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KOBELCO Puts the Customer First with All-in-One Product and Service

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INDIA:
KOBE WELDING INDIA PVT. LTD.
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EUROPE

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KOBE WELDING OF EUROPE B.V.
Tel. (31) 45 547 1111 Fax. (31) 45 547 1100

AMERICA

USA:
KOBE WELDING OF AMERICA INC.
Tel. (1) 281 240 5600 Fax. (1) 281 240 5625
**What is CTOD?**

In the design of steel structures, steel plate thickness, one of the most critical elements, is determined based on the tensile strength (TS) and/or yield strength (YS). However, if a steel structure has a critical defect, the extent of future problems might not be apparent if the whole design is carried out based on TS and/or YS obtained from a defect-free test specimen.

**CTOD test**

Crack Tip Opening Displacement (CTOD) is one of the parameters that can reveal the strength properties of steel structures. It was first proposed by The Welding Institute in the UK and has now been adopted worldwide. Figure 2 illustrates a CTOD test. A bend test is performed on a specimen in which a notch has been machined (a). By gradually applying a bending load, a fatigue crack is carefully induced at the base of the notch, so that the crack tip (which has a curvature radius of zero) opens little by little until it reaches a limit and the specimen suddenly breaks as shown in (b). At this point, the break progresses rapidly without any increase in the bending load. This sudden break is called an "unstable fracture."

CTOD indicates up to how many mm the crack tip opens from a curvature radius of zero. In other words, it shows how much opening a crack tip can bear and tolerate before an unstable fracture occurs. The more ductile the material, the more opening it can tolerate, and, accordingly, the higher its CTOD value.

![CTOD test](image)

Figure 1 shows that the high TS does not necessarily prevent defects. The Type A steel, with high TS (σ_b), retains high fracture strength only when its defect size is zero. Indeed, it becomes much weaker than the Type B steel as the defect size becomes larger – even though the Type B has lower TS.

The fracture of steel structures can be prevented through fracture mechanics, which provides useful parameters that indicate the strength properties of steel structures that have defects such as those described above.

While the test is in progress, the results are recorded automatically on a load/displacement chart as shown in Figure 3. Three basic types of fracture behavior can be investigated with this test: brittle fracture, pop-in, and ductile. Curve (a) shows a test specimen fractured in a brittle manner with little or no plastic deformation; while curve (b) shows a pop-in, where the crack initiates in a brittle manner but is soon arrested by tougher and more ductile material. This behavior can occur many times giving the curve a saw tooth appearance. And curve (c) illustrates a completely plastic or ductile behavior.

![CTOD test](image)

**Figure 2: Schematic CTOD test**

Dear KWT readers! My name is Fusaki Koshiishi, the Head of the Welding Business. I’d like to express my heartfelt gratitude for your kind and continuous patronage of Kobelco products. Last year, I had a chance to visit China as well as Korea, Singapore, Malaysia and could confirm that our business related to offshore structures, LNG storage tanks and transportation systems has continued to expand.

We believe that a trusting relationship is most important in doing business and that this relationship can only be established by providing high quality products as well as services. It is, therefore, essential that we maintain superior technology and quality over our competitors and construct a sales network through which we can provide far better marketing and technical services than our competitors. Our business in the Japanese and ASEAN markets has been supported by “SHINYOKAI,” a Kobelco distribution network. In the Chinese market, the sales and marketing functions of the Welding Business, which had been scattered across the country, were integrated into Kobe Welding of Shanghai Co., Ltd. (KWSH) last year as a first step, and sales and marketing activities through the distribution network have recently commenced.

We promise that we will continue supplying Kobelco’s high quality products and services all over the world this year, too. I plan to visit many different markets in order to listen to your opinions and find out how you evaluate our products and services. Please join me for delicious meals and drinks then, and let’s build a mutual trusting relationship.

By the way, the Rugby World Cup 2015 is going to be hosted in England from September, and some members of Kobe Steel rugby team have been selected to represent the Japanese team. I’m very much looking forward to it.

Lastly, I wish all of our KWT readers much success and good health. See you again in the very near future!
Preface

490 MPa high tensile strength (HT) steels are commonly used in a wide range of industrial fields. For efficiency and ease of welding, gas metal arc welding (GMAW) or flux cored arc welding (FCAW) is applied in all welding positions. GTAW is also suitable for the welding of such critical members as pipes, flanges of chemical reactors. However, users should note the recommended PWHT condition of around 625°C x 5 hours (hr) because the YS decreases during PWHT.

Table 4 shows the typical chemistry of TG-S50 weld metal, and Table 5, the typical mechanical properties in as-welded and PWHT (625°C x 5 hr) conditions. Figure 1 shows the tensile properties in relation to the Larson-Miller Parameters, respectively.

Table 5: Typical mechanical properties of weld metal

<table>
<thead>
<tr>
<th>Product name</th>
<th>Tensile strength at RT (%)</th>
<th>Absorbed energy (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ER70S-G</td>
<td>YS (MPa)</td>
<td>TS (MPa)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>El (%)</td>
</tr>
<tr>
<td></td>
<td>490</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22min</td>
</tr>
<tr>
<td></td>
<td>0.07</td>
<td>0.10-0.14</td>
</tr>
<tr>
<td></td>
<td>0.06-0.15</td>
<td>0.025</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.05-0.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.02-0.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.05-0.15</td>
</tr>
<tr>
<td>ER70S-6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.06-0.15</td>
<td>1.40-1.85</td>
<td></td>
</tr>
<tr>
<td>ER70S-G</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.07</td>
<td>0.10-0.14</td>
<td></td>
</tr>
</tbody>
</table>

Note: Values are maximum.

Table 3: AWS A5.18 specifications for mechanical properties of weld metals

Table 2: AWS A5.18 specifications on TIG rod chemistries (mass%)

Table 6: Typical chemistry of weld metal (mass%)

Table 7: Typical mechanical properties of weld metal

Properties of FAMILARC™ TG-S51T

Like TG-S50, TG-S51T is a C-Si-Mn type of rod - but equivalent to AWS A5.18 ER70S-6. With higher amounts of C, Si and Mn contents, it yields higher TS and YS levels than TG-S50; however, the impact properties of TG-S51T weld metal are nearly the same as those of TG-S50.

Similar to TG-S50 in usability, bead appearance and ease of use, TG-S51T is also used across a wide range of applications.

Because TG-S51T weld metal retains sufficient tensile properties of 490 MPa HT steels, even over longer periods of PWHT, it can be applied to joints of large-scale structural members that require stress relief annealing.

Figure 3 shows the typical chemistry of TG-S51T weld metal, the typical mechanical properties in as-welded and various PWHT conditions and the tensile properties in relation to the Larson-Miller Parameters, respectively.

Figure 4 shows back bead appearance in the 1G position. The groove configuration was of single 60°V, with a root gap of 3.0-3.5mm. The welding conditions were 110A-12V and without back-shielding.

Figure 4: Back bead appearance in 1G position
4 Properties of FAMILIARC™ NO65G

NO65G TIG rod, equivalent to AWS A5.18 ER70S-2, contains less C, Si and Mn contents than TG-S50 or TG-S51T; instead, Al, Ti and Zr are specially added. These elements help to decrease the amount of oxygen in the molten pool, allowing NO65G to provide a weld metal of relatively high cleanliness. On the other hand, it is a little inferior to TG-S50 or TG-S51T in terms of fluidity of molten metal, because of which its surface tension increases while the oxygen content in the molten metal is decreased.

Because Al, Ti or Zr is an element with high oxygen affinity, slag can be generated on the bead surface after a part of the element combines with oxygen in the molten metal during welding. Users are therefore advised to beware of weld defects, such as poor bead appearance or slag inclusion, caused by the slag.

Each chemical element in NO65G rod is strictly controlled to maintain a narrow range within the AWS A5.18 ER70S-2 specification so that it can meet the tough requirements set out by Japanese clients for mechanical properties in critical structural projects.

Table 8, Table 9 and Figure 5 show the typical chemistry of NO65G weld metal, the typical mechanical properties in as-welded and PWHT (625°C) conditions and the absorbed energies in relation to the tested temperatures, respectively.

Table 8: Typical chemistry of weld metal (mass%)

<table>
<thead>
<tr>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cu</th>
<th>Al</th>
<th>Ti</th>
<th>Zr</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.04</td>
<td>0.50</td>
<td>0.12</td>
<td>0.007</td>
<td>0.012</td>
<td>0.02</td>
<td>0.06</td>
<td>0.05</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Table 9: Typical mechanical properties of weld metal

<table>
<thead>
<tr>
<th>Tensile test at RT</th>
<th>Absorbed energy (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>YS (MPa)</td>
<td>TS (MPa)</td>
</tr>
<tr>
<td>As-welded</td>
<td>584</td>
</tr>
<tr>
<td>625°C × 8 hr</td>
<td>545</td>
</tr>
</tbody>
</table>

Figures 6 and 7 show face side bead appearance after root and second passes and back bead appearance after root-pass welding in 1G and 3G (uphill) positions by NO65G (2.4mm dia.), respectively. Figures 8 and 9 exhibit macro-structures of root-pass and second-pass welding in 1G and 3G (uphill) positions, respectively. The groove configuration was of single 60°V, with a root gap of 3.0-3.5mm. The welding conditions were 110A-12V for root-pass without back-shielding and 160A-13V for second-pass welding, respectively.

5 Properties of FAMILIARC™ TG-S70S2

Like NO65G, TG-S70S2 is designed to fulfill AWS A5.18 ER70S-2 specifications though it has some key differences. TG-S70S2 is targeted toward a comparatively more versatile set of structures that fall under the AWS A5.18 ER70S-2 requirements, and its chemistries are wider than those of NO65G within the ER70S-2 specifications.

Because TG-S70S2 contains higher amounts of Al, Ti and Zr, increased slag generation and slightly inferior impact properties may result in comparison with NO65G, in which these elements are more tightly controlled. Higher amounts of Al, Ti and Zr cause impact properties to begin to fluctuate.

Tables 10 and 11, and Figure 10 show the typical chemistry of TG-S70S2 weld metal, the typical mechanical properties in as-welded and PWHT (625°C × 8hr) conditions and the absorbed energies in relation to the tested temperatures, respectively.

Table 10: Typical chemistry of weld metal (mass%)

<table>
<thead>
<tr>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cu</th>
<th>Al</th>
<th>Ti</th>
<th>Zr</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>0.42</td>
<td>1.05</td>
<td>0.010</td>
<td>0.009</td>
<td>0.11</td>
<td>0.09</td>
<td>0.06</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Table 11: Typical mechanical properties of weld metal

<table>
<thead>
<tr>
<th>Tensile test at RT</th>
<th>Absorbed energy (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>YS (MPa)</td>
<td>TS (MPa)</td>
</tr>
<tr>
<td>As-welded</td>
<td>563</td>
</tr>
<tr>
<td>625°C × 8 hr</td>
<td>526</td>
</tr>
</tbody>
</table>

Figure 10 shows back bead appearance in 1G and 3G (uphill) positions by TG-S70S2 (2.4mm dia.).

6 Properties of FAMILIARC™ TG-S70S3

TG-S70S3 is a C-Si-Mn type of rod, like TG-S50 or TG-S51T, but it is designed to meet the AWS A5.18 ER70S-3 specifications. It is, however, designed to contain lower amounts of C-Si-Mn than TG-S50, resulting in the lower tensile properties of the weld metal. Therefore, PWHT is not recommended but for the as-welded condition only.

Tables 12 and 13 show the typical chemistries and mechanical properties of TG-S70S3 weld metal in the as-welded condition, respectively.

Table 12: Typical chemistry of weld metal (mass%)

<table>
<thead>
<tr>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cu</th>
<th>Al</th>
<th>Ti</th>
<th>Zr</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.10</td>
<td>0.53</td>
<td>1.11</td>
<td>0.010</td>
<td>0.015</td>
<td>0.13</td>
<td>0.01</td>
<td>0.02</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

Table 13: Typical mechanical properties of weld metal

<table>
<thead>
<tr>
<th>Tensile test at RT</th>
<th>Absorbed energy (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>YS (MPa)</td>
<td>TS (MPa)</td>
</tr>
<tr>
<td>As-welded</td>
<td>460</td>
</tr>
</tbody>
</table>

Figure 12 compares the tensile properties of weld metals by five TIG rods that meet AWS A5.18 specifications.

7 Comparison of tensile properties

Figure 12 compares the tensile properties of weld metals by five TIG rods that meet AWS A5.18 specifications.
It can be seen that the rod with the highest tensile and yield strength is NO65G, while these properties are lowest in TG-S70S3. These rods are sequenced in terms of tensile properties as follows:

NO65G > TG-S70S2 > TG-S51T > TG-S50 > TG-S70S3

8 Tips for better welding results in GTAW

An advantage of using TIG welding process for 490 MPa HT steels is the ability to obtain weld metal with high cleanness due to the low oxygen content in the weld metal when utilizing pure 100 % Ar shielding gas. On the other hand, hardness may increase in as-welded and not-reheated zones such as after the final pass in multilayer welding or single pass fillet welding.

When the final pass weld metal of a pipe joint with increased hardness is exposed, for example, to an ambience filled with hydro-sulfide (H₂S), the hydrogen, having a small atomic radius, diffuses in the weld metal when utilizing pure 100 % Ar shielding gas. On the other hand, hardness may increase in as-welded and not-reheated zones such as after the final pass in multilayer welding or single pass fillet welding.

When TIG welding is applied to structures that will be exposed to an atmosphere containing H₂S, it is also effective to apply FAMILIARC ™ wires. Tips are recommended to avoid increased hardness and prevent delayed cracking:

1. Prevent excess hardening by maintaining a low cooling rate of the weld metal while applying high interpass rate of the weld metal while applying high heat input.
2. Prevent excess hardening by maintaining a low cooling rate of the weld metal while applying high heat input.
3. Provide an as-welded weld metal with re-heating by PWHT. (This process shall not be utilized on structural members that shall be left in an as-welded condition.)
4. It is also effective to apply FAMILIARC ™ TG-S35.

TG-S35 is used for mild steels, but because it is not as-reheated to final pass welding steel. It is used in Japanese Industrial Standard (JIS) Z3316 W35A5U10. Table 14 shows the JIS classifications of TG-S35.

The typical mechanical properties of TG-S35 weld metal and JIS specification of mechanical properties both in as-welded condition are shown in Table 15. Table 16 shows the typical mechanical properties of TG-S35 weld metal.

Hardness, measured in the center of weld metal and from top to bottom.

![Figure 13: Hardness comparison between TG-S35 and TG-S50 weld metals](image)

**Table 14: AWS and JIS classifications of TG-S35**

<table>
<thead>
<tr>
<th>AWS A5.18</th>
<th>ASME F-No.</th>
<th>ASME A-No.</th>
<th>JIS Z3316</th>
</tr>
</thead>
<tbody>
<tr>
<td>—</td>
<td>6</td>
<td>1</td>
<td>W35A5U10</td>
</tr>
</tbody>
</table>

The typical chemistry of TG-S35 weld metal and the JIS specification of the rod chemistry are shown in Table 15.

**Table 15: Typical chemistry of TG-S35 weld metal and JIS specification**

<table>
<thead>
<tr>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cu</th>
<th>Ni</th>
<th>Cr</th>
<th>Mo</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>TG-S35</td>
<td>0.01</td>
<td>0.02</td>
<td>0.04</td>
<td>0.012</td>
<td>0.008</td>
<td>0.17</td>
<td>0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>JIS Z3316</td>
<td>0.02</td>
<td>0.02</td>
<td>0.04</td>
<td>0.012</td>
<td>0.008</td>
<td>0.17</td>
<td>0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>W35A5U10</td>
<td>0.02</td>
<td>0.20</td>
<td>0.70</td>
<td>0.025</td>
<td>0.025</td>
<td>0.50</td>
<td>0.15</td>
<td>0.10</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Kobelco Welding India’s booth was located

Mr. Maruyama, third from the left, together with IWS board members
At the end of last October, His Majesty King Willem-Alexander and Her Majesty Queen Maxima in the Netherlands visited Japan as state guests. One year after the King’s coronation, Japan was honored as the first country outside the EU to receive the royal couple. The friendly relationship between Japan and the Netherlands has been cultivated for a long time, and the Netherlands is Japan’s biggest investment partner ever in the EU.

Kobe Steel operates Kobelco Welding of Europe B.V. (KWE), a manufacturer and seller of flux cored wires, in Heerlen City, in the Dutch province of Limburg. This year marks the company’s 20th anniversary, and because of this, Kobe Steel operates Kobelco Welding of Europe B.V. (KWE), a manufacturer and seller of flux cored wires, in Heerlen City, in the Dutch province of Limburg. This year marks the company’s 20th anniversary, and because of this.

After the dinner, I also had a chance to have an intimate talk with the Amstelveen City Mayor, M. M. van’t Veld. Finally Mr Henk Kamp, the Minister of Economic Affairs of the Netherlands, closed the reception with a speech.

It was a very wonderful and memorable reception and I, myself, was able to spend a fruitful and enjoyable time. Reported by Fusaki Koshiishi, Head of the Welding Business.

At KWQ, about 130 employees are involved in manufacturing or selling flux cored wires (FCWs) for carbon steel. The company was established in 2008 and is still a young company, in which the average age is 32 years old. The volume of production as well as sales at KWQ has steadily been increasing, and we have more rooms for expansion. Therefore, we hope that prospective customers in China and around the world will recognize and use KWQ’s FCWs more and more.

Situated along the Yellow Sea, Qingdao is a city with delicious and fresh seafood. The taste of Qingdao cuisine is rather mild in comparison with Chinese food elsewhere, which can be heavy with seasoning. It accompanies the well-known Qingdao beer very well. You might be interested to know that Qingdao beer has recently released a black beer, called “Qingdao Stout,” as well as the premium “Augerta 1903,” so that there are more choices of beer to match with the food.

My Chinese colleagues at KWQ are generally cheerful, kind and sociable, once you make friends with them. The key point is how soon you get along with them. And they are never shy, which is what I, as a Japanese, am envious of. At the KWQ’s year-end party, when employees and their children performed dances and KARAOKE songs, they dressed up and danced so enthusiastically, they looked like pop idols as shown in the photo.

My colleagues seem to have a quite different character from ordinary Japanese, which I guess originates from their education in childhood. This unexpected side to the people here has given me a different impression of Chinese people from what I had imagined while I was in Japan.

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Another point that I’d like to mention is the Jiaozhou Bay Bridge. (See photo)

The world’s longest bridge over water, with a total length of 41.6km, it opened in June 2011. Because I live in central Qingdao City with my family, I have to commute to KWQ, which is located to the other side of Jiaozhou Bay, every day, and half of my commute involved crossing this bridge.

I look forward to seeing you somewhere, someday. And please consider visiting Qingdao, which is developing remarkably well and where a subway is currently under construction. Zai Jian (see you again)!