperature in Tables 2.

If ABREX™ steel plates with different thicknesses are welded, employ a value in accordance with the thicker plate (that has a higher necessary preheat temperature).

7) Others

- A weld crossing (3-line crossing, etc.) is highly subject to a weld defect. It is advisable to design as few of them as possible. In execution, care should be taken not to allow bead leading and trailing ends to overlap at multiple points.
- In case a weld defect occurs in a crater, and so on, it is recommended to use an end tab as a measure. When using the end tab, care should be taken not to cause a notch during removal by cutting.
- In case of boxing in fillet welding, it is recommended to avoid starting welding from a corner.
- Welding is strictly prohibited when the steel plate or welding material is wetted by rain, snow, etc. When it is 5℃ or less, heat to 20℃ or more (even if no preheat is required).
- For the welding material for SMAW, a flux generally tends to absorb moisture. Follow the instructions given by the welding material manufacturer such as drying before use, storage in a storage container, redrying after long-time exposure, and so on.
- When welding small articles such as lifting pieces for transportation and jigs, employ the preheat temperature of "repair welding." To remove them by cutting, offset 3 mm or more from the surface of the base material to cut, and then, perform finish grinding with a grinder, thereby avoiding any harmful effect on the base material, for instance.
- Post-Weld Heat Treatment (PWHT) is strictly prohibited because it causes embrittlement, reheat cracking at a weld toe, and hardness reduction.
- When hard-facing the weld zone or base material, adjust to the preheat temperature of the hard-facing welding material with the highest carbon equivalent. When welding a buffering welding material, use general low-hydrogen, low-strength welding materials recommended in Table 1-Ⅱ) according to the hardness level of the hard-facing welding material. In case the general welding material cracks, consider use of stainless steel welding materials in Table 1-Ⅲ).
- When performing backing welding, adhere a backing material and the base material closely within a distance of 0.5 mm. As with the base material, clean the backing material itself (comply with a base material cleaning procedure) and beware of moisture between the backing material and base material.
- For magnetic arc blow control, see the relevant page of our general catalog for thick plates.

5. Cold Cracking

Cold cracking arises from hydrogen and takes place sometime after completion of welding (generally taking place at 300℃ or less). Utmost care should be taken to prevent this weld defect in welding abrasion resistant steel and it is necessary to observe the welding conditions. Its controlling factors are (1) hardened structure, (2) stress, and (3) diffusible hydrogen.

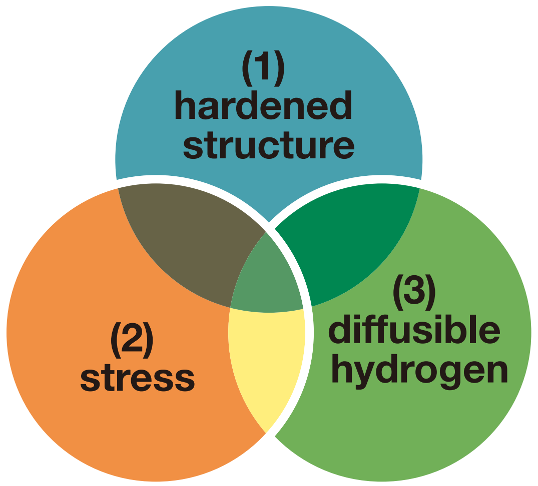

Fig. 5 Controlling Factors for Cold Cracking

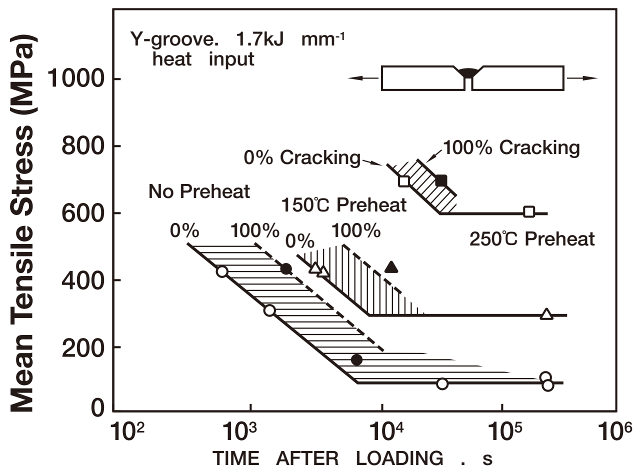

Fig. 6 TRC Test Results Example[2)]

Suzuki et al.: *Journal of Japan Welding Society*, 32 (1963), 44

Fig. 6 shows a TRC test example and is published to help you understand that the latent period to cold cracking differs depending on the stress magnitude expressed in the vertical axis, and that the crack generation critical stress increases as the preheat temperature rises; it is not the data of the abrasion resistant steel. The 200℃ or lower preheat is recommended in order not to damage hardness.

(1) Hardened structure : As the carbon content (Pcm, CEN, CEV, CET, etc.) of a steel plate increases, a hardened structure tends to be generated in the HAZ, allowing cold cracking in the HAZ. For the purpose of obtaining hardness, it must be recognized that the abrasion resistant steel of high carbon equivalent is a material highly sensitive to cold cracking. Particularly, the carbon equivalent tends to increase as hardness and thickness become higher. On the other hand, the carbon equivalent of the welding material is related to sensitivity to cold cracking of a weld metal. Of the welding material and base material, it is necessary to determine the preheat conditions on the premise of higher carbon equivalent. In case of tack welding, welding of small articles such as jigs and pieces, plug welding, and thick-material welding, heat extraction is greater and the cooling speed is higher, adding to the hardness of the HAZ. Accordingly, a higher preheat temperature is required, compared with normal welding and thin-material welding. Preheat has two effects; one is to diffuse/discharge hydrogen from the plate and the other is to slow down the cooling speed to inhibit hardness of the HAZ. Higher heat input also slows down the cooling speed to inhibit the hardened structure and diffuse hydrogen as with the above-mentioned, but is restricted due to the effects of lower toughness of the weld zone, expansion of the softened area of the HAZ and the like.

(2) Stress : A post-weld residual stress increases as the weld metal has higher strength. Accordingly, a low-strength welding material is recommended for the abrasion resistant steel. Note that the weld zone is undermatched. In case a higher-strength welding material is used, it is necessary to increase the preheat temperature as exemplified in Table 2-Ⅱ). The reaction stress is higher in repair welding, plug welding and thick-material welding (intensity of restraint is simply proportional to plate thickness) and requires higher preheat temperature than normal welding and thin-material welding. Note that if a thin material has high intensity of restraint because of many welded parts, the stress may increase at some parts. To prevent concentration of stress, avoid incomplete fusion and incomplete penetration during welding.

(3) Diffusible hydrogen : Cold cracking occurs when the diffusible hydrogen content level contained in a welding material (dependent on production by the manufacturer), hydrogen pickup to the welding material by moisture absorption after production, moisture, rust and oil contamination adhered to the steel plate, hydrogen penetration from a primer and the atmosphere during welding, and the like are diffused and decomposed into molecules in the hardened parts (HAZ and weld metal) generated by heat history due to welding. It is necessary to use a low-hydrogen welding material, observe the storage and management instructions for the welding material, and avoid using moisture absorbed welding material. Our recommended solid wires and flux cored wires made by NIPPON STEEL WELDING & ENGINEERING inhibit diffusible hydrogen. Note that diffusible hydrogen may intrude due to corrosion of steel material in use and the like at times other than during welding.