KOBELCO WELDING TODAY

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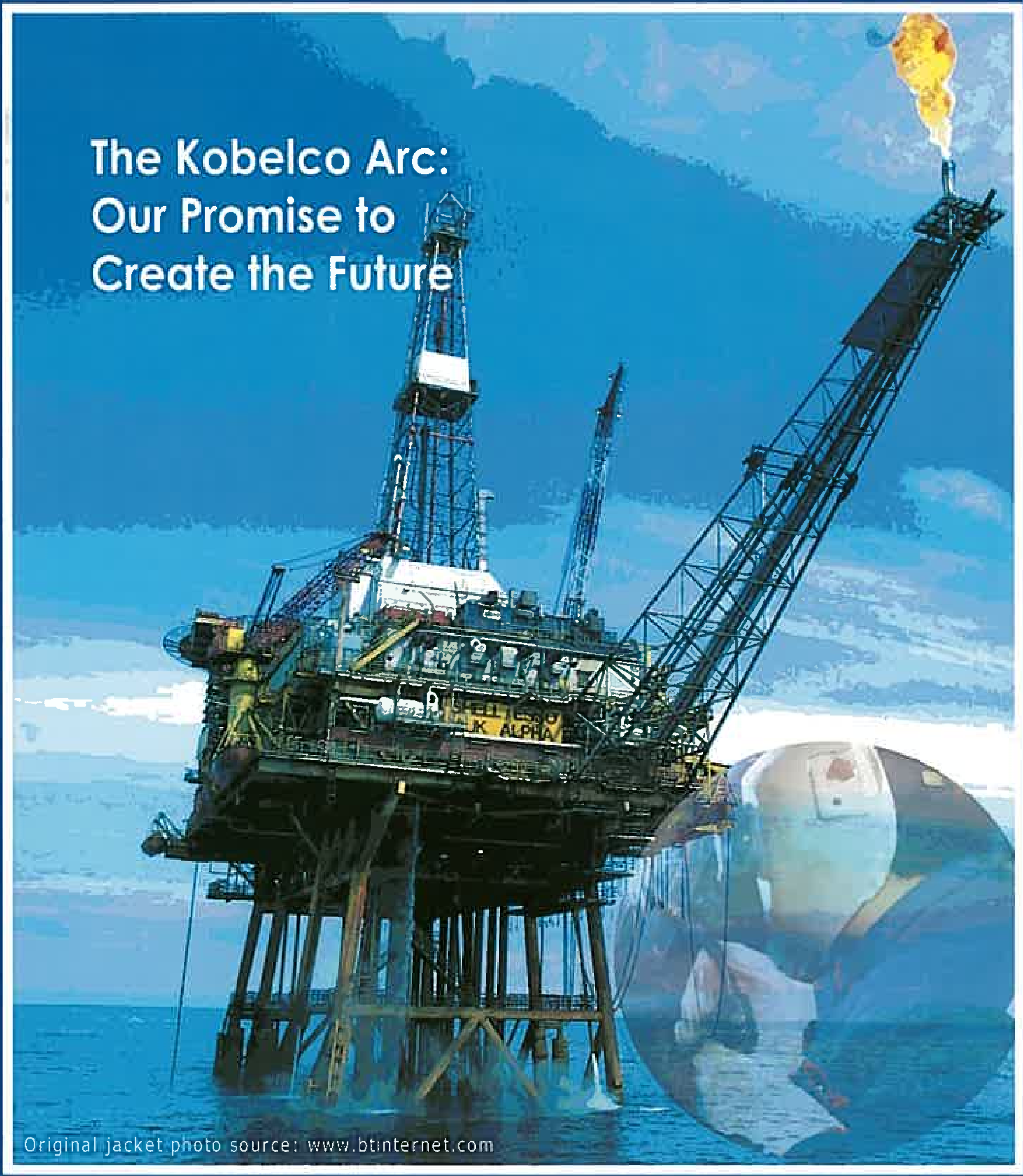


INFRA-KOBELCO Partnership: Strengthened through WELDMEX 2003

INFRA attracted many visitors from the domestic fabrication sectors in Mexico's first welding exhibition, WELDMEX 2003

Mexico is famous for magnificent archeological sites and fabulous beaches such as Acapulco and Cancun. The capital, Mexico City, with a population of 20 million, has been called the biggest megalopolis on Earth. 50km northeast of Mexico City are the ruins of an ancient city, *Teotihuacán*, where two enormous pyramids (The Pyramid of the Sun and The Pyramid of the Moon) attracts many overseas tourists every year.

The Pyramid of the Sun dominating the skyline

Meanwhile Mexico's expanding industrial capacity is also drawing attention from overseas. When the Free Trade Agreement between Mexico and the United States came into effect, Mexico began to play a tremendous role as an industrial goods supplier to the US. The welding and fabrication industry is no exception in this trend. In Mexico, the total consumption of welding materials has reached 70,000 tons per year, and this figure keeps on growing.

As the first welding exposition in Mexican history, WELDMEX was held at the World Trade Center in Mexico City from the 28th to 30th of January. Demonstrating the growth of the Mexican fabrication industry, the exhibition booths were packed with enthusiastic visitors, mostly domestic fabricators, and the total attendance came to over 5,000 visitors over 3 days. Reflecting the Mexican lifestyle, WELDMEX opened the gates at 3:00 pm and closed at 9:00 pm; lunch, occasionally accompanied by *Tequila*, the delicious but powerful Mexican spirit, started late in afternoon and lasted two hours or more until evening.

KOBELCO WELDING of AMERICA (KWAI) participated in WELDMEX together with our Mexican partner, INFRA S. A. DE C. V. as one of the 102 exhibitors. INFRA is a leading manufacturer of industrial gases, welding equipment and welding consumables in Mexico as well as South America. While INFRA manufactures stick electrodes and solid wires in their own facility, INFRA has made inroads into the flux-cored wires market by taking advantage of high quality of KOBELCO flux-cored wires. The flux cored arc welding (FCAW) process is still in an early phase in Mexico, and the consumption of flux-cored wires accounts for 2% of the total consumption of welding consumables.

Since 2000, KWAI has been working together with INFRA in promoting KOBELCO flux cored wires for the fabrication industry, offering the quality of KOBELCO brands and unmatched technical services by INFRA. **FRONTIARC-711** (AWS A5.20 E71T-1) for carbon steel and **DW Stainless Series** flux-cored wires classified in AWS A5.22 for a wide variety of stainless steels have been getting more popular in Mexico through nationally spread INFRA branches and distributors, and further successful expansion is expected on the basis of the tight relationship between KOBELCO and INFRA in the year to come.

Reported by
Tex Ikeda
KWAI

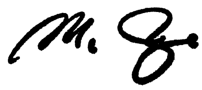
Message from the Editor

Dear readers of Kobelco Welding Today

Winter has gone away and spring has come. However, the economy of Japan is still sluggish, which has been afflicted by deflation, I would say. I hope it will recover like the blooming spring in the near future.

Every morning I look at Mt. Fuji from the porch of my apartment house; it is the highest (3,776m) and the most beautiful mountain in Japan. Especially in winter it looks beautiful at its best with snow on its top. When I am in trouble or depressed, it is always good for me to look upon Mt. Fuji to calm down for a while. I think that Mt. Fuji is a symbol of tranquility for people in Japan. I think you, too, must have your own symbols like Mt. Fuji is to me.

By the way, we have been introducing a lot of new products to the worldwide markets, and we promise you to introduce more advanced products that may provide you with greater value in the future. Last year KOBELCO renovated the organization of the R&D division in order to cope more quickly with the diversified requests of our customers all over the world. This R&D division also supports our overseas affiliates by dispatching engineers to provide customers and their staff with technical services and training— in the local language if necessary. As you may know KOBELCO's activities stand on the "QTQ" slogan, which is our basic principle as a manufacturer of welding consumables. "Back to the Basic"— it means KOBELCO encourages QTQ more and more.



Masakazu Tojo
Editorial Chairman

General Manager

International Operations Department

Welding Company
Kobe Steel, Ltd.

Calling from Tokyo

My sincere greetings to the readers of Kobelco Welding Today

I am Masanori Ashikaga, in charge of the welding material sales for the Korean and Taiwanese markets.

It was only eight years ago that I took an airplane for the first time for my first overseas trip for my honeymoon. Being in a foreign country was quite an exciting experience. At that time, I never thought that I would be some day working for the international market. 6 years have passed since I joined the International Operations Department. Making good friends with many people in various countries through international business is a real pleasure, and they become a lifetime treasure for me.

By the way, I think I am a typical Japanese man including my appearance. But when I am in Korea or Taiwan, I am always taken for a national by local people and spoken to in their language on the street. Dealers and customers often tell me also that I do not look like a Japanese. This makes me feel more intimate with the people of the country I am visiting, and makes me happy. If I could speak fluently in the local language my overseas business trips would be even more pleasurable.

Masanori Ashikaga
Asst Manager
International Operations Dept.
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Contents

Welding of Offshore Structures

Part 2: Essential Factors in Welding Procedure Controls

Photo source: Kansai Design Co. Ltd., Japan

Offshore structures include jacket platforms, jack-up-rigs, semi-submergible rigs, and Floating Production, Storage and Offloading Facilities (FPSO). This article discusses the essential factors in welding procedure controls in the fabrication of jackets, legs for jack-up rigs, and columns and braces of semi-sub rigs. These constructions use higher grade steels and their welding procedures are controlled more strictly than in the case of fabricating ordinary ships. On the other hand, the hulls of FPSOs are fabricated to ship class rules as in the case of ordinary ships.

Jackets Features Thick Pipe Welding by Full Penetration

The jacket comprises the most critical structure to sustain a platform, which is fabricated with braced tubular legs (**Fig. 1**). This tubular construction is welded by full penetration to provide sound welds that will withstand the many directional stresses at sea.

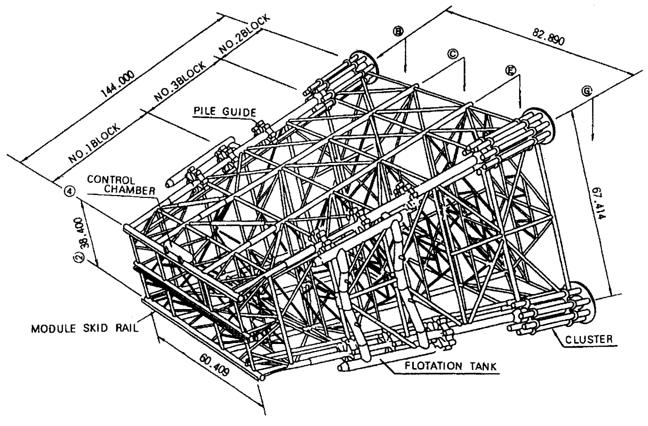


Fig. 1 Jacket of braced tubular steel structure in the as-fabricated condition

Jackets use high tensile strength tubular steels with 350-500 MPa yield strength that have a large thickness: e.g. 40-90 mm (over 100 mm for a large jacket). Large-diameter, thick-section pipes are produced by the following steps:

Step-1: Cold forming the steel plate
Step-2: Two or three layer tacking by shielded metal arc welding (SMAW) in general on the external side of the longitudinal joint
Step-3: Main welding by submerged arc welding (SAW) on the internal side of the longitudinal joint
Step-4: Gouging and grinding the external tacking weld to form a groove suitable for SAW
Step-5: Nondestructive testing (NDT) by magnetic particle test (MT) and dye penetrant test (PT) to confirm the absence of welding defects in the gouged groove
Step-6: Main welding by SAW on the external groove
Step-7: NDT by MT and ultrasonic test (UT) on the entire longitudinal weld
Step-8: Girth welding of rotatable pipes by using almost all the same procedures in Steps-2 through 7

The throat thickness and length of the tack weld bead must be sufficient to maintain the circularity and straightness of the pipe and prevent cracking during SAW on the internal side of the groove. Two- or three-wire SAW is used on the longitudinal joint to improve welding efficiency. However, girth welding of rotatable pipes uses single SAW due to better performance.

In contrast to the welding of large-diameter sections, small diameter (e.g. with an inner diameter of 750 mm or smaller) pipes, rotatable or fixed, are joined by one-side welding, using SMAW or gas tungsten arc welding (GTAW) for the root pass and SMAW, FCAW or gas metal arc welding (GMAW) with solid wires for the filling passes. In one-side welding, minimizing the misalignment at the root of the groove and varying the root opening are essential methods to ensure consistent weld quality. For the root pass welding in one-side SMAW. **LB-52U** (E7016) of 2.6, 3.2, 4.0, and 5.0 mmφ and **LB-52LT-18** (E7018-1) of 2.6 and 3.2 mmφ provide unsurpassed usability.

The node joint (**Photo 1**), where components are crossed forming T-, Y- and K-connections, causes a highly concentrated stress area called the "hot spot." The node joint

- changes its groove angle as out-of-position welding progresses along the joint;
- needs a highly accurate-size groove in one-side welding;
- requires smooth weld surface to improve fatigue strength;
- precludes employment of an automatic welding process due to confined spaces around the joint; and
- tends to cause lamellar tear.

This is why the most precise procedure control is required in the fabrication of jackets. The root pass of the joint is usually welded by one-side SMAW or GTAW. Subsequent filling passes are welded by SMAW or FCAW.

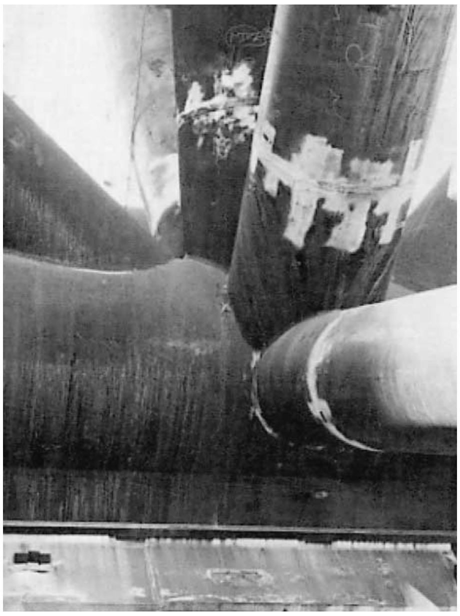


Photo 1 Node joints of a jacket

A lamellar tear (**Fig. 2**) is the most serious defect that can occur in the node joint welds. A lamellar tear is a subsurface terrace and step-like crack that occurs at a location close to the weld fusion line in the base metal, which has a basic orientation parallel to the wrought surface. Lamellar tearing is caused by tension stresses in the through-thickness direction of the base metal weakened by the presence of small, dispersed, planar shaped, nonmetallic inclusions parallel to the metal surface. Diffusible hydrogen in the weld metal is also associated with lamellar tearing. In order to minimize the susceptibility to this type of cracking, the following preventive measures may be taken.

(1) Use steels having greater through-thickness ductility: e.g. greater than 25% (reduction in area)
(2) Use low sulfur steels: e.g. 0.008% max.
(3) Confirm by UT that steels have no lamination
(4) Use low hydrogen type welding consumables
(5) Use preheating

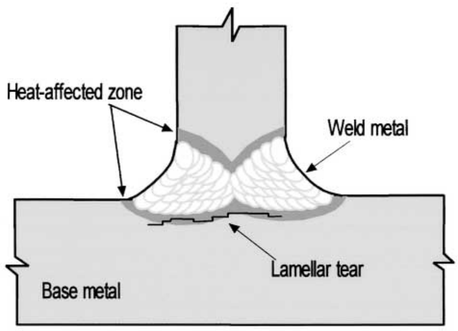


Fig. 2 Schematic lamellar tearing occurring at the area close to the fusion line in the base metal of a node joint

Racks and Chords are Fabricated by Heavy Section Butt Welding

The leg of a jack-up rig (**Fig. 3**) has heavy sections reaching, for racks, approximately 180 mm and uses high tensile strength steels with yield strengths of 500, 550 and 690 MPa. Rack-to-rack joints are butt welded by SAW, where the rack passes through the chord (**Fig. 4**). Where the racks are separated by the chord, rack-to-rack joints are butt welded by GMAW with solid wires. Rack-to-rack double-groove joints are welded from both sides of the joint to highly accurate sizes. Rack-to-chord joints are butt welded by SAW and GMAW from the external side only. The welding procedure for node joints of braces is similar to that for the leg of Jackets.

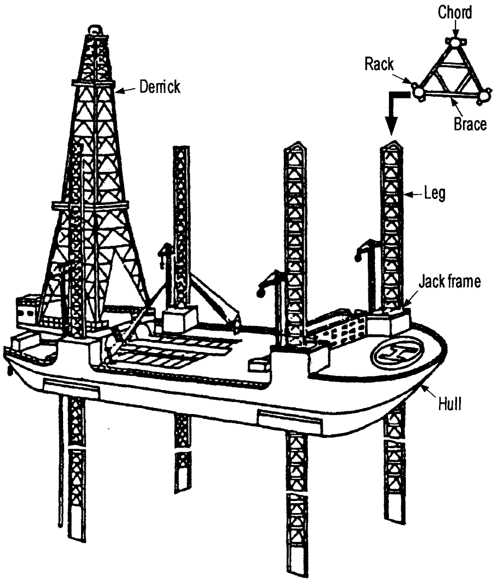


Fig. 3 Legs of a jack-up rig consist of rack, chord, and brace

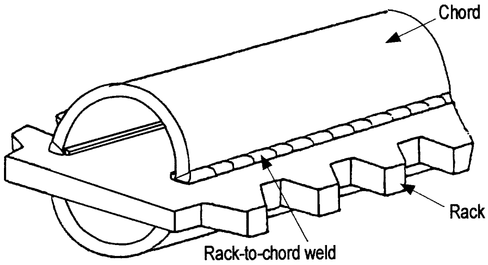


Fig. 4 Rack-to-rack joints are butt welded by SAW, and rack-to-chord joints are butt welded by SAW and GMAW

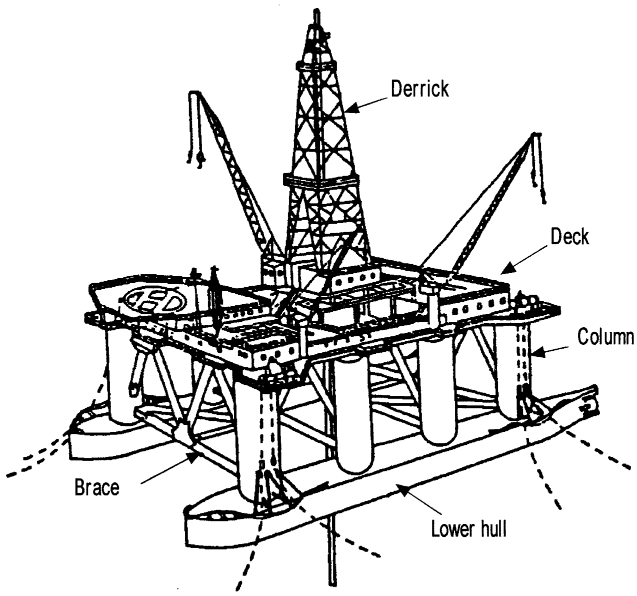


Fig. 5 Columns, braces and lower hulls are the main structural components of a semi-sub rig

Columns Contain Longitudinal and Circumferential Welds

Semi-submergible rigs (**Fig. 5**) consist mainly of lower hulls, columns, braces, decks and derricks. Lower hulls are constructed similarly to those of ships, providing buoyancy to the entire rig. Columns govern the stability of the rig during drilling operations. Columns are mainly fabricated by SAW for joining longitudinal and circumferential joints. Column-to-brace and brace-to-brace joints are welded by FCAW and SMAW. The node joints of braces require strict welding procedure control to prevent lamellar tearing and provide smooth bead appearance for better fatigue strength as in the case of jackets.

Periodical Redrying of Covered Electrodes and SAW Fluxes is Essential to Minimize Diffusible Hydrogen

Welding consumables should be kept in a warehouse that is well ventilated and low in humidity to minimize moisture absorption. Covered electrodes, SAW fluxes and flux-cored wires can pick up moisture in the atmosphere. The absorbed moisture causes an increase of diffusible hydrogen in weld metal. **Figure 6** shows test results of the moisture absorption of **LB-52** (E7016: low hydrogen type) and **LB-80UL** (E11016-G: moisture-resistant, ultra-low hydrogen type). Because of the tendency to absorb moisture, covered electrodes and SAW fluxes should periodically be redried at the factory or job site. Unless there is a conflict with a particular job specification, Kobe Steel recommends periodic redrying of Kobelco covered electrodes and SAW fluxes for offshore structures, as per **Table 1**.

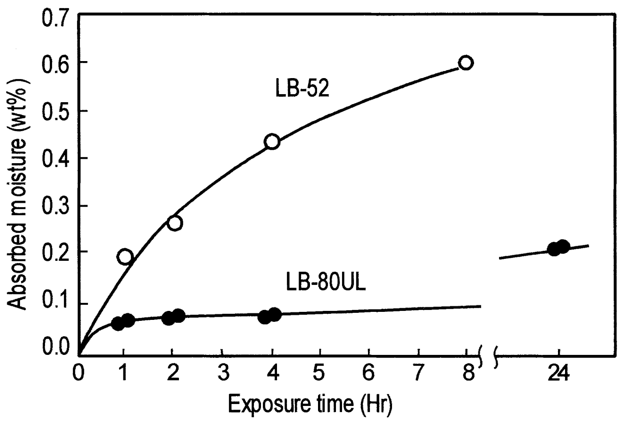


Fig. 6 Moisture absorption curves of **LB-52** (E7016) and **LB-80UL** (E11016-G) tested in the controlled atmosphere (30℃ × 80%RH)

Table 1 Recommended redrying conditions and permissible atmospheric exposure time

KOBELCO brand	Redrying condition	Holding condition after redry	permissible atmospheric exposure time(1)
LB-52, LB-52U	300－350℃ × 30－60 min	100－150℃ × 72 Hr max	4 Hr
LB-52A, NB-1SJ, LB-52NS, LB-57, LB-62, LB-62L, LB-52LT-18	350－400℃ × 60 min	100－150℃ × 72 Hr max	4 Hr
LB-62UL	350－430℃ × 60 min	100－150℃ × 72 Hr max	4 Hr
LB-106	350－400℃ × 60 min	100－150℃ × 24 Hr max	2 Hr
LB-80UL, LB-88LT, LBY-75	350－430℃ × 60 min	100－150℃ × 24 Hr max	2 Hr
MF-300	150－350℃ × 60 min	100－150℃ × 72 Hr max	8 Hr
PFH-55S, PFH-55AS, PFH-55LT	200－300℃ × 60 min	100－150℃ × 72 Hr max	4 Hr
PFH-80AK, PFH-80AS	250－350℃ × 60 min	100－150℃ × 72 Hr max	2 Hr

Note (1) Provided the atmospheric condition is 30℃ × 80%RH

Flux-cored wires cannot be redried by heating. After daily welding work is finished, the spool of flux-cored wire should be dismounted from the wire feeding machine and brought back to the warehouse and returned to the original package to minimize moisture absorption.

Preheating is the Basic Technique to Prevent Cold Cracking in Welds

The proper preheat and interpass temperature to prevent cold cracking depends on several factors, such as the carbon equivalent of the steel, plate thickness, diffusible hydrogen in the weld metal, and heat input. Welding for offshore work is often carried out using preheat and interpass temperatures specified by AWS D1.1 (Structural Welding Code － Steel), BS 5135 (Process of Arc Welding of Carbon and Carbon Manganese Steel), and the client's specifications. Unless in conflict with these specifications, Kobe Steel recommends the following preheat and interpass temperature shown in **Table 2** as a rule of thumb.

The use of higher preheat temperatures safely prevents cold cracking, but inconveniences welders. Therefore, in the case of welding 780 MPa high tensile strength steels with heavy sections, a lower temperature preheat is often used during welding, followed by immediate postweld heating (150－200℃ × 2 Hr). Immediate postweld heating effectively decreases diffusible hydrogen in welds, thereby preventing cold cracking.

Table 2 Recommended preheat and interpass temperature as a rule of thumb

Welding process	KOBELCO brand	Minimum Preheat and interpass temperature(1)
SMAW	LB-52, LB-52U, LB-52LT-18, LB-52A, LB-57, LB-52NS, NB-1SJ, LB-62, LB-62L, LB-62UL	50－100℃
	LB-106, LBY-75 LB-80UL, LB-88LT	100－150℃
FCAW	DW-100E, DW-55E, DWA-55E, DWA-55ESR, DW-55L, DWA-55L, DW-55LSR, DWA-55LSR,	50－100℃
	DWA-65L	50－150℃
GMAW	MGS-50	50－100℃
	MGS-70 MGS-80, MGS-88A	100－150℃
SAW	MF-300/US-36, MF-300/US-49A, MF-300/US-40, PFH-55S/US-49A, PFH-55S/US-40, PFH-55AS/US-36J, PFH-55LT/US36, PFH-80AK/US-56B,	50－100℃
	PFH-80AK/US-255, PFH-80AS/US-80LT, PFH-80AK/US-80LT	100－150℃

Note (1) Exact minimum preheat and interpass temperature should be thoroughly examined taking into account type of steel, plate thickness and heat input.

Heat Input in Conjunction with Preheat Temperature Governs the Mechanical Properties of Weld

Heat input, in conjunction with the preheating temperature, has a predominant effect on the cooling speed of welds, where the thickness of the base metal is constant, and, thereby, affects the microstructure of the weld. A change in microstructure directly influences the mechanical properties of the weld. Refer to KOBELCO WELDING TODAY, October 2000, Vol. 3 (No. 4) to see how heat input and preheating temperature act together on cooling speed.

Figure 7 shows yield strength and tensile strength of **DW-55E** weld metal as a function of cooling rate. This figure shows a decrease in yield strength and tensile strength, as the cooling rate of welds decreases. Impact toughness is also affected by cooling rate, as shown in **Fig. 8**. That is, excessively slow cooling rates cause lower impact energies, particularly at －40℃, but so do excessively fast cooling rates as shown in testing at －20℃. In sum, heat input should be controlled, taking into account preheat temperature and plate thickness, such that cooling rates fall in an appropriate range to maximize the impact toughness of weld metal.

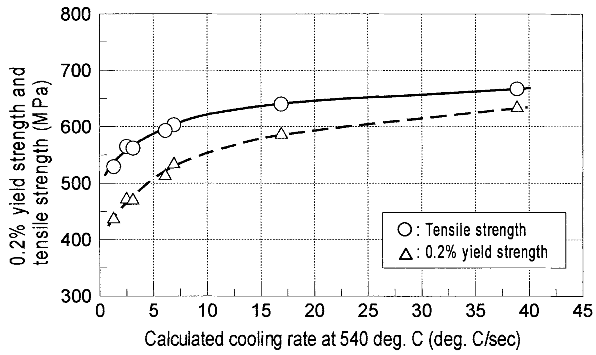


Fig. 7 0.2% yield strength and tensile strength of **DW-55E** weld metal as a function of cooling speed

- Wire size: 1.2 mmφ ▪Welding position: Flat
- Amp. and volt: 280A, 32V ▪Heat input: 15, 25, 35 kJ/cm
- Welding speed: 15.4, 21.5, 36.0 cm/min
- Preheat: RT, 150, 250℃ ▪Plate thickness: 20 mm

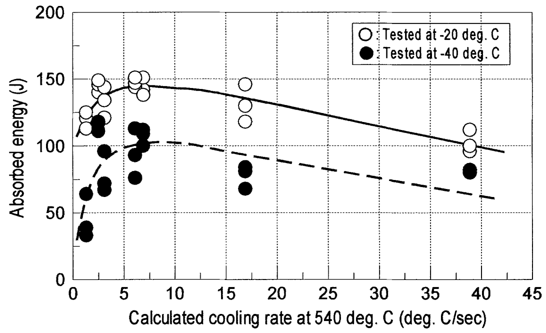


Fig. 8 Charpy impact absorbed energy of **DW-55E** weld metal as a function of cooling speed

- Wire size: 1.2 mmφ ▪Welding position: Flat
- Amp. and volt: 280A, 32V ▪Heat input: 15, 25, 35 kJ/cm
- Welding speed: 15.4, 21.5, 36.0 cm/min
- Preheat: RT, 150, 250℃ ▪Plate thickness: 20 mm

Wind Degrades Weld Soundness

In order to provide sound welds in arc welding, the molten pool must be protected from the air by the shielding agents such as molten slag, decomposed-flux gases, and externally supplied gases. High winds can disturb the shielding effect. The permissible wind velocity depends on the welding process: e.g. approx. 5 m/sec in SMAW and approx. 2 m/sec in FCAW with external shielding gas in general. **Table 3** shows how wind velocity affects the occurrence of porosity in **DW-55L** weld metal with CO_2 shielding gas. The permissible wind velocity increases with increased shielding gas flow rates. However, excessively high flow rates can disturb the gas flow from the welding torch, thereby causing a poor shielding effect.

Table 3 Effects of shielding gas flow rate on the occurrence of porosity in **DW-55L** weld bead on plate

Testing wire	CO_2 gas flow rate (Liter/min)	Wind velocity (m/sec)					
		0	1	1.5	2	2.5	3
DW-55L (1.2 mmφ)	15	○	○	○	×	××	××
	20	○	○	○	△	×	××
	25	○	○	○	○	○	×

Note ○: No porosity
△: Porosity at 1—10 pieces per 300-mm bead length
×: Porosity at over 10 pieces per 300-mm bead length
××: Much more porosity

In addition to degraded X-ray soundness due to porosity, high velocity wind increases the nitrogen content of weld metal as shown in **Fig. 9** and thereby decreases impact toughness as shown in **Fig. 10**. Based on these data, where wind velocity exceeds 1 m/sec, flux-cored wires are recommended to be used with windscreens to cope with strict notch toughness requirements in offshore structures.

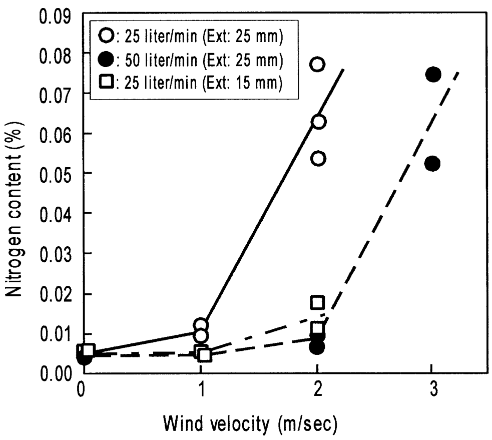


Fig. 9 Effects of wind velocity on nitrogen content of **DW-55L** weld metal

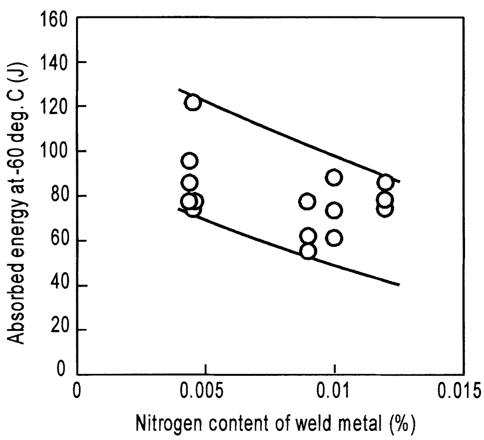


Fig. 10 Effect of nitrogen in **DW-55L** weld metal on Charpy impact absorbed energy

References

1. H. Harasawa, Present Status of the Welding of Large Offshore Structures, Kobelco Technical Guide, No. 148, 1982
2. Kobe Steel, Ltd., Welding of Offshore Structures, Oct. 1985

Question ?

What advantages are there in downhill welding and how should it be used, compared with uphill welding in GMAW and FCAW?

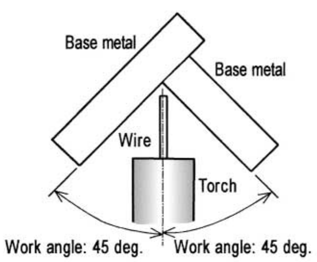
Answer —

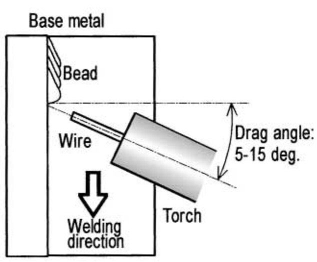
As you may know, we use either downhill or uphill welding in the vertical position. Downhill welding is carried out with a downward progression, conversely, uphill moves in an upward progression. Downhill welding is often used for fillet welding of steel sheets due to the following advantages over uphill welding.

(1) Faster welding speed
(2) Easier to obtain small-leg fillet weld
(3) Shallower penetration
(4) Lower heat input due to faster welding speed
(5) Less welding distortion

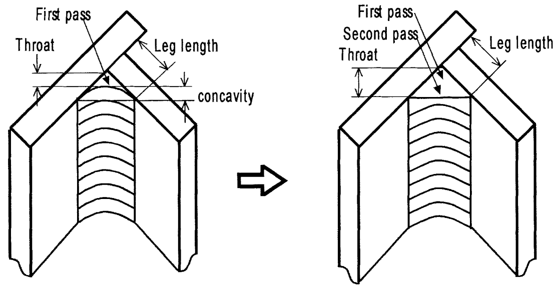
However, downhill welding can inhibit penetration and generate slag inclusions unless a welder can control the arc to track correctly on the welding line at fast speeds (e.g. 60 cm/min or higher with a 1.2-mmφ wire). The following measures can prevent defects in vertical fillet downhill welding.

(1) Use the straight run technique without weaving.
(2) Control the welding torch so that the work angle is 45 degrees and the drag angle, 5-15 degrees as shown below.





Another difficulty with downhill welding is that it tends to cause a concave bead having an insufficient throat (concavity) in vertical fillet welding. To overcome this problem, two-layer welding is recommended as shown in the following figure. Even in the second layer, again, use the straight run technique without weaving.



With respect to welding wires suitable for downhill welding, the following choices are recommended in conjunction with suitable droplet transfer mode and application.

(1) Solid wires for welding sheet metals by using a short-circuiting arc at the low current range (e.g. 50-160A for 1.2mmφ wire), such as **MG-51T** (ER70S-6)

(2) Flux-cored wires for welding sheet metals by using a short-circuiting arc at the low current range (e.g. 50-180A for 1.2mmφ wire), such as **MX-100T** (E71T-1, E71T-1M)

(3) Flux-cored wires for welding thin plates by using a globular arc at the middle to high current range (e.g. 200-300A for 1.2mmφ wire), such as **DWA-50** (E71T-1M), **DW-100** (E71T-1), **DW-110** (E71T-1), and **MX-Z210** (E70T-1)

Before employing downhill welding, weld penetration, joint alignment tolerance and the welder's skill should thoroughly be examined to ensure that the weld satisfies the requirements. For your information, AWS D1.1 (Structural Welding Code — Steel), for example, specifies that a change from uphill to downhill or vice versa is the essential variable requiring requalification of the welding procedure specification.

A Brand-New FCW for High Tensile Strength Steel: DWA-65L (AWS A5.29 E91T1-K2MJ)

Expanding the uses of 500-MPa yield strength steel to low temperature offshore applications (e.g. the top side structure of jacket platforms) has triggered the development of DWA-65L, a rutile type flux-cored wire. DWA-65L offers similar usability but higher tensile strength when compared with DWA-55L. Titanium-boron micro-alloyed (Ti-B type) DWA-65L all-weld metal provides excellent impact notch toughness at low temperatures down to −40℃ and guarantees a minimum yield strength of 540 MPa and tensile strength of 620 MPa as shown in **Table 1**.

Table 1 Typical chemical composition and mechanical properties of DWA-65L all-weld metal

Chemical composition (%)								
C	Si	Mn	P	S	Ni	Mo	Ti	B
0.05	0.35	1.17	0.010	0.009	1.69	0.11	0.05	0.004

Mechanical properties			
0.2% offset strength (MPa)	Tensile strength (MPa)	Elongation (%)	Charpy impact energy at −40℃ (J)
601	660	24	61, 92, 93 (Av. 82)

Testing conditions:
(1) Wire size: 1.2 mmϕ (2) Welding position: Flat
(3) Welding Amperage and voltage: 280A/27-29V
(4) Heat input: 1.7−1.8 kJ/mm (5) Shielding gas: 80%Ar-20%CO_2
(6) Preheat and interpass temperature: 150℃

The effect of heat input on mechanical properties is one factor that should be noted when setting appropriate welding parameters for a particular job. **Figures 1** and **2** show effects of heat input on yield strength, tensile strength and impact energy of DWA-65L all-weld metal.

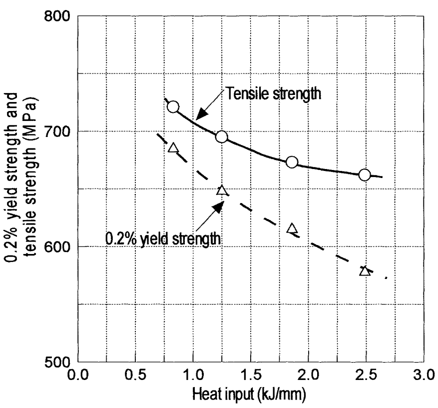


Fig. 1 Tensile strength and 0.2% yield strength of DWA-65L all-weld metal vs. heat input
▪1.2 mmϕ wire ▪280Amp./28-30Volt
▪Flat welding position ▪80%Ar-20%CO_2
▪8-25 passes/5-8 layers
▪Preheat & interpass temp.: 150℃

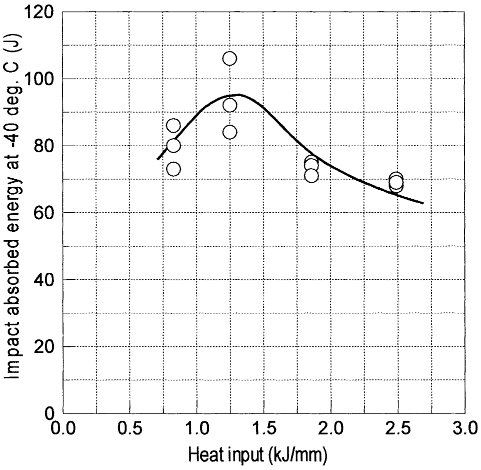


Fig. 2 Impact absorbed energy of DWA-65L all-weld metal vs. heat input
▪1.2 mmϕ wire ▪ 280Amp./28-30Volt
▪80%Ar-20%CO_2 ▪Flat welding position
▪8-25 passes/5-8 layers

The joint welding test results of DWA-65L (1.2 mmϕ wire, KL37 base metal, 80%Ar-20%CO_2, 260A/23-28V, 100℃ preheat) exhibit sufficient tensile properties and notch toughness at −40℃ as shown in **Table 2** and **Fig. 3**. All test specimens were cut from both sides of the joint (**Fig. 4**).

Table 2 Tensile properties of DWA-65L joint weld metals

Welding position	Location of specimen	0.2% OS (MPa)	TS (MPa)	El. (%)
Flat	Backing side	639	679	27
	Final side	592	656	29
Horizontal	Backing side	668	706	28
	Final side	659	701	28
Vertical-up	Backing side	653	695	26
	Final side	615	678	27

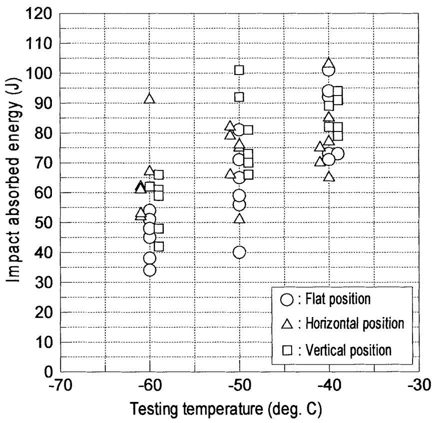


Fig. 3 Impact test results of DWA-65L joint weld metals

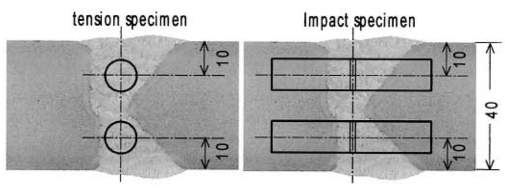


Fig. 4 Locations of test specimens

TGS-80B2 and TGS-90B3: Brand-New GTAW Filler Wires for International Customers

These new brands have been developed by modifying the chemical composition of traditional TGS-1CM (AWS ER80S-G) and TGS-2CM (AWS ER90S-G) to make it easier for international customers to select suitable filler wires per the AWS chemical requirement designation (B2, B3) for welding 1.25%Cr-0.5%Mo and 2.25%Cr-1%Mo steels. The welding usability, mechanical properties and crack resistance of these new brands are comparable to the traditional brands. **Table 1** shows typical chemical compositions of these new brands and the AWS requirements for both filler wires.

Table 1 Typical chemical compositions of TGS-80B2 and TGS-90B3 filler wires in comparison with the AWS requirements (%)

Chemical Element	TGS-80B2 (ER80S-B2)	AWS A5.28 ER80S-B2	TGS-90B3 (ER90S-B3)	AWS A5.28 ER90S-B3
C	0.11	0.07−0.12	0.11	0.07−0.12
Si	0.50	0.40−0.70	0.64	0.40−0.70
Mn	0.67	0.40−0.70	0.67	0.40−0.70
P	0.004	0.025 max	0.006	0.025 max
S	0.004	0.025 max	0.006	0.025 max
Cu	0.15	0.35 max	0.14	0.35 max
Ni	0.01	0.25 max	0.01	0.25 max
Cr	1.40	1.20−1.50	2.44	2.30−2.70
Mo	0.55	0.40−0.65	1.09	0.90−1.20

The mechanical properties of the all-weld metals of TGS-80B2 and TGS-90B3 match the AWS requirements as shown in **Table 2**. In addition, as illustrated in **Fig. 1**, both filler wires satisfy the ASTM requirements for tubular steels such as A213 Gr. T11 (1.25%Cr-0.5%Mo) and A213 Gr. T22 (2.25%Cr-1%Mo), respectively, after extended postweld heat treatment (PWHT).

Table 2 Mechanical properties of the all-weld metals of TGS-80B2 and TGS-90B3 by GTAW with pure argon gas shielding

Filler wire	0.2%OS (MPa)	TS (MPa)	El (%)	vE-20℃ (J)	PWHT (℃ × h)
TGS-80B2	499	625	32	Av. 246	620 × 1
	476	593	32	Av. 256	690 × 1
	440	558	34	Av. 242	690 × 8
ER80S-B2	470 min	550 min	19 min	—	620±15 × 1
TGS-90B3	596	725	27	Av. 237	690 × 1
	497	632	30	Av. 169	690 × 8
	452	595	30	Av. 156	690 × 32
ER90S-B3	540 min	620 min	17 min	—	690±15 × 1

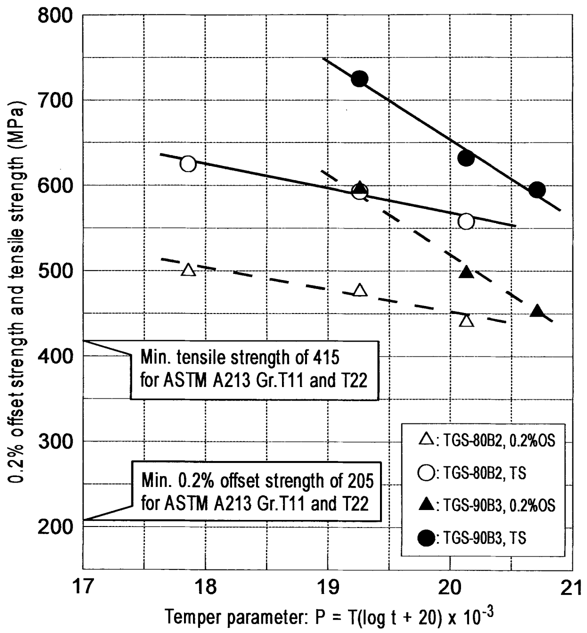


Fig. 1 Mechanical properties of the all-weld metals of TGS-80B2 and TGS-90B3 as a function of PWHT

Temper parameter:
- 620℃ × 1h = 17.86
- 690℃ × 8h = 20.13
- 690℃ × 1h = 19.26
- 690℃ × 32h = 20.71

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