NIPPON STEEL

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ABREX™ —Guidelines for Welding—
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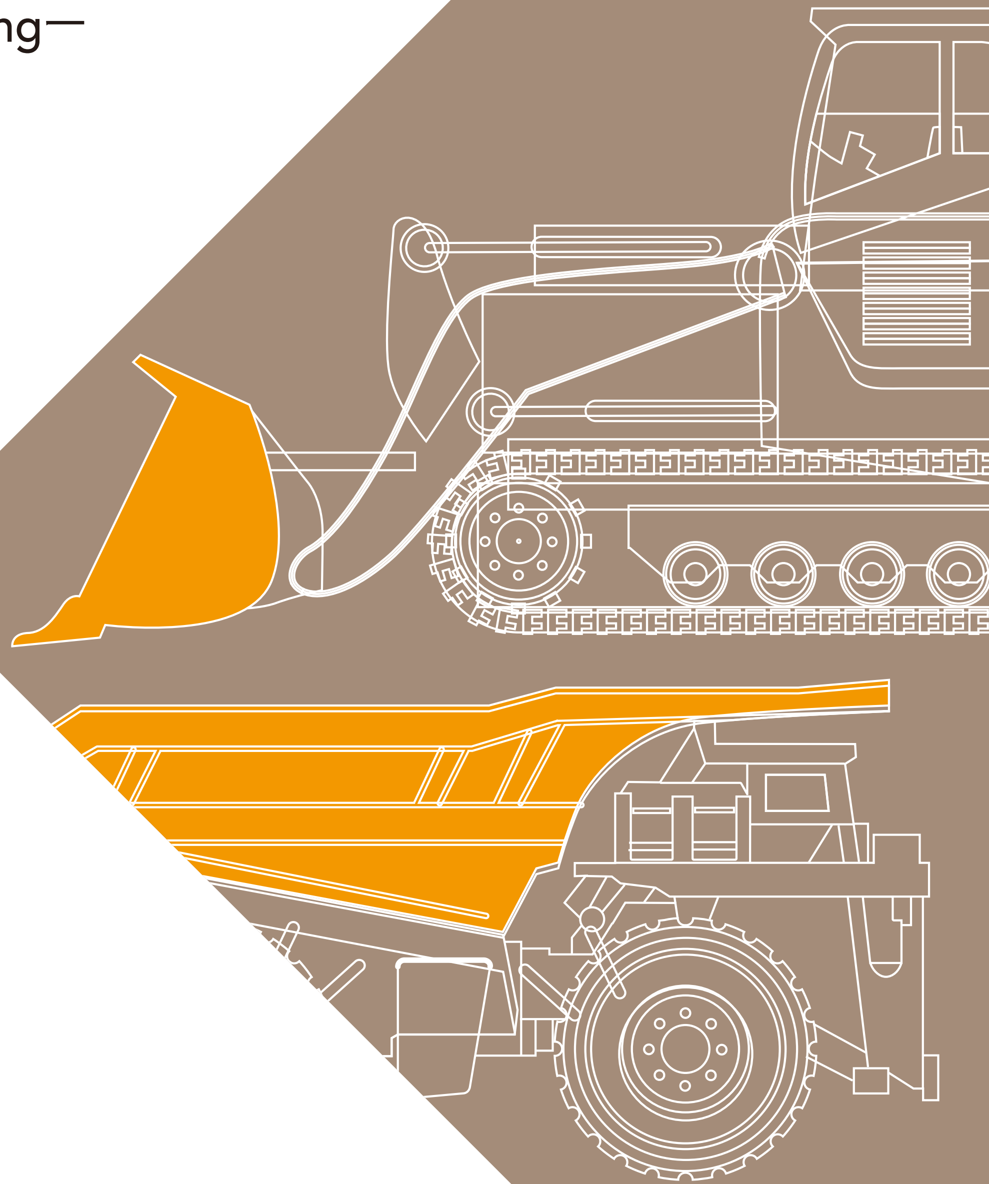
NIPPON STEEL

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 cracking at low-temperature 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

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	Standard	Shield gas	Welding posture
ABREX 400 ABREX 400LT ABREX 450 ABREX 450LT ABREX 500	SMAW	L-55	JIS Z3211 E4916U Applicability to AWS A5.1 E7016	–	All postures
	GMAW	YM-26	JIS Z3312 YGW11 Applicability to AWS A5.18 ER70S-G	CO_2	Flat-position, horizontal fillet, and horizontal
		YM-28S	JIS Z3312 YGW15 Applicability to AWS A5.18 ER70S-G	Ar+CO_2	All postures
		SF-1	JIS Z3313 T49J0T1-1CA-UH5 Applicability to AWS A5.36 E71T1-C1A0-CS1	CO_2	All postures

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

Steel type	Welding method	Welding material					
		Brand	Standard	Shield gas	Required preheat temperature (℃)	Interpass temperature (℃)	Welding posture
ABREX 400 ABREX 400LT	SMAW	L-80	JIS Z3211 E7816-N5CM3U Applicability to AWS A5.5 E11016-G	–	≧100	100～150	All postures
	GMAW	YM-80C	JIS Z3312 G78A2UCN5M3T Applicability to AWS A5.28 ER110S-G	CO_2	≧100	100～150	Flat-position and horizontal fillet
		YM-80A	Applicability to AWS A5.28 ER110S-G	Ar+CO_2	≧100	100～150	Flat-position and horizontal fillet
		YM-100A	–	Ar+CO_2	≧100	100～150	Flat-position and horizontal fillet

Ⅲ) Stainless steel-type welding material

Steel type	Welding method	Welding material			
		Brand	Standard	Shield gas	Welding posture
ABREX 400 ABREX 400LT ABREX 450 ABREX 450LT ABREX 500	SMAW	309･R	JIS Z3211 ES309-16 Applicability to AWS A5.4 E309-16	–	All postures
	GMAW	YM-309	JIS Z3321 YS309 Applicability to AWS A5.9 ER309	Ar+CO_2	Flat-position, horizontal fillet, and horizontal
		SF-309LP	JIS Z3323 TS309L-FB1 Applicability to AWS A5.22 E309L T1-1	CO_2、Ar+CO_2	All postures

Since abrasion-resistant steel has super-high strength, cold-cracking susceptibility is relatively high. For this reason, it is important to select a welding material that has a strength level meeting the purpose and that has a lower generation of diffusible hydrogen.

In case of normal welding material, if abrasion resistance at the welds is not required, it is recommended that you use a low-strength welding material that has good weldability, as in Table 1-Ⅰ).

If a certain level of abrasion resistance at the welds including fillet welds is required, it is recommended that you use high-tensile-strength welding material, as in Table 1-Ⅱ). Even when using a high-strength welding material, a low-strength one is recommended for a root pass which is very easily hardened by low heat input, as far as the target characteristics of a weld zone can be secured.

The preheat temperature described in Table 1-Ⅱ) is the minimum preheat temperature necessary for the welding material. Use the higher temperature of this temperature and the preheat temperature (Table 2) according to the steel to be used.

When you want to reduce the preheat temperature, you may also use austenitic stainless steel welding material such as 309, although it is expensive as shown in Table 1-Ⅲ).

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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

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

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

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 the preheat temperature required (general welding material)

Ⅰ) Guideline for the preheat temperature required for HBW180-class weld metal hardness

ABREX 400LT : t≦60mm

Steel Material	Welding Material	Welding condition	Plate thickness(mm) ~11	~20	~25	~36	~50	~100
ABREX 400	YM-26 YM-28S SF-1	Normal Welding (Small Constraints)	RT	RT	50℃	50℃	75℃	125℃
		Repair Welding (Medium Constraints)	RT	RT	75℃	75℃	100℃	150℃
ABREX 400LT		Normal Welding (Small Constraints)	RT	RT	75℃	75℃	100℃	125℃
		Repair Welding (Medium Constraints)	RT	RT	100℃	125℃	125℃	150℃
ABREX 450		Normal Welding (Small Constraints)	RT	RT	50℃	75℃	75℃	–
		Repair Welding (Medium Constraints)	RT	50℃	75℃	100℃	100℃	–
ABREX 450LT		Normal Welding (Small Constraints)	RT	RT	50℃	150℃	150℃	–
		Repair Welding (Medium Constraints)	RT	50℃	75℃	200℃	200℃	–
ABREX 500		Normal Welding (Small Constraints)	RT	50℃	75℃	100℃	125℃	–
		Repair Welding (Medium Constraints)	RT	100℃	100℃	150℃	150℃	–

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)

Ⅱ) Guideline for the preheat temperature required for HBW240-class weld metal hardness (high-strength welding material)

ABREX 400LT : t≦60mm

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

HI=1.7kJ/mm

Ⅲ) Guideline for the preheat temperature for stainless steel type welding materials

ABREX 400LT : t≦60mm

Steel Material	Welding Material	Welding condition	Plate thickness(mm) ~11	~20	~25	~36	~50	~100
ABREX 400	309・R YM-309 SF-309LP	Normal Welding (Small Constraints)	RT	RT	RT	RT	RT	RT
		Repair Welding (Medium Constraints)	RT	RT	RT	RT	RT	RT
ABREX 400LT		Normal Welding (Small Constraints)	RT	RT	RT	RT	RT	RT
		Repair Welding (Medium Constraints)	RT	RT	RT	RT	RT	RT
ABREX 450		Normal Welding (Small Constraints)	RT	RT	RT	RT	RT	–
		Repair Welding (Medium Constraints)	RT	RT	RT	RT	RT	–
ABREX 450LT		Normal Welding (Small Constraints)	RT	RT	RT	75℃	75℃	–
		Repair Welding (Medium Constraints)	RT	RT	RT	100℃	100℃	–
ABREX 500		Normal Welding (Small Constraints)	RT	RT	RT	RT	RT	–
		Repair Welding (Medium Constraints)	RT	RT	RT	RT	RT	–

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 obtained in a similar way, based on the assumption that, in gas shield arc welding, the heat input is 1.7 kJ/mm and the weld metal diffusible hydrogen is 3 ml/100 g, when a normal mild steel welding material is used (abrasion resistance at the welds is not considered). Maintain the preheat temperature until welding is completely finished.
In table 2, it also shows the preheat temperatures for normal welding and repair welding, respectively. Normal welding assumes fillet welding, less binding butt welding and the like. Repair welding requires higher preheat temperature than normal welding because the cooling speed generally becomes higher and the reaction stress gets higher. In plug welding, tack welding, and welding of small articles such as pieces and jigs, the preheat temperature should be the same as in repair welding.

Table 2-Ⅱ) shows a guideline for the necessary preheat temperature obtained in a similar way, based on the assumption that, in gas shield arc welding, the heat input is 1.7 kJ/mm and the weld metal diffusible hydrogen is 3 ml/100 g or less, when a high-strength welding material is used. Since welding materials tend to crack, the temperature that is higher of the respective necessary preheating temperatures for base metal and welding material is described in the table.

Table 2-Ⅲ) shows a guide to the required preheat temperature when using the austenitic stainless steel welding material shown in Table 1-Ⅲ). Use of the austenitic stainless steel welding material reduces the preheat temperature, although it is expensive.

The necessary preheat temperature is controlled not only by the carbon equivalent, weld metal hydrogen, weld metal yield strength, heat input, and thickness, but also by the outside temperature, number of passes, groove shape, preheating method, and whether or not heating just after welding is performed. Please note that the preheat temperatures in Tables 2 are only guidelines.

In the case of RT (without preheating), if the outside temperature or steel surface temperature is 5℃ or less, dew condensation may occur on the groove surface. It is recommended that you perform preheating to 20℃ or more. In case dew condensation is found on the groove surface even at 5℃ or more, be sure to remove moisture by heating, and so on.

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

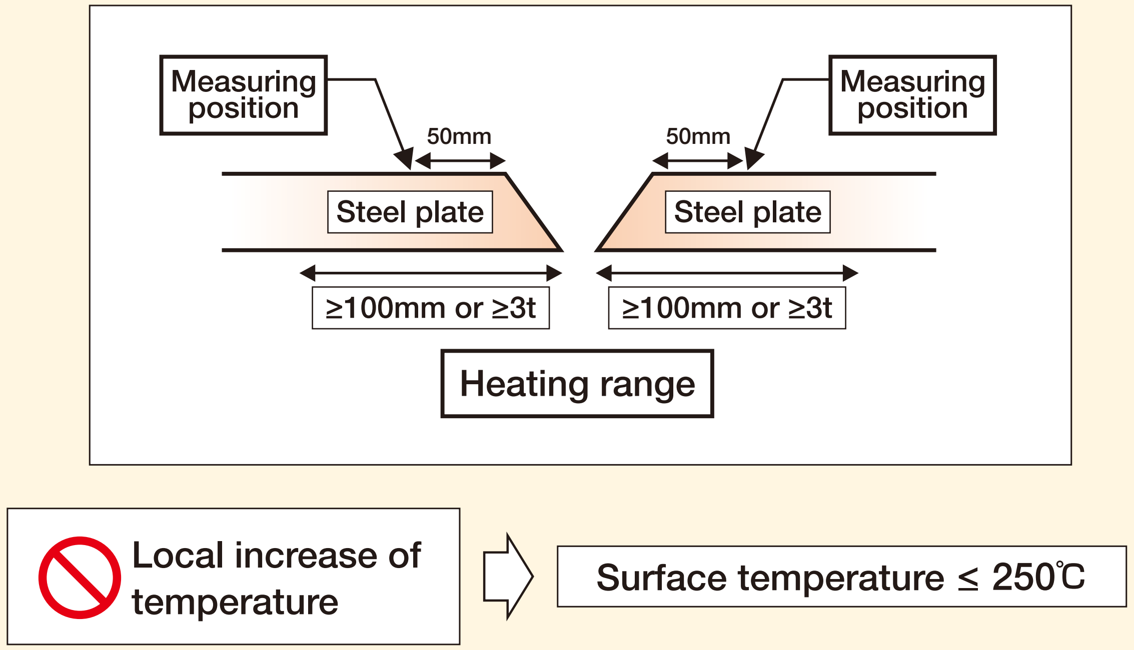

Fig. 1 Preheating range and measuring positions under preheating

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. 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 heat treatment just after welding. In addition, if the thickness is large or if restraint is very strong, heat treatment just after welding together with preheating can improve the function to control cold-cracking. Heat treatment just after welding 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 heat treatment just after welding is to remove hydrogen from the welds. As a guideline, the necessary procedure for the treatment is 150℃ to 200℃, with a thickness/25.4 mm×hr 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 ABREX welding, these should definitely be removed before welding. The diffusible hydrogen content tends to increase as the arc length is extended. Shorten the arc length to implement welding.

(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 GMAW, since shield gas is used, the diffusible hydrogen amount is low. However, if the protrusion length is increased or if the arc voltage is increased, the diffusible hydrogen is increased. Water, rust, oil stain, primer at areas for welding, or wire rust, etc., may become a source of diffusible hydrogen. In ABREX welding, 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 wire positive for the said welding method), and projection length.
- 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 involvement of slag, remove slag generated on the bead surface for each welding pass.
- In order to prevent incomplete fusion in multi-layer welding, take note of the laminating 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, a metal advance phenomenon (a molten metal goes ahead of a molten pool) occurs, easily causing a penetration failure or slag involvement. Select welding conditions, such as increasing the welding speed or employing a sweepback angle, to prevent the metal advance phenomenon.

(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 feed liner for a long period of time, it deteriorates due to wear of the inner surface, adhesion of foreign substances (ground wire refuse, lubricant, etc.), and so on, compounding wire feedability. If this is the case, clean by a method recommended by the manufacturer or replace with new one.

3) Heat input limit in view of base metal properties

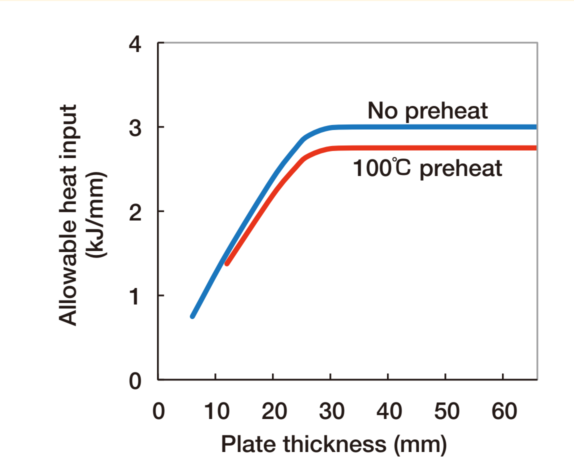

Fig. 2 Guideline for allowable heat input

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

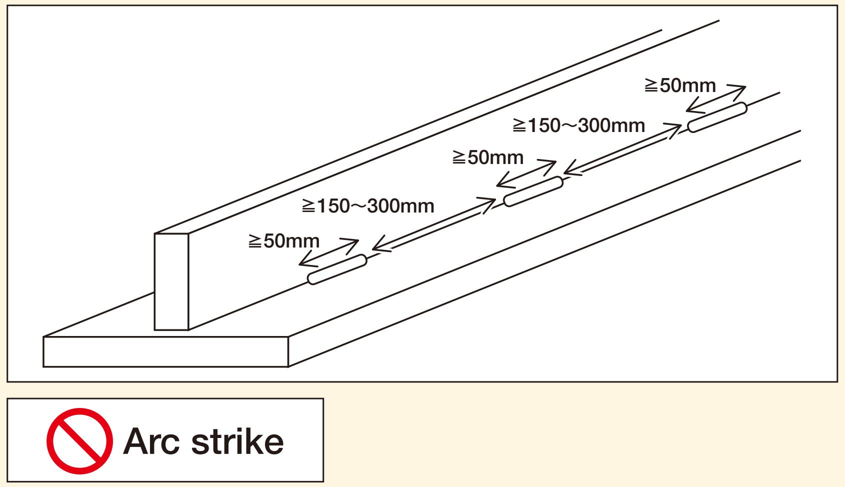

Fig. 3 Bead length and distance of tack welding

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

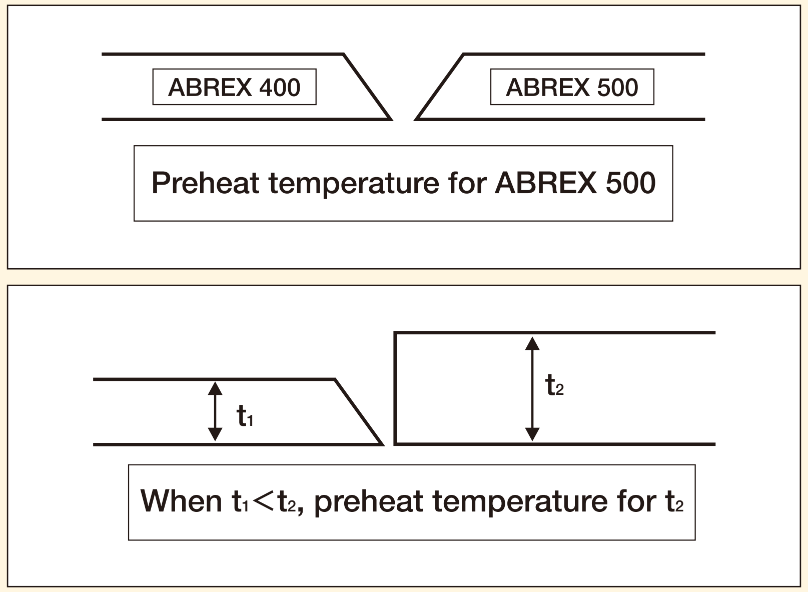

Fig. 4 Dicision procedure of preheat temperature

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/mm^2 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 wear resistant steel and it is necessary to observe the welding conditions. Its controlling factors are (1) hardened structure, (2) stress, and (3) diffusible hydrogen.

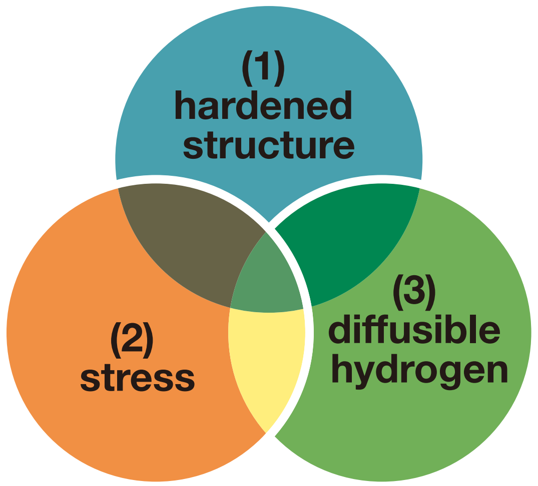

Fig. 5 Controlling Factors for Cold Cracking

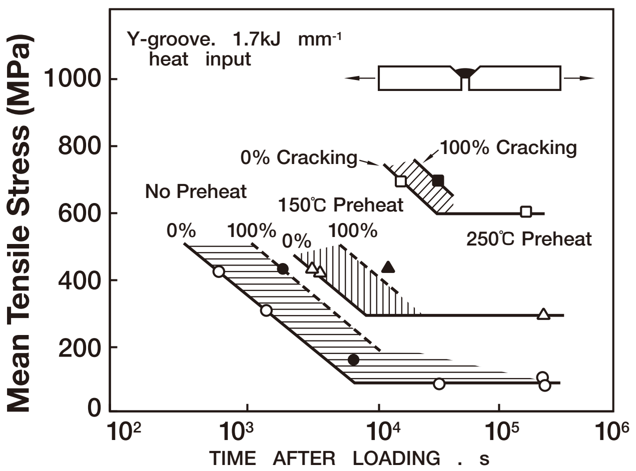

Fig. 6 TRC Test Results Example[2)]

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 wear 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 wear 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 wear 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.